United States
Department of
Agriculture

Soil
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Service

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NATIONAL ENGINEERING HANDBOOK SECTION 19 (SECOND EDITION)
210-VI

SUBJECT: ENG - SECTION 19, CONSTRUCTION INSPECTION

Purpose. To distribute a new edition of Section 19 of the National Engineering Handbook (NEH).

Effective Date. Effective when received.

Explanation of Changes. NEH Section 19 has been updated and completely revised. Construction test details have been removed if they are now covered by American Society for Testing and Materials (ASTM) standards. Use the appropriate current ASTM standards (reference specifications) in conjunction with this handbook. Refer to the National Engineering Manual (NEM), Part 542, for instructions on ordering and distributing these reference specifications. Enough copies of the current reference specifications should be obtained, then filed with copies of NEH Section 19 being used in construction inspection work.

NEH Section 19 provides procedural guidance to be followed in inspecting construction work for most structures and practices under SCS programs. Included are inspection guidelines for clearing, removal of obstructions, site cleanup, earthwork, concrete work, steel reinforcement, structure drainage, pipe structures, metal work, timber construction, rock riprap, soil cement, piling, water control gates and valves, fences, construction safety, and other related work or items.

NEH Section 19 should be readily available as a reference at every project office, construction office, and job site where construction work is underway. It may also be a useful. reference in most area and field offices where SCS or District employees are engaged in layout and inspection of construction work.

Filing Instructions. Remove and discard existing NEH Section 19 and replace with the enclosed NEH Section 19, Second Edition.

Distribution. Distribution of copies to each state and the NTC reflects a survey of the initial needs. Each state, project, and area office and each professional engineer should have access to NEH Section 19.

Ordering Instructions. Additional copies may be obtained from Central Supply by ordering form NEH-019.

Paul M. Howard

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for Technology

Enclosure
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National Engineering Handbook

Section 19

Construction Inspection

Chapter 1

Introduction

Chapter 1 Contents

	Page
Definition ofterms	**1–2**
Abbreviations	**1–3**
ASTM standards	1-3
Engineering forms for construction	**1-4**

Chapter 1
Introduction

This handbook has been prepared to:

- Establish uniform procedures for inspecting the construction of soil and water conservation structures.
- Provide the basis for judging construction compliance with the contract requirements.

This handbook is not intended to be a guide for construction supervision. Construction supervision is the contractor's responsibility. The contractor is **(1)** to purchase andior process specified materials, *(2)* to know how to perform the work in accordance with the specifications and drawings, **(3)** to be responsible for quality control and safety, and **(4)** to know that the products and workmanship being furnished meet contract requirements. The contractor is not to depend on the inspector's determination, unless specifically required to do so.

The handbook is to be used as a reference on matters not covered by the specifications and as a guide in providing the engineering services for all contracted construction projects. Many of the procedures described can also be applied to the construction phases of other programs administered by the U.S. Department of Agriculture, Soil Conservation Service (SCS).

Included in this handbook are **(1)** detailed inspection requirements and descriptions of some specific phases of construction, *(2)* procedures for making field tests, **(3)** forms for recording test data, and **(4)** other required forms. If these instructions conflict with the contract provisions or with SCS policy in a state, contract terms and state directives take precedence.

Construction personnel must become familiar with this handbook to understand the layout, measuring, inspection, testing, and documentation required for contract construction. New or inexperienced personnel in training for construction staffs will find the material especially helpful. Only by firm, fair, and timely contract administration, including engineering services, can SCS expect good Construction and continue to attract good contractors for its work.

Definition of Terms

The following definitions apply throughout this handbook and in all contract documents unless the context of the specifications indicates otherwise:

Bid item is the specified class, kind, or location of the work for which individual prices are stated in the contract.

Contract is a written agreement between the contractor and the buyer of the contractor's services setting forth terms and conditions for performing the work or furnishing the materials.

Contract administration is a collective term which includes the engineering services and the administration of the contract by the owner through the contracting officer and his representatives.

Contracting officer is the person designated by the contracting organization to enter into and administer the contract and to make determinations and findings concerning the contract.

Contracting organization is the organization (federal, state, or other) authorized to contract for installing the work.

Contract price is the unit or the lump sum price for the bid items in the contract.

Contractor is the party of the second part to the contract acting directly or through an authorized agent.

Drawings are documents (or reproductions of them) showing the location and detailed design of the work stipulated in the contract.

Engineering services are technical services (layout, measurement, testing, inspection, records, and reports) required for the project and performed by the responsible party as mutually agreed to in the project agreement or in the engineering services agreement. Engineering services may be provided by SCS personnel, the contracting local organization's (CLO) employees, or a consulting engineering firm (A&E) under contract to SCS or the contracting local organization.

Government representative is the person designated by SCS to cany out its obligations, protect its interests, and provide a liaison with the contracting local organization.

Inspector is the person assigned to do such activities as observe construction and make tests in order to determine on a day-to-day basis that the construction meets contract requirements. The inspector keeps records of the work accomplished and any factors affecting the progress and quality of the work. The inspector is responsible to the project engineer.

Project engineer (engineer) is also the government representative (GR) if SCS is providing engineering services with its own employees. The engineer directs inspections, prepares reports, verifies the work progress, interprets drawings and specifications, and recommends acceptance of the work. When SCS does not provide engineering services, the contracting local organization (CLO) or the consulting engineering firm (A&E) will designate an engineer to carry out the duties of the project engineer.

Specifications are written or printed descriptions in the contract of the work to be done, methods for measurement and payment, qualities of the material, and mode or tolerance for the construction procedures, including special directions or other information not shown on the drawings.

Work is the materials, equipment, operation, and labor needed for construction of the specific improvements as indicated on the drawings or as stated in the contract.

Abbreviations

Names and abbreviations used in the handbook or in the contract document follow:

AA	Aluminum Association
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AGC	Associated General Contractors of America. Inc.
AGMA	American Gear-Manufacturer's Association
AI	Asphalt Institute
AISC	American Institute of Steel Construction
AS	American standards
ASA	American Standards Association
ASTM	American Society for Testing and Materials
AWPA	American Wood-Preserver's Association
AWS	American Welding Society
AWWA	American Water Works Association
BR	Bureau of Reclamation, U.S. Department of the Interior
CRSI	Concrete Reinforcing Steel Institute
CS	Commercial standards

ASTM Standards

The following standards prepared by the American Society for Testing and Materials are referred to in chapters of Section 19, Construction Engineering:

C–31.	Standard Method of Making and Curing Concrete Test Specimens in the Field
C-33.	Standard Specification for Concrete Aggregates
C–70.	Standard Test Method for Surface Moisture in Fine Aggregate
c–117.	Standard Test Method for Materials Finer Than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
C–127.	Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate
C–128.	Standard Test Method for Specific Gravity and Absorption of Fine Aggregate
C–136.	Standard Method for Sieve Analysis of Fine and Coarse Aggregates
C–138.	Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
C–143.	Standard Test Method for Slump of Portland Cement Concrete
C–172.	Standard Method of Sampling Fresh Concrete
C–173.	Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C–231.	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
D–75.	Standard Methods of Sampling Aggregates
D–558.	Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures

D–698.	Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop
D–1556.	Standard Test Method for Density of Soil in Place by the Sand-Cone Method
D–1557.	Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop
D–1558.	Standard Test Method for Moisture-Penetration Resistance Relations of Fine-Grained Soils
D–2167.	Standard Test Method for Density of Soil in Place by the Rubber-Balloon Method
D–2216.	Standard Method for Laboratory Determination of Water (Moisture) Control of Soil, Rock, and Soil-Aggregate Mixtures
D–2487.	Standard Test Method for Classification of Soils for Engineering Purposes
D–2488.	Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)
D–2937.	Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method

The following SCS engineering forms are shown or referred to in chapters of Section 19, Construction Engineering:

SCS-ENG-59	Report on Concrete Test Specimens
SCS-ENG-352	Materials Testing Section Report: Compaction and Penetration Resistance
SCS-ENG-353	Materials Testing Report: Soil Classification
SCS-ENG-359	Work Sheet for Compaction and Penetration Resistance Data
SCS-ENG-522A	Computation Sheet
SCS-ENG-528	Embankment Computation Sheet
SCS-ENG-529	Earthwork Computation Sheet
SCS-ENG-530A	Bulk Sand Density Determination and Calibration of Cone and Base Plate
SCS-ENG-530B	Inplace Moisture-Density Determination: Sand Cone Method—Specified Fraction Control
SCS-ENG-530C	Inplace Moisture-Density Determination: Sand Cone Method—Mass Density Control
SCS-ENG-530D	Inplace Moisture-Density Determination: Rubber Balloon Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve
SCS-ENGB3OE	Inplace Moisture-Density Determination: Calibrated Cylinder Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve
SCS-ENG-530F	Inplace Moisture-Density Determination; Kerosene Method, Fine-Grained Soils-Less Than 5% +No. 4 Sieve

SCS-ENG-530G	Inplace Moisture-Density Determination: Rauid Comuaction Method—Sand Displacement
SCS-ENG-530H	Inplace Moisture-Density Determination: Rauid Comuaction Method-Rubder Balloon Displacement, Fine-Grained Soils—Less Than 5% +No. 4 Sieve
SCS-ENG-5301	Inplace Moisture-Density Determination: Template and Plastic Liner Method
SCS-ENG-531	Moisture Content Determination, Summary Data Sheet
SCS-ENG-532	Weekly Summary of Density Determinations
SCS-ENG-535	Sieve Analysis
SCS-ENG-541	Rapid Method for Determining Density and Moisture, for 5.00 lb of Moist Soil
SCS-ENG-542	Materials Testing Report: Visual Soil Classification
SCS-ENG-543	**Bulk** Specific Gravity and Moisture Determination
SCS-ENG-544	Daily Concrete Batching Record
SCS-ENG-545	Pile Driving Record
SCS-ENG-546	Bid Item Record Sheet
SCS-ENG-547	Construction Completion Report
SCS-ENG-548	Summary of construction Quantities and Costs
SCS-ENG-549	Table of Forms Used by Field Construction mice
SCS-ENG-550	Embankment Construction Report
SCS-ENG-551	Certification of Materials and Concrete Mixture
SCS-ENG-552	Concrete Batch Delivery Ticket
SCS-ENG-553	Concrete Trial Mix Data
SCS-ENG-555	Construction Safety Inspection Record
SCS-ENG-004	Tabular Computations
SCS-ADS-53	Progress Sheet Computations of Contract Pay Items

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Agriculture

Soil
Conservation
Service

National Engineering Handbook

Section 19

Construction Inspection

Chapter 2

Installation

[redacted]

Chapter 2 Contents

	Page
Construction safety	2–1
Environmental protection	2–2
Pollution control	2–15
Clearing and grubbing	2–17
Structure removal	2–17
Earthwork	2–18
Excavation	2–18
Disposal of excavated material	2–18
Blasting	2–19
Borrow areas	2–19
Diversion and control of water	2–19
Foundation	2–19
Embankment andbackfill	2–21
Embankment construction	2–21
Earthfill	2–21
Material requirements	2–21
Control **of** materials and placement	2–21
Moisture control	2–22
Compaction	2–22
Moisture-density determinations	2–25
Coarse-grained soils	2–25
Rock	2–26
Test fills	2–26
Bacbfllconstruction	2–27
Finishing	2–27
Concrete construction	2–28
Job requirements	2–28
Control of concrete mixture proportions	2–28
Watercement ratio	2–28
Workability	2–29
Aggregates	2–29
Job mixtures	2–29
Before concreting	2–29
Inspection and testing of materials	2–29
Cement	2–30
Aggregates	2–30
Water	2–30
Curine comuound	2–30
Foundation preparation	2–30
Rock	2–30
Earth	2–31
Adequate drainage	2–31
Forms	2–31
Embeddeditems	2–32
Joints and water stops	2–32
Contraction joints	2–32
Expansion joints	2–32

	Page
Constructionjoints	2–35
Water stops	2–35
Final inspection	2-35
During concreting	2–36
Batching and mixing	2–36
Batching	2–36
Mixing	2–37
Transit-mixing equipment	2–37
Admixtures	2–38
Consistency	2–38
Delivery and placement	2–40
Placement in hot weather	2–43
Placement in cold weather	2–43
Consolidation	2–44
Finishing	2–44
After concreting	2–45
Form removal	2–45
Curing	2–46
Protection from damage	2–46
Testing concrete	2–47
Test specimens	2–47
Sampling	2–47
Number and frequency	2–47
Molding	2–47
Curing	2–47
Handling and shipping	2–47
Slump	2–47
Air content	2–47
Records and reports	2–48
Mix computations	2–48
Batching andmixing	2–48
Placing and curing	2–48
Strength tests	2–48
Test specimens	2–48
Inplace concrete	2–48
Steel reinforcement for concrete	2–49
Materials	2–49
Steelbars	2–49
Bar sizes	2–49
Bar identification	2–49
Length and bending	2–49
Tolerance limits in fabrication	2–50
Identification for shipment	2–50
Welded wire fabric	2–50
Handling and storage	2–50
Placement in structures	2–50
Single span simple beams	2–50
Continuous beams	2–50
Cantilever beams	2–65
Walls	2–65

Chapter 2 Contents (cont.)

	Page
Retaining walls	2–65
Elastic (continuous) frames	2–65
Footing slabs	2–65
Splices	2–65
Ties and supports	2–65
Structure drainage	2–69
Drainage needs and types	2–69
Cutofftrenches	2–69
Drain fill	2–69
Pneumatically applied mortar	2–70
Preparation of surfaces	2–70
Materials	2–70
Sand	2–70
Cement	2–70
Water	2–70
Reinforcing steel	2–70
Equipment	2–70
Mixer	2–70
Pressure chamber	2–70
Hose and placing nozzle	2–71
Air compressor	2–71
Water pumps	2–71
Placement	2–71
Curing	2–71
Tests andreports	2–71
Pipe structures	2–72
Delivery and storage	2–72
Unloading and handling	2–72
Storage	2–73
Installation	2–73
Alignment and grade	2–73
Layingpipe	2–73
Backfill	2–74
Field testing for water tightness	2–74
Metal fabrication and installation	2–77
Delivery and storage	2–77
Inspection of materials	2–77
Erection	2–78
Welding	2–78
Finishing	2–79
Timber construction	2–80
Inspection and grading	2–80
Defects	2–80
Checks	2–80
Decay	2–80
Holes	2–80
Knots	2–81
Mismanufacture	2–81

Page

Pitch 2-81
Pith 2–81
Shakes 2–81
Splits 2–81
Stain 2–81
Wane 2–81
Warp 2–81
Grading provisions 2–81
Grading face 2–81
Variations 2–81
Trimming 2–81
Heartwood 2–81
Combination grades 2–82
Density rule 2–82
Stress rating 2–82
Moisture content 2–82
Sizes and lengths 2–82
Dressed sizes 2–82
Match workings 2–82
Rough dry sizes 2–82
Length provisions 2–82
Preservative treatment 2–82
Delivery and storage 2–82
Materials check 2–82
Unloading 2–83
Storage 2–83
Treatment of cut surfaces 2–83
Erection procedure 2–83

Asphaltic concrete 2–84
Materials 2–84
Mixture 2–84
Plant operations 2–84
Feeding 2–84
Drying 2–84
Contamination 2–84
Temperature 2–84
Dust collecting 2–84
Screens 2–84
Bins 2–84
Scales 2–84
Mixers 2–85
Transportingthe mixture 2–85
Site preparation 2–85
Placing and compacting 2–85
Paver 2–85
Rolling 2–85
Reinforcement 2–86
Joints 2–86

Loose rock riprap 2–87
Materials 2–87

Chapter 2 Contents (cont.)

	Page
Rock	2–87
Filters and bedding	2–88
Foundation preparation	2–88
Installation	2–88
Equipmentplacement	2–88
Hand placement	2–88
Filters andbedding	2–88
Grouted rock riprap	2–89
Materials	2–89
Foundation preparation	2–89
Placement	2–90
Curing and protection	2–90
Tests	2–90
Sacked concrete riprap	2–91
Materials	2–91
Concrete	2–91
Sacks	2–91
Foundation preparation	2–91
Placement	2–91
Curing and protection	2–91
Tests	2–91
Soil-cement construction	2–92
Types of soil-cement	2–92
Compacted soil-cement	2–92
Cement-modified soil	2–92
Plastic soil-cement	2–92
Materials	2–92
Soil	2–92
Cement	2–92
Water	2–92
Mixture	2–92
Installation	2–92
Initial preparation	2–92
Scarifying and pulverizing	2–93
Adding cement	2–93
Adding water and mixing	2–93
Compaction	2–93
Curing	2–93
Testing	2–93
Water control gates and valves	2–94
Types	2–94
Inspection	2–94
Installation	2–94
Fences and fence construction	2–95
Types	2–95
Materials	2–95
Storage	2–95
Construction	2–95

Chapter 2 Contents (cont.)

	Page
Piles and pile driving	2–95
Piling materials	2–95
Timber	2–95
Steel	2–96
Concrete	2–96
Handling and storage	2–96
Driving equipment	2–96
Types of hammers	2–96
Other equipment	2–97
Determination of bearing capacity	2–97
Formula	2–97
Testing	2–98
Sheet piling	2–98
Installation	2–98
Precautions	2–99
Records	2–99
Site cleanup	2–100

Inspection Checklists

Pollution control	2–16
Clearing and grubbing	2–17
Structure removal	2–17
Earthwork	2–20
Embankments and backfill	2–27
Forms	2–31
Joints and water stops	2–35
Working conditions	2–37
Transit mixers	2–38
Batching and mixing	2–39
Finishing surfaces	2–45
Curing concrete	2–46
Steel reinforcement	2–66
Structure drainage	2–69
Pneumatically applied mortar	2–72
Pipe structures	2–74
Welding	2–79
Metal work	2–79
Timber construction	2–83
Asphaltic concrete	2–86
Rock riprap	2–89
Grouted rock riprap	2–90
Sacked concrete riprap	2–91
Soil-cement construction	2–93
Water control gates and valves	2–94
Fences and fence construction	2–95
Piles and pile driving	2–99
Site cleanup	2-100

Chapter 2 Figures

		Page
2–1	Form SCS-ENG-555, "Construction Safety Inspection Record"	2–3
2–2	Water requirements for compaction	2–24
2–3	Spacing data for form lumber and form ties	2–33
2–4	Correct and incorrect methods of placing concrete	2–41
2–5	Physical requirement for deformed reinforcing bars	2–51
2–6	ASTM standard reinforcing bars	2–51
2–7	US. standard bar identification marks	2–52
2–8	U.S. manufacturers of concrete reinforcing bars	2–53
2–9	Typical bar bends	2–59
2–10	Standard code for designating the dimensions of hooks, stirrups, and ties	2–60
2–11	Sizes and spacing for rectangular welded wire fabric—one-way types	2–61
2–12	Sizes and spacing for square welded wire fabric—two-way types	2–61
2–13	A single-span simple beam, loaded and assumed shapes	2–62
2–14	A continuous beam, loaded and assumed shapes	2–62
2–15	A cantilever beam, loaded and assumed shapes	2–62
2–16	A wall, loaded and assumed shapes	2–63
2–17	A retaining wall, loaded and assumed shapes	2–63
2–18	An elastic (continuous) frame, loaded and assumed shapes	2–63
2–19	A footing slab, loaded and assumed shapes	2–64
2–20	Types of wire ties	2–64
2–21	Precast concrete bar supports	2–67
2–22	Fabricated metal bar supports	2–67
2–23	A few of the more common methods of satisfactorily coupling rubber-jointed concrete pipe	2–75

Chapter 2 Table

2–1	Engineering use chart	2–23

Chapter 2
Installation

Requirements for the (1) quality of materials, (2) construction, (3) safety, and (4) pollution control during construction are in the drawings and specifications or other contract documents for the project. All personnel in contract administration should have a detailed knowledge of these requirements.

In possible conflicts between contract requirements (drawings and specifications) and suggestions contained in this handbook, the contract requirements take precedence.

Not all items given in the checklists in this chapter apply to all contracts. The project engineer is to review suggestions presented and determine those that apply to each phase of the contract in hand. It is equally important to make sure the contract covers all important requirements for construction.

Inspectors must know the grades of materials and standards of workmanship recognized by engineers and responsible contractors as appropriate for the various kinds of construction. All materials must be inspected before they are used in the work. Materials not meeting contract requirements as determined by visual inspection, certification, or testing must be rejected. Inspectors are to list in the job diary all materials not meeting requirements and include reasons for their rejection. Inspection verifies that the contractor strictly complies with the contract requirements for quality of materials and workmanship, for job safety, and for pollution control. No quality, strength, or appearance below the level called for in the contract drawings and specifications can be accepted.

Construction Safety

SCS must provide a safe and healthy job environment for its employees and see that they work safely. SCS must also inspect safety and health conditions and operations on construction contracts for which technical or financial assistance is being provided. When unsafe or unhealthy conditions or actions are found, the project engineer and the inspector are to see that they are corrected. It cannot be assumed that the contractor's workers know and will comply with all safety requirements.

In 1970, SCS adopted, for its own construction activities, the Safety and Health Regulations published by the U.S. Department of Interior, Bureau of Reclamation. After Congress passed the Construction Safety Act, 29 CFR 1926, and the Occupational Safety and Health Act, 29 CFR 1910, the Bureau of Reclamation modified their regulations accordingly. SCS now uses "Construction Standards and Interpretations," in *Occupational Safety and Health,* developed under the Occupational Safety and Health Act, plus SCS supplements.

The general duty clause of the regulations states very succinctly the essence of the ad: "No contractor (or employee) shall require any laborer or mechanic employed in the performance of the contract to work in surroundings or under working conditions which are unsanitary, hazardous, or dangerous to his health or safety." This principle applies to the conduct of the employee himself, as he is a part of this environment.

The contractor is responsible for seeing that safe and healthy conditions prevail. The project engineer and the inspector are to make sure that they prevail. The contractor must also (1) provide

education and training in safety and health for his employees, (2) furnish first aid and medical attention for those injured on the job, (3) keep records of accidents and injuries, and (4) submit required reports.

The contractor has the authority and the responsibility for keeping unauthorized persons away from hazardous activity on the jobsite. If the contractor allows people on the johsite, they must be supplied with hard hats and other appropriate protective equipment and their movement around the johsite restricted as necessary to ensure their safety.

The project engineer and the inspector must know the safety and health regulations applicable to the contract. There are many inspections and tests to be made by SCS and the contractor. Form SCS-ENG-555, "Construction Safety Inspection Record," has been prepared as a checklist that can be used in recording these inspections (fig. 2-1). The form is filed with the contract records. Some inspections and tests must be made several times during the course of the work. If a change is noted in a subsequent inspection, the problem should he corrected and the facts documented in the job diary. Some items may not be listed on the checklist. Some listed may not apply to every project.

The National Environmental Policy Act of 1969 (PL 91–190) specifies action to prevent or minimize damage to the environment, thereby improving conditions for the health and welfare of mankind. SCS fully supports the intent of this act in all SCS activities. Each member of the construction force must see that work is accomplished in the most effective way to enhance the environment and to lessen undesirable impacts on the area as much as is reasonable.

Standards, criteria, and procedures have been established by federal, state, and local governments (1) limiting actions that adversely affect the environment, (2) prescribing methods for controlling erosion and sediment, (3) minimizing pollution of water and air, (4) controlling noise levels, (5) protecting natural features, (6) protecting archeological and historic sites, (7) protecting fish and wildlife, (8) providing for sanitation, and (9) controlling the use of pesticides.

Sediment from soil erosion, in terms of volume, is the greatest single pollutant of streams, lakes, and reservoirs. Careless installation methods and inadequate site protection during construction can result in eroded slopes, haul roads, borrow areas, channels, waterways, and embankments. In turn, this may cause large volumes of sediment to be discharged into water courses. Oils, greases, sanitary wastes, and chemicals not properly disposed of also pollute the soil and water.

Dust and smoke create safety and health hazards to job personnel and to adjacent residents and crops. Construction operations must be controlled to maintain acceptable air and water quality.

Careless equipment operation destroys desirable vegetation, mars rock outcrops, and defaces the landscape. Operations must be managed to avoid damage to the environment.

US. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-555
4-80

CONSTRUCTION SAFETY INSPECTION RECORD

Watershed or Project _____

Site _____ contractor _____ Contract No. _____

Inspection by _____ Title _____ Date _____

Complete before construction begins and during construction. as applicable or as required, to insure safe working conditions throughout contract period.

Fill in required information. Use check, X, circled X, or dash as appropriate between parentheses:

(J) = safe: conforms: done. (X) = unsafe: not conform; not done. (–) = not applicable.

(Ⓧ) = unsafe conditions corrected: nonconformance now conforms: activity now done.

References: ***Construction standards and interpretations,*** Occupational Safety and Health Administration. U.S. Department of Labor. and SCS supplements. Tables and NFPA and ANSI references included.

General requirements

Written safety program received (date) _____ Preconstruction safety meeting held (date) _____

Joint safety policy Committee (names of members):

_____ _____ _____

_____ _____ _____

Safety supervisor (name) _____ Alternate (name) _____

Scheduled weekly safety meeting (time) _____ a.m., p.m.

( ) Contractor requires any subcontractors to comply with all safety requirements.
( ) Contractor certifier compliance with worker's compensation laws to contracting officer.
( ) Adequate Communications and transportation facilities available at jobsite to handle injury situations.
( ) New employees given safety instructions for their jobs and the jobsite.

Medical services and first aid

Medical anention available offsite: Name _____

Address _____ Phone _____

Ambulance service available: Name _____

Address _____ Phone _____

Contractor's employees with first aid training certification (Bureau of Miner or the Red Cross):

Name _____ Title _____

Name _____ Title _____

Name _____ Title _____

( ) Phone numbers of offsite medical attention and ambulance service ported outride first aid facility at jobsite.
( ) Locations Of first aid kits and other medical supplies ported conspicuously on signs outside first aid facilitv.
( ) Complete 16-unit moistureproof first aid kits available—minimum of 1 kit per 25 employees.
( ) Employee qualified in first aid is assigned each work shift.
( ) At least one stretcher and two blankets available at jobsite.

Sanitation

( ) Adequate potable water supply available at jobsite.
( ) Water dispensers identified properly: each equipped with tight cover and tap
( ) Clean "one-use" cups available.
( ) Waste receptacles available for disposable cups and other litter.
( ) Salt tablets available when required.
( ) Adequate toilets provided at jobrite—minimum of 1 toilet per 20 workers.

Figure 2-1.—Form SCS-ENG-555, "Construction Safety Inspection Record"; first page.

Head protection

( ) Hard hats worn by all persons entering any part of jobsite.
( ) Hard-hat area signs. 3- by 4-ft minimum size, "CONSTRUCTION AREA—HARD HATS REQUIRED BEYOND THIS POINT," erected at all jobsite-access locations.

Noise exposure

( ) Sound levels on job not exceed allowable noise exposures (table D-2).
( ) Ear-protection devices used when noise exceeds allowable exposure (table D-2).

Illumination

( ) Work sites, offices, shops. and storage areas lighted as required (table D-3).

Eye and face protection

( ) Eye and face protection provided for hazardous jobs; protection meets requirements (tables E-1 and E-2).
( ) Goggler or other Protective equipment kept clean and in goad repair.

Respiratory protection

( ) Respirators worn by jackhammer operators and helpers when dust concentrations exceed safe hygienic levels.
(I Employees protected from other hazardous concentrations (table E-4).
( ) Respirators kept clean and in good condition; respirators inspected regularly.

Safety belts and lifelines

( ) Employees Protected by safety belts and lines when working on steep slopes or unguarded heights.
( ) Lifelines secured to at least two anchor points.
( ) Lifeline requisites are: at least ¾-in. thick. manila or equivalent. and 5,400-lb breaking strength.
( ) Safety belt and lanyard material made of cast Steel or are drop forged: material has 4,000-lb loading

Working over or near water

( ) U.S. Coast Guard-approved life jackets or vests worn by employees if there is danger of drowning.
( ) Protective equipment inspected for buoyancy and strength.
( ) Ring buoys and 90-ft lifelines readily available for rescue operations.

Fire protection

(I Fire extinguisher with 10 B rating required within 50 ft when more than 5 gal combustible liquid are used.
( ) Carbon tetrachloride extinguishers prohibited on job.
( ) Portable extinguishers serviced and maintained (MFPA 10A-1970).
( ) Fire extinguishers that are provided meet specifications (table F-1).

Fire prevention

( ) Combustion-engine exhaust kept clear of combustible materials.
( ) Signs ported at and around Operations having fire hazards, "NO SMOKING OR OPEN FLAME."
( ) Storage areas kept free of weeds. grass, and other combustible materials.
( ) Materials stored indoors are handled and piled in ways that minimize fire hazard.

Flammable and combustible liquids

( ) Metal Safety Cans (larger than 1-gal capacity) used to store or handle flammable liquids
( ) Storage of flammable liquids in open room or trailer limited to 15 gal.
( ) Storage of liquids in cabinet limited to 60 gal flammable and 120 gal combustible.

Figure 2-1 (cont).—Form SCS-ENG-555; **second page.**

( ) Cabinet containing such liquids labeled conspicuously, "FLAMMABLE—KEEP FIRE AWAY."
( ) Outdoor portable storage tanks positioned at least 20 ft away from any building.
( ) Portable storage tanks equipped with vents (ch. 11, 111, IV, NFPA 30-1969).
( ) Containers. tanks. and hoses interconnected (bonded! electrically when transferring liquids.
( ) Dispensing nozzles equipped with "automatic closing shutoff no latch open" devices.
( ) Flammable liquids kept in closed containers when stored.
( ) Portable fire extinguishers with 20 BC rating required within 75 ft Of refueling truck or station.
( ) Motors of all equipment shut off during refueling.
( ) Sign at refueling area posted conspicuously, "NO SMOKING OR OPEN FLAME WITHIN 50 FT."

Temporary heating devices

( ) Adequate fresh air provided to insure Personnel safety.
( ) Solid noncombustible material used to support heating units; material extends 2 ft beyond each side of heater.
( ) Minimum 10-ft clearance provided in temporary job enclosures between heater and combustible coverings.
( ) Oil-fired heaters equipped with safety oil stop for protection during possible flame out.

Signs, signals, and barricades

( ) Barricades erected and legible traffic signs posted at hazardous locations.
( ) Signs posted and barricades installed to prevent public access.
( ) Nighttime signs and barricades lighted properly or reflectorized.
( ) Flagmen placed when working conditions Warrant.
( ) Red flags or Sign paddler 18-in. square used by flagmen to make hand signals.
( ) Red or orange warning vests or coats worn by flagmen.
( ) Detour signs ported on streets and highways; Sign types and placement meet state/local regulations and codes.

Material handling, storage, use, and disposal

( ) Storage areas kept approximately level, well arranged, and free of flammable materials.
( ) Construction material stacked, racked. or blocked to prevent movement.
( ) Lifelines with safety belts used by workers entering hoppers. silos, or tanks.
( ) Excess material not stored an scaffolds or runways.
( ) All nails removed from used lumber.
( ) Material to be handled by crane stored in area clear of overhead powerlines.

Rigging equipment for material handling

( ) Equipment inspected before use and during material handling.
( ) Equipment is adequate to handle loads (tables H-l through H-20).
( ) Defective equipment removed or replaced.

Chains

( ) Steel alloy chains identified by size, grade. and Capacity.
( ) Hooks, rings, and other attachments not shop-made; their capacity must equal chain capacity.
( ) Hoisting hooks equipped with safety keepers.

Wire rope

( ) Wire rope is adequate for job loads (tables H-3 through H-14).
( ) Eye splices made with at least three full tucks.
( ) Protruding splice ends Covered or blunted.
( ) Hoirting or pulling liner made Of one continuous rope with no knots or splices.
( ) Wire rope replaced when 10 percent of strands are broken in any length that equals 8 diameters of the rope.
( ) U-bolt clips are correct size and spaced properly (table H-20).
( ) U Section attached to dead-end rope.

Figure 2-1 (cant).-Form SCS-ENG-555; third **page**

Fiber rope

( ) Fiber rope slings meet requirements Itable H-15 through H-18).
( ) Repairs made with splices; knots prohibited.
( ) Coding for manufacturer, type of material. and capacity of rating shown on synthetic webbing.
( ) Shackles and hooks meet requirements Itable H-19).

Waste material disposal

( ) Scrap lumber, waste. and rubbish removed as work progresses.
( ) Solvent waste, oily rags. and flammable material stored in covered metal Containers until removed from iobrite.

Power and hand tools

( ) Power tools equipped with guards (as manufactured) over all exposed moving parts.
( ) Hand-held power tools equipped with pressure-control switches.
( ) Goggles and other protective equipment worn by workers as required.
( ) Tools with mushroomed heads or defective handles prohibited.
( ) Electric-powered tools double-insulated or grounded with 3-wire conductors.

Grinders

( ) Machines equipped with guards and tool rests.
( ) Grinding wheels checked for cracks and defects.
( ) Grinder Spindles operated at safe speeds.

Powder-actuated tools

( ) Operators trained properly.
( ) Guard devices tested each day tool is operated.
( ) Guard protects fastener equipment to prevent misfires.

Gas welding and cutting

( ) Gas cylinders meet U.S. Department of Transportation requirements (49 CFR-178-C).
( ) Hose lines distinguished by color—fuel is red, oxygen is green.
( ) Cylinders placed upright when stored or in use, chained to prevent Overturning. and capped tightly when not in use
( ) Cylinders kept upright when moved (tilt and roll on bottom edge) and anchored to pallet before hoisting.
( ) Cylinders protected from excessive heat or cold and from electric currents.
( ) Defective gages, regulators. valves, and hoses repaired or replaced.
( ) Valves closed tight when cylinders not being used.
( ) Valves cracked to clear dust before regulators are attached.
( ) Friction lighters used to ignite gas torches; matches prohibited.
( ) Welding and cutting done only by authorized operators.
( ) Proper goggle6 or shields worn by welders and helpers Itable E-1).

Arc welding and cutting

( ) Capacity of the electrode holder is adequate for current through electrodes.
( ) Handgrips and jaws insulated for maximum ground voltage.
( ) Cables and connectors rubber-covered; splices not made within 10 ft of electrode holders.
( ) Capacity of ground cable exceeds maximum electrical output of welding units.
( ) Framer of welding Units grounded with 3-wire conductors or with separate wires at source
( ) Protective eye shields used by welders and helpers Itable E-1).
( ) Other workers near arc protected by screens or goggler.
( ) Precautions taken to prevent firer; fire extinguisher is available.

Figure 2-1 (cant).—FormSCS-ENG-555; fourth page.

Electrical

( ) Installation procedures and wire capacity conform to NFPA electrical and electric safety coder
( ) Hot circuits deenergized or equipped with guards before starting work.
( ) Hot voltage circuits equipped with guards; signs posted, "DANGER – HIGH VOLTAGE."

Grounding and bonding

( ) Portable plug-in equipment double-insulated or grounded with 3-wire conductors.
( ) Metal parts and frames of fixed equipment grounded adequately.
( ) Circuits extending to ground are continuous and of ample capacity.
( ) Heavy-duty, 3-wire cords used on portable tools.
( ) Insulated lamp sockets used when temporary lighting needed.
( ) Bulbs for temporary lights protected by guards or special reflecton.
( ) Hand lamps equipped with handles; guard attached to each handle.
( ) Extension cords kept clear of walkways. sharp comers, and projections.
( ) Warn or frayed electric conductors not permitted.
( ) Fuses or circuit breakers provided for over-current protection.

Ladders

( ) Enough ladders provided for adequate access to work.
( ) Manufactured ladders meet requirements (ANSI-A14.1-1968).
( ) Portable ladders set on solid bare; space around top and bottom of each ladder kept clear.
( ) Portable ladders pitched no flatter to vertical than 1:4.
( ) Portable ladders tied or blocked to prevent movement.
( ) Minimum dimensions Of job-made wooden ladders are 2- by 4-in. side rails 16 ft long, ¾- by 3-in. Cleats 18-23 in. long, and 12 in. between cleats; rails notched to fit cleats, or fill blocks used to secure cleats.
( ) Length between supports (base and top landing) of job-made ladders do not exceed 30 ft.
( ) Top of each ladder extends at least 36 in. above top landing.

Scaffolding

( ) Guardrails, sides. and ends installed on all platforms that are 45 in. wide or less and built more than 4 ft above ground or adjoining surfacer and on all platforms built more than 10 ft above ground or adjoining surfaces.
( ) Guardrail dimensions are 2- by 4-in. rails installed 42 in. above floor, 1- by 6-in. intermediate rail. 4-in.-high toeboardr, and 2- by 4-in. supports at 8-ft spacing.
( ) Platform planking extended at least 6 in. over supports; planking overlapped 12 in. or anchored.
( ) Ladders provided for access.
( ) Adequate overhead protection provided in hazardous areas.
( ) Platform surfaces kept clean so workers are not in danger Of dipping.
( ) Design and construction of wooden scaffolds meet requirements (tables L-4 through L-10).
( ) Approved type of metal-tube-and-coupler scaffolds used; scaffolds erected as specified by manufacturers; expected loading meets minimum Safety factor 14).
( ) Metal scaffolds installed plumb and level and anchored to structure: maximum scaffold dimensions are 30 ft horizontal by 26 ft vertical.

Floor and wall openings and stairways

( ) Floor openings on all rider except at entrances protected by covers or guardrails.
( ) Guardrails built if wall openings are less than 3 ft above floors and drops are more than 4 ft; toeboards built if openings are more than 3 in. above floors.
( ) Guardrails built along open-sided floors that are 6 ft or more above ground.
( ) Handrails built along stairways that have at least four risers.
( ) Handrails placed 30-34 in. above top of each riser: raised handrail built along open side of stairs and landings.
( ) Smooth surfacer of handrail material positioned on top and aides; handrail mounted at least 3 in. from sidewalls.
( ) Stairs interrupted every 12 ft (vertical distance) with 30-in. landing.

Figure 2-1 (cont).—Form SCS-ENG-555; fifth page.

Convevorr

( ) Operators' stations equipped with start and stop controls.
( ) Warning signal included in conveyor equipment: signals tested before conveyors are started.
( ) Adequate access ladders. platforms, and walkways with guardrails and handrails provided.
( ) All moving parts properly guarded.
( ) Necessary rides and screens installed to protect workers.
( ) Conveyors locked out and tagged during repairs.

Motor vehicles and mechanized equipment

( ) Lights or reflectorized barricades placed around equipment parked adjacent to highways or streets.
( ) Safety tire cages used when inflating tire6 on split or lock-type rims.
( ) Before repairs are started, controls set in neutral, brakes set, and motor shut off.
( ) Adequate blocking and cribbing provided to prevent movement of equipment during repairs.
( ) Safety precautions to be taken with all parked equipment include: setting brakes, chocking wheels, and fully lowering blades, buckets, and dumpbeds.
( ) Special caution taken in changing and charging batteries to Prevent acid Contact with eyer and skin.
( ) Passengers transported only in cabs or vehicles: mounting and dismounting from moving vehicles not allowed.

Pile-driving equipment

( ) Boilers, compressors, and piping systems maintained in good condition: equipment has adequate guards.
( ) Stop block positioned in leads to prevent hammer from striking head block.
( ) Safety block inserted in leads to support hammer when workers are below hammer.
( ) Cable guards installed across head block sheaves.
( ) Fixed leads equipped with rings for attaching safety-belt lanyards.
( ) Work platforms an leads protected by guardrails.
( ) Safety chains (¼-in. diameter) attached at steam and airhose connections and to hammers.
( ) Steam and air lines equipped with two controls—one has quick-action capability and is at operator's station
( ) Adequate guys, outriggers, and counter balances installed to stabilize equipment.
( ) Piles attached properly to hoisting lines for placement in leads.
( ) Employees kept clear of area when piles are hoisted.
( ) Driving stopped during cutoff if within a distance equal to two times the length of the longest pile.
( ) Pit walls sloped or sheet piling placed and braced before each pile is driven.
( ) Only authorized personnel allowed in work area during driving operations.

Excavations, trenching, and shoring

( ) Walkways and runways kept clear of excavated material.
( ) Walkway planks placed parallel to length of walk. Closely spaced, fastened to prevent displacement, and cleated if slick conditions will prevail.
( ) Reflectorized vests worn by flagmen and others exposed to traffic.
( ) Personnel not permitted under loads being handled by power equipment.
( ) Truck and other haul-unit operators kept clear of units during loading (exception allowed if cab is braced and shielded)
( ) Wells, pits, and shafts Covered or barricaded to protect all Personnel.
( ) Underground utilities located and staked before excavation.
( ) Utilities left in place are protected by barricades, shoring, or suspension.
( ) Slide-danger areas sloped to stable angler or shored and braced.
( ) Cribbing and shoring designed and installed to meet accepted engineering standards.
( ) Excavated material placed and other material stored at least 2 ft from excavation edges.
( ) When work is done below hazardous rock slopes, workers and equipment protected by scaling slopes as necessary to minimize danger, bolting rocks and affixing wire mesh after scaling, and placing timber or wire-mesh barricades.
( ) Scalers equipped with safety belts or boatswain chairs.
( ) Scalers' lifelines tied to at least two secure objects.
( ) Workers not permitted to work one above the other in rock material.

Figure 2-1 (cont).—Form SCS-ENG-555; sixth **page**

( ) Rock removed from top downward on Steep slopes; access to slope is from top only.
( ) Sides of steep excavations shored and braced when heavy equipment operated close to excavation edges.
( ) Dust controlled to acceptable levels.
( ) Guardrails built along walkways over excavations.
( ) Workers in trencher more than 5 ft deep protected with shields or by sloping or shoring and bracing excavation banks (tables P-1 and P-2).
( ) Trench bracing and shoring installed during excavation: cross braces or jacks placed horizontally, spaced vertically, and secured to prevent movement.
( ) Trench supports removed from bottom upward: roper used to remove jacks in unstable soil.
( ) Ventilation provides adequate oxygen and acceptable atmospheric conditions.
( ) Ladders or steps installed no more than 25 ft apart in trenches more than 4 ft deep.

Concrete, concrete forms, and shoring

( ) Excavations sloped or shored so forms and concrete materials can be installed safely.
( ) Work platforms provided or Safety belts worn by workers when Steel placed in walls, piers, and columns.
( ) Work not allowed above unprotected vertical-protruding rebars.
( ) Vertical steel guyed or supported to prevent collapse.
( ) Wire-mesh rolls secured at both ends to prevent recoiling.
( ) Access points at all work areas determined safe before Concrete placing begins.
( ) Silos and bulk storage bins for concrete built with tapered bottoms and equipped with vibrators to start flow.
( ) Bull float handles made of nonconductive material.
( ) Powered Concrete trowels equipped with hand-release shutoff switches.
( ) Handles on Concrete buggies not extend beyond wheels.
( ) When pump-creting is used, hose lines and discharge pipe Supported adequately and joints and connectors protected with Safety chains or by other positive methods.
( ) Cranes used to position concrete buckets; crane cable equipped with safety hook.
( ) Personnel prohibited from riding Concrete buckets—for any purpose.
( ) Placing and vibrating crews not allowed under suspended buckets.
( ) Wheels chocked and brakes set on Concrete trucks when discharging on slopes.
( ) Protective eye and face equipment worn by workers placing pneumatically-applied Concrete.
( ) Forms and shoring material are free of splits, rots, cuts, or other defects.
( ) Forms installed that wiii support all concrete loads safely.
( ) Forms stockpiled in Safe manner after stripping: nails and other accessories removed.
( ) Slings fastened securely to gang forms if forms moved by crane.
( ) Workers vacated from lower levels before forms are released and moved.
( ) Personnel not permitted to ride forms being raised or moved.
( ) Face helmets. goggles, or airline hoods worn by sand-blasting crews.
( ) Eye protection worn by finishers doing chipping or grinding repairs.
( ) Concrete heating units and accessories meet safety requirements.
( ) Heating units placed to provide safe clearance from enclosure frames and coverings.
( ) Concrete enclosures adequately lighted and ventilated.

Blasting and the use of explosives

( ) Only authorized personnel permitted to handle or use explosive..
( ) Blasting personnel required to furnish evidence of competency in handling and using explosives.
( ) Smoking. matches, open flame, sparks, firearms. and other heat-producing devices prohibited near storage magazines and during transport and use of explosives.
( ) All explosives stored in locked magazines when not being used.
( ) Storage magazines ventilated; magazines are fire resistant, weatherproof, and bulletproof.
( ) Contractors maintain inventory and use records of all explosives.
( ) Appropriate authorities notified of loss or theft or of entry into magazines.
( ) Explosives transported to jobsite in original containen.
( ) Blasting caps not transported in Same vehicle with other explosives.
( ) Signs, flags, and barricades erected and other precautions taken to ensure employee and public safety.
( ) Blasting operations restricted to daylight hours.

Figure 2-1 (cont).—Form SCS-ENG-555; **seventh page.**

( ) All personnel removed from blasting areas during electrical storms.
( ) Warning signs, 4-in. red letters on white backgrounds, "BLASTING AREA—RADIO TRANSMITTING PROHIBITED," posted on all roads within 1,000 ft of blasting areas.
( ) Radio transmitters prohibited within 100 ft of electric blasting caps.
( ) Empty explosive boxes and paper wrappings destroyed by burning.
( ) Utility companies and owners or operators of adjacent properties notified before blasting; necessary precautions taken to prevent property damage.
( ) All blasts fired electrically except in areas of extraneous electric currents.

Transporting explosives

( ) No other material, including blasting caps, transported with explosives.
( ) Vehicles are in good condition, and floors are tight with no exposed spark-producing metal.
( ) Warning signs, 4-in. red letters on white backgrounds, "EXPLOSIVES," posted on front, rear, and sides of vehicles.
( ) Charged fire extinguisher with 10 ABC rating carried with each vehicle.
( ) Vehicles not repaired or serviced in shops while carrying explosives or caps.

Loading and wiring

( ) Drill holes are sufficiently large to permit free insertion of cartridges of explosives.
( ) Tamping sticks made of wood or other nonmetallic material.
( ) Drilling or heavy equipment prohibited within 50 ft of loaded holes.
( ) Explosives loaded only in holes to be fired in next round of blasting.
( ) Blasting wires kept clear of energized electric conduits or wiring.
( ) Blasting-cap wires kept short circuited until connected for firing.
( ) Caps for single blast determined to be all of same style and manufacture.
( ) Connecting and lead wires well insulated and have adequate capacity.
( ) Number of connected caps not exceed rated capacity of blasting machines.
( ) Blasting galvanometers used to test circuits to charged holes.
( ) Adequate audible warning signals given before and after firing.

Inspection after firing

( ) Firing lines disconnected from blasting machines immediately after firing.
( ) All wires traced and checked for misfires by the blasting foreman.
( ) If misfires occur, all employees evacuated from blasting areas and kept away for 1 hour.

Blasting agents

( ) Blasting agents handled and stored properly (see Information Circular 7988, U.S.D.I., Bureau of Mines).
( ) Containers kept dry; storage areas kept well ventilated.
( ) Workers instructed to evacuate all people from jobsite if there is fire.

Field mixing of fuel-sensitized ammonium nitrate

( ) Mixing areas kept clean and free of spilled fuel oil and prills.
( ) Ammonium nitrate stored away from fuel oils.
( ) Mixing fuels determined to be less volatile than No. 2 diesel.
( ) Maximum of 8 percent fuel oil used in blasting agents.
( ) Smoking prohibited in mixing area; signs posted; "NO SMOKING."
( ) Mixing equipment grounded and bonded.
( ) Vertical holes loaded by pouring the premixed agent into holes.
( ) Safety precautions observed for wiring and shooting (same precautions taken for conventional explosives).
( ) Maximum of 1 day's production of field-mixed ammonium nitrate blasting agent permitted in or near mixing area.

Figure 2-1 (cont).—Form SCS-ENG-555; eighth page.

Material-handlingequipment
Track-type tractors and self-propelled compactors

Tractors can be "plain" or equipped with a bulldozer blade, ripper, push blocks, or front-end loader.
Fill in headings at front of form and required information below. Use check, X, circled X. or dash as appropriate in parentheses.

Description of equipment

Make _____ Model No. _____ Identification No. _____
Type of Unit _____ Year manufactured _____

Bulldozel: make _____ blade (straight or angled) _____
Ripper: make _____ number of teeth _____
Front-end loader: make _____ rated capacity _____
Earth compactor: number Of wheels or drums _____ drum width(s) _____ total weight (lb) _____

( ) Protective canopy and frame (rollover protection structure) meets structural requirements.
ROPS: manufacturer _____ model No. _____
( ) ROPS secured to unit in manner that provider adequate safety for operator.
( ) Design criteria and performance certification received for ROPS.
( ) Clearing tractors equipped with deflector guards and rear-deck screens.
( ) Guards installed on hazardous scissor paints, such as on front-end loaders.
( ) Unit equipped with quick-release seatbelts.
( ) Service brakes stop unit within one unit-length distance (unit tested at maximum speed on level ground).
( ) Parking brakes hold stopped unit completely an 15-percent slope.
( ) Unit equipped with satisfactory muffler system; noise level is acceptable.
( ) Unit equipped with two headlights and two taillights when operations require.
( ) Unit equipped with audible horn and reverse signal alarm.

Overall condition of unit _____

Inspected by _____ Date _____

Rubber-tired graders, scrapers, trucks, wagons, truck- or tractor-mounted water units, and tractors

Tractors include agriculture-type tractors.
Fill in headings at front of form and required information below. Use check, X. circled X, or dash as appropriate in Parentheses.

Description of equipment

Make _____ Model No. _____ Identification No. _____
Type of unit _____ Rated capacity _____ Year manufactured _____

Offhighway motor vehicles

( ) Unit equipped with service, emergency. and parking brakes; brake stopping and holding capacity tested with Unit fully loaded.
( ) Unit equipped with two headlights and two taillights when Operations require.
( ) Unit equipped with brake lights, audible horn, and reverse signal alarm.
( ) Unit with cab equipped with powered windshield wipers; cracked or broken glass prohibited.
( ) Heavy-duty cab shields installed in all units to be loaded by power equipment.
( ) Unit equipped with quick-release seatbelts.
( ) Dump beds equipped with positive supports to prevent lowering if beds are raised during repairs.
( ) Bed-hoist Controls equipped with safety latches to prevent accidental tripping.
( ) Vehicles equipped with fenders.

Figure 2-1 (cont).—Form SCS-ENG-555: ninth page

Earthmoving equipment

( ) Unit equipped with seatbelts (SAE J386-1969, J333a-1970).
( ) Service brakes Stop unit within distance allowed when fully loaded (see table within brake testing standards).
( ) Service. emergency. and parking brakes of a unit manufactured after Jan. 1, 1972, stop Unit within distance allowed (see table within brake testing standards for limits on service and emergency brakes).
( ) Trucks, trailers. scrapers, and tractors built with fenders if manufactured after Jan. 1, 1972, and if designed for maximum speeds over 15 milh.'
( ) Fenders added to trucks, trailers. scrapers. and tractors manufactured before Jan. 1, 1972.[1]
( ) Protective canopy and frame (rollover protection structure) meets structural requirements.
ROPS: manufacturer _____ model No. _____
( ) Design criteria and performance certification received for ROPS.
( ) ROPS secured to unit in manner that provider adequate safety for the operator.
( ) Unit equipped with two headlights and two taillights when operations require.
( ) Guards installed on hazardous scissor points. such as on frontend loaders.
( ) Manufacturer's approval required before increasing the capacity of the haul equipment.
( ) "Spinner" knobs on steering wheels prohibited except on-hydraulic power control units (knob mounted within outer periphery of wheel).
( ) Unit equipped with satisfactory muffler system; noise level is acceptable.

'Suspended Ocf. 5, 1973.

Overall condition of unit _____

_____

Inspected by _____ Date _____

Brake testing

Test-rite criteria and brake-test requirements

The Society of Automotive Engineers (SAE) has set up performance Criteria and tests for brake systems. The following paragraphs are based on their recommendations.

An area or course for brake testing must:

- Have a clean, dry surface made of concrete or other approved material.
- Be long enough to allow the vehicle to attain a uniform, stabilized travel speed.
- Have a flat reach for the braking Section with no more than a 3 percent variation from level across the reach and a 1 Percent variation in grade.
- Be equipped with enough flags or markers to mark correctly on the course where the brakes were set and where the vehicles fully stopped; the same reference point on the vehicle must be used far both measurements.
- Have accurate equipment to measure the stopping distance.

When testing the brakes. the:

- Vehicle's brake system must be at a fully charged energy level.
- Vehicle must be loaded to the manufacturer's gross weight rating or to the vehicle's maximum payload.
- Stopping distance must be measured in feet between points where the brakes were set and the vehicle fully Stopped.
- Vehicle speed when the brakes were set must Conform to SAE standards (see brake testing standards).
- Transmission gear used must be appropriate for the specified speed and load.
- Auxiliary retarders are permitted if activated simultaneously by the applicable brake control being tested.

Brake testing standards

Fill in the vehicle weight and stopping distance Obtained during testing for service and emergency brakes on the line of the appropriate weight range. Attach additional sheets if more than two vehicles per Category are being tested.

Scrapers are tested at 20 milh ISAE J319b-1971), trucks and wagons at 20 milh ISAE 5166-1971), front-end loaders and bull dozers at 15 milh ISAE J237-1971), and self-propelled graders at 18 mi/h ISAE J236-1971).

Figure 2-1 (cont).—Form SCS-ENG-555; **tenth page.**

Self-Propelled Scrapers. Trucks, Wagons, Front-End Loaders, Bulldozers, and Self-Propelled Graders

Vehicle weight range (lb)	Vehicle 1 weight (lb)	Vehicle 2 weight (lb)	SAE maximum allowable stopping distance (ft)		Vehicle 1 stopping distance (ft)		Vehicle 2 stopping distance (ft)	
			Service brakes	Emergency brakes	Service brakes	Emergency brakes	Service brakes	Emergency brakes
			Self-propelled scrapers					
up to 50,000			60	180				
50,001-100,000			70	210				
100,001-150,000			90	270				
over 150,000			100	300				
			Trucks and wagons					
up to 100.000			60	180				
100.001-200,000			90	270				
200.001-400,000			125	375				
over 400,000			175	525				
			Front-end loaders and bulldozers					
up to 36,000			28	84				
36.001- 70,000			37	111				
70,000-140,000			45	135				
140,001-280,000			53	159				
over 280,000			65	195				
			Self-propelled graders					
up to 35,000			35	105				
over35.000			45	135				

Service brakes
(primary system for stopping vehicle)

( ) Vehicle has brakes on wheels on at least one prime-mover axle and on one axle of each wagon or trailer.
( ) Service brakes stop vehicle within allowable distance (see table in brake testing standards).
( ) Brakes deliver at least 70 percent of full stopping capacity when applied three times per minute; vehicle speed conforms to SAE standards (see brake testing standards).
( ) Visual or audio warning devices function effectively when brake system energy level drops below 50 percent of manufacturer's specified Operating energy level; reliance on pressure or vacuum gages is unacceptable.

Emergency brakes
(used if service brakes fail)

( ) Emergency brakes stop vehicle within allowable distance (see table in brake testing standards).
( ) Brakes applied manually from driver's Seat position.
( ) Brakes cannot be released after application unless they can be reset immediately.

Parking brakes
(used to hold vehicle stationary)

( ) Braked vehicle (loaded to manufacturer's gross weight rating) held Stationary on hard. smooth, clean surface having a 15 percent grade

Figure 2-1 (cont).—Form **SCS-ENG-555; eleventh page**

Cranes, backhoes, and hoists

Cranes and backhoes can be track type. rubber tired. or wheel mounted.
Fill in headings at front of form and required information below. Use check, X, circled X, or dash as appropriate in Parentheses.

Description of equipment

Make or type _____ Model No. _____ Identification No. _____
Rated capacity (on plate) _____ Counterweight (lb) _____ Year manufactured _____
Boom: length (ft) _____ type Of stops _____ Bucket: size _____ type _____
Boom hoist line: size _____ condition _____ Boom load line: size _____ condition _____

Unit equipped with:
( ) Safety hook.
( ) Capacity rating plate.
( ) Boom angle indicator.
( ) Audible reverse signal alarm.
( ) Truck mount.
( ) Outriggers.
( ) Sign in cabs, "10-FT LIMITATION FROM ENERGIZED FACILITIES."

Most recent annual inspection: date: _____ name of inspector _____

( ) Moving parts guarded.
( ) Cab glass is in good condition.
( ) Enough guardrails and handrails built into unit or installed.
( ) Antiskid surfaces on platforms and walkways built into unit or installed.
( ) Exhaust system guarded; system is free Of leaks.
( ) Fuel filler pipe built or positioned to be clear of exhaust pipe.
( ) Fire extinguisher with 5 BC rating available in unit.
( ) Manufacturer's approval required before unit carrying capacity can be modified.
( ) Worker designated to tell unit Operator when powerlines are cleared if lines carry more than 50 kv.
( ) Electric-proximity warning equipment installed when required by laws or regulations.
( ) Electric ground line installed when unit is operated in vicinity of high voltage lines.
( ) Unit equipped with satisfactory muffler system; noise level is acceptable.

Test performance of main boom 1115 percent rating)

Boom load (lb) _____ Boom radius _____ Boom swing (degrees) _____
Outriggers: number _____ length (ft) _____

( ) Lifting is satisfactory.
( ) Lowering is satisfactory.
( ) Braking is satisfactory.
( ) Boom swings 360 degrees

Boom load under travel test (lb)[1] _____ Boom radius under travel test' _____
Remarks _____

Overall safety condition _____

Inspected by _____ Date _____

[1] Complete if applicable to job.

Figure 2-1 (cont).—Form SCS-ENG-555; twelfth page.

Pollution Control

The contract specifies the environmental protection measures for the project. General provisions in the contract require that "good housekeeping" he maintained. Special provisions in the contract state the limit in timing or sequence of operations. Items of work and construction details in the specification describe the measures to he constructed and provide the supplemental information needed to construct the specific job.

Before inviting bids, the project engineer must review the contract to determine that adequate measures are provided to protect the environment during construction. Drawings are to delineate access roads, temporary stream crossings, temporary stilling basins, equipment parking areas, temporary building sites, material processing areas, and storage locations. These areas must he managed and protected to prevent or minimize sedimentation or other forms of pollution.

Prospective bidders viewing the site should he alerted to the pertinent environmental protection features in the bid invitation. Structures or other control measures, specified sequences, and completion dates for installation of certain phases of the work should be emphasized.

The project engineer, the contract specialist, and the contractor must thoroughly review the contract during the preconstruction conference to make certain the contractor understands the environmental protection requirements. A review of the contractor's construction schedule, plan of operation, and procedures is necessary to be sure all will adequately protect the environment.

All erosion and sediment control features, both permanent and temporary, must he installed in a timely manner in accordance with the contract. Proper planning and scheduling of construction activities are major factors in controlling erosion and sediment pollution. Activities should be clearly shown in the contractor's proposed construction schedule. The project staff must not allow construction operations that cause excessive soil erosion or sediment pollution during any phase of the contract work.

All earth and soft or broken rock areas disturbed by construction operations, such as stripping, excavating, or traffic, are vulnerable to erosion by concentrated runoff, falling rain, or wind action. Concentration of runoff on or across slopes must he prevented. Channels, ditches, deflector dikes, berms, or diversions that will effectively intercept and safely transmit surface flow to nonerosive outlets must be installed as early in the project as practical. The use of construction equipment in a manner that increases erosion potential must he avoided. Wheel tracks or ruts, particularly downslope, permit the concentration of surface flows that result in excessive erosion. Fording of streams stirs bed materials and damages aquatic habitat.

Use of water from a stream or impoundment for construction can alter the temperature of the remaining water enough to affect aquatic life.

The project engineer must know state and local laws for burning of cleared or other combustible material. Firebreaks or other firecontrol measures must be installed before beginning any activity that may create a hazard.

Toilet facilities meeting safety and health regulations must be provided at locations accessible to all construction personnel on the job. Pit toilets, if permitted by state or local ordinances, must be properly located and maintained to prevent contamination of all water sources. Toilets must he provided by the start of work.

During construction operations, the project engineer must see that public access, construction haul roads, and the construction site in general are adequately treated with water or other suppressant to control dust. Dust is a hazard to both safety and health. In addition to SCS requirements, state and local laws impose air pollution standards. These standards may require measuring and recording air pollution levels.

Excessive noise levels in the contractor's operation can cause physical harm to project personnel and annoyance and inconvenience *to* those working or living near the project. The job-noise level must be kept within the limits specified in the contract. If administrative or engineering controls fail to reduce the noise to acceptable levels, the contractor must provide personal protective equipment for employees.

Chemical pollutants, such as drained oil and grease, asphaltic materials, soaps and cleaning detergents, and other harmful materials, must be stored in closed metal containers, tanks, barrels, sumps, or other acceptable facilities. If there is a possibility of ground-water or stream pollution, sumps must be lined with plastic or other impervious material. After work is completed, containers are removed from the site and open sumps are carefully filled.

Discarded waste paper, shipping bags, sacks, cartons, and other debris resulting from the contractor's operations are to be stored in closed containers and disposed of off the site or as directed by the project engineer. Household garbage created by the contractor or his employees at the construction site must be stored in fly-tight containers, collected, and disposed of in accordance with local sanitary requirements or as otherwise directed.

At all times the construction staff should strive to maintain or enhance the natural beauty at the construction site. Because most construction operations adversely affect the beauty of the surrounding area, each employee should be alerted to avoid unnecessary alteration.

Construction yards, parking areas, construction offices, material storage and processing sites, and other similar areas should be located, arranged, and managed to serve their functional purpose with the least adverse effect on the visual appearance of the locality. Trees should be felled in a manner that will not damage other vegetation.

If a serious environmental hazard develops during Construction, the project engineer must limit the contractor's work until the needed control can be instituted. The limitation might apply to clearing, burning, excavation, embankment construction, material processing, or other items. Control measures necessary might include stream crossings, sediment basins, slope drains, diversions, fine grading, seeding, mulching, or various temporary or permanent treatments.

The contracting officer should modify the contract as necessary to direct the contractor to install additional temporary or permanent pollution-control measures.

Inspection checklist: pollution control

(Some items may not be listed. Some listed may not apply to every project.)

1. Surplus scrap and debris—currently removed.
2. Equipment storage and maintenance sites—orderly, safe.
3. Sediment basins—location, size, timing of installation, effectiveness, vegetation or mulching, maintenance, removal.
4. Access haul roads—location, design, construction, culverts or bridges, erosion protection, maintenance, removal.
5. Dust control—access roads, haul roads, other areas of site.
6. Clearing and grubbing—location, amounts, timing, disposal.
7. Burning of debris—limitations, conditions, methods, fireguards.
8. Stream diversion—design, erosion protection
9. Dewatering system—design, operation.
10. Diversions, terraces, and berms—design, location.
11. Side inlets—design, timing of installation
12. Stripping—timing, area limitation, erosion control, finish.
13. Borrow areas—timing, area limitation, erosion control, finish.
14. Vegetation—temporary, permanent, seeding mixtures, seedbed preparation, fertilizer or soil amendments, rate of seeding, irrigation.
15. Mulch—kind, amount, method of application
16. Chemicals (oils, grease, etc.1-containment, disposal.
17. Toilets—number, location, type, maintenance
18. Wells or pipelines—plugging, removal
19. Water quality—monitoring.
20. Litter and garbage—containment, disposal
21. Noise level—measurement, abatement, protection.

Clearing and Grubbing

Clearing and grubbing are usually the first items of work performed. If carefully done and properly sequenced, the impact on slope stability, erosion, and desiccation is minimal. If carelessly done, clearing and grubbing can add to the cost of operating and maintaining the project.

Before clearing and grubbing start, the project engineer or inspector should review the clearing and grubbing limits with the contractor. At the same time, they can consider utilities that could be damaged, methods of operation and disposal, and any stakes, trees, buildings, fences, or facilities to be saved or protected.

Inspection checklist
clearing and grubbing

(Some items may not be listed. Some listed may not apply to every project.)

1. Clearing and grubbing—marking
2. Fence to be removed—marking.
3. Salvage material—disposal.
4. Trees to be protected or salvaged—marking.
5. Logs to be salvaged—properly cut, piled, decked.
6. Stumps—specified height
7. Stump removal—specified depth, hole back-filled.
8. Structures and utilities—marking, protection.
9. Explosives—proper storage, blasting plan.
10. Safety—hand tools, power tools, intervals between workmen, protective canopies on tractors, protection for workmen on steep slopes, slippery terrain, rock outcrops.
11. Burning—regulations, methods, time, protection (fire control).
12. Disposal—location, complete.
13. Record—quantities, job diary.

Structure Removal

Site preparation often requires removing or relocating public utilities such as telephone, power, water, and gas lines. The organization owning or operating the utility normally does this work. Unless otherwise specified, the contractor is responsible for protecting and safeguarding all utilities within the work area during the work. The project engineer should check to be sure that safeguards are in force.

Structures or obstructions may need to be removed and salvaged or disposed of if they interfere with construction or impair the usefulness of the proposed structure. These obstructions may be bridges, buildings, culverts, foundations, wells, debris, or other manmade features.

The contractor must clearly understand which structures to remove and what to do with them. Contract drawings and specifications are to show the disposition of all known obstructions. Since details for demolition and removal usually are not specified, the inspector may need only be concerned about compliance with safety and fire requirements, salvage or disposal, and protection of other elements of the work. Salvaged material is inventoried, delivered, and stored as directed in the contract.

Progress as well as any instructions or interpretations given the contractor are recorded in the job diary.

Inspection checklist
structure removal

(Some items may not be listed. Some listed may not apply to every project.)

1. Utilities—shown on drawings, identified in field, removal, disposal, areas restored.
2. Utility owner—notified of construction, requested to mark or move utility, requested to be present for work.
3. Contractor—knows utility location, safeguarded.
4. Unidentified utility or obstruction—advise contracting officer.

5. Other elements of work—safeguarded.
6. Safety—workmen, ,public, signs, lights, barricades.
7. Record—quantities, job diary.

Earthwork

The inspector on earthwork operations must be familar with the lines, grades, and typical sections shown on the drawings; with the specifications that control the work; and with the staking procedures used on the project. He or she is to carefully review the geologic, soil mechanics, and design reports and other information, such as test pits and rock cores, relating to the foundation and to the removal and placement of material. The inspector must know the extent and intent of excavations and the specified use of the excavated materials. As the work progresses, he or she arranges for surveys needed to measure quantities. The inspector sees that earthwork is properly graded and drained at all times. Inspection includes periodic checks of the alignment and grade of excavations and embankments to be sure they comply with contract requirements and making and recording those tests necessary to verify compliance with specifications. Normally, excavation and earthfill are bid schedule items, each with its own method of measurement and payment.

The excavation is classified as common, rock, or unclassified. It is further classified as foundation, structural, and borrow.

Quantities of earthwork are computed from measurements taken in accordance with contract requirements. The variability of most geologic deposits and formations almost insures that construction quantities will differ from design estimates. It is rarely possible to conduct so extensive a site investigation as to fully define all geologic or depositional detail. Consequently, changes in type or classification of excavation may be necessary.

The inspector must recognize these variations so that timely measurements can be made. If the variation in estimated quantity exceeds 15 percent or if there is a change in the work or site. (General Provision clauses 3 or 41, measurements of the affected items will be needed. The contractor must not be allowed to do the "changed" or excess work until the contract has been modified.

Since conditions may change gradually as the work progresses, the inspector must know where changes might occur and be alert to recognize them. He or she should also know when a change affects other elements of the structure to the degree that the design is no longer adequate. By reporting any apparent change to the project engineer immediately, this effect can be verified and proper action taken.

The inspector should know the capabilities and limitations of the contractor's equipment, plan of operations, and proposed methods of performing unique items of work, such as drilling, blasting, and site dewatering. The inspector is not to require specific methods or equipment unless they are specified in the contract. It is the contractor's prerogative to provide the type of equipment he or she considers most efficient and economical. The contractor's choice depends on the nature of the material being excavated, grades to be traveled, length of haul, working room, cost, and availability.

Excavation

Earth, rock, or other materials are removed to the lines and grades as shown on the drawings or as staked in the field. The inspector must know these requirements, especially those for the foundations of embankments and subgrades of the structures, and be able to recognize conditions that may require a change in extent or location. He or she also must recognize latent conditions that are different from those described in the contract.

The classification and estimated amounts of excavation are summarized in the contract. If foundation conditions or excavated materials differ significantly from those shown in the drawings or laboratory reports, the inspector is to inform the project engineer immediately.

Disposal of Excavated Material

To the extent needed, all suitable materials from specified excavations are to be used in construction of the required earth or rock fills. If specified, the top soil must be removed and stockpiled in the designated locations.

Unsuitable or surplus excavated material is disposed of at the locations and in the manner set forth in the contract. Usually, waste or surplus materials are spread uniformly with consideration for drainage and appearance and are not compacted. Wet materials that are otherwise suitable can be stockpiled for use after drying. The inspector must require the removal and disposal of unsuitable materials, even though this was not originally planned or anticipated and even though it may require that the contract be modified.

Blasting

Since blasting is hazardous, the inspector must be especially diligent in seeing that the contractor stores, transports, and handles blasting materials in accordance with safety regulations and local governing codes, in addition to meeting excavation requirements.

Blasting operations that loosen rock outside the planned subgrade or slope lines are generally objectionable. Although the depth of holes is frequently extended a short distance below structure subgrade or slope to eliminate the need for secondary blasting, the blasting of areas much below grade or the overloading of powder may seriously damage foundations. The inspector can check the contractor's operations by plotting depth, direction, and spacing of the holes on cross sections. Or the inspector can mathematically calculate the relation of the holes to the finish grade to be sure they are not too deep. Unless specified differently, the depth of each hole and the amount and strength of the powder used are recorded for example, *4* sticks, 60-percent blasting powder at Sta: 3+92, 10 ft right of centerline at 3.9-ft depth.

Borrow Areas

Borrow areas are selected and approved in the design phase. Their locations are shown on the drawings unless the contract makes the locating and furnishing of borrow the contractor's responsibility.

The inspector is to check borrow areas to verify that adequate quantities of a suitable borrow material are available, the site has been properly cleared, and provision has been made to dispose of unsuitable material. In determining that adequate material is available, the shrinkage of any fine-grained soils taken from the "bank" to the "compacted embankment" condition or the bulking of blasted rock (bank to embankment) must be taken into account. If the borrow quantities do not appear to be adequate, the inspector must advise the project engineer immediately. If the borrow material is included as a pay item, cross sections will be required before and after removal to determine the quantity of borrow material excavated. Borrow areas must be graded and drained as specified.

Diversion and Control of Water

Methods and equipment used to divert streamflow or to dewater the site can affect the stability of the subgrade or foundation and its ability to safely support design loads. The contractor is responsible, unless otherwise specified, for designing and building needed diversion works. The contractor must provide the equipment and operate it in a manner that keeps foundations, structures, and borrow areas free of excess water. The inspector is to check diversions and dewatering installations and operations to be sure that the project site is dewatered or protected adequately.

Foundation

A properly prepared foundation is essential for a safe and effective structure. The foundation must support the structure, and the structure must be bonded to the foundation. Conditions to watch for are slippage planes, soft unstable materials, and free water from seeps or springs.

Foundations fail when:

- Foundation material is displaced by the structure.
- The foundation consolidates at different rates or to different degrees, cracking the embankment or breaking the bond with the structure.
- The strength of the foundation decreases significantly when saturated.
- Slippage planes in the foundation cause displacement.
- Permeable strata in the foundation permit seepage, causing an uplift pressure or a loss of water.

The abutment areas of the foundation are frequently the most difficult to prepare properly. Unless talus material, slippage planes, and rock surfaces are given special attention, they may be covered up during construction and not be treated properly. Foundations should be scarified, have moisture added when needed, and be compacted to the specified density.

Fat clay soils and some clay shales change volume measurably during wetting and drying. It is imperative they not be permitted to lose moisture. If already desiccated, it may be necessary to add moisture before proceeding with construction. The rate of the wetting and the time allowed for a thorough distribution of the moisture depends on the response of the soil. Covering the material, excavating the final few inches just before backfilling, maintaining the moisture level artificially, and rapidly placing the initial stages of the embankment or structure are all methods of alleviating moisture loss.

Rock foundations must be cleaned carefully to permit a satisfactory bonding with the embankment or structure foundations. Earth and weathered material may have to be removed from the surface and from any cracks or crevices. Washing and brooming may be necessary, particularly where concrete mixtures are to be applied. Overhanging rock or other undesirable formations should be removed or corrected by filling with concrete so that direct contact with the structure is ensured.

Under certain conditions, the subsurface area below the foundation must be grouted. The location, depth, and mixtures of the grout materials needed will be indicated on the drawings and specifications. Each location presents a distinct problem, and changes or additions may be required as the work progresses.

The inspection staff is to check and approve all foundations before the earth embankments or other structural materials are placed.

Inspection checklist: earthwork

(Some items may not be listed. Some listed may not apply to every project.)

All excavations

1. Limits—clearly marked.
2. F'reconstruction measurements—complete.
3. Stripping and cleanup—area, depth, disposal of materials.
4. Excavated foundation material—as anticipated in design, significant differences considered with engineer.
5. Subgrade—satisfactory surface, density, elevation.
6. Dewatering, drainage, and diversion systems-meet requirements.
7. Oversize rock, loose rock, and roots, etc.-removal, disposal.
8. Cavities or depressions—cleaned, properly filled.
9. Scarification, moisture, and compaction—meet requirements.
10. Final grade and finish grade—meet specifications.
11. Final measurements—complete.
12. Record—quantities, job diary.

Additional items for rock excavations

1. Drilling plans, blasting plans, and personnel-approval.
2. Storage, handling, and use of explosives-proper procedures, meet codes and safety requirements.
3. Protection of public—meets requirements.
4. Protection of surrounding area—meets standards.
5. Blasting areas—limits not exceeded.
6. Rock foundation—cleaned, moistened for dental grout.
7. Dental grout—complete, cured, protected.

The availability and quality of material and the foundation conditions are major factors in determining the type of dam that can be economically constructed at a given location. Most dams in SCS projects are constructed of soil or rock, or a soil and rock combination.

The inherent variability of earth materials requires a greater tolerance in design and construction than for most other construction materials. Materials range from fine-grained soils (50 percent or more passing a No. 200 sieve) to rocky soils (predominantly gravel and cobbles) or combinations of these. The kinds of soil available at a site, their engineering properties, and the purpose of the structure directly influence the design.

Homogeneous embankments (single zone) are generally designed for sites having materials of about the same gradation and properties. Multiple-zoned embankments may be designed if there are two or more different kinds of soil. The inspector must be sure that the material being placed in the embankment meets specifications. If there is significant variation in the material from that in the boring logs, the design engineer should determine if the material is suitable.

The proper use of earth as a construction material requires special attention in selection, moisture control, and compaction. Specifications are written and must be complied with explicitly to obtain the best quality embankment possible.

Inspection of embankment construction requires knowledge, experience, and judgment, plus the exercise of authority to ensure compliance with the specifications.

Embankment Construction

Earthfill

Material requirements.—Normally, embankments are constructed from the most suitable materials available at or near the site. The physical properties of these materials must be analyzed to determine their characteristics, such as permeability, strength, and compressibility. Well-established laboratory and field tests have been developed for this purpose. Interpretation and evaluation of test results predict the suitability of the material for the type of structure planned.

The Unified soil classification system, developed by the U.S. Army Corps of Engineers and U.S. Department of Interior, Bureau of Reclamation, has been adopted by SCS as a standard for all engineering work. This system is published as ASTM **D–2487.** ASTM **D–2488** provides field methods for classifying soils in accordance with the Unified system. All SCS engineers and inspectors working on construction must be familar with the classification system and the procedures outlined in these standards.

In the Unified system, soils are classified according to their texture, plasticity, and performance as construction materials. The engineering properties of soils pertinent to the satisfactory performance of an earth embankment are (1) shear strength, (2) deformability, (3) resistence to piping, (4) compressibility, and (5) compactibility. For structures designed to store water, another important property is low permeability.

An example of how the Unified system can be applied to engineering uses of materials is shown in table **2–1.**

The four properties shown are permeability, shearing strength, compressibility, and workability. The relative desirability of the soils in rolled earth dams, channel sections, and foundations is indicated by a numerical rating ranging from **1** as the most desirable to **10** as the least desirable.

Classifying soils according to the Unified system alone does not always provide enough information to predict soil performance. Gravelly and stony soils used as compacted embankment material have been classed by SCS in three groups and three subgroups on the basis of the durability of the coarse rock and soil material. The details of this classification and its use are explained in SCS Technical Release No. **26,** "The Use of Soils Containing More Than **5** Percent Rock Larger Than the No. **4** Sieve" (December **1964).**

Embankment details in the construction drawings and specifications are generally based on the laboratory tests of samples taken from the foundation and borrow areas at the structure site. The inspector must determine (1) if materials being placed in the embankment differ significantly from the test samples and (2) that, for zoned fills or selective placement, specified materials are routed to correct locations in the embankment.

Control of materials and placement.-Materials are selected, placed, and compacted uniformly in each zone or in a gradual transition between zones in accordance with the contract

requirements. The addition of water and the blending of embankment materials must be inspected carefully.

Before placing any structure or fill material, the subgrade and all trenches in the foundation must be inspected to ensure that they meet specifications. Some soils tend to shrink and crack when exposed to the air. If the foundation soils become dry and cracked, they must be removed and replaced or reworked with moisture added as necessary to ensure a competent foundation.

Unless otherwise permitted in the specifications, the foundation must be free of surface water when the earthfill is placed. Earth materials are spread in loose, approximately horizontal layers to depths not exceeding specified limits. All roots, vegetative growth, oversize rocks, and other debris that may have been brought to the embankment must be removed. Any large hard lumps or masses of soil must be pulverized by disking, harrowing, or other means and brought to the proper moisture content before compacting. The inspector is to make sure that a new lift is not placed on a smooth or frozen surface and that snow, ice, or frozen materials are not mixed with the fill materials. All lifts must be well bonded.

During construction, the embankment top surface must be maintained approximately level with just enough slope for the drainage, regardless of the number of zones or the types of earth material. Unless otherwise specified, this slope should drain upstream.

Moisture control.—Each soil mixture has a specific moisture content at which a given compaction effort will produce the maximum density. Soil density increases up to a point as the water content is increased, then decreases as more water is added. The water content at the point of maximum density is the optimum moisture content for that soil mixture at the compaction effort.

The maximum density is related to the compaction effort. For most soils as the compaction effort is increased, the maximum density increases and the optimum moisture content decreases. A moisture density curve can be drawn for each compaction effort for any given soil. Moisture content (percent of dry weight) is plotted as the abscissa, and density of compacted soil (pounds per cubic foot) as the ordinate (fig. 3–50). Test procedures and methods for preparing moisture density curves are presented in ASTM D–698 and D–1557.

The moisture content of the fill materials must be carefully controlled. Moisture can be added or removed much more effectively and efficiently in the borrow area. Both processes take time for good distribution of the moisture throughout the soil mass. By working in alternate borrow areas the production is not delayed. If moisture is added or removed on the embankment, it is very difficult to keep the rate of placement low enough to get proper distribution and the process of mixing or aerating is very costly. Inspection and testing then become more critical. It is possible to have the proper moisture content without good distribution.

The contractor is responsible for controlling the moisture content and density of the embankment and backfill materials. Historically, SCS has permitted the contractor to base this control on SCS testing. The contractor can also make his or her own tests. Figure 2–2 is a quick reference for estimating the number of gallons of water required for a given soil to increase the moisture content one percent. The dry density of the material must be known or estimated.

Compaction.—Contract specifications state the degree of compaction or the type and performance of the compaction equipment needed. They specify the rock and soil materials to be used and the tests to be performed.

Systematic placing and processing are necessary to be sure that all materials have the proper moisture and compaction.

If the surface of the embankment is allowed to dry out or attain a smooth, glazed condition during construction, the next lift will not bond with it. If a bond is weak, a 1- to 2-in. vertical slice of the compacted fill removed by a shovel will always break at the contact of the lifts.

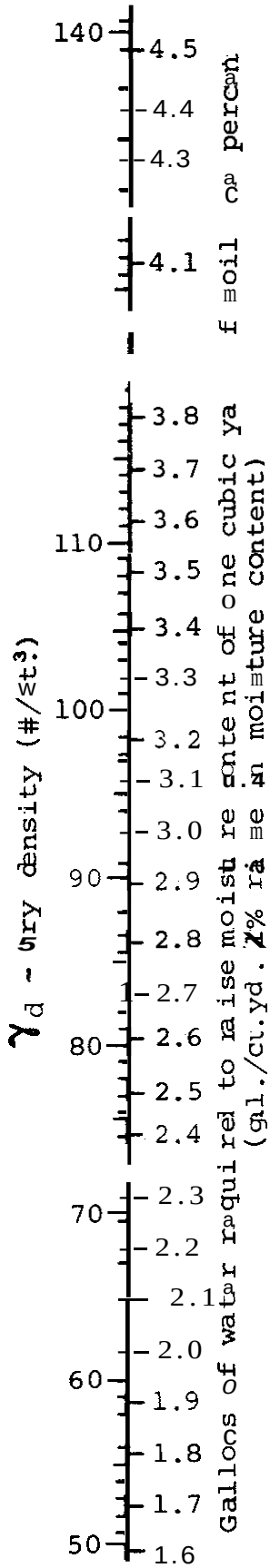
If a ramp is to provide access to the embankment, it should be insulated from the embankment by a few feet of the material to avoid a high density at that location.

Manually directed tampers or other approved equipment is used to compact parts of the embankment not accessible to heavy rollers. The lift thickness should be reduced to that specified for the backfill.

After a temporary or seasonal shutdown, the moisture and density of the surface of a partial fill must be checked for compliance. It may be necessary to recondition or remove part of the material before resuming placement operations.

Table 2–1.—Engineering use chart (from "The Use of the Unified Soil Classification System by the Bureau of Reclamation" by **A. A.** Wagner, an article published through the Bureau of Reclamation, USDI, Denver, Colorado)

Typical names of soil groups	*Croup ymbofs*	*Important properties*				*Relative desirabil for various uses*						
						Rolled earth dams			*Canal sections*		*Foundations*	
		Permea-bility when compacted	*Shearing strength when com-pacted and saturated*	*Compress. bility when com-pacted anc saturated*		*Homo-geneous embank-ment*	*Core*	*Shel*	*Erosior resist-ance*	*Com-pacted earth lining*	*Seepage im-portant*	*Seepage not im-portant*
Well-graded gravels gravel-sand mixtures, little or no fines	*GW*	pervious	excellent	negligible	excellent	—	—	1	1	—	—	1
Poorly graded gravels, gravel-sand mixtures, little or no finer	*GP*	cry perviot	good	negligible	good	—	—	2	2	—	—	3
Silty gravels, poorly graded gravel-sand-silt mixtures	*GM*	mi-perviot , imperviot	good	negligible	good	2	4	—	4	4	1	4
Clayey gravels, poorly graded gravel-sand-clay mixtures	*GC*	imperviou	good to fair	very low	good	1	1	—	3	1	2	6
Well-graded sands gravelly sands, little or no fines	*SW*	pervious	excellent	negligible	excellent	—	—	3 if gravel	6	—	—	2
Poorly graded sands, gravelly sands, little or no fines	*SP*	pervious	good	very low	fair	—	—	4 if gravel	7 if gravelly	—	—	5
Silty sands, poorly graded sand-Silt mixtures	*SM*	mi-perviou imperviot	good	low	fair	4	5	—	8 if gravelly	5 erosion critical	3	7
Clayey sands, poorly graded sand-clay mixtures	*SC*	impervious	good to fair	low	good	3	2	—	5	2	4	8
Inorganic sills and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	*ML*	mi-perviou , imperviou	fair	medium	fair	6	6	—	—	6 erosion critical	6	9
Inorganic clays of low to medium plasticity, gravelly clays. sandy clap, silty clays. lean clays	*CL*	mpervious	fair	medium	good to fair	5	3	—	9	3	5	10
Organic sills and organic silt-clays of low plasticity	*OL*	mi-perviou impervious	poor	medium	fair	8	8	—	—	7 erosion critical	7	11
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	*MH*	mi-perviou impervious	fair to poor	high	poor	9	9	—	—	—	8	12
Inorganic clays of high plasticit fat clays	*CH*	mpervious	poor	high	poor	7	7	—	lo	8 volume change critical	9	13
Organic clays of medium to high plasticity	*OH*	impervious	poor	high	poor	10	10	—	—	—	10	14
Peat and other highly organic roils	*PI*		—	—	—	—	—	—	—	—	—	—



This graph can be used to arrive at the gallons of water of the material at the time the water is added. (In-bank density, loose density, or compacted density.)

EXAMPLE: Material has a moisture content of 14%. Optimum moisture content is 20%. Water is to be added to material on fill. Estimated density at time water is added is 100#/ft.³ How much water will be required to raise moisture content to optimum?

From Graph: 3.24 gal./cu.yd./1% increase in moisture content where density = 100#/ft.³

Water Required: 3.24(20-14)= 19.4 gal./cu.yd.

Moisturedensity determinations.—The contract specifies tests for determining the density of the soil in place. The moisture content is usually specified in a range near optimum, and the density is specified as a percentage of the maximum for the moisture-density relation.

The inspector must know that materials being placed in the fill are the same as the samples tested in the laboratory. In some soils, field classification alone confirms this. But generally, borrow materials are so variable that moisture-density relations must be determined frequently as the work progresses. If the field test values vary significantly from those used in the design, the inspector must inform the engineer immediately.' Field density tests made on the compacted fill should verify that fill densities at all times equal or exceed the percentage values cited in the specifications. For some materials a maximum density may be specified.

More frequent density tests of the inplace fill should be taken at the start of the work so that the inspector can quickly become experienced in judging the behavior of the materials and their reactions to the compaction, and in evaluating the consistency and effectiveness of the contractor's operation.

The number of inplace density tests needed varies and is largely a matter of judgment based on the contractor's operations and on test results. At the start of the work the project engineer should plan the minimum number of moisture-density tests required for the various zones and locations on the project. Since these moisture-density tests verify acceptable performance, the minimum should be one test for each work shift. Borrow material, operating conditions, and other variables may warrant more frequent testing. Some critical areas are those near structures, in cutoff-trench backfills, in material compacted by manually directed tampers, and at contacts with abutments.

Parts of the fill not meeting the specified density must be corrected by (1) removing and replacing the fill, (2) scarifying, correcting the moisture content, and recompacting the fill, and (3) additional rolling.

Insufficient compaction can occur most easily at areas where:

- There are junctions between mechanically tamped and rolled parts of the embankment along abutments, pipe conduits, risers, or other restricted locations.
- Rollers turn during compaction operations.
- Too thick a layer is placed.
- The moisture content of the material is not correct.
- Insufficient roller passes are made.
- Dirt-clogged rollers are used.
- Oversize rock is overlooked.
- Materials are placed at near-freezing temperatures or contain minor amounts of frost.
- Rollers lose part of their ballast.
- Materials differ substantially from the average.

Overcompaction can be just as bad as insufficient compaction. Overcompaction caused by the travel of haul equipment or by other construction operations should be avoided.

Accurate locations must be recorded for each field test. The location and number of each test should be marked on the plan and profile drawings of the structure to facilitate representative sampling of the total embankment. If a test indicates that the fill does not meet specifications, at least one additional check test must be made close by to verify results of the first test before the contractor is advised that the fill does not meet specifications. The limits of unsatisfactory fill should be defined. The reworked material should be tested.

Forms, **SCS-ENG-530,** B through **I** (fig. **3–14, 3–15, 3–19, 3–29, 3–30, 3–34, 3–35,** and **3–40),** and **SCS-ENG-532** (fig. **4–11,** are appropriate for recording these tests. Job diary entries must note unsatisfactory tests, citing the test number, results obtained, and corrective actions taken.

Coarse-Grained Soils

Materials that contain **5** percent or more gravel and cobble retained on a No. **4** sieve are termed coarse-grained soils. Compaction-control methods for these soils may be different from those used for fine-grained soils.

'Field procedures for determining the density of soil in place are outlined in Chapter 3.

The drawings and specifications are to show the:

- Source and type of the materials.
- Location for placing the materials
- Maximum thickness of the uncompacted layers.
- Maximum size of the rock.
- Compaction method (usually the number of passes of a specified type and weight of compaction equipment).
- Limits, if any, on the moisture content for compaction.

The drawings will show the specified zones where coarse-grained soils are to be placed. Materials must be thoroughly mixed so that fines are distributed throughout the mass.

The moisture content of the coarse-grained soils may or may not be critical, depending on the fines in the material. If the fines are noncohesive, excessive moisture generally has little effect on compaction. Usually, coarse-grained soils compact best when dry or completely saturated. Sand placed at certain low-moisture contents tends to bulk, which can seriously affect the density of the compacted soil. Bulking can be overcome by altering the moisture content or by using vibration for the compaction. If the fines are plastic, the best compaction is attained when the moisture is at or near optimum.

If no density is specified, compaction is controlled by the method of placement. Occasional density tests on large samples are helpful in evaluating the effectiveness of the compaction method.

Rock

Rockfill consists of rock fragments that are reasonably hard, durable, and larger than gravel-size material. Generally, rockfill contains little or no sand and finer earth materials.

Drawings and specifications are to show where rock materials will be placed. They may include rock type, thickness of lifts, gradation, maximum size, and percentage of fines.

Usually, materials are dumped on the compacted lift and then spread uniformly. Compaction equipment must meet job requirements. Clustering or nesting large stones must be avoided, and adequate spalls or gravel materials must be available to fill large voids. If rock is placed in conjunction with earth or filter zones, the construction procedure should be such that the earth and rock materials do not intermix.

Test Fills

Test fills may be needed to provide workable design values and construction control specifications for soil with more than 35 percent hard durable rock that is retained on a No. 4 sieve. Usually, mass density is the basis for compaction control of these materials. Mass density varies with the amount, size, and shape of rock particles, with the plasticity of the matrix materials, and with the compaction applied. The size of rock in the materials to be used often exceeds the maximum size that can be tested in the laboratory.

Theoretical adjustments in density to account for oversize rock can result in density predictions that are not realistic. Test fills overcome this problem and provide a sound basis for design and construction control.

Test fills are almost essential to determine design values and Construction controls for soils having shale, sandstone, and other degradable materials that are retained on a No. 4 sieve.

The density of degradable coarse-grained soils varies with the amount of breakdown or degradation achieved with the construction equipment. Shear strength and permeability also depend on the degree of breakdown achieved. If test fills are specified, procedures for constructing will be stated in the contract. Some of the following may apply:

- Place material from the proposed borrow sources in the test fill. If this is not possible, such as in deep cuts for emergency spillways, take material from adjacent identical deposits that are exposed and available.
- Whenever practical, construct test fills in locations that can be incorporated into the final embankment.
- Make sure the test fill is at least 2 ft thick before testing. When building on a soft foundation, make sure the test fill is at least 4 ft thick before testing.
- Make test sections at least 30 ft wide and 200 ft long to provide realistic space for the placement and rolling.

- When testing and evaluating test fills:
  - Determine the gradation of the material before and after compaction.
  - Determine the inplace *dry* density of the mass.
  - Keep detailed records on the type and kind of processing used, compaction equipment used, number of passes, lift thickness before and after compaction, equipment performance, wetting or drying, borrow excavation, and sequence of operations on the fill.
  - Collect undisturbed cores or hand-cut samples of shales, sandstones, or other degradable material from the test fills.
- Reference all tests pertaining to the final product at a specific location to the same immediate area and elevation; that is, make gradation samples before and after the compaction, make inplace density tests, and take core samples as close to the same station and elevation as possible.
- Test at least four locations for each change in the material or variance in the type or performance of the equipment. Place test areas at least *25* ft from the ends and *5* ft from the sides of the fill.
- Sample and test material in the lift below the surface lift. In some soils, it may be necessary to sample deeper than this to measure compacted properties of the fill.
- Make tests in at least three separate lifts of material.

Backfill Construction

Backfilling is the placement of the various types of earthfill needed for the installation of such features as concrete structures, pipelines, and culverts. Backfill materials are supplied from the required excavation or specified borrow areas.

Testing for backfill requiring density control is done in the same way as on compacted embankments. Cohesionless, free-draining materials usually are placed according to a specified procedure and may not require density testing. The quality of materials, moisture control, and compaction is usually given in the same way as the requirements for the placement of embankments.

Generally, the control techniques outlined previously for the embankments, including records and reports, also apply to the backfill. Placing compacted backfill to meet a specified density requires careful inspection of the materials, amount and uniformity of moisture, gradation, and layer thickness. All backfill must be placed to the lines and grades shown on the drawings.

When backfilling around and over structures, the contractor must conform to the specified time and loading limitations.

Finishing

Embankment and cut slopes must be dressed to the lines and grades that are specified or are staked in the field. All cut-and-fill surfaces should be smooth and pleasing in appearance. All stones, roots, and other debris must be removed from the site or disposed of as required.

If specified, topsoil is spread as a top dressing on the embankment, cut slopes, and other disturbed areas to provide a seedbed for vegetation. More favorable bonding of the material is obtained on the embankment slopes if the topsoil is placed during construction rather than after the embankment is finished.

Inspection checklist: embankments and backfill

(Some items may not be listed. Some listed may not apply to every project.)

1. Preconstruction measurements—complete.
2. Stakes—set, marked.
3. Excavations—proper limits.
4. Dewatering—drainage, diversion systems
5. Access and haul roads—properly located and constructed.
6. Haul ramps—sufficient depth (prevents uneven compaction).
7. Fill materials—properly blended, within zone limits.

8. Frozen materials—none.
9. Lift thickness—as specified.
10. Moisture requirements—satisfied.
11. Foundation or embankment surface—conditioned for bonding, grades, density.
12. Oversize stones, roots, and debris—removed, disposed of.
13. Embankment surface—approximately horizontal, sloped for drainage.
14. Moisture-density—as specified.
15. Moisture-density relations—appropriate for materials.
16. Embankment section—line, grade.
17. Concrete strength—adequate for backfill.
18. Rock and coarse-grained materials—gradation, quality.
19. Rock zones—equipment, method, thickness, gradation.
20. Topsoil—composition, thickness.
21. Final grade and finish—as specified.
22. Final measurements—complete.
23. Record—tests, quantities, job diary.

Concrete is used as a construction material in a wide variety of structures. Since the quality of the concrete depends largely on the workmanship, all phases of the concreting operation must be inspected carefully. The size of a job is not a true index of the complexity. Some small jobs may need closer inspection than large ones.

Because many excellent publications relating to concrete design, manufacture, and placement are available (see Chapter 5, Concrete), most of the discussion in this handbook is confined to various inspection phases that pertain to the actual construction.

Job Requirements

Contract drawings and specifications designate the concrete class, admixtures, procedures for quality control, and control of the mixture. General requirements for the strength, uniformity, durability, water tightness, resistance to wear, exposure, and other destructive agents of concrete are considered in the design. These requirements are satisfied by a careful selection, proportioning, and gradation of the aggregates, by control of the water-cement ratio, and by use of the proper methods of mixing, placing, and curing.

Three general types of concrete construction are formed work, slabs, and mass concrete. Quality of formed concrete is complicated by the limited space into which the concrete must be placed and by restrictions imposed by the reinforcing steel. It is extremely important that the concrete be properly vibrated and spaded so that it is dense, smooth, and free of honeycombing. In slab construction, the surface must be finished and properly protected when the concrete is placed. Special problems with mass concreting are controlling the temperature caused by the heat of hydration and securing a bond between consecutive lifts.

Control of Concrete Mixture Proportions

Water-Cement Ratio

Concrete is a mass of relatively inert aggregates bound together by a paste of chemically active cement and water. The strength of concrete depends largely on the quality of the cement and water paste. As the paste is diluted, the strength and

durability of the concrete are reduced. Designing a concrete mixture, therefore, consists of (1) selecting the water-cement ratio (gallons/bag of cement) that produces concrete of the desired strength and resistance to exposure and (2) finding the best combination of aggregates for workability and economy. The water-cement ratio expresses the total available water. Often aggregates, particularly sand, contain free water. This free water must be included, and the amount of water added must be adjusted. The mixture usually is designed with the lowest water-cement ratio that will meet project requirements. Inspectors must be sure that excess water is not introduced into the mixture, regardless of its source.

Workability

Workability is a measure of the effort with which the ingredients of concrete can be mixed, placed, consolidated, and finished satisfactorily. A workable mixture has a uniform character and plastic consistency. Well-graded aggregates, entrained air, and certain admixtures increase workability. Concreting in narrow forms with closely placed steel requires a highly workable mixture.

The slump test is used to measure workability. Workers can get a feel of the workability by trowelling the fresh concrete. Concrete that has exceeded the time limit in the mixer becomes harsh and unworkable, and tends to segregate.

But slump tests may only be indicators. Two mixtures with the same slump can have contrasting workabilities, such as one mixture being more plastic and showing far less tendency to segregate during handling. A change in water content or a change in the gradation of aggregates, especially the fineness of sand, affects workability.

Aggregates

Fine and coarse aggregates amount to two-thirds to three-fourths of the volume of concrete, and their characteristics influence the proportions to use. Aggregates must be clean, hard, durable, and properly graded. The maximum size has an important bearing on the relative proportions, workability, economy, porosity, and shrinkage. The larger the maximum size, the smaller the amount of mortar and paste required for a given concrete quality. Because walls and other structural members are relatively thin in much SCS work, the maximum size of aggregate is generally limited to 1½ in. Generally, the maximum size of aggregates is one-fifth of the minimum dimension of the member or three-fourths of the clear spacing between reinforcing bars and forms.

Job Mixtures

The specifications state whether the engineer or the contractor is to design the concrete mixture.

The design is based on representative samples of the ingredients that the contractor proposes to use in the work. Trial mixtures and compressive strength tests are required to prove the proposed mixture is acceptable for the job. It may be possible to select a satisfactory job mixture from designs and test data that the plant has on hand.

If the contractor is responsible for the job mixture, he or she must submit a statement of the materials intended to be used for each specified class of concrete. This statement must include evidence satisfactory to the engineer that the materials and proportions selected will produce concrete of the quality, consistency, and strength specified. The engineer should carefully check this information.

Sometimes the information of the trial mixture submitted by the contractor shows a slump to be near or below the minimum specified for the work. To produce concrete of the specified quality through the full range of slump, the mixture must be designed for the maximum slump.

Acceptance of concrete is based partly on the compressive strength. Because there is an inherent variation in the testing of cylinders and in the batching of concrete, the contractor should select a mixture that provides an additional margin of strength. This margin will help ensure that the strength test values do not fall below the specified strength. For 4,000 lb/in^2 class concrete with good control of batching and testing this margin is about 600 lb/in^2.

Regardless of who designs the mixture, the inspector must be alert to detect any deviation from the approved mixture in the concrete delivered on the job.

Before Concreting

Inspection and Testing of Materials

The engineer must determine that all contract requirements for testing and approving concrete materials have been met and that satisfactory con-

trol is ensured, including batching, mixing, and other items of manufacture.

Materials must be inspected frequently to see that they continue to meet requirements. Specifications must be explicit in defining the tests that apply. Actual testing of manufactured products, such as cement, admixtures, and steel reinforcement, may not be needed if the manufacturer or supplier furnishes properly documented evidence certifying that the materials furnished for the job meet specifications. Certifications must be received before the product is used. Any omissions or irregularities in the certificates must be cleared up or detailed tests must be made of the product before permitting its use in the work.

Cement.—Five basic types of portland cement are manufactured:

- Type I (normal)—ordinarily available; used in general construction where special properties of the other cements are not required.
- Type 11—used where the structure is exposed to moderate sulphate action or where moderate heat of hydration is needed; tricalcium aluminate content must never exceed 8 percent (some contracts require an even smaller percentage).
- Type III (high-early-strength)—used if high strength is needed at an early date; used in cold weather to reduce the heating period; often it is a finer grind; often it contains increased amounts of tricalcium aluminate.
- Type N—used for minimizing the amount and rate of heat generation.
- Type V (sulphate-resistant)—used in concrete exposed to severe sulphate action; it has a very low tricalcium aluminate content, usually less than 5 percent.

The suffix "A" added to Types I, II, and III indicates that an air-entraining agent is included in the cement. The suffix "P" added to Type I indicates pozzolan cement. The suffix "S" added to Type I indicates blast-furnace slag cement.

The cement used must meet contract specifications. If more than one type of cement is required, the inspector must make sure that each type is used only for the parts of the work for which it is specified. The cement should be inspected to make sure it has not been contaminated or damaged by moisture, even if satisfactory certifications are in hand.

Aggregates.—The inspector must constantly check on the concrete aggregates furnished throughout the job to be sure that they meet the specifications. The sampling, testing, and grading of aggregate must conform to the contract specifications.

Samples of aggregate selected for testing must be representative of the materials used on the job.[2] If required, the contractor is to advise the contracting officer of the source of aggregate at least **35** days before the aggregate is used so that it can be tested. The contractor should also furnish test data at this time that verifies that the aggregate meets contract requirements. When the material has been accepted, no change in the source or gradation is permitted unless approved by the engineer.

Water.—Water used in the concrete must be free of injurious amounts of sewage, oil, acid, alkali, salts, silt, or organic matter. Normally, a water supply is not a problem. If there is doubt, samples must be submitted to a recognized laboratory for tests before using the water in the mixture.

Curing compound.—The curing compound must be delivered to the worksite in its original container that carries the manufacturer's name and the brand name. Compounds must be protected against freezing if they are water emulsions.

Foundation Preparation

Design requirements and the type and condition of the foundation material dictate the work necessary to prepare the foundation to support or abut a structure. Detailed requirements in the project drawings and specifications must be carefully followed.

Rock.—The surface of the rock subgrade should be sound, completely exposed, dressed to a fairly uniform surface, and moist. Rock surfaces should be cleaned of loose and drummy rock, flaky or scaly coatings, organic deposits, and other foreign materials unless otherwise specified. Cleaning with steel brooms, picks, sandblasters, high-velocity water and air jets, or any other means is acceptable if it does the job satisfactorily. Often the contract provides for overexcavation with a backfill of

[2] *Testing requisites and procedures are in ASTM D-75.*

earth or granular bedding material to meet the subgrade elevation. The inspector should check for high points in the rock, for acceptable compaction, and for an even surface of the bedding materials.

Earth.—Earth foundations are cut to grade and uniformly compacted to the degree specified. Subgrade surfaces prepared for the concrete must be moist but not wet when the concrete is placed. Moisture penetration into the subgrade should be at least **2** in.

Adequate drainage.—Underdrains are constructed of sand and gravel and often include a pipe conduit. The aggregates specified are sized and graded to provide proper drainage and to exclude soil material. The inspector must be sure that the material is not allowed to segregate as it is placed and that waterproof materials, if required, are placed over the drain material to prevent mortar from entering and sealing it.

Inspection checklist:
foundation preparation

(Some items may not be listed. Some listed may not apply to every project.)

1. Concrete subgrade—location, dimension, grade, moisture, free from frost, ice, mud, and water.
2. Subgrade backfill—specified material, density.
3. Overexcavation—measured if pay items, satisfactorily corrected, documented.
4. Filter material—properly placed, proper gradation and compaction.
5. Waterproof materials (membrane)—in place.
6. Rock foundations—sound, completely exposed, clean, reasonably uniform surface, moist.
7. Adjacent concrete surfaces—clean, no laitance or curing compound.
8. Record—job diary.

Forms

Forms for the concrete structures must be tight, rigid, and strong enough to sustain the weight of the concrete, men, and equipment during the concreting. Loose forms permit bleeding of the mortar, resulting in honeycombing or sand streaking. Forms must be aligned and graded as specified, be adequately braced on the outside, and have the required spacers and form ties installed to maintain their position during the concreting operation. Figure **2–3** shows form design, anchorage, and tie spacing.

A frequent blemish on formed concrete surfaces is an offset at the horizontal construction joints where the forms have spread a fraction of an inch at the bottom of a new lift. To prevent these offsets, the forms must be tightly anchored against the sides and near the top surface of the previous lift by an ample number of form ties. Contact surfaces of the forms must be smooth, mortar tight, and free of holes and offsets. If metal forms are used, surfaces must be smooth and clean but not be abraded to a bright finish. Sheathing, studs, and wales used in the forms must be of the proper dimensions and spacing to withstand the hydrostatic pressure exerted by the fresh concrete. Before the concrete is placed, form surfaces must be coated with a nonstaining oil. Oil must not get on the construction joint surfaces or reinforcing bars.

Inspection checklist:
forms

(Some items may not be listed. Some listed may not apply to every project.)

1. Forms—location, alignment, dimension (use transit or plumb line on risers and other high walls), structural strength, bracing, form ties as specified.
2. Form surfaces—clean, smooth, oiled, free from holes and blemishes, mortar tight.
3. Chamfer, screed, grade strips, and embedded items—positioned accurately, firmly anchored.

4. Metal forms—clean, not abraded to a bright surface.
5. Form oil—none on construction joints, reinforcing steel, or embedded items.
6. Chips, blocks, sawdust, dried mortar, dirt, and other foreign materials—removed, preferably by air or water jets.
7. Inspection openings of deep, narrow forms—built before concreting starts, with doors to close them.
8. Drop chutes, elephant trunks, and tremies—available if required.
9. Reinforcing steel—free of loose rust, mill scale, or mortar coatings from previous lifts.
10. Scaffolds, platforms, railings, and ladders, etc.—properly constructed and used.
11. Record—job diary.

Embedded Items

Items such as anchor bolts, inserts, pipe sleeves, pipes, conduits, wiring, manhole cover frames, instruments, and other embedded fixtures or mechanical equipment must be firmly fixed in position before the concrete is placed unless otherwise specified. Correct locations of the embedded items must be verified from the drawings and specifications. Where wooden inserts, keys, joint fillers, and similar items are used, they must be constructed so as not to damage the concrete during removal. All embedded items must be free from rust, oil, grease, paint, or other coatings, unless otherwise specified, and protected against damage during and after the concreting. Bolt threads or polished surfaces must be checked for proper covering. Light metal sleeves or boxes must he checked for internal bracing. Open pipes or conduits must be checked for capping or plugging.

Forms must be readily accessible for proper placing and vibrating of the concrete and for inspection during the concrete operations. A scaffold will frequently be needed. Openings (doors or ports) through the forms must be big enough and adequately spaced for efficient operation and comply with the specifications for placing the concrete.

Joints and Water Stops

Contraction joints.—These joints are constructed to control the location of cracking. They extend into the concrete surface one-fourth to one-fifth the thickness of the member and provide a place of weakness for drying-shrinking stresses to be relieved. The depth of the joint is important; if it is too shallow, cracks will occur at other locations; if it is too deep, the member is weakened. Exposed contraction joints can be sawed with power saws after the concrete has hardened sufficiently (about 10 hr or when the saw does not scuff the edge of the joint). Joints can also be formed by templates or be cut with hand-finishing tools. Joints made in plastic concrete may not retain their shape and may require recutting.

Expansion joints.—These joints separate concrete segments and act as positive breaks in the total unit. They allow changes in the shape or dimension of a separate segment without introducing damaging stresses in other segments. Such joints consist of preformed materials or are constructed by forming keyways or overlapping sections. The joint and the bond-breaking material will be specified. Joint materials must be carefully aligned and held securely in place. Joints in continuously placed slabs should be positioned on the unsupported side. Any protruding joint filler can be cut off with a sharp tool after the concrete hardens.

Preformed materials placed in the formed walls should extend the full thickness of the wall. Chamfer strips are placed on exposed surfaces along both sides of the expansion material. After forms are removed, the excess expansion material should be cut away with a sharp chisel. Any mortar overlapping the joint material or any fins or wedges of concrete must be removed.

Contraction and expansion joints are constructed to the shape and location shown on the drawings. They should not be confused with the specified construction joints. For certain types of construction, dowel assemblies are required as a part of the joint installation. These assemblies must be properly positioned and aligned, and the free half of the dowel bar must be surface coated or covered with a sleeve of adequate length to keep it free from the concrete.

Spacing Data for Form Lumber and Form Ties

These tables are based on the use of me

Lumber and Form Tie Date

Lumber Sizes	Form Ties: Type	Safe Load	Ultimate Capacity	Pouring Temperatures / Rite of Pour—Fl of Height Per Hour / Concrete Pressure Per Sq Ft of Forms
1" (13/16") Sheathing or ¾" Plywood 2 x 4 Studs 2-2 x 4 Wales	3M Snap Ties A.C. Ties No. 2 Rod Clamps with 3/8" Plain Rods	3.000 lbs	4.500 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties and/or Wales
1" 1131161 Sheathing or ¾" Plywood 2 x 4 Studs 2-2 x 4 Wales	5M* Snap Ties Superties* Tilt Locks with 3/8" cold rolled rods No. 3 Rod Clamps with ½" Plain Rods	5,000 lbs	7,500 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties and/or Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 4 Studs 2-2 x 6 Wales	5M* Snap Ties Tilt Locks with 3/8" cold roiled rods No. 3 Rod Clamps with ½" Plain Rods	5,000 lbs.	7.500 lbs	Study Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties andlor Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 4 Studs 2 2 x 6 Wales	½" Coil Ties	6.000 lbs	9.000 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties and/or Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 6 Studs 2-2 x 6 Wales	½" Coil Ties	6,000 lbs	9,000 lbs	Study Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties and/or Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 6 Studs 2-2 x 6 Wales	½" and ¾" Coil Ties Tilt Locks with ½" cold rolled tie rods	9,000 lbs	13,500 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties andlor Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 6 Studs 2-3 x 6 Wales	½" and ¾" Coil-Ties Tilt Locks with ½" cold rolled tie rods	9,000 lbs	13.500 lab	Study Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Ties andlor Wales
2" (1-5/8", Sheathing 3 x 6 Studs 2-3 x 6 Wales	½" and ¾" Coil Tier Tilt Locks with ½" cold rolled tie rods	9,000 lbs	13.500 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Vaiue of Tier andlor Wales
1" (13/16") Sheathing or ¾" Plywood 2 x 6 Studs 2-2 x 6 Wales	¾" Coil Ties	12.000 lbs	18,000 lbs	Stud Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing for Safe Value of Tier andlor Wales
2" (1-5/8") Sheathing 3 x 6 Studs 2-3 x 6 Wales	¾" Coii Ties	12,000 lbs	18.000 lbs	Study Spacing for Safe Value of Sheathing Wale Spacing for Safe Value of Studs Tie Spacing fur Safe Value of Ties and/or Wales

*Ultimate Capacity 7,000 lbs.

ne use of mechanical vibration inside the forms

Safe Spacing of Studs, Wales, and Form Ties

atures	50° Fahrenheit							70°Fahrenheit						
ght Per Hour	2 Ft.	3 Ft.	4 Ft.	5 Ft.	6 Ft.	8 Ft.	10 Ft.	2 Ft.	3 Ft.	4 Ff.	5 Ft.	6 Ft.	8 Ft.	10 Ft.
, Ft of Forms	520 lbs	630 lbs	860 lbs	1030 lbs	1210 lbs	1470 lbs	1580 lbs	100 lbs	520 lbs	630 lbs	750 lbs	860 lbs	1090 lbs	1110 lbs
Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
Studs	30	27"	26	24"	23"	22"	22"	31"	30"	28"	27"	26	24"	23"
Ties andlor Wales	27"	23"	19	17"	15"	13"	12"	32"	21"	24"	21"	19"	16	16"
Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
Studs	30"	27"	26	24"	23"	22"	22"	31"	30"	28"	21"	26	24"	23"
ies andlor Wales	30"	28"	26	25	23"	22"	20"	32"	30	29	27"	26	25"	24"
{Sheathing	20"	18"	16"	15"	14"	13"	12"	23"	20"	18"	17"	16	14	14"
Studs	30"	27"	28"	24"	23"	22"	22"	31"	30"	28"	21"	26	24"	23"
es and/or Wales	46	38"	32	29	25"	22	20"	56	46	40"	35"	32"	21"	26
.Sheathing	20"	18"	16"	15	14"	13"	12	23"	20"	18"	17"	16"	14"	14"
Studs	30"	27"	26"	24"	23"	22"	22	31"	30"	28"	27"	26	24	23"
es and/or Wales	51"	46	38"	34"	31"	26"	25"	56"	50"	46	45"	38"	33"	32"
Sheathing	20"	18"	16'	15"	14"	13"	12"	23"	20"	18"	17"	16	14"	14"
Studs	46	42'	40"	38"	36	34	34	49	46	44"	42	40"	38"	36
es andfor Wales	36	30"	25"	22	19"	17"	16"	44"	38"	31"	27"	25"	21"	20
Sheathing	20"	18"	16	15	14"	13"	12"	23"	20"	18"	17"	16"	14"	14"
Studs	46	42	40"	38"	36"	34"	34"	49	48"	44"	42"	40"	38	36
es and/or Wales	42	38"	35"	33"	30'	26"	24"	47"	42"	39'	36"	35"	31"	30"
Sheathing	20"	18"	16"	15	14"	13"	12"	23"	20"	18"	11"	16"	14"	14"
Studs	46	42	40'	38"	36	34"	34"	49"	45"	44"	42"	40"	38"	36
es andlor Wales	52"	45"	38"	38"	30"	26	24"	57"	52"	46	41"	37"	31"	30"
Sheathing	40	31"	34"	32"	30"	28"	27"	44"	40"	38"	35"	34"	31"	31"
Studs	42"	38	35"	33"	32"	30"	29	45"	42'	38"	37"	34"	33"	32"
es and/or Wales	41"	37"	35	33"	31"	29	29	45"	39	38"	37"	36	32"	31"
Sheathing	20"	18"	16"	15"	14"	13	12"	23	20"	18"	17"	16"	14	14"
Studs	46	42"	40"	38"	36	34	34'	49	46"	44"	42	40"	38"	36
es andlor Wales	42"	38"	35"	33"	31"	29	28"	41"	42	39	31"	35"	31"	31"
Sheathing	40"	37"	34	32	30	28"	27"	44"	40"	38	35"	34"	31"	31
Studs	42"	36"	35	33"	32'	30"	29	45"	42'	39	37"	34"	35"	32"
es and/or Wales	41"	37"	38"	33"	31"	29	29	45"	39	33"	37"	36	32	31"

gure 2 – Spacing data fa rm lum and form ties. The ables are based the use mecha al vibra msic forms
ourtes Superior Concret Accessor . Inc.)

Construction joints.—These joints are installed to aid in the building of forms and the placing of concrete and reinforcing steel. They are usually specified on the drawings. Sometimes in field operations additional joints are needed. But installing unplanned joints should be avoided if possible since they can be less resistant to water movement and weathering. Special care is needed to get a good bonding of the new concrete to the concrete already in place. Wet mixtures must be avoided when completing the final part of the lift since they tend to segregate and produce a thick surface coating or laitance that is difficult to remove.

When a construction joint surface is completed, coarse aggregates must be well consolidated into the mass and the surface must be relatively smooth, similar to a surface that has been screeded. A very rough surface is difficult to clean and makes complete contact with fresh concrete difficult to obtain.

Cleanup of the construction joint before placing new concrete requires removing loose surface materials and coatings. Exposing underlying coarse aggregates that are properly bonded is unnecessary. Excessive abrasion can damage the surface by removing the fine aggregates and mortar from around and under the edges of the coarse materials. Methods in general use for cleaning joint surfaces include air-water cutting and sandblasting, as well as the use of manual or power-driven wire brushes.

The air-water cutting method is not often used on small jobs because it requires special equipment and the work must be done while the concrete is still green for a satisfactory job of cleaning.

Sandblasting is very practical and is in general use for large monoliths or long channel projects. Excellent results are obtained rapidly and with relatively small costs for equipment and labor. Sandblasting gives good results regardless of the age or condition of the concrete surface.

Regardless of the cleaning method, after loosening all materials, the total joint area is washed by a water jet to expose a clean, sound surface. The joint should be damp with no free surface water when new concrete is placed. The first layer of new concrete must be carefully vibrated to form a continuous bond at the joint. A wet mixture should be avoided since the extra water weakens the bond and overall strength of the joint.

Water stops.—These stops are installed in joints to inhibit the passage of water. Particular care is needed in anchoring water stops in the forms and in placing concrete to get a thorough filling on both sides of the material. That part of the water stop (rubber or other material) to be embedded in the fresh concrete must be firmly anchored by inserting tie wires at frequent intervals through the extended edge of the water stop and fastening the wires to the reinforcing steel. Placing concrete around water stops in a circular conduit is most difficult at the top and bottom of the conduit.

Inspection checklist: joints and water stops

(Some items may not be listed. Some listed may not apply to every project.)

1. Expansion, contraction, and construction joints—properly located.
2. Expansion and contraction joints—coated to inhibit bonding.
3. Preformed expansion joint filler—securely in place.
4. Expansion joints—free from irregularities or debris that might inhibit free movement.
5. Construction joints—clean, relatively smooth, moist.
6. Dowel assemblies—sleeves correct size, properly positioned, coatings or wrapping in place.
7. Water stops—firmly secured, correctly located, undamaged, spliced or welded according to manufacturer's instructions (test welds by pulling and twisting).
8. Preformed expansion joint material and water stops—exposed edges free of mortar, etc.
9. Record—job diary.

Final Inspection

Just before concrete is placed, a final inspection is made of all preparations. The inspection includes

the forms, foundation cleanup, joint preparation, drain tile, weep holes, water stops, reinforcement, and other metal work and equipment to be embedded.

In addition, the contractor's plan of operation must be sound, the equipment must be ready, and the personnel able to place the concrete in accordance with contract requirements. If any deficiency is evident that might preclude a satisfactory performance, the contractor should not be allowed to begin. A frequent problem is starting too late in the day to complete the work satisfactorily.

Inspection checklist: working conditions

(Some items may not be listed. Some listed may not apply to every project.)

1. Planned work—materials on hand, work preparations satisfactory.
2. Work force—adequate personnel, properly skilled, proper work conditions.
3. Equipment and methods—satisfactory for entire job, consolidating and vibrating particularly important (have extra vibrator).
4. Rain and cold or hot weather protection—facilities on hand.
5. Lighting—available if work cannot be completed during daylight hours.
6. Safety—railings, kickboards, proper scaffolding, etc.
7. Record—iob diary

During Concreting

The manufacture of consistently good concrete requires careful handling and batching of the materials.

Batching and Mixing

Batching.—Generally, mix proportions are determined and materials are batched by weight. The measurement of cement by the sack (1 ft^3) and the measurement of water by the volume is also satisfactory since their unit weights are universally known.

The storage, handling, and batching equipment must be inspected to determine if operating procedures and the mechanical condition of the plant are satisfactory. Weighing hoppers must be clean and equipped to completely discharge the contents of each batch. A separate hopper must be provided for weighing the cement. The accuracy of the scales and batching devices must be verified by certificates of accuracy issued by state or county departments of weights and measures or verified by some other acceptable procedure.

If there is any question about the accuracy of the weighing equipment for the cement or aggregate, a test should be made as follows:

- (1) Inspect the scale assembly and hopper to be sure that the hopper is empty and clean, the scale equipment is clean and free of exterior obstructions, and the scale assembly has free movement.
- (2) With the hopper empty, set the scale reading at 0.
- (3) Distribute the test weights (10- to 50-lb weights recommended) evenly on or around the hopper.
- (4) Record the dial reading and calculate the plus or minus error; for example, weights and supports = 557 lb, scale dial reading = 554 lb, so the error = -3 lb or 0.5%.
- (5) Remove the test weights and add the same amount of the material to the scale hopper as shown on the dial reading (in No. 4); for example, 554 lb.
- (6) Add test weights and supports, record the reading, and calculate the error.
- (7) Add increments (from No. 4 and 5) until they exceed the total batch weight. In batching different aggregate sizes cumulatively, check the accuracy after each addition against the specifications, making each check at slightly above the batch weight; for example, if the aggregate batch weight = 3,376 lb, then test to at least 3,400 lb.
- (8) Check the actual batch-weight error against the allowable error in the specifications.

- (9) If the equipment is defective, the contractor must correct the problem before the work continues.

The accuracy of the water-measuring devices is especially important. The measuring equipment used at the batching plant, on job mixers, and on transit mixer trucks must be maintained and operated so that all mixing water can be measured within a specified tolerance. The accuracy of the meters or supply tank capacity scales must be verified by acceptable test reports or by observed onsite calibration tests.

Before starting a calibration test, a visual check should be made to determine that all conduits and joints are free from leaks and that control valves function satisfactorily. Valves and other mechanisms should be operated several times under working conditions. When calibrating any type of equipment, the discharge line to the mixing drum is bypassed. The amount of water in volume that is shown on the measuring meter or on the tank scale is checked by measuring the volume or weighing the water. A large container, such as a 50-gal barrel, and a platform scale are useful in getting accurate weight data. To achieve the accuracy needed for the meter, several trial runs are needed, including runs at 1 gal (minimum) up to 50 gal (or the maximum indicated by the dial readings).

Tanks with mounted measuring equipment (including transit-mixing units) that supply all or part of the required mixing water must be checked through a range of 1 gal to slightly more than the maximum amount to be used in the work. Water tanks should be positioned so that they are nearly level. The glass over the gauge scale should be cleaned and the scale calibrated. The greatest chance of error in using a sight gauge scale is when the tank is near maximum or minimum capacity. Graduations must be accurate for small quantities throughout the range of the gauge.

Equipment for measuring both dry and liquid admixtures should be tested. The reliability and accuracy of the equipment are especially important since comparatively small amounts are required. Testing the air content of the freshly mixed concrete will give an indication of the accuracy of the meter as well as the quality of the admixture. If the air content fluctuates from one batch to another, the dispensing equipment probably has malfunctioned. Changing the brand of air-entraining admixture can also cause variation. For other admixtures, an error in measurment is not so easy to determine. If the admixture is set-retarding, the effect of measurement errors shows up to some degree as a delay in the time required for the concrete to set. However, variations in setting time can also result from variations in surface exposure, wind velocity, humidity, temperature, and other factors.

Since there is no test for fresh concrete to verify the rate of hardening, it is especially important that the amount of a set-retarding admixture added to each batch of concrete be correct. The job mixture should be clearly posted at the batching plant to aid in batching.

A batch slip properly made out and signed is to accompany each delivery of concrete.

If the contractor is responsible for the mixture and the quality of concrete, a plant inspector is not essential.

Mixing.—Concrete ingredients must be uniformly distributed, and all aggregates must be well coated with cement paste. To accomplish this, the mixer must be in good condition, the size of batch must not exceed the rated capacity of the mixer, and the mixing time and drum speed must be controlled to meet specifications.

Unless limited by contract provisions, mixing water is fed continuously into the mixer as dry materials are added. Feeding should start just before and end just after the dry materials are placed in the mixer. The loss of materials while charging should not be allowed. Cement bails should not be permitted to form in the mixture. They can result from (1) worn mixer blades, (2) hot cement or aggregates, (3) feeding the cement into the mixer ahead of the coarse aggregate, or (4) delaying the initial mixing. Mixing water must not be hotter than 100°F.

Transit-mixing equipment.—Transit-mixed concrete is often furnished on SCS work. The National Ready Mixed Concrete Association certifies approved ready-mix plants. Not all plants have requested or received this certification for producing quality concrete and maintaining their equipment to these standards.[3] Even if a supplier is certified, the mixing equipment should be inspected.

[3] *See ASTM C-94, "Standard Specifications for Ready-Mixed Concrete"*

The following procedures and precautions can help in getting satisfactory transit-mixed concrete:

- Use a mixer equipped with an accurate water meter and a revolution counter. Overmixing can reduce the slump, especially in hot weather.
- Remove the wash water from the drum before batching.
- Limit the amount of water added during batching so as not to exceed the specified slump.
- Feed the concrete ingredients into the mixer in a uniform blend while the mixing drum is turning.

Inspection checklist: transit mixers

(Some items may not be listed. Some listed may not apply to every project.)

1. Drum—interior condition satisfactory, no buildup of hardened concrete.
2. Mixing blades—blade wear 10 percent or less of original height (measure at maximum drum diameter nearest the drum head or, when blades are curved or have additional deflection, from drum shell to top of straight section).
3. Charge and discharge openings, chutes—no buildup of hardened concrete.
4. Manufacturer's rating plates—readily visible, either drum capacity (operated as mixer) or gross drum capacity.
5. Drum mixing speed—4 rpm or more (but not greater than a speed resulting in drum peripheral velocity of *225* ft/min at its largest diameter).
6. Loaded drum agitating speed—2 to 6 rpm.
7. Batching water—no leaks; all controls, meters, and gauges work.
8. Revolution counter—working.

Admixtures.—Any materials incorporated into concrete other than cement, aggregates, and water are called admixtures. They can be used to increase workability, accelerate or retard hardening, improve water tightness, reduce water requirements, or expedite curing. The inspector must make sure that admixtures are used only when specified or authorized and that only specified or approved materials are used. The inspector must determine that the admixture is received in good condition and is correctly stored, handled, measured, and introduced into the mixture, as required by the specifications or the manufacturer's recommendations. Because small quantities are generally used, close control is required to attain the desired results.

Air-entraining admixtures must meet requirements outlined in the contract specifications. The specifications are to state the appropriate tests for proving the suitabilitv of the admixtures.

Under some conditions a water-reducing and set-retarding admixture can be specified or approved for the work. Certain organic compounds or mixtures of organic and inorganic compounds are used in both air-entrained and nonair-entrained concrete to reduce the water requirements or retard the set. The amount of admixture used is of great importance because it may simultaneously affect the water requirement, air content, hardening rate, bleeding, and strength of the concrete.

Admixtures are available in either powder or liquid form. The powered form can be mixed with the dry cement. The liquid (including job-mixed solutions) must not come in contact with the cement powder alone. Liquid forms can be mixed with the water or added after the water and cement are mixed.

Combinations of admixtures can be used in concrete to achieve both air-entraining and water-reducing, and water-reducing and set-retarding results. Manufacturers' recommendations must be followed when combining admixtures or adding them simultaneously through the same discharge line. Some combinations may not be compatible when intermixed and will need to be added separately to the mixture.

Consistency.—In concrete batching, consistency is the fluidity of the mixture and is measured by the slump test. The primary purpose in specifying the slump is to control directly the consistency and workability for proper placement and to control

indirectly the water-cement ratio. Batches of the same mixture that have the same consistency must have the same water-cement ratio if the batch weight, aggregate grading, and temperature of the materials are uniform. Variation in the slump most often results from a variation in the moisture content of the fine aggregate. Controlling consistency essentially regulates the amount of water in the mixture.

Regulating the amount of mixing water to maintain a given slump is a delicate operation. Even a slight variation in the moisture content of the aggregates can result in an appreciable variation in the slump. For instance, if an average mix that produces 1 yd^3 of concrete has a 1 percent change (by weight) in the surface moisture of the sand, the slump will vary by more than 1 in. For this reason the contractor must know the amount of moisture in the aggregate materials. Ideally, the sand should be well drained and the surface of the coarse aggregates should be moist but contain no free water.

Slump is a very important measure of the quality of concrete. The inspector should watch the mixing operation, check the cohesion of the mass in the conveying devices, and note how easily and uniformly the concrete goes into place so that he can relate his observations to the slump test results. Remarkable accuracy in judging the slump of the mixture can be achieved after a short period of observation.

Low-slump concrete is difficult to place properly in confined areas. A high slump probably indicates unsatisfactory strength, and the concrete is difficult to place without segregation and bleeding.

Inspection checklist batching and mixing

(Some items may not be listed. Some listed may not apply to every project.)

1. Batching equipment—good condition, adequate capacity, hoppers discharge completely.
2. Scales—perform satisfactorily under varied and repeated loadings, aggregate scales checked in 500-lb increments to full-batch load, cement scales checked in 300- to 500-lb increments to full-batch load.
3. Aggregate stockpile—sites cleared, smoothed; sites have no dust, mud, water; fine and coarse aggregate not intermingled; no segregation; drained.
4. Aggregate gradation—meets specifications
5. Air-entraining agent and water-measuring equipment—accurate.
6. Air-entraining admixtures—previously added with mixing water.
7. Cement—meets specifications.
8. Free moisture in aggregates—determine before batching, always determine after rains or delivery of new supply.
9. Concrete mixing drum and discharge chute—no hardened concrete.
10. Mixing blade wear—not enough to prevent adequate concrete mixing.
11. Water tanks, pipes, and fitting—good condition, valves close tightly.
12. Mixer load—not exceed manufacturer's rating.
13. Drum rotation rate (fully loaded)—meets manufacturer's specifications, revolution counter operates properly.
14. Concrete batch—uniform when placed (inconsistencies or abnormal appearance indicates deviations from approved mixture).
15. Retempering concrete—not permitted.
16. Batch tickets—properly written, delivered to inspector with each load of transit-mixed concrete, weights confirmed with job-mix specifications.
17. Certification of materials in concrete—received, satisfactory.
18. Records of field tests of all concrete—maintained, rejection reasons included (if rejected concrete is placed, record exactly where; inform project engineer as soon as possible of all facts relating to the placement of the reiected concrete).

Delivery and Placement

Even though the concrete mixture is carefully designed and properly batched, improper or careless transporting and placing may seriously impair its quality. Within the limitations of the construction specifications, the contractor can select methods and facilities to be used, but they must do the job. Any equipment or procedure incapable of producing acceptable results must be modified promptly or replaced.

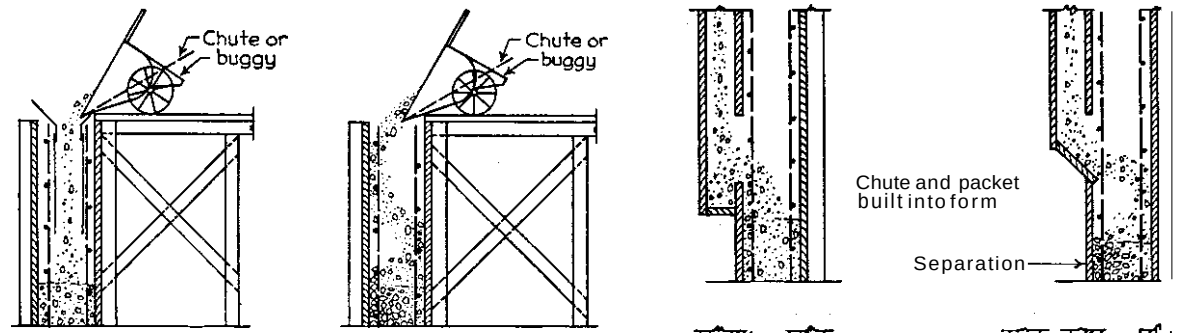
Segregation of the aggregate before batching, segregation of the coarse aggregate from the mortar, or loss of free water (bleeding) from the concrete mixture must be avoided. If the concrete is discharged at an angle from the mixer or conveyor, the largest aggregate is thrown to the far side of the container or form while the mortar is thrown to the near side. For this reason, all hoppers, chutes, buckets, and other concrete conveyors must be provided with vertical drops at their point of discharge.

Methods of handling and transporting concrete include chutes, buggies, crane-operated buckets, trucks, conveyor belts, and pumping equipment. The method used must not impair the specified consistency of the concrete.

In placing concrete for slab construction, the first batch must be placed at the far end of the form. Then each new batch is dumped against—not away from—previously placed concrete. The concrete should not be dumped in separate piles, then leveled and integrated. In placing concrete for walls, the first batch must be placed at one end of the section and subsequent batches placed toward the other end. The same procedure should be used for each layer. On all jobs, it is necessary to prevent water from collecting at the ends and corners and along the form faces. Figure 2 4 , taken from the Portland Cement Association publication, "Design and Control of Concrete Mixtures," shows correct and incorrect methods of placing concrete.

The quality of concrete greatly depends on the handling of the mixture during placement. Inspection of the operation must be continuous and uninterrupted by the taking of tests. In the placing operation, the following conditions and requirements must be met, unless specific exemptions are authorized

- The concrete must be conveyed from the mixer or transit mixer to the forms or subgrades as rapidly as practical by methods that prevent segregation or loss of the ingredients.
- When chutes are used, concrete must be moved in a uniform mass that does not segregate. Slopes of the chutes must be no steeper than 1 horizontal to 2 vertical unless baffles are provided.
- Vertical drops must be no greater than 5 ft unless a tremie or similar device is used to prevent segregation.
- Concrete placement is restricted to the amount that can be satisfactorily consolidated and properly finished at one time.
- The concrete is deposited as close as possible to its final position. Rehandling must be held to a minimum, and the concrete must not be moved laterally by vibrators.
- Vibrators must be operated so as not to distort forms. Forms must be checked continually during concrete placing to be sure that they have not moved and that wedges, ties, and bracings have not loosened or failed.
- Concrete should be placed in uniform, continuous layers no more than 20 in. deep until the monolith is completed. If placing is interrupted long enough for initial hardening to take place, a proper construction joint must be formed. The total time between batching and final placement must not exceed the maximum time allowed by the specifications.
- The consistency of the concrete may have to be changed to prevent the excessive accumulation of laitance.
- Construction joints must be allowed to cure for at least 12 hr before additional rebars and forms are installed or before new concrete is placed. The construction joint must be prepared as stated in the specifications.
- A mechanical vibrator is used to consolidate all concrete. Vibration should not be applied through the forms or used to move the concrete laterally. Vibration should be supplemented by hand spading on the exposed faces along the forms. Too much vibration causes segregation, sand streaking, excessive laitance, and bleeding.



CORRECT

Separation is avoided by discharging concrete into hopper feeding into drop chute. This arrangement also keeps forms and steel clean until concrete covers them.

INCORRECT

Permitting concrete from chute or buggy to strike against form and ricochet on bars and form faces causes separation and honeycomb at the bottom.

PLACING IN TOP OF NARROW FORM

CORRECT

Start placing at bottom of slope so that compaction is by weight of newly added concrete. Vibration consolidates the concrete.

INCORRECT

When placing is begun at top of slope the upper concrete tends to pull apart especially when vibrated below as this starts flow and removes support from concrete above.

WHEN CONCRETE MUST BE PLACED IN A SLOPING LIFT

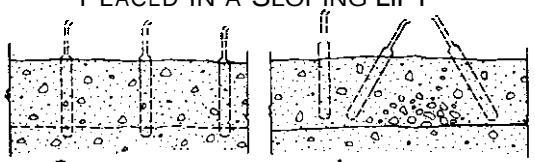
CORRECT

Drop concrete vertically into outside pocket under each form opening so as to let concrete flow easily over into form without separation.

INCORRECT

Permitting rapidly flowing concrete to enter forms on an angle invariably results in separation.

PLACING IN DEEP NARROW WALL THROUGH PORT IN FORM



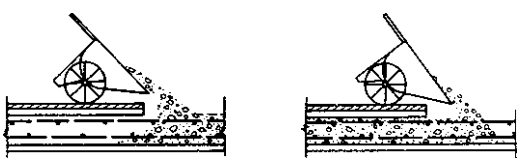
CORRECT

Vertical penetration of vibrator a few inches into previous lift (which should not yet be rigid) at systematic regular intervals will give adequate consolidation.

INCORRECT

Haphazard random penetration of the vibrator at all angles and spacings without sufficient depth will not assure intimate combination of the two layers.

SYSTEMATIC VIBRATION OF EACH NEW LIFT



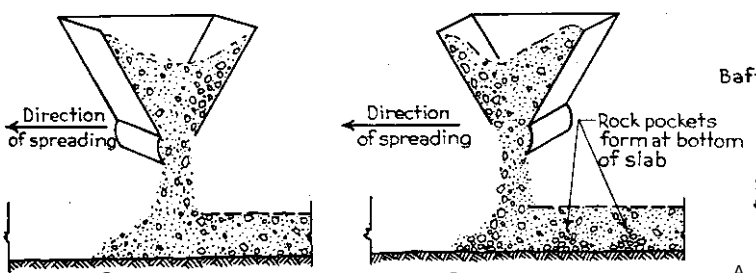
CORRECT

Concrete should be dumped into face of previously placed concrete.

INCORRECT

Dumping concrete away from previously placed concrete causes separation.

PLACING SLAB CONCRETE FROM BUGGIES



CORRECT

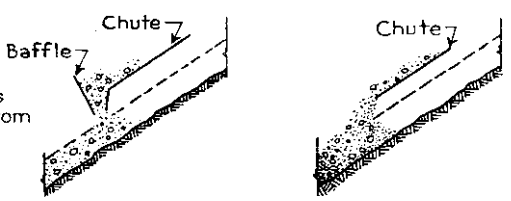
Bucket should be turned so that separated rock falls on concrete where it may be readily worked into mass.

INCORRECT

Dumping so that free rock falls out on forms or subgrade results in rock pockets.

IF SEPARATION HAS NOT BEEN ELIMINATED IN FILLING PLACING BUCKETS

(A temporary expedient until correction has been made)



CORRECT

A baffle and drop at end of chute will avoid separation and concrete remains on slope.

INCORRECT

Discharging concrete from free end chute onto a slope causes separation of rock which goes to bottom of slope. Velocity tends to carry concrete down the slope.

PLACING CONCRETE ON A SLOPING SURFACE

Figure 2-4.—Correct and incorrect methods of placing concrete.

Too little vibration results in poor consolidation and honeycombing.

Placement in hot weather.— When the weather is hot and the temperature of the concrete mixture approaches 90°F, special measures are necessary to get concrete of good quality. Wind and low humidity increase the problem. High temperatures cause rapid evaporation of the mixing water, resulting in erratic air content, reduction in slump, plastic shrinkage cracks (crazing), excessive volume change, rapid hydration, and early setting. All these reduce the ultimate strength of the concrete. Finishing the surfaces also becomes more difficult because of the erratic, initial set.

Requirements for overcoming the deleterious effects of hot weather are given in the specifications. It is very important to wet the subgrade several hours before placing the concrete. The subgrade must be kept moist up to the time of placement to eliminate the withdrawal of moisture from the concrete mixture. However, there must be no free water on the subgrade surface when the concrete is placed.

The delivery schedule of the concrete and the adequacy of labor to place and finish the concrete as rapidly as possible are particularly important. If necessary, the layer thickness and the area of deposit must be reduced so that the concrete stays plastic and cold joints do not form. The concrete can also be placed in the early morning or late afternoon when temperatures are lower. Finishing concrete on hot, dry, windy days can be especially difficult since the rapid drying of the surface causes erratic and early setting, produces shrinkage cracks, and reduces surface quality. Windbreaks, shade, and the application of water through fog nozzles or blankets will protect the concrete surface and make a proper finishing operation easier.

The curing process is to start as soon as the surface has set enough to prevent disfiguration. If a curing compound is used, it should be applied immediately after the finishing is completed.

A record must be kept of the concrete mixture and air temperatures for each placement. A record of the maximum temperatures on the concrete surface must be kept for 24 hr after placement.

Further information on concrete placement in hot weather is available in ACI Standard 305, "Recommended Practice for Hot Weather Concreting" (American Concrete Institute, Detroit, Michigan).

Placement in cold weather.—Special measures are required for concrete placement in cold weather. Concrete gains strength very slowly when temperatures are below 40°F. Serious damage can result when concrete freezes and thaws at an early age.

Concrete of good quality can be placed throughout the winter if protection is provided when temperatures of 40°F or lower occur during the placing or during the curing periods. Materials for closures, insulation, heating equipment, fuels, and other incidentals must be available at the site before the work starts. Concrete must not be placed on a frozen subgrade. All snow and ice must be completely removed from forms, the subgrade, reinforcing steel, and other materials. Any of these items with which concrete may come in contact must be above 40°F.

When concrete is placed, it is important that its temperature be above 50°F so that initial hydration can take place normally. Heating the mixing water is the simplest way to raise the temperature; often this is all that is required. Aggregates are often heated by steam coils or steam jets. Small amounts of the aggregate can also be heated over a piece of metal pipe culvert material fiied from one end. A short chimney section attached to the other end of the culvert material improves heat distribution within the conduit. Overheating the water or the aggregate must be avoided to prevent flash setting of the cement.

After the concrete is placed and finished, it is covered and heated to keep the temperature of the concrete and the surrounding air above 50°F during curing. The heating equipment must be tended so that there is no chance for a malfunction to go uncorrected or for the concrete to freeze during the first 48 hr of curing.

When minimum temperatures are near 32°F, the concrete can be covered with insulating materials and a canvas or plastic exterior seal. For lower temperatures, the concrete structure must be enclosed and artificially heated. Steam generators, oil- or gas-fired blowers, oil- or coke-burning salamanders, or other acceptable forms of heating equipment can be used. Salamanders and other fuel-burning heaters, unless vented, produce carbon dioxide that can be harmful to the concrete. These heaters also produce a dry heat that will reduce the moisture in the concrete unless all exposed areas of the structure are covered with a curing compound, plastic covering, or wet cure. The

humidity of the air inside an enclosure can also be controlled by adding moisture to the heated air.

Not all enclosures are adequately constructed or maintained and temperature can vary widely unless heat vents or other circulation and heat-control methods are used.

Enough thermometers should be available to determine the temperatures of the air and the concrete at the time of placing the mixture and of the surrounding air (ambient) and the concrete during the curing period. Daily high and low readings should be taken on representative surfaces, edges, and corners of the structure.

Further information on concrete placement in cold weather is available in ACI Standard 306, "Recommended Practice for Cold Weather Concreting" (American Concrete Institute, Detroit, Michigan).

Consolidation

The objective in consolidating concrete is to eliminate voids within the concrete. Well-consolidated concrete is free from entrapped air and rock pockets. It is in close contact with the forms, reinforcements, and embedded items. Proper consolidation is not possible if segregation or a decrease in slump occurs during the transport and placing of the concrete. Figure **2 4** shows the proper methods for vibrating fresh concrete.

The use of vibrating equipment makes it possible to place a mixture that could not be consolidated by hand spading. This is particularly beneficial when working in deep narrow forms or around closely spaced reinforcements, because stiff mixtures that are less subject to shrinkage, bleeding, and segregation can be used. Vibration cannot correct segregation resulting from faulty handling and placing. Vibration should continue only until the concrete is thoroughly consolidated and the voids are filled. The exposed surface of the concrete after vibration should have a level appearance. Further vibration is harmful, causing coarse aggregates to settle to the bottom and water or paste to rise to the top. If the concrete segregates readily during vibration, the slump may need to be reduced rather than the amount of vibration. Poor results can more often be traced to too little rather than too much vibration.

If air-entrained concrete is used, overvibration can reduce the air content. Ordinarily, vibrating at uniformly spaced points no further apart than the radius of the vibrator's visible effectiveness (about 18 in.) produces the results desired within 5 to 15 sec. An internal vibrator must be operated from a vertical position and inserted and withdrawn slowly so that the space occupied will be filled. Vibration should continue through the full depth of the layer being placed and into the previous layer of concrete.

Finishing

Finishing includes both the treatment of exposed nonformed surfaces after the concrete is placed and the treatment of defects, tie holes, and the surface of formed elements after the forms have been removed.

Nonformed surfaces must be carefully screeded and checked for tolerance as the concrete is placed. Any cutting or filling needed should be done before the concrete starts to set. The final float finish should be delayed until some stiffening has taken place in the surface and the moisture or shine on the surface has disappeared. Only enough float finishing is needed to get a uniform texture free from irregularities, depressions, small pockets, and float marks.

Steel-trowel finishing, if specified, should follow the float finishing after the concrete has hardened enough to prevent an excess of fine material and water from working to the surface. **A** stainless steel or magnesium trowel gives a superior finish with air-entrained concrete. Troweling at too early a stage can result in fine surface cracks and reduced surface durability. Delaying troweling too long results in a surface too hard to finish properly. Troweling should be performed with a firm pressure to produce a dense surface free of blemishes, ripples, and trowel marks.

For greater resistance to wear, additional troweling can be applied when the surface has nearly hardened. This trowling should continue with firm pressure until the surface has a slightly glassy appearance.

Overworking the concrete surface at any stage tends to concentrate water and fines at the surface and cause fine hairline cracking (crazing), dusting, and poor surface durability. Cracking also can result from rapid drying or cooling of the concrete surface. To prevent surface cracking when the temperature is high and the humidity is low, it may be necessary to apply a fine spray (fog) of water to the surface until it has fully set and can be covered.

Forms should be removed as soon as specifications permit. Forms provide a poor environment for properly curing concrete unless they are kept wet. As the concrete sets, it shrinks and leaves a void next to the form, allowing air circulation and a loss of moisture from the concrete. Keeping forms wet is a burdensome job and is hard on the forms. Surface treatment and repair and the curing of concrete are also much easier and more effective if done while the concrete is green. Defects, such as small rock or air pockets, tie holes, ridges, bulges, and fins, should be treated as specified. All surface treatment must be done before applying a curing compound.

When repairing defects or applying special finishes, concrete surfaces must be clean and thoroughly wetted. A burlap sack works well for filling small voids with the patching mortar. After the voids are filled, any mortar on the concrete must he removed (for example by rubbing with *dry* burlap). Removal of the excess mortar is important because any thin coatings that are allowed to remain will crack and spall in a few years. The repaired area should be kept moist for a few hours to allow the mortar to set before applying a curing compound.

In some instances the plans and specifications may require that formed concrete have a special treatment or finish. This may include sandblasting to produce a pebble effect, sack rubbing, or stone rubbing. Such finishing is applied after any patching or repairing of surface defects has been completed and the repair materials have set.

If a stone-rubbed finish is specified, the first rubbing should be done with a coarse carborundum stone as soon as the concrete is hard enough that the aggregate is not pulled out by the operation. Any mortar worked up in this process or applied to assist in the stone rubbing should be removed from the surface. The concrete needs to be damp when the rubbing is done. The final rubbing is then done after the concrete is moist cured.

If a sack-rubbed finish is required, the mortar is thoroughly rubbed into the cleaned, moist concrete surface with clean burlap sacks. Sometimes sponge-rubber floats are specified. In the rubbing process, all holes, pockets, and other minor imperfections must be completely filled. A dry mixture having the same proportions as the patching mortar should be rubbed over the surface while the mortar in the pits and holes is still plastic. This serves to remove the excess plastic material and insures that the final surface is even and free of mortar. The finished surface should be kept wet for a day or two before the curing compound is applied.

In all special finishes the final product should be smooth and uniform in texture and have no excess mortar remaining on the finished surface.

Inspection checklist: finishing surfaces

(Some items may not be listed. Some listed may not apply to every project.)

Nonformed surfaces

1. Concrete—screeded to line and grade
2. Surface—not overworked in floating.
3. Finish—as specified, no water or dry cement used in final floating or troweling.
4. Record—job diary.

Formed surfaces

1. Concrete surfaces—inspected immediately after forms removed.
2. Repair or patching—concrete moist, mortar removed.
3. Fins and form marks—removed and rubbed smooth, as specified.
4. Honeycombed and damaged areas—cut out to expose sound concrete, filled as specified with concrete that matches structure.
5. Rough areas and high spots—rubbed or ground down to smoothness or tolerance specified.
6. Finish on all areas—as specified.
7. Record—job diary.

After Concreting

Form Removal

Forms should be removed as soon as specifications allow so that any necessary repairs or surface treatments can be made while the concrete is still

green and conditions are most favorable for a good bond. Forms must he removed carefully to avoid damaging the concrete. There should be no measurable deflection or distortion and no sign of damage due to either the removal of supports or the stripping itself. Because forms do not provide the best curing environment, the specified curing should be applied as soon as practical.

Curing

The object of curing is to prevent the loss of moisture from the concrete mixture during the "rapid" stage of hydration. The water content of fresh concrete is more than adequate for hydration of the cement. But evaporation and sometimes bleeding or absorption by the dry forms or the foundation allow enough mixing water to be lost to delay or prevent complete hydration. It is very important to follow specified curing procedures so that the concrete can reach its full strength.

Methods in general use for curing concrete are (1) applying curing compounds, (2) keeping the surface continually moist by spraying or ponding, and (3) covering the surface with wet earth or blankets for the time specified. Steam can also be applied within an enclosure.

Under most conditions, a curing compound will seal the surface and allow the concrete to retain enough moisture for hydration. A white-pigmented compound is very good because it reflects sunlight and is more easily checked for uniform coverage.

The compound should be applied to exposed, unformed surfaces as soon as the finish is completed and the surface water has disappeared. It must not be applied if the concrete surface is shiny or has free water.

Formed surfaces must be coated immediately after the forms are removed and surface repairs are completed. Areas to be repaired must be kept continuously moist until the repair is complete and extended curing is applied. Moist curing before and during the form removal may he specified.

To ensure complete coverage, approximately one-half of the curing compound for a given area should be sprayed back and forth in one direction, and the remainder sprayed at a right angle over the first coat. The spray head is moved in even, side-to-side sweeps to systematically cover the concrete. Special care is required to be sure that the edges, corners, and rough irregular surfaces are uniformly covered. Any breaks in the coating will allow a loss of moisture from the concrete. The compound must never be applied before patching is done.

It is preferable to have a pressure-tank type of spraying equipment. If compressed air lines are used, they must be equipped with traps to prevent moisture or oil from getting into the compound. Because the pigment often settles to the bottom of the container while in storage, the compound must be checked to see that it is thoroughly mixed before being used. Continual agitation of the contents is necessary while spraying.

Coated areas subject to traffic or damage from other causes must be protected with earth or other effective covering.

Inspection checklist:
curing concrete

(Some items may not be listed. Some listed may not apply to every project.)

1. Curing and protection materials—available before concrete placement begins.
2. Curing moisture—adequate for full period.
3. Curing temperature—as specified.
4. Time of application—as soon as possible after form removal.
5. Curing water—meets specifications.
6. Concrete in forms—wetted as specified.
7. Curing compounds—meets material specifications.
8. Record—job diary.

Protection from Damage

The contractor is required to protect all concrete from injury and damage until final acceptance by the contracting agency. The contractor must take necessary precautions to keep equipment away from the concrete until it has cured and the backfill has been placed.

Special attention is needed to avoid:

- Overloading, jarring, or surface-marring the green concrete.
- Moving falsework before the concrete has hardened enough to support its own weight.
- Stressing projecting reinforcing steel.
- Backfilling in a way that overloads or damages the concrete.
- Fires on or near the unprotected concrete.

Testing Concrete

Test Specimens

Sampling.—Methods for sampling fresh concrete are in ASTM C–172.

Number and frequency.—There is no prescribed frequency for sampling and testing fresh concrete. The project engineer and the SCS state conservation engineer must consider the structures in the contract and schedule a realistic testing program. Strength tests provide one of the primary evidences of quality.

Initially, frequent sampling and testing are necessary to verify the suitability of the concrete. Extra cylinders at this time provide specimens for tests at 7 or 14 days to obtain an early indication of the 28-day strength. Frequent tests also may be needed for critical elements of a given structure or when the materials, equipment, weather, or other conditions indicate a need to verify strength results. Fewer tests are needed after the job mixture has proved satisfactory and all manufacturing operations are well controlled.

Specimens taken at the beginning of a job and tested at 3-, 7-, or 14-day intervals will give an early indication of the adequacy of the mixture. For type III (high-early strength) cements, a test at 1 or 3 days will indicate the ultimate strength that will be attained. Test results at an early age are not conclusive and should be regarded only as indicators. If early tests indicate relatively low or marginal strength, the contractor can use a higher strength mixture, or discontinue concreting and wait to see if the 28-day tests prove that the original mixture was adequate.

Sampling and testing must be done if the appearance of the concrete changes.

Molding.—The procedure for molding test cylinders for compressive strength tests is described in ASTM C–31.

Curing.—Procedures for curing test specimens are described in ASTM C–31.

Handling and shipping.—Concrete specimens must be protected from jarring and vibration during the first 24 hr after molding and from rough handling at all times. They must remain upright until they have hardened. Careless treatment of specimens can destroy the validity of the test results.

Test specimens can be moved to the laboratory for testing any time after the first 24 hr. The laboratory will complete the curing if it is not already complete. Specimens should be packed in wet sand or sawdust in suitable shipping containers and should be protected from freezing during shipment. Each shipment must have complete identification and sampling data (includes dates, location of the sampling in the structure, mixture, slump, amount of air entrainment or admixtures, concrete and air temperatures, curing method, kind of test, age at which the tests on the concrete are made, and what conditions existed when the specimens were taken). This information is recorded on Form SCS-ENG-59 (fig. **3–63).** Copies of this form will give the laboratory the information it needs and also provide a record for the contract files.

Slump

The slump test should be made as often as needed to ensure that concrete delivered to the site is within the specified limits. Slump tests should be made if there is an apparent change in the consistency of the concrete or if a strength specimen is made. Procedures for making the slump test are in ASTM C–143.

Air Content

Tests for determining the amount of entrained air in the concrete are described in ASTM C–138, C–173, and C–231. A change in atmospheric pressure does not affect the pressure test equipment required for ASTM C–231. This equipment is best used for contract control tests and is not recommended for testing concrete made from lightweight or cellular aggregates. The use of ASTM C–173 is preferred when testing such lightweight aggregates.

Records and Reports

Mix Computations

Form SCS-ENG-553 can be used to record computations of the trial mixtures or to check a proposed mixture for the work (fig. 4–5). Accepted methods for determining mixture proportions are discussed in detail in various concrete manuals (see Chapter 5, Concrete). Computations for the trial mixtures and their adjustments and the selection of the job mixture (or documentation of the contractor's proposed mixture and approval thereof) should be placed in the contract files.

Batching and Mixing

Batching and mixing records must be placed in the job file. A summary of these records and the volume of each class of concrete placed should be entered in the job diary.

If the engineer designs the concrete mixture, he or his designated representative must inspect the batching. If the contractor is responsible for designing the mixture, the contractor would do well to inspect the batching. The inspector at the job site should check and validate the batching record before the concrete is placed. Form SCS-ENG-544 can be used to record the daily batching operations (fig. 4–6). Form SCS-ENG-552 or a similar batch form should be used to record batch weights for each load (fig. 4–4). If the engineer designs the mixture, the plant inspector prepares the batch ticket. Otherwise, it is the contractor's responsibility.

Placing and Curing

The amount of concrete placed in individual parts of the structure each day and the time that (1) the curing medium was applied, (2) forms were removed, (3) defective surfaces were repaired, and (4) curing was completed must be recorded in the job diary.

Strength Tests

Test specimens.—A cross-reference to each SCS-ENG-59 (fig. 3–64) used must be noted in the job diary. Included should be the SCS-ENG-59 report number, numbers assigned to all test specimens shipped to the laboratory, and the location and amount of concrete represented by each strength test.

Inplace concrete.—If tests do not verify that the concrete has the compressive strength specified in the contract, further tests may be necessary to determine whether to accept or reject the structure or the part of the structure represented by the low-strength tests.

To further test the concrete, compressive strength tests can made on core samples cut from the structure. The "Swiss Hammer" can help determine the extent of concrete having questionable strength. This lightweight, hand-operated hammer works on the impact principle. When operated according to manufacturer's instructions, it is recognized to be accurate within a range of 10–15 percent. Test results are based on the empirical relationship between the strength of the concrete and the rebound of the steel plunger.

During testing the hammer is placed against a smooth, flat surface of concrete. A carborundum stone is furnished to smooth the concrete. The plunger is pressed against the concrete surface and pressure is gradually increased until the hammer trips. Then the rebound number is read on an indicator dial. A calibration curve for the concrete is determined by correlating hammer readings made on the test samples with actual breaking strengths recorded for the samples. This curve shows the compressive strength of the concrete for each hammer reading. The samples should be placed on a solid surface to give them a resistance to impact comparable with that of the concrete in the structure.

The impact hammer should not be used to determine either concrete strength for acceptance or the earliest time that forms can be stripped.

Plain concrete has good compressive and shear strength but is relatively weak in tensile strength the ratio is about 10 to 1. Reinforcing steel is used to increase the tensile strength of a concrete section so it may carry heavier loads of tensile stress. Some designs may require steel reinforcement to increase shear and compressive strengths. Because all concrete is subject to temperature stresses, most concrete contains reinforcing steel to overcome these stresses. Design drawings show the size and location for all required reinforcement.

The position of reinforcing steel in the concrete section is very critical in the function of a structure (see Placement in Structures, below). A small error in placement can reduce the strength of a section drastically.

Bar schedules and bending diagrams are in the contract drawings or will be furnished by the steel fabricator as shop drawings.

Materials

Steel Bars

The three types of steel and the strength, grades, and bar sizes in the ASTM specifications (and adopted by the American Concrete Institute) are shown in figure 2–5.[4] Billet steel, grades 40 and **60,** is most often specified in SCS designs. Where limited clearance or extra strength is required, a high strength or special type of reinforcement can be specified.

Bar sizes.—Sizes of reinforcing bars are numbered from 2 through 18. The number designates the diameter in 118-in. multiples. For example, No. **7** has a 718-in. diameter. This designation is valid for bars 2 through 9. For sizes larger than No. 9, the multiple is slightly more than 1/8 in. Under present standards, No. 2 is a plain round bar and No. **3** through 18 are deformed round bars. Weights and nominal dimensions for all bar sizes are shown in figure 2–6.[4]

The overall maximum diameter (including deformations) may vary slightly, since bar diameters are nominal. To determine the overall diameter needed for holes for the reinforcing bars or to check sleeve sizes, 1116 in. should be added to No. 3, **4,** and **5** bars, 118 in. added to No. 6, 7, 8, and 9 bars, and 3116 in. added to No. 10 and **11** bars.

Bar identification.—Standard bar identification marks are used for the types and grades of reinforcing steel produced by U.S. manufacturers (fig. 2–7).[4] Also shown are those manufacturers who identify steel grades with a line system and those who use a number system. These manufacturers all produce reinforcing steel meeting ASTM requirements (fig. 2–8).[4] The number preceding the manufacturer's name is the same on both figures. Deformation requirements and the method for measuring them are in the ASTM specification for the type of steel specified.

The contract requires the contractor to furnish properly documented certifications showing that the reinforcing steel meets specifications. If the material does not appear to be as certified, additional laboratory test data or samples for testing can be requested.

Length and bending.—Reinforcing steel can be shipped to the jobsite as cut-to-length bars or as cut-and-bent bars. The supplier normally furnishes a bar schedule and a bending diagram. On large jobs the contractor often subcontracts the whole reinforcement operation to a steel fabricator including fabrication, transportation, labor, and incidentals involved in setting the reinforcing steel in place.

Various names have been assigned to reinforcing steel when it is cut and bent to a certain shape. Each shape has a definite functional use. Some of the standard shapes are trusses, stirrups, ties, spirals, radial bends, continuous slab, corner bars, offset column bars, and standard hooks. The bar shapes in general use have been standardized and numbered by the American Concrete Institute. Designers usually refer to the bend shapes on their drawings by numbers.

Each dimension of a cut-and-bent bar has a letter assigned to it. To get a bar fabricated exactly to its typical shape, all dimension letters designated for that bar shape must be listed. To modify the shape of the bar, one or more letters are omitted from the bar list. For example, by omitting "G" from a type **1** bar, a bar with one hook would result. Figures 2–9[5] and 2–10[5] show typical bar bends and the standard code for designating their dimensions. The Concrete Reinforcing Steel Institute design handbook, "Placing Reinforcing Bars" (see Chapter **5,** Concrete), has a section, Recommended Practice

[4] *Provided courtesy of Concrete Reinforcing Steel Institute*

[5] *Provided courtesy of Concrete Reinforcing Steel Institute*

for Placing Reinforcing Bars, that provides more information on steel reinforcement, fabrication, and placement.

Tolerance limits in fabrication.—The following deviations in bar length from the true dimensions shown on the drawings are within the tolerance limits used by many fabricators and are accepted on SCS projects unless specified otherwise:[6]

Straight bars.,	±1 in.
Bars with hooks	
Overall dimensions	
No. 7 and smaller..	±½ in.
No. 8 and larger..	±1 in.
Truss bars	
Overall dimensions—length	
No. 7 and smaller.	±½ in.
No. 8 and larger..	fl in.
Overall dimension—height.	±0, −?4 in.
Spirals, circles, or column ties	
Overall dimensions.	±½ in.
Stirrups	
Overall dimensions.	±½ in.

The manufacturer of the reinforcing steel is allowed a variation of ±3½ percent in total weight for one lot of deformed bars and a maximum of 6 percent under weight for any individual bar.

Identification for shipment.—Reinforcing steel fabricated for a project must be bundled and tagged for identification. Generally, the bundles should contain bars of one size, length, and mark. Various methods of tagging are used, but each bundle's tag must show the purchaser's name or order number, number of pieces, bar length, and where each piece will be located in the structure. Symbols or marks are used to show placement. Since fabricators use various methods and systems, the contractor and the inspector must ascertain at the time of delivery which system was used in order to decide if the materials satisfy the specifications. The contractor is to provide copies of the delivery invoices and any bar-bending and placing diagrams the fabricator may have prepared for the work.

Welded Wire Fabric

Welded wire fabric (wire mesh) is available in rolls for light gauges and in large sheets for heavier gauges. It is manufactured in square and rectangular patterns and may have one-way reinforcement of heavy-gauge wires closely spaced in a lengthwise direction or two-way reinforcement of heavy-gauge wires spaced equally in each direction. The wire fabric must be checked for the correct size and mesh spacing when delivered. After placement, splicing and supports of the material are inspected to be sure that they meet specifications. Figures 2-11 and 2-12 show sizes and spacing of the widely used wire styles.

Handling and Storage

Reinforcing steel must be examined on delivery to be sure that it has not been bent or otherwise damaged during transport and handling. The yard or area for storing should have wooden or other approved supports to keep the steel off the ground and to permit separation by size, shape, and structure for proper inspection and protection.

Placement in Structures

The inspector must know the correct size for each bar and its location in the structure and see that it is correctly placed. If in doubt, the inspector should check with the engineer.

Figure 2-13 through 2-19 are sketches[6] that show where the primary steel reinforcement should be placed to carry the expected loads most efficiently (an exaggerated effect of these loads on the concrete members is shown). Because of other stresses, such as temperature, the design may show the steel to be in the center of the section or closer to one face, or it may show steel in more than one plane in the member. The important thing to remember is that placing the steel exactly as shown on the drawings is very critical in the successful performance of the structure.

Single Span Simple Beams

Top-loaded beams of one span (supported as shown) require steel to be placed toward the bottom of the beam for its full length (fig. 2-13).

Continuous Beams

Top-loaded beams extending over more than one span (supported as shown) tend to sag between supports and hump over supports (fig. 2-14). The reinforcing steel must be placed toward the top over the intermediate supports. Frequently, an

[6] *Reproduced with permission from "Placing Reinforcing Steel," published by the Concrete Reinforcing Steel Institute*

Type of Steel and ASTM Specification No.	Size Nos. Inclusive	Grade	Tensile Strength Min., psi	Yield (1) Min., psi	Elongation in 8" Min. Percent (2)	Cold Bend Test (3)
Billet Steel A615	3-11 14, 18	40	70,000	40,000	1.100.000 Tens. Str. Min. 12%	Under Size No. 6 – 90", d=3t Nor. 6, 7, 8 – 90°, d=4t Nos. 9, 10, 11 – 90°, d=5t
						Nor. 14, 18 – None
	3-11 14, 18	60	90,000	60,000	1,000,000 Tens. Str.	Under Size No. 6 – 90". d=4t Nor. 6, 7, 8 – 90°, d=5t Nor. 9, 10, 11 – 90°, d=6t
					7	Nor. 14, 18 – None
	11, 14. 18	75	100,000	75.000	Varies with bar size, 5% to 7½%	No. 11 – 90°, d=8t
						Nor. 14, 18 – None
'Axle Steel A617	3-11	40	70,000	40,000	1,100,000 Tens. Str. Min. 12%	Under Size No. 6 – 90°, d=3t Nor. 6, 7, 8 – 90". d=4t Nor. 9, 10, 11 – 90°, d=5t
	3-11	60	90,000	60,000	1,000,000 Tens. Str.	Under Size No. 6 – 90", d=4t Nor. 6, 7, 8 – 90, d=5t Nor. 9, 10, 11 – 90°, d=6t
Rail Steel A616	3-11	50	80.000	50,000	1,000,000 Tens. Str. Min. 4.5 to 5%	NONE
	3-11	60	90,000	60,000	1,000,000 Tens. Str. Min. 5%	NONE

ASTM STANDARD REINFORCING BARS

BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS – ROUND SECTIONS DIAMETER INCHES	CROSS SECTIONAL AREA SQ. INCHES	PERIMETER INCHES
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.65	1.693	2.25	5.32
#18	13.60	2.257	4.00	7.09

Sizes #14 and #18 are large bars generally not carried in regular stock. There sizes available only by arrangement with your supplier.

Figure 2-5.—Physical requirement for deformed reinforcing *bars.* (Courtesy of Concrete Reinforcing Steel Institute.)

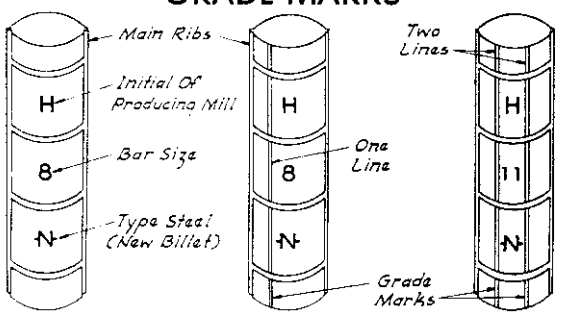
Figure 2-6.—ASTM standard reinforcing bars. (Courtesy of Concrete Reinforcing Steel Institute.)

Lower Strength Bars Show Only 3 Marks (no grade mark) in the following order:

1st – Producing Mill (usually an initial)
2nd – Bar Sire Number (#3 through #18)
3rd – Type (N for New Billet; A for Axle; I for Rail)

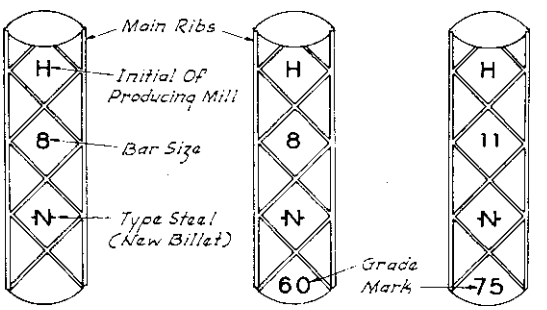
High Strength Bars Must Also Show Grade Marks:
60 or One (1) Line for 60,000 psi Strength
75 or Two (2) Lines for 75,000 psi Strength
(Grade mark lines are smaller and between the two main ribs which are on opposite sides of all U.S. mode bars.) Number grade marks are 4th in order.

CONTINUOUS LINE SYSTEM–GRADE MARKS



Grade 40 Grode 60 Grade 75
Grade 50

NUMBER SYSTEM–GRADE MARKS



Grade 40 Grode 60 Grode 75
Grade 50

BAR PRODUCERS USING THE LINE SYSTEM

1. Allison Steel Mfg. Co. Rolling Mill Div.
2. Armco Steel Corp.
5. Border Steel Mills, Inc.
8. CF&I Steel Corporation
11. Etiwondo Steel Producers, Inc.
12. Florida Steel Corp.
14. Great Lakes Steel Div. National Steel Corp.
18. Inland Steel Company
20. Judson Steel Corp.
21. Kaiser Steel Corporation
22. Kalmar Steel Corp.
23. Kankakee Electric Steel Co.
24. Laclede Steel Co.
26. Milton Manufacturing Company, Subsidiary of The Ceco Corporation
27. Mississippi Steel Corp.
28. Missouri Rolling Mill Corp.
29. North Star Steel Company
32. Northwestern Steel & Wire Co.
33. Oregon Steel Mills
34. Owen Electric Steel Co. of S. C.
35. Pacific States Steel Corp.
36. Phoenix Manufacturing Co.
37. Pollak Steel Co., The
39. Roanoke Electric Steel Corp.
43. Southern Electric Steel Company, Division of The Ceco Corporation
44. Southwest Steel Rolling Mills
46. Tennessee Forging Steel Corp.
49. West Virginia Works, Connors Steel Division, H. K. Porter Company, Inc.
51. Youngstown Sheet & Tube Co., The

BAR PRODUCERS USING THE NUMBER SYSTEM

3. Atlantic Steel Co.
4. Bethlehem Steel Corporation
6. Calumet Steel Div., Borg-Warner Corp.
7. Ceco Corporation, The
9. Connors Works, Connors Steel Div., H. K. Porter Co., Inc.
10. Continental Steel Corp.
13. Franklin Steel Div., Borg-Warner Corp.
15. Hawaiian Western Steel Limited
16. Hoster Investment Co.
17. Industrial Siderurgica, Inc.
18. Inland Steel Co.
19. Jones & Loughlin Steel Corp.
25. Lone Star Steel Co.
30. Northern Steel, Inc.
31. Northwest Steel Rolling Mills, Inc.
38. Republic Steel Corp.
41. Schindler Bros. Steel Co.
42. Soule Steel Co.
45. Structural Metals, Inc.
47. Texas Steel Co.
48. United Stater Steel Corp.
50. Witteman Steel Mills

*See *bar* photos in sequence as *numbered above* for the *first* three identification *marks and deformation patterns used* by each mill,

VARIATIONS: Bar identification marks may also be oriented to read horizontally (at 90" to those illustrated above.)
Grode mark lines must be continued at least 5 deformation spacer.
Grode mark numbers may be placed within separate consecutive deformation spaces lo read vertically or horizontally.

Figure 2-7.—U.S. standard bar identification marks. (Courtesy of Concrete Reinforcing Steel Institute.)

DENTIFICATION OF U.S. REINFORCING BARS

STM and AASHO Specifications require that all reinforcing bars be identified by permanent, mill-imprinted markings

1. Allison Steel Mfg. Co., Rolling Mills Div.
   Phoenix. Arizona
2. Armco Steel Corp.
   Kansas City, Missouri
3. Atlantic Steel Company
   Atlanta, Georgia
4. Bethlehem Steel Corporation
   Bethlehem, Pennsylvania
5. Border Steel Mills, Inc.
   El Paso, Texas
6. Calumet Steel Div., Borg-Warner Corp.
   Chicago Heights, Illinois
7. Ceco Corpomtion. The
   Chicago, Illinois
8. C F & I Steel Corp.
   Denver, Colorado
9. Connors Works, Connors Steel Div., H. K. Porter Co.
   Birmingham. Alabama
10. Continental Steel Corporation
    Kokomo, Indian.
11. Etiwanda Steel Producers, Inc.
    Etiwanda, California
12. Florida Steel Corporation
    Tampa, Florida
13. Franklin Steel Div., Borg-Warner Corp.
    Franklin, Pa.
14. Great Lakes Steel Corp., Div. of Notional Steel Corp.
    Detroit, Michigan
15. Hawaiian Western Steel Limited
    Honolulu, Hawaii
16. Hoster Investment Co.
    Oklahoma City, Okla.
17. Industrial Siderurgica, Inc.
    Bayamon, Puerto Rico
18. Inland Steel Company
    Chicago, Illinois
19. Jones & Laughlin Steel Corpomtion
    Pittsburgh, Pennsylvania
20. Judson Steel Corporation
    Emeryville, California
21. Kaiser Steel Corporation
    Oakland, California

1 ALLISON STEEL MFG. COMPANY

N

2 ARMCO STEEL CORPORATION

N

3 ATLANTIC STEEL COMPANY

N

4 BETHLEHEM STEEL CORPORATION

N

NOTE: DEFORMATIONS OMITTED FOR FIVE BAR MARKS (BLANKSARE FOR DE MARK

5 BORDER STEEL MILLS, INC.

N

6 CALUMET STEEL DIVISION

N

6 CALUMET STEEL DIVISION

I

6 CALUMET STEEL DIVISION

A

7 CECO CORPORATION, THE

N

Bars #14S and #18S only

7 CECO CORPORATION, THE

N

Bars #3 through #11, inclusive

Figure 2-8. –US. manufacturers of concrete reinforcing bars. (Courtesy of Concrete Reinforcing Steel Institute.)

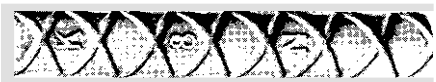
8 CF&I STEEL CORPORATION

N

9 CONNORS WORKS
CONNORS STEEL DIV H K PORTER CO INC

N

10 CONTINENTAL STEEL CORPORATION

N 

#3, #4, #5 ONLY

11 ETIWANDA STEEL

N

12 FLORIDA STEEL CORPORATION

N

One space between marks

13 FRANKLIN STEEL DIV., BORG-WARNER

I

13 FRANKLIN STEEL DIV., BORG-WARNER

A

14 GREAT LAKES STEEL CORPORATION

N

15 HAWAIIAN WESTERN STEEL LTD.

N

16 HOSTER INVESTMENT CO.

Type not designated

17 INDUSTRIAL SIDERURGICA, INC.

N

18 INLAND STEEL COMPANY

N

18 INLAND STEEL COMPANY

I

19 JONES & LAUGHLIN STEEL CORP.

N

20 JUDSON STEEL CORPORATION

N

21 KAISER STEEL CORPORATION

N

Figure a-a (cont.)

DENTIFICATION OF U.S. REINFORCING BARS

STM and AASHO Specifications require that all reinforcing bars be identified l
int, mill-imprinted markings,

22. Kalmar Steel Corporation
    Magnolia. Arkansas
23. Kankakee Electric Steel Company
    Kankakee, Illinois
24. Laclede Steel Company
    St Louis, Missouri
25. Lone Star Steel Company
    Dallas, Texas
26. Milton Manufacturing Co., Subsidiary of the Ceco Corporation
    Milton, Pennsylvania
27. Mississippi Steel Corp.
    Jackson, Mississippi
28. Missouri Rolling Mill Corp.
    St. Louis, Missouri
29. Nanh Star Steel Company
    St. Paul, Minnesota
30. Northern Steel, Inc.
    Boston, Massachusetts
31. Northwest Steel Rolling Mills, Inc.
    Seattle, Washington
32. Northwestern Steel & Wire Co.
    Sterling, Illinois
33. Oregon Steel Mills
    Portland, Oregon
34. Owen Electric Steel Co., of So Carolina
    Cayce, South Carolina
35. Pacific States Steel Corp.
    Union City, California
36. Phoenix Manufacturing Co
    Joliet, Illinois
37. Pollak Steel Co., The
    Cincinnati, Ohio
38. Republic Steel Corp.
    Cleveland, Ohio
39. Roanoke Electric steel Corp.
    Roanoke, Virginia
40. Ross Steel Works, Inc.
    Amite, Louisiana
41. Schindler Bros Steel Co.
    Sealy, Texas
42. Soulé Steel Co.
    San Francisco, California

22 KALMAR STEEL CORPORATION

#3. #4. #5 ONLY

23 KANKAKEE ELECTRIC STEEL CO.

24 LACLEDE STEEL COMPANY

24 LACLEDE STEEL COMPANY

25 LONE STAR STEEL CORPORATION

Marks are 7 spaces apart

26 MILTON MANUFACTURING CO.

SUBSIDIARY OF THE CECO CORPORATION

27 MISSISSIPPI STEEL CORPORATION

28 MISSOURI ROLLING MILL CORP.

28 MISSOURI ROLLING MILL CORP.

29 NORTH STAR STEEL COMPANY

Figure 2-8 (cont.)

30 NORTHERN STEEL, INCORPORATED

I

31 NORTHWEST STEEL ROLLING MILLS, INC

N

32 NORTHWESTERN STEEL & WIRE CO.

N

33 OREGON STEEL MILLS

N

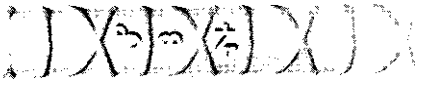
34 OWEN ELECTRIC STEEL COMPANY

N

35 PACIFIC STATES STEEL CORPORATION

N

36 PHOENIX MANUFACTURING CO.

N 

36 PHOENIX MANUFACTURING CO.

A

37 POLLAK STEEL COMPANY

N

37 POLLAK STEEL COMPANY

A

37 POLLAK STEEL COMPANY

I

38 REPUBLIC STEEL CORPORATION

N

39 ROANOKE ELECTRIC STEEL CORP.

N

40 ROSS STEEL WORKS, INC.

N

41 SCHINDLER **BROS.** STEEL CO.

N

42 SOULE STEEL COMPANY

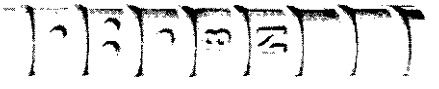
N 

Figure 2-8 (cont.)

DENTIFICATION OF U.S. REINFORCING BARS

STM and AASHO Specifications require that all reinforcing bars be identified by perma ent, mill-imprinted markings.

43. Southern Electric Steel Company
    Division of The Ceco Corporation
    Birmingham, Alabama
44. Southwest Steel Rolling Mills
    Lor Angeles, California
45. Structural Metals, Inc.
    Seguin, Texas
46. Tennessee Forging Steel Corporation
    Harriman, Tennessee
47. Texas Steel Co.
    Fort Worth. Texas
48. United States Steel Corp.
    Pittsburgh, Pennsylvania
    - Duquesne Mill
    - Torrance Mill
    - Birmingham Mill
    - Gary Mill
    - Fairless Mill
    - McDonald Mill
    - Duluth Mill
49. West Virginia Works. Connors Steel Dir.
    H. K. Porter Co.. Inc.
    Huntington. West Virginia
50. Witteman Steel Mills
    Fontana, California
51. Youngstown Sheet & Tube Co.. The
    Youngstown, Ohio
    - Youngstown Mill
    - Chicago Mill

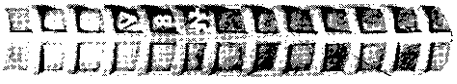
43 SOUTHERN ELECTRIC STEEL CO.
DIVISION OF THE CECO CORPORATION

N

44 SOUTHWEST STEEL ROLLING MILLS

N

45 STRUCTURAL METALS, INCORPORATED

N 

46 TENNESSEE FORGING STEEL CORP.

N

47 TEXAS STEEL COMPANY

N

48 U. S STEEL CORPORATION

N

McDonald Mill

48 U. S. STEEL CORPORATION

N

Birmingham Mill

48 U. S. STEEL CORPORATION

N

Duluth Mill

48 U. S. STEEL CORPORATION

N

Gary Mill

48 U. S. STEEL CORPORATION

N

Fairless Mill

Figure 2-8 (cont.)

48 U. S. STEEL CORPORATION

N

Torrance Mill

48 U. S. STEEL CORPORATION

N

Duquesne Mill

49 W. VA. WKS., CONNORS STEEL DIV.

H K PORTER CO INC

N

50 WITTEMAN STEEL MILLS

N

51 YOUNGSTOWN SHEET & TUBE CO.

N

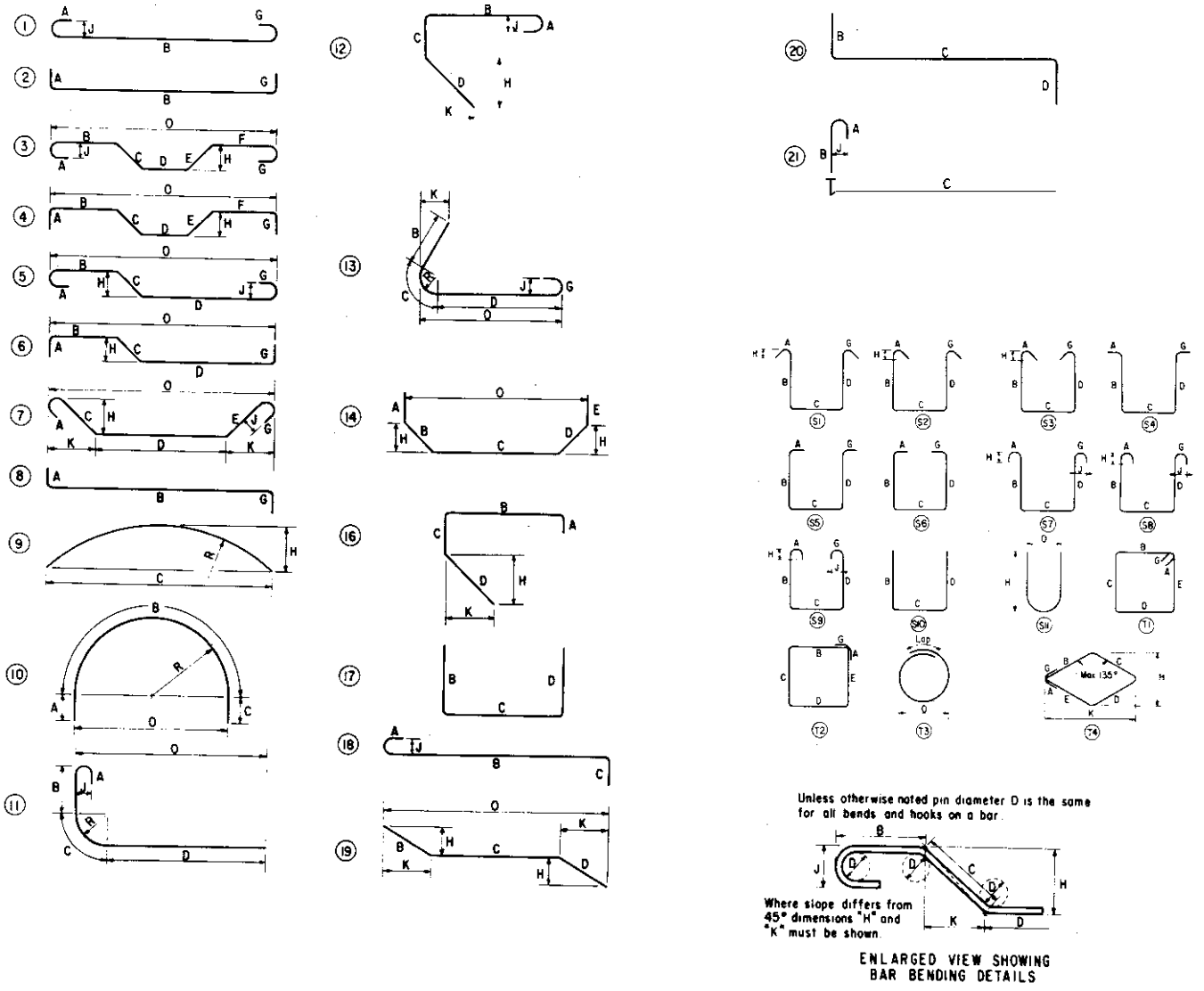
Youngstown Mill

51 YOUNGSTOWN SHEET & TUBE CO.

N

Chicago Mill

Figure 2-8 (concluded)



NOTES:
1. All dimensions are out to out of bar except "A" and "G" on standard 180° and 135° hooks.
2. "J" dimension on 180° hooks to be shown only where necessary to restrict hook size, otherwise standard hooks are to be used.
3. Where "J" is not shown, "J" will be kept equal to or less than "H" Where "J" can exceed "H", it should be shown.
4. "H" dimension on stirrups to be shown where necessary to fit within concrete.
5. Where bars are to be bent more accurately than standard bending tolerances, bending dimensions which require closer working should have limits indicated.
6. Figures in circles show types.
7. For recommended pin diameter "D", of bends, hooks, etc. see tables.

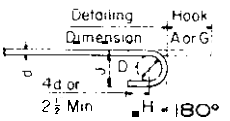
Figure 2-9.—Typical bar bends. (Courtesy of Concrete Reinforcing Steel Institute.)

†All specific sizes recommended by CRSI below meet requirements of ACI 318-63.

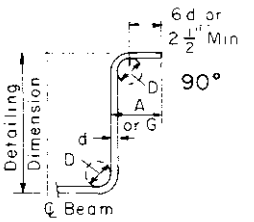
RECOMMENDED 180° HOOKS

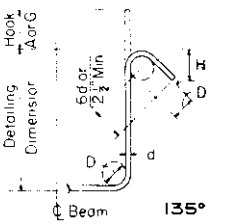
Grade 40 ksi
- D = 5d for #3 through #11
- D = 10d for #14 and #18

Grader 50-60-75 kri
- D = 6d for #3 through #8
- D = 8d for #9, #10, and #11
- D = 10d for #14 and #18



STIRRUP AND TIE HOOK





RECOMMENDED 180 END HOOK DIMENSIONS

Bar Size	Grades 50-60-75 ksi A or G	Grades 50-60-75 ksi J	Grade 40 ksi A or G	Grade 40 ksi J
#3	5	3	5	2¾
#4	6	4	6	3½
#5	7	5	7	4½
#6	8	6	8	5¼
#7	10	7	9	6¼
#8	11	8	10	7
#9	1-3	11¼	1-0	8
#10	1-5	1-0¾	1-1	9
#11	1-7	1-2¼	1-2	10
#14*	2-2	1-8½	2-2	1-8½
#18*	2-11	2-3	2-11	2-3

STIRRUPS
(TIES SIMILAR)

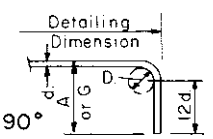
STIRRUP AND TIE HOOK DIMENSIONS
Grader 40-50-60 kri

Bar Size	D (in.)	90° Hook Hook A or G	135° Hook Hook A or G	135° Hook H Approx.
#3	1½	4	4	2½
#4	2	4½	4½	3
#5	2½	6	5½	3¾
#6	3	6½	6½	4½

NOTE—When supporting bars are used, stirrup hooks may be bent to not less than the diameter of the supporting bars.

RECOMMENDED 90" END HOOK DIMENSIONS

All Grades
- D = 6d for #3 through #8
- D = 8d for #9. #10, and #11
- D = 10d for #14 and #18



Size	A or G
#3	6
#4	8
#5	10
#6	1-0
#7	1-2
#8	1-4
#9	1-7
#10	1-10
	2-0
*	2-7
	3-5

TABLE 3 — MAXIMUM SPACING OF COLUMN TIES*

Vertical bar size	#3	#4	#5
#5	10	—	—
#6	12	—	—
#7	14	—	—
#8	16	16	—
#9	18	18	—
#10	18	20	—
#11	18	22	22
#14	18	24	27
#18	18	24	30

Figure 2-10.—Standard code for designating the dimensions of hooks, stirrups, and ties. (Courtesy of Concrete Reinforcing Steel Institute.)

TABLE VIII—COMMON STYLES OF RECTANGULAR WELDED WIRE FABRIC—ONE-WAY TYPES

Style designation	Spacing of wires, in.		Size of wires AS&W gauge		Sectional area sq in. per ft		Weight lb per 100 sq ft
	ngi	rans.	ngit	rans	ngit	rans	
241414*	2	4	14	14	030	015	16
212-04	2	12	0	4	443	040	59
212-15	2	12	1	5	377	034	14
212-26	2	12	2	6	325	029	14
212-37	2	12	3	7	280	025	07
212-48	2	12	4	8	239	021	91
212-59	2	12	5	9	202	017	77
212-610	2	12	6	10	,174	014	56
212-711	2	12	7	11	.148	011	56
312-04	3	12	0	4	.295	.040	19
31215	3	12	1	5	.252		02
31226	3	12	2	6	.216		87
31237	3	12	3	7	.187		15
312-48	3	12	4	8	,159	021	64
31249	3	12	5	9	.135	017	54
312410	3	12	6	10	,116	014	46
312-711	3	12	7	11	.098	011	39
312412	3	12	8	12	.082	009	32
412-26	4	12	2	6	.162		69
412-37	4	12	3	7	.140	025	59
412-48	4	12	4	8	.120	.021	51
412-59	4	12	5	9	.101	,017	43
412-610	4	12	6	10	.087	,014	36
412-711	4	12	7	11	.074	.011	31
412-810	4	12	8	10	.062	,014	27
412412	4	12	8	12	.062	.OW	25
412-912	4	12	9	12	.052	.OW	22
412-1012	4	12	10	12	,043	.OW	19
412-1112*	4	12	11	12	,034	.009	16
412-1212'	4	12	12	12	.026	.OW	13
48-711	4	8	7	11	.074	,017	33
48-812	4	8	8	12	.062	,013	W
48-912	4	8	9	12	.052	,013	23
48-1012	4	8	10	12	.043	,013	20
461112*	4	8	11	12	.034	,013	17
48-1212 *	4	8	12	12	.026	,013	14
48-1214 *	4	8	12	14	.026	.008	12
612-3/04	6	12	00	4	.206	.040	91
612-2/04	6	12	W	4	.172	.040	78
612-00	6	12	0	0	.148	,074	81
612-03	6	12	0	3	.148	.047	72
612-11	6	12	1	1	.126	.063	69
612-14	6	12	1	4	.126	.040	61
612-22	6	12	2	2	.108	.054	59
612-25	6	12	2	5	.108	.034	52
612-33	6	12	3	3	.093	.047	51
612-44	6	12	4	4	.080	.040	44
612-66	6	12	6	6	.051	.029	32
612-77	6	12	7	7	.049	.029	W

Fabric with longitudinal wires up to and including 7/0 can be furnished.

* The styles of fabric listed above are standard and are obtainable from stock. If additional transverse steel area is required the gauge and spacing of the transverse wires may be changed from that indicated above—usually for orders of 5 tons or more.

TABLE IX-COMMON STYLES OF SQUARE WELDED RE FABRIC—TWO-WAY 1 'ES

Style designation	Spacing of wins, in.		sir. of win. AS&W gauge		Sectional area sq in. per ft		Weight lb per 100 sq ft
	ngit	rans.	Longit.	rans	ongit	Trans	
2 x 2—10/10	2	2	10	10	.086	.086	60
2 x 2—12/12 *	2	2	12	12	.052	.052	37
2 x 2—14/14'	2	2	14	14	.030	.030	21
2 x 2—16/16 *	2	2	16	16	.018	.018	13
3 x 3—8/8	3	3	8	8	.082	.082	58
3 x 3—10/10	3	3	10	10	.057	.057	41
3 x 3—12/12 *	3	3	12	12	.035	.035	25
3 x 3—14/14 *	3	3	14	14	.020	.020	14
I x 4—4/4	4	4	4	4	.120	.120	85
4 x 4—6/6	4	4	6	6	.087	.087	62
I x 4—8/8	4	4	8	8	.062	.062	44
4 x 4—10/10	4	4	10	10	.043	.043	31
4x 4—12/12 *	4	4	12	12	.026	.026	19
I x 4—13/13 *	4	4	13	13	.020	.020	14
4 x 4—14/14 *	4	4	14	14	.015	.015	11
6x 6—0/0	6	6	0	0	.148	.148	07
6 x 6—1/1	6	6	1	1	.126	.126	91
6 x 6—2/2	6	6	2	2	.108	.108	78
6x 6—3/3	6	6	3	3	.093	.093	68
5x 6—4/4	6	6	4	4	.080	.080	58
6x 6—4/6	6	6	4	6	.080	.058	50
6 x 6—5/5	6	6	5	5	.067	.067	49
6 x 6—6/6	6	6	6	6	.058	.058	42
6 x 6—7/7	6	6	7	7	.049	.M9	36
6 x 6—8/8	6	6	8	8	.041	.M1	30
6x 6—9/9	6	6	9	9	.035	.035	25
6x 6—10/10	6	6	10	10	.029	.029	21

* Usually furnished only in galvanized wire.

Two-way fabric usually consists of equal-sized wires, equally spaced in both directions, as shown in the above table.

CONCRETE REINFORCING STEEL INSTITUTE

Figure 2-11.—Sizes and spacing for rectangular welded wire fabric—one-way types.

Figure 2-12.—Sizes and spacing for square welded wire fabric—two-way types.

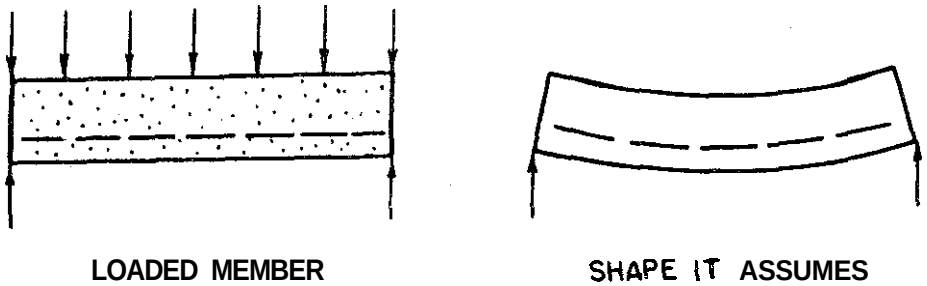


Figure 2-13.—A single-span simple beam, loaded and assumed shapes.

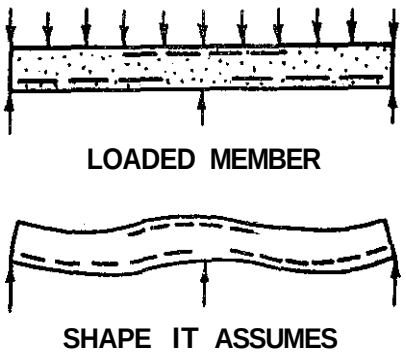


Figure 2-14.—A continuous beam, loaded and assumed shapes

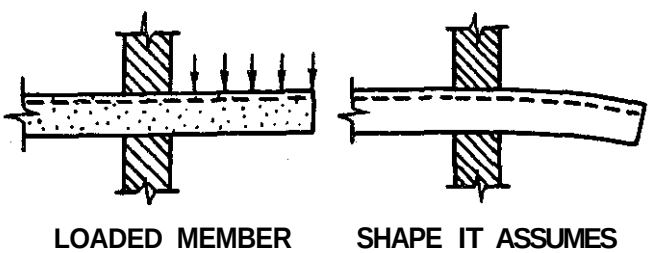


Figure 2-15.—A cantilever beam, loaded and assumed shapes.

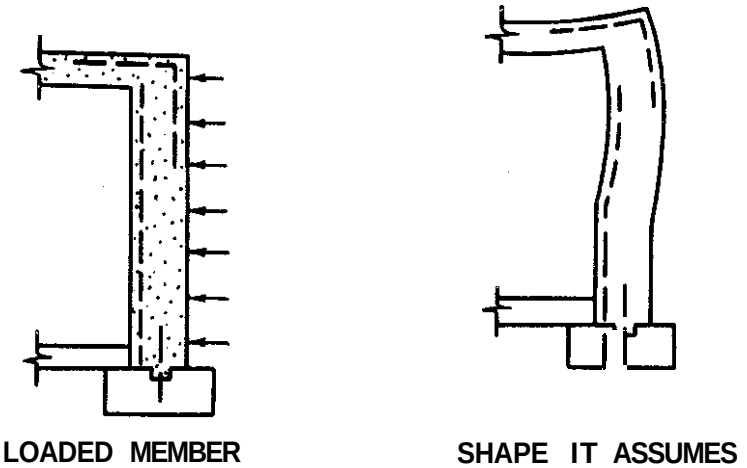


Figure 2-16.—A wall, loaded and assumed **shapes.**

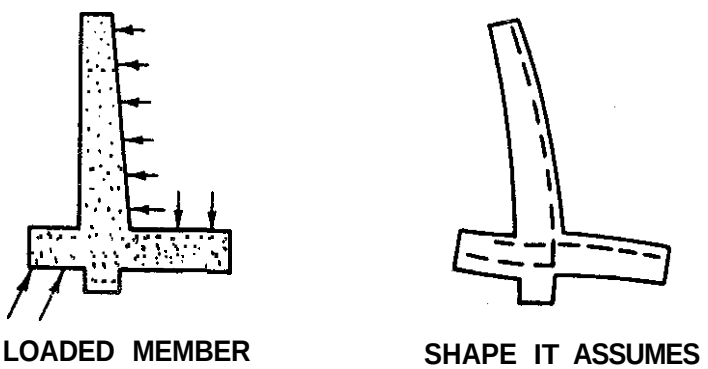


Figure 2-17.—A retaining **wall, loaded** and **assumed** shapes.

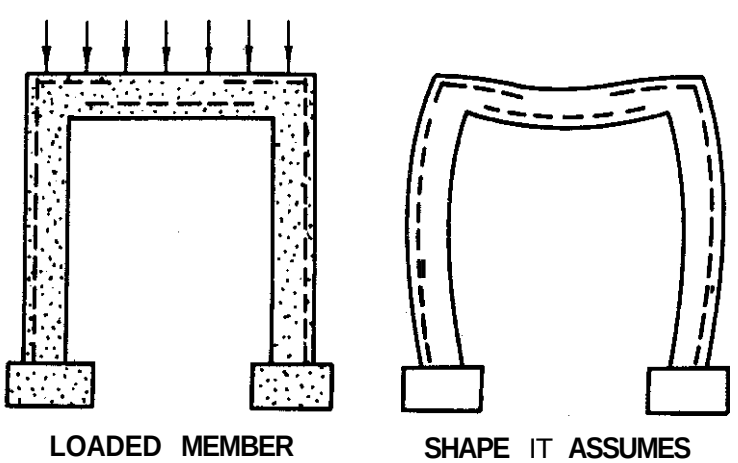


Figure 2-18.—An **elastic (continuous) frame, loaded and assumed** shapes.

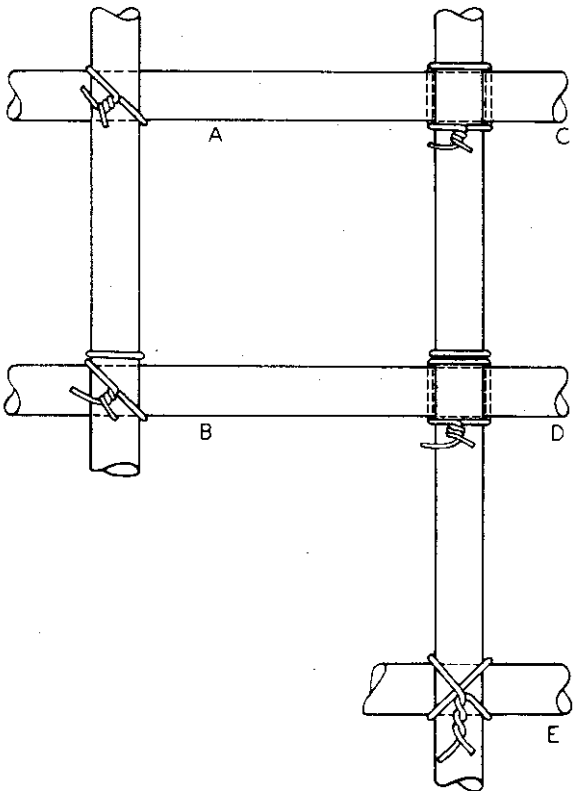


Figure 2-20.—Types of **wire** ties. **(Courtesy** of **Concrete** Reinforcing Steel Institute.)

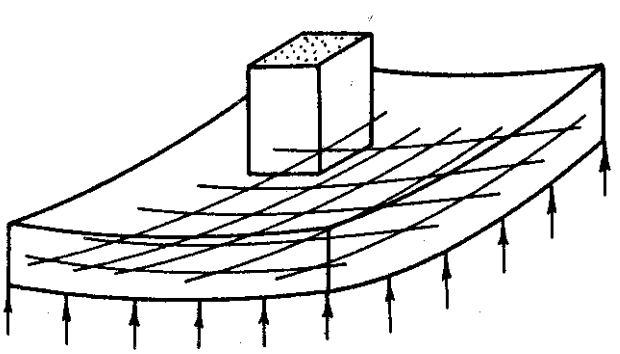


Figure 2-19.—A footing **slab.**

individual piece of reinforcing steel is formed to lie in both planes; such a formation is called a truss bar.

Cantilever Beams

Cantilever beams or slabs that have top loads tend to bend down (fig. 2–15). The reinforcing steel must be placed toward the top of the beam. Steel placed in the cantilever must extend straight through or around a corner to provide steel support.

Walls

Walls with rigidly supporting slabs at the top and bottom and having horizonal loads tend to bow inward (fig. 2–16). The reinforcing steel must be placed toward the inside face of the wall. Reinforcement is also needed toward the outside face at the top corner.

Retaining Walls

Retaining walls designed as a cantilever and receiving loading as shown will need reinforcement steel placed toward the outside (loaded face) of the vertical wall, toward the top of the inside footing, and toward the bottom of the outside footing (fig. 2–17).

Elastic (Continuous) Frames

A structure designed as a continuous frame but top-loaded only tends to buckle the side walls outward (fig. 2–18). The reinforcing steel must be placed toward the outside of the sides bending around the corners into the top slab. Steel must also be placed toward the bottom face of the top slab.

Footing Slabs

A column load acts downward in the center of a slab or footing (fig. 2–19). If the bearing capacity is uniform, the soil moves upward tending to raise the corners. A mat of reinforcing steel should be placed toward the bottom of the slab with steel bars in both directions.

Splices

Splices in reinforcing steel are necessary on most projects. To transfer the stress from one steel bar to the next, a certain length of lap must be provided. The drawings specify the minimum length of lap permitted. Usually this is stated in terms of the diameter of the bar being spliced. Bars are spliced by lapping them the required length and wiring them securely together. It is not desirable to splice bars at points of maximum stress. Welded laps or butt joints are unacceptable unless specified.

Ties and Supports

All reinforcing bars must be securely tied and supported in their proper location with wire, patented clips, or chair supports before concrete placement begins. Bars assembled inplace in horizontal mats must be tied at each intersection around the periphery of the mat and at least at every fourth bar within the mat. Horizontal bars placed in the vertical mats should be tied in at least three locations for each length or at every third intersection, whichever results in closer spaced ties. If mats are preassembled, they should be adequately tied so they remain rigid during handling and placement. Usually, a soft annealed black wire of No. 16 gauge is used for tieing. Some of the types of ties used by the concrete industry (fig. 2–20) are the:

- Snap or single tie (A) that is used in flat horizontal work. It consists of a single diagonal wrap around two crossed bars. Wire ends are tightly twisted with pliers, and loose ends are cut and flattened to prevent snagging or protruding through the surface of the slab. A strong tie, called a doubling snap tie or single tie-double wire, can be made by doubling the wire.
- Wrap and snap tie (B) that is normally used to secure horizontal bars to vertical bars in vertical mats. The loop around the vertical bar helps prevent movement of the horizontal bar. The tie is made by wrapping the wire 1½ times around the vertical bar, then diagonally around the intersection with the horizontal bar. Wire ends are tightly twisted, cut, and flattened.
- Saddle tie (C) that is used most often on footing or other mats to hold hook ends of bars in position or for fastening column ties to vertical bars. The wire passes around the front of the vertical bar, down behind the back of the horizontal bar (on both sides of the vertical bar), and back around the front of the vertical bar. Wire ends are tightly twisted, cut, and flattened.

- Wrap and saddle tie (D) that is used to secure heavy mats handled by a crane and to secure column ties to vertical bars at points of heavy strain. This tie is similar to the saddle tie except that the wire is wrapped 1% times initially around the vertical bar; completion is as for (C).
- Figure eight tie (E) that is used only occasionally because of the time needed to make the tie.

Reinforcing steel must he firmly supported to resist stress during the placing of concrete. Often it gets stressed during handling by workmen or by being stepped on. Chairs, bolsters, or fabricated rebar spacers are the supports used most often to minimize stress.

Concrete chairs are preferred for earth subgrades. Three types of precast concrete chairs usually available from retail concrete products firms are plain chairs, chairs with wire, and doweled chairs (fig. 2-21). Chairs with wires (dobbies) are suitable for placing between the vertical steel and the forms. Doweled chairs (candlestick) are best used to support two mats of slab steel. The dowel holds the upper mat, and the concrete chair supports the lower mat.

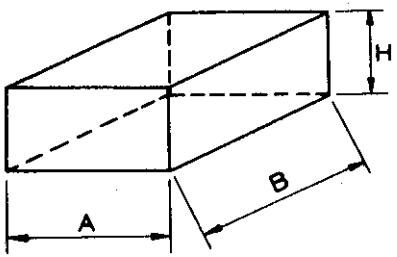
Commercial fabricators make special bar supports (fig. 2-22). They can be furnished with galvanized or plastic coatings. A galvanized coating should be used if bar supports are placed on surfaces that will be exposed on the lower face of slabs or beams. Supports must not be used where they would be exposed in finished or formed concrete surfaces.

Inspection checklist: steel reinforcement[7]

(Some items may not be listed. Some listed may not apply to every project.)

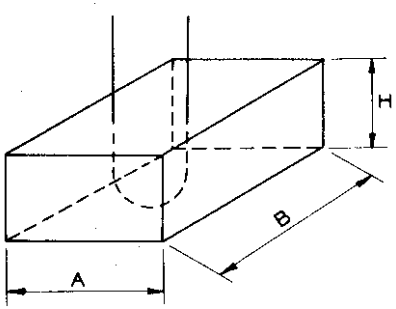
1. Materials—meet specifications, checked for damage, proper bends.
2. Reinforcing steel—stored off ground, adequate room for sorting and checking.
3. Placement drawing—available, adequate.
4. Ungalvanized metal supports—none exposed, not touching earth.
5. Inplace steel—proper size, bends, spacing, location, installation.
6. Multiple-bar placement in beams—vertically aligned.
7. Bars—adequately supported.
8. Wire fabric—lapped, tied as specified.
9. Splices, ties, spacers, anchorage, and cover—adequate.
10. Tie-wire ends—flush with steel or bent for specified cover.
11. Hooks or "lifters" for raising reinforcement in slabs—not allowed.
12. Condition of steel before concrete placement—free of mud, concrete, grease, oil, paint, loose rust, mill scale, other coatings.
13. Position of steel—unchanged during concrete placing.
14. Certification—receivedbefore placing concrete.
15. Record—tests, quantities, job diary entries.

[7] *Each inspector should have access to the Concrete Reinforcing Steel Institute design handbook, "Placing Reinforcing Bars" (see Chapter 5, Concrete). Each inspector should become familiar with the section, Recommended Practice for Placing Reinforcing Bars, and mith procedures that relate to the types of construction under consideration.*



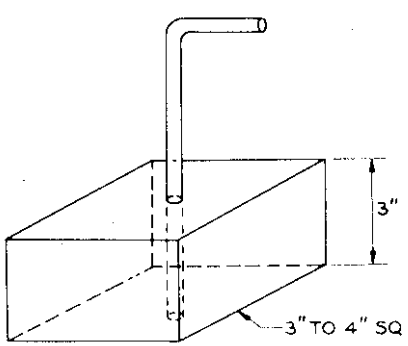
Plain Precast Concrete Blocks

A	B	H
2″	2″	¾″
2″	2″	1″
2″	2″	1½″
2″	2″	2″
3″	3″	2″
3″	3″	3″
3″	3″	4″
4″	4″	3″
4″	4″	4″
6″	6″	3″

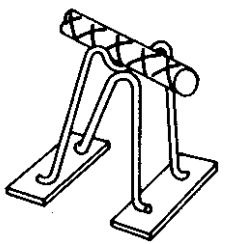


Precast Concrete Blocks With Wires

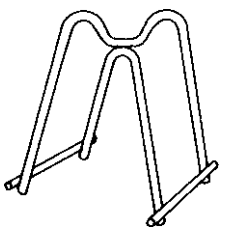
A	B	H
2″	2″	¾″
2″	2″	1″
2″	2″	1½″
2″	2″	2″
3″	3″	3″



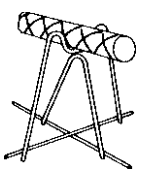
Precast Concrete Doweled Blocks



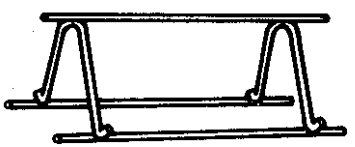
HCP—High Chairs with Plates



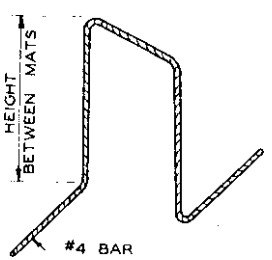
FHC—High Chair for Fill



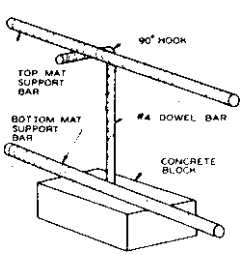
SHC—Special High Chairs



UCHC—Upper Continuous High Chairs



Bent Bar Chair
("Standee")



Dowel Block

Figure 2-21 (left).—Precast concrete bar supports. **Figure 2-22 (right).**—Fabricated **metal** bar supports. **(Both** courtesy **of** Concrete **Reinforcing** Steel **Institute.)**

Drainage Needs and Types

Drainage needs are dictated by the site conditions and the functional nature of the structure. Drainage is installed to control leakage and to relieve pressure. The types of drains used in most SCS work and descriptions of their basic functions are in SCS Soil Mechanics Note No. 3, "Soil Mechanics Consideration for Embankment Drains" (May 1971).

Cutoff Trenches

Although an impervious barrier (cutoff) constructed in the foundation is not a drainage device, it has a very significant effect on the internal movement of water in and through the foundation. Cutoffs inhibit the movement of water through a porous foundation. **As** such, they reduce the volume of water lost through seepage and reduce the hydrostatic pressure beneath the embankment downstream from the cutoff.

Drain Fill

The selection and placement of drain materials are extremely critical to the proper functioning of a structure. If very fine or cementitious materials are present, they may seal the drain. Variations from the specified gradation or segregation will significantly affect the drain capacity and effectiveness. Variations may allow the foundation or embankment material to move into the drainage system, either clogging the drain or jeopardizing the integrity of the foundation and embankment.

The drain fill must be installed with a minimum of segregation or contamination. The system the contractor selects for placing the material must be simple enough that the work personnel can do the work properly. The sieve analysis for gradation is described in ASTM C–136. Data are recorded on Form SCS-ENG-535 (fig. 3–78). **ASTM** C–117 gives details for determining the fraction finer than the ZOO-mesh sieve.

Placement methods to prevent segregation are similar to those for concrete placement. Drain materials must not free-fall more than 5 ft. Chutes, clamshell buckets, skips, or other equipment must be used to place materials in the deep excavations. Tremies or similar devices must be used when placing materials in water. The tremie must be kept full of the material and the discharge end kept in contact with the material already in place.

The inspector is to check materials for proper compaction and for placement to the lines and grades shown on the drawings or as otherwise directed. The inspector is to check all drainage pipes, connections, and weep holes for the correct location grade and alignment. Weep holes and other outlets must be checked after their installation to be sure they are free from obstructions and will function as planned.

Inspection checklist:
structure drainage

(Some items may not be listed. Some listed may not apply to every project.)

1. Alignment, cross section, and grades—as specified.
2. Quality and gradation, and placement—as specified, certifications on hand, no segregation, uncontaminated.
3. Tests—adequate number, recorded.
4. Pipes—certifications, location, orientation, bedded, secured, perforations clear, properly joined, coating intact, capped, outlets guarded.
5. Backfill—uniform placement, compacted as specified.
6. Relief wells—material certifications on hand, construction and development as specified.
7. Quantities for payment—measure.
8. Record—job diary.

Pneumatically Applied Mortar

Pneumatically applied mortar (PAM), often referred to as Shotcrete, Airblown Mortar, or Gunite, is blown by an air jet onto the surface to be treated. This is the most versatile method for placing mortar on concrete structures or other surfaces since it is adaptable to flat slabs and walls with any degree of slope or warp. PAM can also be used to repair concrete or masonry surfaces or to coat structural steel.

Preparation of Surface

Loose materials, dirts, grease, oil, scale, and other contaminations must be cleaned from all surfaces. Concrete surfaces must be sandblasted or otherwise prepared for a satisfactory bond. Earth subgrade must be shaped and compacted to the specified grade and alignment. Reinforcing steel, forms, gaging wires, and embedded items must be securely anchored. Wire fabric must be anchored by dowels grouted in the drill holes when treating old concrete surfaces or anchored with blocks or other approved supports on earth subgrade. All surfaces must be kept continually moist for **3** hr before the mortar is placed. There must be no free water on the surface when PAM is applied.

Materials

Sand

Concrete sand that meets the contract requirements for gradation and the fineness modulus (specified range, usually **2.50** to **3.30)** is important for a satisfactory operation. The moisture content of the sand must be within a close range. If it is less than about **3** percent, the material will not feed uniformly, the sand and cement will tend to separate, and the amount of rebound will increase. If the moisture range exceeds about **5** percent, slugging can occur in the equipment and in the discharge hose.

Cement

Generally, Type I or Type 11 portland cement is used. It must be carefully protected from moisture while it is stored on the job. Bagged cement should be piled for easy inventory.

Water

The water used for mixing the mortar and for curing must meet contract specifications.

Reinforcing Steel

The steel reinforcement must be firmly anchored and supported to withstand the impact of the mortar placement. Laps and ties must be made as shown on the drawings or as otherwise specified.

Equipment

Processing and placing pneumatically applied mortar follow generally standard procedures. **A** standard concrete mixer is used to mix the sand and cement (and water if a wet mixture). The mixture is placed in a mechanical feeder or pressure chamber. For larger operations, two chambers are used to maintain a continuous feed. The mixture is moved by a feed wheel or by screws from the pressure chamber into a delivery hose. Air pressure forces the mixture through a delivery hose into the placing nozzle. Water is forced under pressure into the placing nozzle through a separate hose. For dry mixtures, a special surrounding ring or manifold at the nozzle sprays water radially into the dry sand and cement.

Mixer

The mixing equipment must be able to thoroughly mix a continuous supply of sand and cement (and water if a wet mixture). Thorough mixing is essential for good quality mortar. The mixing time and the waiting time between the mixing and placing must be as specificed. To produce a good uniform product, a mixing time of 1½ to **2** min is usually needed. Because materials can stick to the mixing blades, frequent cleaning of the mixer may be necessary.

Pressure Chamber

A vertical double-pressure chamber is most frequently used. Materials are fed into the upper chamber and pressurized. Materials release automatically into the lower chamber when it is empty. As the upper chamber empties, pressure is released so that new materials can be fed and the chamber repressurized. Metering equipment in the lower chamber determines the volume of feed into

the delivery hose. Chambers, feed assemblies, and valves should be cleaned as necessary to maintain uniform delivery to the placing nozzle.

Hose and Placing Nozzle

Mortar placement is best when a hose shorter than 100 ft is used. **A** longer hose can be used, but the pressure must be increased to maintain the proper nozzle velocity. Uniform pressure at the nozzle is necessary, and the limits are specified. The premixing type of placing nozzle, which has a perforated water-feed ring built into the nozzle and distributes water through the mixture, gives the most uniform performance for dry mixtures. Mixtures that are not uniform will wear the liner excessively.

Air Compressor

The air supply must be adequate to furnish the volume and pressure specified without interruption for the longest length of delivery hose. Air is also needed for blowing away the rebound and for other incidental uses.

Water Pumps

Water pressure and air pressure must be uniform and free of surges. The pumping equipment should be able to supply the required volume at a pressure at least 15 lb/in.^{2} greater than the minimum needed for placement.

Placement

A crew of three is usually needed to place pneumatically applied mortar—a nozzle operator, a machine operator, and a person to clear away the rebound. All three should be experienced in working as a team. The quality of the finished job depends primarily on the skill of the nozzle operator.

The machine operator usually regulates the air pressure, water pressure, and feed rate of the mixture so that a uniform flow of mortar is available at the nozzle. Besides clearing away loose materials, the rebound person helps in moving the hose and in other placing details.

Pneumatically applied mortar should be placed systematically. The placing nozzle should be held about **3** ft from and normal (perpendicular) to the receiving surface. The air pressure is adjusted to control the rebound and density of the mortar. Once optimum pressure has been established for a given application, it is held constant throughout the application. With a *dry* mixture, the nozzle operator must also adjust for the proper amount of water. Thickness limits for the various surfaces and the timing of application of subsequent layers must be carefully controlled to avoid sloughing and to ensure a good bond. Surface uniformity is necessary for good appearance and performance. Enough header boards or gauging wires should be used to control the thickness. With skillful mortar placement the need for "fill-ins" and repairs can be avoided. Surfaces for mortar placement must not be frozen, and temperatures must be within the specified range. The operation must be protected or shut down during high winds because they cause the mixture to separate at the nozzle.

Curing

Curing pneumatically applied mortar is just as critical as curing other concrete. The specifications for curing under normal conditions and during hot and cold weather must be followed exactly. The equipment and materials for the approved curing method should be on hand before mortar placement begins so there is no delay in the application.

Tests and Reports

Test cylinder cores from the test panels must be taken as specified. Each cylinder should be properly marked for identification and the required reports prepared. The gradation and moisture content of the sand must be checked.

The types of equipment, size and length of the feed hoses, operating pressure, and the production rate used should be recorded. Reasons for any shutdowns, equipment failures, or other delays must be noted.

Inspection checklist:
pneumatically applied mortar

(Some items may not be listed. Some listed may not apply to every project.)

1. Earth subgrade—shaped as on drawings, firm, moist.
2. Surfaces of concrete and other materials—clean, moist.
3. Reinforcement—properly placed, supported.
4. Header boards and gauging wires—proper dimensions, adequate number.
5. Placing equipment—adequate capacity, good operating conditions.
6. Materials and mixture—meet specifications.
7. Batching and placing equipment—good condition, free from dried mortar.
8. Delivery hose length and pressure—meet specifications.
9. Water pressure—exceeds feed line pressure.
10. Mixing—as specified.
11. Mortar placement speed—previous layer does not set before next layer is placed, maximum delivery times not exceeded.
12. Rebound—not excessive (20–40% is normal).
13. Rebound material—cleared away, not reused.
14. Finished surface—uniform, meets tolerances specified.
15. Sand or slough pockets—cut out and repaired.
16. Weep holes and other drains—proper installation, free from obstruction.
17. Finished mortar—cured as required.
18. Subgrade frozen, air temperatures below specified minimum, or wind excessive—mortaring stopped.
19. Tests—as specified.
20. Materials—certificates received, meet specifications.
21. Record—tests, quantities, job diary entries.

Delivery and Storage

The contractor and the inspector should inspect all material to be used in the work as soon as convenient after delivery to provide the maximum time for the contractor to correct any deficiencies. The material must be insoected to determine that it meets specifications and has not been damaged in transit. Concrete and clay pipes, if dry and standing on end, give a clear ringing sound if tapped with a light hammer. Drain tile, clay sewer pipe, and nonreinforced concrete pipe must be inspected for such manufacturing defects as cracks, blisters, warps, and significant variations in shape. Reinforced concrete pipe must be inspected for the following defects: cracks passing through the shell, transverse cracks around the periphery of the pipe, imperfect mixing or molding, spalls, exposure of the circumferential reinforcement, honeycombed areas, and end finish.

Specifications require that most pipe sections be marked with the manufacturer's name, the pipe class, sue, and head, and the date of manufacture. Pipe for principal spillways requires special marking—concrete pipes are usually **marked** with a stencil and clay pipes are marked by etching the exterior.

Concrete pipe having elliptical reinforcement must be marked with "TOP" on the outside of the pipe to permit the proper orientation. Pipe that requires a particular orientation to carry the loading must not be used in principal spillways.

Pipe lacking the required identification and certification must not be used. The inspector should clearly mark as rejects any sections not meeting specifications. All rejected pipe should be marked in such a manner that the markings will not impair the salvage value of the rejected pipe.

Unloading and Handling

After the concrete pipe is transported to the jobsite, it should be unloaded carefully to prevent damage. If pipe is rolled from trucks or down the embankments, it must be kept under control. If it is pushed with bulldozers or tractors, great care must be taken not to damage it.

Metal pipe must not be pushed or dragged over gravel **or** rocky surfaces since damage to the coatings can adversely affect pipe durability. The pipe must never be lifted with a sling running through it because the resultant forces can damage or break the ends.

Storage

After the pipe is delivered to the worksite, it should be stored in an accessible location—as near as possible to the place it will be installed but not where it can interfere with equipment movement and other preparatory operations. Pipe must never be stacked. Corrugated metal pipe having paved inverts must be stored with the paving at the bottom to prevent the asphaltic invert lining from flowing.

Installation

Trenches are normally excavated to within a few inches of grade with heavy equipment. Then the work is finished and shaped by hand. Because trenches are known to cave in, appropriate safety measures must be used. If material is removed below the subgrade, the void must be backfilled as specified. A uniform bearing strength is essential in any structure foundation. In some places, it may be necessary to excavate below the subgrade to remove unsatisfactory material.

Excavation is usually specified to some depth below the invert of the pipe in rock foundations, and a backfill of earth or concrete is placed to eliminate variation and to provide uniform support for the pipe. The contractor's method of excavation, such as ripping or blasting, must not damage the structure foundation.

The rock foundation must be prepared as specified.

Since the final load on the pipe varies greatly with the dimensions of the trench in a trench installation, it is imperative that the depth, width, and slopes of the trench be constructed exactly as designed.

Drying and cracking (desiccation) of foundation soils can jeopardize the integrity of a hydraulic structure. Special protective measures, such as wetting or sealing, particularly for high shrink-swell soils, may be necessary.

Trench excavation and pipe installation normally proceed upgrade to allow drainage during construction.

Although the flattening of side slopes or shoring trenches is primarily for the safety of the workmen, they also may be required in some places to preserve the integrity of the adjacent foundation. If shoring is used, it must be constructed of materials and in such a manner that it can withstand imposed loads with a margin of safety. If there is any question, the engineer should require the contractor to furnish an analysis of the shoring design for approval.

During excavation for the foundation, ground water is frequently encountered. The contractor's plan for construction should provide for adequate dewatering facilities. They should be installed and functioning satisfactorily at the start of the work.

Alignment and Grade

Pipe conduits must be placed accurately to the line and grade specified. If a concrete cradle or bedding is specified, the pipe can be temporarily supported by blocks of concrete precast from the same concrete specified for the cradle or bedding. These support blocks take many forms, and usually one or two types are shown on the drawings.

For earth beddings, the bottom of the trench excavation is fine-graded and shaped to fit the outer circumference of the pipe (as shown on contract drawings or as directed), then backfilled to a specified grade with the granular material, allowing for consolidation and shaping to fit the pipe. The pipe must rest against solid undisturbed earth, compacted earth, or granular material, as specified, for its entire length except for the couplings or bells, which must be free from the bedding.

Laying Pipe

Unsatisfactory performance of any step in laying pipe can impair the quality of the final product. Intermittent inspection may not reveal these faults so continuous inspection during the pipe laying is imperative.

Before any pipe is placed, the inspector must know that the foundation is satisfactory, is at the right elevation throughout, and contains no cobbles or oversize rock closer to the grade of the pipe than specified. The inspector also must know that the bedding material has been graded uniformly and to the proper thickness and that any bell holes required are properly dug.

The contractor must know how and be able to transfer the grade and the alignment from the stakes to the pipe.

As the pipe is placed, the handling and joining must be inspected. Careless or improper handling can crack or chip rigid pipe, deform flexible pipe, and damage coatings or surfaces. Joint material will be stated in the specification or shown on the

contract drawings. Joints that require a gasket must be checked for positioning of the gasket.

Figure 2–23 shows typical methods of coupling concrete pipe sections. For a pressure pipe, it is desirable to complete each joint individually as the sections are placed, rather than completing a number of the joints at one time. For pipe joints with rubber seal rings or gaskets, the closing should be made as follows: (1) close the joint to ½ in. using inserts (spacers) in the gap, (2) check the correct position of the rubber gasket with a feeler gauge, and (3) remove inserts and complete the closing to the gap specified. All measurements should be made from inside the pipe if the pipe size permits.

For some types of pipe, such as perforated pipe and certain reinforced concrete pipe, it is very important that they be properly oriented. If a concrete pipe is constructed for a specific orientation, the top must be so marked. Perforated pipe must always be laid with perforations at the bottom unless otherwise specified.

Corrugated metal pipe should be laid with the inside of the circumferential lap downstream. The longitudinal laps should be at the sides or quarter points, not on the bottom. To properly position coupling bands on corrugated metal pipe, a clear space is usually required between abutting ends of the pipe sections so that the grooves of the coupling band will match the grooves of the pipe and make a tight joint. During tightening, connecting bands should be tapped with a hammer to fully seat the band. If strutting is specified, it should be checked for proper installation and orientation as the pipe is laid. Any damaged coating must be repaired before the pipe is placed.

The joints of pipes to be placed in embankments are designed to be watertight and to allow elongation and rotation. Failure to follow specifications carefully during installation will impair these features. For example, if concrete mortar is allowed to enter a pipe joint, the joint ceases to be flexible and can no longer rotate without damage to the spigot and bell. Open ends of the pipelines should be kept covered when work is not in progress.

Backfill

Before compacting the backfill under the haunches of any pipe, particularly corrugated metal pipe or steel pipe, it may be necessary to weight the pipe to prevent it from being displaced by the work. In very plastic soils, even weighting may not be enough. Selected excavation or borrow materials should be uniformly placed along both sides of the pipe in layers of the specified depth and moisture content, then compacted to the specified density by manually directed power or hand tampers.

Heavy construction equipment must not be operated within 2 ft of any part of the unprotected structure or be allowed to cross over the structure until it has been covered by at least 2 ft of compacted fill. If concrete is an integral part of the pipe conduit, the curing period required before backfilling is specified. The inspector should examine the backfill to be sure that each layer bonds securely to the previous one and that moisture and density are uniform throughout. Desiccation of the surface is frequently a problem if the work progresses slowly. If this occurs, wetting and scarification are necessary so that the new lift of backfill bonds properly with the old lift.

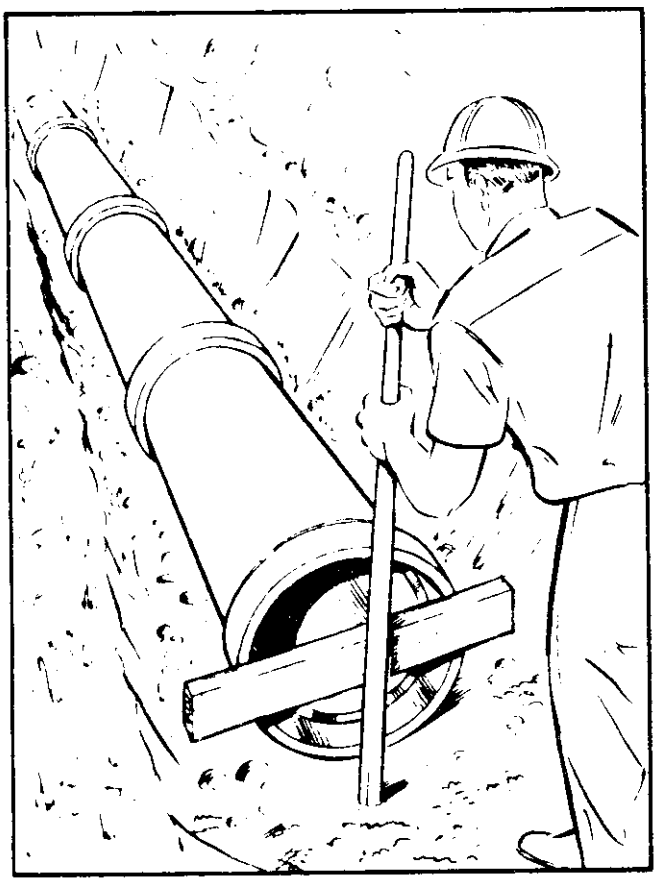
Field Testing for Water Tightness

If field testing of the pipelines is required, the equipment and procedures are specified in the contract. The contractor normally provides all equipment and facilities for making these tests.

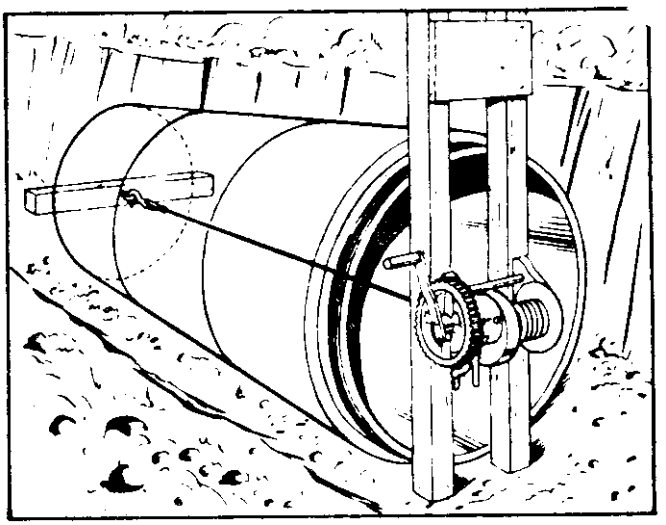
Inspection checklist: pipe structures

(Some items may not be listed. Some listed may not apply to every project.)

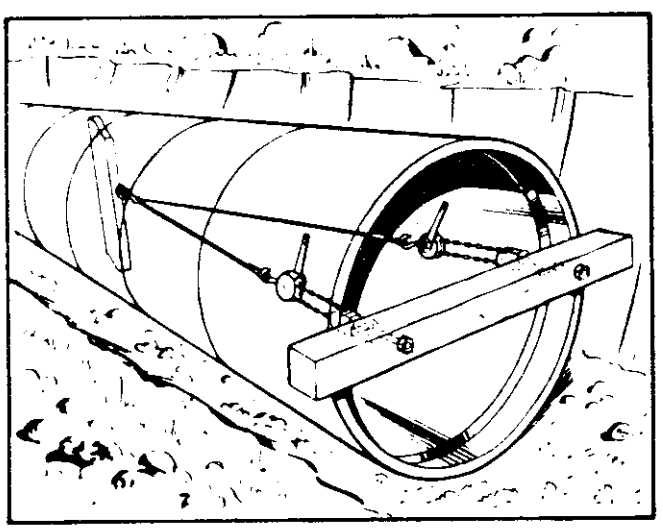
1. Material—certifications, quality.
2. Condition—good.
3. Markings—proper.
4. Diameter—wall thickness, concentricity.
5. Joints—ball and spigot thickness, length; material bonded, cured.
6. Fittings—types, sizes, material.
7. Perforated pipe—size, length, type of perforations, orientation, perforations open.
8. Coating—thickness, integrity.
9. Excavation—line, grade, shape, safe, bell holes.



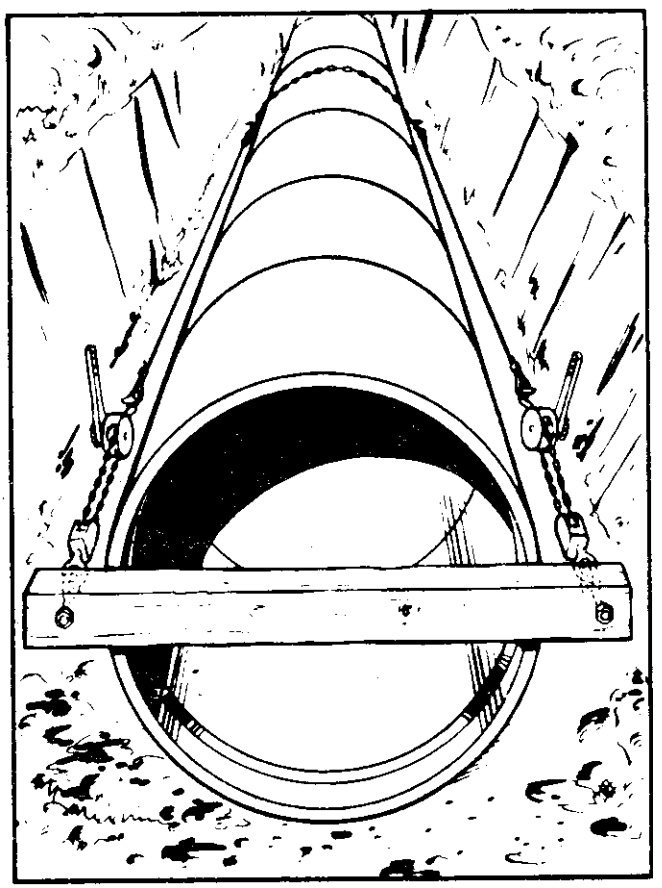
Small bore pipe may be coupled manually, using a cross-member and bar.



Suggested design for winch and cross-members, using an inside pull (manhole to manhole).



For large bore pipe the double come-along inside the pipe is used with a cross-member and deadman.



For an evenly distributed pull, a double come-along is used on the outside with a cross-member and tail-hold

Figure 2-23.—A few of the more common methods of satisfactorily coupling rubber-jointed concrete pipe.

10. Foundation—satisfactory
11. Bedding—quality, thickness, uniformity, shape.
12. Pipe sections—placed, jointed, strutted, supported.
13. Backfill—placement, density, moisture, bond.
14. Record—tests, quantities, job diary entries.

Metal Fabrication and Installation

All metal materials must be of the grade, quality, and size specified. Unless otherwise specified, metal fabrication and installation must conform to the requirements shown in part **5,** Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings, of the publication "Manual of Steel Construction"' or in part **4,** Standards and Specifications, of the publication "Aluminum Construction Manual."[8]

Delivery and Storage

All metal materials must be checked by the contractor and the inspector for quality and quantity and for damage in transit as soon as possible after delivery. This gives the contractor the maximum time possible to replace any material that is unsatisfactory or is missing before it is needed for installation. Certifications of quality should be in hand at this time and must be verified.

Metal materials must be handled carefully during unloading. Clip angles, secondary members, flanges, machined faces, bearing surfaces, and coated members are particularly vulnerable to damage.

Metal materials must be stored off the ground on platform skids or other supports and protected from mechanical injury and surface deterioration.

Inspection of Materials

The contract drawings and specifications (and shop drawings when required) show the dimensions of the materials and the details necessary for their assembly. If the metal is not fabricated properly, it must be rejected and replaced. Sharply kinked, warped, or bent steel must be rejected. Only minor straightening is permissible.

The workmanship and finish must be true and smooth to ensure a proper fit. Rivet and bolt holes must be the proper size, in the correct location, normal to the surface, and not deforming the material. Multiple plies must be clamped tightly together so that no cutting or burrs are forced out between the plies. All outside burrs must be removed. Holes must be drilled **1/16** in. larger than the bolt diameter unless otherwise specified. The drilling and reaming of the holes for turned bolts must be truly cylindrical and no larger than the approved tolerances.

The inspector must verify that shop-installed bolts and nuts meet the class, finish, form, and size specifications. The temporary bolting used during shipping should be removed and replaced with rivets or bolts as specified. The threads must be nicked or upset, if specified, to prevent the nuts from backing off. High-strength bolts are identified by three radial marks in the head and three long indented marks on the nut. They are used with high-carbon steel washers. The bolts need the proper tension applied with a torque wrench. Bolts and rivets must not be used in the same connection. Any mismatched holes must be rereamed, not burned.

All parts of the shop-riveted members must be well secured and rigidly held together. The rivets must be tight and their heads in full contact with the surface. The finished heads should be approximately hemispherical in shape and of uniform size throughout the work. Rivet heads should be full, neat, and concentric with the holes. The rivets can be checked by tapping with a light hammer. A clear ringing sound indicates a tight rivet.

Loose mill scale, slag or flux deposits, rust, spatter, dirt, grease, oil, and other foreign materials must be carefully cleaned from all surfaces intended for welding. Gas cutting of edges should be done with a mechanically guided torch if possible. Welding is done only where specified (as shown on the drawings) and only by qualified welders. All foreign material must be thoroughly cleaned from

[8] *See Chapter 5, General construction.*

all metal surfaces and joints before a prime coat is applied. The coat should be continuous and uniform on the surfaces and worked into the joints. Metal surfaces or edges to be welded or those to be embedded in concrete must not be painted.

Steel metal work is galvanized by the bot-dip process. The required weight in ounces per square foot, if specified in the contract, must he certified by the fabricator or treating plant. The material should be inspected to determine that the zinc coating is continuous, reasonably smooth, and uniform. All blisters, sal ammoniac black spots, and other chemical flux or projections must be removed so that the coating bonds to the steel. The bond should he strong enough that, under heavy pressure, paring or whittling with a strong knife will expose only minute areas of the steel base. All holes must be clean and reasonably free of excess spelter. All steel members and assemblies must be rejected if they are warped or distorted so much that they cannot be installed or function as intended if installed.

Galvanized members and assemblies should be transported and handled in a manner that will not cause abrasion or other damage to the zinc coating. The use of hooks, chains, or other metal to hoist assemblies is prohibited. Any damaged surfaces must be thoroughly cleaned, repaired, and coated as specified.

The inspector must detect any fabrication or assembly errors. They must be corrected before the final riveting or welding is done and preferably before the steel is erected.

Erection

The contractor must take all necessary safety precautions for employees on the job and comply with applicable federal, state, and municipal safety laws and building and construction codes.

As the steel is erected, it must be adequately held and supported to guard against collapse resulting from any abnormal winds or erection loads. If guys are used, they should be taut and adequately anchored. Sufficient bracing and secondary steel should be erected and bolted to maintain the stability of the work. Enough bracing must be erected before the final alignment is started so that aligned parts will not be displaced when adjacent parts are added. The final alignment needs to be started as early as possible during erection so that errors do not accumulate and magnify. Kough handling of the material during erection is not necessary if the fabrication is proper. Hard pounding with sledges and excessive drifting must not be allowed, Holes cannot be recut with a torch.

The inspector is to make sure that enough temporary bolts are placed in all connections to guarantee that the steelwork will hold its alignment during the final riveting or welding operations. Guys or other temporary braces or supports must be removed before the final bolting, riveting, or welding. Adequate facilities should be provided for heating, passing, and driving the rivets. **All** rivets must be uniformly heated without burning, then driven while still hot. Each driven rivet must be tapped individually for tightness and checked visually to make sure that the heads are full, concentric, and properly shaped. If the heads are repeatedly undersize or oversize, the contractor must provide longer or shorter stock. Rejected rivets must be clearly marked and removed without damaging members or holes. If the holes are elongated or distorted, they should be reamed or redrilled and the proper-size rivets be driven. Rivets that are pitted or pockmarked by overheating and burning should not he used.

Welding

Welding is very important in connecting all types of metals. Welding requires careful procedural workmanship. **A** careful, detailed inspection by qualified personnel is essential. Mistakes in welding are often hidden from view unless the entire welding procedure is reviewed. Even then, X-ray testing may be necessary to establish that a joint is fully effective.

Welders should be tested according to an approved welding procedure, and the testing should be overseen by a qualified testing laboratory. Welding qualification is by the position of the weld. The inspector should see that no welding is done in a position by persons not qualified.

To avoid distortion of the members, welds should be performed in a prearranged pattern that is planned for the best distribution of heat. The inspector should verify and check all dimensions of the welds. Overwelding, either in size or length, should not be permitted. The placing of welds in the wrong locations may be as serious as omitting them. Before welding, the joint should be inspected

to see that surfaces are parallel, level, and clean and that the members are aligned. Welding rod or other miscellaneous metal must not be used to fill large voids and spaces. The inspector should examine all electrodes and reject those with damaged or wet coatings and those that are otherwise improper to ensure a quality weld of the members. The number of electrodes per welding pass or bead should be checked. All slag and flux should be removed before laying down the next bead. All defects should be chipped, chiseled, or ground back to base metal before proceeding with the welding.

Welds should be inspected for throat dimension, uniformity, absence of cracking, and specified penetration. This can be accomplished by observing the welding as it is done and checking the completed weld for surface appearance and for surface defects, craters, undercutting, cracks, and other defects. When specified, welds should be inspected by X-ray, magnetic flux, or ultrasonic testing; the minimum percentage of welds judged acceptable with such testing must meet job specifications.

All safety requirements should be checked, and strict compliance with those applicable should be ensured.

Inspection checklist
welding

(Some items may not be listed. Some listed may not apply to every project.)

1. Qualifications of welders—review each welder's qualification records.
2. Location—all welds made and in required locations.
3. Sizes and types—as specified.
4. Testing—X-ray, magnetic flux, or ultrasonic testing as specified, test locations identified and recorded.
5. Procedure—cleaning, leveling, clamping, supporting members as specified; in accordance with standard practice.
6. Materials—proper type of rod, flux, other material used.

Finishing

Before the final coating of metal work, the assembly should be inspected to be sure that it is complete and that all surfaces are clean and *dry.* Paint for the final coats and painting procedures must be as specified. Atmospheric conditions must be within the limits specified. The prime coat should be retouched whenever it has been marred. The paint should be sprayed or brushed on evenly to prevent running or beading. Each coat must be thoroughly *dry* before another coat is applied.

Inspection checklist
metal work

(Some items may not be listed. Some listed may not apply to every project.)

1. Certification—complete.
2. Members-dimension, shape, condition.
3. Shop coating—intact.
4. Storage—protected.
5. Warped or bent members—replaced.
6. Anchor bolts—size, location.
7. Erecting equipment—methods, safety.

Bearing plates or frames

1. Concrete surface—clean.
2. Bearing plates—set, anchored, shimmed.
3. Bedding mortar—placed, cured.

Assembly

1. Members—fitted, leveled, guyed, temporarily connected.
2. Material handlings—no undue force, no refabrication.

Bolted connections

1. Bolts, nuts, and washers—as specified.
2. Seating—clean, uniform.
3. Holes—size, alignment.
4. Tension—torqued.

5. Coatings—before, after.

Riveted connections

1. Holes—alignment, size, reaming, no burning.
2. Rivets—proper heat, tight, uniform heads, no reheating or reforming, mark rejects (includes pitted or pockmarked rivets), paint rivets, touch up shop coat.
3. Marked or deformed member—poor workmanship, improper material or equipment.

Welded connections

1. Surface—clean, no fins or tears.
2. Welds—where specified, size, length, shape, defects.
3. Overwelding—reject.
4. Unspecified holes in members—not permitted.

Painting

1. Assembly—complete, clean.
2. Paint—certified.
3. Weather—acceptable.
4. Painting—skilled, limited to proper surfaces.

Tests

1. Tests, quantities, job diary entries—recorded.

All timber materials to be incorporated in the work must be of the grade, quality, and size specified.

Inspection and Grading

Structural timber and structural lumber (the terms are used interchangably) are generally graded according to the standard grading rules set by the association of producers of that kind of lumber. These rules define the imperfections affecting quality and thereby determine the grade.

The lumber used and the inspection rules followed must conform to whichever set of standard grades and grading rules is specified in the contract. All materials must be marked or stamped for easy identification of the quality and grade. If treated timber is specified, the method of treatment and the chemical retention per cubic foot should be indicated by markings or by a treatment plant report.

The definitions and standards of measurement and classification of typical defects and blemishes in lumber vary with the kinds of lumber and with each set of grading rules. The inspector must thoroughly understand details of the applicable inspection and grading rules.

Defects

Checks.—Checks are lengthwise grain separations that take place during seasoning. They usually cut through or across the growth rings. Checks are further described by their type, location, and size.

Decay (also called rot or dote).—Decay is the disintegration of the organic substances of the wood caused by destructive fungi. There are various stages of decay. Incipient decay changes the color but may not seriously affect the strength or hardness of the wood or make it entirely unfit for use. Advanced decay results in complete breakdown of the wood structure, leaving it soft, spongy, or punky and entirely useless. Peck is a form of pocket rot that occurs in cypress, leaving longitudinal holes.

Holes.—Regardless of the cause, holes affect the utility and grading of lumber. Holes are classified as pinholes, medium holes, and large holes. Grading limitations are frequently based on the

percentage of waste if no holes are permitted in the finished work.

Knots.—Sections of limbs become embedded in tree trunks. They show up as knots when logs are cut into lumber. Knots are generally classified as to size (pin, small, medium, or large knots), form (round if cut crosswise or spike if cut lengthwise), growth (intergrown, watertight, or encased), and stability (tight, fixed, or loose).

Mismanufacture.—Mismanufacture includes defects and blemishes caused during the manufacture of logs into lumber. Examples include: chipped, loosened, raised, or torn grain; skips or unsurfaced areas in dressed lumber; miscuts or variations in sawing from the true line of cut; machine burns or gouges; uneven fits between adjoining pieces; and insufficient tongues, grooves, or laps.

Pitch.—Pitch is a resin accumulation in the wood cells of pine, fir, or spruce. It usually appears in more or less irregular patches or in streaks or pockets. Pitch accumulations are visually judged as light, medium, heavy, or massed. Pitch streaks and pockets are judged by their size and distribution.

Pith.—In the center of a log is a small soft core called the pith. The combination of the pith and the wood immediately around it is called the heart center. The surrounding wood can be discolored and contain small checks, shakes, or pin knots.

Shakes.—Lengthwise grain separations between or through the growth rings are called shakes. A ring shake occurs between the growth rings and is cylindrical in form. A pith shake is radial like a check but is not uniform, being widest near the pith. Shakes are classed by size as fine, slight, medium, or open. They are also classed by extent, as through (extend from one surface to another), round (completely encircle the pith), or cup (partially encircle the pith).

Splits.—Lengthwise separations caused by the tearing apart of wood cells are called splits. They are classed as short, medium, or long.

Stain.—Any discoloration on or in lumber that appears different from the natural color of the wood is a stain. Stains are classed as light, medium, or heavy.

Wane.—Any remaining bark on the edge or corner of lumber or the lack of wood on the edges from any cause is called wane. It is classed in some grading rules as slight, medium, or large by the dimensions of the cross section and by the proportion of the length and thickness of the piece affected.

Warp.—Any variation from a true or plane surface is warp. It includes bow (a deviation in flatness from end to end), cup (a deviation in flatness from side to side), and crook (a deviation along the edge from end to end).

Grading Provisions

Because lumber is a natural material, it is subject to variations that cannot be evaluated precisely. The grading of lumber is not an exact science, but a matter of judgment based on intelligent and reasonable interpretation of the rules. The following provisions are important.

Grading face.—Rules generally specify the lumber face to be graded. Dimension lumber, heavy joists, and structural timber are graded on the basis of the poorest face. Yard lumber, rough or surfaced, is graded on the better side. Lumber surfaced on one side only is graded on the surfaced side; however, the reverse side usually should not be more than one grade lower.

Variations.—Rules generally specify the poorest pieces admissible in each grade but require that materials furnished must be representative of the full range of the grade and not be mostly pieces close to the borderline of the next lower grade. The number of imperfections permitted generally varies with the size of each piece, but the allowable size of any one defect is fixed regardless of the size of the piece. Lumber to be dressed can have defects in its rough form, provided the defects are removed when it is dressed.

Trimming.—Standard lumber must be trimmed to remove splintered ends and spurs. Thin yard lumber must be trimmed at both ends to the specified tolerance over the nominal length.

Heartwood.—The minimum content of heartwood is specified for the select, prime, and merchantable structural lumber grades of longleaf pine. It is no longer specified for the other grades of longleaf lumber or for any shortleaf lumber grade, except as optional special requirements. Cypress is available in all heartwood grades. The percentage of heartwood is the ratio of the minimum girth of the

heartwood to the girth of the piece. Heart face lumber is free from sapwood on the face side.

Combination grades.—For the dealer's convenience in handling certain stocks, different grades of lumber can be combined. For example, A and B grades can be combined as B-and-better grade.

Density rule.—The Southern Pine Association has adopted the so-called density rule for grading dense southern pine lumber. Each piece is to average, on one end or the other, not less than six annual rings per inch and have one-third or more summerwood (the darker harder portion of each annual ring) as measured over a prescribed portion of a radial line from the pith. Lumber not meeting the density-rule requirement is graded as close-grained or medium-grained. Similar rules apply to Douglas-fir and redwood.

Stress rating.—Standard dense structural grades of southern pine are assigned definite working stresses in pounds per square inch for fiber stress in bending, tension parallel to the grain, compression across the grain, horizontal shear, and compression parallel to the grain. Grades are available under the established modified rules for special working stresses in horizontal shear. Stress-rated lumber can be obtained in almost all kinds of softwood and hardwood usually used for construction lumber. The maximum slope of the grain with respect to the longitudinal axis is specified for each stress grade in such terms as 1 in 12 or 1 in 14.

Moisture content.—The strength and volume of lumber vary greatly with the moisture content. Most grading rules specify the maximum moisture percentages allowable for various grades and thicknesses of both air-dried and kiln-dried lumber. But the rules provide enough latitude to meet any more restrictive moisture-content requirements if specified.

Sizes and Lengths

The dimensions of dressed and rough lumber mentioned below are typical under present standards. The inspector should check contract requirements to determine the exact dimensions of lumber materials required for the work.

Dressed Sizes

Minimum actual dimensions are usually specified in the grading rules in considerable detail. Dimensions of dressed lumber are always less than the nominal sizes. For lumber more than 2 in. thick, the thickness and width are ½ in. scant for faces less than 8 in. and ¾ in. scant for faces 8 in. and more.

Match Workings

Tongue-and-grooved flooring, shiplap siding, and other patterned lumber are manufactured to overall widths that are slightly less than the actual widths specified for dressed sizes. However, the width and depth of the tongues and laps are fixed for each grade.

Rough Dry Sizes

Dimensions of rough lumber (when *dry)* are generally between the nominal size and the specified dressed size.

Length Provisions

Boards, strips, dimension lumber, joints, and timbers are furnished in standard lengths from *4* to 20 ft in 2-ft multiples. Flooring, ceiling, and millwork are furnished in these same lengths, but in 1-ft multiples. Longer lengths can be obtained if specially ordered. An assortment of random lengths between 4 and 20 ft can be ordered, but a fair proportion must he more than 10 ft.

Preservative Treatment

Preservative treatment is essential if lumber is to resist various exposure conditions. When inspecting treated timber, American Wood-Preservers Association inspection standards must be followed unless other standards are specified.

Delivery and Storage

Materials Check

As the lumber to be used in a structure is delivered to the worksite, the contractor and the inspector should check to see that it has been inspected and marked for the grades specified. If the lumber is treated, the inspector must check the treatment report to be sure that the treatment meets the specifications and that the lumber *is*

stamped in such a way as to identify it with the report. Materials not meeting the specifications must be plainly marked "REJECT". A description of the materials and the reasons for rejection must be recorded in the job diary. Any timber delivered to the site by the contractor for temporary use during construction does not require inspection. But lumber for formed surfaces, whether or not the surfaces are exposed, must be inspected to ensure that it will produce a satisfactory surface.

Unloading

The inspector is to observe the unloading operations of the structural lumber to be sure that there is no damage in the handling, particularly to the surface layers of materials treated with creosote or other preservative.

Storage

The lumber must be stored in a well-drained area clear of the ground. It must be stacked so there is good air circulation through the pile and so that all pieces hold their shape. One end of the pile should be raised so that water can drain. Lumber must be piled in such a way that the lower layers are not crushed or damaged by the weight of the material above. Kiln-dried lumber must be stored under cover.

Treatment of Cut Surfaces

Unless otherwise specified, damaged surfaces of treated materials, whether cut, planed, or defaced, must be painted or brushed with the type of preservative used in the original treatment.

Erection Procedure

The inspector must make sure that construction meets the specified quality and safety standards. All lumber must be cut accurately and framed to a close fit. An even bearing over the entire contact surface is required. Shimming of the joints is not permitted.

Bolt holes must be drilled to the specified size and alignment. All bolts should be checked in place for washers and tightness. All nails and spike heads must be carefully driven flush. Bent or otherwise damaged nails, overdriving, and deep hammer marks in the wood surface are not acceptable. Any wood surfaces needing field painting must be prepared and coated as specified. Painting should be done only when moisture and temperature are within the limits specified.

Inspection checklist
timber construction

(Some items may not be listed. Some listed may not apply to every project.)

1. Materials—dimensions, shapes, condition, grade, marking, treatment.
2. Erection—alignment, bearing, no shims.
3. Bridging—installed, nailed.
4. Splices—lapped, spiked, bolted.
5. Bolt holes—location, alignment, size.
6. Damaged treated surfaces—re-treated
7. Bolts, driftpins, ring connectors, spikes, etc.—dimensions, location, finish, installation, retightened.
8. Bracing and guying—adequate, removed.
9. Wood surfaces—prepared, painted, treated.
10. Certifications—received.
11. Record—iob diary.

Hot-mix asphaltic concrete consists of a combination of aggregates uniformly graded and mixed with asphaltic cement. It is called hot mix because the aggregates must be dry and the cement must be hot to get the fluidity required for satisfactory mixing, workability, and compaction.

Materials

The concrete product consists of asphalt cement and coarse and fine aggregates, including a mineral filler (materials passing a 200-mesh sieve), that meet specified grading requirements.

The contract specifies the tests to be used to verify the qualities of the materials. Some tests may be required before construction begins. They should be repeated as often as necessary to be sure that the asphaltic concrete meets specifications.

Mixture

The contract is to state who is responsible for the design and control of the mixture. The best combination of aggregate gradations available should be used in the design of the mixture at a near-optimum asphaltic content. The size of a batch should not exceed the capacity of the mixer.

Plant Operations

Successful production of a uniform concrete product requires that the aggregates be properly graded and the aggregates and asphalt cement be uniformly blended at a consistent temperature. The plant inspector should watch for mixing irregularities that may alter the quality of the concrete. Some of the problem areas are described below.

Feeding.—The cold feed must deliver aggregates of uniform gradation from the stockpile to the drier at a constant rate. Improper stockpiling, malfunctioning of the feeders, and variable moisture or debris in the aggregates can cause an unsatisfactory feed.

Drying.—The drier has a revolving drum to dry and heat coarse and fine aggregates. The drum's diameter, length, slope, turning speed, and arrangement of cups or lifters control the time the aggregate remains in the drier. It may be necessary to vary the amount of heat, change the rate of flow of the aggregate, or change the angle of the drum to obtain drying of the aggregate.

Contamination.—Since driers are often fired with fuel oil, aggregates should be checked for smoke coating as they leave the drier. Incomplete combustion can result in an oily residue on the aggregates that later cause the asphalt to coat unevenly. The blower air, draft air, and amount of fuel must be in proper balance.

Temperature.—The aggregate heat-measuring device, one of the most important control accessories of the plant, must operate within a specified temperature range. The sensing element of the heat indicator extending into the main aggregate streamflow must have a protective shield sturdy enough to protect it from aggregate abrasion but not so thick that it will give a distorted temperature reading. Dust accumulation on the sensing element can cause a time lag in the temperature measurement. Heat-measuring instruments should be checked frequently for accuracy. Such devices should be located so that they ensure accurate and representative readings.

Dust collecting.—The dust collector system provides the draft through the drier and also collects and returns a uniform amount of fine material. Regular checking of the system is needed.

Screens.—Screens separate aggregates into sizes as they go from the drier into the bins. The fine screen (¼ in.) is generally the controlling factor. If the quantity fed from the drier exceeds the screen capacity, there will be a carryover of the finer material into the next larger size. The allowable carryover percentage is limited by the specifications. The use of worn or broken screens with enlarged openings results in oversize material in a bin. Screens should be inspected daily, preferably before production begins.

Bins.—Bins of adequate size are needed to keep the hot aggregates separate after screening. Overflow vents control the level of the material. The use of undersize bins, bins without overflow vents, or bins with holes in adjoining bin walls can result in mixing of the particle sizes.

Scales.—All scales must operate properly and be free from bind or drag. They must be checked for accuracy to be sure that the aggregate is properly proportioned and that the proper amount of asphalt is batched. Incorrect amounts of an aggregate size or the incorrect quantity of asphalt are common

problems and are the most frequent causes of poor quality concrete.

Mixers.—Most asphalt plants use a pug mill mixer consisting of a chamber with two horizontal shafts equipped with a system of mixing paddles. Settings for the paddles and the direction of throw may vary, depending on whether the plant operation is continuous or a batch type. The mixer must not be overloaded or underloaded. Overloading can cause part of the material to float above the paddles, and underloading lets paddles rake through the material with little mixing action. The inspector must see that all aggregates are uniformly coated and that there are no dead spots in the mixer.

Transporting the Mixture

Asphaltic concrete is usually hauled from the mixing plant to the jobsite in trucks. Coatings used to keep the material from sticking to the truck bed must be used sparingly to avoid contaminating the asphaltic concrete material. Any excess should be drained away before the truck is loaded. Trucks should be equipped with covers of heavy canvas or other suitable material to protect the mixture from the weather and to retain heat. Trucks must be properly constructed so that they dump the mixture without delay or waste into the spreading machines, in windrows, or at other locations. Temperature control of the mixture can become a problem caused by bunching of the trucks, intermittent plant operations, spreading too far in advance, or atmospheric conditions. The inspector must not approve placement of the materials at temperatures lower than specified.

Site Preparation

The subgrade must be moist, free from organic and loose materials, and compacted to a uniform, specified cross section. Underdrains must be installed at the locations specified.

Because weeds and other vegetative growth are potential hazards to apshaltic concrete, the contract may specify the materials and procedures for soil sterilization. The inspector should be sure that the sterilizing materials are well mixed and that the spraying equipment has the proper pressure to achieve uniform distribution at a rate that can be fully absorbed by the soil. Sterilizing materials must be applied well in advance of placing the asphaltic concrete.

Placing and Compacting

The concrete mixture is usually placed with a paver or placed in a windrow to be spread with a blade. Rolling should accompany or closely follow the spreading.

Paver

A paver consists of a hopper, conveyor, distributing screws, and screed capable of spreading the mixture to the line, grade, and cross section specified. It usually has either tamping bars or a vibrating screed to partially compact the material. The screed should be heated when starting a spread and as necessary thereafter. The paver must be able to place the mixture without tearing, ridging, or gouging, and it must produce a uniform, even-textured surface. The operation should be maintained as continuously as possible so that the mixture does not cool below the optimum viscosity of the asphalt for proper spreading and compaction. Edge joints should be kept straight with as near a vertical face on the first course as possible. The joints should be kept free of loose materials.

Rolling

After the concrete mixture is placed and shaped, the mixture is rolled. The rolling should start as soon as the mixture can bear the roller weight without serious displacement.

A steel-wheeled roller is used for the initial rolling to set the mixture and prevent later displacement. Rolling must be continuous until the roller marks disappear and the mass is compacted to a uniform surface and to the required density. Steel rollers must be equipped with scrapers.

A pneumatic-tired roller can be used for the secondary rolling. Pneumatic rolling may have to be delayed until the mixture temperature has dropped enough to prevent rutting during rolling. The tire pressure and spacing should be checked for proper coverage. Roller wheel surfaces must be properly moistened. If the material tends to stick, a soluble oil mixture (about 1 part oil to 50 parts water) can be added to the roller water.

Reinforcement

In canal linings that are relatively thin, steel mesh or some other kind of reinforcement may be required. All reinforcement materials must be placed as specified and kept free from mud, grease, or other harmful coatings. The reinforcement should be installed well before placement of the asphaltic concrete to permit inspection. The placement and anchorage of supports for the reinforcement are vitally important. Additional checks should be made as the asphaltic mixture is placed to be sure that the reinforcement is not disturbed.

Joints

Transverse ioints must be well sealed and bonded as specified. The edge of the inplace concrete may need to be cut back to its full depth to expose a fresh surface before placing the new concrete mixture. The contact surface of the inplace concrete may require preheating to ensure a good bond. Contact surfaces of the joints and inplace structures may need a thin coat of hot asphaltic cement before the new concrete mixture is placed.

If the areas to be concreted cannot accommodate regular equipment for placement and rolling, the mixture can be handraked and compacted with heated tampers. A careful inspection of these areas is needed to be sure that there is a satisfactory bond between the hand-placed mixture and machine-placed concrete and that density requirements are met.

Inspection checklist: asphaltic concrete

(Some items may not be listed. Some listed may not apply to every project.)

1. Aggregates—gradation, contamination, segregation.
2. Cold feed—calibrated, clear.
3. Drier—rate, heat, air, clean burning.
4. Dust collector—proper draft, returns.
5. Screens—wear, size, overload.
6. Hot bins—load, release, overload
7. Scales—check operation.
8. Timer—operation.
9. Mixing—coating, temperature.
10. Trucks—clean. coated. covered
11. Subgrade—moist, firm, sterile, grade, cross section.
12. Steel reinforcement—tied, supported.
13. Placement—section, temperature, density, finish.
14. Roller—clean, weight, type.
15. Joints—straight, vertical, clean, coated.
16. Material—weight, slips, tests
17. Record—tests, quantities, job diary.

Loose Rock Riprap

Loose rock riprap is a blanket of well-graded, durable rock pieces placed to prevent erosion. It is used to protect the upstream slopes of earth dams against wave action. It also is used on bridge abutments, canal slopes, railroad and highway embankments, levees, culvert headwalls, and stream channels to protect the earth from the erosive forces of flowing water. Sometimes the flowing water is laden with ice or debris that increases the erosive force on the riprap or soil.

Materials

Rock

The quality and gradation of the rock must be as specified. Frequently a fine material will be used under the riprap for bedding or a filter. The rock for riprap must resist abrasion, be sound and durable, and have a high specific gravity. The best kinds of rock, in the preferred order of quality, are **(1)** igneous rock, (2) massive metamorphic and metamorphosed sedimentary rock, and (3) well-cemented sandstone or limestone. The quality gradation and testing standards are specified in the contract.

If the specifications require testing or the engineer deems testing to be necessary, rock samples should be selected and sent to the laboratory well before the material is to be used. Often the proposed rock source has been used by other construction agencies, such as state highway departments, and they may have up-to-date test data. If available, these data should be reviewed to see if they verify the adequacy of the rock. If they do, there may be no need for additional testing. But if the rock is to be taken from untested sources or from excavations on the jobsite, it must be tested as specified before it can be used. Tests are not required if the rock source is specified in the contract and the quality of the material has already been determined.

One procedure for checking the gradation is to have a representative load of rock of known weight delivered to the jobsite. Individual pieces of the rock are then examined visually and measured. (The smallest dimension of any rock should not be less than one-third of its largest dimension.) In this manner the entire load can be separated into various size groups.

If the specifications require that certain percentages of the rock fall within stated weight ranges, each stone in the test is measured for volume and the weight is computed. Volume can be converted to weight if the actual specific gravity of the rock is known; otherwise, a value must be assumed. For a hard, dense rock, a specific gravity of **2.6** is often used. For other kinds of rocks, the specific gravity may range from **2.3** to **2.8,** depending on the characteristics of each material.

To find the weight in pounds per cubic inch of rock with a specific gravity of **2.6:**

Specific gravity times standard measure of pounds per cubic foot of water equals rock weight in pounds per cubic foot:

$$2.6 \times 62.5 \text{ lb/ft}^3 = 162.5 \text{ lb/ft}^3$$

Pounds per cubic foot divided by cubic inches per cubic foot equals rock weight in pounds per cubic inch:

$$162.5 \text{ lb/ft}^3 \div 1{,}728 \text{ in}^3\text{/ft}^3 = 0.094 \text{ lb/in}^3$$

As each piece of rock in the sample is measured and separated by size into piles, the results can be tabulated as shown below. (The measured sizes and computed weights of each piece are rounded to the nearest whole number.)

Size of rock pieces	Volume each piece	Weight each piece: vol. x 0.094	Rocks per category	Weight per category
inches	in^3	lb/in^3		lb
15 x 18 x 12 . .	3240	305	6	1830
12 x 12 x 15 . .	2160	203	10	2030
12 x 8 x 15 . . .	1440	135	12	1620
12 x 10 x 8 . . .	960	90	15	1350
6 x 8 x 8	384	36	60	2160
6 x 6 x 4	144	14	100	1400
4 x 4 x 4	48	5	150	750

Total weight of sample load = **11,140** lb.

Rocks weighing between **200** and **350** lb each = **3,860** lb **(34.6%** of total).

Rocks weighing between 75 and **200** lb each = **2,970** lb **(26.7%** of total).

Rocks weighing under **75** lb each = **4,310** lb **(38.7%** of total).

The load weight as determined above should be compared with the delivery weight of the sample to be certain that there is no large discrepancy between the two figures. If greater accuracy is needed, the rocks of different sizes must be weighed.

Filters and Bedding

Sand and gravel material for drainage or for bedding for riprap should be tough, hard, durable, well-graded, and reasonably free of thin, flat, and elongated particles. The material should not contain organic matter or soft friable particles that will disintegrate. It can be composed of sand, a sand and gravel mixture, gravel, or crushed stone graded within the limits specified.

Foundation Preparation

Surfaces on which the filter blanket or the rock riprap will be placed must be trimmed to the lines and grades shown on the drawings. Surfaces below grade must be brought up to grade by filling with compacted material. Unless otherwise specified, the contractor can choose to place additional bedding, filter, or riprap material in lieu of compacted earth.

Installation

Equipment Placement

The rough surface of equipment-placed riprap helps reduce wave travel on an embankment slope. Where a heavy protective cover is required, equipment placement is often more economical than other methods since little or no labor is needed. However, hand placement may be specified for areas adjacent to structures or for other critical locations.

A power crane equipped with a clamshell or orangepeel bucket or a dump-type skip is preferred for placing rock riprap. If properly operated, it can maintain the gradation and thickness with a minimum amount of reworking of the material. Front-end loaders can also be used for the rock placement. If equipped with tracks, the loaders can work on steep slopes. A bulldozer equipped with a rock rake attachment is sometimes used to place rock. However, maintaining the specified gradation in placement is difficult.

Equipment-placed riprap must be spread on surfaces to the depths indicated on the drawings or as staked on the ground. The riprap should be placed to its fullest thickness in one operation in a way that will not seriously displace the underlying materials. As the riprap is spread, the mass of stones inplace must be reasonably well graded, with the larger rocks uniformly distributed and the smaller rocks and spalls filling voids between the larger rocks. Some hand placement may be necessary to fill the voids. The surface must be reworked and dressed as necessary to provide a pleasing appearance and meet the finish limits specified. Plating (compacting the rock with a heavy steel plate suspended from a crane) may be specified.

Hand Placement

Hand placement of riprap is usually limited to small areas, such as around structures. Rock for hand placement is usually quite uniform in size and must be placed systematically. Rock spalls and small fragments are sledged in place to fill spaces between larger single rocks and to bind the surface. The principal disadvantages of hand-placed riprap are the weakness of its single-course construction and its relatively high cost. Displacement exposes the underlying material to erosion.

If hand placement is specified, the rock must be placed to the depths indicated. The adjacent stones must be set in close contact, generally with the greatest dimension across the slope. Spaces between the large pieces should be filled with smaller fragments, but several small pieces should not be grouped to fill a large space. Flat slab rocks have poor stability; if used, they should be placed on edge.

Filters and Bedding

Granular materials proposed for filters or bedding should be tested before delivery to the site to ensure that the gradation and quality meet the specifications. The material must be spread uniformly, without segregation or contamination, on the prepared surface to the line and depths shown on the drawings or staked on the ground and compacted as specified. The surface must be reasonably smooth and even. If large surface areas must be covered, the blanket material can be placed in narrow horizontal strips or courses and covered with riprap before additional strips of the blanket material are placed.

Inspection checklist
rock riprap

(Some items may not be listed. Some listed may not apply to every project.)

1. Foundation—lines, grade, density.
2. Filter or blanket material—quality, gradation
3. Placement—thickness, segregation, density.
4. Rock—quality, gradation.
5. Placement—thickness, uniformity, voids, clusters, blanket integrity, plating.
6. Weight slips—delivered.
7. Records—tests, certificates, job diary.

Grouted rock riprap is often used if larger rock is not economically available and heavy-duty protection is needed. In this type of riprap, rocks are bound together by concrete grout. Grouted **rock** riprap is suitable for all surfaces and for most flow conditions. Sometimes it is designed with oversize rocks placed in a variable pattern to produce a rough surface that will retard the water velocity or wave runup in a protected area. Grouting the rock also inhibits vandalism. Normally the grout should not be so deep that the mass will not crack to allow the riprap to maintain contact with the subgrade if settlement occurs.

Materials

Rock for grouted riprap must be sound, dense, free from any adherent coating, and meet specifications. Shape and gradation are important €or good construction. Well-graded angular rock is preferred. An excess of the large sizes increases the voids and requires more mortar, whereas an excess of the small sizes can limit penetration of the grout and produce weak and short-lived protection.

Concrete grout is composed of cement, concrete sand, coarse aggregate (usually limited to a 3/4-in. maximum), and water mixed in the proportions specified in the contract or as directed by the engineer. Grout should have enough slump for the mixture to flow into the voids between rock fragments, yet be stiff enough to go no further. The use of air-entraining admixtures improves workability.

Foundation Preparation

A good foundation is essential for grouted riprap protection. Because there are no joints, uneven settlement of the subgrade can leave voids below the riprap or cause the riprap to break into sections. The subgrade must he excavated to the lines and grades shown on the drawings. Soft areas should normally be removed and replaced with backfill that is equal to the surrounding material in supporting capability. The beginning and end sections must be carefully installed to prevent their being undermined.

Filter, bedding, rock, and cement materials must meet contract specifications for quality, gradation, and the required thickness. The contractor should

furnish samples far enough in advance of the work that they can be tested. Materials for the weep holes and other drainage features must meet specifications.

Placement

The filter or bedding material must be placed to the specified thickness and in a manner that avoids segregation and contamination. The rock should be placed to the proper thickness in a manner that will not unduly disturb the bedding material. The gradation should be relatively uniform, with the small fragments distributed throughout the voids of the larger stones. Before the grout is placed, the rock should be flushed with water under enough pressure to clean the rock surfaces and remove excess fine materials. The rock must be kept continuously moist for at least 1 hr before the grout is placed.

The grout should be mixed to the proper proportions and slump. It can be placed with almost any type of conveyance as long as the materials do not segregate. The placement should be continuous and should cover a strip about 10 ft wide at a time. On slopes the placement should start at the foot and proceed to the top. A landing platform to receive the grout from the conveyance may be needed to avoid displacing the riprap.

The grout should penetrate to the specified depth and completely fill any voids. Small vibrators and bars aid penetration. Shovels and stiff-bristled push brooms are useful for moving excess mortar up the slope and for cleanup of the surface area. It is desirable to clean grout coatings off the faces of any exposed larger rocks, since such coatings tend to weather and spall. On the steep slopes it may be necessary to place the grout in two separate courses to prevent excessive downslope movement. The final operation is brooming up the slope to eliminate runs and to make sure all voids are filled.

Curing and Protection

The curing specifications for the regular concrete also apply to the grouted riprap. If water is used for curing, it must be applied with fog nozzles or in a wet absorptive cover as soon as the concrete has taken the initial set. The grouted riprap must be kept wet for the specified curing period or covered with a curing compound. If curing compounds are used, they should be applied at the specified rate after final grout placement as soon as surface water has disappeared (concrete no longer has a shiny surface).

During hot and cold weather placement, the grout must be protected to maintain the temperature for the duration of the curing period in the same manner as for regular concrete. Grout must not be placed when the subgrade is frozen.

The surface of freshly placed mortar should be protected from rain or running water. Foot travel over the surface of fresh grout during the first 24 hr should be limited to that needed to complete the work.

Tests

Tests of grouted rock riprap are not usually required. Tests of rock and concrete ingredients may be specified.

Inspection checklist:
grouted rock riprap

(Some items may not be listed. Some listed may not apply to every project.)

1. Foundation—line, grade, density, moist.
2. Materials—quality, gradation, weights, batch tickets.
3. Placement—thickness, uniformity.
4. Grout—mixture, slump.
5. Placement—no disturbance, penetration, segregation, sequence.
6. Finish—as specified.
7. Drainage—as specified.
8. Curing—as specified, temperature, protection.
9. Tests—as specified.
10. Record—job diary.

Sacked Concrete Riprap

Sacked concrete riprap is a revetment type of protection consisting of portland cement concrete placed in cloth or composition sacks and laid in a pattern similar to rock masonry. To be successful, the foundation must be essentially free from settlement and section ends must be keyed into the foundation and abutments sufficiently to resist erosion. Sacked concrete riprap is used to protect streambanks and to control erosion adjacent to the structures or other appurtenances.

Materials

Concrete

The quality of the materials and gradation of the aggregate are specified in the contract. If a dry mix of portland cement, sand, and coarse aggregate is specified, the water for hydration is provided by the moisture in the aggregates and by sprinkling the bags after their placement. In a wet mix, slump control is important to facilitate the installation. Generally, concrete is mixed on the "wet side" with about a 5-in. slump. Strength tests are not normally required since the relatively low strength (approximately 2,000 lb/in^2) is usually adequate for this kind of construction.

Sacks

Sacks can be burlap or any other material specified that has adequate capacity and strength. Grain-type burlap sacks are good because of their size, about 20 by 36 in., and the openness of their weave.

Foundation Preparation

The foundation areas must be graded as shown on the drawings. The subgrade must be firm and shaped as specified. Drainage materials or appurtenances must be installed as specified.

Placement

The drawings and specifications describe the pattern for the riprap. If a double-base course is required, the bottom tier is two side-by-side rows of stretchers (length of the sack parallel to the slope). The second tier is placed as headers (sacks placed side by side at right angles to the stretcher tier). Succeeding rows are usually placed as stretchers and are laid so that joints between the sacks in consecutive tiers are staggered. Sacks should be placed immediately after they are filled. Sacks laid as stretchers are placed so that folded ends do not abut. Sacks laid as headers are placed with the tied ends toward the subgrade or bank.

After placement, each sack must be lightly trampled to conform its shape to that of the subgrade and adjacent inplace sacks and to extrude some of the cement (dry) or mortar through the sack material. This helps create a bond between the tiers. All dirt or other debris must be carefully swept off the top of the inplace tier before starting a new tier.

Curing and Protection

Proper curing can improve the strength and durability of sacked concrete riprap. Because of the sack material, a wet curing method must be used. Curing is to start as soon as the concrete sets.

The riprap surface should be sprinkled lightly at least every 2 hr during the daytime, or the surface should be covered with earth or other absorptive materials that are kept wet for the specified curing period. If the riprap is placed during hot or cold weather, the restrictions and protection pertaining to "cold or hot weather" portland cement concrete construction apply.

Tests

There are no tests for quality of inplace sacked concrete riprap. Tests of the cement and aggregates may be specified.

Inspection checklist:
sacked concrete riprap

(Some items may not be listed. Some listed may not apply to every project.)

1. Foundation—line, grade, density, moisture.
2. Materials—as specified.
3. Placement—as specified, continuous, compacted, clean, bonded.

4. Drains—installed.
5. Extremities—keyed.
6. Curing—moisture, temperature.
7. Record—tests, certifications, job diary.

Soil-Cement Construction

Soil-cement is a mixture of pulverized soil and measured amounts of portland cement and water that is compacted to a high density. When mixed with soil, the cement reduces the plasticity of the soil, decreases its water-holding and volume-change capacities, and increases its bearing value and shearing strength. For steep slopes or restricted areas, soil-cement can be mixed in a central plant or in position at the site. After mixing, it must be moved quickly to its final position and spread.

Types of Soil-Cement

Compacted Soil-Cement

Compacted soil-cement contains enough cement to harden the soil and enough water for compaction of the soil and hydration of the cement. The descriptions that follow under headings Materials, Mixture, Installation, Curing, and Testing pertain to this type of soil-cement.

Cement-Modified Soil

The cement-modified soil is an unhardened or semi-hardened mixture of soil and cement. Compared to compacted soil-cement, it has a lower cement requirement (just enough is used to change the soil's physical properties to the degree desired). Construction procedures are similar to those used for compacted soil-cement, although not as exacting. To get the maximum benefit, the cement and water should be blended uniformly and the mixture compacted as it is placed. Curing is often omitted for cement-modified soils.

Plastic Soil-Cement

The plastic soil-cement contains enough water to get a consistency similar to concrete or to plastering mortar. Plastic soil-cement is used primarily for irregular or confined areas where it is difficult to place and compact the soil cement.

Since plastic soil-cement has a concretelike consistency, it is usually blended in a concrete mixer. Placing, vibrating, finishing, and curing are carried out much the same as for concrete.

Materials

Soil

Most of the soil used for the soil-cement is taken from site materials or from sources within a short distance of the site. The class and quality of the soil materials will be specified.

Cement

Any type of portland cement meeting specifications can be used.

Water

The water should be free from injurious amounts of alkalies, acids, and organic matter.

Mixture

The cement content is important. Too little cement results in inferior strength and durability; too much cement results in waste. It must be well mixed with the soil.

Water in the soil and cement mass facilitates compaction and hydrates the cement. How much water to add depends on the optimum moisture content specified for the mixture and the amount of moisture present in the untreated soil. The range for total moisture content will be specified in the contract.

Installation

Initial Preparation

The area to receive the soil-cement must be shaped to the lines and grades shown on the drawings. Unsuitable soil must be removed and replaced with acceptable material, and additional soil must be placed as required. The subgrade must be firm and capable of supporting construction equipment during treatment as well as supporting the design loads afterward.

Scarifying and Pulverizing

If the inplace soil can be used, the first construction operation is scarifying to the depth specified. The effective depth of the scarifying must be checked immediately after starting, and adjustments must be made until the specified depth is reached. The equipment must be routed so that it operates on an undisturbed surface to maintain a uniform depth. After the material is loosened, it is pulverized as specified.

Each soil type has its own pulverizing characteristics. Often its moisture content significantly affects the breakdown rate and dictates the equipment needed. Generally, friable soils pulverize quite readily, even when the moisture content is near the plastic limit. Heavier soils having a moisture content either near the shrinkage limit or near the plastic limit can be very difficult to break down. Rotary mixers, harrows, offset disks, rollers, or moldboard plows can be used for pulverizing.

Adding Cement

Just before spreading the cement, the pulverized surface must be checked for the correct cross section and grade. Control of the cement distribution is critical—it can be spread mechanically or by dumping bagged cement accurately in a predetermined pattern. Mixing must start immediately after the cement is added.

Some of the equipment used for scarifying and pulverizing can also be used to mix the soil and cement. A mobile mixing machine can be used that simultaneously adds cement and water and mixes them with the inplace soil. The uniformity and depth of the soil-cement mixture must be checked frequently.

Adding Water and Mixing

Cement can be mixed with soil without cement balls forming if the moisture does not exceed the specified optimum by more than two percentage points for that particular mixture. The best mixing condition is about two percentage points below optimum. Moisture tests should be made as the cement and soil are mixed. Water is added as required and final mixing started as soon as possible after the cement has been added to the soil. The moisture content for the soil-cement mixture is critical for the compaction operation that follows and should be between optimum and two percentage points above optimum at the time of compaction.

Compaction

Soil-cement mixtures must be compacted as soon as possible after mixing (no more than 30 min after mixing). Pneumatic-tired, steel-wheeled, or sheepsfoot rollers are usually used for compaction. Occasionally, the equipment is specified. It should be routed in a pattern that provides uniform coverage. As the work proceeds, the density of the compacted material must be checked with the maximum density obtained in the field moisture density test to verify that the specifications are met.

Curing

Compacted soil-cement contains enough moisture for cement hydration. Some type of cover or seal must be placed over the finished surface right after compaction to retain the moisture. A light application of bituminous material is usually specified, but canvas, burlap, waterproof paper, moistened straw. or soil can also be used.

Testing

Soil-cement construction requires tests similar to those required for compacted embankments. Test procedures are specified in the contract.

ASTM D–558, "Moisture-Density Relations of Soil-Cement Mixtures," is used to determine the optimum moisture and maximum density of the specific soil. Tests of the complete work are made for density and depth. Field checks for pulverization, uniformity of cement content, uniformity of the mixture, and depth of treatment are essential to verify a satisfactory job.

Inspection checklist:
soil-cement construction

(Some items may not be listed. Some listed may not apply to every project.)

1. Foundation—line, grade, density, temperature, moist.

2. Soil—as pretested
3. Scarification—depth, uniformity.
4. Pulverization—as specified.
5. Cement-certified, content, distribution.
6. Mixing—uniformity, depth, continuous
7. Moisture—for cement application, for compaction.
8. Density—testing, specifications.
9. Protection—curing, weather, temperature.
10. Product—thickness, appearance.
11. Record—tests, certificates, job diary.

Water Control Gates and Valves

Types

Many types of gates and valves are used in the soil and water conservation systems that SCS assists in constructing. Details are shown on the contract and shop drawings and are listed in the contract specifications.

Inspection

When the gates and valves are delivered to the jobsite, all parts should be examined by the contractor and inspector for manufacturing defects, damage in transit, conformity to the specifications, accessory parts, and compatible assembly. Defective or damaged materials must be rejected and the reasons for rejection documented in the job diary.

Gates and valve assemblies should be stored in a manner that prevents corrosion or other damage.

Installation

Gates, valves, and appurtenances must be carefully installed in accordance with the contract drawings and the manufacturer's instructions. They must be carefully made and adjusted at the factory. Assemblies should not be dismantled on the job. Gate seat castings must be carefully positioned and rigidly held in place to prevent warping or distortion. Strutting may be necessary for those diameters greater than 24 in. Concrete surfaces used for bearing or support must be smooth and uniform. Anchor bolts should be tightened to a uniform tension, making sure that the metal parts retain their correct fit and alignment.

After installation, all valves, gates, and appurtenances should be tested by opening and closing through the full operating range. Each part of the assembly should be observed during the operation to make sure that all parts are properly aligned and anchored and that they function without unnecessary strain or distortion. Adjustments may be necessary to provide a watertight, smooth-working installation.

Inspection checklist: water control gates and valves

(Some items may not be listed. Some listed may not apply to every project.)

1. Valves, gates, and appurtenances—certified
2. Templates and installation instruction—furnished.
3. Storage and handling—satisfactory.
4. Assemblies—assembled, painted, coated, water tight, clean, lubricated, operation.
5. Embedded metal—clean, aligned, anchored
6. Recesses—formed.
7. Seats—smooth, true.
8. Hoists, stems, stem guides, and other appurtenances—aligned, anchored.
9. Flap gate seat—vertical or bottom projecting slightly downstream.
10. Record—tests, certifications, job diary.

Fences and Fence Construction

Types

Barbed wire, woven wire, and chain link fences are all used with soil and water conservation measures.

Materials

The drawings and specifications prescribe the details of the fence system. Materials should be inspected for conformance with the contract requirements as soon as possible after they are delivered to the jobsite. Certifications should be in hand at this time. Any damage in handling or transit must be noted and provisions made for repair or replacement.

Storage

Fencing materials must be stored in a clean *dry* place.

Construction

All posts should be set vertically and carefully aligned. Size of holes and types of backfill must be as specified. The wire must be stretched carefully to avoid overstressing the pull-post assemblies and the tension bends in woven wire, particularly if it is installed in very hot weather. Gates should be installed after the fence is in place so that the gate anchorage is not disturbed and that the gates operate satisfactorily.

Inspection checklist:
fences and fence
construction

(Some items may not be listed. Some listed may not apply to every project.)

1. Wooden posts—species, size, length, straight, peeled, treated, certified.
2. Metal posts—shape, size, weight, coated, certified.
3. Fencing, fasteners—as specified, certified.
4. Storage—protected.
5. Staking—completed.
6. Posts—spacing, embedment, vertical, aligned, backfill crowned.
7. Damaged posts—replaced.
8. Bracing—tight.
9. Concrete—placed, cured.
10. Wire—location, tension, splices, fastenings.
11. Damage—repaired.
12. Gates—certified, assembled, functioning.
13. Record—job diary.

Piles and Pile Driving

Piles are structural members driven into the ground to support a load or, in the case of sheet piles, to provide a wall. Piles are made of wood, concrete, steel, or a combination of steel and concrete. Concrete piles can be precast or cast in place. Steel piles can have structural shapes, such as round and **H** section, or be formed as sheets for sheet piling. Wood piles can be round or be in structural shapes (wood-sheet piling is often called Wakefield sheeting).

Piling Materials

Timber

Wood-bearing piles are cut from straight, sound trees, free from large or loose knots and other defects that impair strength or durability. Douglas-fir, yellow pine, redwood, southern cypress, and similar species are used. Trees should be uniformly tapered from butt to tip. **A** straight line from the center of the butt to the center of the tip must be within the pile body. Unless otherwise allowed, trees should be cut when the sap is down and peeled soon after cutting.

Dimension lumber is placed in two or three laminated rows for wood-sheet piling (Wakefield) and may occasionally be driven as a bearing pile.

The tree species and the kind and amount of preservative treatment and other special processing needs are specified in the contract.

Steel

The usual shapes for steel bearing piles are **H** and I shapes. Rolled-steel sections, steel pipe, and railroad rails are also used. Special shapes, usually with an interlock, are manufactured for sheet piling.

Concrete

Concrete piles can be cast in place by drilling holes, which are then filled with concrete, or by driving sheet shells into the ground and filling the shells with concrete. Precast piles are reinforced concrete members that are cast before driving. They may be prestressed. Precast concrete pilings are also formed in tongue-and-groove sections for sheet piling.

Handling and Storage

Piles must be unloaded carefully to avoid damaging them and in a way that complies with safety regulations. Stacked or loaded pilings can be very hazardous. A crane should be used for unloading. Each pile must be picked up by at least two lift points with an equalizer in between to prevent undue strain at any point on the pile. When "H' piles are unloaded, a safety hook on each end of a lifting beam will hold the pile securely. Similar precautions should be taken with other types of piling.

Piles must be stacked in an orderly manner on timber blocking with the axis of the pile in a straight line. They must be properly braced so that there is no danger of their falling or rolling. Each pile must be taken off the stack in a way that does not cause the rest of the piles to roll. Precast piles must be placed on level blocks that are spaced at pickup points. A clean, well-arranged storage yard free of obstructions and overhead wires is essential for safe and efficient pile handling and driving operations.

Driving Equipment

The piledriver supports the pile and hammer in a fixed position during driving. The rig must be stable and of adequate. capacity to lift the pile and to control both the pile and hammer during the driving. The leads should be long enough to drive the pile in one complete operation.

Piledrivers are classed as land drivers or floating drivers.

Mobile-crawler or truck-mounted cranes are commonly used. Any crane can be equipped with a spotter, hammer, leads, and accessory equipment. Specially built drivers are equipped for driving battered piles.

Types **of** Hammers

Although drop (gravity) hammers are the oldest type, they are fast becoming obsolete. The main disadvantages are the slow driving rate, which may allow some temporary "setting" of the pile, and the high-velocity impact stress, which sometimes fractures the head of the pile or causes internal failure. Drop hammers weigh from 10,000 to 5,000 lb.

Single-acting hammers, often called the vulcan type, differ from drop hammers only in that the ram is raised by air or steam power rather than by a winch and cable. The ram or hammer falls by gravity. Hammers usually weigh 5,000 to **6,500** lb. The setting of the valve is critical. Improper timing permits steam or air to enter the lower side of the cylinder, act as a cushion, and prevent a complete downstroke. Improper timing can also cause the valve to cut off too soon, resulting in a short upstroke of the hammer. A single-acting hammer in good condition operating under pressure delivers 50 to **55** blows per minute. If any power-driven hammer does not operate properly, it should be shut down until adjusted or repaired.

Double-acting hammers use steam or air for both raising and driving the ram. The action is faster, but the hammer has a lighter blow than the single-acting hammer for an equal amount of energy per blow. Uniform pressure is required to ensure the rated capacity. The valve setting and the condition of the rings and cylinder walls directly affect the impact of the hammer. The operating speed of double-acting hammers is about **75** percent greater than that of a single-acting unit with a ram of the same weight. Differential hammers are double-acting hammers with pistons of two different diameters.

In diesel hammers the ram is the cylinder of the hammer and is free falling. Compression takes place within the cylinder on the downward stroke of the ram and tends to cushion the blow. The diesel hammer is desirable because of its compact-

ness and simplicity. It has the disadvantages of not being a self-starting unit and not delivering a uniform blow.

For proper driving, it is important to consider the weight of the hammer, the stroke and speed, and their relation to the weight of the pile. The stroke or fall of a hammer determines the energy or impact delivered. A heavy ram working on a short stroke is usually more effective than a lightweight long-stroke hammer. On modern steam hammers, the slide bar can be fixed to deliver a constant blow and be adjusted to increase or soften the impact. No hammer should be allowed to operate with a loose slide bar.

Other Equipment

Driving heads fabricated from steel are shaped to fit the particular pile being driven. They protect the pile head and transmit the blow of the hammer to the pile.

Cushion blocks made of hardwood, plywood, or other composition are placed on the top of the driving heads to soften the hammer blow just enough to prevent injury to the pile head. The selected cushion material must be of the proper strength—too soft a wood acts as a sponge in absorbing the energy of the hammer stroke while too hard a wood tends to splinter. Wood blocks should be cut to size with the grain vertical. They must be replaced when they become compressed to less than half their original thickness or when they heat up to the point of starting to smoke.

A jet or stream of water under pressure is sometimes needed to help drive a pile into some soils. Usually, the water jet is worked alongside the pile (placement of concrete piles may include or even require the use of jets). The water flow must be regulated for the soil condition encountered. In granular soils, a jet having holes that distribute an equal upward and downward cutting force is most effective. In cohesive soils, a straight jet should be used. Only enough jetting should be used to place the pile. Overjetting can reduce the friction on the pile being driven and loosen the soil around piles already in place. Jets cannot be used for driving piles in very coarse gravels. Jetting removes the fines and allows the coarse material to concentrate in the hole, making driving even more difficult.

Determination of Bearing Capacity

Specifications for capacity or driving requirements for the piles are given by the (1) depth of penetration, (2) bearing capacity as determined by the dynamic pile-driving formula, or (3) pile length and size as determined from the load testing of a test pile driven at the site.

Driving piles to a specified depth of penetration is required to ensure stability, particularly if some erosion of the material surrounding the piling is expected. Depths for end-bearing piles are specified to reach the supporting strata. Piles can be damaged by overdriving.

Formula

Friction piles are driven to a bearing value as determined by a specified formula. Capacity requirements, procedures to be used, and the formula for computing the required bearing value are specified in the contract. Although many formulas have been devised, the true static bearing value of a pile can only be determined by loading.

The Engineering News formula[9] for dynamic pile driving has three forms:

For gravity (drop) hammer:

$$R = \frac{2\,WH}{S + 1.0}$$

For single-acting steam and diesel hammers having unrestricted rebound of the ram:

$$R = \frac{2\,wH}{S + 0.1}$$

For double-acting steam and diesel hammers having enclosed rams:

$$R = \frac{2H\,(W + AP)}{S + 0.1}, \text{ or } = \frac{2E}{S + 0.1}$$

where

- R = Safe bearing capacity, in pounds.
- W = Weight of the striking parts of the hammer, in pounds.
- H = Height of fall, in feet.
- A = Area of piston, in square inches.
- P = Pressure of steam or air exerted on the

[9] *Originally published in 1888 in Engineering News 20:509–512, the formula has since been shown and discussed in many engineering textbooks.*

hammer piston or ram, in pounds per square inch.

E = The manufacturer's rating for foot pounds of energy developed by double-acting steam or air hammers, or 90 percent of the average equivalent energy, in foot-pounds, developed by diesel hammers having enclosed rams as evaluated by gauge and chart readings.

S = Average penetration for the last 5 to 10 blows of a gravity hammer or the last 10 to 20 blows for steam, air, or diesel-powered hammers, in inches per blow.

The major benefit of determining the value R for each pile driven is that it serves as a measure of uniformity for all piles driven. If the formula method is specified, all field driving data and calculations must be completely documented to show that the contractor has driven each pile to the required bearing capacity.

Testing

Load testing consists of applying an incremental load, usually as much as twice the design load of the pile, leaving this load in place for a specified time. The pile is considered to have a safe bearing value equal to the design load if the permanent settlement after testing does not exceed a specified amount. Test loads of sand, steel ingots, or concrete can be set directly on the exposed pile head or be placed on a rigid platform on the pile head. Test loads can also be applied by jacks between the pile head and a beam anchored to the piles on either side. The contract specifies the procedure and performance required when load tests are to be made.

Installation data specified below should be recorded in the field notes (fig. 4–8 to 4–10):

- Pile locations (number).
- Date driven.
- Kind of pile material (if wood, indicate the kind).
- Tip diameter
- Butt diameter.
- Diameter at the ground line.
- Length of the pile (to the nearest tenth of a foot).
- Penetration per blow per foot (in inches or hundredths of a foot).
- Number of blows per foot (record for total penetration).
- Hammer data (complete description, including size, type, fall, and pressure).
- Time required for driving (note any shutdowns and why).

Test piles should be driven without the use of jets if possible. If a jet is used, the jetting procedure must be recorded in detail.

Sheet Piling

Sheet piling is used to reduce the lateral movement of water or prevent the movement of adjacent soil material, or both.

Installation

It is necessary to drive sheet piling within or against some type of guide frame or template. Horizontal templates at two levels are recommended for vertical light steel walls, one near the ground level and the other near the cutoff elevation. For sites with difficult driving conditions, such as cobbles or other obstructions, templates should be provided for both sides of the piling. The templates or guides must be close enough to the sheet piling to ensure the support needed for proper alignment. A guide system may consist of mobile timber or steel beams or fixed beams that are anchored to temporary piles.

Air-powered or steam-powered hammers are the most popular for driving sheet piling. Vibratory and sonic driving equipment are also used. The hammer weight is more critical in driving lightweight sheets because of the danger of damage to the piling. A very light single- or double-acting hammer is usually adequate. A heavier hammer may be needed to drive more than one sheet at a time or in highly resistant soil materials. A light drop hammer (1,000–1,500 lb) can he used if carefully controlled. For lightweight steel, two sheets are usually driven together. A rapid driving action is desirable for sand and gravel conditions. A heavier hammer and a slower driving action is usually more effective in clay soils.

The use of steel driving heads is recommended for all major jobs to spread the impact of a small

hammer on a single sheet and of a heavy hammer when driving two sheets. Driving heads must be made to fit the shape of the piling and must be thick enough to withstand the driving action without distortion.

Precautions

Lightweight sheet piling tends to creep or move out of alignment during the driving, usually outward and in the direction the piling is being installed. To combat this tendency, the contractor can:

- Drive the first pile plumb.
- Drive piles in pairs—they are easier to guide and have less frictional resistance.
- Drive piles in stages, with each adjacent pile being driven one-third the depth or less.
- Crimp the interlock at the bottom to prevent clogging.
- Tip the hammer or plumb with a guy to help realign a pile.
- Stop the driving when any obstructions are encountered. Use adjacent piles free of obstructions as guides to help support the blocked pile.
- Do jetting when needed on both sides of the piling and stop a few feet above the final grade.

By knowing the geology of the foundation from the log of borings and by observing the reaction of the pile during driving, an experienced inspector can make sound deductions about the condition of the pile during driving, the material being penetrated, and the final condition of the pile. The earth and the inplace piling should be watched for heaving. A bouncing hammer or kicking pile usually indicates refusal; if driving is not suspended, it may damage or break the pile. Sound and vibration are good indicators of the driving conditions.

After the piling is in place, the cutoffs and other structural adjustments are made, including installing and anchoring wales, tiebacks, and bracing. Anchors and tiebacks that are properly located and installed prevent misalignment or failure of the structure. Bolting, welding, and dead-man installation must be inspected carefully to be sure that the structure is completed as shown on the drawings and that it can perform in a safe manner.

Records

The lengths of the pile furnished, lengths driven, and lengths cut off must be recorded (use Form SCS-ENG-545, fig. 4–7). Load test and jetting information and delays in driving operations must be recorded in a field notebook (use a format similar to those in fig. 4–8 to 4–10).

Inspection checklist: piles and pile driving

(Some items may not be listed. Some listed may not apply to every project.)

Before driving

1. Pile—type, material, size, certified, cut, tipped, reinforcement recessed, splicing.
2. Support—bearing, friction, penetration
3. Equipment—proper, condition, safe.
4. Plan of operations—approved.
5. Driving head cushion block—fit, satisfactory
6. Rejects—marked, recorded.

Driving

1. Handling—safe, proper.
2. Rigging—secure.
3. Penetration—geology, rate, reaction.
4. Equipment—operation.
5. Driving—continuous.
6. Delays—time, penetration.
7. Foundation and other pile—heaving.

Jetting

1. Depth—approved.
2. Other pile—undisturbed, reseated.
3. Structures—unaffected.
4. Record—tests, certification, job diary.

Site Cleanup

The project engineer is to see that the worksite and surrounding areas used by the contractor are kept in orderly condition at all times during the work, and that all areas are properly restored before the completed work is accepted. Cleanup requirements are stated in the contract.

Inspection checklist:
site cleanup

(Some items may not be listed. Some listed may not apply to every project.)

1. Plant, buildings, unused materials, cleared material, and other debris—removed from site and vicinity of site.
2. Access and haul roads—appropriately restored.
3. Fences, utilities, and other facilities temporarily removed—restored.

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Section 19

Construction Inspection

Chapter 3

Sampling and Testing

Chapter 3 Contents

Page

Sampling and testing of soils.. 3–1

Field identification and description of soils (test S-1). 3–2

Laboratory and field-test procedures for controlling density and moisture in compacted earth embankments, ... 3–2
- Fine-grained and nongravelly soils. 3–2
  - Laboratory tests and design values.. 3–2
  - Construction control 3–2
- Coarse-grained soils—Group I. 3–9
  - Subgroup IA 3–9
    - Laboratory tests and design values. 3–9
    - Construction control 3–9
  - Subgroup IB 3–10
    - Laboratory tests and design values, ... 3–10
    - Construction control. 3–10
  - Subgroup IC 3–10
- Coarse-grained soils—Group II. 3–10
  - Subgroup IIA 3–10
    - Laboratory tests and design values.. 3–10
    - Construction control.. 3–10
  - Subgroup IIB 3–13
    - Laboratory tests and design values., ... 3–13
    - Construction control.. 3–13
  - Subgroup IIC 3–14
    - Laboratory tests and design values.. 3–14
    - Construction control. 3–14
- Coarse-grained soils—Group III. 3–14
    - Laboratory tests and design values.. 3–14
    - Compaction control.. 3–14

Construction control tests for rocky soils in compacted earth fills. 3–14
- Test site selection., ... 3–14
- Test site preparation 3–15
- Test hole excavation 3–15
- Test hole volume measurements. 3–15
  - Sand cone method 3–15
  - Template and plastic liner method.. 3–15
  - Measurement procedures 3–16
  - Equations and conversions. 3–16
- Separation of coarse and fine fractions. 3–16
  - Hard rock separation 3–16
  - Rock separation. 3–19
    - Low plasticity fines. 3–19
    - Plastic fines 3–19
- Volume measurements of rock fractions. 3–19
  - Siphon can or other overflow volume measure.. 3–19
  - Direct-reading volume measurements. 3–20
  - Measurement of moderately durable (Group ID rock.. 3–20
  - Measurements of soft rock or soil clods.. 3–20
- Moisture determinations. 3–21
- Example computations of density and moisture. 3–21

Chapter 3 Contents (cont.)

	Page
Example 1	3–21
Volume determination—12-in. sand cone	3–21
Moisture-density determination	3–22
Example 2	3–22
Volume determination	3–22
Moisture-density determination	3–22
Example 3	3–22
Volume determination—30-in. template and plastic sheet	3–23
Moisture-density determination	3–23
Methods, specifications, and forms for moisture and density determinations of soils	3–24
Field density tests	3–24
Sand cone method (test S-2)	3–24
Test procedures and recording data	3–24
Precautions	3–51
Rubber balloon method (test S-3)	3–51
Calibrated cylinder method (test S-4)	3–51
Kerosene method (test S-5)	3–51
Apparatus	3–51
Test procedures and recording data	3–51
Rapid compaction control method (test S-6	3–52
Nomenclature and definitions	3–52
Principles and equations	3–52
Use of parabola	3–53
Moisture and density calculations	3–54
Completion of test for record purposes	3–58
Example 1	3–58
Example 2	3–59
Sand displacement	3–59
Rubber balloon displacement	3–60
Template and plastic liner method (test S-7)	3–60
Apparatus	3–65
Test procedures and recording data	3–65
Moisture-density relation of soil (test S-8)	3–65
Modified method (test S-9)	3–66
Penetration resistance of soils (test S-10)	3–66
Moisture content tests	3–66
Oven method (test S-11)	3–66
"Quick-dry" method (test S-12)	3–66
Apparatus	3–66
Loss by ignition	3–85
Test procedures and recording data	3–85
Alcohol method (test S-13)	3–85
Apparatus	3–85
Test procedures and recording data	3–86
Speedy moisture tester (test S-14)	3–86
Apparatus	3–86
Calibration curve	3–86
Test procedures (using 26-g tester) and recording data	3–87
Precautions	3–87
Absorption and specific gravity tests of rock formations (test S-15)	3–87

Chapter 3 Contents (cont.)

	Page
Standard methods of testing concrete and concrete materials	3–87
Sampling fresh concrete (test C-1)	3–87
Slump test of portland cement concrete (test C-2)	3–81
Making and curing compression test specimens (test C-3)	3–87
Air content of freshly mixed concrete (pressure method) (test C-5)	3–87
Air content of freshly mixed concrete (volumetric method) (test C-6)	3–88
Air content of freshly mixed concrete (air indicator) (test C-7)	3–88
Apparatus	3–88
Test procedures and recording data	3–88
Weight (per cubic foot), yield, and air content (gravimetric) of concrete (test C-8)	3–88
Sampling stone, slag, gravel, and stone block (for highway construction) (test C-9)	3–88
Concrete aggregates (test C-10)	3–88
Specific gravity and absorption of fine aggregate (test C-11)	3–88
Specific gravity and absorption of coarse aggregate (test C-12)	3–88
Surface moisture in fine aggregate (test C-13)	3–105
Screen analysis determination for drain fill aggregate (test D-1)	3–105
Washing material finer than No. 200 sieve from mineral aggregates (test D-2)	3–105
Graphical method for blending aggregates or soils of three sues to obtain a specified gradation (test D-3)	3–105
Test procedures and recording data	3–105
Graphical method for blending aggregates or soils of two or more sizes to obtain a specified gradation (test D-4)	3–105
Test procedures and recording data	3–105
Graphical method for blending aggregates or soils of two or more sizes to obtain a specified range in gradation (test D-5)	3–105
Test procedures and recording data	3–105

Chapter 3 Figures

		Page
3–1	Form SCS-ENG-542, "Materials Testing Report: Visual Soil Classification".	3–3
3–2	Grain shapes, shaking test, breaking test, and plasticity test.	3–5
3–3	Comparison of the laboratory breakdown with Fourche Maline test fill cores for Oklahoma shales.	3–11
3–4	Two methods of measuring volume of solids by water displacement.	3–18
3–5	Equipment for calibrating sand.	3–25
3–6	Weighing a full jar of sand and the cone..	3–25
3–7	Filling the cone with sand (to determine volume).	3–25
3–8	Weighing the remaining sand.	3–25
3–9	Removing soil (field sample) within the open mold and placing it in a can.	3–26
3–10	Filling the cone and hole with sand (to determine volume).	3–26
3–11	Weighing the remaining sand..	3–26
3–12	Weighing the field sample in a can..	3–26
3–13	Form SCS-ENG-530A, "Bulk Sand Density Determination and Calibration of Cone and Base Plate".	3–27
3–14	Form SCS-ENG-530B, "Inplace Moisture-Density Determination: Sand Cone Method—Specified Fraction Control".	3–29
3–15	Form SCS-ENG-530C, "Inplace Moisture-Density Determination: Sand Cone Method—Mass Density Control".	3–31
3–16	Equipment used in determining inplace density by the rubber balloon method.	3–33
3–17	Obtaining the initial calibration reading on the volumeasure.	3–34
3–18	Obtaining the final reading. Balloon and water fill the hole from which the sample was taken.	3–35
3–19	Form SCS-ENG-530D, ''Inplace Moisture-Density Determination: Rubber Balloon Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve".	3–37
3–20	Sketch of the calibrated cylinder compaction sampler.	3–36
3–21	Equipment used in calibrating the cylinder.	3–39
3–22	Weighing the empty calibrated cylinder.	3–40
3–23	Preparing the surface of the embankment before making the test.,	3–41
3–24	Driving the cylinder into the embankment.	3–42
3–25	Removing the material from around the cylinder.	3–43
3–26	Separating the sample from underlying material.	3–44
3–27	Trimming the excess material at the cylinder ends..	3–45
3–28	Weighing the cylinder and compacted soil sample.	3–46
3–29	Form SCS-ENG-530E, "Inplace Moisture-Density Determination: Calibrated Cylinder Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve".	3–47
3–30	Form SCS-ENG-530F, "Inplace Moisture-Density Determination: Kerosene Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve".	3–49
3–31	Graphical solution for obtaining peak point of parabola.	3–55
3–32	Form SCS-ENG-541, "Rapid Method for Determining Density and Moisture, For 5.00 lb of Moist Soil." In this example the fill moisture content is less than optimum..	3–56
3–33	Form SCS-ENG-541. In this example the fill moisture content is greater than optimum.,	3–57
3–34	Form SCS-ENG-530G, "Inplace Moisture-Density Determination: Rapid Compaction Method—Sand Displacement".	3–61
3–35	Form SCS-ENG-530H, "Inplace Moisture-Density Determination: Rapid Compaction Method—Rubber Balloon Displacement, Fine-Grained Soils—Less Than 5% +No. 4 Sieve".	3–63
3–36	Angle-iron frame in place for the calibration.	3–67
3–37	Filling the frame, lined with polyethylene sheeting, with water for the calibration.	3–68
3–38	Preparing to replace the sheeting in the excavated hole..	3–69
3–39	Filling the lined hole and frame with water by a siphon.	3–70

Chapter 3 Figures (cont.)

		Page
3–40	Form SCS-ENG-530I, "Inplace Moisture-Density Determination: Template and Plastic Liner Method"	3–71
3–41	Weighing the mold	3–73
3–42	Placing soil in the mold	3–73
3–43	Compacting soil in the mold	3–74
3–44	Trimming the sample flush with the mold	3–74
3–45	Weighing the mold and compacted sample	3–75
3-46	Raising the compacted sample out of the mold	3–75
3–47	Obtaining a soil sample for a moisture determination	3–76
3–48	Weighing the soil sample in a moisture container	3–76
3–49	Form SCS.ENG.359, "Work Sheet for Compaction and Penetration Resistance Data"	3–77
3–50	Form SCS.ENG.352, "Materials Testing Section Report: Compaction and Penetration Resistance"	3–79
3–51	Form SCS.ENG.531, "Moisture Content Determination, Summary Data Sheet"	3–80
3–52	Obtaining a sample for moisture determination	3–81
3–53	Obtaining and recording the wet weight of the sample plus pan	3–82
3–54	Drying a sample by the quick-drying method	3–83
3–55	Obtaining and recording the dry weight of the sample plus pan	3–84
3–56	Speedy Moisture Tester and accessories	3–89
3–57	Equipment setup for determining the submerged weight of rock	3–89
3–58	Form SCS.ENG.543, "Bulk Specific Gravity and Moisture Determination"	3–90
3–59	Filling the mold with concrete	3–91
3–60	Rodding the concrete to eliminate air pockets	3–91
3–61	Lifting the mold off the concrete sample	3–92
3–62	Measuring the slump	3–92
3–63	Form SCS.ENG.59, "Report on Concrete Test Specimens"	3–93
3–64	Concrete sample to be used for molding test cylinders	3–95
3–65	Placing the concrete into test cylinders and rodding the concrete in three equal layers in each cylinder	3–96
3–66	Numbering the test specimens	3–97
3–67	Protecting the molded specimens with a cloth cover	3–98
3–68	Air meter for testing the entrained air content of fresh concrete (meter assembled)	3–99
3–69	Air meter lid removed and meter ready for placement of concrete sample	3–99
3–70	Plastic squeeze bottle, isopropyl alcohol, and air indicator are used in determining the air content of freshly mixed concrete	3–99
3–71	Composite sample is placed in a cone formation	3–100
3–72	Cone is depressed to a uniform frustrum section	3–100
3–73	Sample is divided into four equal segments	3–100
3–74	Opposite segments have been removed to be used for testing or to be further reducedby quartering	3–100
3–75	Form SCS.ENG.535, "Sieve Analysis"	3–101
3–76	Form SCS.ENG.353, "Materials Testing Report: Soil Classification"	3–103
3–77	Nomograph for determining free moisture in fine aggregate with a calibrated flask	3–104
3–78	Form SCS.ENG.535, "Sieve Analysis"	3–106
3–79	Example 1A: How to proportion a mixture of soils A and B to obtain a specified gradation	3–111
3–80	Example 2A: How to proportion a mixture of soils A, B, and D to obtain a gradation with a higher percentage passing a No. 100 sieve in soil C (mixture of soils A and B) from example 1A	3–112

Chapter 3 Figures (cont.)

		Page
3–81	Example 1B: How to proportion a mixture of soils A and B (having single-gradation characteristics) to obtain a specified gradation..	3–114
3–82	Example 2B: How to proportion a mixture of soils A and B (having variable-gradation characteristics) to obtain a specified gradation.	3–115

Chapter 3 Table

3–1	Soil identification and construction properties.	3-6
3–2	Characteristics of Oklahoma shales used for comparison of laboratory breakdown tests and test fill breakdown results..	3–12
3–3	Inplace density test specifications.	3–17

Chapter 3 Exhibits

3–1	Graphical method simplifies economical blending of aggregates.	3–108
3–2	Graphical method for proportioning a mixture of soils to obtain a specified gradation of materials.	3–110
3–3	Procedures for proportioning mixtures of soils to obtain a specified range in gradation of materials.	3–113

Chapter 3
Sampling and Testing

Sampling and testing procedures described in this chapter are used in the construction industry to ensure that soil or concrete products meet contract requirements. A few quick indicator tests are included. If these indicator tests show that quality is borderline or lower, standard tests must be made to verify the condition and to support actions taken. All testing must be done in strict accordance with test specifications. Any variation can prejudice the contractor's or the contracting agency's interests.

"Instructions to Bidders" state that the specifications to be used include all revisions and amendments in effect on the date that the invitation for bids is issued.

American Society for Testing and Materials (ASTM) test specifications are used by SCS for most construction materials. ASTM specifications mentioned in this handbook are available in SCS area or state offices. These offices will maintain current ASTM specifications.

Data from tests and computations of control parameters are recorded on specified forms. An example of each form is placed **with** the test or determination for which it is most pertinent. In the text of that test the form is identified by title and figure number, but by figure number only in other parts of the handbook. Sketches, charts, and photographs of equipment and procedures are also indicated by figure numbers.

Sampling and Testing of Soils

ASTM D–2488 and SCS Technical Release No. 27, "Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankments" (March 1965), are useful when sampling and testing soils.

If any quick-dry procedures are used for the moisture determinations, duplicate samples must be tested periodically by ovendrying to verify the accuracy of the quick-dry method being used. Ovendrying must be used if there is any question of accuracy. Samples of the compacted fill should be taken at least one lift below the surface lift to ensure their integrity. In some soils it may be necessary to take samples two or three lifts below the surface lift.

The "Earth Manual," published by the Bureau of Reclamation, U.S. Department of the Interior, has additional information on testing soils.

Field Identification and Description of soils

Test No. S-1

Soil identification and description are essential for proper control during the construction of earth and related structures. Field determinations are necessary because borrow materials vary and lengthy laboratory analyses would delay the work. A classifier's skills can be improved by comparing his or her identifications with those of samples submitted for laboratory analysis. Soils seldom exist separately as basic types, but rather as various combinations of gravel, sand, silt, clay, or organic matter. Construction personnel need to know the structural characteristics of the soils and how they react to manipulation.

Procedures for making visual-manual descriptions of soils are given in ASTM D–2488, "Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)." Form SCS-ENG-542, "Materials Testing Report: Visual Soil Classification," can be used for recording visual-manual soil classifications (fig. 3–1). Figure 3–2 supplements in. formation in ASTM D–2488. Table 3–1 has additional detailed characteristics and uses for various soil groups.

Laboratory and Field-Test Procedures for Controlling Density and Moisture in Compacted Earth Embankments[1]

The soil classification and rock durability (if any) dictate the test procedures to be used. Laboratory procedures for classifying soils are in ASTM D–2487, "Standard Test Method for Classification of Soils for Engineering Purposes."

Fine-Grained and Nongravelly Soils

Soils are classified as fine-grained and nongravelly if 95 percent or more passes a No. 4 sieve.

Laboratory tests and design values.—The laboratory tests and design values are based on the moisture-density relation of the soil processed to pass a No. 4 sieve and on the maximum density obtained by procedures described in ASTM D–698. However, some highly plastic CL and CH soils perform better under greater compaction. For these soils, laboratory tests, design values, and construction control may be based on the maximum density determined by ASTM D–1557.

Construction control.—Dry density and moisture contents of the compacted fill are determined by one of the following tests: S-2 (ASTM D–1556), S–3 (ASTM D–21671, S–4 (ASTM D–29371, S–5 and S–7. Moisture tests include: S–11 (ASTM D–2216), S–12, S–13, and S–14. Testing procedures are described in the applicable ASTM specification or in the handbook text of these tests.

The degree of compaction of the material in the fill is determined by computing the ratio of the in-place embankment density to the maximum density of the same material as determined by moisture-density tests described in ASTM D–698 or in ASTM D–1557, or by test S–6. Results from the moisture-density tests previously determined can be used as bases for computing the degree of compaction in the fill provided that (1) materials tested in the fill are nearly the same as those for which moisture-density curves were previously prepared, (2) the moisture content of the material tested in the fill is near optimum, and (3) the density value "one point," determined by compacting one specimen of the material (at placement moisture) taken from the immediate area of the inplace embankment test, falls on or very near the predetermined moisture-density curves (using the same procedure for both compaction tests).

[1] *SCS Technical Release No. 27.*

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-542
2-80

MATERIALS TESTING REPORT: VISUAL SOIL CLASSIFICATION

_____ _____ Tested by _____ _____

Identification				Coarse fraction					Fine fraction				Total soil			Classification	
Testing section sample No.	Test hole No.	Field sample No.	Depth (ft.)	Maximum size (mm)	Particle shape	Particle condition	Gravel (3 in. to No. 4)	Sand (No. 4 to 200)	Fines (– No. 200)	Plasticity	Dry strength	Dilatance	Organic odor (wet)	Reaction to HCl	Color (wet)	Description (classification, grading, structure, consistency, moisture condition, inclusions, etc.)	Group symbol

Remarks _____ Signature _____

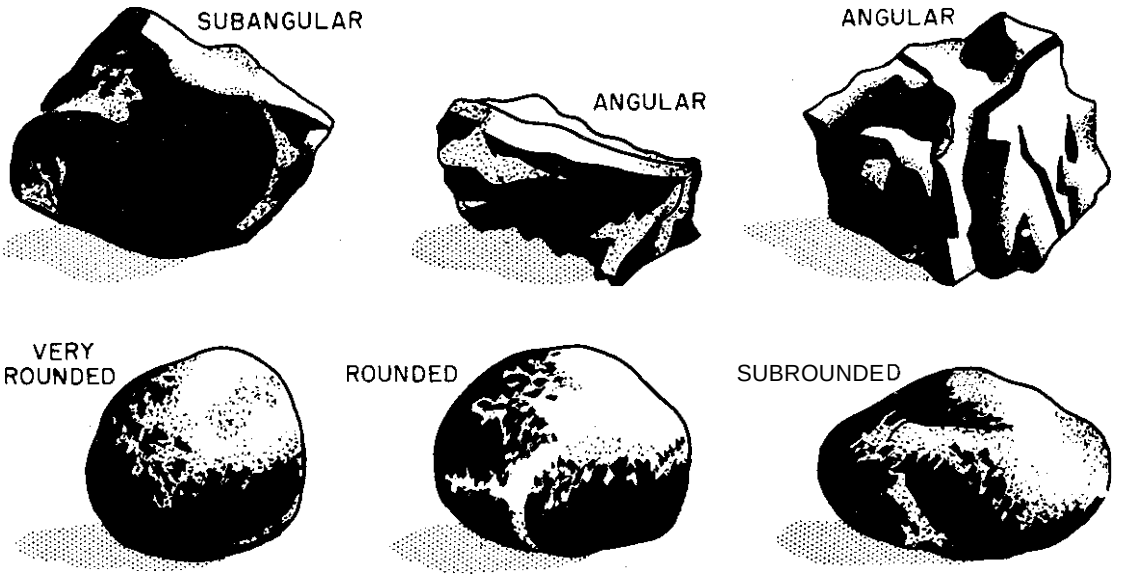
_____ Title _____ Date _____

Figure 3-1.—Form SCS-ENG-542, "Materials Testing Report: Visual Soil Classification."

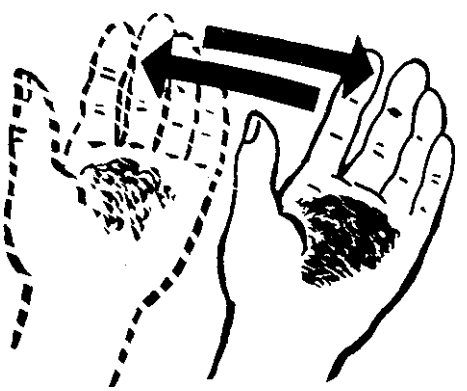
Test	Description	Symbol	Identification or test reaction
	Angular	A	Irregular shape: sharp edges.
	Subangular	SA	Irregular shape; fairly sharp edges.
	Subrounded	SR	Irregular shape; rounded edges.
	Rounded	R	Fairly regular shape; rounded edges.
Particle condition	Soft	S	Rubber pestle will break particles.
	Vesicular	V	Individual grains contain air voids.
	Dense	D	Massive: grains contain no air voids.
Plasticity	High	H	Tough thread, will remold below plastic limit,
	Medium	M	Medium tough thread, crumbles below plastic limit.
	LOW	L	Weak thread, will not remold at plastic limit.
	None	N	Will not form thread.
Dry strength	High	H	Difficult to break by finger pressure.
	Medium	M	Considerable finger pressure to crumble.
	LOW	L	Will crumble at light finger pressure.
	None	N	Will not form soil pat.
Dilatance	Rapid	R	Water surfaces immediatelv.
	Slow	S	Water surfacer slowly.
	None	N	Water will not surface.
HCL	Positive	+	Effervescence.
	Negative	—	No reaction.
Organic odor	Strong	S	Strong odor when moist and hot.
	Weak	W	Weak odor when moist and hot.
	None	N	No organic odor.

Group	Organic odor	Visual examination			Character of fines (— No. 40)		
		Grading	Percent fines	Dominant fraction	Dilatance	Dry strength	Plasticity
ML	Weak	Not a criterion for classification	Over 50	Fines	Rapid	None—Low	None—Low
CL	"		"	"	None—Slow	Medium—High	Medium
CH	"		"	"	None	High	High
MH	"		"	"	None—Slow	Low—Medium	Low—Medium
OL, OH	Strong		"	"	None	Low—Medium	Medium (spongy)
SM	Weak		12—50	Sand	Fines classify as ML or MH		
GM	"		"	Gravel			
SC	"		"	Sand	Fines classify as CL or CH		
GC	"		"	Gravel			
SP	"	Poor	Under 5	Sand	Not a criterion for classification		
GP	"	"	"	Gravel			
SW	"	Well	"	Sand			
GW				Gravel			
Pt	Strong	Identify by high fibrous organic content					

Figure 3-1 (cont).—Form SCS-ENG-542; reverse side.

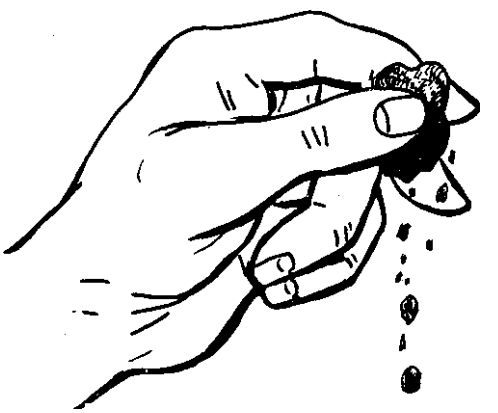


GRAIN SHAPE



Method of shaking

SHAKING TEST



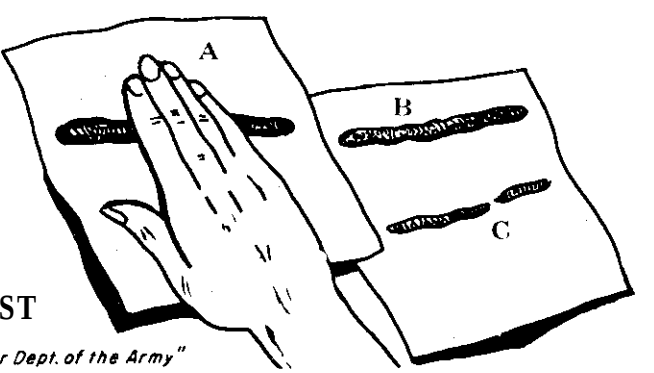
Method of crumbling soil between fingers

BREAKING TEST

A Method of roliing thread.

B Thread of soil above plastic limit

C Crumbling thread as plastic limit is reached



PLASTICITY TEST

"After Dept. of the Army"

7-L- 14373

Figure 3-2.—Grain shapes, shaking test, breaking test, and plasticity test.

Table 3-1. – Soil identification and construction properties.

Field Identification Procedures											Suitability for Embankments
Coarse grained soils	More than half of material (by weight) is of individual grains not visible to the naked eye.	Clean, little fines	Gravels (more than 50% larger than #4)								Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	Very stable — pervious shells of dikes or dams.
											Predominantly one size or a range of sizes with some intermediate sizes missing.	Reasonably stable, pervious shells of dikes and dams.
		Will not leave a dirt stain on wet palm	Sands (more than 50% smaller than #4)								Wide range in grain sizes and substantid amounts of all intermediate particle sizes.	Very stable, pervious sections, slope protection required.
											Predominantly one size or a range of sizes with some intermediate sizes missing.	Reasonably stable. pervious sections with slope protection.
		With appreciable fines (more than 12%)	With plastic fines								Gravel with plastic fines. (For identification of fines. see characteristics of CL and CH below.)	Fairly stable — may be suitable for impervious core.
											Sand with plastic fines. (For identification of fines. see characteristics of CL and CH below.)	Fairly stable. impervious core, flood control structures.
		Will leave a dirt stain on a wet palm	With non-plastic fines								Gravel with nonplastie fines or fines with low plasticity, (For identification of fines, see characteristics of ML and MH below.)	Reasonably stable — limited use for impervious core or blankets.
											Sand with nonplastic fines or fines with low plasticity. (For identification of fines. see characteristics of ML and MH below.)	Fairly stable — not particularly suited to shells. may be used for impervious cores or dikes under limited conditions.
Fine grained soils	More than half of material (by weight) is of individual grains not visible to the naked eye.	Silts and clays (low plastic)	Pronounced	Slight	Rapid	Low to none	None	Dull			Poor stability — may be used for embankments with proper design and control in placing.
				High	Medium to slow	Medium	Weak	Slight to shiny			Stable — impervious cores and blankets.
				Medium	Slow to none	Low	None	Dull to slight			Not suitable for embankments.
		Silts and clays (highly plastic)		Medium	Very slow to none	Medium	Weak	Slight			Poor stability — not desirable in core rolled fill embankments.
				Very high	None	High	Strong	Shiny			Fair stability with flat slopes, thin cores, blankets and dikes.
			Pronounced	High	None	Low to medium	Weak	Dull to slightly			Not suitable for embankments.
Highly organic soil					Readily identified by color, odor, spongy feel and frequently by fibrous texture.						Do not use for construction.

Notes: For visual classification the size may be used as equivalent to the No. 4 sieve size. No. 200 sieve size is about the smallest particle visible to the naked eye. See Identification Procedures. Odor. Dry crushing strength. Dilatancy (shake) reaction. Toughness. Ribbon (near the P.L.). Shine (near the P.L.).

able 3-1 (cont.)

Value for Foundation (Seepage Control)	Typical Names	Unit Dry Wt. Lbs. per Cu. Ft. (ATSM D-698)	Compaction Characteristics	Suggested Compaction Equipment	Unified Soil Classes
Good bearing value. (Requires positive cut-off)	Well graded gravels, gravel-sand mixtures. little or no fines.	125-135	Goad	Tractors, rubber tired equipment. Vibrating compactors or grid type rollers.	GW
Good bearing value. (Requires positive cut-of0	Poorly graded gravels, gravel-sand mixtures. little or no fines.	115-125	Goad	Tractors. rubber tired equipment. Vibrating compactors or grid type rollers.	GP
Good bearing value. Upstream blanket and toe drains.	Well graded sands. gravelly sands, little or no fines.	110-130	Good	Tractors, rubber tired equipment. Vibrating compactors or grid type rollers.	SW
Good to poor—depends on density. (Blanket and toe drains)	Poorly graded sands. gravelly sands. little or no fines.	100-120	Good	Tractors, rubber tired equipment. vibrating compactors or grid type rollers.	SP
Good bearing value. (None)	Clayey gravels. gravel-sand-clay mixtures.	115-130	Fair	Rubber tired. sheepsfoot or grid rollers.	GC
Good to poor. (None)	Clayey sands. sand-clay mixtures.	105-125	Fair	Sheepsfoot or rubber tired rollers.	SC
Good hearing value. (Toe trench to none)	Silty gravels, gravel-sand silt mixture.	120-135	Good—with close control	Rubber tired. sheepsfoot or grid rollers. Vibrating compactors.	GM
Good to poor bearing value depending on density. (Upstream blanket and toe drainage)	Silty sands, sand-silt mixtures.	110-125	Good—with close control	Rubber tired. sheepsfoot or grid rollers. Vibrating compactors.	SM
Fair to very poor — susceptible to liquefaction. (Toe drainage to none)	Inorganic silts and very fine sands, rock flour. silty or clayey tine sands or clayey silts with slight plasticity.	95-120	Good to poor	Rubber tired or sheepsfoot rollers.	ML
Good to poor. (None)	Inorganic clays of low to medium plasticity. gravelly clays, sandy clays. silty clays, lean clays.	95-120	Fair to good	Sheepsfoot or rubber tired rollers.	CL
Fair to poor bearing. excessive settlement may result. (None)	Organic silts and organic silty clays of low plasticity.	80.100	Fair to poor	----------	OL
Poor bearing (None)	Inorganic silts. micaceous or diatomaceous fine sandy or silty soils, elastic silts.	70-95	Fair to very poor	Sheepsfoot roller.	MH
Fair to poor bearing. (None)	Inorganic clays of high plasticity, fat clays.	75-105	Fair to poor	Sheepsfoot roller.	CH
Very poor bearing. (None)	Organic clays of medium to high plasticity, organic silts.	65-100	Poor t" very poor	----------	OH
Remove from foundations.	Peat and other highly organic soils.		Compaction not practical	----------	Pt

Moisture-density curves should be prepared for each kind of material to be used in the fill. Soil masses are too variable to expect that all material from a specific borrow source will duplicate the small sample tested in a laboratory. If the maximum density curve prepared on the job varies significantly from that in the embankment design, the design engineer must be informed immediately so that he or she can ascertain if the material still fulfills design requirements.

Materials excavated from different borrow sources can vary significantly from load to load because of the stratification, irregular topography and depth, spotty and irregular areal patterns of deposition, or other causes. In these situations, several moisture-density curves may have to be prepared to form a basis for computing the degree of embankment compaction. For these compaction tests, soil for density determinations must be taken from the immediate area of the inplace-embankment test excavation. Four or more individual compaction test molds are needed to determine the value of maximum density to optimum moisture for each sample. A sample can be split and a different portion used for determining each point on the moisture-density curve if this is more convenient than using and reusing the same material for each point.

In many situations, variations in borrow material that at first appeared significant will have little effect on the relation of maximum density to optimum moisture. Then moisture-density curves previously determined can serve as the basis for using "one point" moisture-density tests.

Coarse-Grained Soils—Group I

Soils are classified as coarse-grained if less than 95 percent passes a No. 4 sieve.

Subgroup IA

These are gravelly and stony soils of hard, durable rock. More than 65 percent passes a No. 4 sieve.

Laboratory tests, design values, and construction control are based on the moisture-density relation of the soil matrix. The soil matrix is that fraction of the soil-rock mixture whose maximum size is equal to that used in the compaction test. Specifications require a Class A compaction based on a percentage of the maximum density obtained by procedures described in ASTM D–698 or D–1557.

Laboratory tests **and** design values.—Laboratory tests and design values are based on the maximum density obtained by procedures described in ASTM D–698. To obtain improvement in some engineering properties, greater compaction is needed and the maximum density obtained by procedures described in ASTM D–1557 should be used.

Construction control.—The density of the inplace soil can be measured as follows with any of the density tests:

- Determine the moist weight and volume of the total sample.
- Screen the total sample through a No. 4 or a 3/4-in. sieve, depending on the method specified.
- Determine the moisture content of a representative portion of this soil matrix.
- Obtain the moist weight and volume of the rock fraction retained on the No. 4 or the 314-in. sieve by using a siphon can or graduated cylinder for displacement (see Chapter 3, Construction Control Tests, Volume Measurements of Rock Fractions). This method may not be practical if rock materials exceed 4 in. in diameter.[2]
- Deduct the moist weight of the rock from the moist weight of the total sample.
- Deduct the volume of the rock from the volume of the total sample.
- Compute the approximate moist weight, the volume, and the moist density of the soil matrix.
- Using the moist density and moisture content of the soil matrix, compute its dry density.

The degree of compaction is the ratio of the inplace *dry* density to the maximum dry density. For soils uniform in gradation and composition, the *dry* density of one compacted mold or specimen (one point) can be plotted on a previously prepared form containing several complete compaction curves to help determine the maximum compacted density.

[2] *If the rock is uniform in composition, the volume can be computed by dividing the dry weight of the rock by its bulk density as given in the laboratory report or determined by test S–15.*

Subgroup IB

These are gravelly and stony soils of hard, durable rock. From 35 to **65** percent passes a No. 4 sieve.

Laboratory tests and design values.—Laboratory tests and design values are based on the moisture-density relation of the soil processed to pass a 3/4-in. sieve and on the maximum density obtained by procedures described in methods C or D, ASTM **D–698.** This is applicable when less than **30** percent of the total sample is retained on a %-in. sieve and the total sample has about the same gradation characteristics. To obtain improvement in some engineering properties, greater compaction is needed and the maximum density obtained by procedures described in ASTM D–1557 should be used.

Mass density can be used when more than **30** percent of the proposed borrow material is retained on a %-in. sieve or when the material passing a ¾-in. sieve is quite variable in gradation. In such instances, laboratory tests are performed on the material passing a 1-in. or a 3-in. sieve; the material is compacted to an arbitrary base density of the mass even though there are varying amounts of rock. The base density is generally set at **95** percent of the maximum density of the fraction passing a ¾-in. sieve (compacted as in **ASTM** D–698 and readjusted for 40 percent rock). If the rock content of the borrow material varies greatly, the design should be based on characteristics of the material in its least desirable condition; random fill should be specified.

Construction control.—Selecting a representative site for the inplace density test is very critical for soils in this subgroup (see Chapter 3, Construction Control Tests, Test Site Selection).

If Class A compaction is specified, inplace density tests and the maximum density test must be made using procedures for soils in subgroup IA. If the equipment to be used and the number of passes per lift are specified, enough density tests must be made to correlate equipment performance in the various materials. Inplace density tests are made the same way as tests for the control of Class A compaction and are based usually on the fill matrix (material passing a 3/4-in. sieve).

Determination of the mass density may suffice for checking the condition of the random fill from selected borrow sources.

Subgroup IC

These are gravelly and stony soils of hard, durable rock. Less than 35 percent passes a No. 4 sieve.

Types of equipment and the number of passes per lift are specified for controlling the compaction of these materials. Occasionally, inplace mass-density tests may be required to determine equipment performance in the various materials.

Coarse-Grained Soils—Group II

These are soils of moderately durable rock, such as hard shale, siltstone, and schist. Less than **95** percent passes a No. 4 sieve.

Excavation and compaction. including the manipulation of necessary moisture-density tests, change the gradation of these materials. The rock fraction is hard enough, however, to allow physical sieving of the various sizes of fractions without any further breakdown.

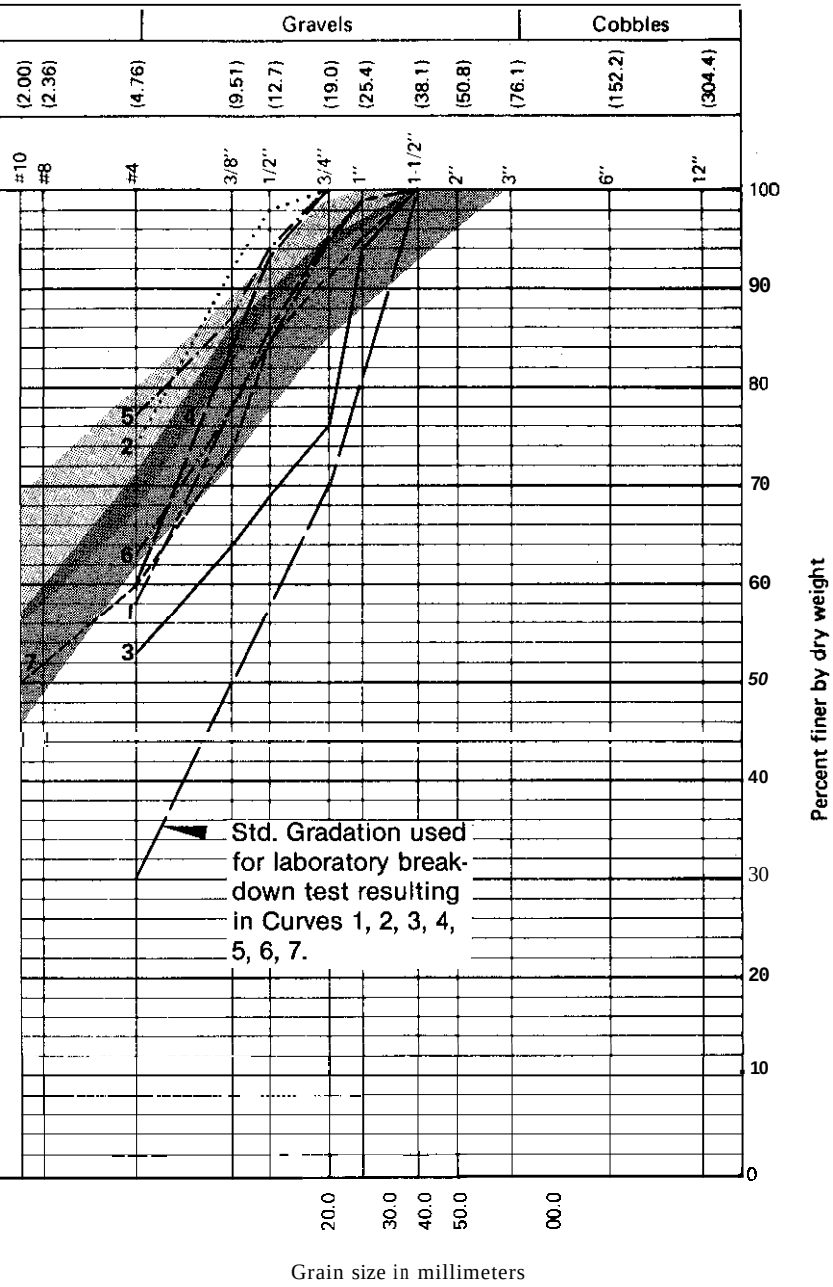
Wherever possible, laboratory testing, design values, and construction control must be based on the characteristics of samples taken from test fills. Test-fill information is required to determine the breakdown characteristics of these materials before the design of any moderate or high-hazard dam **or** other large structure. Breakdown predictions must be based on special laboratory tests and correlation studies if data from constructed embankments or test fills are not available (fig. 3–3 and table 3–2).

Subgroup **IIA**

These are gravelly and stony soils of moderately durable rock. More than **65** percent passes a No. 4 sieve after compaction.

Laboratory tests and design values.—Laboratory tests and design values are based on the maximum density obtained by procedures described in ASTM **D–698, or** the maximum density obtained by procedures described in ASTM **D-1557.** The percentage of the breakdown may be specified; for example, more than **65** percent passing a No. 4 sieve—to obtain engineering properties such as strength and impermeability.

Construction control.—The density of the inplace Subgroup IIA soil can be measured as follows by any of the density tests:



	Sample No.	Formation Name	Hulk G_s	H	% Abs	Laboratory Compaction γd < 1½"*	Laboratory Compaction γd < #4
1.	64W2408	Des Moines	2.10	2−	12	123	121
2.	2409	Woodford	1.76	3+	16	95	97
3.	2410	Savanna	2.29	2+	7	128	129
4.	2411	Atoka	2.14	2	10	124	124.5
5.	2412	Cloud Chief	1.70	2−	13	110	116.5
6.	2413	Doxey	2.11	2+	8.5	125	124
7.	Test Fill	Atoka	2.10		10	115	125

*Laboratory compaction & breakdown test consists of Modified effort on minimum 1%" material with standard gradation in 6" diam. x 4.6" mold at natural moisture.

Test Embankment Treatment	Bulk G_s	% Abs	Embankment Cores γd Mass	Embankment Cores γd < #4
Fourche Maline #1 Coarsest gradation = 6 passes Grid Roller Finest gradation = 2-3 passes Grid, 3-5 passes Sheepsfoot	2.10	10	109-114	99-110
Fourche Maline #3 4" lift, 1 grid, 1 disc, 5 grid	1.94	16	102-107	99-104

Table -Characteristics c)klahoma shales used for comparison of laboratory breakdown tests and test fill breakdown results

Sample NO. 64W	Site	Geologic Formation	Hard-ness	Free Swell %	Slaking (1 hour)	Atterberg Limits (- #40) LL	Atterberg Limits (- #40) PI	Class	Salt	Disp	Fines G_s	Bulk Density of Rock γd pcf	Bulk Density of Rock w %	COMPACTION Mod. (- #4) γd	COMPACTION Mod. (- #4) w_o %	One Point at Mod. Effort - 6" Mold Gradation - (Before)/(After) Test.	< #4	< 3/4"	< 1-1/2"	γd	w %	roject Engineers Evaluation of o. 4 Separation fter Compaction on Fill
2408	Upper Clear Boggy #24	Des Moines (Mid-Penn) Gray Mod. hard Breaks easy w/fingers	2-	30	Severe	43	22				2.74	130.0	10.0	121.0	12.5	(a)	32/58	69/95	100/100	123.3	12.5	Impossible
																(b)	32/60	97/95	100/100	122.8	12.2	
																(c)	0/61	0/97	100/100	132.2	11.0	
2409	Upper Clear Boggy #33	Woodford (Penn) Hard, flat platy shale Brittle	3+	20	None	43	11				2.50	110.0	11.3	97.0	21.0	(a)	32/74	69/100	100/100	94.6	15.7	
																(b)	32/74	69/100	100/100	95.1	15.1	
																(c)	0/57	0/95	100/100	102.0	11.7	
2410	Fourche Maline #4	Savanna Hard, soapy shale very difficult to break with fingers	2+	20	Slight	34	13				2.76	143.0	6.6	129.0	10.5	(a)	32/53	69/86	100/100	127.5	7.2	Possible
																(b)	32/52	69/87	100/100	128.0	7.3	
																(c)	0/39	0/74	100/100	134.3	6.5	
2411	Sallisaw #11	Atoka Hard, slatey Difficult to break w/fingers	2	30	None	37	13				2.83	134.0	9.8	124.5	12.0	(a)	32/59	69/99	100/100	124.1	10.1	Difficult
																(b)	32/61	69/98	100/100	122.9	10.2	
																(c)	0/56	0/99	100/100	127.1	9.4	
2412	Boggy #28	Cloud Chief (Perm) Red-brown soft siltstone Breaks easy w/fingers	2-	0	Severe	36	15				2.72	106.0	12.7	116.5	13.5	(a)	32/77	69/100	100/100	110.8	12.6	Impossible
																(b)	32/71	69/99	100/100	109.6	13.7	
																(c)	0/82	0/95	100/100	119.6	9.1	
2413	Boggy #13	Doxey (Perm) Red-brown hard siltstone very difficult to break	2+	20	Slight	31	9				2.75	132.0	7.6	24.0	12.5	(a)	32/63	69195	100/100	125.3	8.6	Difficult
																(b)	32162	69195	100/100	124.4	8.6	
																(c)	0/54	0/92	100/100	132.1	7.8	

Comp. Test (a) Natural Moisture: Standard Gradation, 100% < 1-1/2", 69% < 3/4", 32% < #4
Comp. Test (b) Test (a) Sample with Absorbed Water.
Comp. Test (c) Special Gradation: 100% < 1-1/2", 0% < 3/4".

- Separate the coarse material from the sample on a No. 4 sieve or a ¾-in. sieve.
- Clean the coarse material as well as possible without washing (see Chapter 3, Construction Control Tests, Separation of Coarse and Fine Fractions).
- Determine the moist weight and volume of the coarse material.
- Subtract the moist weight and volume of the coarse material from the moist weight and volume of the total sample.

Note: Unless the coarse material is near saturation, it must be soaked to saturation before it can be measured by water displacement (see Chapter 3, Construction Control Tests, Volume Measurements of Rock Fractions). If the material disintegrates in water, a kerosene or diesel fluid may be used instead of water. To determine the volume, the *dry* weight of several of the large rocks is divided by their bulk density, obtained from the laboratory report, or determined by test S–15.

If the moist bulk density of individual rocks is used to compute the volume of the material, then the moisture content of the rocks in the test sample and the moisture content of the rocks used in the bulk density determination must be comparable. If the test sample has various kinds of material or the moisture content of the individual rocks varies, then individual rocks of the test sample and of the bulk density determination must be dried and the bulk density computed on the basis of the *dry* weight. Material used for determining maximum density values (using ASTM D–698 or D–1557) must be collected from and immediately around the inplace test excavation site.

Subgroup IIB

These are gravelly and stony soils of moderately durable rock. After compaction, 35 to 65 percent passes a No. 4 sieve. The gradation of passage through the sieve may result from the lack of natural hardness in the material or from the breakdown required for different engineering properties, such as impermeability and strength.

Laboratory tests, design values, and construction control should be based on characteristics of materials compacted in the test fill whenever possible. Use of these materials in critical sections of any structure must have test fill information for design and construction control.

The long-term weathering and stability characteristics of all materials containing more than 35 percent nondurable rock must be considered in establishing design values and placement specifications.

If Class A compaction is specified, laboratory tests and construction control must be based on the mass density of the material.

Laboratory tests and design values.—Laboratory tests and design values are based on the maximum density (obtained by procedures described in ASTM D–698 or ASTM D–1557) of that fraction passing a No. 4 sieve, adjusted for 40 percent rock.

For example, shear and permeability tests might be performed on samples of the mass passing 1-in. or 3-in. sieves and graded according to laboratory breakdown tests (fig. 3–3). All test specimens would be compacted to a specified base density equal to a specified percentage or maximum modified (ASTM D–1557) density of the fraction passing a No. 4 sieve, adjusted for 40 percent rock. Different amounts of rock would be added to each set of test specimens. For example: (a) the maximum modified density of the fraction of a shale sample passing a No. 4 sieve might be 105 lb/ft³, (b) 90 percent of the maximum modified γ_d would equal 95 lb/ft³, (c) assuming a bulk density of 140 lb/ft³ for the shale, the adjusted γ_d of the mass with 40 percent rock would be 108 lb/ft³, and (d) all test specimens would be compacted to a mass density of 108 lb/ft³ with one set containing 35 percent, one set 50 percent, and another set 65 percent rock of uniform gradation between the No. 4 size and the maximum size to be tested.

Construction control.—The density of inplace soil can be measured by any appropriate density test. The sand cone and the template and plastic liner test methods are the most often used. (When size separations are required, see Chapter 3, Construction Control Tests, Separation of Coarse and Fine Fractions and Volume Measurements of Rock Fractions.)

Compaction requirements may stipulate the minimum mass density regardless of the amount of rock, or they may specify a certain mass density for each different rock content. If the rock contents vary, the percentage of *dry* weight of the material retained on a No. 4 sieve must be determined for

each inplace density test Moisture tests on these materials may require specific methods (see Chapter 3, Construction Control Tests, Moisture Determinations).

Subgroup IIC

These are gravelly and stony soils of moderately durable rock. Less than 35 percent passes a No. 4 sieve after compaction.

Laboratory tests and design values.—Laboratory tests generally are not needed. Design values are based on the results of tests of similar materials adjusted for rock content of more than 65 percent, on field evaluation of actual performances of materials in constructed fills, and on published data for large-scale field and laboratory tests. Long-term weathering and stability characteristics of these materials are extremely important in establishing design and placement recommendations.

Construction control.—Compaction tests generally are not performed on these materials. Compaction requirements will be stated in the specifications as a placement method.

Coarse-Grained Soils—Group III

These are gravelly and stony soils containing soft, nondurable rock. The rock is so soft and breaks down so easily that it is impossible to physically separate the various sizes. It is important that the testing laboratory know this when the samples are submitted; otherwise, laboratory tests and design values might be based erroneously on a physical separation not possible in construction.

Laboratory tests and design values.—Laboratory tests and design values must be based on mass density, since separation is not possible. A series of tests must be made, based on the varying moisture-density relations and using the total material processed to pass the No. 4 sieve. Individual samples of the material in combination with various amounts (20 to 40 percent) of the coarse material (retained on the No. 4 sieve) will be processed and tested.

Compaction control.—Compaction specifications require a minimum mass density. Inplace density can be determined by any "density inplace" method.

The methods and equipment needed for moisture-density (compaction) control tests in rocky soils differ from those ordinarily used in testing fine-grained soils. The amount, durability, and size of the rock in the embankment to be tested affect the selection and preparation of a representative test site, dimensions of the control test hole, type and size of the equipment of the control test hole, type and size of the equipment used to measure the volume of the test hole, and sample sizes needed for the moisture determinations.

Test Site Selection

The site selected for an inplace density test in rocky soils must represent average soil and rock conditions for a particular zone or lift of fill or borrow source.

A site containing rocks larger than normally encountered is considered nonrepresentative. Randomly occurring rocks two to three times larger than the maximum sue in most of the embankment material being tested also make the site nonrepresentative. This is particularly true for many of the fine gravelly tills and alluviums containing less than 30 percent rock and having occasional cobbles.

For compacted materials having a mass density of 110 to 125 lb/ft^3 and a rock density of 120 to 140 lb/ft^3, a 5-in.-diameter rock equals about 35 percent of the total sample from a test hole 6 in. across by 8 in. deep. If all other rock in the sample is 2 in. or less in diameter, a 5-in.-diameter rock is obviously not representative of the rock fraction. Similarly, a 2-in. rock can cause misleading results in a density-test sampling of material that otherwise contains as much as 65 percent rock that passes a ½-in. sieve.

If random, oversize rocks are encountered in a test, a new site must be selected or the weight and volume of the oversize rock deducted from the total weight and volume of the test sample. If adjustments in the weight and volume are made for oversize rock, they should be recorded in the density-test records. In other words, the amount of rock in a density-test sample should represent average con-

[3] *This information was presented in an appendix in SCS Technical Release No. 27, "Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankment" (March 1965).*

ditions. A site containing 5 to 10 percent rock is hardly representative if most of the fill material contains 25 to 35 percent rock.

Test Site Preparation

Any inplace density test site should be as level and smooth as practical. However, surface irregularities generally are inevitable when testing rocky soils.

Test Hole Excavation

Excavating and preparing the hole for inplace density measurements must be done carefully. The top of the hole must be the same size as the hole in the sand cone base plate or liner template. The bottom of the hole must be as dished or cupped as possible, and the sides as smooth as possible.

Rocks and stones protruding from the sides can prevent the sand and water-filled plastic from completely filling all voids and filling around the rocks. This is particularly true if the stones are flat or angular and are oriented at right angles or obliquely downward to the vertical axis of the hole. Such stones should be removed if possible, then the resulting cavity enlarged and flared to allow free and full occupancy by the sand or the liner.

Test Hole Volume Measurements

The size of the test hole and the type of equipment used to measure the volume of the material removed vary with the amount and maximum size of the rock.

Table 3–3 shows the recommended minimum volume and dimensions of the inplace density test holes for different sizes of rocky materials. Bottom-width dimensions for test holes are necessary because it is difficult to dig vertical sidewalls for test holes in rocky soils.

Of the methods shown for measuring test-hole volume, the sand cone method (test S–2), which uses 6.5- and 12-in.-diameter cones, generally works well for materials with rock as large as 4 in. in diameter.

For materials with rocks larger than 4 in., the template and plastic liner method (test S–7) is recommended. A thin rubber or polyethylene sheet liner is fitted into the test hole. Then the water volume needed to fill the lined hole is measured. Plastic drop sheets classified as No. 4 (0.004 gauge) are available in most paint and hardware stores and work well for this test. Sheets must be thin enough to conform to surface irregularities in the test hole, yet sturdy enough to resist punctures by sharp rocks.

Sand Cone Method

For density tests with a sand cone, use of a base plate is required. The tare weight of the sand needed to fill the cone and base plate must be determined for each calibrated lot of sand and then used as a standard weight in subsequent tests.

If, however, surface irregularities exist at the site of the inplace density test, this standard weight is not applicable. If rocks extend above the surface of the plane to be excavated, the use of a standard correction for the amount of sand that is required to fill the cone will result in undermeasurement of the true volume of the material removed; that is, the density will be higher than true density. A volume greater than the true volume of the material removed, that is, a lower density than the true density, results if the surface of the plane to be excavated has holes and indentations or if the base plate is not flush with the surface and sand moves into any annular space between the base plate and test surface.

If the surface cannot be leveled, a test should be run at the site before the hole is excavated to determine the amount of sand needed to fill the cone, base plate, and surface irregularities.

Template and Plastic Liner Method

Volume measurements on irregular surfaces by the template and plastic liner method are also subject to error. The following procedures are recommended if the surface of the test location cannot be leveled

- Seat the template firmly over the test location in as level a position as possible. A metal template is preferred over wood. The template can be square or rounded and can range in size from 24 to 72 in. across by 2 to 6 in. high.
- Remove rocks immediately under the template edges and discard them without disturbing the surrounding soil.

- Fit the plastic liner inside the template taking care to eliminate all folds in the plastic, to fit the plastic snugly into the corners of a square template, and to line any cavities along the edge of the template resulting from the removal of rocks in the seating process.
- Use a hook gauge or other accurate means to measure the water needed to fill the template to a point of overflowing or some arbitrary level, and record the amount. It is generally easier to weigh the water than to measure it volumetrically.
- Remove the water and plastic liner and complete the test. It is best to remove at least part of the water before trying to lift out the liner.

Measurement Procedures

All weight and volume measurements must be done carefully and recorded. Even very small errors in any measurement are cumulative and become significant when converted to units of pounds per cubic foot. The following procedures are recommended for measuring the material volumetrically:

- Seat the template and liner on the surface.
- If the surface is not smooth and level, determine the amount of water needed to fill the template to overflowing or to a predetermined level.
- Excavate the hole, and save and weigh the excavated material.
- Fit the plastic liner into the hole as snugly and evenly as possible. This is best done by working the liner against the sides of the hole as it fills with water.
- Determine the amount of water needed to fill the hole and template to overflowing (or to the same predetermined level on the template that was used if there were surface irregularities). Generally, water measurements are made in pounds (to the nearest 0.01 lb), grams, or cubic centimeters.
- After emptying and removing the liner, check the hole to be sure the plastic did not leak.

Equations and Conversions

The volume of material removed from the test hole equals the volume of water used to fill the hole and template minus the volume used to fill the template on the surface of the ground (tare):

$$\text{Volume (ft}^3) = \text{total water (lb)} - \text{tare water (lb)} \times \mathbf{0.01603}, \text{ or}$$

$$= \text{total water (g or cm}^3) - \text{tare water (g or cm}^3) \times \mathbf{0.0000353}$$

Other useful conversion factors are:

1 gal water @ **62°F** = **8.337** lb = **0.13368** ft^3 = **3,785.5** cm^3

1 lb (avoir) water = **0.01603** ft^3 = **453.6** g or cm^3

1 cm^3 = **1** g water = **0.0000353** ft^3

1 ft^3 = **62.4** lb

Separation of Coarse and Fine Fractions

This procedure is used when it is necessary to determine the amount of rock retained on a specified sieve. The methods vary with the nature of the rock.

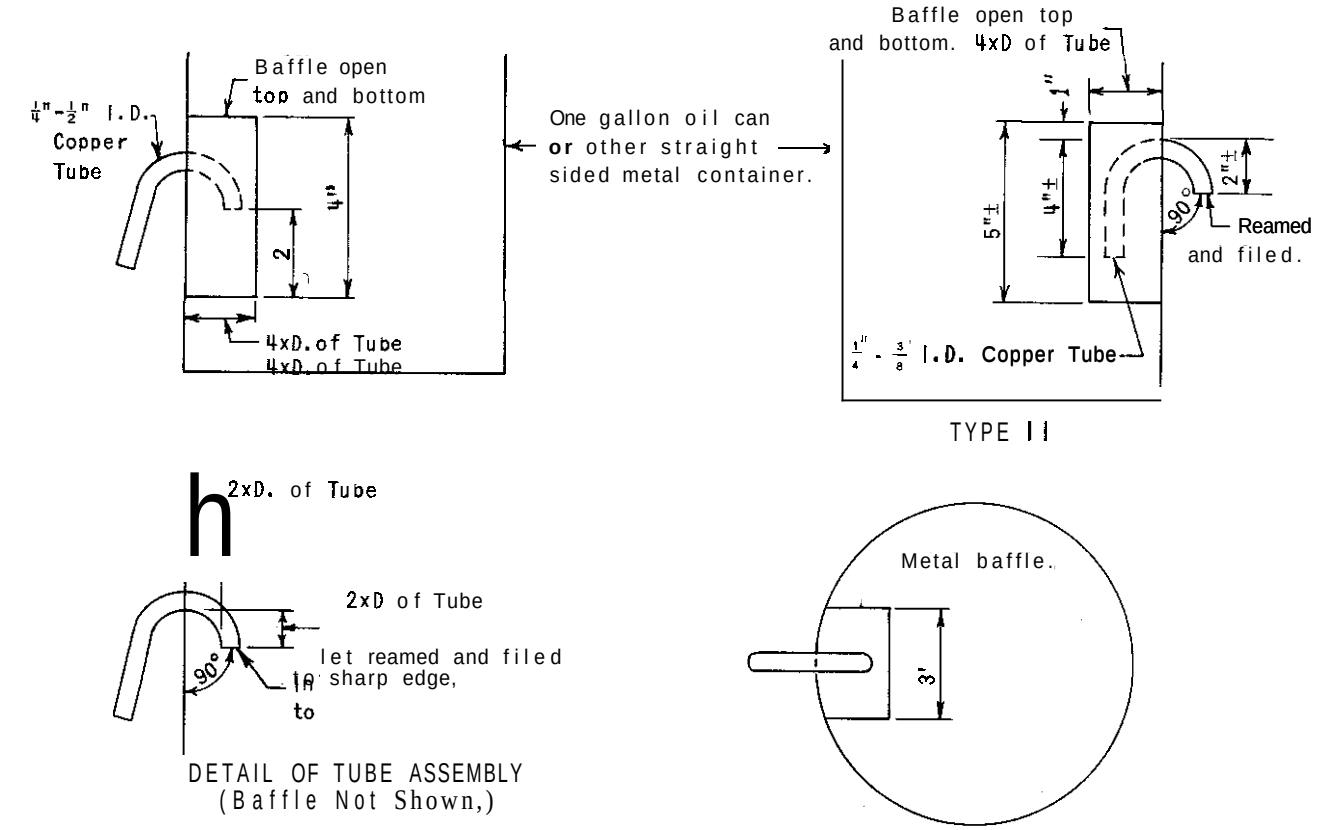
Hard Rock Separation

The following procedures are recommended for hard rock with less than **5** percent absorption capacity:

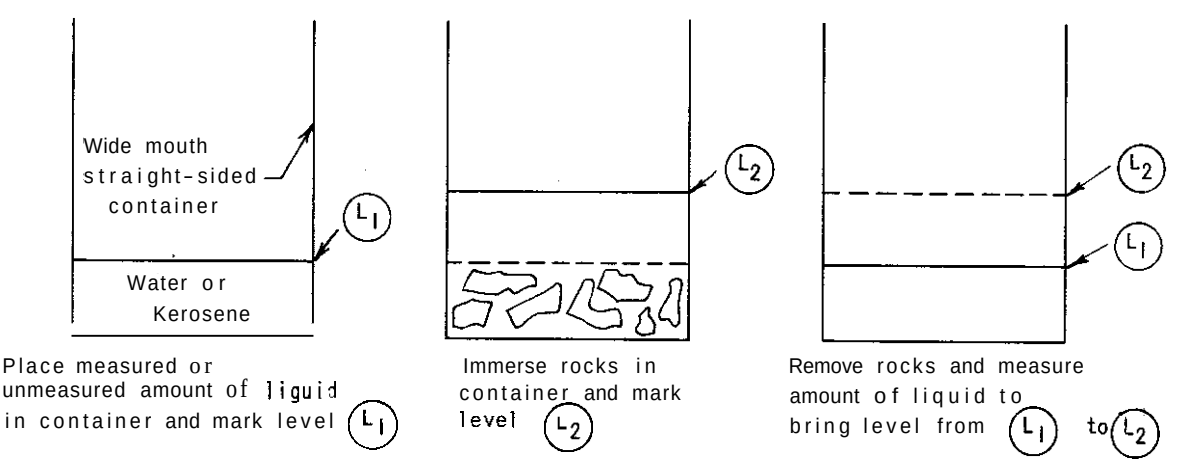
- Collect a representative sample of the fine fraction for the moisture determination before washing. The entire sample can be washed on the specified sieve if all rock in the sample has a low absorption capacity.
- Check the absorption capacity of several samples of rock before separating the sample to be sure that the sample consists of low absorptive materials.
- Determine absorption capacity by (1) soaking the specimens in clear water for at least 24 hr, **(2)** taking the specimens from the water and blotting and patting them with absorbent paper to remove all surface water, (3) weighing the saturated, surface-dry specimens, and (4) oven-drying the specimens to a constant weight (sometimes this takes **24** hr or longer).

Table 3-3.--Inplace density test specifications

Soil groups	Rock >No. 4	Compaction control	Maximum particle size in mass diameter	Inplace density tests: Method (cone or template size)	Test hole volume	Test hole dimensions: Top	Bottom	Depth
	percent		*inches*		*cubic feet*	*inches*	*inches*	*inches*
IA, IIA	<35	<No. 4	2	Sand cone (6½-in)	0.10	6.5	4	8
			2 - 4	Sand cone (12-in)	0.40	12	8	12
IB, IIB	35 - 65	Generally on <3/4 in. or mass for IB; generally on mass for IIB	2	Sand cone (6½-in)	0.10	6.5	4	8
			2 4	Sand cone (12-in) or template & plastic liner (12-in)	[illegible] 40	12	8	12
			4 6	Template & plastic liner (24- to 30-in)	1 00 to 2 00	≥4 to 30	12 to 18	12
			[illegible] 12	Template & plastic liner (48-in)	10 00 to 14 00	48	24	18
IC, IIC	>65	Mass and method	[illegible]	Sand cone (12-in) or template & plastic liner (12-in)	[illegible] ≥0 to 0.40	12	Variable	12
			6	Template & plastic liner (30-in)	1.00 to ≥ 00	[illegible]	Variable	12
			12	Template & plastic liner (48-in)	10.00 to 14 00	48	Variable	18
			15	Template & plastic liner (72-in)	15.0 to 18.0	72	Variable	18
III	5 - 65	Mass	Indeterminate	Sand cone (6½-in)	0.10	6.5	4	8



a, SIPHON CAN FOR MEASUREMENT OF VOLUME BY DISPLACEMENT.



NOTE: If initial amount of liquid is measured into container as V_1, only the final level, L_2, need be marked; then volume of solids V_s = VOLUME REQUIRED TO FILL TO LEVEL L_2 MINUS V_1.

b. MEASUREMENT OF DISPLACEMENT IN UN-GRADUATED CYLINDER.

Figure 3-4.—Two methods of measuring volume of solids by water displacement.

The percent absorption is:

$$\frac{\text{Wet weight} - \text{dry weight}}{\text{Dry weight}} \times 100$$

Rock Separation

Examples of rock with more than 5 percent (moderate to high) absorption capacity include some hard rock, shale, sandstone, and chalk as well as mixtures of rock with variable absorption capacity. When these materials form the rock fraction, they must not be separated from the sample by washing because the rock will absorb water.

Low plasticity fines.—The following procedures are recommended for the separation of materials with low plasticity fines (SW, SP, GW, GP, SM, GM):

- Weigh the total sample.
- Extract a representative sample of the fine fraction (passing a No. 4 or a 314-in. sieve) for the moisture determination. This may require screening of a portion before processing the entire sample.
- Separate the total sample on the specified sieve, and brush or rub off as much soil as possible from each rock.
- Determine the moist weight of the cleaned rock.
- Measure the volume of the cleaned rock by displacement in a siphon can or graduated cylinder (as described in a following section).
- Compute the moist weight and volume of the fine fraction by subtracting the moist weight of rock from the moist weight of the total sample and the volume of rock from the volume of the total sample.
- If the percentage of rock by weight is required, ovendry the rock.

Plastic fines.—It is usually impossible to clean plastic fines from rock by rubbing or brushing. Therefore, the following procedures are recommended for the separation of materials with plastic fines (SC, GC):

- Determine the moist weight of the total sample.
- Extract a representative sample of the fine fraction for the moisture determination.
- Separate the entire sample on the specified sieve.
- Rub and brush off as much soil as possible from the rock.
- Determine the moist weight of the brushed rock plus the adhering soil.
- Wash the rock as clean as possible and determine its weight and volume.
- Compute the weight of the moist soil adhering to the rock by subtracting the washed rock weight from the brushed rock moist weight. This weight is added to the moist weight of the fine fraction passing the sieve. When the entire sample is screened, the total moist weight of the fine fraction is given as:

  Fine fraction moist weight = (total sample moist weight – brushed rock moist weight) + (brushed rock moist weight – washed rock weight)
- If the percentage of rock weight is required, determine the *dry* weight of the rock.[1]

Volume Measurement of Rock Fractions

Rock fractions not passing a specified sieve must be measured volumetrically. Rock with greater than 5 percent absorption must be saturated before volume measurements are made.

Several methods of measuring volume are available. The characteristics of the rock fraction being tested may dictate the method of use.

Siphon Can or Other Overflow Volume Measure

This is a direct measurement of the liquid volume displaced through an overflow pipe when a sample is completely immersed in the measuring device. Figure 3–4 (part a) illustrates two types of siphon cans used for displacement measurements.

In the Type I device, the siphon tube outlet is below the inlet. The siphon tube drains completely

[1] *When testing large samples with either the 12-in. sand cone or plastic liner test, it is often easier to dry the entire sample than to do the sieving operation. If so, then a representative sample of the fine fraction is extracted for the moisture determination before the remainder of the material is dried.*

at the end of each measurement and must be reprimed for each test. If the volume of the sample to be measured is too small to activate the siphon, nonabsorbent articles of a known volume can be added with the sample. The known volume must be subtracted from the total volume displaced to determine the net volume of the sample.

In the Type II device, the siphon tube outlet is higher than the inlet. The siphon tube retains its "prime" and does not drain out at the end of each measurement. When operating properly, this type of siphon can is very sensitive and is activated as soon as any object is inserted.

In making the Type I siphon can measurement, it is important that the end of the siphon tube inside the can is cut squarely and set in a plane parallel with the bottom of the can and that it is reamed and filed to a sharp edge. The positioning and shaping of the inlet end of the siphon tube are less critical for the Type II can, but the outlet end should be reamed and sharp. A small-diameter tubing (<3/8-in. inside diameter) must be used for the Type II can since proper operation depends on its prime. Larger diameter tubing can be used for the Type I can. The curved section of the siphon tube for both types needs to be round and have the same diameter as the rest of the tube. A baffle around the inlet of the siphon tube is particularly helpful in maintaining a quiet surface in the liquid surrounding it.

To use a siphon can or other overflow volume measure, the following procedures are recommended

- Place the siphon can in a level position on a solid base during the measuring.
- Check the action and accuracy of the device several times before actual field use by measuring the displacement from a nonabsorbent article of a known volume.
- Fill the siphon can to a level above the siphon tube summit, then allow it to drain to the level of the inlet before making volume measurements.

Overflow tubes other than a siphon tube can be used to measure displacement. Straight tubes have some disadvantages. The last of the overflow can dribble out for several seconds, whereas the flow through a properly constructed siphon stops instantly when the liquid level in the can reaches that of the siphon inlet. Also, the surface tension of the liquid at the inlet of a straight tube can vary from test to test.

Direct-Reading Volume Measurements

The volume of liquid displaced by a rock sample can be determined by recording the water level in a graduated cylinder before and after immersing a sample.

Volume can be measured in any container by marking the container at the water level without the sample, then at the level with the sample. The amount of liquid between these marks is then measured or weighed. Figure 3–4 (part b) shows one method of volume measurement in an ungraduated container.

Measurement of Moderately Durable (Group II) Rock

The volume of moderately durable rock that disintegrates when soaked in water can be measured by using kerosene or diesel fuel instead of water as the displacement liquid.

Measurements of Soft Rock or Soil Clods

The volume of materials that disintegrate when immersed in water can be measured by waxing the specimen and then measuring displacement as follows:

- Clean and brush all soil and loose particles from the sample.
- Weigh each sample (generally in grams).
- Carefully waterproof each specimen with a coating of melted wax.[5]
- Weigh each waxed specimen (generally in grams); then for each waxed specimen determine the volume (generally in cubic centimeters).
- Strip the wax off each specimen and determine the moisture content of the specimen.

[5] *Waterproof fishline or nylon hairnets can be used for cradles to hold samples while immersing them in wax. A wax with a high melting point, usually a mixture of beeswax and paraffin, provides a more uniform mating than ordinary paraffin. The temperature of the wax needs to be just above the melting point when immersing samples. Wax that is too hot readily penetrates the pores. Two or more immersions in wax may be needed for waterproofing.*

- Calculate the specific gravity of the wax by molding or trimming part of the wax into easily measured forms, weighing the forms, and accurately measuring their dimensions. Another way is to measure the water displaced by a wax form of a known weight. The form can be submerged by weighting it with an impervious article **of** known volume.
- Compute the volume of the wax coating on the specimen by dividing the weight of the wax by the specific gravity of the wax:

$$\text{Wax volume} = \frac{\text{Waxed sample weight} - \text{unwaxed sample weight}}{G_s \text{ of wax}}$$

- Compute the volume of the specimen by subtracting the volume of the wax from the **total** volume of the waxed specimen.
- Record the test data on Form SCS-ENG-543 (fig. 3–58).

Moisture Determinations

ASTM D–1556 provides the following guide for minimum amounts of material required for moisture determinations:

Maximum size of particles in total sample	Sample required for moisture
Sieve designations	***gram***
No. **4**	100
½-in.	300
1-in.	500
2-in.	1,000

Large amounts of material (50 lb or more) are excavated for inplace density tests on embankments having rock larger than 2 in. Selecting a representative sample **for** moisture determinations on such materials is no problem if density control is based on the fraction passing a No. 4 or a 3/4-in. sieve and the fine material is used to determine moisture content. The moisture content of the coarse fraction is not needed when the volume of the oversize rock is measured.

However, selecting a portion of the total sample that will represent the moisture content of the mass is very difficult if large particles are involved. Then alternative procedures must be used. This is particularly true if the materials contain rock **of** varying composition and moisture absorption characteristics.

For materials having more than 35 percent rock retained on a **No.** 4 or a 3/4-in. sieve and having maximum rock sizes larger than 2 in., the preferred procedure is to dry the entire sample taken from the test excavation. This takes large drying equipment and considerable time.

If drying the entire sample is not practical, the sample should be separated at some arbitrary size and the moisture determined for a portion of the fine fraction and for a portion or all of the coarse fraction.

The problem in trying to represent the moisture content of the mass by drying a portion of the total mass arises from the difficulty in splitting out a small sample that truly represents the gradation content of the total sample, especially if the rock sizes range from ¼ in. to 6 in. or larger. **A** better representation of the smaller sizes can be made by separating the sample on **a** 1- or 2-in. sieve and determining the moisture content of 500 to 1,000 g of this fraction. If the rock in the coarser fraction is uniform in composition and hardness, only a part of this **rock** need be dried for moisture determinations. But if the sample contains different kinds of rock, the entire coarse fraction must be dried.

Example Computations of Density and Moisture

The following examples illustrate computations of inplace density and moisture.

Example 1

Given: 35 to 50 percent of the embankment material is retained on the No. **4** sieve. The maximum size of the material is 4 in. The rock consists of mixed quartzite, conglomerate, and hard sandstone. Specifications call for construction control on the fraction passing a 3/4-in. sieve.

Volume determination—12-in. sand cone.—

- ① Weight, sand to fill cone and plate in place ..... = 5.00 lb
- ② Weight, sand to fill cone, plate, and hole = 45.00 lb

- (3) Weight, sand in hole,
  (2) − (1) ..... = 40.00 lb
- (4) Bulk density, test sand..... = 100.00 lb/ft³
- (5) Volume, test hole,
  (3) ÷ (4) ..... = 0.40 ft³

Moisturedensity determination.–

* (6) Total weight, moist material ..... = 60.00 lb

- (7) Moist weight, >3/4-in. fraction .... = 15.00 lh
- (8) Volume, >3/4-in. fraction ..... = 0.10 ft³ (measured)
- (9) Volume, <3/4-in. fraction,
  (5) − (8) ..... = 0.30 ft³
- (10) Moist weight: <3/4-in. fraction,
  (6) − (7) ..... = 45.00 lb
- (11) Percent moisture, <3/4-in. fraction (from 500-g sample) . = 15.0%
- (12) Dry weight, <3/4-in. fraction,
  $(10) \div \left(1 + \frac{(11)}{100}\right)$. = 39.13 lb
- (13) γ_d, <3/4-in. fraction,
  (12) ÷ (9) ..... = 130.4 lb/ft³

Moisture content and *dry* weight determinations of the fraction retained on a 3/4-in. sieve are not needed since specifications call for construction control on the fraction passing the 314-in. sieve, requiring only the volume of the coarse fraction.

Example 2

Given: The embankment material is the same as in Example 1. Specifications call for compaction control on the mass.

Volume determination—12-in. sand cone.–

* Steps (1) through (5) are performed the same as in Example 1. The volume of the test hole equals 0.40 ft³.

Moisturedensity determination.–

* @ Total weight, moist material ..... = 60.00 lb

- (7) Moist weight, >3/4-in. fraction (sample can be split for better representation of the moisture content)... = 15.00 lb
- (8) Volume, >3/4-in. fraction ..... = 0.10 ft³ (measured)
- (9) Volume, <3/4-in. fraction,
  (5) − (8) ..... = 0.30 ft³
- (10) Moist weight! <3/4-in. fraction,
  (6) − (7) ..... = 45.00 lh
- (11) Percent moisture, <3/4-in. fraction (from 500-g sample) . = 15.0%
- (12) Dry weight, <3/4-in. fraction,
  $(10) \div \left(1 + \frac{(11)}{100}\right)$. = 39.13 lb
- (13) Dry weight, >3/4-in. fraction (entire fraction dried because of variance in the rock) = 13.55 lh
- (14) Dry weight, total mass,
  (12) + (13) ..... = 52.68 lb
- (15) γ_d, mass,
  (14) ÷ (5) ..... = 131.7 lb/ft³
- (16) Percent moisture, mass,
  $\left(\frac{(6) - (14)}{(14)}\right) \times 100$ = 13.9%
- (17) Percent, >3/4-in. fraction,
  ((13) ÷ (14)) × 100 = 25.7%

Example 3

Given: 35 to 60 percent of the embankment material is retained on a No. 4 sieve. **The** maximum size of the material is 6 in. The rock consists

of hard granite and gneiss. Specifications call for compaction control of the mass.

Volume determination—30-in. template and plastic sheet.—

* (1) Weight, water to fill template before excavating. . . . . = 62.40 lb

• (2) Weight, water to fill template and excavation . . . . . = 187.20 lb

• (3) Net weight, water to fill excavation,
(2) − (1) . . . . . = 124.80 lb

• (4) Volume, excavated material,
(3) ÷ 62.4 . . . . . = 2.00 ft^3

Moisture-density determination.—

* (5) Moist weight, total material excavated (material separated on a 1-in. sieve for moisture determination) . . . . . = 303.00 lb

• (6) Moist weight, >1-in. fraction . . . . . = 116.50 lb

• (7) Moist weight, <1-in. fraction,
(5) − (6) . . . . . = 186.50 lb

• (8) Moist weight, portion of >1-in. fraction (sample can be split because of the uniformity of the rock) . . . . . = 10.00 lb

• (9) Dry weight, portion of >1-in. fraction . . . = 9.61 lb

• (10) Percent moisture, >1-in. fraction,
$\left(\frac{(8) - (9)}{(9)}\right) \times 100$. . = 4.1%

• (11) Dry weight: total >1-in. fraction,
$(6) \div \left(1 + \frac{(10)}{100}\right)$. = 111.91 lb

• (12) Moist weight, portion of <1-in. fraction (sample split) . . = 5.52 lb

• (13) Dry weight, portion of <1-in. fraction . . . = 5.16 lb

• (14) Percent moisture, <1-in. fraction,
$\left(\frac{(12) - (13)}{(13)}\right) \times 100$. = 7.0%

• (15) Dry weight, total <1-in. fraction,
$(7) \div \left(1 + \frac{(14)}{100}\right)$ = 174.30 lb

• (16) Dry weight, total sample,
(11) + (15) . . . . . = 286.21 lb

• (17) γ_d, mass,
(16) ÷ (4) . . . . . = 143.11 lb/ft^3

• (18) Percent moisture, mass,
$\left(\frac{(5) - (16)}{(16)}\right) \times 100$. = 5.9%

Methods, Specifications, and Forms for Moisture and Density Determinations of Soils

This supplement contains test specifications (by reference or in their entirety) for the moisture and determinations needed and forms required for recording and analyzing moisture-density test data when construction involves placing compacted earth fill. A separate form is suggested for each test. However, if two or more inplace density tests are made concurrently on the same sites (except for rapid tests), space is available on each form for recording both sets of data.

Form SCS-ENG-530A is used to record bulk sand density determinations and cone and base plate calibrations (fig. 3–13).

Form SCS-ENG-530B and SCS-ENG-530C are used in test S–2, the sand cone method (fig. 3–14 and 3–15). Data used and obtained in testing embankment materials containing fine-grained soils, sand, gravel, and rock that pass a No. 4 or a 3/4-in. sieve are recorded on SCS-ENG-530B. Data from tests of materials containing large percentages of gravel and rock are recorded on SCS-ENG-530C. If the materials have rocks 4 in. or larger in diameter. Form SCS-ENG-530-I should be used (fig. 3–40).

Form SCS-ENG-530D is used in test S–3, the rubber balloon method, which is for testing fine-grained soils with less than 5 percent of the particles retained on a No. 4 sieve (fig. 3–19). A potential for error exists if the maximum particle size exceeds ½ in.

Form SCS-ENG-530E is used in test S–4, the calibrated cyliner method, which is for testing fine-grained cohesive soils (fig. 3–29). Coarse, hard-grained materials must all be able to pass a No. 4 sieve because larger materials would damage the cutting edge of the cylinder.

Forms SCS-ENG-530F is used in test S–5, the kerosene method, which is for testing cohesive soils (fig. 3–30). Coarse-grained materials just passing a No. 4 sieve can cause difficulty in shaping the test sample and also permit penetration of the test fluid.

Form SCS-ENG-530G and SCS-ENG-530H are used in test S–6, the rapid compaction control method by sand and rubber balloon displacement (fig. 3–34 and 3–35). Data from tests of embankments containing less than 35 percent rock retained on a No. 4 or a 314-in. sieve are recorded on SCS-ENG-530G. The funnel diameter must be about three times the maximum size of the rock materials tested. Data from tests of soils containing more than 95 percent materials that pass a No. 4 sieve are recorded on SCS-ENG-530H. When the maximum rock size approaches ½ in. in diameter, there is a potential for error and another method is preferable.

Form SCS-ENG-530-I is used in test S–7, the template and plastic liner method, which is for testing materials containing gravel and rock with diameters larger than 4 in. (fig. 3–42).

Information should be recorded on the form during testing. Tests that deviate from the prescribed procedures and test results that are irregular or unusual must be explained in the remarks section. Tests on a given jobsite are numbered consecutively. A predetermined letter or abbreviation is desirable as a prefix to the test number to identify the jobsite. Test reports are kept in the construction office.

Field Density Tests

Sand Cone Method — Test No. S–2

This test determines the density of inplace soil and can be used on a variety of embankment materials. The 6%-in.-diameter cone is restricted to soils containing particles no larger than 2 in. in diameter, and the 12-in.-diameter cone to soils containing particles no larger than 4 in. in diameter. Before using the sand cone, the bulk density of the sand must be determined by calibrating the sand.

Test procedures and recording data.— Procedures for calibrating the sand (to obtain bulk density) and for determining the density of inplace soil are in ASTM D–1556, "Standard Test Method for Density of Soil in Place by the Sand-Cone Method." Some procedures are shown in figures 3–5 to 3–12. ASTM D–1556 does not describe the use of the 12-in. cone, but procedures are the same.

Form SCS-ENG-530A, "Bulk Sand Density Determination and Calibration of Cone and Base Plate," is used for recording data on calibrating the sand cone and base plate (fig. 3–13). Form SCS-ENG-530B, "Inplace Moisture-Density Determination: Sand Cone Method—Specified Fraction Control," is used when the moisture and density of the embankment are controlled on a specified fraction of the material (fig. 3–14). Form SCS-ENG-530C, "Inplace Moisture-Density Determination: Sand Cone Method—Mass Density Control," is used when the moisture and density are controlled on the total mass of the material (fig. 3–15).

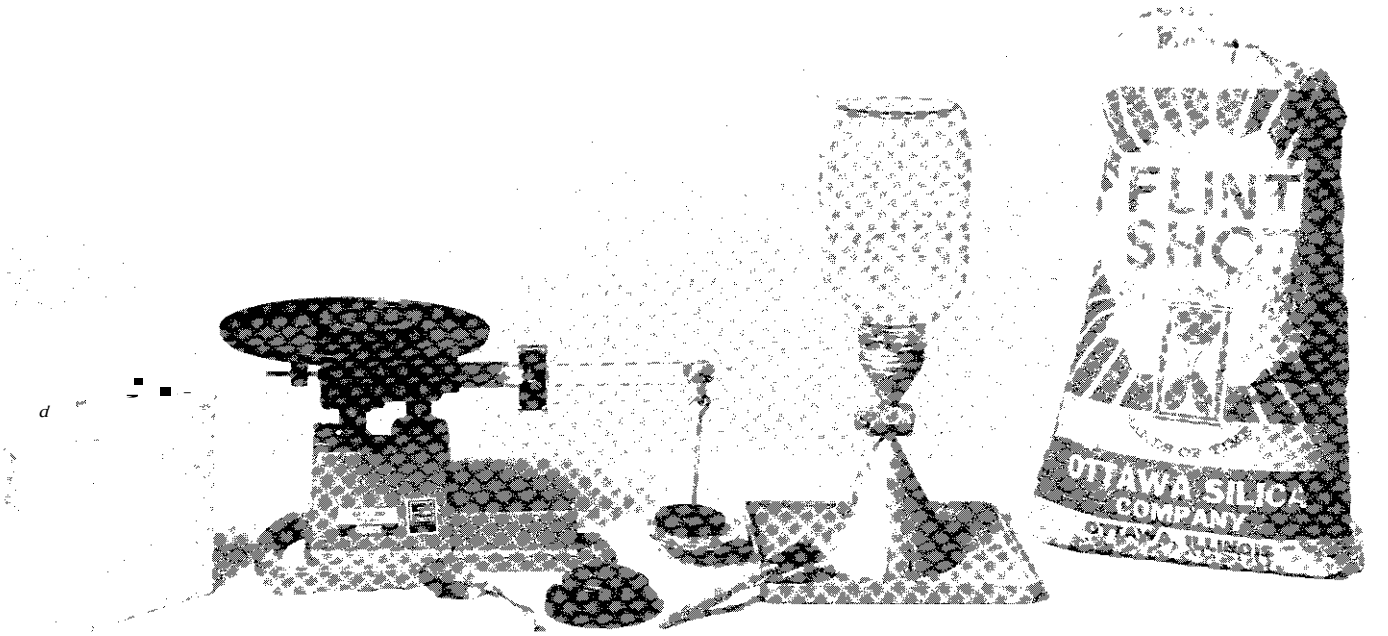
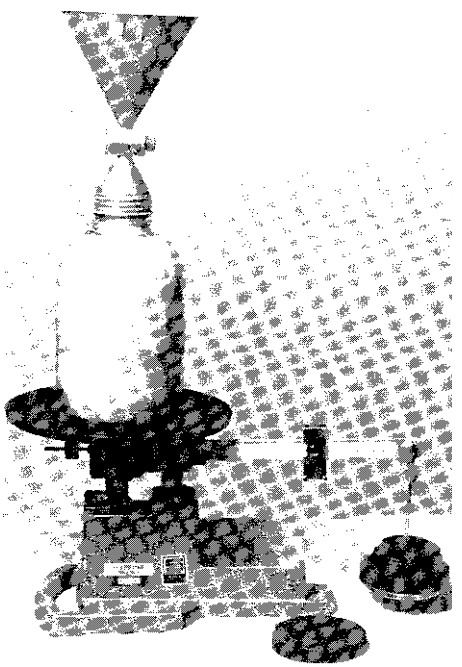


Figure 3–5.—Equipment for calibrating sand.



re 34-Weighing a full jar of sand the cone.

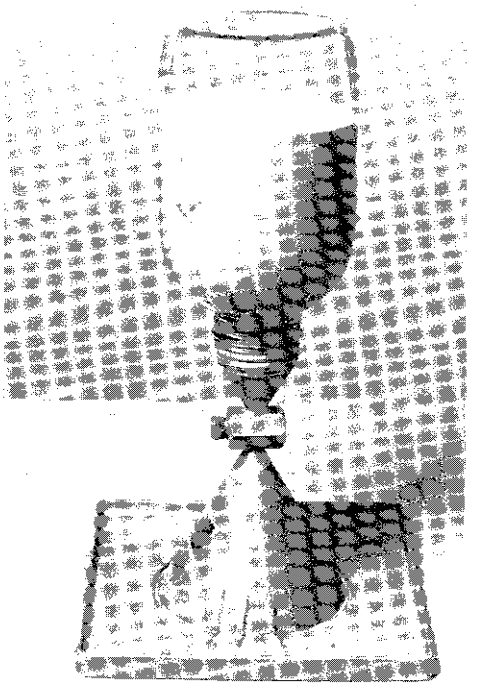


Figure 3-7.-Filling the cone with sand (to determine volume).

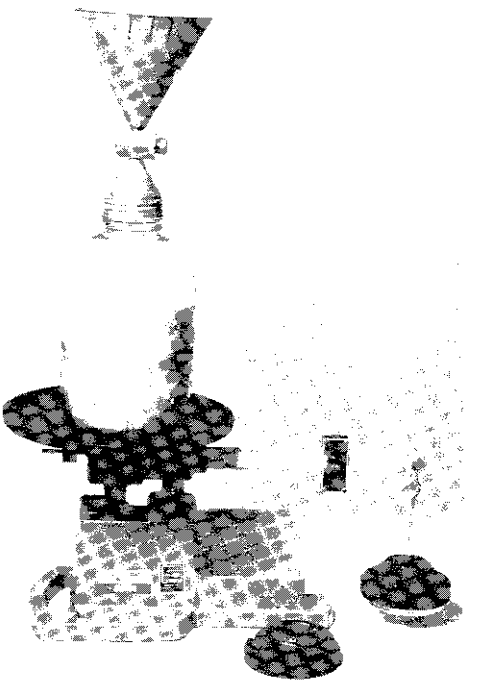


Figure 3-8.-Weighing the remaining sand (photos are of laboratory simulations).

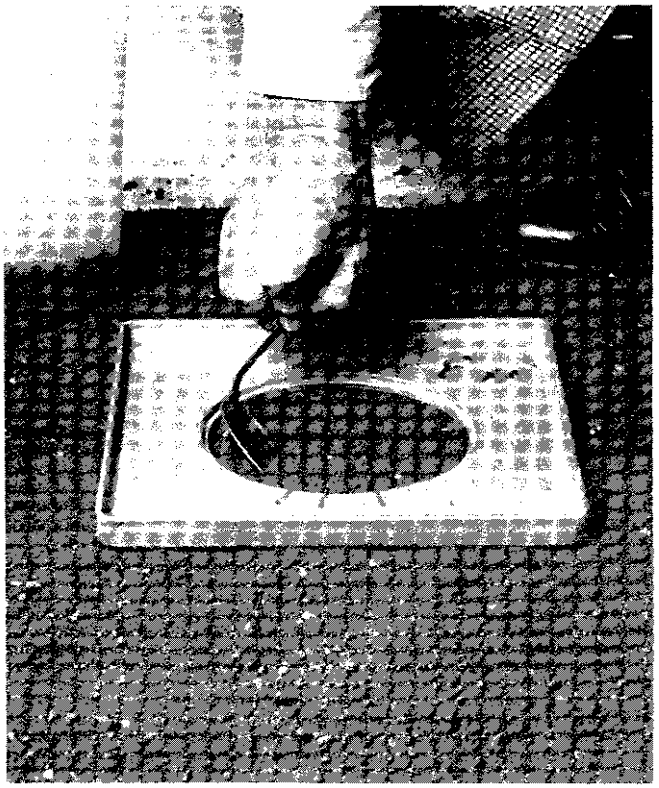


Figure 3-9.-Removing soil (field sample) within the open mold and placing it in a can.

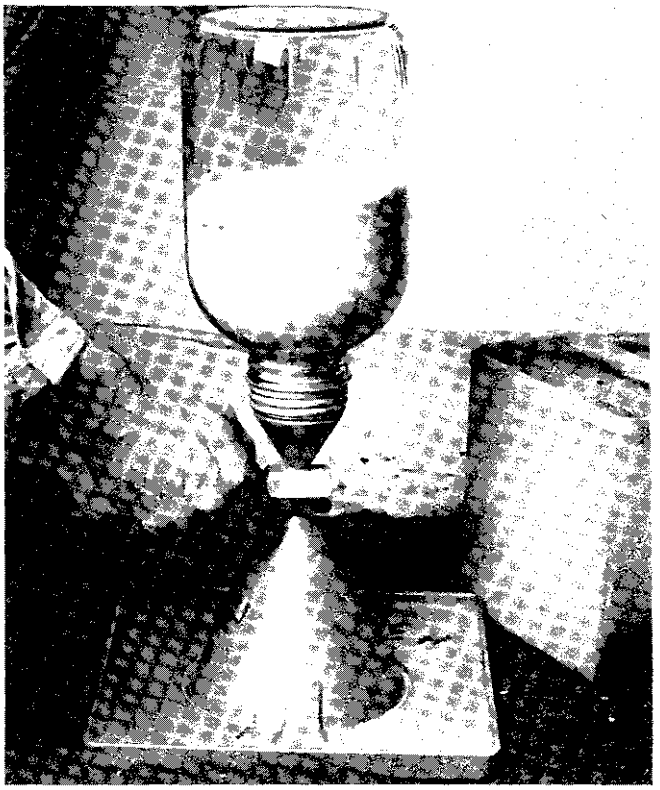


Figure 3-lO.-Filling the cone and hole with sand (to determine volume).

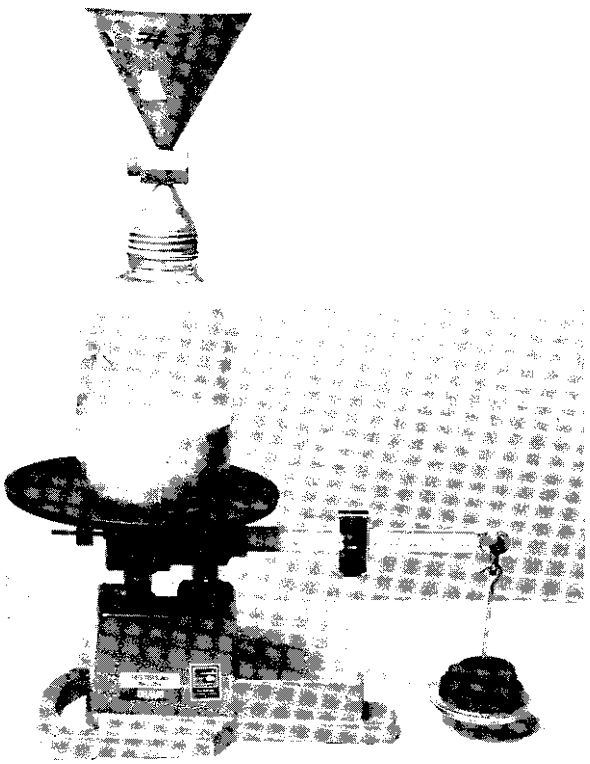


Figure 3-ll.-Weighing the remaining sand,

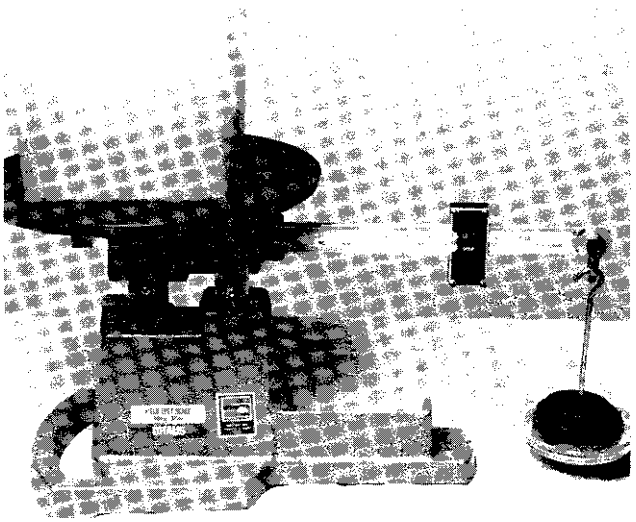


Figure 3-12.-Weighing the field sample in a can (photos *are* of laboratow simulations).

BULK SAND DENSITY DETERMINATION AND CALIBRATION OF CONE AND BASE PLATE

Watershed PINE RIVER Site 2B

Contractor Smith Constructional Company Contract No. 210-108 Test No. 1

Material source Tested by C. JONES Date 4-15-69

Volume of Jar and Funnel Apparatus	Trials 1	Trials 2	Trials 3
(g)	5,051.5	5,029.0	5,021.0
(g)	1,153.5	1,156.5	1,156.5
(g)	3,898.0	3,872.5	3,864.5
	4°C	20°C	32°C
(ml/g)	1.00000	1.00177	1.00497
(ml)	3,898.0	3,879.4	3,883.7

Bulk Density of Sand		Trials 1	Trials 2	Trials 3
8. Weight of apparatus plus rand	Id	7,483.3	7,451.6	7,452.9
9. Weight of apparatus empty	(9)	1,154.0	1,155.0	1,155.5
10. Weight of rand in apparatus = @ − 9	lgl	6,329.3	6,296.6	6,297.4
11. Bulk density of rand = (62.427 x 10) ÷ 7	(lb/ft³)	101.65	101.13	101.14

Weight of Sand to Fill Funnel and Bare Plate				
13. Weight of sand plus apparatus before test	(lb)	17.73	17.57	17.55
14. Weight of rand plus apparatus after test	(lb)	13.47	13.36	13.31
15. Weight of sand in funnel and base plate = 13 − 14	(lb)	4.26	4.21	4.24

16. Apparatus calibration factor (average 3 trials) 4.24 lb

Conversion table—volume o i water per gram, based on temperature

Degrees C.	Degrees F.	Volume of water (ml/g)	Degrees C.	Degrees F.	Volume of water (ml/g)
12	53.6	1.00048	24	75.2	1.00268
14	57.2	1.00073	26	78.8	1.00320
16	60.8	1.00103	28	82.4	1.00375
18	64.4	1.00138	30	86.0	1.00435
20	68 0	1.00177	32	89.6	1.00497
22	71.6	1.00221			

Note: 4539 = 1 lb; 1 g @ 4°C (39.2°F) = 1 ml

Figure 3–13.—Form SCS-ENG-530A, "Bulk Sand Density Determination and Calibration of Cone and Base Plate."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-530B
2-80

INPLACE MOISTURE-DENSITY DETERMINATION: SAND CONE METHOD
Specified Fraction Control

Location SUNNY SLOPE U.S.A Site No. 2B

Watershed PINE RIVER Subwatershed West Branch

Contract No. 12-10-210-108 Contractor Smith Construction Company

Tested by C. JONES Computed by C. JONES Checked by R. BROWN

Test No.	Date	Location of test			Borrow source, location, and depth	Material classification
		Station	℄ offset	Elevation		
1	4-21-69	3+50	Rt 25ft	525.5	Borrow Area #2 ± 6.0 ft	CL

Size of screen for separation #4 Size of sand cone 6 1/2 IN. diameter

Test No.	Date	Spec. requirements (%)		Test results (%)		Curve No.	Wet density check	
		Moisture range	Compaction	Moisture	Compaction		1-Point	Curve
1	4-21-69	± 2 (18-22)	95	19.4	97.4	3	124.1	123.5

Remarks Materials are satisfactory

Figure 3-14.—Form SCS-ENG-530B, "Inplace Moisture-Density Determination: Sand Cone Method—Specified Fraction Control."

Volume Determination		Test No. 1			
1. Bulk density of sand (predetermined)	lb/ft³	101.3			
2. Initial weight of sand, cone, and container	lb	17.73			
3. Final weight of rand. cone, and container	lb	1.63			
4. Weight of sand in hole. plate, and cone = (2) − (3)	lb	16.10			
5. Weight of sand in plate plus cone (predetermined)	lb	4.26			
6. Weight of rand in hole = (4) − (5)	lb	11.84			
7. Volume of hole = (6) ÷ (1)	ft³	0.117			

Moisture Determination					
Speedy moisture meter					
8. Dial reading					
9. Moisture content (calibration curve)	(%)				
Sample tested using: quick dry ☐ alcohol ☐ oven @–		Container No. 13			
10. Weight of moist fines plus container	g	257.76			
11. Weight of dry fines plus container	g	220.42			
12. Weight of moisture = (10) − (11)	g	37.34			
13. Weight of container	g	28.30			
14. Weight of dry fines = (11) − (13)	g	192.12			
15. Moisture content = ((12) ÷ (14)) 100	(%)	19.44			
16. Correction for ignition	(%)	—			
17. Corrected moisture content = (15) − (16)	(%)	19.44			

Density Determination					
18. Weight of moist sample plus container	lb	16.76			
19. Weight of container	lb	2.12			
20. Weight of moist fined plus rock = (18) − (19)	lb	14.64			
21. Weight of moist rock and container	lb	2.82			
22. Weight of container	lb	2.08			
23. Weight of moist rock = (21) − (22)	lb	0.74			
24. Weight of moist fines = (20) − (23)	lb	13.90			
25. Wet density of rock (predetermined)	lb/ft³	145.3			
26. Volume of rock = (23) ÷ (25)	ft³	0.0051			
27. Volume of fines = (7) − (26)	ft³	0.1119			
28. Weight of dry fines = [(24) ÷ (100 + (17))] 100	lb	11.64			
29. Dry density of finer = (28) ÷ (27)	lb/ft³	104.0			
30. Maximum dry density of finer (predetermined)	lb/ft³	106.8			
31. Ratio[2] = ((29) ÷ (30)) 100	(%)	97.4			

[1] Fines are materials smaller than the separating screen specified by the standard method used.

[2] Ratio of dry density of fines to maximum dry density.

Indicate Weight and Volume Units Used in Test

Figure 9-14 (cont).—Form SCS-ENG-530B; reverse side

INPLACE MOISTURE-DENSITY DETERMINATION: SAND CONE METHOD
Mass Density Control

Location West Hollow USA Site No. 4

Watershed Rooty Creek Subwatershed 1A

Contract No. 12-10-398-220 Contractor Power Construction Company

Tested by A. Smith Computed by B. Smith Checkedby J. Roe

Test No.	Date	Location of test			Borrow source, location, and depth	Material classification
		Station	℄ offset	Elevation		
14	4-19-69	10+75	Lt 30ft	4,536.0	Emergency spillway ±12 ft	GM

Sire of sand cone

Test No.	Date	Specification requirements		Test results	
		Moisture range (%)	Mass dry density (lb/ft^3)	Moisture (%)	Mass dry density (lb/ft^3)
14	4-19-69	3-5	125.0	3.7	131.33

Remarks

Figure 3–15.—Form SCS ENG-530C, "Inplace Moisture-Density Determination Sand Cane Method—Mass Density Control"

Volume Determination		Test No.			
		14			
1. Bulk density of rand (predetermined)	lb/ft³	101.32			
2. Initial weight of sand, cone. and container	lb	17.57			
3. Final weight of sand, cone, and container	lb	1.57			
4. Weight of sand in hole, plate, and cone = (2) − (3)	lb	16.00			
5. Weight of sand in plate plus cone (predetermined)	lb	4.21			
6. Weight of rand in hole = (4) − (5)	lb	11.79			
7. Volume of hole = (6) ÷ (1)	ft³	0.12			

Moisture Determination		Container No.			
		12			
Sample tested using: quick dry ☐ oven ☐					
8. Weight of moist sample and container	g	117.58			
9. Weight of dry sample and container	g	114.04			
10. Weight of moisture = (8) − (9)	g	3.54			
11. Weight of container	g	17.58			
12. Weight of dry sample = (9) − (11)	g	96.46			
13. Moisture content = ((10) ÷ (12)) 100	(%)	3.67			
14. Correction for ignition	(%)	—			
15. Corrected moisture content = (13) − (14)	(%)	3.67			

Density Determination					
17. Total dry weight = [16 ÷ (100 + (15))] 100	lb	15.76			
	lb/ft³				

Indicate Weight and Volume Units Used in Test

Figure 3-15 (cont).—Form SCS-ENG-530C; reverse side.

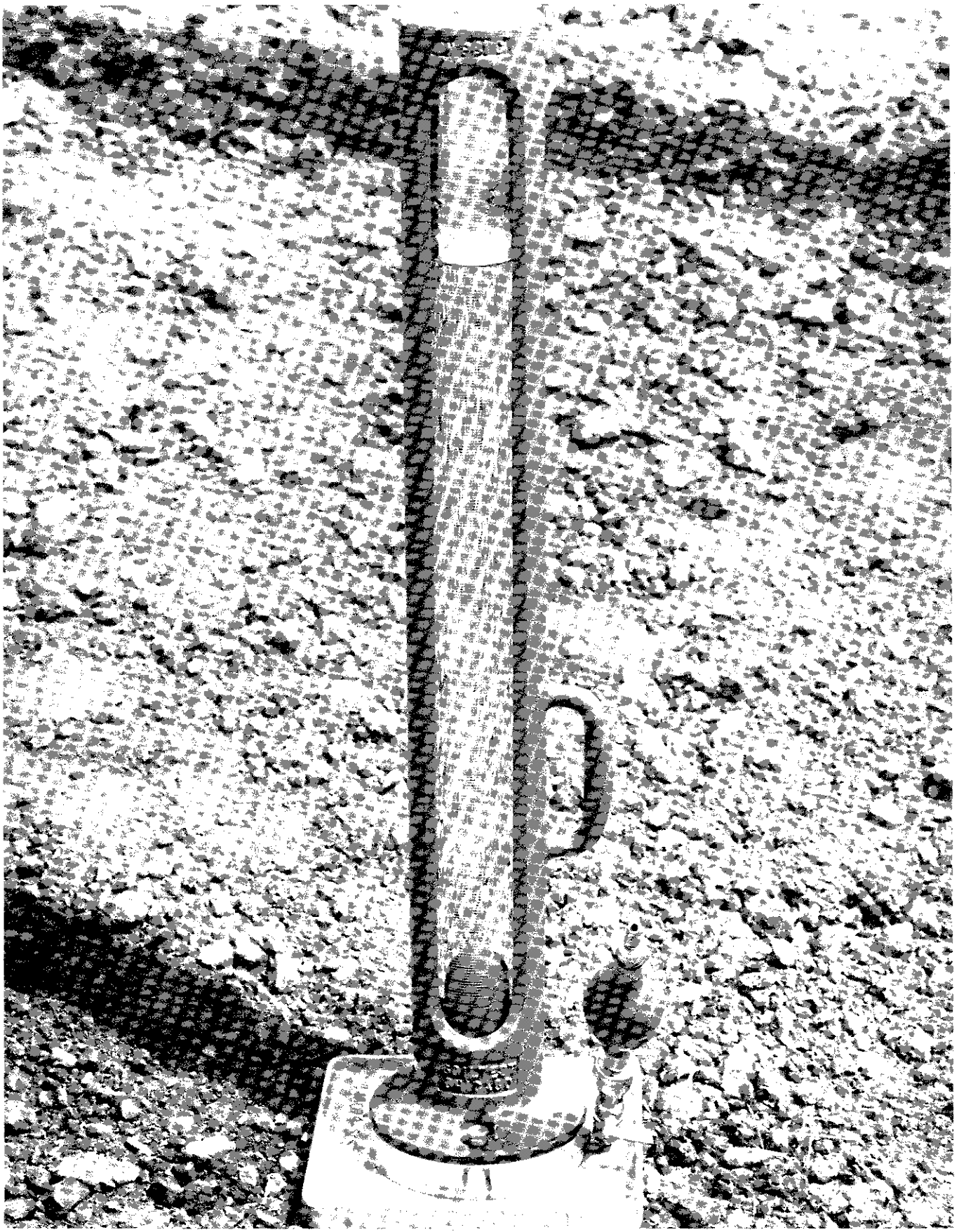


Figure 3-16.—Equipment used in determining inplace density by the rubber balloon method (photos are of field simulations).

Figure 3–17.—Obtaining the initial calibration reading on the volumeasure (note the surface of water column).

Figure 3-18.—Obtaining the final reading. Balloon and water fill the hole from which the sample was taken (note the surface of water column). (Photos are of field simulations.)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-530D
2-80

INPLACE MOISTURE-DENSITY DETERMINATION: RUBBER BALLOON METHOD

Fine-Grained Soils – Less than 5% +No. 4 Sieve

Location WEST HOLLOW U5A Site No. 4

Watershed Rooty Creek Subwatershed 1A

Contract No. 12-10-390-200 Contractor POWER CONSTRUCTION COMPANY

Tested by B. Smith Computed by B. Smith Checked by J. ROE

Test No.	Date	Location of test			Borrow source, location, and depth	Material classification
		Station	℄ offset	Elevation		
15	5-2-69	5+50	℄	4,486.5	Borrow Area #1 5-8 ft	ML

Test No.	Date	Specification requirements (%)		Test results (%)		Curve No.	Wet density check	
		Moisture range	Compaction	Moisture	Compaction		1-Point	Curve
15	5-2-69	±2 (17-21)	95	18.94	96.5	5	125.7	123.2

Remarks

Figure 3-19.—Form SCS-ENG-530D, "Inplace Moisture-Density Determination: Rubber Balloon Method, Fine-Grained Soils—Less Than 5%+No. 4 Sieve."

Volume Determination		Test No.			
		15			
1. Final base reading	ft^3	0.0520			
2. Initial case reading	ft^3	0.0124			
3. Volume of hole = (1) − (2)	ft^3	0.0396			

Moisture Determination					
Speedy moisture meter					
4. Dial reading					
5. Moisture content (calibration curve)	(%)				
Sample tested using: quick dry ☐ alcohol ☐ oven ☑		10	Can No.		
6. Weight of moist sample plus container	g	259.64			
7. Weight of dry sample plus container	g	221.52			
8. Weight of moisture = (6) − (7)	g	38.12			
9. Weight of container	g	20.21			
10. Weight of dry sample = (7) − (9)	g	201.31			
11. Moisture content = ((8) ÷ (10)) 100	(%)	18.94			
12. Correction for ignition	(%)	—			
13. Corrected moisture content = (11) − (12)	(%)	18.94			

Density Determination					
14. Weight of moist sample plus container	lb	5.42			
15. Weight of container	lb	0.45			
16. Weight of moist sample = (14) − (15)	lb	4.97			
17. Weight of dry sample = [(16) ÷ (100 + (13))] 100	lb	4.18			
18. Fill dry density = (17) ÷ (3)	lb/ft^3	105.6			
19. Maximum dry density	lb/ft^3	109.4			
20. Ratio[1] = ((18) ÷ (19)) 100	(%)	96.5			

[1] Ratio of fill dry density to maximum dry density.

Indicate Weight and Volume Units Used in Test

Figure 3–19 (cont).—Form SCS-ENG-530D; reverse side.

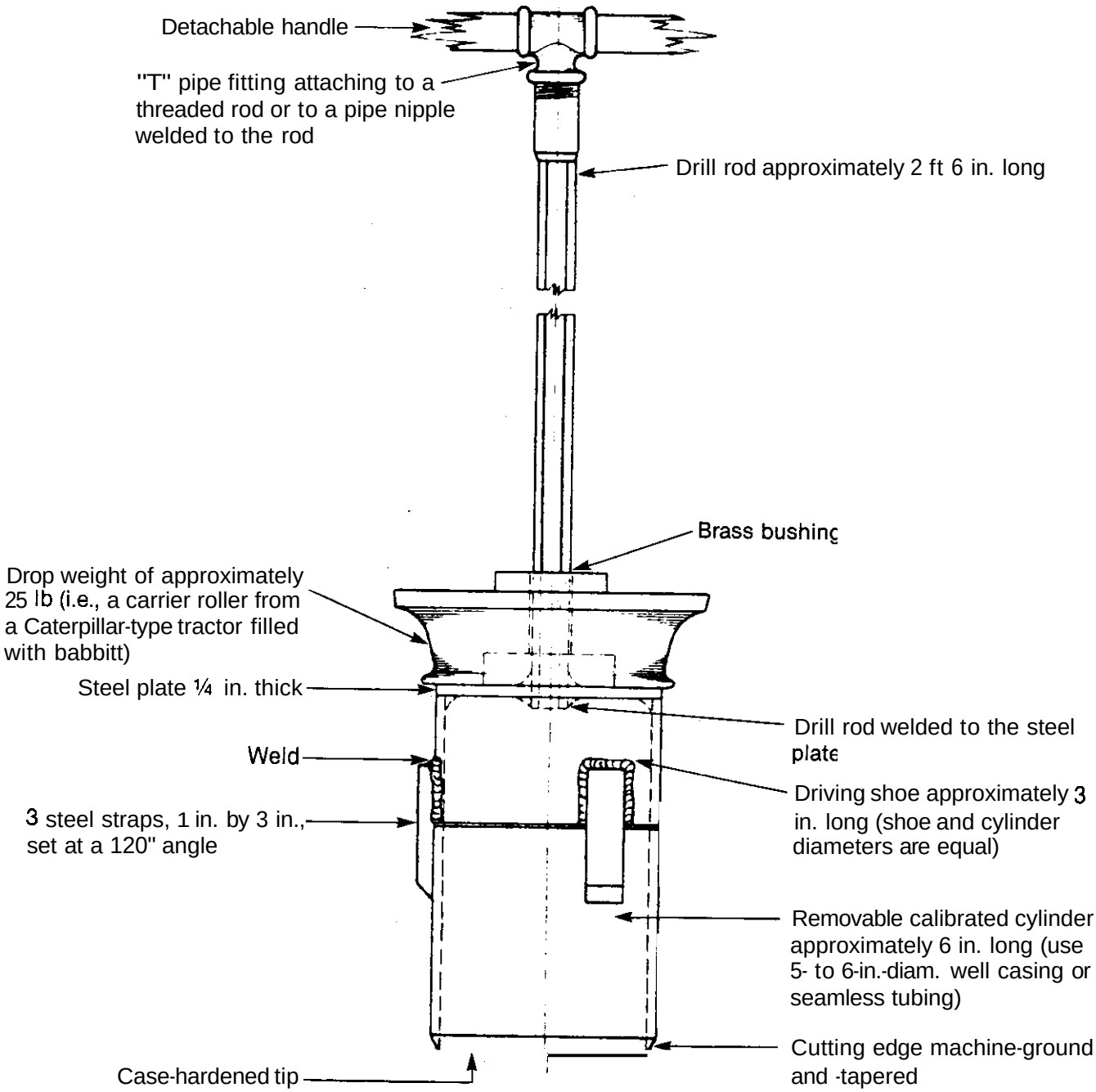


Figure 3-20.—An example of a field-assembled, calibrated, cylinder devise that is used in conjunction with ASTM D-2937 in testing the density of earth fills. The Calibrated cylinder is to be machined to a constant length and diameter with sufficient accuracy to provide volume measurements to ± 0.0004 ft^3. The driving shoe must have the same diameter as the cylinder. All other parts of the dense can be of any size that provides adequate strength and smooth operation.

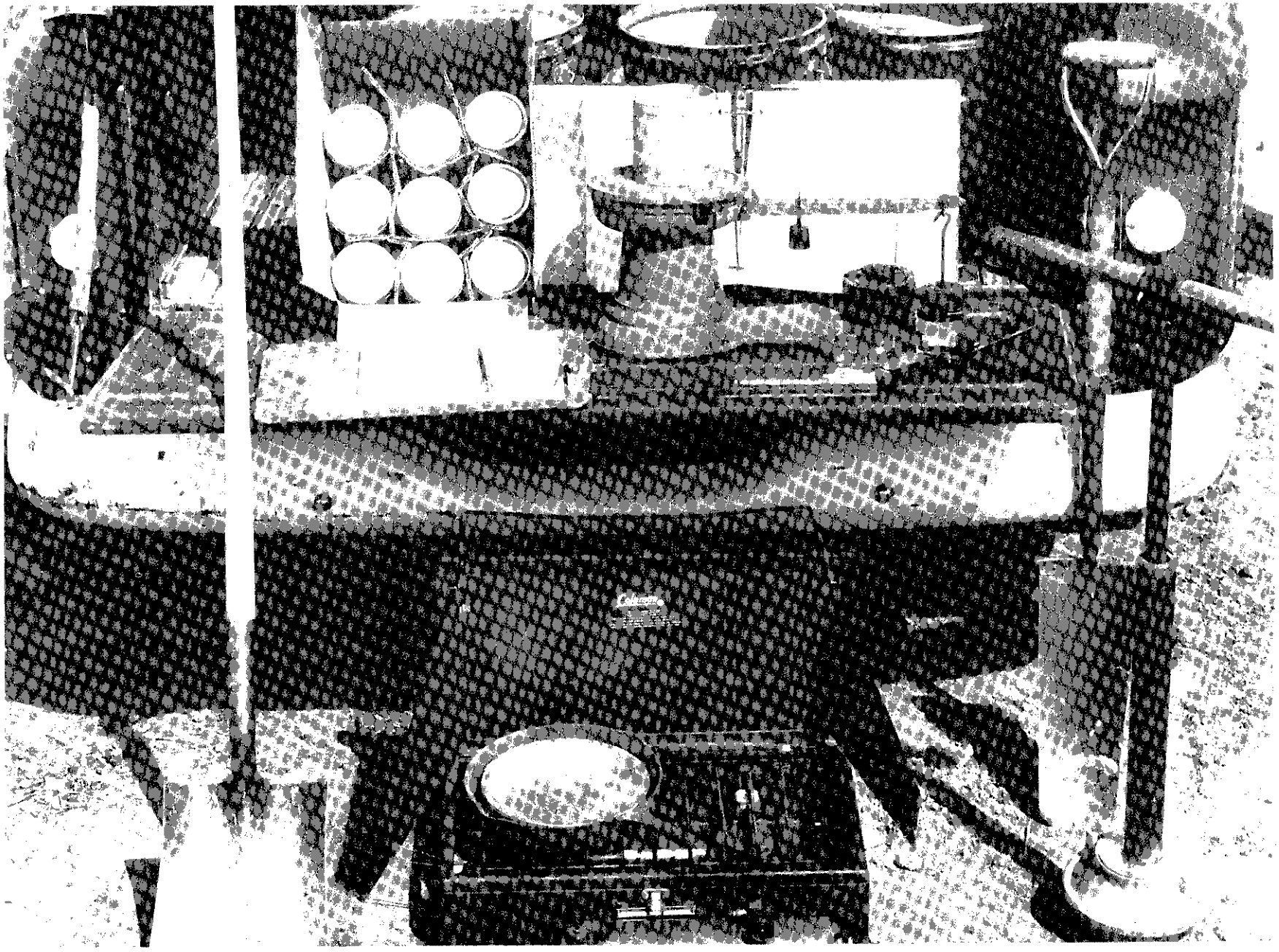


Figure 3–21.—Equipment used in calibrating the cylinder,

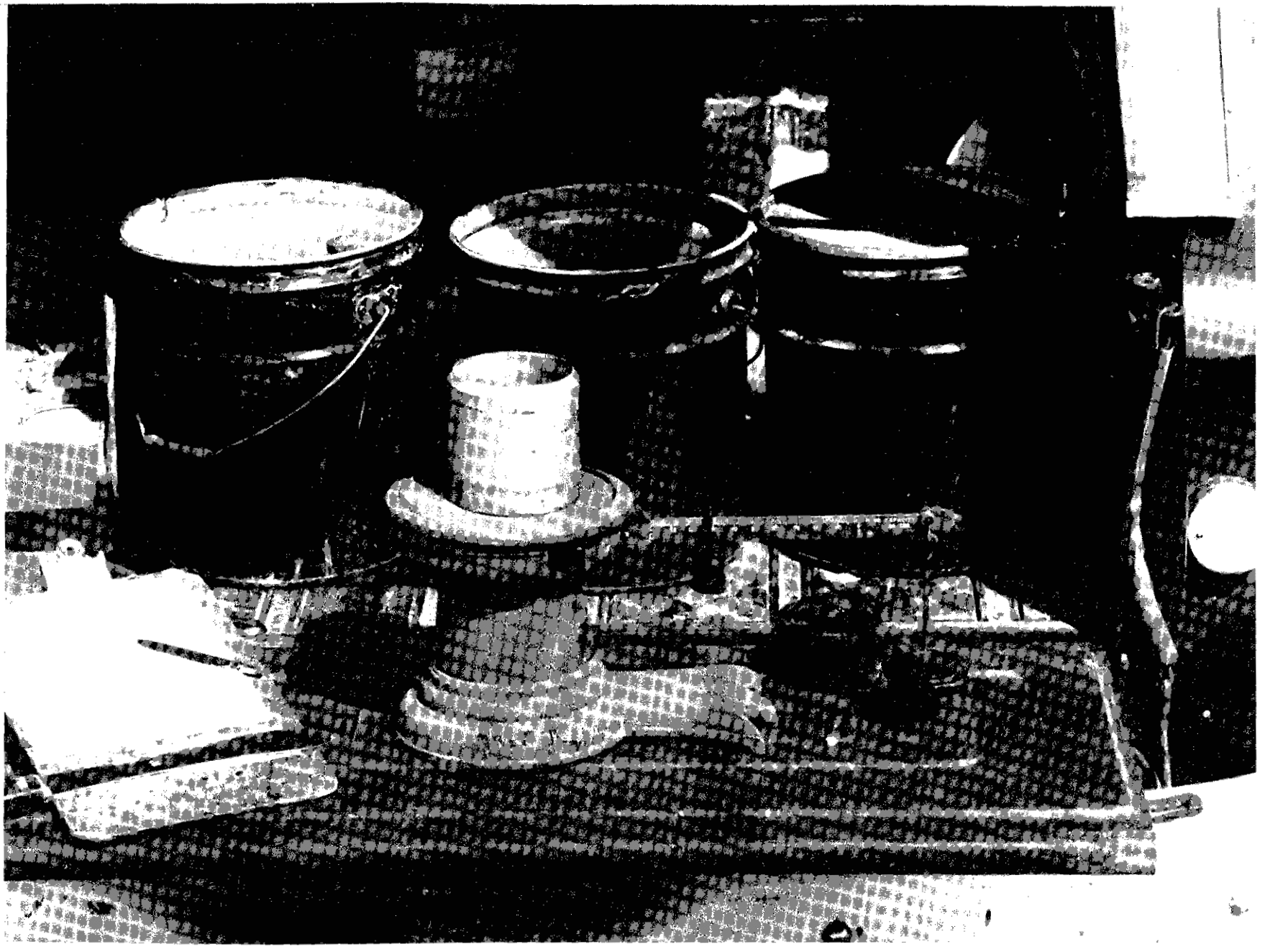


Figure 3-22.—Weighing the empty calibrated cylinder (photos are of field simulations).

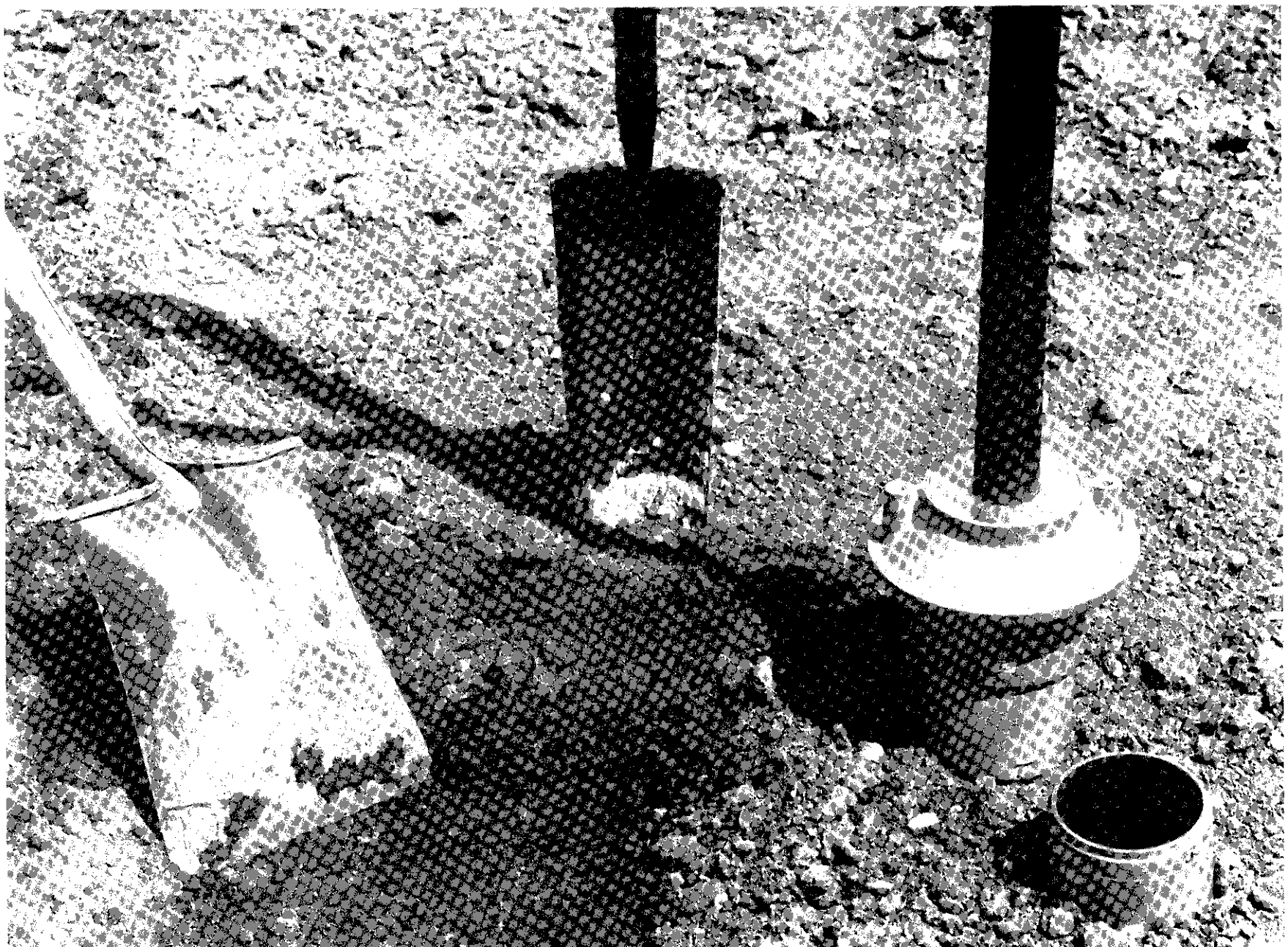


Figure 3-23.—Preparing the surface of the embankment before making the test.

Figure 3–24.—Driving the cylinder into the embankment (photos are of field simulations).

Figure 3-25.—Removing the material from around the cylinder

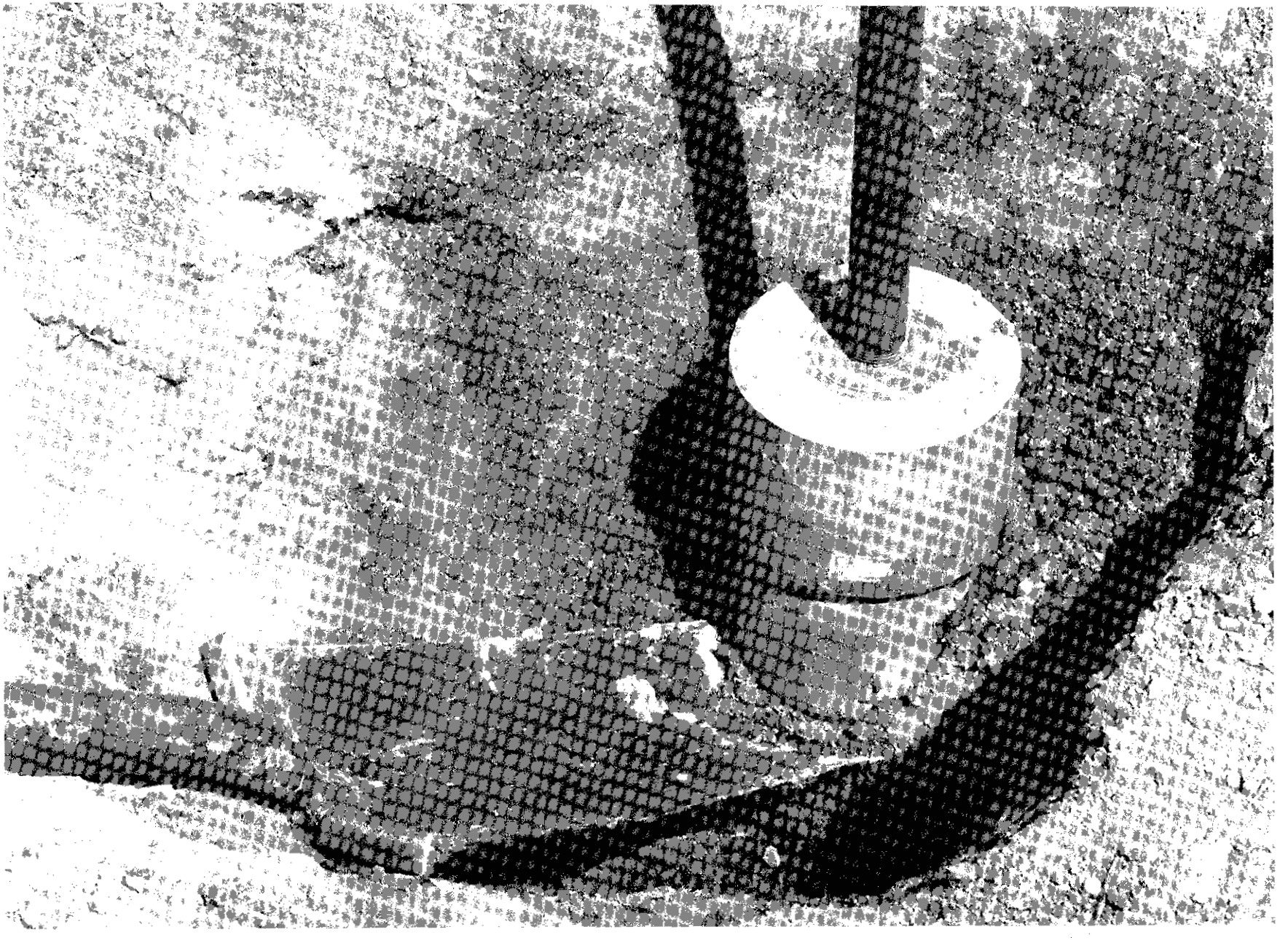


Figure 3–26.—Separating the sample from underlying material (photos are of field simulations).

Figure 3-27.—Trimming the excess material at the cylinder ends.

Figure 3-28.—Weighing the cylinder and compacted soil sample (photos are of field simulations).

INPLACE MOISTURE-DENSITY DETERMINATION: CALIBRATED CYLINDER METHOD

Fine-Grained Soils—Less Than 5% +No. 4 Sieve

Location FRENCH TOWN, USA Site No 3

Watershed BEAVER Creek Subwatershed Middle Fork

Contract No 12-ID-400-150 Contractor Reed Construction Company

Tested by G. Hicks Computed by G Hicks Checked by H. Black

Test NO.	Date	station	℄ offset	Elevation	Borrow source, location, and depth	Material classification
11	4-10-69	2+80	R+ 15 ft	2,416.0		

Test NO.	Date	Specification requirements (%)		Test results (%)		Curve No.	Wet density check	
		Moisture range	Compaction	Moisture	Compaction		1-Point	Curve
11	4-10-69	-3+1 (14+18)	95	17.4	96.4	4	111.5	108.0

Remarks Appears there is a change in texture in borrow materials — need to develop a new moisture-density curve to verify optimum moisture and density.

Figure 3-29.—Form SCS-ENG-530E, "Inplace Moisture-Density Determination: Calibrated Cylinder Method, Fine-Grained Sails—Less Than 5% +No. 4 Sieve."

Volume Determination		Test No.			
		11			
1. Volume of cylinder (volume of hole)	ft^3	0.224			
Moisture Determination					
Speedy moisture meter					
2 Dial reading					
3 Moisture content (calibration curve)	(%)				
Sample tested using: quick dry ☑ alcohol ☐ oven ☐		Container No			
		4			
4. Weight of moist sample plus container	lb	2.77			
5. Weight of dry sample plus container	lb	2.56			
6. Weight of moisture = (4) – (5)	lb	0.21			
7. Weight of container	lb	1.39			
8. Weight of dry sample = (5) – (7)	lb	1.17			
9. Moisture content = ((6) ÷ (8)) 100	(%)	17.95			
10. Correction for ignition	(%)	-0.60			
11. **Corrected moisture content** = (9) – (10)	(%)	17.35			

Density Determination					
12. Weight of moist sample Plus cylinder	lb	31.15			
13. Weight of cylinder	lb	6.12			
14. Weight of moist sample = (12) – (13)	lb	25.03			
15. Weight of dry sample = [(14) ÷ (100 + (11))] 100	lb	21.33			
16. Fill dry density = (15) ÷ (1)	lb/ft^3	95.2			
17. Maximum dry density	lb/ft^3	98.8			
18. Ratio[1] = ((16) ÷ (17)) 100	(%)	96.4			

[1] Ratio of fill dry density to maximum dry density.

Indicate Weight and Volume Units Used in Test

Figure 3–29 (cont).—Form SCS-ENG-530E; reverse **side.**

INPLACE MOISTURE-DENSITY DETERMINATION: KEROSENE METHOD

Fine-Grained Soils—Less Than 5% +No. 4 Sieve

Location Stump Lake U.S.A Site No. U-1

Watershed Unitu #1 Subwatershed —

Contract No. 12-10.L02-43 Contractor Strong Construction Company

Tested by R. White Computed by R. White Checked by E. Fox

Test No.	Date	Location of test			Borrow source, location, and depth	Material classification
		Station	℄ offset	Elevation		
9	4-21-69	7+25	4+25 ft	7,063.0	Borrow area #3 8-12 ft	ML

Test No.	Date	Specification requirements (%)		Test results (%)		Curve No.	Wet density check	
		Moisture range	Compaction	Moisture	Compaction		1-Point	Curve
9	4-21-69	±2% (18-22)	95	19.3	15.0	2	115.5	114.0

Remarks More Compaction Required
Later - moisture Content by oven indicates 1% error in calibration Curve for Speedy Meter

Figure 3-30.—Form SCS-ENG-530F, "Inplace Moisture-Density Determination: Kerosene Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve."

Moisture determination	Test No.			
	9			
Speedy moisture meter				
1. Dial reading _____	lb.b			
2. Moisture content Icalibration curve) _____ (%)	19.3			

Sample tested using: quick dry ☐ alcohol ☐ oven ☑	Container No.			
		13		
_____ (g)		359.62		
_____ (g)		302.24		
_____ (g)		57.38		
_____ (g)		27.30		
_____ (g)		274.94		
_____ (%)		20.87		
_____ (%)		—		
_____ (%)	19.3	20.87		

Density Determination				
11. Weight of moist sample _____ (g)	469.6			
12. Volume of moist sample (displacement) _____ (cm^3)	256.0			
13. Wet density of sample = (11) ÷ (12) _____ (g/cm^3)	1.83	1.83		
14. Fill dry density = [(13) ÷ (100 + (10))] 100 x 62.4 _____ (lb/ft^3)	95.7	94.5		
15. Maximum dry density (predetermined) _____ (lb/ft^3)	100.7	100.7		
16. Ratio[1] = ((14) ÷ (15)) 100 _____ (%)	95.0	93.8		

[1]Ratio of fill dry density to maximum dry density.

Figure 3-30 (cont).—Form SCS-ENG-530F; reverse side.

Precautions.—The valve on the sand cone must operate freely and have no constrictions that will affect the flow rate and cause erratic results.

The test operation must be free from vibration or jarring, because these movements will affect the density of the sand and cause erratic results. It is helpful to anchor the base plate with spikes or pins.

The test sand must be *dry* and uniformly graded. The salvage of test sand is not recommended because of contamination.

Rubber **Balloon** Method — Test **No. S–3**

Procedures for determining the density of inplace soil are in ASTM D–2167, "Standard Test Method for Density of Soil in Place by the Rubber-Balloon Method." Some procedures are shown in figures 3–16 to 3–18. Form SCS-ENG-530D, "Inplace Moisture-Density Determination: Rubber Balloon Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve," is used for recording the data (fig. 3–19).

Calibrated Cylinder Method — Test **No. S–4**

Procedures for determining the density of inplace soil are in ASTM D–2937, "Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method." Some procedures and equipment are shown in figures 3–20 to 3–28. Form SCS-ENG-530E, "Inplace Moisture-Density Determination: Calibrated Cylinder Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve," is used for recording data (fig. 3–29).

Kerosene Method — Test **No. S–5**

This test determines inplace soil densities on undisturbed samples of the compacted earthfill. Because of the test procedures, this method has certain limitations: fill materials must be taken from a fine-grain soil that forms a solid, dense mass when compacted, and materials must be free of large stone and gravel fragments.

Apparatus.—The following equipment is used

- Balance; 500- to 1,000-g capacity, accurate to 0.1 percent.
- Pan or similar container; approximately 6 in. across by 6 in. deep.
- Siphon can with overflow tube outletting at about 2/3 capacity of the unit (see fig. 3–14, part a).
- Graduate; minimum 500-cm^3 capacity.
- Kerosene; stored in container that protects from contamination and fire.
- Tile spade, chisel, knife, and sealed cans for removing and transporting test samples.
- Equipment for drying samples.

Test procedures and recording data.—Care is needed when taking and handling a sample for a density test to avoid cracking the sample or increasing its density. The sample is usually obtained by removing the loose surface material from the test area and excavating around a 4- to 6-in. column of compacted earth to about 6 in. deep. Then the column is carefully cut off near the base of the excavation, the material immediately placed in an airtight container to prevent moisture loss, and the sample moved to a field laboratory as soon as possible.

Form SCS-ENG-530F, "Inplace Moisture-Density Determination: Kerosene Method, Fine-Grained Soils—Less Than 5% +No. 4 Sieve," is used for recording data (fig. 3–30). The sample is divided into two portions, one of 200 g or more for the moisture test and the other trimmed to slightly less than 500 cm^3 in volume for the density determination.

Moisture can be determined by using tests S–11, S–12, S–13, or S–14 (all in this chapter). Moisture data are recorded under items 1–10 of SCS-ENG-530F. If a quick-dry procedure is used, it should be verified occasionally by drying the material in the oven.

The sample for the density determination must be handled carefully. All loose particles and protrusions are trimmed off. The sample is then weighed immediately to avoid moisture loss and the weight is recorded in item **11.**

Next the sample is submerged in a pan of kerosene. A good procedure is to gently lower the sample in a sling or net made of a strong thread into the pan. The sample should stay submerged until air bubbles cease to escape from voids. Then a siphon can is filled to the overflow level with kerosene. When the liquid ceases to drip from the overflow, a clean 500-cm^3 graduate is placed under the spout. The sample is removed from the pan of kerosene, gently blotted with a *dry* cloth to remove the excess fluid, and, using a thread sling, lowered carefully into the siphon can. After the flow ceases

from the overflow spout, the volume of kerosene in the graduate is read and recorded as the volume of the wet sample, item **12.**

The inplace dry density, item **14,** is determined by dividing the wet density of the sample, item **13,** by the percent of moisture, items **2** or **10,** and then multiplying by **62.4** (weight per cubic foot of water) to convert to pounds per cubic foot. The maximum dry density, item 15, is the maximum unit weight determined for the embankment material by ASTM **D–698** or D–1557. The percent moisture, items **2** or 10, and the percent of maximum *dry* density, item **16,** are recorded on the front of the form.

Rapid Compaction Control Method "Test No. *S–6*"

This method is particularly applicable to borrow materials that contain less than **30** percent rock greater than the specified control size and consist of variable soils or zones of differing grain size. Even though the excavation of these materials is carefully controlled to ensure mixing, the moisture requirements and resultant density can vary appreciably. When they vary, moisture-density curves prepared in the laboratory, or infrequently in the field, may be erroneous as indexes or standards for the borrow materials being used. The "rapid method"[6] quickly provides the standard needed to judge the specific compacted fill.

Studies of compacted cohesive soils show that the ratio of the fill *dry* density to the laboratory maximum dry density and a very close approximation of the difference between the optimum moisture content and fill moisture content of a field density sample can be determined without knowing the moisture content of the fill material. These studies also show that by compacting a series of specimens and plotting the amount of water added to or removed from the sample as a percentage of the wet weight of the sample, a curve of the wet densities can be established. This curve can be converted to wet density on a fill-moisture-content basis. Then the percentage of the fill *dry* density to the laboratory maximum *dry* density can be obtained. This method does not require drying the soil sample, so the most time-consuming part of a moisture-density determination is eliminated.

[6] *The "rapid method" was developed by the Bureau of Reclamation. Presentation and discussion are in the Earth Manual (Bur. Reclam., U.S. Dep. Inter.).*

Nomenclature and definitions.—The following svmbols are used in the procedures and computations:

C	=	Ratio of fill wet density to cylinder wet density.
D	=	Ratio of fill dry density to specified maximum dry density.
w	=	Moisture content; percent.
w_f	=	Fill moisture content; percent.
w_o	=	Optimum moisture content; percent.
y_m	=	Ordinate at peak point of $\gamma_d(1 + w_f)$ versus z curve.
z	=	Amount of water added to or dried from sample; percent of fill wet weight.
z_m	=	Abscissa of peak point of $\gamma_d(1 + w_f)$ versus z curve.
z_1, z_2	=	Abscissas of points used in plotting $\gamma_d(1 + w_f)$ versus z curve.
γ_{d_c}	=	Cylinder *dry* density.
γ_{d_f}	=	Fill dry density.
γ_{d_m}	=	Specified maximum dry density.
γ_{d_1}, d_2, d_3, etc.	=	Dry densities at points **1, 2, 3,** etc., or $\gamma_d(1 + w_f)$ versus z curve.
γ_{w_c}	=	Cylinder wet density.
γ_{w_f}	=	**Fill** wet density

Principles and equations.—The procedure shown is for a field density test made on soil containing no gravel. The test on soils with gravel is similar, except that screening is required and computations are necessary to obtain the fill wet density of the fraction passing a No. **4** sieve. Materials taken from the test hole are protected against evaporation and are compacted by a standard method while at the fill moisture content, w_f, to what is called the cylinder wet density, γ_{w_c}.

The value of C, the ratio of the fill wet density, γ_{w_f}, to the cylinder wet density, γ_{w_c}, is identical with the value of the ratio of their dry densities,

since both wet densities are at the same water content:

$$C = \frac{\gamma_{w_f}}{\gamma_{w_c}} = \frac{\gamma_{d_f}(1 + w_f)}{\gamma_{d_c}(1 + w_f)} = \frac{\gamma_{d_f}}{\gamma_{d_c}} \qquad \textbf{(3–1)}$$

The value of C indicates the relation between the compactive effort used on the fill and the specified compactive effort.

The value of D, the ratio of the fill dry density, γ_{d_f}, to the laboratory maximum *dry* density (the basis of density control), γ_{d_m}, can be obtained from the wet densities in a similar manner:

$$D = \frac{\gamma_{d_f}(1 + w_f)}{\gamma_{d_m}(1 + w_f)} = \frac{\gamma_{d_f}}{\gamma_{d_m}} \qquad \textbf{(3–2)}$$

if the value $\gamma_{d_m}(1 + w_f)$ is found. The "rapid method" is used to obtain the value $\gamma_{d_m}(1 + w_f)$.

For example, a sample of soil is taken from a fill with a moisture content, w_f, somewhat less than optimum, and compacted in a cylinder in the specified manner (ASTM D–698 or **D–1557).** If the resulting cylinder *dry* density, γ_{d_c}, is designated, the cylinder wet density will be $\gamma_{d_c}(1 + w_f)$.

Note: High plasticity clays must have a moisture content lower than optimum at the start of the test, because screening (if necessary) and uniform drying of these soils are difficult and time consuming.

The cylinder wet density, γ_{w_c}, can be readily obtained for any fill moisture content, w_f, by a compaction test. This point should be the origin of new curves obtained by translating the origin of abscissas to the fill moisture content. The amount of water added to the soil, z (in percent of fill wet weight), is used for the abscissa of the new curves. This change in origin is equivalent to considering that the moist soil removed from the fill is dry; that is, the water associated with the soil at fill moisture content is treated as solid material. Values of z are then percentages of that dry weight.

By adding water to samples of the moist soil (all samples are at fill moisture content to start with) and by mixing and compacting samples in the usual manner, a wet density versus z curve is obtained. Ordinate values of this curve are the same as the values of the wet density curve. However, the abscissas are values of z rather than of w. The analogy between the standard compaction wet density curve and the new curve can be completed by drawing the converted wet density curve. This is done by dividing each ordinate of the upper curve by $(1 + z)$. The resulting curve is similar in shape to the dry density curve. Ordinate values of the converted wet density curve equal the *dry* density multiplied by the expression $(1 + w_f)$. Basic or standard compaction curves cannot be drawn unless the values of the moisture content are determined, whereas new curves presented in this procedure are compaction curves and can be drawn without knowing values of the water content.

Values of z presented here are ratios of pounds of water added to pounds of moist soil removed from the fill and are known. Hence, the value of D, the ratio of the fill *dry* density to the specified maximum *dry* density, can be obtained precisely from wet densities alone by finding the peak point of the $\gamma_d(1 + w_f)$ curve. This curve is obtained by plotting points:

$$\gamma_{d_1}(1 + w_f),\ \frac{\gamma_{d_2}(1 + w_2)}{1 + z_2},\ \frac{\gamma_{d_3}(1 + w_3)}{1 + z_3} \text{ etc.}$$

The value $z = (w - w_f) \div (1 + w_f)$ can be negative as well as positive.

The determination of the maximum ordinate of the $\gamma_d(1 + w_f)$ versus z curve presents the same problem encountered in finding the maximum *dry* density in a dry density versus moisture content curve. Generally, the more points that are plotted the more accurate is the determination of the peak point of the converted wet density curve. At least three points are needed. If they are spaced so that the point of maximum ordinate falls within the range of their abscissas, the maximum ordinate can be determined graphically. This is done by assuming that the portion of the $\gamma_d(1 + w_f)$ versus z curve in the vicinity of the maximum point is a parabola whose axis is parallel to the $\gamma_d(1 + w_f)$ coordinate axis. Use of the parabolic method is not essential to the rapid method, but it does help reduce the number of points needed and provide a value for the peak point without sketching the curve.

Use **of** parabola.—Figure **3–31** shows the graphical solution for obtaining z_m and γ_m, the vertex of the parabola (shown as letter 0).

To obtain D more simply, the coordinate sheet on which the curve is plotted has a series of diagonal lines which allow graphical division of the wet density by the quantity, $(1 + z)$. This allows coordinate points z and $\gamma_d(1 + w_f)$ to be plotted without using a slide rule or a calculating machine. Once the maximum ordinate, $\gamma_{d_m}(1 + w_f)$, is obtained, the value of D, the ratio of the fill dry density to the specified maximum *dry* density, can be obtained graphically by using the diagonal lines (fig. **3–31).**

Moisture and density calculations.—The location of the peak point of the $\gamma_d(1 + w_f)$ versus z curve shows whether the soil is at the optimum moisture content, w_o, or is less or greater than optimum. However, the exact magnitude of the difference between the optimum moisture content and fill moisture content *is* unknown. Therefore, the following calculations are needed

$$w_o - w_f = z_m (1 + w_f) \qquad \textbf{(3-3)}$$

When z_m equals 0, the quantity w_o minus w_f equals 0 for any value of w_f. For values of z_m other than 0, the magnitude of w_f is needed to obtain the quantity w_o minus w_f. It can also be shown that:

$$1 + w_f = \frac{1 + w_o}{1 + z_m} \qquad \textbf{(3-4)}$$

Another expression for the difference between optimum and fill moisture contents is obtained by combining equations (3-3) and (3-4):

$$\qquad \textbf{(3-5)}$$

Since neither w_o nor w_f is known, it is necessary in (3-3) and (3-5) to use a trial value for either w_o or w_f to obtain the value of $w_o - w_f$. If the trial value is inaccurate, a very small error will be reflected in the value of $w_o - w_f$. For example, in equation (3-5) if z_m equals 0.02, an error of **0.05** in estimating w_o is reduced to: (0.02 ÷ **1.02)** 0.05 = **0.00098,** for $w_o - w_f$. This small an error is acceptable for control purposes.

To avoid the need for estimating either w_o or w_f for each density test, a set of curves has been prepared to use in automatically estimating w_o for the coordinates of the peak point of the converted wet density curve.' These lines show the correction value to be added to z_m to give $w_o - w_f$. The correction value (to the nearest 0.1) shown by the curved line closest to the peak point of the converted wet density curve, coordinates z_m and y& **(1** + w_f), is added algebraically to z_m to give a value of $w_o - w_f$ that is sufficiently accurate for control purposes.

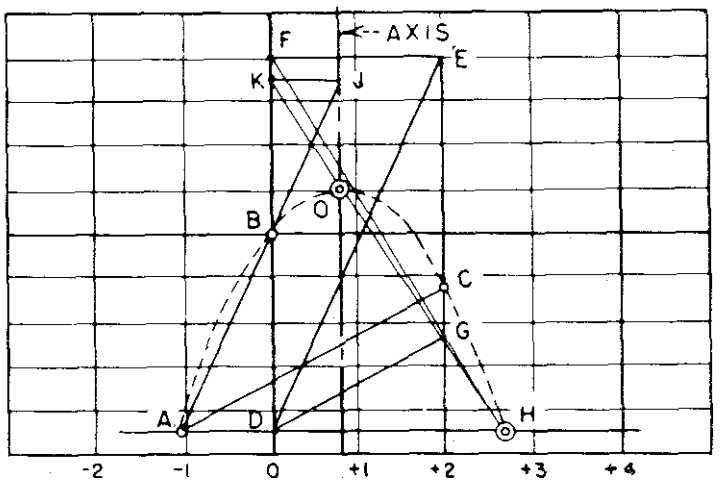
The density and moisture of the fraction passing a **No. 4** sieve are determined by tests **S–2, S–3, S–4,** or **S–5.** The value of D, the ratio of the fill *dry* density to the specified maximum dry density, and the value of $w_o - w_f$, in percent, is determined as follows:

- Obtain Point (1) by compacting the soil at the fill moisture content into a standard cylinder. Plot the resulting wet density as Point **(1)** on the **0** percent vertical line (interpolate if necessary) on Form **SCS-ENG-541,** "Rapid Method for Determining Density and Moisture, For **5.00** lb of Moist Soil" (fig. **3–32).'**
- Obtain Point (2) by adding 45 cm^3 (2 percent) water to 5.0 lb of soil at fill moisture content, mix and compact into a cylinder, and determine the wet density. From the point on the +2 percent diagonal line (interpolate if necessary) corresponding to this wet density, project vertically to the 0 percent diagonal line, thence horizontally to the +2 percent vertical line to plot Point (2). The ordinate of plotted Point (2) is the wet density divided by **1.02.**
- Obtain Point (3) by first noting whether Point (1) or Point (2) is greater in ordinate. If Point (2) is greater in ordinate, add 90 cm^3 **(4** percent) water to the **5.0** lb of soil at fill moisture content, mix and compact into a cylinder, and weigh. From the point on the +4 percent diagonal line corresponding to this wet density, project vertically to the 0 percent diagonal line, thence horizontally to the +4 percent vertical line to plot Point (3). The ordinate of the plotted Point (3) is the wet density divided by **1.04.**
- If Point (1) is greater in ordinate than Point (2), allow 5.0 lb of soil at fill moisture content to

'Form SCS-ENG-541 was *prepared from material developed by the Bureau of Reclamation, U.S. Department of Interior, except for a change in the procedure that reduces the size of the soil sample from 7.5 to 5.0 lb. Necessary changes in the procedural writeup were mode accordingly. Form SCS-ENG-541-A, for 7.5 pound sample, may be obtained from central supply.*

Parabola Method

Graphical solution for vertex, O, of a parabola whose axis is vertical, given three points A, B, and C If more than three points are available, use the three closest to optimum.



1. Draw horizontal base line through the left point, A, and draw vertical lines through points B and C.
2. Draw line DE parallel to AB, point E lies on the vertical line through point C; project E horizontally to establish point F on the vertical line through B.
3. Draw line DG parallel to AC, point G lies on the vertical line through point C.
4. Line FG intersects the base line at H. Axis of parabola bisects AH; draw the axis.
5. Intersection of line AB with the axis is at J; project J horizontally to K, which lies on the vertical line through point B.
6. Line KH intersects the axis at O, the vertex.

NOTE: If points A, B, and C are equally spaced harizantally (this is true when 2 points are obtained by adding water or when soil is dried exactly 2 percent) steps 2 and 3 above are eliminated. Point F coincides with point 6 and point G is halfway between the base line and point C. Hence, point H is obtained by drawing BG and point O is obtained by steps 5 and 6 as usual. See graph below.

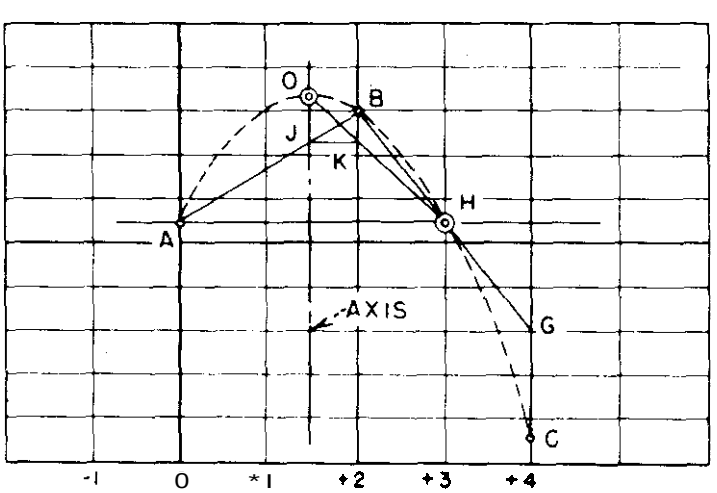
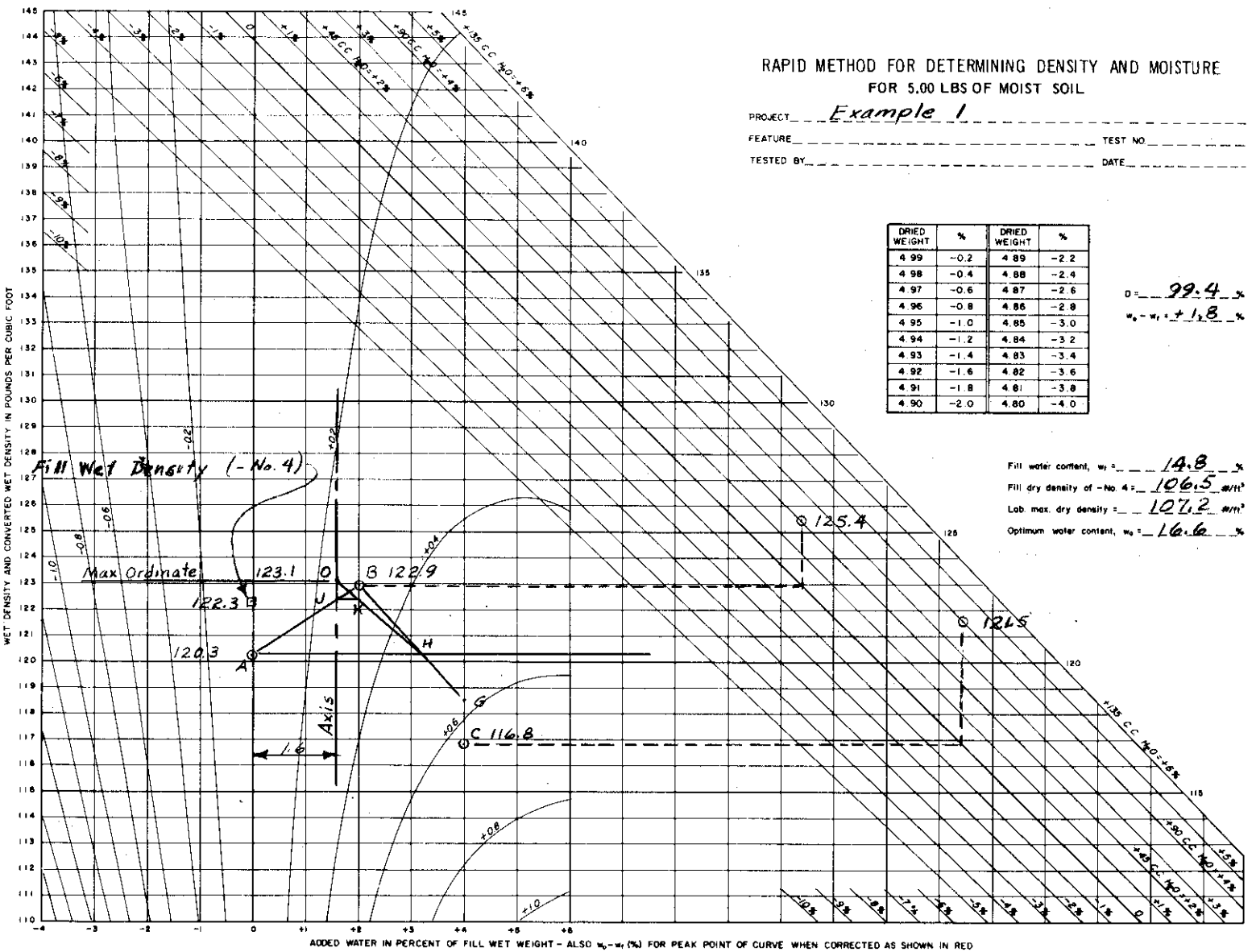


Figure 3-31.—Graphical **solution** for obtaining **peak** point of parabola.

U.S. Department of Agriculture
Soil Conservation Service

SCS-ENG-541 (Rev. 3-81)

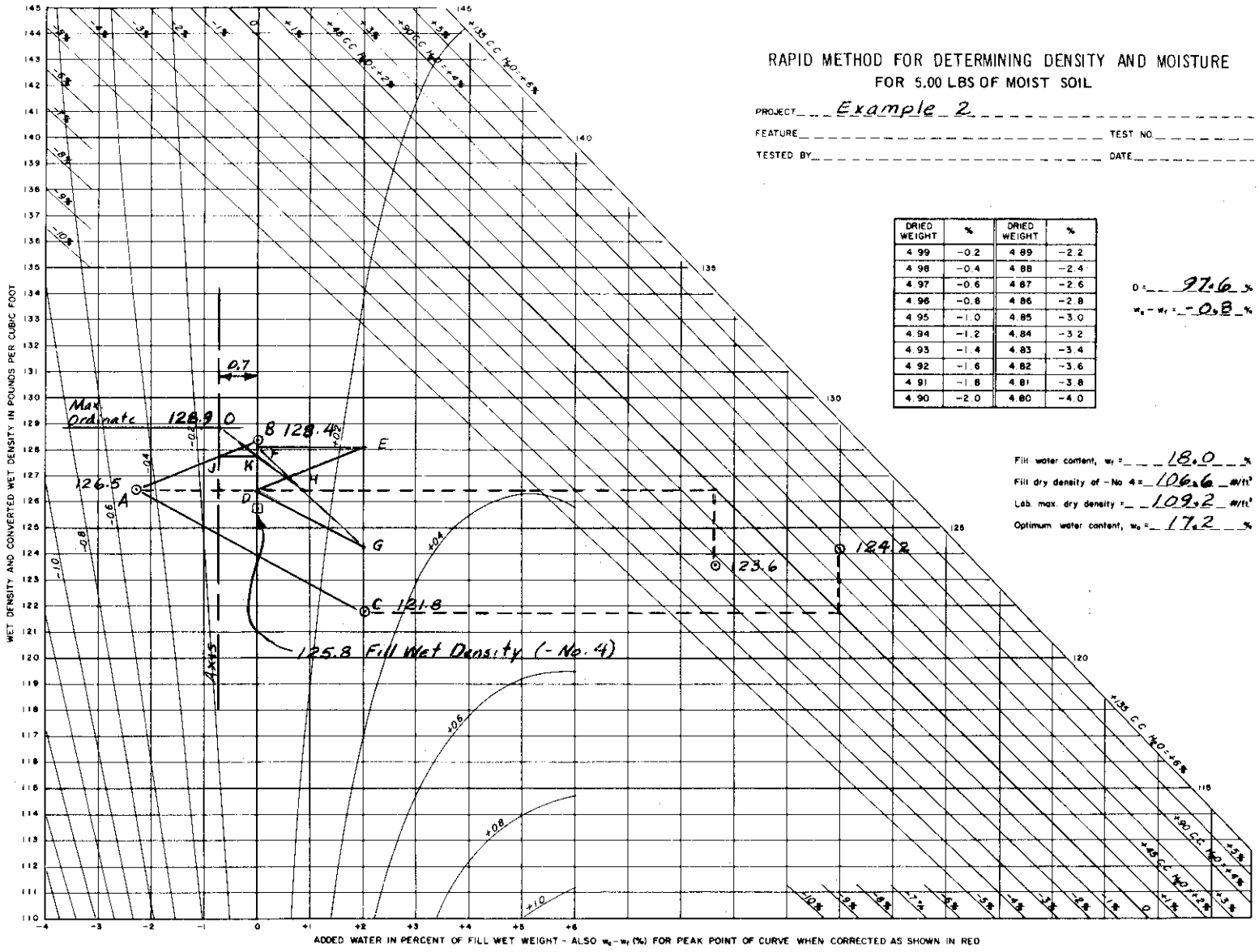


DRIED WEIGHT	%	DRIED WEIGHT	%
4.99	−0.2	4.89	−2.2
4.98	−0.4	4.88	−2.4
4.97	−0.6	4.87	−2.6
4.96	−0.8	4.86	−2.8
4.95	−1.0	4.85	−3.0
4.94	−1.2	4.84	−3.2
4.93	−1.4	4.83	−3.4
4.92	−1.6	4.82	−3.6
4.91	−1.8	4.81	−3.8
4.90	−2.0	4.80	−4.0

Figure 3–32.—Form SCS-ENG-541, "Rapid Method for Determining Density and Moisture, For 5.00 lb of Moist Soil." In this example the fill moisture content is less than optimum.

U.S. Department of Agriculture
Soil Conservation Service

SCS–ENG–541 **(Rev.** 3-81)



DRIED WEIGHT	%	DRIED WEIGHT	%
4.99	−0.2	4.89	−2.2
4.98	−0.4	4.88	−2.4
4.97	−0.6	4.87	−2.6
4.96	−0.8	4.86	−2.8
4.95	−1.0	4.85	−3.0
4.94	−1.2	4.84	−3.2
4.93	−1.4	4.83	−3.4
4.92	−1.6	4.82	−3.6
4.91	−1.8	4.81	−3.8
4.90	−2.0	4.80	−4.0

Figure 3-33.—Form SCS-ENG-541. In this example the fill moisture content is greater than optimum.

dry without any soil loss and weigh the soil. Use the table on the right-hand portion of SCS-**ENG-541** (fig. **3–32)** to determine the percentage of water loss corresponding to the dried weight. Then compact the dried soil into a cylinder and weigh. At the point on the diagonal line (interpolate if necessary) corresponding to the wet density, project vertically to the 0 percent diagonal line, thence horizontally to the vertical line corresponding to the percentage of water loss to plot Point **(3).** The ordinate of the plotted Point **(3)** is the wet density divided by **1** plus the negative percentage, that is **1 + (–0.02) = 0.98.**

Three plotted points are sufficient if both the left and right points are lower in ordinate than the center point; if not, a fourth point is necessary. First, the point of maximum ordinate of the curve is determined by the parabola method (or by sketching the curve if the number and locations of the points permit accuracy without the parabola method). Then the fill wet density of the soil fraction passing a No. **4** sieve is plotted on the 0 percent vertical line. The density and moisture are determined as follows:

- Obtain D by projecting the maximum ordinate horizontally to the 0 percent diagonal line, thence vertically to the value of the fill wet density. D equals **100** percent plus the interpolated percentage represented by the diagonal lines, taking minus signs into account. D is the fill wet density divided by the maximum ordinate of the curve.

The value, $w_o - w_f$, is the abscissa of the point of maximum ordinate and is corrected by adding the value shown on the curved (red) line on the chart nearest to the peak point, interpolating where necessary and taking minus signs into account.

Completion of test for record purposes.—A sample of the soil fraction passing a No. ***4*** sieve is dried to a constant weight in an oven at approximately **110°C (230°F)** to obtain fill moisture content, w_f. Optimum moisture content, w_o, is determined as follows:

$$\text{Fill dry density of –No. 4} = \frac{\text{Fill wet density of –No. 4}}{(1 + w_f)}$$

$$\text{Specified maximum dry density} = \frac{\text{Maximum ordinate}}{(1 + w_f)}.$$

$$\text{Optimum moisture content} = w_f + (1 + w_f)\, z_m$$

Example **1.**— Figure **3–32** is an example in which the fill moisture content is less than optimum. The test data are:

Fill wet density = **126.6** lb/ft³

Point	Wet density (lb/ft³)	z (percent)	Converted wet density (lb/ft³)
1	**120.3**	**0.0**	**120.3**
2	**125.4**	**2.0**	**122.9**
3	**121.5**	**4.0**	**116.8**
0'	**—**	**1.6**	**123.1**

'By the parabola method.

then

$$D = \left(\frac{126.6}{123.1}\right) 100 = 102.8\%$$

$$w_o - w_f = +1.6 + 0.2 = +1.8\% \text{ (dry of optimum)}$$

These values are sufficiently accurate to accept or reject the compacted fill if it is not within the specified limits.

After the fill moisture content has been determined by drying a sample to a constant weight at **110°C,** the field density is completed for record purposes as follows:

$$w_f = 14.8\%$$

$$\gamma_{d_f} = \frac{126.6}{1.148} = 110.3 \text{ lb/ft}^3$$

$$\gamma_{d_m} = \frac{123.1}{1.148} = 107.2 \text{ lb/ft}^3$$

$$w_o = 0.148 + 1.148\,(0.016) = 0.166 \text{ or } 16.6\%$$

Note: In this example, the fill *dry* density, γ_{d_f}, considerably exceeds **95** percent of the maximum dry density, γ_{d_m}. In such a situation, it is advisable to tell the contractor he is overcompacting the

material and to determine if the greater density adversely affects the quality of the fill.

Example 2.—Figure 3–33 is an example in which the fill moisture content is greater than optimum. The test data are:

Fill wet density = **125.8** lb/ft³

Point	Wet density (lb/ft³)	z (percent)	Converted wet density (lb/ft³)
1	**128.4**	**0**	**128.4**
2	**124.2**	**2**	**121.8**
3	**123.6**	**−2.3**	**126.5**
0'	**—**	**−0.7**	**128.9**

'By the parabola method.

then

$$D = \left(\frac{125.8}{128.9}\right) 100 = 97.6\%$$

$$w_o - w_f = -0.7 + (-0.1) = -0.8\% \text{ (wet of optimum)}$$

These values are sufficiently accurate to accept or reject the compacted fill if they are not within the specified limits.

After the fill moisture content has been determined by drying a sample to a constant weight at 110°C, the field density test is completed for record purposes as follows:

$$w_f = 18.0\%$$

$$\gamma_{d_f} = \frac{125.8}{1.18} = 106.6 \text{ lb/ft}^3$$

$$\gamma_{d_m} = \frac{128.9}{1.18} = 109.2 \text{ lb/ft}^3$$

$$w_o = 0.18 + (1.18 \times -0.007) = 0.172 \text{ or } 17.2\%$$

Sand displacement.—This method is used to test embankment materials when less than **30** percent of the particle sizes are larger than the specified control size. The diameter of the sand cone must be adequate for the maximum size of rock in the fill material, and the sieve size must meet contract specifications for separating fines.

Form SCS-ENG-530G, "Inplace Moisture-Density Determination: Rapid Compaction Method—Sand Displacement," is used for recording data (fig. **3–34),** Form SCS-ENG-541 must also be completed (fig. **3–32** and **3–33);** one side of this form is for low-density soils.

ASTM D–1556 procedures (test S–2) are used to determine the bulk density of the sand and the volume of the sample from the excavated hole. Volume determinations are entered in items **1–7** of Form **SCS-ENG-53OG.**

Density determinations are entered in items **8–23** of SCS-ENG-530G. The moist weight of the separated fines and rock contained in the sample is determined by weighing the total sample and the separates. These data are entered in items **8–14.** Procedures for separating plastic fines from the rock are in test S–2. The wet density of the rock, item **15,** can be determined by measuring the water displacement after the rock is placed in a full siphon can or graduated cylinder or by weighing the rock in air and in water (see tests **S–2** and **S–15).** When the wet density of the rock is known the volume and density of the separated fines and rock can be determined. These data are entered in items **16–19.**

Before finding D, item **20,** compaction tests are needed to determine the maximum *dry* density. This requires at least three cylinders (procedures are described in test S–8): one of a field sample at field moisture content and two of the same material with water added or removed then compacted to provide three densities that plot *so* that the left and right points are below the midpoint. Compaction of the fines has to meet contract specifications and procedures in tests **S–8 or S–9.**

The data to determine the wet densities of the different cylinders are entered in items **24–28.** Wet densities, item **28,** are plotted on Form SCS-**ENG-541,** labeling each point **A,** B, C, and showing the wet density and converted wet density (fig. **3–32** and **3–33).** Converted wet densities, item **29,** can be read directly from the plotted points on the chart or calculated by dividing the wet density, item **28,** by **100,** plus or minus the percent of water added to or removed from the fill moisture content in the original sample. After knowing values for three plotted points, **A,** B, and C, the maximum density for the fill sample is determined graphically by the parabola method (see test **S–6** and fig. **3–31).**

The value of D, item 20, the ratio of the fill dry density to the specified maximum *dry* density as determined by the parabola method, can be read directly from the plots on the chart, by projecting horizontally from the maximum ordinate 0 to the zero percent diagonal line, thence vertically to the value of the fill wet density **as** projected to these diagonal lines. D equals 100 percent plus the interpolated percentage of water represented by the diagonal lines on the chart, taking minus signs into account. D can be computed by dividing the fill wet density by the density represented by the maximum ordinate 0 of the parabola, then multiplying by 100.

The value, $w_0 - w_f$, item 21 (optimum moisture content minus the fill moisture content, in percent), is determined from the chart by taking the value of the abscissa of the point of maximum ordinate as referenced to the vertical zero moisture line, then adding the value shown on the nearest curved (red) line, interpolating where necessary and taking minus signs into account. It is not necessary to know the percentage of the fill moisture in or the maximum dry density of the embankment to control the work when the "rapid method" is used, since the relations of the fill dry density to the specified maximum *dry* density and of the fill moisture to the optimum moisture have been determined. However, for record purposes it is desirable to determine the fill moisture and maximum dry density and to record the values. They can be used to check the ratio of the fill dry density to maximum *dry* density and values used in the design.

The fill moisture content, item 22, is determined with an ovendry test on the fine fraction (procedures are described in test S–11). Moisture determinations are entered in items 30–36. After the fill moisture content has been determined, the fill dry density, maximum dry density, and optimum moisture content can be computed to complete the records.

The fill dry density, item 23, is calculated as shown on Form SCS-ENG-530G.

The maximum dry density is calculated as:

$$\text{Maximum dry density} = \frac{\text{Maximum ordinate 0}}{1 + \text{item 36}}$$

$$= \frac{123.1}{1 + 0.148} = 107.2$$

The optimum moisture content is calculated as:

$$\text{Optimum moisture content} = \text{item 36} + [(1 + \text{item 36}) (\text{abscissa of maximum ordinate})]$$

$$= 0.148 + [(1 + 0.148) (0.01611 = 16.6\%$$

After completing all entries of Form SCS-ENG-530G, attach Form SCS-ENG-541 (fig. 3–32 or 3–33) to complete the report.

Form SCS-ENG-541A has been developed for **7.5** lh of sample and the 6-in. compaction mold when the sample is based on the ¾ in. screen. Procedures are essentially the same except **1** percent moisture is 34 cm^3, 2 percent is 68 cm^3, etc.

Rubber balloon displacement.—This method can be used to test fine-grained fill materials that contain minor amounts of rock fractions retained on a No. 4 sieve. The equipment and procedures for determining the size of the hole must conform to ASTM D–2167 requirements and to precautions noted in test S–3.

Form SCS-ENG-530H, "Inplace Moisture-Density Determination: Rapid Compaction Method—Rubber Balloon Displacement, Fine-Grained Soils—Less Than 5% + No. 4 Sieve," is used for recording data (fig. 3–35). Procedures and calculations of individual items for density, compaction, and moisture content on this form are identical to Form SCS-ENG-530G (fig. 3–34), except that the density determination involves only the soil fraction passing a No. 4 sieve and no correction is made for minor amounts of the soil fraction retained on the sieve. If the fill material contains many oversize rocks, the sand cone method should be used. Complete items 1–24, then do the front of the form.

Template **and** Plastic Liner Method — Test **No.** S–7

This test is used to determine the density of material containing significant amounts of cobbles, gravels, or shale that exceed **4** in. in diameter (see earlier discussion in this chapter).

To determine the volume of the hole, a thin sheet of rubber or polyethylene is fitted in the excavated area, then filled with water. Normally it is difficult to maintain a smooth, uniform working surface at

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SCS-ENG-530G
2-80

INPLACE MOISTURE-DENSITY DETERMINATION: RAPID COMPACTION CONTROL METHOD-SAND DISPLACEMENT

Subwatershed Beaver

Test NO	Location of test				Borrow source, location, and depth	Material classification
	Date	Station	℄ offset	Elevation		
23	2-28-69	4+00	℄	2,690.5	Borrow Area C 3-4 ft	SC

Sample tested using: total mass ☐ separated screen size No. 4

Specified requirements

Moisture range ± 2.0 %

Ratio of fill dry density to maximum dry density 95 %

Test results

Ratio of fill dry density to specified maximum dry density, "D," item 20 99.4 %

Moisture content variation from optimum ($w_o - w_f$), item 21 +1.8 %

Fill moisture content (w_f), item 36 14.8 %

Fill dry density, item 23 106.5 lb/ft^3

Maximum dry density 107.2 lb/ft^3

Optimum moisture content 16.6 %

Remarks SCS-ENG-541, "Rapid Method for Determining Density and Moisture," example 1, is referenced as a part of this test report (fig. 3-32).

Figure 3-34.—Form SCS-ENG-530G, "Inplace Moisture-Density Determination: Rapid Compaction Method—Sand Displacement."

Volume Determination		Test No. 23
1. Bulk density of sand (predetermined)	(lb/ft³)	101.3
2. Initial weight of sand, cone, and container	(lb)	17.73
3. Final weight of sand, cone. and container	(lb)	1.23
4. Weight of sand in hale. plate. and cone = (2) − (3)	(lb)	16.50
5. Weight of sand in Plate plus cone (predetermined)	(lb)	4.26
6. Weight of sand in hole = (4) − (5)	(lb)	12.24
7. Volume of hole = (6) ÷ (1)	(ft³)	0.1208

	17.43
	2.54
	14.89
	2.82
	2.08
	0.74
(10)	14.15
	145.3
	0.00509
	0.1157
	123.3
	122.3
	99.4 %
	+ 1.8 %
	14.8 %
=	106.5

Compaction		−		%	+	
24. Water content, added or subtracted	(%)			0	2	4
25. Weight of mold plus finer	(lb)			13.39	13.56	13.43
26. Weight of mold	(lb)			9.38	9.38	9.38
27. Weight of fines = (25) − (26)	(lb)			4.01	4.18	4.05
28. Wet density = (27) ÷ volume of mold	(lb/ft³)			120.3	125.4	121.5
29. Converted wet density = ((28) ÷ 100 ± % water) 100	(lb/ft³)			120.3	122.9	116.8

Moisture Determination[3]						
30. Container No.	(g)			14		
31. Weight of moist fines plus container	(g)			273.67		
32. Weight of dry fines Plus container	(g)			241.92		
33. Weight of moisture = (31) − (32)	(g)			31.75		
34. Weight of container	(g)			27.31		
35. Weight of dry weight fines = (32) − (34)	(g)			214.61		
36. Fill moisture content = ((33) ÷ (35)) 100	(%)			14.8		

[1]Finer are materials smaller than the separating screen.

[2]D equals the ratio of fill dry density to specified maximum dry density.

[3]Use oven test method.

Figure 3–34 (cont).—Form **SCS-ENG-530G reverse** side

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SCS-ENG-530H
2.80

INPLACE MOISTURE-DENSITY DETERMINATION: RAPID COMPACTION CONTROL METHOD–RUBBER BALLON DISPLACEMENT

Fine-Grained Soils–Less Than 5% + No. 4 Sieve

Location SAND Ridge, USA Site No. WB-1

Watershed Willow Creek Subwatershed West Branch

Contract No. 12-10-049-23 Contractor HALL Brothers, INC

Tested by H. PARKS Computed by H. Parks Checked by J. Simms

Test No.	Date	Location of test: ~~station~~ Station	~~℄ offset~~ ℄ offset	~~Elevation~~ Elevation	Borrow source, location, and depth	Material classification
19	4-16-69	10+20	Lt 15 ft	3,168.0	BORROW Area C 6-10 ft	SC

Specified requirements

Moisture range ± 2 %

Ratio of fill dry density to maximum dry density 95 %

Test results

Ratio Of fill dry density to specified maximum dry density, "D," item (8) 97.6 %

Variation from optimum moisture content ($w_o - w_f$), item (9) -0.8 %

Fill moisture content (w_f), item (24) 18.6 %

Fill dry density. item (11) 106.6 lb/ft^3

Maximum dry density 109.2 lb/ft^3

Optimum moisture content 17.2 %

Remarks SCS-ENG-541, "Rapid Method for determining Density and Moisture." example 2, is referenced as a part of this test report (fig-3-33)

Figure 3–35.—Form SCS-ENG-530H, "Inplace Moisture-Density Determination: Rapid Compaction Method—Rubber Balloon Displacement, Fine-Grained Soils—Less Than 5% + No. 4 Sieve."

Volume Determination		Test No. 19
1. Final base reading	(ft³)	0.0520
2. Initial bare reading	(ft³)	0.0124

Density Determination		
		7.13
		2.15
		4.98
		125.8
		97.6 %
		-0.8 %
		18.0 %
[7 ÷		106.6

Compaction		–		%	+	
12. Water content. added or subtracted	(%)		2.3		2	
13. Weight of mold plus sample	(lb)		13.50	13.66	13.52	
14. Weight of mold	(lb)		9.38	9.38	9.38	
15. Weight of sample = 13 – 14	(lb)		4.12	4.28	4.14	
16. Wet density = 15 ÷ volume of mold	(lb/ft³)		123.6	128.4	124.2	
17. Converted wet density = 16 ÷ 100 ± % water)	(lb/ft³)		126.5	128.4	121.8	

Moisture Determination[2]						
18. Container No.				29		
19. Weight of moist Sample plus container	(g)			267.34		
20. Weight of dry sample plus Container	(g)			230.53		
21. Weight of moisture = 19 – 20	(g)			36.81		
22. Weight of container	(g)			26.32		
23. Weight of dry sample = 20 – 22	(g)			204.21		
24. Fill moisture content = (21 ÷ 23) 100	(%)			18.0		

[1] D equals the ratio of fill dry density to specified maximum dry density

[2] Use oven test method.

Figure 3–35 (cont).—Form SCS-ENG-530H reverse side.

the test site because of large rock. Therefore a metal or wooden frame (template) should be anchored on the prepared surface to function as a control for the test. The size of the frame and the dimensions of the test hole can vary, depending on the kind and size of rock involved. Table 3–3 shows recommended volumes and dimensions for testing different soil groups and particle sizes.

Apparatus.—The following equipment is needed

- Square or rectangular frame; minimum 2-in. height, angle iron preferred.
- Scale; minimum 100-lb capacity, sensitive to 0.1 lb.
- Balance; 1,000-g capacity, sensitive to 1 g.
- Oven or stove for drying samples.
- Large cans or buckets for weighing water.
- Pick, shovel, and trowel for excavating hole.
- Containers to collect test sample.
- Rubber or polyethylene sheeting; 4-ft square, No. 4 or 0.004 gauge.

  Hand-suction pump to remove water from hole.
- Drying pan, cans, screens, spoons, and other minor laboratory items.
- Siphon can, calibrated flask or scales, and basket for determinations of specific gravity.

Test procedures and recording data.—A pick, shovel, or trowel is used to level an area of adequate size for the template frame. The frame is firmly seated and is anchored with pins if needed. Rocks under the template edges that prevent firm contact should be removed and discarded (fig. 3–36). The liner is fitted snugly inside the template and worked into the corners and cavities. The folds are smoothed along the sides.

The liner is filled with water to a predetermined level marked by a hook gauge or other means (fig. 3–37), and the weight of the water used is determined. Then the water and liner are removed from the frame.

A test hole is excavated and shaped within the frame. The frame should not be disturbed. Large protruding stones should be removed and their cavities filled so surfaces of the excavation are smooth enough to permit full contact with the liner (fig. 3–38). The excavated material is placed in a sealed container, then the liner is fitted in the hole.

The liner is filled with water to that predetermined level (fig. 3–39). Manipulation of the liner as it fills will improve its contact with the hole and frame surfaces. The weight of the water used is computed to the nearest 0.1 lb. Then the water is removed (make sure the liner has not leaked).

The size of the test hole must be within prescribed limits, but the larger the hole the more accurate is the test. To determine accurately the volume of the hole, the water must not be spilled as the template is filled and as the water is weighed. All weight measurements and calculations must be made with precision and checked for accuracy. Errors may be accumulative and can become critical when conversions are made to units of weight.

Form SCS-ENG-530-I, "Inplace Moisture-Density Determination: Template & Plastic Liner Method," is used to record and compute data (fig. 3–40).

Volume determinations are made and entered in items 1–8. Moisture determinations are made on a representative portion of the total sample removed from the fill and entered in items 9–16. A large portion is needed because of the variation in size and gradation of the materials. With a known moisture content, the *dry* weight and mass density can be calculated and entered in items 17–19.

Moisture-Density Relation of Soil — Test No. *S–8*

This test determines the relation between the moisture content and the density of the soil under a given compactive effort. The test[8] was devised as a laboratory procedure to duplicate results obtained by the construction equipment in the field.

From laboratory moisture-density test data (curves) the design engineer learns about some of the structural characteristics of the soil on a construction site. Data also are used by construction personnel before and during the work. Variations in the earth material, however, necessitate additional testing on the job before and during construction. If moisture and density of the embankment do not correspond to data assumed from

[8] *The test was originated by R. R. Proctor (Proctor, R R., Fundamental principles of soil composition, Engineering News Record, Aug. 31, Sept. 7, 21, 28, 1933).*

previous tests, the soil may not be compacted correctly, the moisture content may not be proper, or borrow materials may have changed in character. If the borrow material changes, new curves are needed.

The compacted embankment should not be rejected on a one-point curve test or on a single-standard test. Both results should be checked with a second standard test.

Procedures for determining the moisture-density relation of the soil are given in ASTM D–698, "Standard Test Methods for Moisture-Density Relations of Soils Using 5.5-lb (2.5-kg) Rammer and 12-in. (304.8-mm) Drop." Some procedures are shown in figures 3–41 to 3–48. Form SCS-ENG-359, "Work Sheet for Compaction and Penetration Resistance Data," is used for recording data (fig. 349).

Modified Method — Test No. S–9

When the contract specifies, the curve for moisture-density will be based on the modified test.

Procedures for determining the moisture-density relation with the modified method are given in ASTM D–1557, "Standard Test Methods for Moisture-Density Relations of Soils Using 10-lb (4.5-kg) Rammer and 18-in. (457-mm) Drop." Forms SCS-ENG-359 (fig. 3–49) and SCS-ENG-352, "Materials Testing Section Report: Compaction and Penetration Resistance" (fig. 3–50) are used for recording and computing data.

Penetration Resistance of soils — Test No. 9–10

The Proctor Needle measures the penetration resistance of fine-grained soils at different moisture levels. It is used principally as a rapid, approximate check on the moisture content of soils in the borrow areas or embankments. Test results indicate the bearing capacity of a soil.

The test is not valid in sand or soils with coarse, granular particles. Procedures for determining the penetration resistance of soils at different moisture levels are given in ASTM D–1558, "Standard Test Method for Moisture-Penetration Resistance Relations of Fine-Grained Soils." Forms SCS-ENG-359 (fig. 3–49) and SCS-ENG-352 (fig. 3–50) are used for recording and computing data.

Moisture Content Tests

Oven Method — Test No. 9–11

The moisture in a soil sample (or any material), expressed as a percentage, is the weight of the moisture in the sample divided by the weight of the ovendry sample that has been dried at approximately 105°C (220°F) to a constant weight.

Various field methods have been described in this chapter for rapid determination of the moisture in a soil (see tests S–12, S–13, and S–14), but oven-drying is the official method. The oven method is also used to determine the absorption and specific gravity of rock fractions (test S–15).

Procedures for determining the moisture content using an oven are given in ASTM D–2216, "Standard Method of Laboratory Determination of Moisture Content of Soil." Form SCS-ENG-531, "Moisture Content Determination, Summary Data Sheet," is used for computing and recording data (fig. 3–51). Data from this test are entered on one of the SCS-ENG-530 forms (variously numbered figures between 3–13 and 340); the particular form used, B, C, D, etc., depends on the field procedure used.

"Quick-Dry" Method — Test No. S–12

With a "quick-dry" method, a soil sample can be dried and calculations made in 10–30 min to determine the percentage of moisture in a soil. Results are subject to slight errors but will seldom exceed the accuracy limits required for field control of the moisture content for most soils. If the percentage of loss by ignition exceeds 5 percent, a "quick-dry'' method cannot be used.

Apparatus.—The following equipment is needed

- High temperature source; i.e., blowtorch, gasoline stove, or a butane gas burner.
- Balance; minimum 25-lb capacity and sensitive to 0.01 lb, or minimum 1,000-g capacity and sensitive to 0.1 g.
- No. 4 standard sieve.
- Heavy, cast-iron skillet or pan; 10- to 12-in diameter.
- Suitable container and airtight cover.
- Brass wire brush for cleaning equipment.
- Large spoon for stirring the sample as it dries.

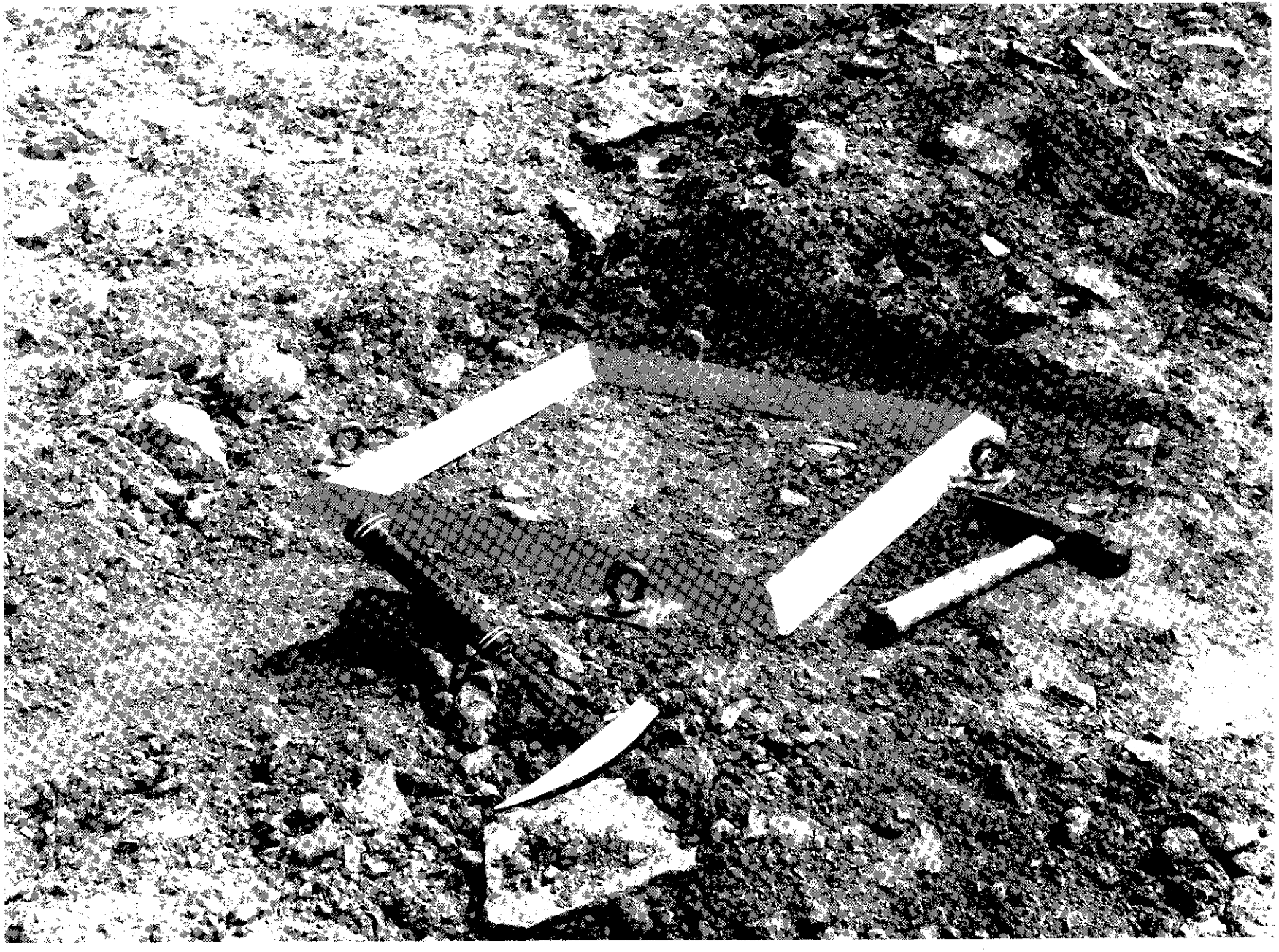

Figure 3-36.—Angle-iron frame in place for the calibration (photo is of a field simulation).

Figure 3-37.—Filling the frame, lined with polyethylene sheeting, with water for the calibration (field simulation)

Figure 3-38.—Preparing to replace the sheeting in the ex cavated hole (photo is of a field simulation).

Figure 3-39.—Filling the lined hale and frame with water by a siphon (photo is of a field simulation).

INPLACE MOISTURE-DENSITY DETERMINATION: TEMPLATE & PLASTIC LINER METHOD

Mass Density Control

Location Eastend, USA Site No NB-3

Watershed Blue River Subwatershed North Branch

Contract No 12-10-302-572 Contractor Con inental Construction Company

Tested by G-White Computed by G white Checked by R. Simmons

Test NU.	Date	Location of test: Station Station	Location of test: ℄ offset ℄ offset	Location of test: Elevation Elevation	Borrow source, location, and depth	Material classification
8	4-18-69	12+50	℄	5,872.0	Borrow area A 10ft	GP

Size of template 18 in. diameter

Test No.	Date	Specified requirements: Moisture range (%)	Specified requirements: Density (lb/ft^3)	Test results: Moisture (%)	Test results: Density (lb/ft^3)	Test results: Compaction (%)
8	4-18-69	6-10	130.0	8	132.4	101.8

Remarks

Figure 3-40.—Form SCS-ENG-530I, "Inplace Moisture-Density Determination: Template and Plastic Liner Method."

Volume Determination		Test No.			
	lb	8			
1. Weight of water plus container before filling template	lb	45.6			
2. Weight of water plus container after filling template	lb	31.8			
3. Weight of water required to fill template = (1) – (2)	lb	13.8			
4. Weight of water plus container before filling template and hole	lb	218.6			
5. Weight of water plus container after filling template and hole	lb	39.3			
6. Weight of water to fill template and hole = (4) – (5)	lb	179.3			
7. Net weight of water to fill hole = (6) – (3)	lb	165.5			
	ft^3	2.65			

Moisture Determination		Container No.			
Sample tested using: quick dry ☑ oven ☐					
9. Weight of moist sample and container	lb	27.49			
10. Weight of dry sample and container	lb	25.84			
11. Weight of moisture = (9) – (10)	lb	1.65			
12. Weight of container	lb	5.20			
13. Weight of dry sample = (10) – (12)	lb	20.64			
14. Moisture content = ((11) ÷ (13)) 100	(%)	8.0			
15. Correction for ignition	(%)	—			
16. Corrected moisture content = (14) – (15)	(%)	8.0			

Density Determination					
17. Total wet weight	lb	379.0			
18. Total dry weight = [(17) ÷ (100 + (16))] 100	lb	350.9			

Indicate Weight and Volume Units Used in Test

Figure 3-40 (cant).-Form **SCS-ENG-5301;** reverse **side.**

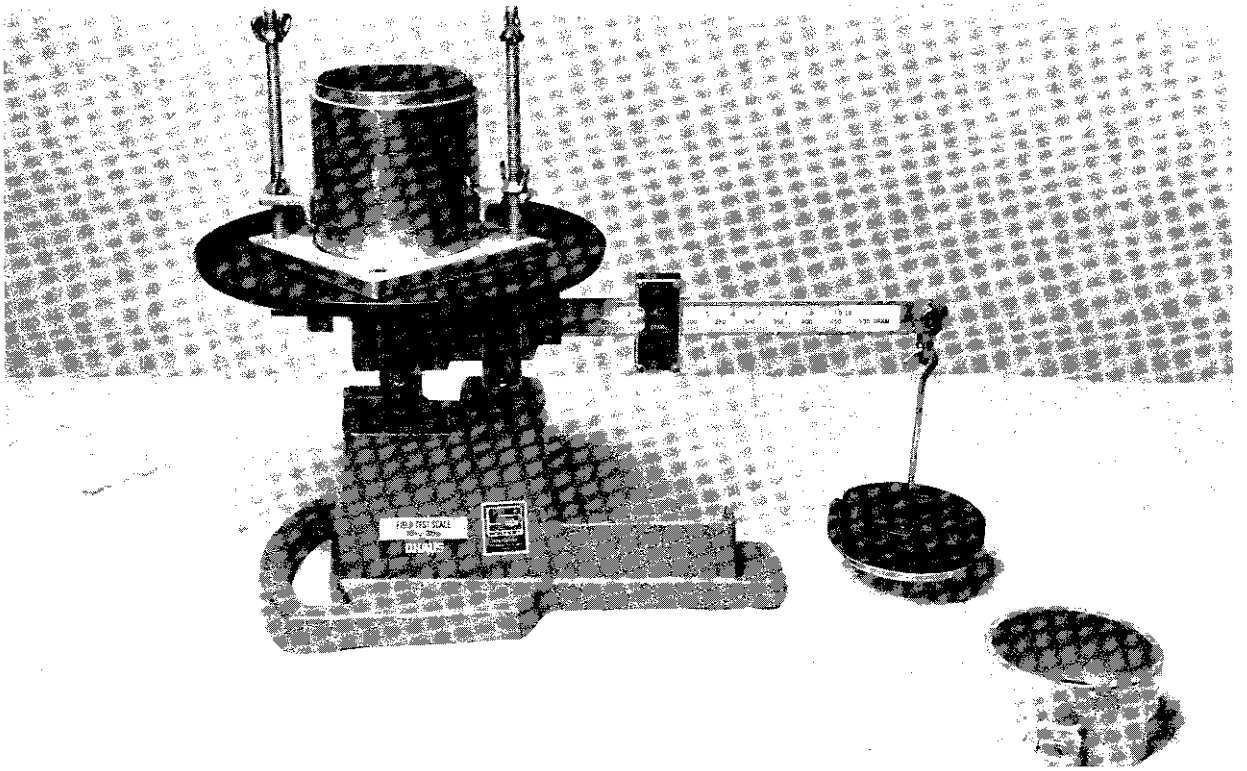

Figure 3-41.—Weighing the mold.

Figure 3-42.—Placing sail in the mold (photos *are* of laboratory simulations).

Figure 3-43—Compacting soil in the mold.

Figure 3-44.—Trimming the sample flush with the mold (photos are of laboratory simulations).

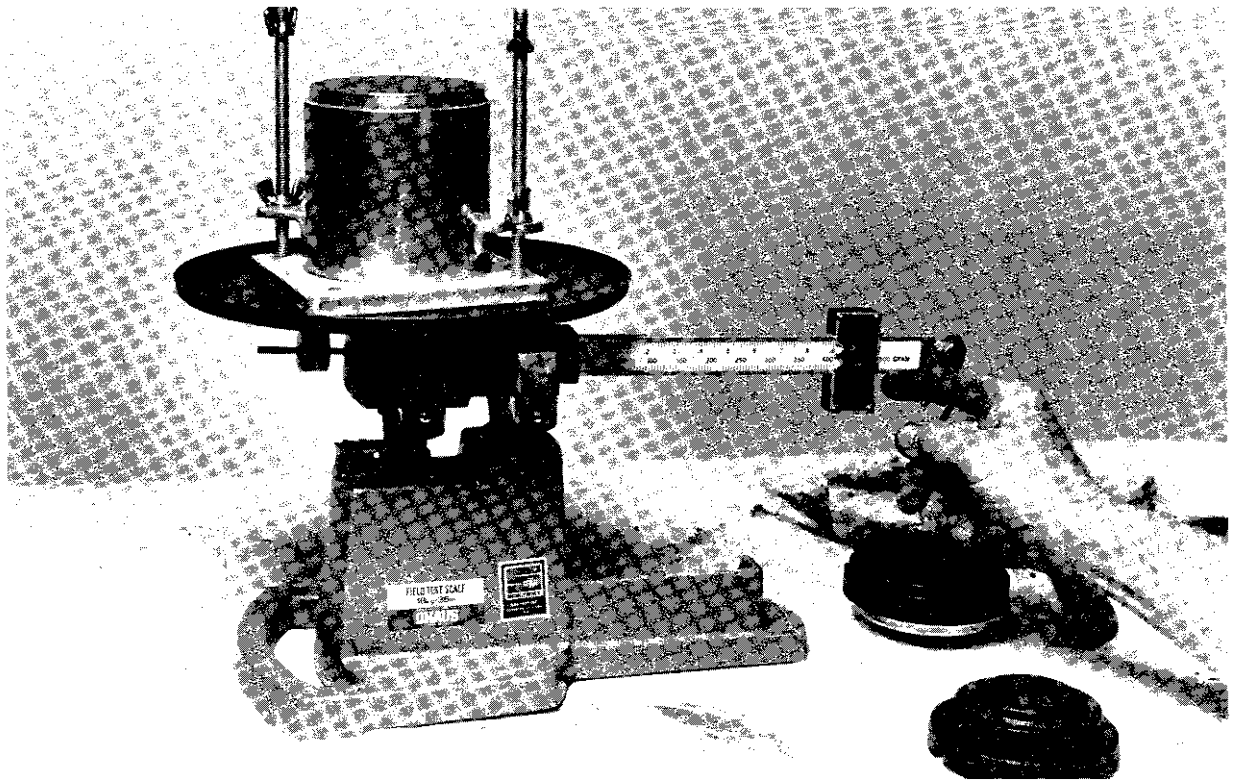

Figure 3–45.—Weighing the mold and compacted sample.

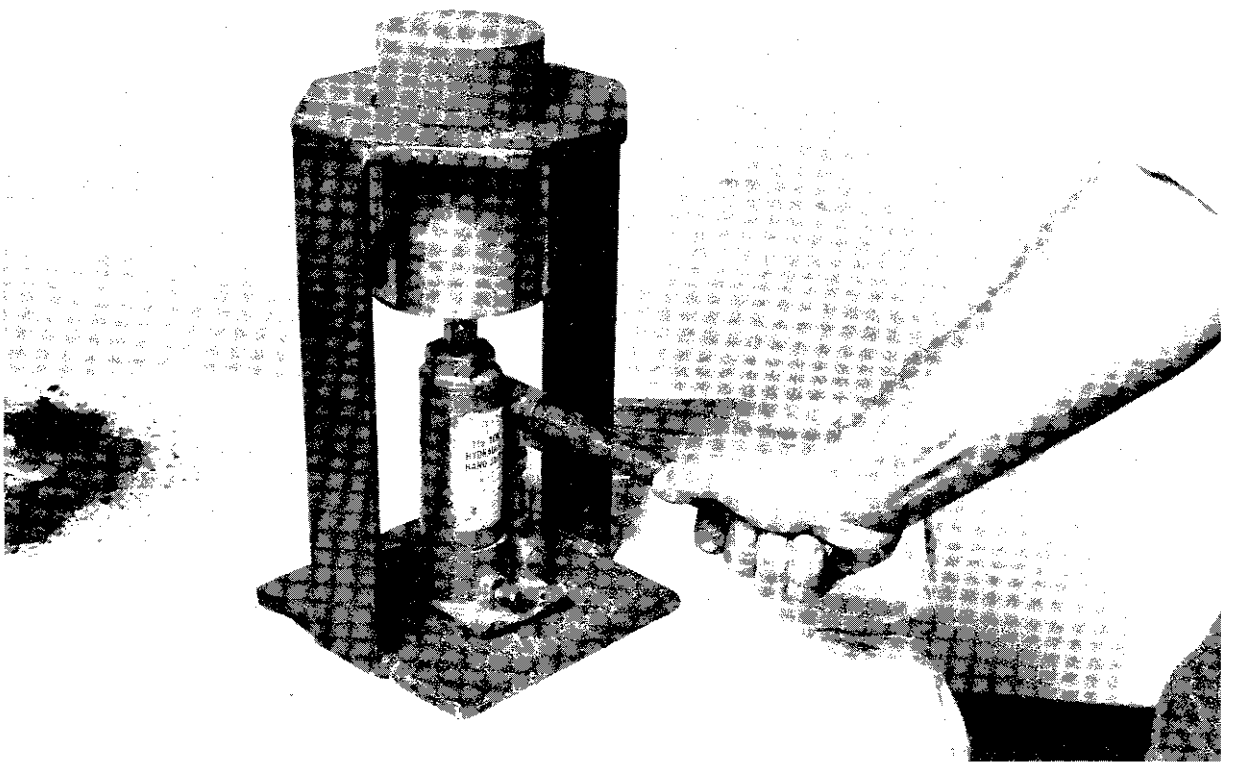

Figure 3–46.—Raising the compacted sample out of the mold (photos are of field simulations).

Figure 3-47.—Obtaining **a soil sample** for **a moisture determination.**

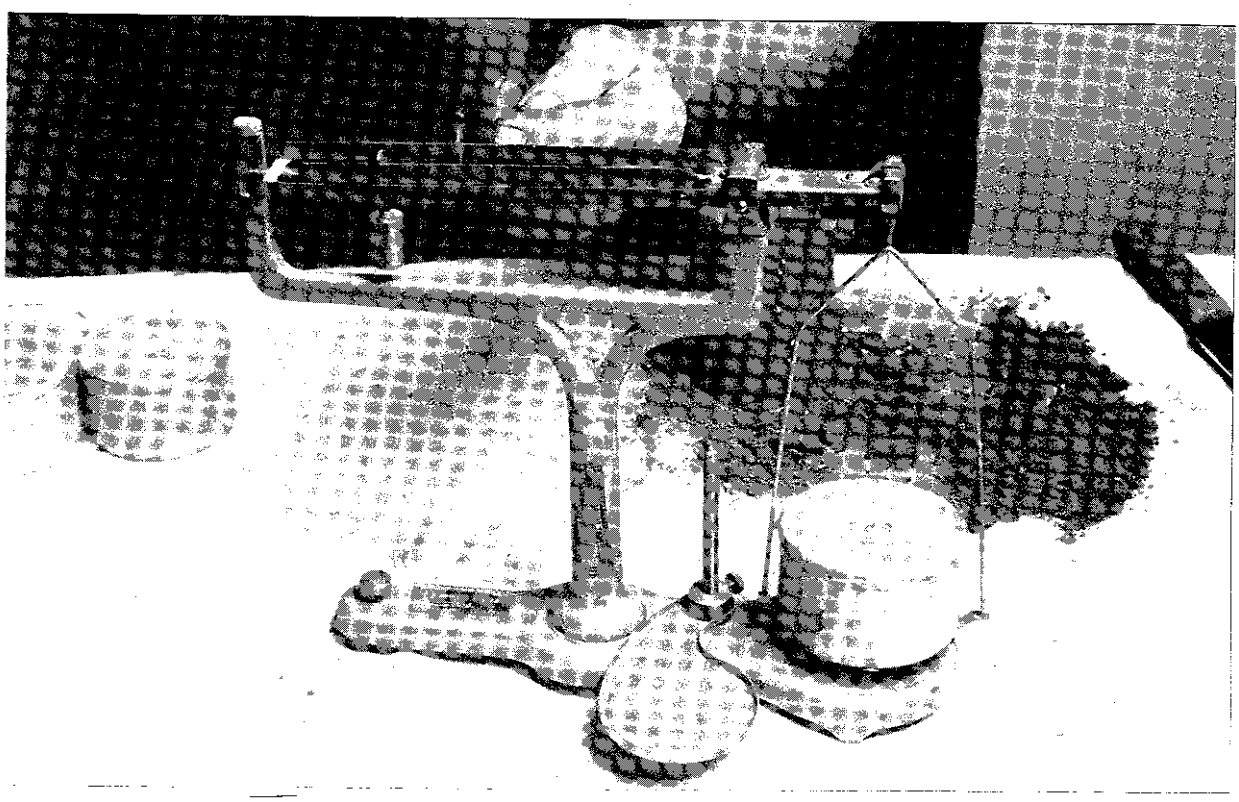

Figure 34.—Weighing the soil sample in a moisture container (photos are of laboratory simulations).

WORK SHEET FOR COMPACTION AND PENETRATION RESISTANCE DATA

Project Hometown Watershed Site 3A Sample No. 404-3

Compaction Data							
1. Weight of cylinder plus moist soil (lb)	8.87	9.22	9.45	9.60	9.61	9.58
2. Weight of cylinder (lb)	5.18	5.18	5.18	5.18	5.18	5.18
3. Weight of moist soil = (1) − (2) (lb)	3.69	4.04	4.27	4.42	4.43	4.40
4. Wet density[1] = (3) ÷ volume of cylinder (lb/ft³)	110.7	121.2	128.1	132.6	132.9	132.0
5. Dry density[1] = ((4) × 1001 ÷ (100 + (9)) (lb/ft³)	105.0	111.7	116.1	117.9	116.5	113.5
6. Proctor Needle reading	100+	91	80	61	39	8
7. Size of needle (in.²)	1/20	1/20	1/20	1/20	1/20	1/20
8. Penetration resistance[1] = (6) ÷ (7) (lb/in.²)	2,000+	1,820	1,600	1,220	780	160

Moisture Determination Data						
9. Moisture content[1] = ((13) ÷ (15)) 100 (%)	6.3	8.5	10.3	12.5	14.1	16.0
10. Container No.	1	3	4	5	6	7
11. Weight of container plus moist soil (g)	118.4	136.1	146.7	154.7	149.8	167.4
12. Weight of container plus dry soil (g)	113.0	127.5	135.5	140.5	134.5	148.0
13. Weight of moisture = (11) − (12) (g)	5.4	8.6	11.2	14.2	15.3	19.4
14. Weight of container (g)	27.0	26.0	26.5	27.0	26.0	26.5
15. Weight of dry soil = (12) − (14) (g)	86.0	101.5	109.0	113.5	108.5	121.5

Volume of cylinder. 1/30 ft³, using: ASTM or other standard ASTM D-698, method A
Procedure data: weight of hammer 5.5 lb, drop 12 in., number of lifts 3 (25 blows each)

Completed by CRS date 5-23-83 Computed by CRS date 5-23-83
Checked by CPR date 5-23-83 Recorded by CPR date 5-23-83

Density: wet - 132.9; dry - 117.9 water (%): 12.6

[1]Density, Penetration resistance, and moisture content values (No. 4, 5, 8, 9) are plotted on Form SCS-ENG-352.

Figure 349.— Form SCS-ENG-359, **"Work Sheet for** Compaction **and Penetration Resistance Data."**

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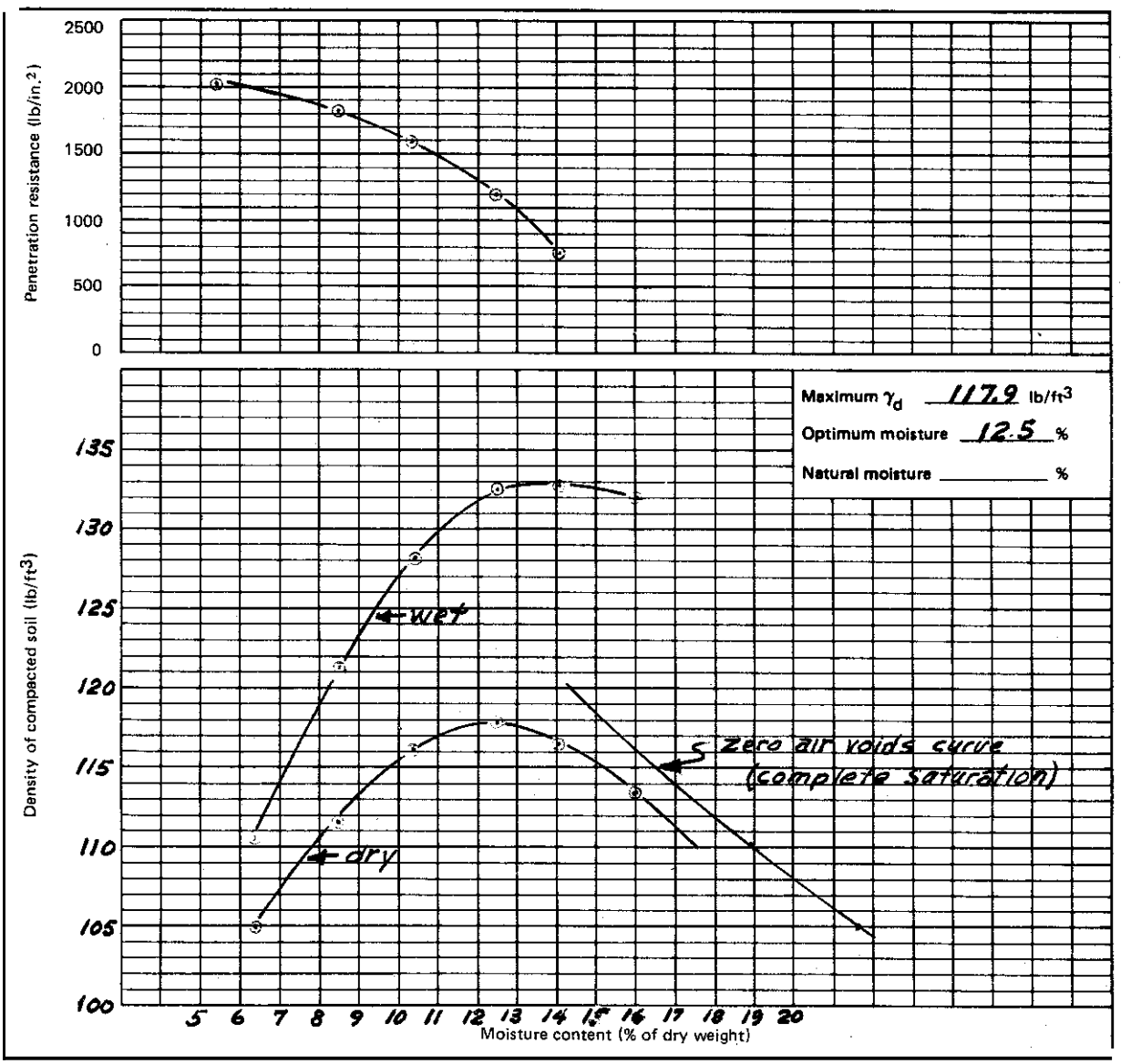
SCS-ENG-352
2-80

MATERIALS TESTING REPORT: COMPACTION AND PENETRATION RESISTANCE

Project and state Hometown Watershed Site 3A Laboratory No. —
Field sample No. 404-3 Location Borrow Area C Depth 6.0' - 10.8'
Geologic origin Alluvium Tested at Brooks, Co. Approved by LPR Date 5-23-83
Classification Silty Sand (SM) LL 25 PI 3 Curve No. 3 of 12
Maximum particle size in test 4.76mm ~~in.~~ Standard (ASTM D-698) ☒; method A
Specific gravity (G_s) – No. 4 2.65 Modified (ASTM D-1557) ☐; method
+ No. 4 2.13 Other test ☐ (see remarks)



Remarks

Figure 3–50.—Form SCS-ENG-352, "Materials Testing Section Report: Compaction and Penetration Resistance."

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SCS-ENG-531
2-80

MOISTURE CONTENT DETERMINATION
Summary Data Sheet

Kind of material _____ Location _____ Owner _____
Watershed _____ Subwatershed _____ Site No. _____
Contract No. _____ Contractor _____
Dried by: oven ☐ quick pan ☐ quick alcohol ☐ quick _____ ☐

Test No.	Date of test	Location of test (structure or station, offset)	Elevation	WW[1]	DW[1]	TW[1]	Moisture content (%)[2]				Tested by
							Oven method	Quick method	Correction factor	Corrected moisture	

1/ WW = Weight of moist sample and container. DW = Weight of dry sample and container. TW = Wright of container.
2/ Moisture content (%) = [(WW – DW) ÷ (DW – TW)] 100.

Figure 3–51.—Form SCS-ENG-531, "Moisture Content Determination, Summary Data Sheet."

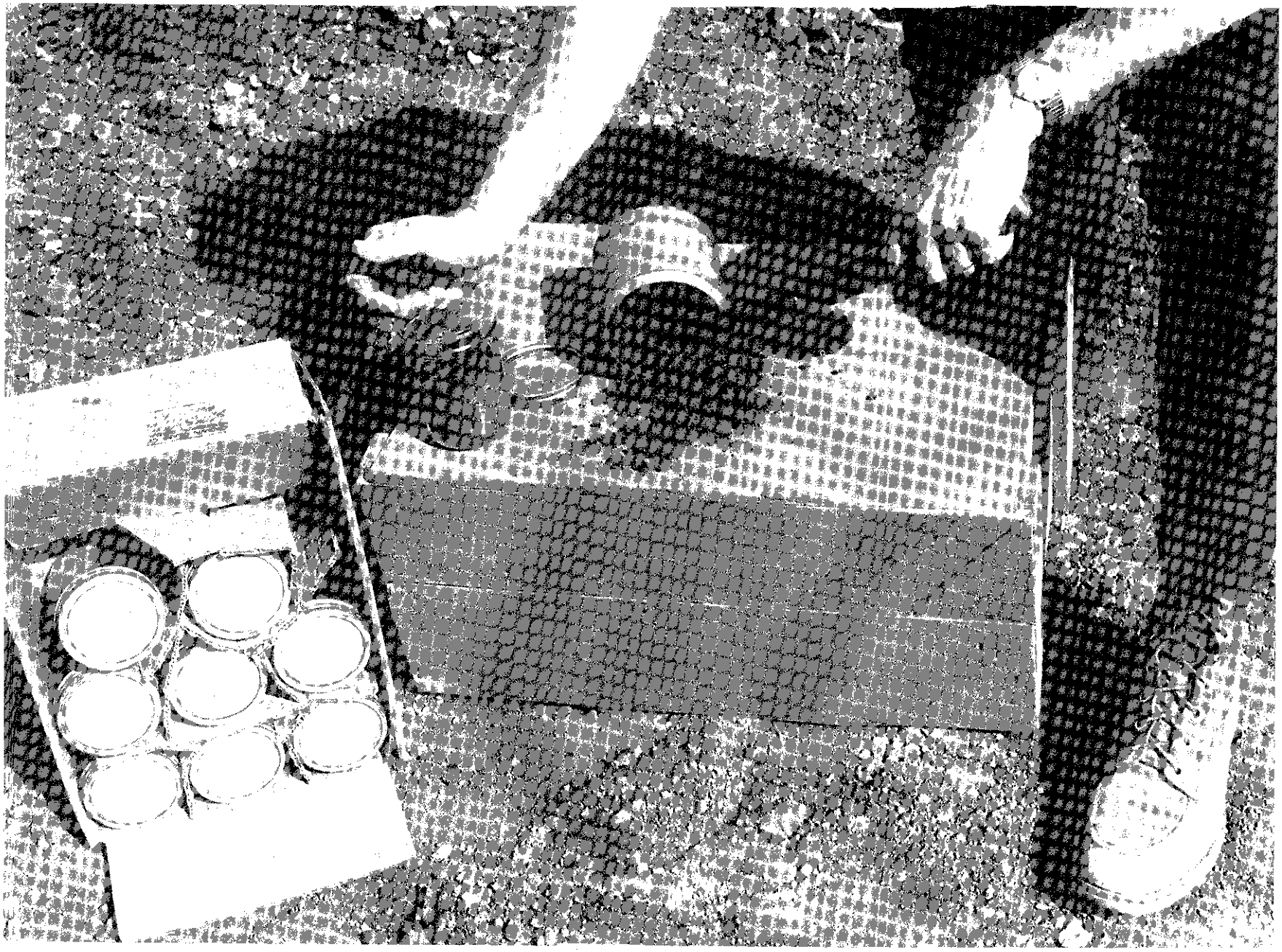

Figure 3-52.—Obtaining a sample for moisture determination (photo is of a field simulation).

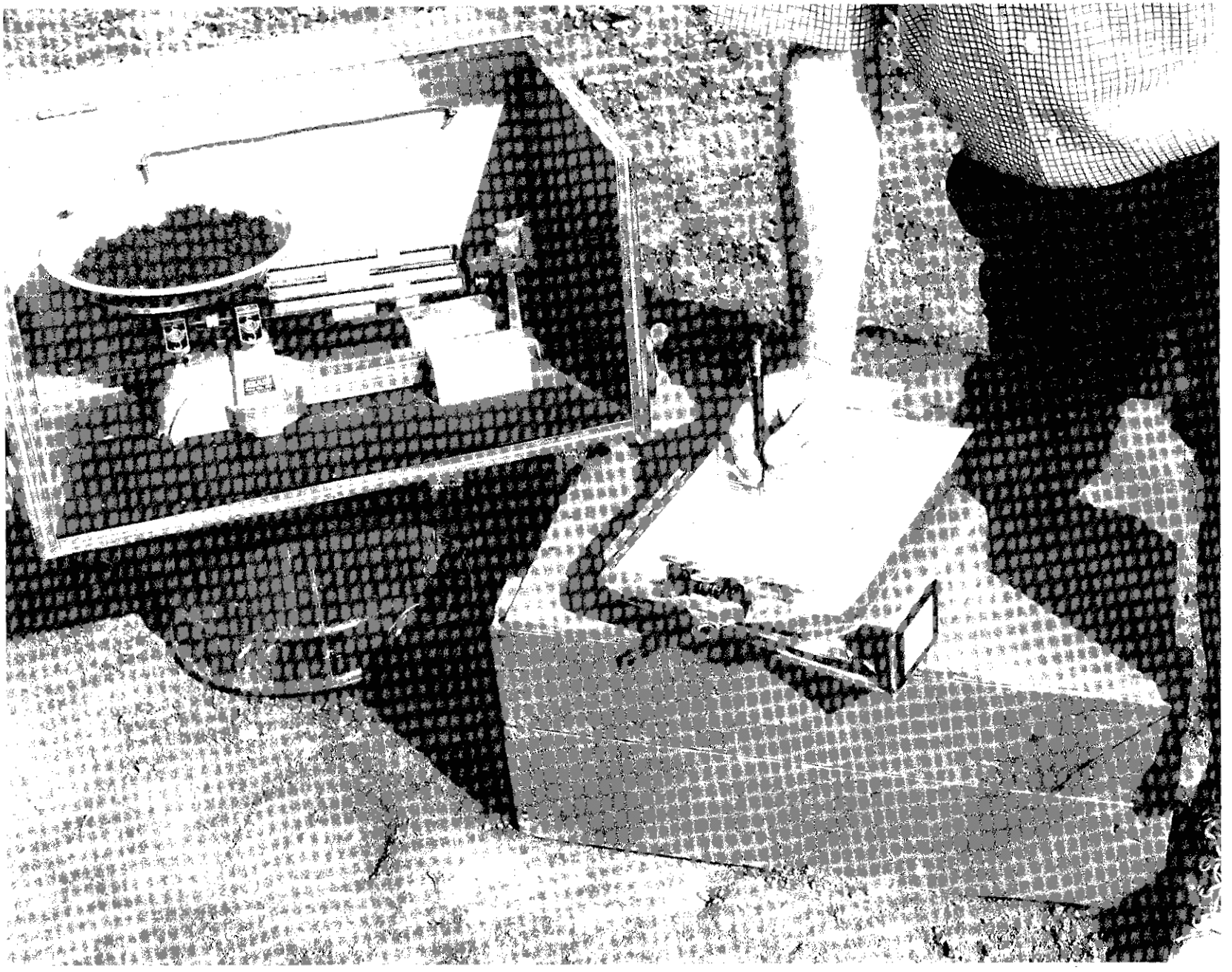

Figure 3-53.—Obtaining and recording the wet weight of the sample plus pan (photo is of a field simulation).

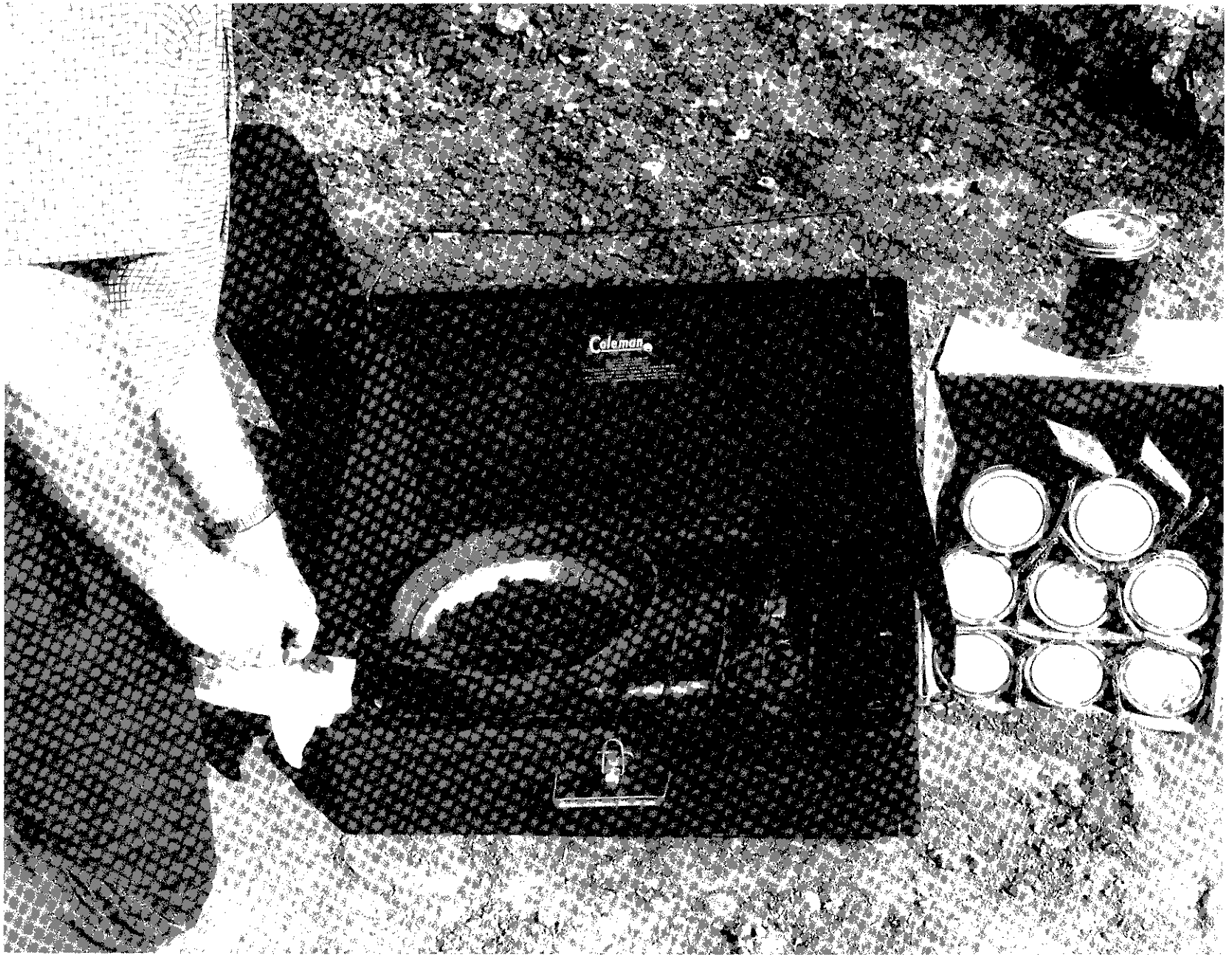

Figure 3–54.—Drying a sample by the quick-drying method (photo is of a field simulation).

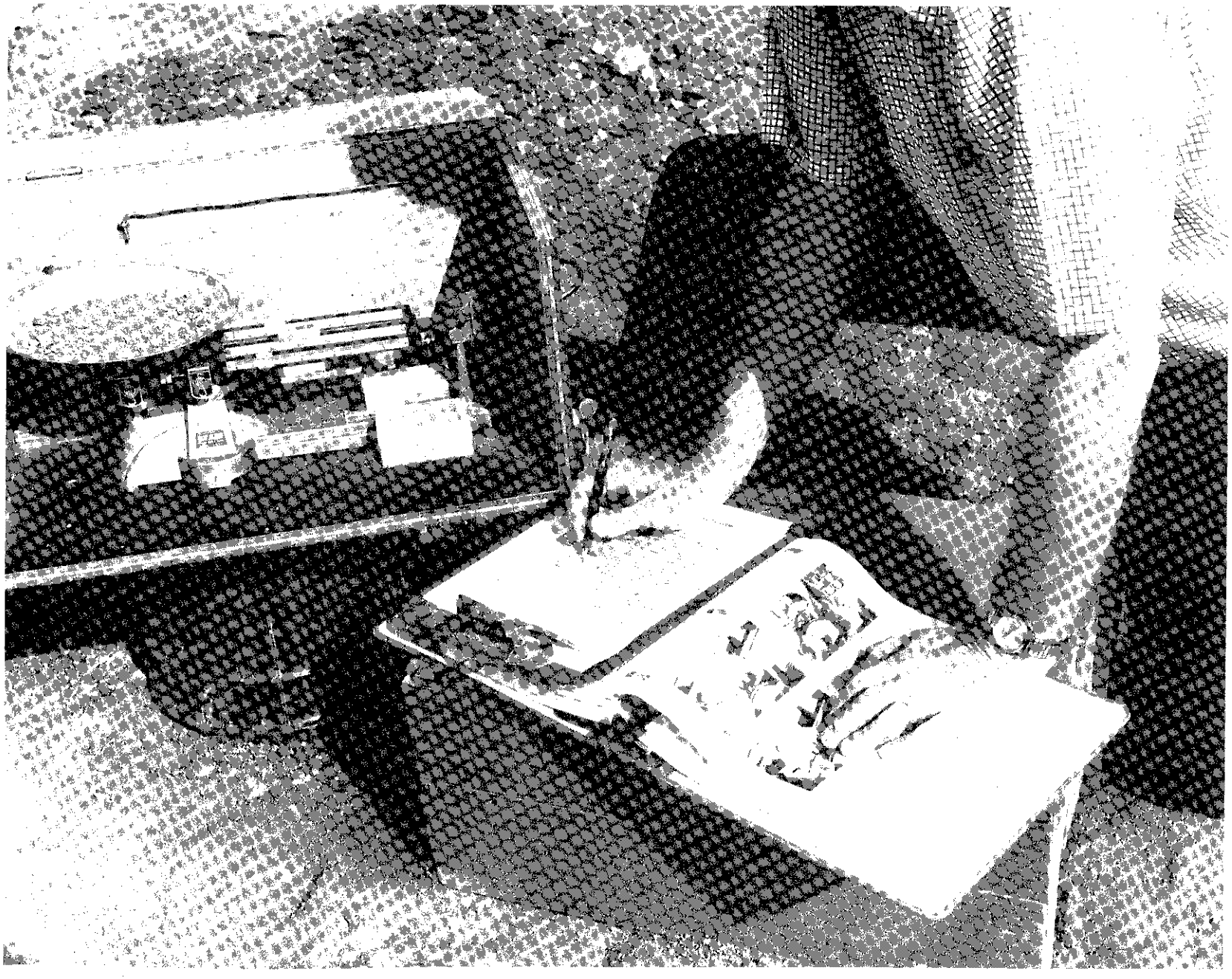

Figure 3-55.—Obtaining and recording the dry weight of the sample plus pan (photo is of a field simulation).

Loss by ignition.—The moisture in a soil, expressed as a percentage, is the weight of the moisture in the soil sample divided by the weight of the ovendry sample that has been dried at approximately 105°C (220°F) to a constant weight. If a "quick-dry" method is used, the small amount of combustible material in the soil which would remain unburned at 105°C will be burned at the higher temperature. This quantity, expressed as the percent of loss by ignition, would show up in the calculations as a loss in moisture. Therefore, each type of soil must be checked to determine the percent of loss by ignition in a quick-drying test so a correction factor can be established and applied during testing.

To determine this correction (calibrating a soil test), conditions such as sample size, stirring method, drying temperature, flame size, container-to-flame distance, and drying-period length must be kept constant, Preliminary trials are needed to learn the procedures necessary to dry the wet soil sample to a constant weight. A minimum of three representative soil samples should be collected for checking. Sample size depends on the maximum size of soil particles in the sample and the sensitivity of the weighing device. Samples all need some moisture present but identical amounts are not necessary.

Each sample is quartered and two portions (quarters) saved for testing. Immediately after quartering, each portion to be tested is accurately weighed.

One test portion per sample is dried to a constant weight in a controlled oven at approximately 105°C (220°F). The other test portion of the same sample is dried by the "quick-dry" method chosen for field control. Then each test portion is cooled and weighed. The moisture in the soil is calculated as:

$$\text{Moisture content in percent} = \frac{WV - DW}{DW - TW} \times 100$$

where

WW = weight of moist sample plus container
DW = weight of dry sample plus container
TW = tare weight of container

For each sample, the percent of moisture when quick-drying minus the percent of moisture when ovendrying is the percent of loss by ignition. The average of these percent losses by ignition for the samples checked must be subtracted from all future percent moisture calculations for this type of soil when quick-drying is used.

Test procedures and recording data.—Each soil sample must be kept in a separate airtight container between collection and testing times.

After passing at least 1 lb (approximately 500 g) through a No. 4 sieve, the soil sample is placed in a container (skillet or pan) and the weight of the moist sample and pan (WW) determined. The pan and sample are placed over a hot flame to dry. Stirring with a large spoon will facilitate drying. Then the sample and pan are aliowed to cool and are reweighed. This weight is DW. The difference between WW and DW is the weight of the moisture in the sample plus any loss by ignition.

The pan is emptied and weighed alone to determine the tare weight (TW). The percent of apparent moisture loss is calculated as:

$$\text{Apparent moisture loss in percent} = \frac{WW - DW}{DW - TW} \times 100$$

The percent of moisture in the soil is the apparent moisture loss minus the loss by ignition.

For samples containing a large amount of material retained on a No. 4 sieve, a moisture determination may also be needed on the coarse fraction or on a composite of all samples. Often a larger sample will be needed when testing these materials.

Some procedures for "quick-dry" tests are shown in figures 3–52 to 3–55. Form SCS-ENG-531 is used for computing and recording data (fig. 3–51). Data from this test are entered on one of the SCS-ENG-530 forms (variously numbered figures between 3–13 and 3–40); the particular form used, B, C, D, etc., depends on the field procedure used.

Alcohol Method

This test can determine the moisture content of the soil fraction passing a No. 4 sieve if rapid results are needed. Results are satisfactory for most soils but not when the percent loss by ignition exceeds 5 percent.

Apparatus.—The following equipment is needed:

- Alcohol-burning cup with perforated bottom and tight cover.

- Filter papers to fit the burning cup.
- Balance; minimum 100-g capacity and sensitive *to* 0.1 g.
- Glass or metal stirring rod
- Wood or grain alcohol; a grade manufactured for burning purposes.

Test procedures and recording data.—Each soil sample must be kept in a separate airtight container between collection and testing. The tare weight of the burning cup is determined with filter paper in place.

From materials passing a No. **4** sieve, a sample of approximately 30 g (wet weight) is placed in the burning cup and the weight of the sample plus the cup determined. The cover is inverted and placed beneath the cup to form a saucer.

Enough alcohol is stirred into the sample to produce a thin mush or slurry. Soil particles that dry on the stirring rod are brushed into the cup. The alcohol in the cup and saucer is lit and allowed to burn off (stirring the sample while it burns may help). After it is burned, the sample should cool about one minute. The process of adding alcohol, stirring, and burning is repeated three times. After the last burning, the weight of the dry soil plus cup is determined.

The percent of moisture is calculated as:

$$\text{Moisture content in percent} = \frac{WW - DW}{DW - TW} \times 100$$

where

WW = weight of wet sample, cup, and filter
DW = weight of dry sample, cup, and filter
TW = tare weight of cup plus filter

If the loss by ignition is significant, correction must be determined by the method outlined in the test procedures of test S–12.

Form SCS-ENG-531 is used for computing and recording data (fig. 3–51). Data from this test are entered on one of the SCS-ENG-530 forms (variously numbered figures between 3–13 and 340); the particular form used, B, C, D, etc., depends on the field procedure used.

Speedy Moisture Tester Test **No.** 5–14

This test uses calcium carbide as the reagent in a chemical reaction to determine the moisture content **of** a soil or sand-aggregate material. The principle is that a given quantity of moisture will react with calcium carbide to produce a specific volume of acetylene gas. The gas pressure gauge located in the base of the pressure vessel is calibrated to read the percent of moisture in the sample (fig. 3–56).

The Speedy Moisture Tester is manufactured in several sizes to meet various moisture and soil conditions. It has proved reasonably accurate for quick field tests if properly used.

Apparatus.—The following equipment is needed

- Speedy Moisture Tester; has balance for weighing sample, small scoop for measuring calcium carbide, and table to convert percent moisture to a dry-weight basis.
- Carbide.
- No. **4** standard sieve.
- Balance, oven, sample cans, and other laboratory items needed for standard, ovendry moisture determinations.

Calibration curve.—A conversion factor is necessary to relate tester readings to the true moisture content. This conversion factor will be different for different soil types. There is likely to be a variation between two different testers. Therefore a calibration curve to determine this conversion factor between readings of a given moisture tester and ovendry results must be prepared for each site or for each change in earth material within a site.

To prepare a calibration curve, soil samples are tested for a fairly complete range of moisture contents (make more than one test for each sample) by both the oven method (test S–11) and the moisture tester method. Ovendry results versus tester readings are plotted as a calibration curve which is used in converting tester readings to the true moisture content.

During the work, tester readings should be compared to the calibration curve to determine if the conversion factor is still accurate. Periodic checks by ovendrying are needed. How often to make checks depends on the consistency of the tester readings. Fewer oven checks are needed if the tester readings are close to the established calibration curve. If not, moisture contents need to be redetermined by both methods and the curve replotted.

Test procedures (using 26-g tester) and recording data.—The manufacturer's instructions should be followed carefully.

Three measures (approximately 22 g) of calcium carbide and two 1¼-in. steel balls (0.4 lb) are placed in the large chamber of the tester. A 26-g soil sample passing a No. 4 sieve is placed in the cap on the tared scale. A 13-g sample can be used if the moisture content exceeds the limit of the pressure gauge.

While holding the pressure vessel horizontal, the cap is inserted and the clamp tightened to seal it in place. The tester is turned to vertical, dumping the soil into the pressure vessel.

The tester is held horizontally and rotated for 10 sec, putting the steel balls in orbit around the inside of the vessel, then rested 20 sec. The steel balls must not fall against and damage either the cup or orifice to the dial. Shake-and-rest cycles are repeated for 3 min. Then 3 min at rest should be allowed for the reaction to be completed.

The moisture content of the wet samples is determined from reading the pressure gauge. The correct moisture content of the sample in percent is then read from the calibration curve,

Form SCS-ENG-531 is used to record and compute the data (fig. 3–51). Data from this test are entered on one of the SCS-ENG-530 forms (variously numbered figures between 3–13 and 340); the particular form used, B, C, D, etc., depends on the field procedure used.

Precautions.—Overloading the test apparatus can severely damage the equipment. If the sample consists of very wet material, such as organic soil, pressures can build up that can rupture the equipment and possibly injure the operator.

The Speedy Moisture Tester is not an official method for determining the moisture content of compacted specimens when preparing moisture-density curves or when determining the moisture content of inplace embankment materials. The contract must specify that the Speedy Moisture Tester can be used before this test method will be considered a basis for accepting or rejecting the work. Otherwise, the meter can be used only as an indicator test.

Absorption and Specific Gravity Tests of Rock Fractions — Test **No. S–15**

Procedures for determining the absorption and specific gravity of the rock formations are given in ASTM C–127, "Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate." The equipment for this test is shown in figure 3–57. Form SCS-ENG-543, "Bulk Specific Gravity and Moisture Determination," is used for recording and calculating data (fig. 3–58).

Standard Methods of Testing Concrete and Concrete Materials

Sampling Fresh Concrete — Test **No.** C–1

Procedures for sampling fresh concrete are given in ASTM C–172, "Standard Method of Sampling Fresh Concrete." Form SCS ENG-59 is **used** for recording data (fig. 3–63).

slump Test **of** Portland Cement Concrete — Test **No.** C–2

Procedures for testing concrete for slump are given in ASTM C–143, "Standard Test Method for Slump of Portland Cement Concrete." Some procedures are shown in figures 3–59 to 3–62. Form SCS-ENG-59, "Report on Concrete Test Specimens," is used for recording data (fig. 3–63).

Making and Curing Compression Test Specimens — Test **No.** C–3

Procedures for making and curing concrete compression test specimens are given in **ASTM** C–31, "Standard Method of Making and Curing Concrete Test Specimens in the Field." Some procedures for preparing test cylinders are in figures 3–64 to 3–67. Form SCS-ENG-59 is used for recording data (fig. 3–63).

Air Content *of* Freshly Mixed Concrete (pressure method) — Test **No. C–5**

Procedures for determining by pressure the air content **of** freshly mixed concrete are given in **ASTM** C–231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method." Procedures for testing by the pressure method are **shown** in figures 3–68 and 3–69. Form **SCS·ENG59** *is* used for recording data (fig. 3–63).

Air Content of Freshly Mixed Concrete (volumetric method) — Test No. C–6

Procedures for determining volumetrically the air content of freshly mixed concrete are given in ASTM C–173, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method." Form SCS-ENG-59 is used for recording data (fig. 3–63).

Air Content of Freshly Mixed Concrete (air indicator) — Test No. C–7

This rapid test determines whether the air content of freshly mixed concrete meets contract requirements. Results showing that requirements are not met must be confirmed by additional tests using equipment and procedures in test C–5 or C–6.

Apparatus.—The following equipment is needed:

- Air indicator (fig. 3–70)
- Plastic squeeze bottle containing isopropyl alcohol.
- Knife or spatula; narrow, metal-bladed.

Test procedures and recording data.—A knife or spatula is used to fill the cup of the air indicator with a sample of concrete (mortar), excluding particles retained on a No. 10 sieve. A rod is used to compact the mortar, and any excess is struck off level across the cup.

The cup assembly is inserted in the glass tube. Alcohol from a plastic bottle is introduced into the tube through the graduated stem until the liquid reaches the top mark. A finger is placed over the stem opening, and the tube is slowly rolled from side to side to gently mix all the mortar in the alcohol.

After placing the tube upright and level, a reading is made by counting the number of marks the liquid dropped in the stem. The reading must be made immediately. Warm temperatures and direct sunlight on the meter can expand the alcohol and cause an erroneous reading. If the sample represents a mixture of 15 ft^3 of mortar (water, air, cement, and fine aggregate), the reading will represent the percent of air in a cubic yard of concrete. For other proportions of mortar, a correction is made usng the conversion table furnished with the meter.

After the test is completed, all equipment must be cleaned promptly and thoroughly dried.

The percent of air content, method of determination, batch number sampled, and location where concrete was placed in the structure are recorded in the job diary.

Weight (per cubic foot), Yield, and Air Content (gravimetric) of Concrete — Test No. C–8

Procedures for determining the weight, yield, and air content (gravimetric) of the concrete are given in ASTM C–138, "Standard Test Method of Unit Weight, Yield, and Air Content (Gravimetric) of Concrete." Form SCS-ENG-553 is used for recording and computing data (fig. 4–5).

Sampling Stone, Slag, Gravel, and Stone Block (for highway construction) — Test No. C–9

Procedures for sampling the stone, gravel, sand, and stone block for highway construction are given in ASTM D–75, "Standard Methods of Sampling Aggregates." Some procedures for dividing a sample are shown in figures 3–71 to 3–74.

Concrete Aggregates — Test No. C–10

Procedures for determining concrete aggregate specifications are given in ASTM C–33, "Standard Specification for Concrete Aggregates." Forms SCS-ENG-535, "Sieve Analysis," and SCS-ENG-353, "Materials Testing Report: Soil Classification," are used for recording data (fig. 3–75 and 3–76).

Other ASTM's applicable to determining specific characteristics of fine and coarse aggregates and concrete mixtures are listed in ASTM C–33.

Specific Gravity and Absorption of Fine Aggregate — Test No. C–11

Procedures for determining the specific gravity and absorption of fine aggregate are given in ASTM C–128, "Standard Test Method for Specific Gravity and Absorption of Fine Aggregate." Form SCS-ENG-544 is used for recording and computing data (fig. 4–6).

Specific Gravity and Absorption of Coarse Aggregate — Test No. C–12

Procedures for determining the specific gravity and absorption of coarse aggregate are given in ASTM C–127. Form SCS-ENG-543 is used for recording and computing data (fig. 3–58).

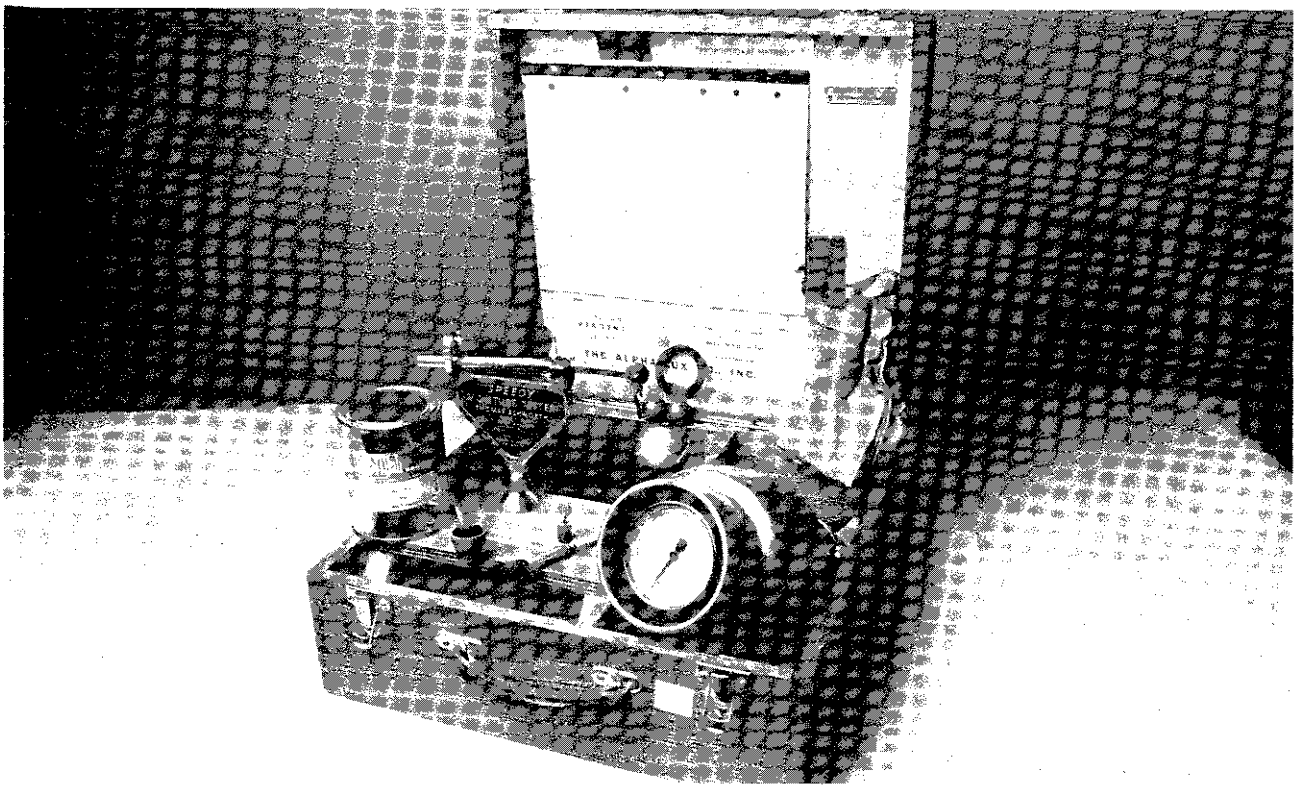

Figure 3-56.—Speedy Moisture Tester and accessories.

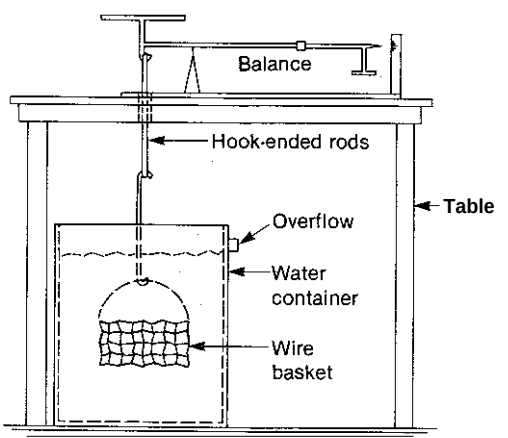

Figure 3-57.—Equipment setup for determining the submerged weight of rock.

BULK SPECIFIC GRAVITY AND MOISTURE DETERMINATION
(Rock, Gravel, Shale, Soil Clods, etc.)

Location Columbia Falls Date 5-2-69

Watershed Dry Creek Subwatershed — Site DAM #1

Contract No 12-10-300-210 Contractor Jones Contruction Company

Tested by D.C. Smith Computed by D.C. Smith Checked by Roy Brown

Moisture determinations

1.	Weight of moist sample plus container		g
2.	Weight of dry Sample plus container		g
3.	Weight of container		g
4	Weight of dry sample = (2) − (3)		g
5	Moisture content = [((1) − (2)) ÷ (4)] 100		%

Bulk specific gravity—method A—hard, round rock or gravel

6.	Weight Of container (basket) or card in air	235	g
7.	Weight of container (basket) or cord in water	155	g
8.	Weight of sample. natural moisture. plus basket in air	2,655 ✓	g
9.	Weight of sample. natural moisture, in air = (8) − (6)	2420	g
10.	Weight of sample, saturated, plus basket in air	2,655 ✓	g
11.	Weight of sample, saturated. in air = (10) − (6)	2,420	g
12.	Weight of sample. saturated, plus basket in water	1,663	g
13.	Weight of sample. saturated. in water = (12) − (7)	1,508	g
14.	Volume of sample by weight = (11) − (13) or measured volume	912	cm³
15.	Bulk specific gravity, natural moisture (G_{mm}) = (9) ÷ (14)	2.65	g/cm³
16.	Bulk specific gravity, ovendry (G_m) = (4) ÷	—	g/cm³
17.	Bulk density. natural moisture (γ_m) = (16) X 62.4	165.4	lb/ft³
18.	Bulk density. ovendry (γ_d) = (15) x 62.4	—	lb/ft³

Bulk specific gravity—method B—materials that disintegrate in water

19.	Weight of sample in air		g
20.	Weight of sample plus wax in air		g
21.	Weight of wax in air = (20) − (19)		g
22.	Weight of sample plus wax in water		g
23.	Volume of sample plus wax by weight = (20) − (22) or measured volume		cm3
24.	Volume of wax = (21) ÷ specific gravity of wax		cm3
25.	volume of sample = (23) − (24)		cm3
26.	Bulk specific gravity, natural moisture (G_{mm}) = (19) ÷ (25)		g/cm³
27.	Bulk specific gravity, ovendry (G_m) = (26) ÷ [(1 + (5)) 1001		g/cm³
28.	Bulk density, natural moisture (γ_m) = (26) X 62.4		lb/ft³
29.	Bulk density, ovendry (γ_d) = (27) X 62.4		lb/ft³

Figure 3–58.—Form SCS-ENG-543, "Bulk Specific Gravity and Moisture Determination."

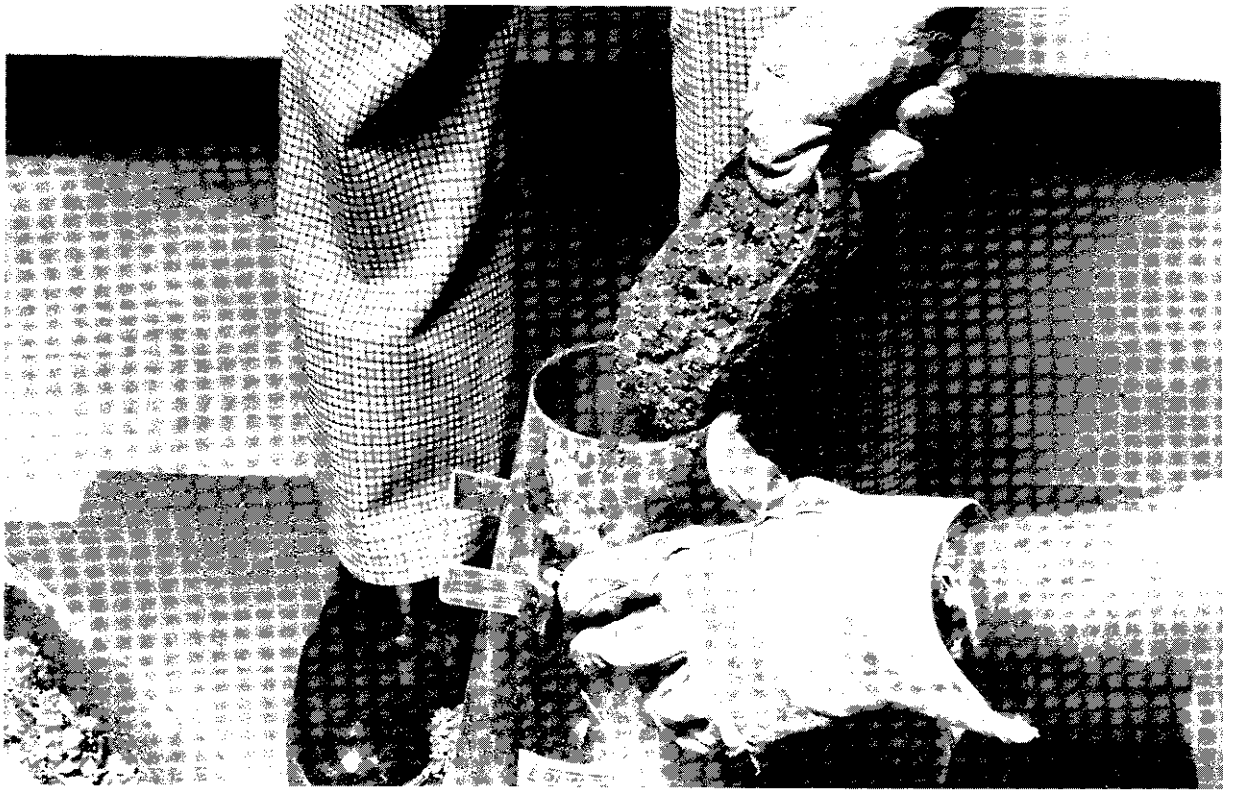

Figure 3-59.—Filling the mold with concrete

Figure 3-60.—Rodding the concrete to eliminate air pockets (photos are of laboratory simulation).

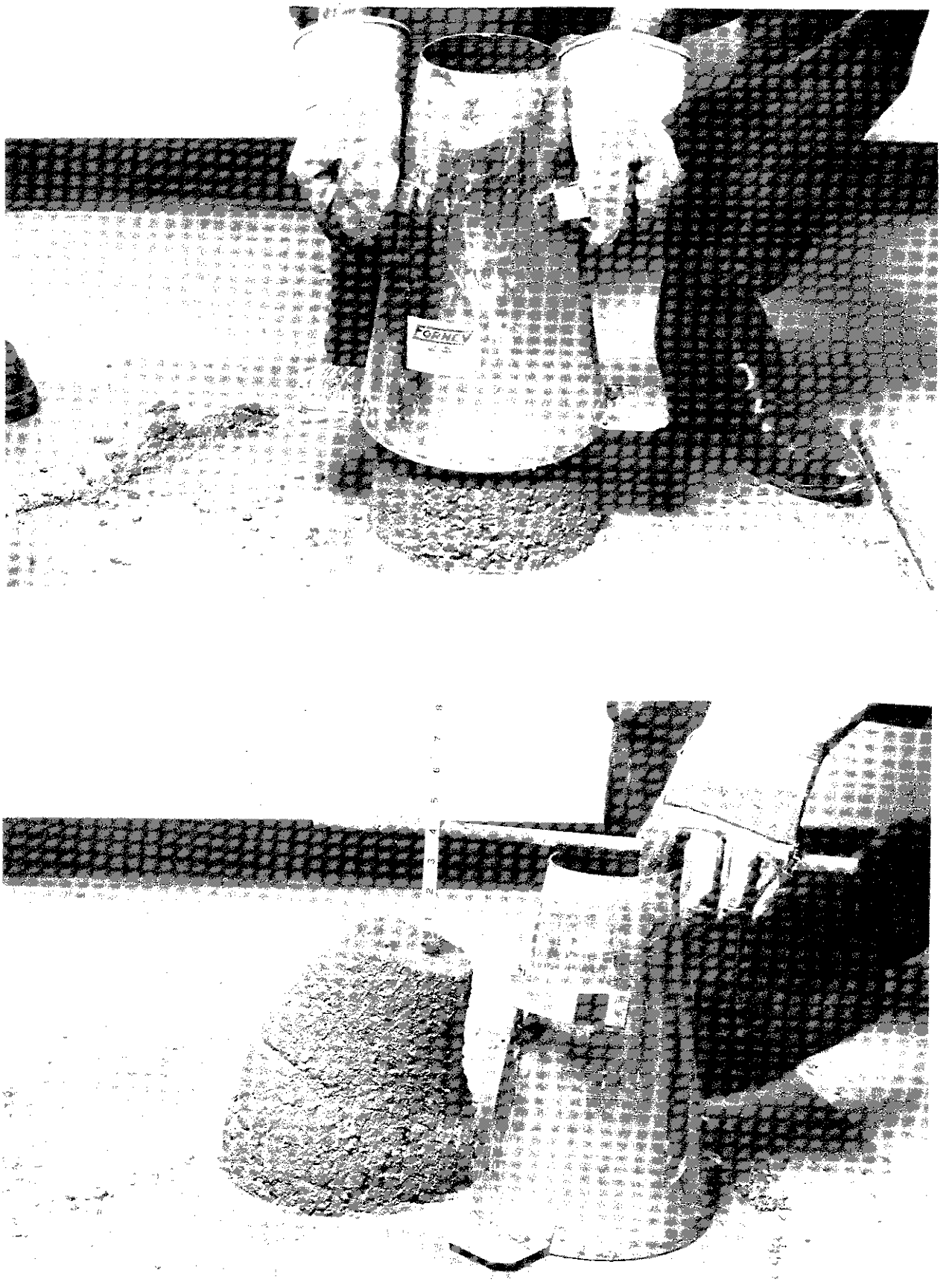

Figure 3-62.—Measuring the slump (photos *are* of laboratory simulation).

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-59
381

REPORT ON CONCRETE TEST SPECIMENS

Project Marsh Kellogg WPP — Contract No. 12-10-040-[illegible] Report No. 6
Site Marsh Creek Dam — Structure Spillway
Watershed Marsh-Kellogg — Subwatershed Marsh Creek
Specimens: number 6 — Type of specimens linder ☒ beams ☐ cores ☐, 6 in. diameter
Concrete class 3000# — Specification mix No. — Batch volume 1.0 yd³ — Type mix: job ☐ ready ☐
Location in structure Base of drop inlet riser
Date placed 5-9-61 — Date extracted (cores) – — Date shipped 5-10-61 — Prepared by B.B. Brown

Field data

Job-mix materials	Batch scale weight (lb)	Additional description		
Cement	564.0	Brand Permanente		ASTM type I
Coarse aggregate	2,020.0	Maximum size 1.5 in.	Moisture 1.6 %	Source symbol C-1
Fine aggregate	1,400.0	Fineness modulus 2.85	Moisture 4.2 %	Source symbol A-2
water	312.0	Temperature 61°F		
Admixture	3.5 oz	Type Protex	Brand	
Mixing time 10 min		Remarks Air temperature 87°		

Ready-mix materials:
Source and/or plant location _____ Load ticket No. _____

Note- Make in triplicate. Original & one copy to Testing Lab.

Summary of laboratory data

Field specimen No.	Slump (in.)	Air content (%)	Laboratory specimen No.	Date Received	Date Tested	Age (d)	Strength (lb/in.²)	Type of break
31	4	4	1264	5-10-61	5-16-61	7	2,406	Normal
32	4	4	1265	5-10-61	5-16-61	7	2,375	Normal
33	4	4	1266	5-10-61	5-16-61	7	2,479	Normal
34	3½	5	1267	5-10-61	6-6-61	28	3,128	Normal
35	3½	5	1268	5-10-61	6-6-61	28	3015	Diagonal
36	3½	5	1269	5-10-61	6-6-61	28	3,300	Normal

Method of curing Fog Room @ 75°F — Method of capping Sulphur Compound
Name of laboratory Bay Testing Laboratory, Richmond, CA

Figure 3-63.—Form SCS-ENG-59, "Report on Concrete Test Specimens."

Figure 3-64.—Concrete sample to be used for molding test cylinders (photo is of a field simulation).

Figure 3-65.—Placing the concrete into test cylinders and rodding the concrete in three equal layers in each cylinder (photo is of a field simulation).

Figure 3–66.—Numbering the test specimens (photo is of a field simulation).

Figure 3-67.—Protecting the molded specimens with a cloth cover (photo is of a field simulation).

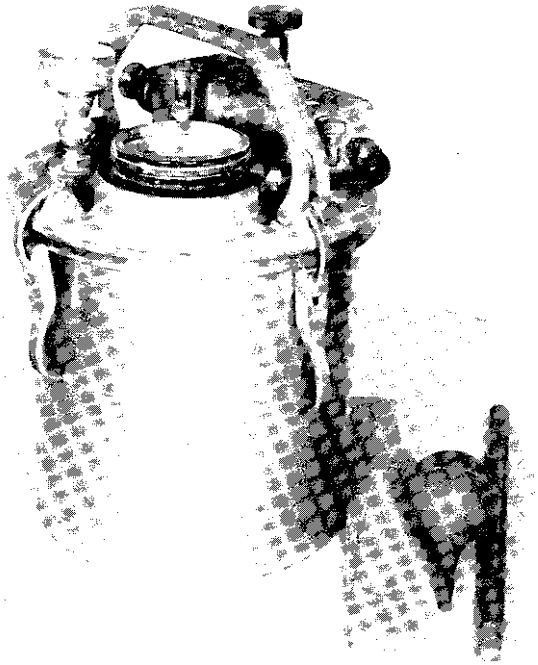

Figure 3-68.—Air meter for testing the entrained air content of fresh concrete (meter assembled).

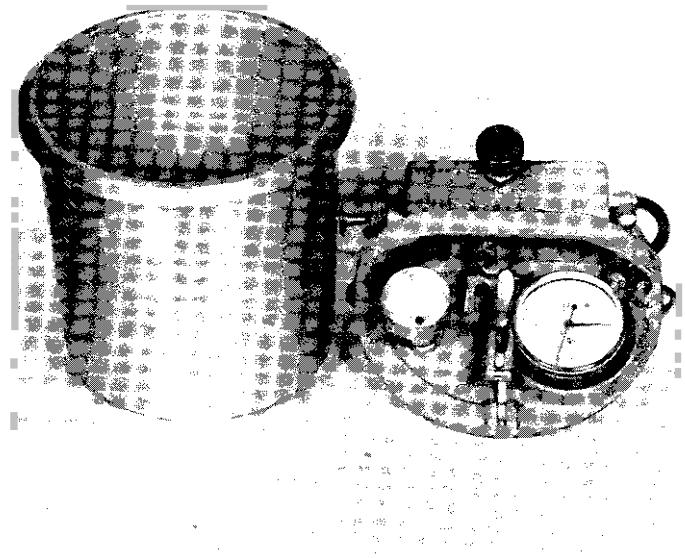

Figure 3-69.—Air meter lid removed and meter ready for placement of concrete sample.

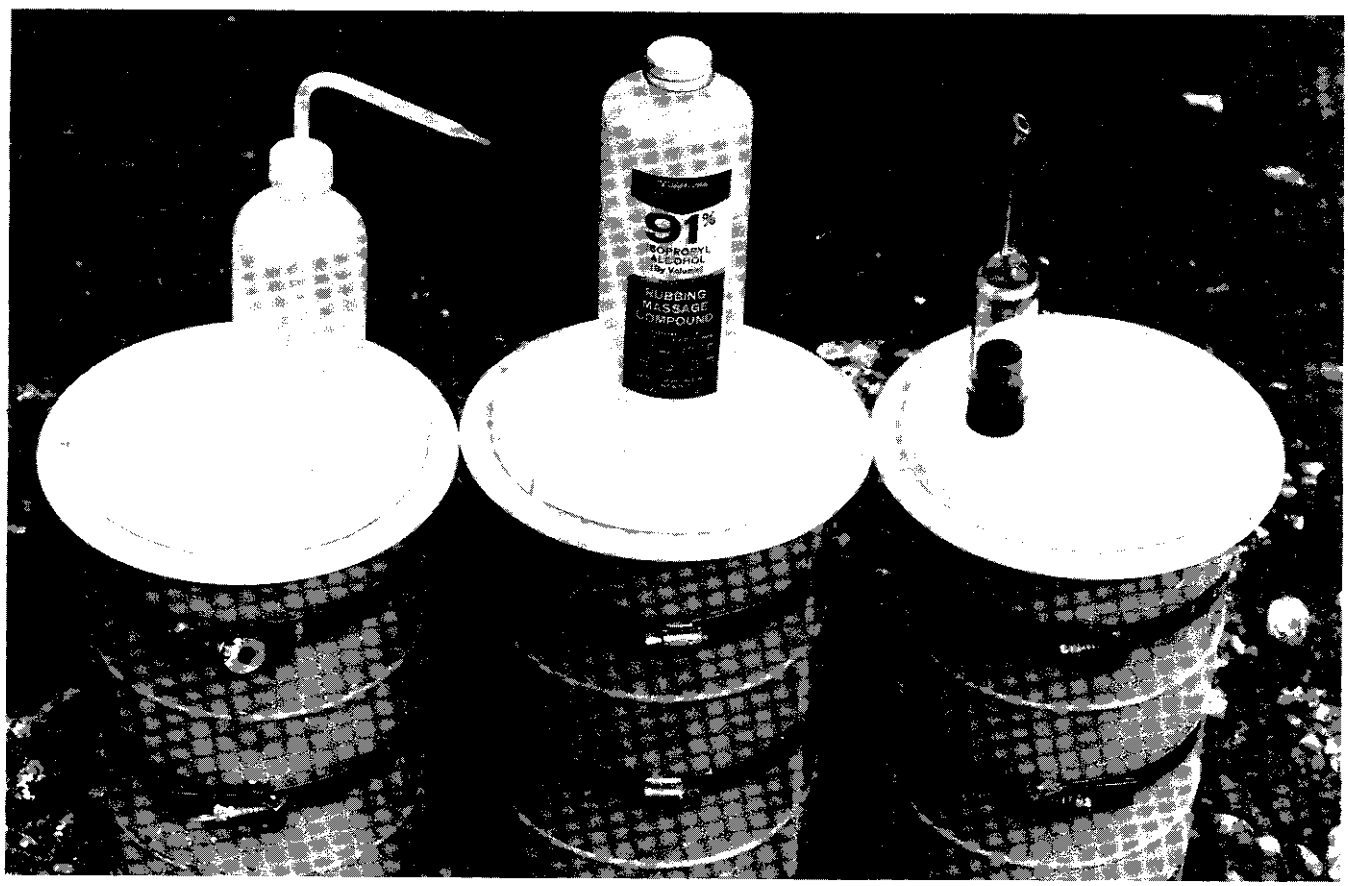

Figure 3-70.—Plastic squeeze bottle, isopropyl alcohol, and air indicator are used in determining the air content of freshly mixed concrete.

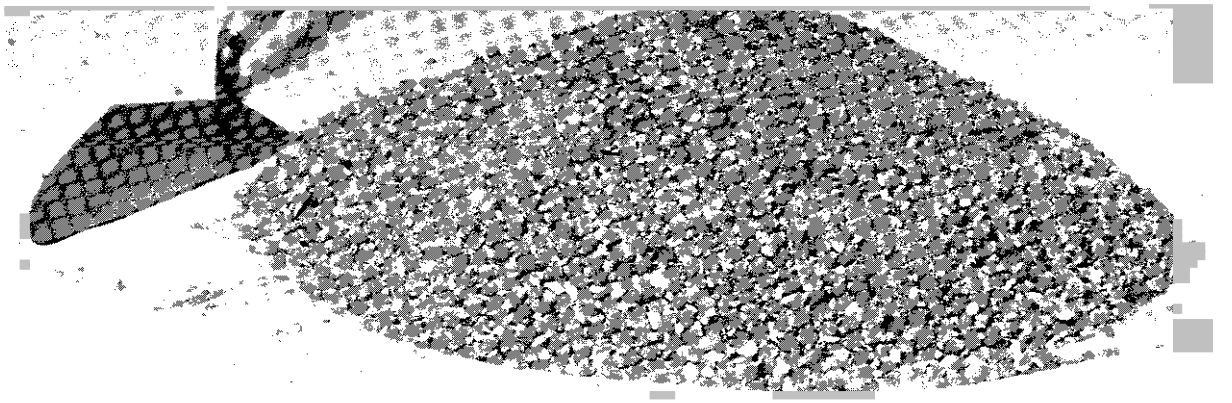

Figure 3-71.—Composite sample is placed in a cone formation.

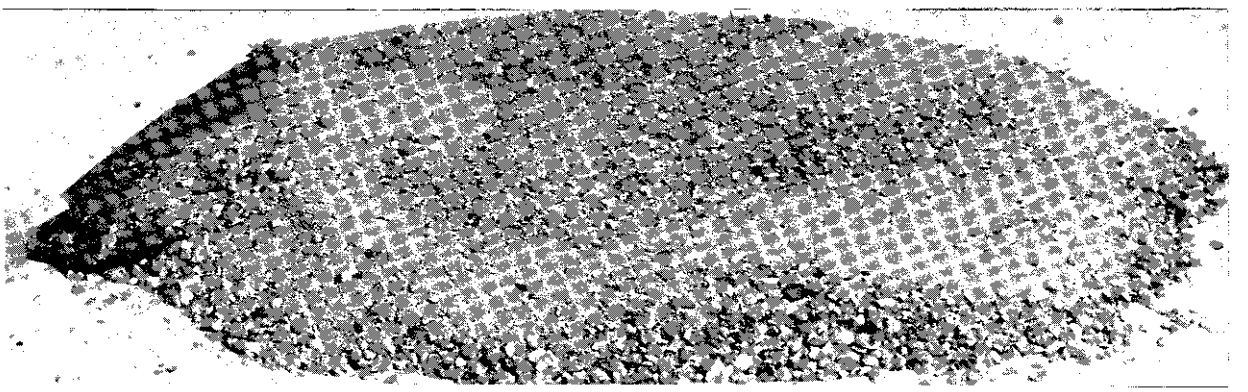

Figure 3-72.—Cone is depressed to *a* uniform frustrum section

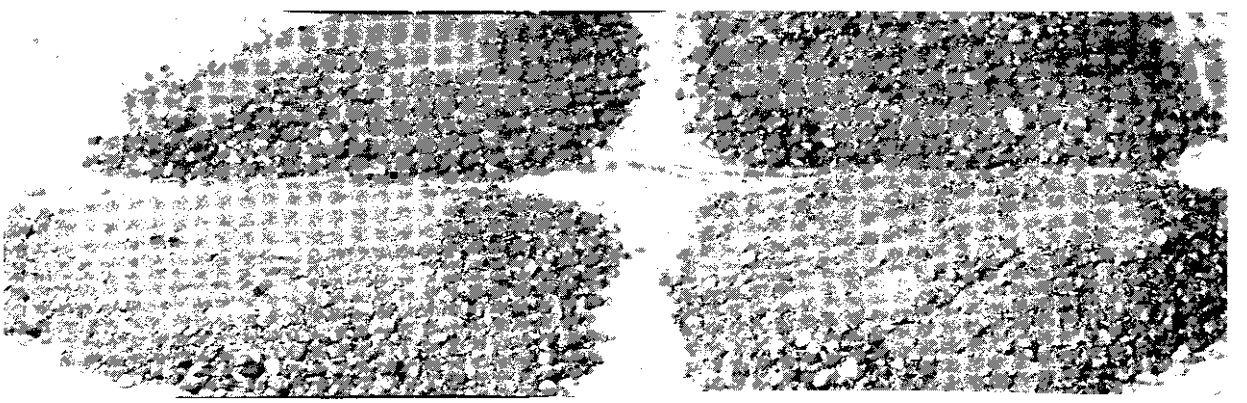

Figure 3-73.—Sample is divided into four equal segments

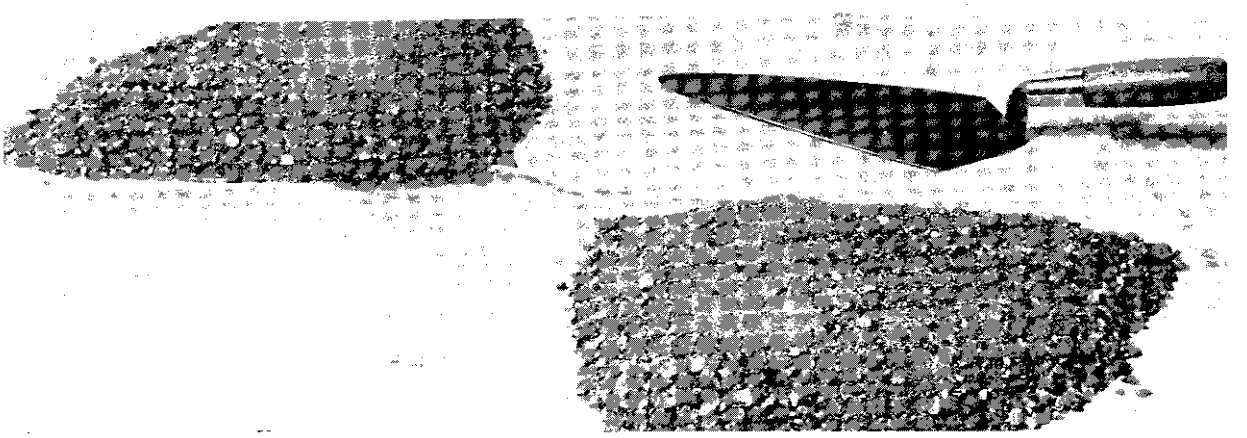

Figure 3-74.—Opposite segments have been removed to be used far testing or to he further reduced by quartering (photos are of laboratory simulations).

SIEVE ANALYSIS

Location Round up U.S.A. Site No. 2-C

Watershed Lucky Peak Subwatershed South Branch

Contract No. 12-10-500-106 Contractor Johnson & Sons Construction Co.

Tested by A-Sullivan Date 4-17-69 Checked by R. Elgin

Source of material Blue Mountain Sand & Gravel Sampled depth: _____ to Stock pile

Material tested: concrete aggregate ☑ drain fill ☐ filter ☐

Bid item No. 8 Reference contract specification M.S.-522 (ASTM C-33) (ASTM C-136)

Coarse aggregate

Weight of container plus dry sample 48.84 lb

Weight of container 5.64 lb

Weight of dry sample (W) 43.20 lb

Sieve size	① Weight of sieve plus material retained (lb)	② Weight of sieve (lb)	③ Weight of material retained = ① − ② (lb)	④ Material retained = (③ ÷ W) X 100 (%)	Cumulative ⑤ Percent retained; subtotal of ④ (%)	Cumulative ⑥ Percent passing = 100% − ⑤ (%)	Specification limits (percent passing)
4 in.							
3½ in.							
3 in.							
2½ in.							
2 in.	1.29	1.29	0.00	0.0	0.0	100.0	100
1½ in.	2.96	1.23	1.73	4.0	4.0	96.0	95-100
1 in.							
3/4 in.	18.91	1.20	17.71	41.0	45.0	55.0	35-70
1/2 in.							
3/8 in.	16.31	1.18	15.13	35.0	80.0	20.0	10-30
No. 4	8.06	1.14	6.92	16.0	96.0	4.0	0-5
No. 8	2.47	1.17	1.30	3.0	99.0	1.0	
Pan	3.02	2.62	0.40	0.9			

Figure 3-75.—Form SCS-ENG-535, "Sieve Analysis."

Fine aggregate

Weight of container and dry sample 10.3 lb

Weight of container 2.1 lb

Weight of dry sample (W) 8.2 lb

Sieve size	① Weight of sieve plus material retained (lb)	② Weight of sieve (lb)	③ Weight of material retained = ① − ② (lb)	④ Material retained = (③ ÷ W) X 100 (%)	Cumulative ⑤ Percent retained; subtotal of ④ (%)	Cumulative ⑥ Percent passing = 100% − ⑤ (%)	Specification limits (percent passing)
318 in.	0.92	0.92	0	0	0	100	100
No. 4	0.99	0.91	0.08	1	1	99	95-100
No. 8	2.43	0.95	1.48	18	19	81	80-100
No. 16	2.57	0.93	1.64	20	39	61	50-85
No. 30	2.48	0.92	1.56	19	58	42	25-60
No. 50	2.42	0.94	1.48	18	76	24	10-30
No. 100	2.21	0.90	1.31	16	92	8	2-10
No. 200							
Pan			0.66	8			
Fineness modulus					$\frac{285}{100}$ [1]	= 2.85	

Materials finer than No. 200 sieve by washing

1. Weight of Container plus moist sample _____ g
2. Weight of container plus dry sample _____ g
3. Weight of container _____ g
4. Weight of dry sample (original) = ② − ③ _____ g
5. Weight of Container plus dry sample (after washing) _____ g
6. Weight of Container _____ g
7. Weight of dry sample (after washing) = ⑤ − ⑥ _____ g
8. Material content finer than No. 200 sieve = [(④ − ⑦) ÷ ④] 100 _____ %

[1] Total of cumulative percent retained, excluding percent retained on No. 200 sieve and material in pan.

Figure 3–75 (cont).—Form SCS-ENG-535; reverse side.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

MATERIALS TESTING REPORT:
SOIL CLASSIFICATION

Project and state *Lucky Peak W.S. Site 2C* Sample location *Blue Mt. Sand & Gravel* Laboratory No.

Field sample No. *2* Depth *–* Geologic origin *Stockpile*

Type of sample *Disturbed* Tested at *Podunk, PA* Approved by *LRS* Date *5-2*

Symbol *SP* Description *Concrete Fine Aggregate*

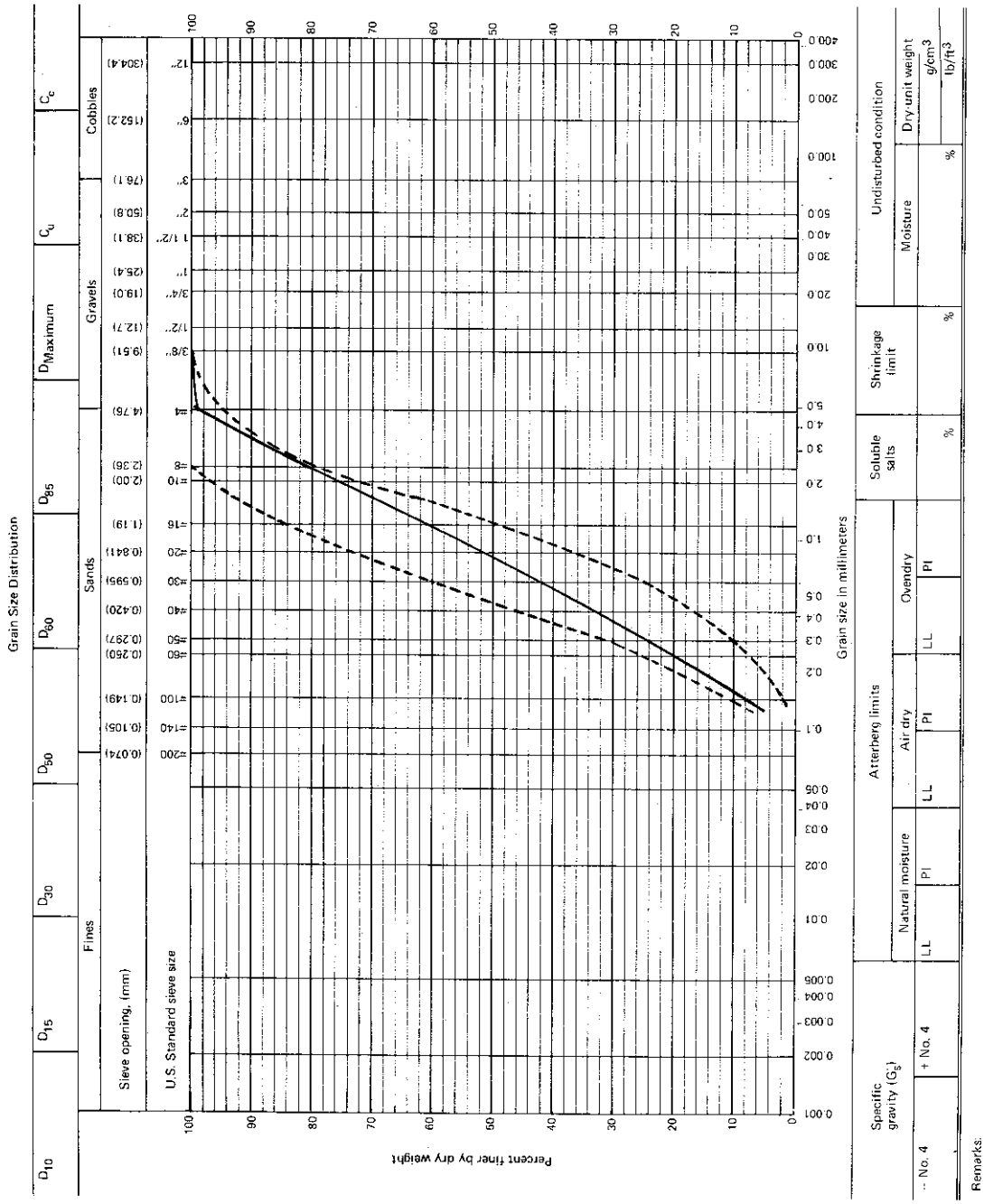

Figure 3–76.—For Soil Classification.

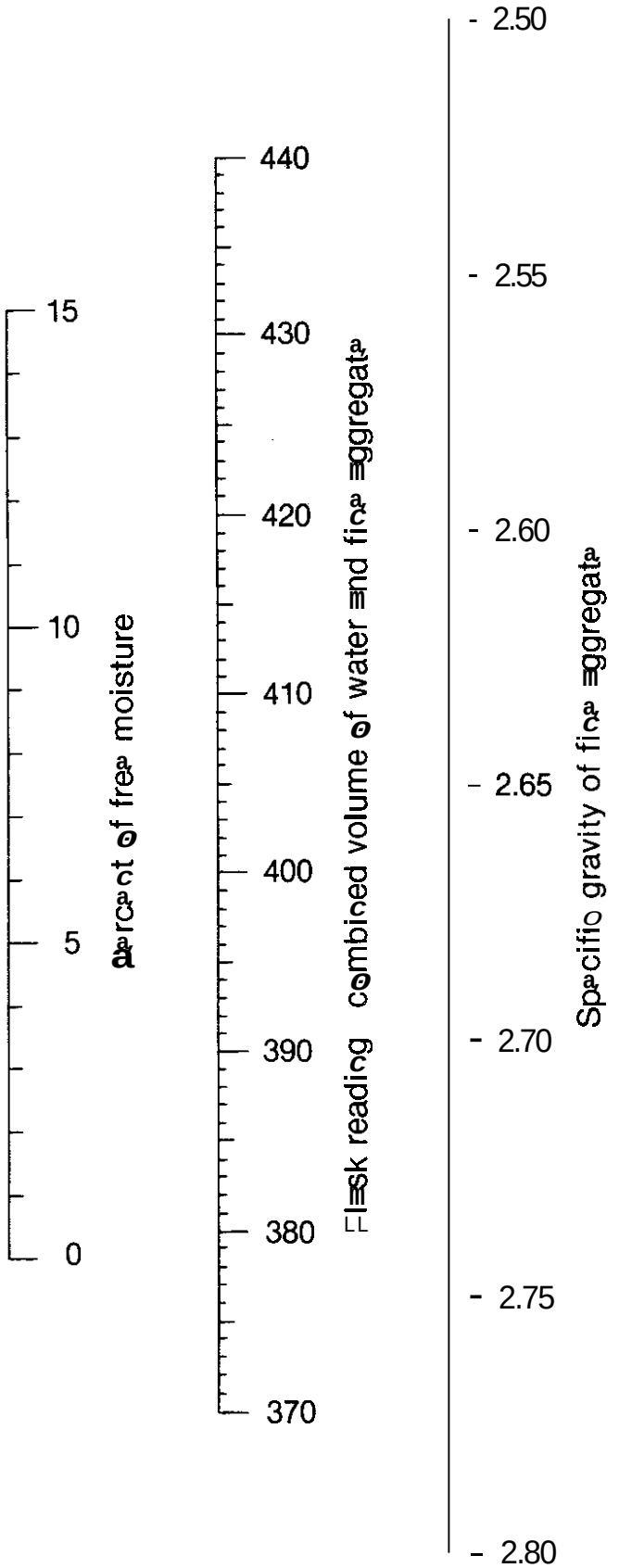

Figure 3-77.—Nomograph for determining free moisture in fine aggregate with a calibrated flask (from Bureau of Reclamation *Concrete Manual*).

Surface Moisture in Fine Aggregate — Test No. C-13

Procedures for determining the surface moisture in fine aggregates are given in ASTM C–70, "Standard Test Method for Surface Moisture in Fine Aggregate." A nomograph may be used (fig. 3–77). Form SCS-ENG-553 (fig. 4–5) or Form SCS-ENG-544 (fig. 4–6) is used for recording and computing data.

Screen Analysis Determination for Drain Fill Aggregate — Test No. D–1

Procedures for determining the sieve analysis of drain fill aggregates are given in ASTM C–136, "Standard Test Method for Sieve or Screen Analysis of Fine and Coarse Aggregates." Form SCS-ENG-535, "Sieve Analysis," is used for recording and computing data (fig. 3–78). Data may be plotted on Form SCS-ENG-353 (fig. 3–76).

Washing Material Finer than No. 200 Sieve from Mineral Aggregates — Test No. D–2

Procedures for testing for materials in mineral aggregates that are finer than a No. 200 sieve are given in ASTM C–117, "Standard Test Method for Materials Finer Than No. 200 Sieve (75 μm) in Mineral Aggregates by Washing." Form SCS-ENG-535 is used for recording and computing data (fig. 3–78).

Graphical Method for Blending Aggregates of Soils of Three Sizes to Obtain a Specified Gradation — Test No. D–3

This is a procedure for rapidly determining the mixture of three sizes of materials to obtain a specified gradation.[9]

Test procedures and recording data.—A sieve analysis is required for each proposed aggregate. If not available, materials must be sampled and tested (use test C–10). The contract will specify the gradation limits.

Graphical work sheets used in determining the acceptable blend of materials and the sieve analysis should be filed with the contract. Entries are needed in the job diary of testing and acceptance or of other action taken to correct deficiencies.

[9] *This graphical method hy George F. Driscoll (then an associate professor of civil engineering at the Uniuersity of Dayton) was published in Engineering News-Record 1961, McGraw-Hill fall rights reserved). The entire presentation is exhibit 3-1; figures I through 4 are grouped in Figure 3–83.*

Graphical Method for Blending Aggregates or Soils of Two or More Sizes to Obtain a Specified Gradation — Test No. D–4

This is a procedure for rapidly determining the mixture of two or more sizes of materials to obtain a specified gradation." It cannot be used to proportion a mixture when each material has variable gradation; for example, 40–60 percent of a material passing a No. 4 sieve. Tests D–3 and D–5 can be used for materials with a variable gradation.

Test procedures and recording data.—A sieve is required for each proposed aggregate or soil. If not available, materials must be sampled and tested (use test C–10). The contract will specify the gradation limits.

Graphical work sheets used in determining the acceptable blend of materials and sieve analysis data should be filed with the contract. Entries are needed in the job diary of testing and acceptance or other action taken to correct deficiencies.

Graphical Method for Blending Aggregates or Soils of Two or More Sizes to Obtain a Specified Range in Gradation — Test No. D-5

This is a procedure for rapidly determining the mixture of two or more sizes of materials to obtain a specified range in gradation?'

Test procedures and recording data.—A sieve analysis is required for each proposed aggregate or soil. If not available, materials must be sampled and tested (use test C–10). The contract will specify the gradation limits.

Graphical work sheets used in determining the acceptable blend of materials and sieve analysis data should be filed with the contract. Entries are needed in the job diary of testing and acceptance or other action taken to correct deficiencies.

"This graphical method was prepared hy SCS engineer Joseph E. Perry, Grenada, Mississippi The entire presentation is exhibit 3–2; examples 1A and 2A mentioned are in figures 3–79 and 340.

"This graphical method was prepared by former SCS geologist Robert C. Boyce, Upper Darby, Pennsylvania. The entire presentation is exhibit 3–3; examples 1B and 2B mentioned are in figures 3–81 and 3–82.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-535
2-80

SIEVE ANALYSIS

Location Round up U.S.A. Site No. 2-C

Watershed Lucky Peak Subwatershed South Branch

Contract No. 12-10-500-106 Contractor Johnson & Sons Construction Co.

Tested by A. Sullivan Date 4-23-69 Checked by A. Elgin

Source of material _____ Sampled depth: _____ to _____

Material tested: concrete aggregate ☐ drain fill ☑ filter ☐

Bid item No. 13 Reference contract specification M.S.5211 (ASTM C-136) (ASTM C-117)

Coarse aggregate

Weight of container plus dry sample _____ lb

Weight Of container _____ lb

Weight of dry sample (W) _____ lb

Sieve size	(1) Weight of sieve plus material retained (lb)	(2) Weight of sieve (lb)	(3) Weight of material retained = (1) − (2) (lb)	(4) Material retained = ((3) ÷ W) X 100 (%)	Cumulative (5) Percent retained; subtotal of (4) (%)	Cumulative (6) Percent passing = 100% − (5) (%)	Specification limits (percent passing)
4 in.							
3½ in							
3 in.							
2½ in.							
2 in.							
1½ in.							
1 in.							
3/4 in.							
1/2 in.							
3/8 in.							
No. 4							
No. 8							
Pan							

Figure 3-78.—Form SCS-ENG-535, "Sieve Analysis."

Fine aggregate

Weight of Container and dry sample 52.65 lb

Weight of container 6.09 lb

Weight of dry sample (W) 46.56 lb

Sieve size	1 Weight of sieve plus material retained (lb)	2 Weight of sieve (lb)	3 Weight of material retained = 1 − 2 (lb)	4 Material retained = (3 ÷ W) X 100 (%)	5 percent retained: subtotal of 4 (%)	6 percent parsing = 100% − 5 (%)	Specification limits (percent parsing)
2 in	1.25	1.25	0.00	0.0	0.0	100	100
1½ in	5.24	1.12	4.12	8.8	8.8	91.2	90-100
¾ in		1	4.9	10.3	1.1	80.9	80-95
318 in.							
No. 4	1.53	1.24	8.29	17.8	36.9	63.1	60-90
No. 8							
No. 16							
No. 30	1.83	1.19	8.64	18.6	55.5	44.5	30-60
No. 50	1.80	1.04	10.76	23.1	78.6	21.4	10-50
No. 100	8.36	1.10	7.26	15.6	94.2	5.8	5-30
No. 200	2.82	1.14	1.68	3.6	97.8	2.2	0-5
Pan	2.64	1.62	1.02	2.2			
Fineness modulus	Ck-46.56 → 100.0				$\frac{1}{100}$	=	

Materials finer than No. 200 sieve by washing

1. Weight of container plus moist sample 9,670.0 g
2. Weight of container plus dry sample 9,406.0 g
3. Weight of container 1,640.0 g
4. Weight of dry sample (original) = 2 − 3 7,766.0 g
5. Weight of container plus dry sample (after washing) 8,986.0
6. Weight of container 1,640.0 g
7. Weight of dry sample (after washing) = 5 − 6 7,346.0 g
8. Material content finer than No. 200 sieve = [(4 − 7) ÷ 4] 100 5.4 %

[1]Total of cumulative percent retained, excluding Percent retained on No. 200 sieve and material in pan.

Figure 3-78 (cont).—Form SCS-ENG-535; **reverse side.**

Graphical Method Simplifies Economical Blending of Aggregates

Economical blending of three differently sized aggregates to meet a specified gradation presents a challenge to engineers, contractors and aggregate producers. Proportioning methods are available, including one presented previously by the author (ENR June 19, 1952, p. 108).

The method described below offers advantages of simplicity and completeness. It is not necessary to make several trials; one solution shows all possible proportions. If the three available aggregates cannot be proportioned to meet the specification, one solution clearly indicates that fact.

The work can be done without a scale or any computations if a T-square and triangle are us-

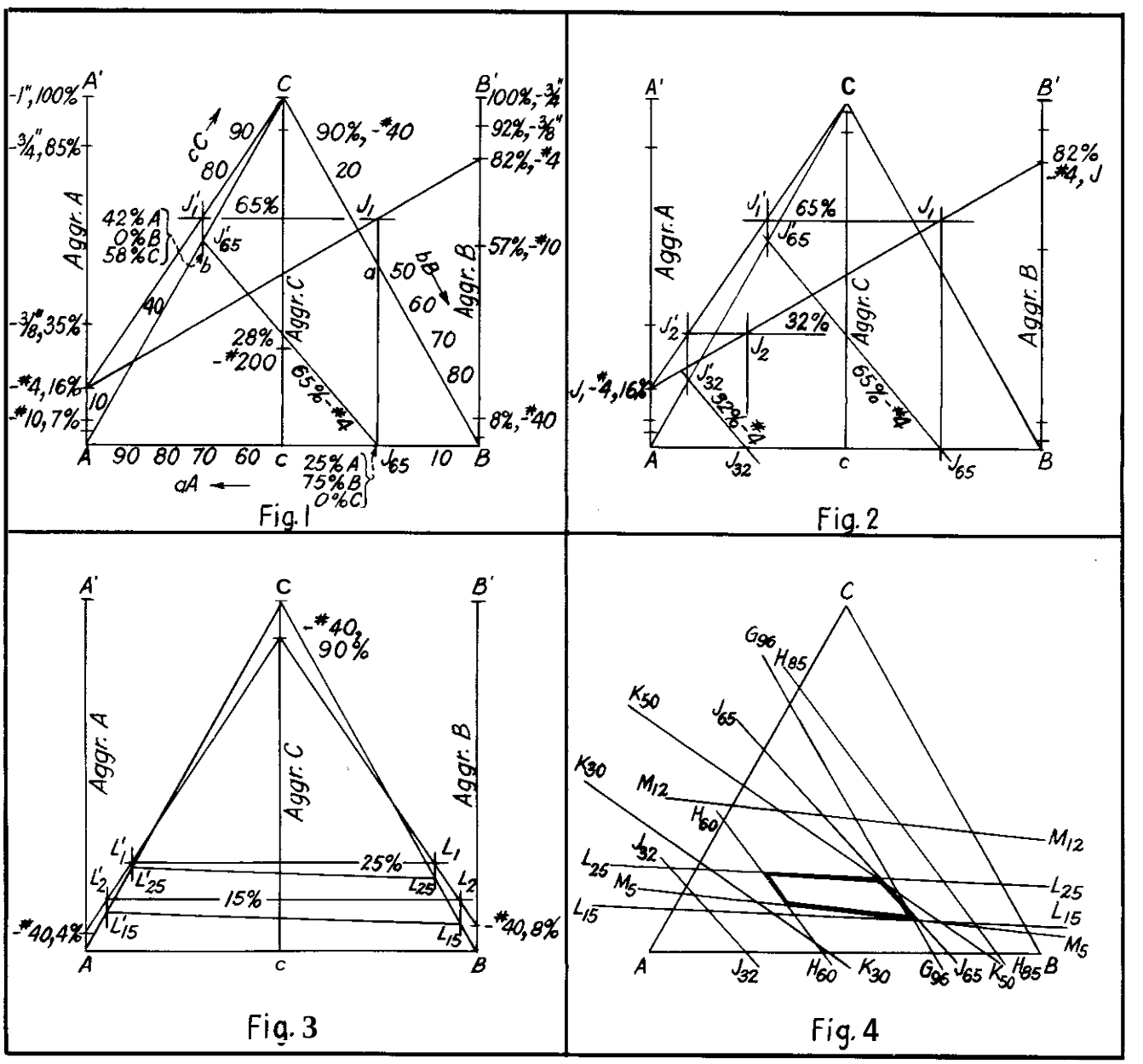

Figure 3–83.—Exhibit 3–1 figures

ed. It is helpful to use several sheets of triangular coordinate paper, transferring the limit lines to an answer sheet as developed.

The method uses gradations of the separate aggregates expressed in terms of total percentages passing each size of sieve.

The use of triangular coordinate paper is based upon the fact that the sum of the distances from any point in an equilateral triangle to the three sides is constant and equals the length of one side. In this case, the sum is **100%.**

In a plot like figure **1,** the point A represents **100%** of Aggregate A, measured from point a; point B represents **100%** of Aggregate B, measured from point b; and point C represents **100%** of Aggregate C, measured from point c.

As an example of the use of the method, consider three aggregates, gradings for which are given in the table. The aggregates are to be combined in such proportions that the blend will meet the specification limits given in the last column.

Aggregate Gradings

Total Percentages Passing

Symbol	Sieve Size	Available Aggregates A	B	C	Specification Limits
F	**1** in.	100	**100**	**100**	**100**
G	3/4 in.	**85**	**100**	**100**	**75–96**
H	**318** in.	**35**	**92**	**100**	**60–85**
J	#4	**16**	**82**	**100**	**32–65**
K	#10	**7**	**57**	97	**30–50**
L	**#40**	**4**	*8*	**90**	**15–25**
M	#200	**0**	**3**	**28**	**5–12**

As a first step, erect a vertical line for each aggregate; A'A, B'B and Cc (see figure **1).** Represent the grading of each aggregate by measuring the respective percentages from the base line (AcB) to the mark for each sieve size.

If Aggregates A and B are blended you can measure the percentage of A in the blend on line AcB; for a blend of A and C, measure the percentage of C on line AC; and for a blend of C and B, measure the percentage of B on line CB.

Consider that portion of the aggregates passing the No. **4** sieve, symbol J (specification limits, **32–65%).** Draw a line from **16%** on A'A to **82%** on B'B. Blends of Aggregates A and B will yield from **16** to **82%** of **–**No. **4** material, as the percentage of A in the blend varies from **100%** to 0%.

Next, find the percentage of A required to yield **65% J** by locating the intersection of the **16%–82%** line with the **65%** horizontal line at **J,.** Project this intersection vertically to the AB line at J_{65}.

Since the line AB is **100%** long, the distance J_{65}–B is the percentage of A which, when proportioned with B, will yield a blend with **65%** of **–**No. **4.**

Draw the line **16%** (A'A) to **100%** (Cc) in figure **1** and find its intersection **J',** with the horizontal **65%** line. Project this intersection vertically to the line AC at J'_{65}.

The point J'_{65} represents the percentage of C necessary to make the **–**No. **4** portion of the blend of A and C equal to **65%.**

Draw a line from J'_{65} to J_{65}. This line represents numberless blends of aggregates A, B and C, all yielding **65%** of **–**No. **4** material. Note that point J_{65} represents **25% A, 75%** B and **0%** C; J'_{65} represents **42%** A, 0% B and **58% C.**

To complete the work on the **–**No. **4** fraction, refer to figure **2.** Intersect the **16%–100%** line with the **32%** horizontal line at J'_2. Project this intersection vertically to the AC line at J'_{32}, which indicates that an **81% A–19%** C blend will have **32%** passing the No. **4** sieve.

Next, intersect the **16%–82%** line with the **32%** horizontal line at J_2.

Project this intersection vertically downward to the AB line at J_{32}, which indicates that a **76%** A–24% B **(0%** C) blend will have **65%** passing the No. **4** sieve.

Draw a straight line from J'_{32} to J_{32}. Any proportion of A, B and C represented by points on the line J'_{32}–J_{32} will yield a blend with **32%** passing the No. **4** sieve.

Consideration of the area enclosed by the line J'_{65} and J_{65} and the line J'_{32} and J_{32} reveals that

the method is simple and complete. Any point in this area represents a blend of Aggregates A, B and C that will meet the specifications for the No. 4 sieve.

Figure 3 shows how the limits of proportions to meet the specifications for the No. 40 sieve are determined using the same basic procedures.

Diagrams illustrating the work for fractions F, G, **H, K** and M are not shown, but all limit lines have been transferred to figure 4 to show the final results. It is unnecessary to draw any lines for the 1-in. size (F); only one line is shown for the 314-in. size (G). The other 314-in. line passes through point A, since 100% of Aggregate A would yield the smallest percentage passing a 314-in. sieve.

In figure 4, the area enclosed by heavy lines is within all limits and encloses points representing all possible proportions of aggregates A, B and C that can be used to obtain a specification blend. Aggregate A can vary from 28.7 to 59.6%; B from 17 to 60%; and C from 11 to 23.5%.

If an area is not enclosed by each pair of limit lines, it is impossible to meet the size specifications with the available aggregates.

Graphical Method for Proportioning a Mixture of Soils to Obtain a Specified Gradation of Materials

Proportioning the amounts of two or three different soils to be mixed to obtain a predetermined gradation has often been a time-consuming trial-and-error process. The Grenada, Mississippi, Project Engineer's staff used the following method for two construction seasons and found it to be reliable:

- List the sieve sizes (specified gradations) and the percentages of soils A and B (and D if needed) passing each sieve.
- As shown in example 1A, designate the percentages (in increments of 20) for soil A in the mixture along the top of a graph with descending values from left to right. Do the same for soil B along the bottom with descending values from right to left. Designate percentages (in increments of 20) passing a sieve size for soil **A** along the left side with descending values from top to bottom. Do the same for soil B along the right side with descending values from top to bottom.
- Plot the percentages for each sieve size of soil A along the left side and of soil B along the right side. Connect soil **A** and B plots for each sieve size with straight lines, and mark each line with the appropriate sieve size.
- Review the allowable percentages of material passing each sieve size as a guide in selecting a trial mixture. In this example, the mixture could range from 52% **A** + 48% B to 31% A + 69% B; the approximate middle is 40% A + 60% B. Draw a vertical line connecting the 40–60 percentages and designate it as the trial mixture.
- Mark on the graph at each intersection of a vertical line (trial mixture of 40% A + 60% B soils) with a diagonal line (sieve size) the percentage passing each sieve size. If each percentage falls within the specified sieve size, the trial mixture is acceptable. List the percentages under soil C (40% **A** + 60% B soils) opposite their respective sieve sizes.
- Fill in the acceptable mixture for the two soils.

Example 1A

Sieve size	Specified gradation (percent passing)	Soil A (percent passing)	Soil B (percent passing)	Trial mixture: 40% soil A + 60% soil B (percent passing)	Acceptable mixture for Soil C
2 in	100	100	100	100	40% of Soil A
1 in	85–95	80	100	92	
½ in	70–90	53	100	81	
⅜ in	60–80	29	100	71	
No. 4	50–70	9	96	61	60% of Soil B by dry weight
No. 10	40–60	4	81	50	
No. 20	30–50	0	70	42	
No. 30	20–40	0	56	34	
No. 50	10–30	0	38	23	
No. 100	0–20	0	8	4	
No. 200	<5	0	2	1	

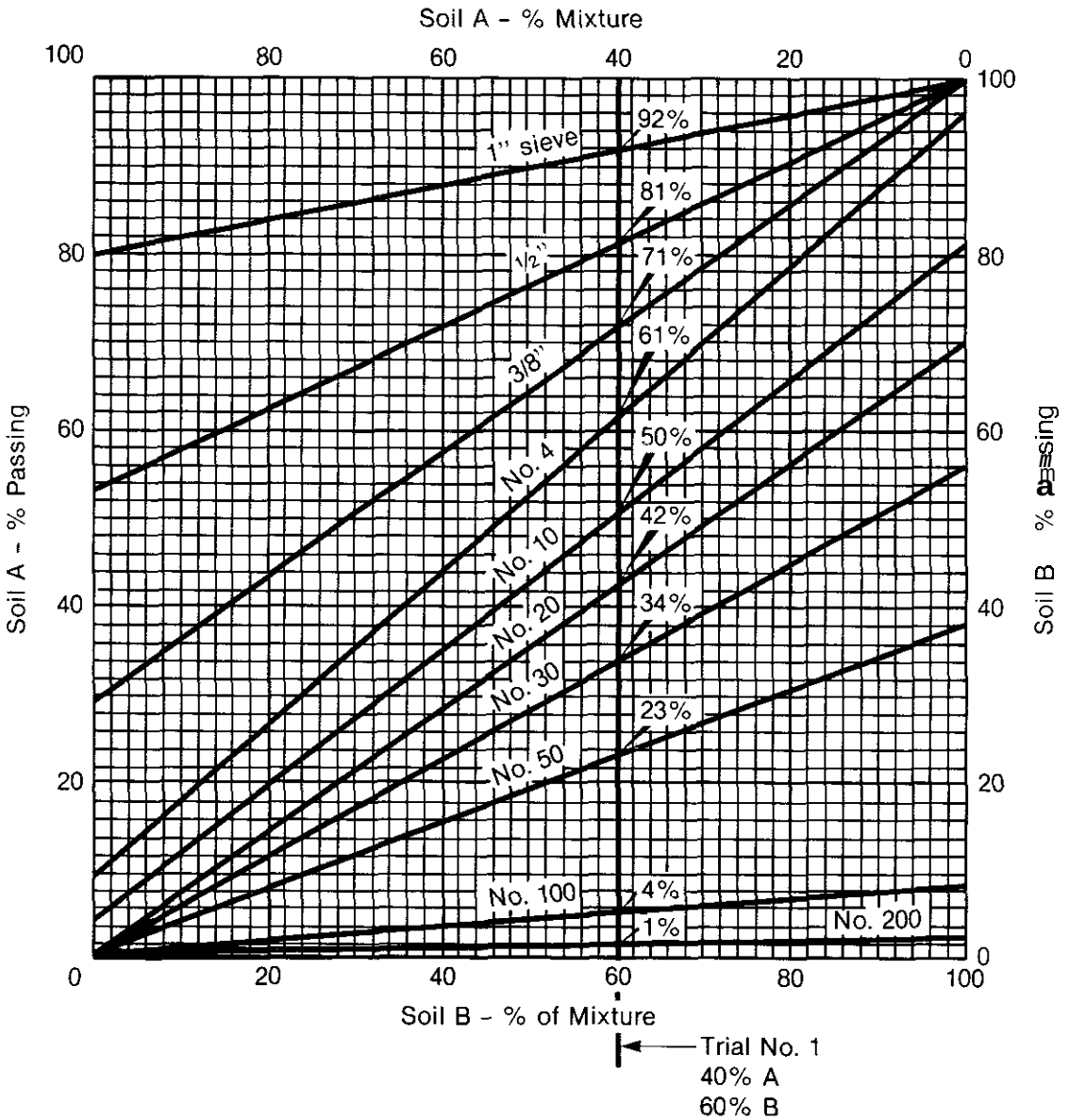

Figure 3–79.—Example 1A: How to proportion a mixture of soils A and B to obtain a specific gradation.

Example 2A

Sieve sue	Specified gradation	Soil A	Soil B	Soil C from example 1A: 40% soil A 60% soil B	Soil D	Trial mixture 80% soil C + 20% soil D
	(percent passing)	(percent passing)	(percent passing)	(percent passing)	(percent passing)	(percent passing)
2 in	100	100	100	100	100	100
1 in	85–95	80	100	92	100	93
½ in	70–90	53	100	81	100	85
⅜ in	60–80	29	100	71	100	77
No. 4	50–70	9	96	61	71	63
No. 10	40–60	4	81	50	56	51
No. 20	30–50	0	70	42	38	41
No. 30	20–40	0	56	34	36	34
No. 50	10–30	0	38	23	30	24
No. 100	0–20	0	8	4	28	9
No. 200	<5	0	2	1	6	2

Final mixture: 40% soil A of the 80-percent soil C = 32% soil A +
60% soil B of the 80-percent soil C = 48% soil B +
20% soil D = 20% soil D

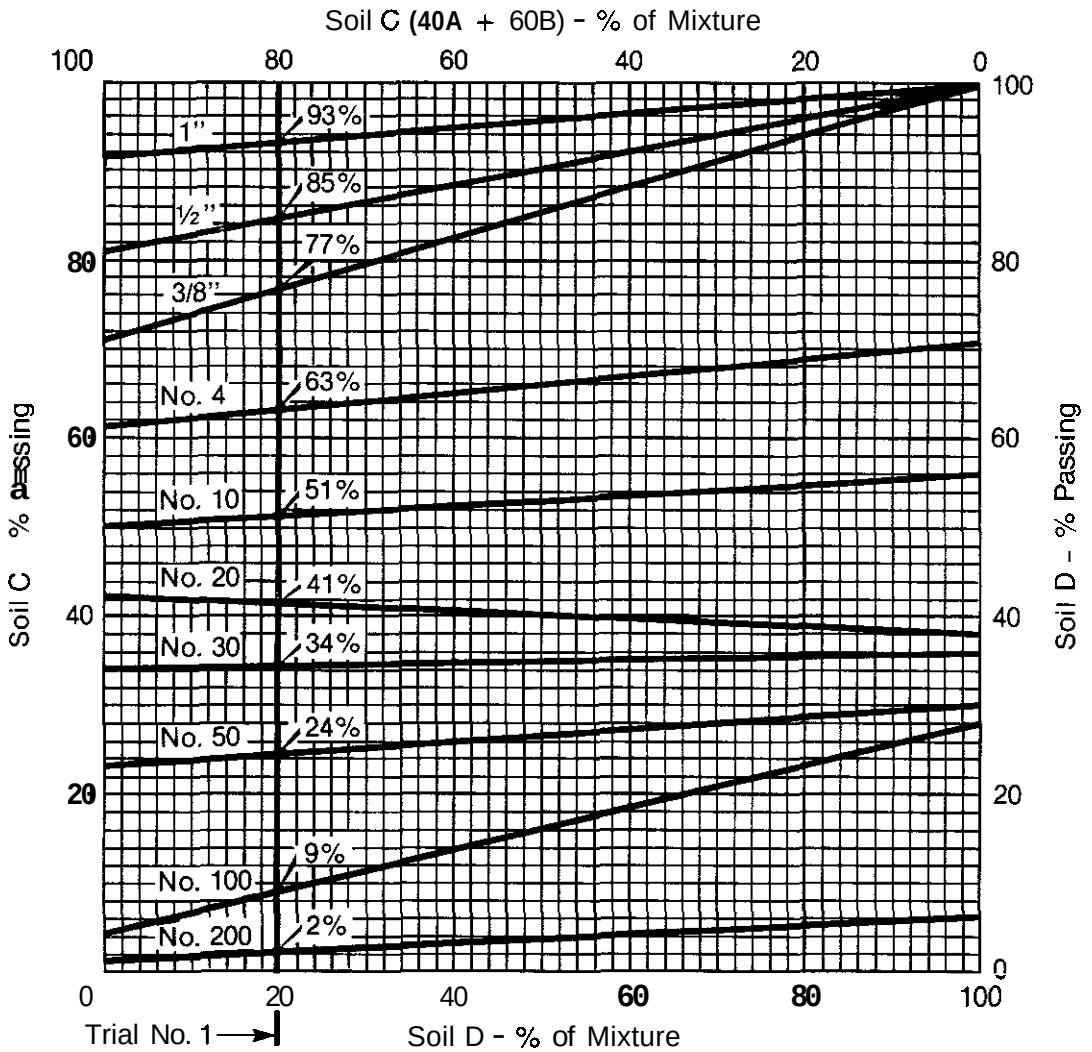

Figure 3-80. — Example 2A: How to proportion a mixture of soiis A, B, and D to obtain a gradation with a higher percentage passing a No. 100 sieve than in soil C (mixture of soils A and B) from example 1A.

Example 2A shows the blending of soil C (mixture of 40% **A** + 60% B soils) with a soil D to increase the amount of material passing the No. 100 sieve in the final mixture.

For each sieve size, plot the percentages of soil C along the left side and plot the percentages of soil D along the right side. Connect C and D plots, mark appropriate sieve sizes, review allowable percentages, select a trial mixture (80%C + 20% D soils appears a good choice), mark percentages at each intersection, and compare percentages with the specified gradation of percentages allowed. If each percentage falls within the gradation, then the trial mixture is acceptable; and it shows 0% passing the No. 100 sieve compared to *4%* for the mixture of soils A and B.

The final mixture can now consist of:

Soil **A** = 40% of the 80-percent Soil C = 32% of the mixture by *dry* weight.
Soil B = 60% of the 80-percent Soil C = 48% of the mixture by *dry* weight.
Soil D = 100% of the mixture by *dry* weight minus **32%** and minus 48% = 20% by dry weight.

Procedures for Proportioning Mixtures of Soils to Obtain a Specified Range in Gradation of Materials

- List the sieve sizes, their specified gradations, and the percentages of soils A and B passing each sieve.
- As shown in example 1B, designate percentages (in increments of 20) for soil A in the mixture along the top of a graph with descending values from left to right. Do the same for soil B along the bottom with descending values from right to left. Designate percentages (in increments of 20) passing a sieve size for soil A along the left side with descending values from top to bottom. Do the same for soil B along the right side with descending values from top to bottom.
- Plot the percentages for each sieve size of soil **A** along the left side and of soil B along the right side. Connect soil A and B plots for each sieve size with straight lines, and mark each line with the appropriate sieve size.
- On these straight lines connecting the **A** and B plots, mark the gradation-limit percertages for each sieve size (see specified gradation column % passing). In example 1B, limits for the 1-in. sieve are 85 and 95%. The 85-percent mark corresponds to a blend of **75%** soil A + 25% soil B; the 95-percent mark corresponds to 25% soil A + **75%** soil B. So any mixture of soils A and B containing 25–75% soil A will meet gradation specifications for the 1-in. sieve. Plotting the 70- and 90-percent limits for the ½-in. sieve shows that any mixture of soils A and B containing 21–64% soil **A** will meet gradation specifications.
- After plotting all gradation limits, connect the minimum limits with a line and the maximum limits with another line. Note the maximum limit with the lowest percentage and the minimum limit with the highest percentage. Draw vertical lines at or just inside these limits to mark the span of acceptable mixtures. In example 1B, any mixture of soils A and B having 30–52% soil A will meet gradation specifications.
- Any blend of soils **A** and **B** between these vertical lines will meet gradation specifications for any sieve size. If no range of acceptable mixtures can be drawn (maximum limit with the lowest percentage overlaps with the minimum limit with the highest percentage), then the two

Example 1B

Sieve size	Specified gradation (percent passing)	Soil **A** (percent passing)	Soil B (percent passing)	Acceptable **mixture** of **A** and B
2 in	100	100	100	*all soil*
1 in	85–95	80	100	***A** and B*
½ in	70–90	53	100	*maxtures*
⅜ in	60–80	27	100	*with*
No. 4	50–70	9	96	*30-52%*
No. 10	40–60	4	81	*Soil **A***
No. 20	30–50	0	70	
No. 30	20–40	0	56	
No. 50	10–30	0	38	
No. 100	0–20	0	8	
No. 200	<5	0	2	

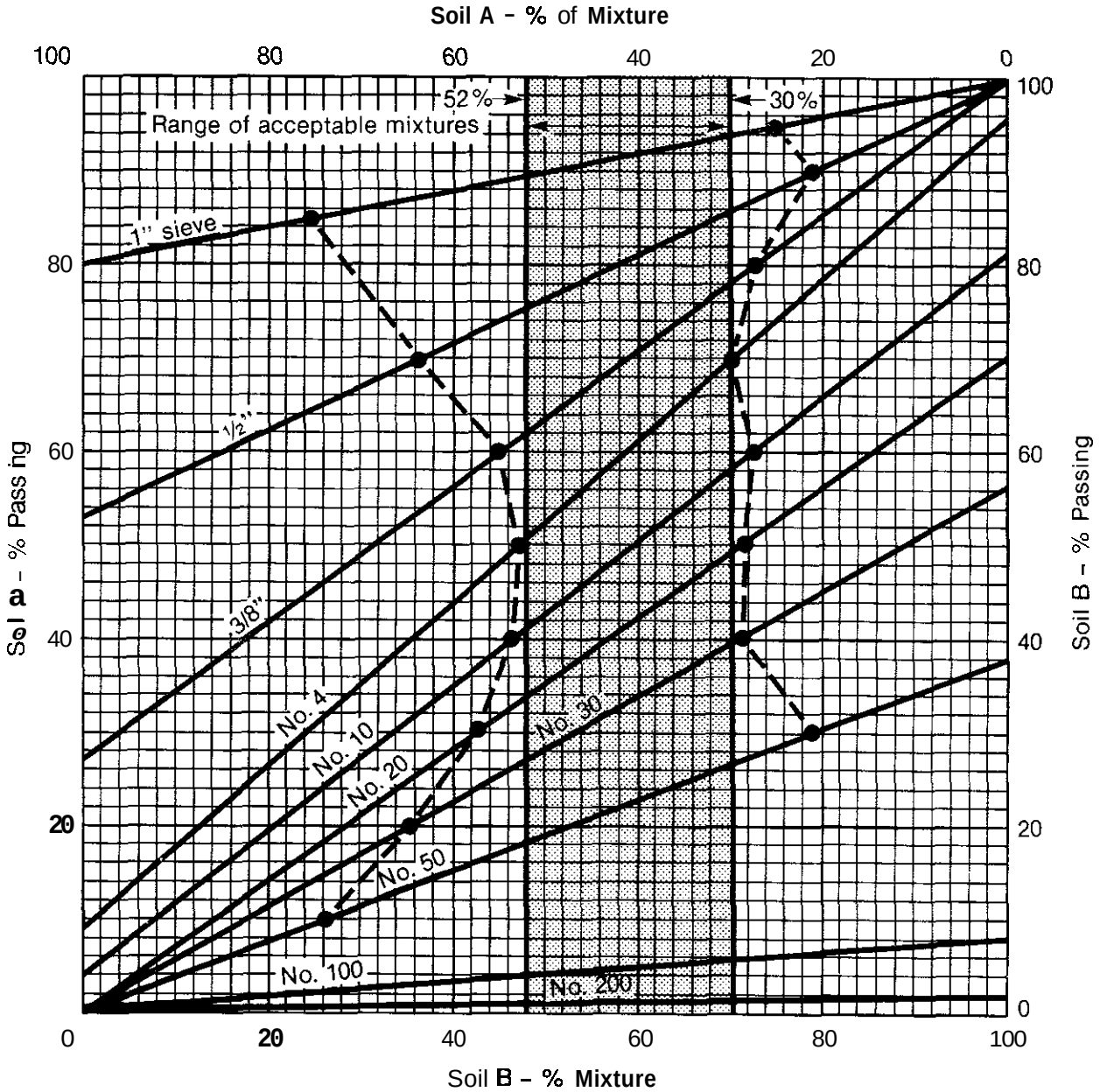

Figure 3-81.—Example 1B: How to proportion a mixture of soils **A** and B (having **single-gradation** characteristics) to obtain a specified gradation.

Example 2B

Sieve size	Specified gradation (percent passing)	Soil A (percent passing)	Soil B (percent passing)	Acceptable mixture of A and B
2 in	100	100	100	all soil A and B mixtures with 30-43% Soil A
1 in	85–95	75–80	100	
½ in	70–90	50–53	100	
⅜ in	60–80	20–27	90–100	
No. 4	50–70	5–9	90–96	
No. 10	40–60	0–4	75–81	
No. 20	30–50	0	65–70	
No. 30	20–40	0	50–56	
No. 50	10–30	0	30–38	
No. 100	0–20	0	5–8	
No. 200	<5	0	0–7	

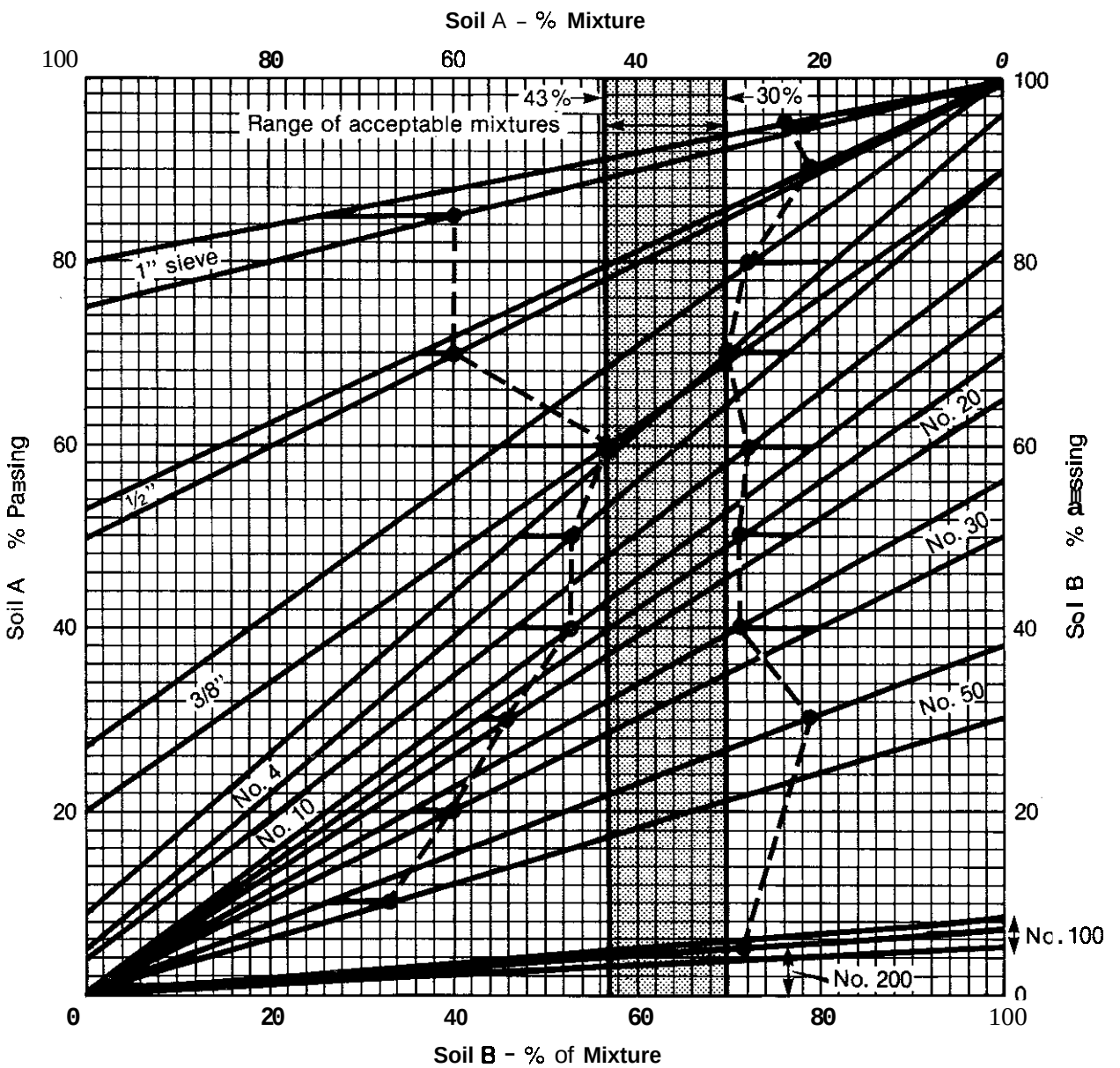

Figure 3-82.—Example 2B: How to proportion a mixture of soils A and B (having variable-gradation characteristics) to obtain a specified gradation.

soils cannot be blended to meet gradation specifications.

- Borderline blends should be avoided because the gradations that can be shown graphically may not represent exactly the natural materials. For the 30–52% soil **A** range in example 1B, a good choice for a blend would be 40% soil **A** and 60% soil B.

Example 2B graphically shows soil-blending determinations when several test results of soil-passing percentages for soils **A** and B are used for each sieve size.

Plot the greater and lesser percentages for each sieve size of soil **A** along the left side and those of soil B along the right side. Connect the greater percentage of soil **A** and the greater percentage of soil B with a straight line. Do the same between the lesser percentages of soils **A** and B. This produces an envelope for each sieve size. Mark the appropriate sieve size between the "greater" and "lesser" lines.

Mark the gradation-limit percentages on these straight lines. Connect the minimum-limit points and maximum-limit points with separate lines. The maximum limit with the lowest percentage and the minimum limit with the highest percentage mark the vertical-line edges of the span of acceptable mixtures. In example 2B, for soil **A,** the span is 30–43%. Percentage blends between these limits meet gradation specifications for all sieve sizes. Borderline blends should be avoided. In example 2B, 40% soil **A** + 60% soil B or 35% soil **A** + **65%** soil B would be good choices.

The graph can become cluttered where sieve-size envelopes for variable-gradation materials overlap. This is less of a problem if each envelope is completed, carefully labeled and color-coded, and its maximum and minimum gradation limits marked before plotting the next sieve size.

United States
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Soil
Conservation
Service

National Engineering Handbook

Section 19

Construction Inspection

Chapter 4

Records and Reports

Chapter 4 Contents

	Page
Weekly summary of density determinations (SCS-ENG-532)	4–1
Heading	4–1
Columns of table	4–1
Distribution	4–2
Embankment construction report (SCS.ENG.550)	4–2
Instructions.,	4–2
Concrete materials and the job mixture (SCS.ENG.551)	4–2
Heading	4–2
Materials	4–2
Batch per cubic yard	4–7
Signature and date	4–7
Concrete batch delivery ticket (SCS.ENG.552)	4–7
Heading	4–7
Batching record	4–7
Jobsite record	4–7
Concrete trial mixture data (SCS.ENG.553)	4–8
Daily concrete batching record (SCSENG.544)	4–8
Heading	4–8
Center table	4–8
Quantities per cubic yard	4–13
Total production	4–13
Remarks and signature	4–13
Concrete batch and yield computations	4–13
Distribution	4–13
Pile driving record (SCS.ENG.545)	4–13
Heading	4–13
Table	4–13
Reverse side	4–13
Engineering notes	4–13
Pile-driving record	4–13
Test pile-driving record	4–14
Test pile-loading record	4–14
Quantity computations and other records (SCS-ENG-552A, SCS.ENG.528, SCS.ENG.529, SCS.ENG.546. SCS.ENG.004. SCS.ADS.53)	4–14
Earthwork	4–14
Formula for computing end areas	4–31
Level cross sections	4–31
Three-level sections	4–31
Irregular cross sections	4–32
Borrow areas	4–32
Concrete	4–32
Steel	4–33
Other items	4–33

Page

Completion of contract. 4–33
As-built drawings. 4–33
Construction completion report. 4–34
Content 4–34
"Form" completion report (SCS-ENG-547, SCS-ENG-548). 4–35
Distribution 4–35

Table of forms used by field construction offices (SCS-ENG-549). 4–35
Preparation of form. 4–35

Chapter 4 Figures

4–1 Form SCS-ENG-532, "Weekly Summary of Density Determinations". 4–3
4–2 Form SCS-ENG-550, "Embankment Construction Report", ... 4–4
4–3 Form SCS-ENG-551, "Certification of Materials and Concrete Mixture". 4–6
4–4 Form SCS-ENG-552, "Concrete Batch Delivery Ticket". 4–9
4–5 Form SCS-ENG-553, "Concrete Trial Mix Data". 4–10
4–6 Form SCS-ENG-544, "Daily Concrete Batching Record". 4–11
4–7 Form SCS-ENG-545, "Pile Driving Record". 4–15
4–8 Engineering notes; example of field notes for pile driving 4–16
4–9 Engineering notes; example of field notes for test pile driving. 4–17
4–10 Engineering notes: example of field notes for test pile loading. 4–18
4–11 Form SCS-ENG-522A, "Computation Sheet". 4–19
4–12 Form SCS-ENG-528, "Earthwork Computation Sheet"; example 1. 4–20
4–13 Form SCS-ENG-528; example 2. 4–21
4–14 Form SCS-ENG-528; example 3. 4–22
4–15 Form SCS-ENG-528; example 4. 4–23
4–16 Form SCS-ENG-529, "Earthwork Computation Sheet". 4–24
4–17 Form SCS-ENG-004, "Tabular Computations". 4–25
4–18 Form SCS-ENG-546, "Bid Item Record Sheet": example 1. 4–26
4–19 Form SCS-ENG-546; example 2. 4–27
4–20 Form SCS-ENG-546; example 3. 4–28
4–21 Form SCS-ADS-53, "Progress Sheet Computations of Contract Pay Items". 4–29
4–22 Form SCS-ENG-547, "Construction Completion Report". 4–36
4–23 Form SCS-ENG-548, "Summary of Construction Quantities and Costs". 4–39
4–24 Form SCS-ENG-549, "Table of Forms Used by Field Construction Office". 4–40

Chapter 4 Table

4–1 Earthwork computation table. 4–30

Chapter 4
Records and Reports

One of the most important responsibilities of a project engineer is keeping the records and reports required in administering the construction contract. This section of the National Engineering Handbook, the Federal Acquisition Regulation (FAR) for Federal Contracting and Contract Administration, and parts 516 and 517 of the Contract Grants and Cooperative Agreements Manual show what records and reports are required and give instructions for their use. Documentation pertaining to specific inspections and tests is described in earlier sections of this handbook. For project or other offices to have a complete set of instructions and forms for contract administration, they should have these references.

Weekly Summary of Density Determinations (SCSENG-532)

Form SCS-ENG-532, "Weekly Summary of Density Determinations," is used to record weekly field density determinations of earthwork on a particular construction site (fig. 4-1).

Heading

Location—Give the location of the field office administering the contract.

Owner—Name the contracting organization or landowner.

Submitted by—Name the engineer or the inspector.

Date—Give the date the report was submitted.

Watershed, subwatershed, site No., contractor, contract No.—Show these exactly as they are in the contract.

Report period *(from-to)*—State the month, day, and year.

Columns of Table

Data for these columns are taken directly from the moisture-density determination sheets (the SCS-ENG-530 forms, B through I) prepared in connection with the field-density determinations (variously numbered figures between 3-13 and 3-40). Instructions given the contractor should be summarized in the report if any corrective action was taken after any tests. Data of the retests made on the reworked embankments should be included.

Distribution

Original—Keep it in the office responsible for engineering services.

Copies—Send to the SCS state conservation engineer, government representative (when non-SCS engineering services are involved), and the NTC if appropriate.

Embankment Construction Report (SCS-ENG-550)

Instructions

Form SCS-ENG-550, "Embankment Construction Report," is useful to supplement the moisture-density test data (fig. **4–2).**

If embankment materials consist of fine-grained, nongravelly soils, only a brief description of the materials is needed—classification, origin of materials (such as loess, till, alluvium), and any other characteristics that might affect the job. Normally, reports contain brief descriptions of the placement and watering operations, including the compaction equipment, number of passes, and lift thicknesses before and after compaction.

If gravelly and stony soils, degradable shale, sandstone, siltstone, disintegrating gneiss and schist, or similar materials are present, each type of material must be described as fully as possible. It is important to evaluate placement methods and equipment performance in ripping and excavating these materials. **All** operations and equipment used to obtain specified results for each type of material must be described in detail. Adequate gradation determinations are needed before and after compaction to provide a fair evaluation of the equipment and methods used.

Data reported under the "borrow source" and "inplace density test numbers" must conform to the data reported individually on the SCS-ENG-530 forms (variously numbered figures between 3–13 and 3–40). Group inplace density tests must be identified by the proper number of each borrow material source and each change in the equipment or method used in the compaction; for example, under borrow source, emergency spillway; test numbers, H–3, H–5, H–9, and H–15; and group, IIB; or for example, under borrow source, borrow area B; tests, **H–4,** H–7, H–10, and H–19; and group, III.

SCS-ENG-550 is especially useful in evaluating test fills because individual density tests can be compared to specific equipment, methods, and materials and to gradation characteristics. This form, when used concurrently with inplace moisture-density determinations (from SCS-ENG-530, B through I), provides a complete record of the placement and compaction results, which then can be related to changes in material, equipment, or methods. This information is invaluable in selecting criteria for testing, preparing construction specifications, and controlling construction of all variable materials, particularly those containing durable or degradable gravel and rock.

Concrete Materials and the Job Mixture (SCS-ENG-551)

The contractor is to use Form SCS-ENG-551, "Certification of Materials and Concrete Mixture," to submit a proposed concrete mixture design to the engineer before delivering concrete to the job-site (see fig. 4–3 and the contract specifications). If the engineer is responsible for formulating the mixture, the engineer can also use the form to record sources of the concrete materials and the mixture for each part of the work. The engineer must review the information submitted by the contractor to determine that the materials are satisfactory and that the mixture will produce concrete of the characteristics and quality specified.

Heading

The information for the heading is in the contract.

Materials

The contractor is to complete all entries under materials unless the contract specifies otherwise.

Cement—State the type, brand name, and manufacturer.

Aggregates—Identify the supply source and bulk specific gravity of each size.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-532
2-80

WEEKLY SUMMARY OF DENSITY DETERMINATIONS

Location Safford Arizona owner Frye Creek-Stockton Wash Submitted by: D. Riddle date 3-23 19 64
Watershed Frye Creek-Stockton Wash Subwatershed Stockton Wash Site No.
contractor Rouden Construction Company Contract No. F.C.S.W. ** Report period: from 3-16 19 64 to 3-20 19 64

Test No.	Date of test	Location of sample: From (dam, core, etc.)	Station No.	Distance right or left of ℄	Elevation	Particle control size	Corrected moisture (%)	Dry density (lb/ft³)	Optimum moisture (%)	Maximum dry density (lb/ft³)	Compaction (%)	Compaction specified (%)	Instructions to contractor	Tested by
5-109	3-16	Dam	125+00	Rt 10ft of ℄	2,994.6	#4	13.4	116.1	13.6	119.0	97.6	95	OK	ET
5-110	3-16	Dam	132+00	℄	2,998.4	#4	15.9	112.9	13.6	119.0	94.9	95	OK	ET
5-111	3-16	Dam	122+00	℄	2,992.9	#4	17.0	102.6	18.3	104.0	98.7	95	OK	ET
5-112	3-16	Dam	110+00	Rt 30ft of ℄	2,992.5	#4	18.9	105.6	17.1	106.2	99.4	95	OK	ET
5-113	3-17	Dam	117+00	℄	2,995.6	#4	13.7	112.8	15.3	114.8	98.3	95	OK	ET
5-114	3-17	Dam	114+00	℄	2,995.2	#4	10.3	104.4	12.1	110.3	94.7	95	Additional milling required	ET
5-115	3-17	Dam	111+00	Lt 20ft of ℄	2,997.5	#4	16.7	111.5	15.3	114.8	97.1	95	OK	ET
5-116	3-17	Dam	126+00	Rt 10ft of ℄	2,995.2	#4	11.5	115.3	10.9	117.0	98.5	95	OK	ET
5-117	3-18	Dam	109+00	Rt 20 ft of ℄	2,997.0	#4	18.8	107.1	16.4	109.3	98.0	95	OK	ET
5-118	3-18	Dam	116+00	Rt 40ft of ℄	2,994.3	#4	10.1	114.6	10.9	117.0	97.9	95	OK	ET
5-119	3-18	Dam	134+00	Rt 59ft of ℄	2,999.8	#4	11.2	113.1	10.9	117.0	95.0	95	OK	ET
5-120	3-19	Dam	131+00	℄	3,000.7	#4	16.2	113.7	15.3	114.8	99.0	95	OK	ET
5-121	3-19	Dam	108+00	Lt 50ft of ℄	2,998.0	#4	17.2	112.2	16.4	114.1	98.3	95	OK	ET
5-122	3-20	Dam	128+00	℄	2,999.2	#4	7.2	109.8	12.6	119.4	92.0	95	Add water, mix, and recompact	ET
5-123	3-20	Dam	133+00	Lt 22ft of ℄	2,999.7	#4	12.2	111.2	13.1	114.0	97.5	95	OK	ET
5-124	3-20	Dam	128+00	℄	2,999.3	#4	10.1	113.8	12.5	119.2	95.4	95	OK after rework (see #122)	ET

Figure 4–1.—Form SCS-ENG-532, "Weekly Summary of Density Determinations."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Borrow source	Equipment for processing and excavating barrow	Equipment for processing on the fill (raking. grading, disking. etc.)	Compaction equipment (type, total weight. average Pressure-roller dimension, number and area of tamping feet or tires)

Description of material processing and com :tion operations

Borrow source	Inplace density test No.	Methods and equipment performance in barrow	Placement and compaction on fill (equipment, number of passes, sequence of operations lift thickness before and after treatment. etc.

Figure 4-2.—Form SCS-ENG-550, "Embankment Construction Report."

Description of materials

Borrow source	Laboratory sample NO.	Inplace density test No.	Classification	Group (i.e., IA, III)	Geologic form and description	Gravel and rock		Average gradation for each borrow group and inplace tests for specific processing and compaction operations	
						Hardness	Bulk density	As dumped-on fill; percent passing sieve (maximum size 6", 3", 1½", ¾", No. 4)	After compaction; percent passing sieve (maximum size 6", 3" 1½", ¾", No. 4)

Figure 4–2 (cont).—Form SCS-ENG-550; **reverse side**

U.S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-551
2-80

CERTIFICATION OF MATERIALS AND CONCRETE MIXTURE

Location Columbia Falls State U.S.A.

Watershed Dry Creek Contract No. 12-10-300-210

Structure Cedar Creek Dam Class of concrete 3000#

Materials

Cement: type II Ideal Ideal Portland Cement Company
(brand name, manufacturer)

Aggregates:

Fine Blue Mountain Pit Bulk Sp. Gr. (SSD) 2.65
(kind. supply source)

Coarse Blue Mountain Pit Bulk Sp. Gr. (SSD) 2.62
(kind. supply source)

Air-entraining agent rotex - Autolene Lubricant Company
(brand name, manufactured

Other admixtures NONE
(brand name. manufacturer)

Mixing water source Speedy Redi Mix Company well

Batch per cubic yard

Cement 517 lb Water 35 gal

Aggregates (SSD): fine 1220 lb coarse 1½ - 3/4 in. 620 lb

3/4 - 1/4 in. 1,250 lb

Air-entraining agent 3.5 oz Air content 4.0 %

Other admixtures: kinds NONE amounts —

Mix designed by Pittsburg Testing Laboratory
(name of laboratory, ready-mix plant, or project engineer)

Remarks

I certify that the above mentioned materials and mix for the specified class of concrete meets the requirements of the contract and will be furnished for the work.

Contractor Jones Construction Company

Signature Clude Jones

Date 4-2-69 Title President

Note: A revised copy Of this certification shall be furnished for each change in materials or mix proportion that may occur during construction.

Figure 4-3.—Form SCS-ENG-551, "Certification of Materials and Concrete Mixture."

Air-entraining agent—Give the brand name and manufacturer.

Mixing water—State the supply source.

Batch per Cubic Yard

Either the contractor or the engineer, whichever is responsible for formulating the mixture, is to complete the section under batch per cubic yard.

Cement—State the total pounds.

Water—State the total gallons needed.

Aggregates—State the total pounds of each aggregate (saturated, surface-dry).

Air-entraining agent—Give the amount required.

Air content—State the anticipated air content of the air-entraining agent.

Other admixtures—Identify the kinds and amounts proposed for use in the mixture.

Signature and Date

The prime contractor is to sign and date the form.

Note: If the engineer designs the mixture, the words "and mix for the specified class of concrete" must be deleted from the certification statement. A new form must be prepared if the materials are changed. The engineer must approve the change before the new mixture is used.

Concrete Batch Delivery Ticket (SCS-ENG-552)

A delivery ticket or report form showing the ingredients, time of batching, and the revolution counter reading when batching starts is required for each batch of concrete mixed offsite. Normally, a commercial ready-mix concrete supplier prepares a delivery ticket that furnishes this information. The engineer must determine in advance if the supplier has a ticket form that will meet project needs or if Form SCSENG-552, "Concrete Batch Delivery Ticket," should be used (fig. 4-4).

If the contractor designs the mixture, the plant operator is to prepare whichever form or ticket the engineer has designated. The "job site" part of the SCS form can be used in conjunction with the supplier's delivery ticket to complete the installation record for each batch of concrete. If the engineer designs the mixture and inspects the batching, the plant inspector is to prepare the form and must use SCS-ENG-552.

Heading

The information for the heading is in the contract.

Batching Record

The plant inspector or the plant operator is to supply the data for the batching record. The batch operator upon arriving at the jobsite is to deliver this form to the job inspector.

Time *batched*—Indicate the time that all ingredients are put in the mixture (to nearest 5 min).

Size of batch—Give the total volume of the batch.

Cement—Give the total pounds of cement in the mixture.

Aggregates—Give the total pounds of each size. Indicate the percent of free moisture included in the batch weight.

Admixture—State the kind and total amount.

Water required *(design)*—State the total gallons specified.

Water in aggregate—State the total gallons of free moisture.

Water added—Give the total gallons metered into the mixture.

Water in mixture *(total)*—Show the sum of the gallons of free water in the aggregate and gallons of water added to the mixture.

Revolution counter reading—Show the reading when batching starts.

Signature—Name the plant operator or the inspector.

Jobsite Record

The job inspector is to complete the jobsite portion of the form when the concrete is placed.

Time *of arrival*—Show the time when the transit truck arrives on the jobsite (to nearest 5 min).

Time discharge complete—Show the time when placement of the total batch was complete (to nearest 5 min).

Water added *on* job—State the amount of water added at the jobsite.

Slump—Give the amount of the slump (and time of test).

Air content—Give the amount of the air content (and time of test).

Temperature *(air)*—Show the actual temperature reading in degrees F (especially important if the temperature is critically high or low).

Temperature (concrete)—Show the temperature reading of the mixture in degrees F when it is placed (especially important if air temperatures are high or low).

Test cylinders—Give the number of each cylinder molded for testing.

Placement record—Identify the structure and where in the structure each batch was placed.

Revolution counter reading—Give the number at the start of discharge for the batch.

Signature—Give the name of the inspector receiving the concrete.

The job inspector is to check batch weights on the delivery ticket with those shown on the job mixture when the load is delivered to verify that the concrete was properly batched at the plant.

Concrete Trial Mixture Data (SCS-ENG-553)

The engineer is to use Form SCS-ENG-553, "Concrete Trial Mix Data," as a work sheet in designing a concrete mixture or in checking the proposed mixture submitted by the contractor (fig. 4–5).

The strength, air content, slump, type of cement, and maximum size of aggregate for the concrete are specified in the contract. The guidance for designing a mixture to establish the water-cement ratio (w/c), the weight of the fine aggregate (based on the fineness modulus), and the weight of the coarse aggregate (considering maximum size) is available in concrete design references (see Chapter 5, Concrete). Tests and observations of the mixture will prove its adequacy and suitability. Small variations in the proportioning of the fine and coarse aggregates may be necessary to improve workability and produce a satisfactory finish.

The filled-in data on figure 4–5 shows a trial design batch. Batch quantities are listed in column 1. Procedures at the bottom are used to calculate data for columns 2 through 5. Data in columns 1 and 3 can be expanded to obtain a cubic yard batch.

After adequate testing to determine the unit weight of the concrete mixture, the batch and air volumes, yield, and cement factor are computed as shown.

For contracts specifying cement as a separate pay item, field tests are needed to determine the unit weight of the concrete placed. The computed yield is compared with the design mixture to arrive at the actual quantity of cement for payment.

Daily Concrete Batching Record (SCS-ENG-544)

If the contracting organization designs and controls the mixture, it is necessary to inspect batching plant operations. If the contractor designs the mixture, the materials and mixture must meet specifications. The plant inspector is to use Form SCS-ENG-544, "Daily Concrete Batching Record," to record plant operations and batching (fig. 4–6).

Heading

Information for the heading is available from the construction office and batching plant records.

Center Table

A new line must be used for each change in the scale setting. This reflects a change in the mixture of the volume of a batch.

Number *of* batches and volume per batch—Give the total number of batches and the volume of each batch in cubic yards. Record the scale setting for the day's run.

Mix No.—Give the number of the mixture or the actual water-cement ratio used.

Cement and aggregate weights—List the scale batch weights in their proper columns and lines for each material or material size, including proper allowance for surface water in the aggregates.

Mixing water—State the number of gallons of surface water in the aggregates and gallons of water in the mixture.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-552
2-80

CONCRETE BATCH DELIVERY TICKET

Project Dry Creek Watershed Contract No. 12-10-300-210

Contractor Jones Construction Company Mix No. 24-M

Concrete supplier Speedy Redi Mix (name) Pine Bluff, USA. (address)

Rated capacity mixer 6.5 yd³ Truck No. 14 Ticket No. 15

Batching record

Time batched 9:25 a.m. ~~p.m.~~ Date 4-18-69

Size of batch 6.0 yd³

Cement 3102 lb Revolution counter reading 4.793

Aggregate:

Fine 7,615 (@ 4% moisture) lb Remarks 7 gal of water maybe added at job site

Coarse 1 1/2 - 3/4 in. 3,720 lb

- 4 in. 7,500 lb

Admixture Protex 3.5 oz

Water required (design) 210 gal

Water in aggregate 35 gal Signature D. Moore (inspector or supplier)

Water added 168 gal

Water in mix (total) 203 gal Title Nt Inspector

Job site record

Time of arrival 9:45 a.m., ~~p.m.~~ Revolution counter reading 4,867

Time discharge complete 10:18 a.m., ~~p.m.~~

Water added on job 0 gal Remarks Mix placed OK.

Slump 3 1/2 in Minimum air content - increase 1.2 %

Air content 4.0 %

Temperature:

Air 62 °F

Concrete 70 °F

Test cylinders, No. I-58

I-59

I-60

Placement record

Structure Emergency Spillway

Station 14+67 to 14+97 (pour #2)

Section Invert Slab

By CJ Manning (job inspector)

Note: Transit truck driver shall deliver this ticker *to* the inspector *upon* arrival at the job sire

Figure 4–4.—Form SCS-ENG-552, "Concrete **Batch Delivery Ticket.**"

DAM

8-

II

Materials	① Batch quantity (lb)	② Specific gravity[1]	③ Solid volume (ft^3)	④ Weight/bag of batch (lb)	⑤ Weight/ yd^3 (lb)	⑥ Remarks
Cement	30.00	3.15	0.153	94	515	
Water	16.94	1.00	0.271	53	291	
Fine aggregate (S.S.D.)[2]	70.79	2.65	0.428	222	1,214	
Coarse aggregate (S.S.D.)[2]	108.51	2.62	0.664	340	1,861	
Air	0.35 oz		1.516 Total solid volume of material			

Measured slump 4 in. Measured air 4 % Workability good

Unit weight of concrete = $\frac{\text{Weight of concrete in container}}{\text{Volume of container}} = \frac{28.15}{0.196} = 143.62$ lb/ft^3

Volume of batch = $\frac{\text{Total weight of batch}}{\text{Unit weight of Concrete}} = \frac{726.24}{143.62} = \frac{1.575\ ft^3}{27\ ft^3/yd^3} = 0.0583$ yd^3

Volume of air = Volume of batch (ft^3) − Solid volume of ingredients = 1.575 − 1.516 = 0.059 ft^3

Air content = $\frac{\text{Volume of air } (ft^3)}{\text{Volume of batch } (ft^3)} \times 100 = \frac{0.059}{1.575} \times 100 = 3.75$ %

Concrete yield = $\frac{\text{Volume of batch } (ft^3)}{\text{Number of cement bags}} = \frac{1.575}{0.319} = 4.94$ ft^3/cement bag

Cement factor = $\frac{27\ ft^3/yd^3}{\text{Yield } (ft^3/\text{bag})} = \frac{27}{4.94} = 5.47$ bags/yd^3

Water = $\frac{\text{Water } (lb/yd^3)}{8.34\ lb/gal} = \frac{291}{8.34} = 35$ gal/yd^3

Fine aggregate content = $\frac{\text{Weight of fine aggregate}}{\text{Total weight of aggregate}} \times 100 = \frac{1,214}{3075} \times 100 = 39.5$ %

Col. 1 – Weight of materials used in trial mixture
Col. 2 – Specific gravity of materials
Col. 3 – Absolute volume = $\frac{\text{weight}}{(\text{Sp. Gr.})\ 162.41}$

Col. 4 – $\frac{(\text{Col. 1})\ (94)}{\text{Weight of cement used}}$
Col. 5 – (Col. 41 (cement factor), or $\frac{\text{Col. 1}}{\text{Volume batch } (yd^3)}$

[1] Specific gravity and absorption of coarse aggregates (from ASTM C-127). Specific gravity and absorption of fine aggregates (from ASTM C-128).

[2] Saturated surface dry.

Figure 4-5.—Form SCS-ENG-553, "Concrete Trial Mix Data."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-544
2-80

DAILY CONCRETE BATCHING RECORD

Watershed Pine Creek Watershed Project Dam #3 Date 3-16-64

Structure or site No Principal Spillway Plant name American Concrete Company Report No 3

Contractor Woods Construction Company Plant location Lakeside, U.S.A. Weather Cloudy. Cool

Type of mixing equipment Transit truck Kind of admixture Air-entraining Class of concrete 3000#

Source cement Lehigh sand Lakeside Pit #2 coarse aggregate Lakeside Pit #2

Time of operation from 8:00 am to 11:30 p.m. Placement No or location Floor slab-emergency spillway

Number of batches	Volume /batch (yd³)	Mix No.	Cement weight /batch (lb)	Fine aggregate S.S.D. (lb)	Fine aggregate Moisture (%)	Fine aggregate Batch (lb)	#4 Coarse aggregate 1½ in S.S.D. (lb)	#4 Coarse aggregate Moisture (%)	#4 Coarse aggregate Batch (lb)	Coarse aggregate S.S.D. (lb)	Coarse aggregate Moisture (%)	Coarse aggregate Batch (lb)	Mixing water (gal) In aggregate	Mixing water (gal) Added	Mixing water (gal) Total	Admixture (lb)	Air-entraining admixture (oz)
12	6.0	A-4	3102	7,050	3.0	7,260	11,400	0.5	11,457	–	–	–	32	178	210	–	24
1	3.0	A-4	1,551	3,025	3.0	3,630	5,700	0.5	5,730	–	–	–	16	89	105	–	12

Quantities for 0 yd³

		Fine aggregate	Coarse aggregate		
Aggregates (saturated and surface dry)	(lb)	1175	1900		
Moisture in aggregates	(lb)	30	0.5		
Moisture content in aggregates	(%)	353	q.S		
Aggregates (scale batch weight)	(lb)	1,210.3	1909.5		

Cement: 5.5 sacks 517 lb

Water: in aggregates 5.4 gal; added 29.6 gal; total 35.0 gal

Total Production

Total batches 12.5 Volume/batch 6.0 yd³

Total volume 75.0 yd³

Total cement sacks 41,775 lb

Remarks

Inspector J. R. Smith

Figure 4–6.—Form SCS-ENG-544, "Daily Concrete Batching Record."

Computations of Concrete Batch Quantities for 1 yd^3 Batch

Property		Cement	Water	Sand	Coarse aggregate 1½ in			Total
Proportion by weight	(%)							
Batch weight (saturated and surface dry aggregates)	(lb)	517	247	1,175	1,900			3,839
Total moisture in aggregated	(% by weight)	—	—	—	—			
Absorption of aggregates (saturated	(% by weight)	—	—	—	—			
Surface moisture in aggregates (by test or assumed)	(% by weight)	—	—	3.0	0.5			
Surface moisture in aggregates = (percent x aggregate weight) ÷ 100	(lb)	—	—	353	9.5			45.0
Batch weight	(lb)	517	247	1,210	1,910			3,884

Computations of Concrete Yield for 1 yd^3 Batch

Property		Cement	Water	Sand	Coarse aggregate			Total
Batch weight (saturated and surface dry aggregates)	(lb)	517	292	1,175	1,900			
Specific gravity (assumed for cement, by test, or assumed for aggregate)		3.12	1.00	2.65	2.65			
Absolute volume = weight ÷ (Sp. Gr. x 62.4)	(ft^3)	2.66	4.68	7.11	11.49			25.94 + 1.30 = 27.24
			Assume	5%	air			

Concrete yield per rack of cement 4.84 ft3

Cement per cubic yard of concrete 5.54 sacks

Yield = Total materials (lb) ÷ Unit weight of concrete (lb/ft^3) = 3,884 / 145 = 26.8 ft3

[1] If surface moisture of the aggregate is determined directly by test *or* assumed. omit the lines for total moisture and absorption.

Figure 4-6 (cont).—Form SCS-ENG-544; reverse **side.**

Admixture—State the amount added to each batch.

Air-entraining admixture–State the amount added to each batch.

Quantities per Cubic Yard

Data in quantities per cubic yard are necessary for checking scale settings for the different size batches.

Total Production

Data needed to determine the total production of concrete and cement include the total batches, total volume per batch, and total cement.

Remarks and Signature

The plant inspector is to sign each day's report.

Concrete Batch and Yield Computations

The reverse side of SCS-ENG-544 has columns in which to enter the quantities of ingredients required for a batch and to compute the actual yield of a batch, both on a one-sack and a cubic-yard basis.

Distribution

This form is filed in the project office.

Pile Driving Record (SCS-ENG-545)

Form SCS-ENG-545, "Pile Diving Record," is for keeping a progressive record of installation as individual piles are placed for a structure or a specific portion of a structure (fig. 4–7).

Heading

Information for the heading is in the contract or the work agreement. The bearing value formula, bearing capacity, and maximum "S" apply only when the formula is specified for control. The type of hammer used must be indicated.

Table

A complete driving record is needed using a separate line for each pile. All the necessary data for the various columns should be available in the engineering notes.

Reverse Side

This blank side can be used to sketch the location and approximate dimensions of the driving site. The relative position of each pile, including its assigned number, must be indicated. The bent number, stationing, orientation arrow, and other data necessary to identify the site must be included. Reference to the layout in the contract drawings can be used in lieu of a sketch if drawings are sufficiently detailed.

Engineering Notes

Pile-Driving *Record*

Engineering notes for pile driving illustrate how a field notebook can be set up for recording driving data for the various kinds and types of individual piles (fig. 4–8). One field book or a section of a specific field book is used to keep a continuous record of all pile-driving operations for a given structure. Headings in the notebook must be compatible with the headings shown on SCSENG-545 (fig. 4–7).

Elevation notes are a necessary part of the record; figure 4–8 shows how to include them. When elevation and cutoff measurements are determined by the survey party, the survey party chief must enter them in the elevation columns in the engineering notes and on SCS-ENG-545.

It is important to prepare a master plan showing the location of each pile in the structure. The actual work is cross-checked with this plan throughout the job. The pile number is recorded in

the engineering notes exactly as shown on the plan.

Before driving starts, it is desirable to record (on the same line as the pile number) the extremity diameters where applicable and the pile length.

Penetration determinations usually are made from the temporary reference marks established by the inspector on the fair leads or the pile as the driving progresses. Measurements made with a hand or pocket rule permit the driving to proceed with a minimum of delay.

Just below the last line of driving data, the inspector is to include a brief, clear summary of unusual conditions; physical reactions that were evident, such as changes in the equipment or driving procedures; and observations that would be significant.in a later study or evaluation (see chapter 2, Piles and Pile Driving).

Test Pile-Driving Record

Test pile driving is more or less a special requirement and is usually limited to one or two piles for a given site. It is important that a detailed record be kept of the materials, equipment, and driving procedures for each test pile.

Figure 4–9 shows headings and the general layout the inspector uses to document the driving operation.' The pile number must be clearly identified, both in the notes and on the drawings. After the test pile is driven to the correct depth and becomes a part of the permanent works, it is entered on the as-built drawings.

Just below the last line of the driving data, the inspector is to include a brief, clear summary of any unusual conditions; physical reactions that were evident, such as changes in equipment or driving procedures; and observations that would be significant in a later study **or** evaluation.

Test Pile-Loading Record

The ability of a foundation to support a vertical load can be determined by applying a load to a specific pile in a prescribed manner (see Chapter **2).** This must be performed with care, and readings must be taken at the proper time intervals and recorded. Load-settlement data resulting from the field test and the apparatus and procedures used must be recorded in detail.

Figure 4–10 shows headings and the general layout the inspector uses to document the incremental load-settlement results? These results and related data are used to supplement the test pile-driving record.

The inspector is to include a brief, clear summary of unusual conditions, physical reactions that were evident, observations that would be significant in a later study or evaluation, and other pertinent information. Photos or drawings to show the equipment layout should be included.

Quantity Computations and Other Records (SCS-ENG-522A, SCS-ENG-528, SCS-ENG-529, SCS-ENG-004, SCS-ENG-546, SCS-ADS-53)

Form SCS-ENG-522A, "Computation Sheet"; Form SCS-ENG-528, "Earthwork Computation Sheet"; Form SCS-ENG-529, "Earthwork Computation Sheet"; and Form SCS-ENG-004, "Tabular Computations," are used for earthwork computations (fig. 4–11; 4–12 to 4–15; 4–16; and 4–17).

Form SCS-ENG-546, "Bid Item Record Sheet," is an optional form that personnel in the field construction office can use to maintain a complete record of all approved work for each bid item or of extra work specified in the contract (fig. 4–18 to 4–20).

Form SCS-ADS-53, "Progress Sheet Computations of Contract Pay Items," is an optional form that can be used to summarize quantities of work or materials for pay estimates (fig. 4–21).

Earthwork

A number of acceptable methods are used for computing earth quantities. The best formula or method to use depends on the topography of the ground when the original and the final cross sections of the area are made. Normally, earthwork quantities are determined by averaging the end areas of the mass and multiplying this average by

'Suggested headings and arrangements were assembled from the procedures for reporting test pile driving data presented in Test E–26 in the Earth Manual (U.S. Dep. Inter., Bur. Reclam.).

²Suggested headings end arrangement were assembled for the procedures for reporting test pile loading data presented in Test E–26 in the Earth Manual (U.S. Dep. Inter., Bur Reclam.).

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCSENG-545
2-80

PILE DRIVING RECORD

Watershed Doe Creek Contract No. I-DC-64

Structure A-I Contractor D.H. Hammer & Sons

Name & model of hamrner Vulcan "V" (gravity type) Manufacturer's rating—"E" — ft-lb/blow Average blows/minute —

Bearing value formula—"R" $\frac{(2W)H}{S+1.0}$ lb Minimum bearing capacity required 59 000 lb Maximum allowable "S"[1] .044 in.

Weight of hammer or ram (W) 3,000 lb Length of stroke or fall (H) 12 ft Effective area of piston (A) — in.^{2} Mean effective pressure (P) — lb/in.^{2}

Type & kind of piles Round, creosote-treated ft timber

Date	Pile No.	Penetration: Number of blows at drop (in.)	Penetration: Total (in.)	Penetration: "S" (in.)	Computed bearing "R" (lb)	Elevation: Top pile (ft)	Elevation: After cutoff (ft)	Length of cutoff (ft)	Length of pile in leads (ft)	Length of pile in place (ft)	Diameter of pile: Butt (in.)	Diameter of pile: Tip (in.)	Remarks
5/20/64	1	50@12	1 3/4	0.35	53,833	145.9	145.1	0.8	18.2	17.4	10	8	
" " "	2	50@12	2.0	0.40	51,429	146.4	145.1	1.3	18.5	17.2	11	8 1/2	

[1] "S" i–the average penetration/blow during last few blows.

Figure 4–7.—Form SCS-ENG-545, "Pile Driving Record."

Station	B.S.	H.I.	F.S. or grade rod	Elev. or planned elev.	Corrected elevation
B.M. #2	4.98	157.52		152.54	152.54
B.M. #3			5.01	152.51	152.50

Penetration			Computed	Top of pile	
Blows and drop	Total (in)	Average in/blow	bearing Numbers	after Rod	driving Elevation
Pile	#1-	Fir - C.R. Tr. (8:30 - 9:10 AM)			
5 @ 12	3.0	0.60	44,900		
5 @ 12	2 1/4	0.45	49,650		
5 @ 12	1 3/4	0.35	53,250	11.62	145.9
Pile	#2-	Fir - C.R. Tr. (9:50 - 10:40 AM)			
5 @ 12	3 1/4	0.65	43,550		
5 @ 12	2 3/4	0.55	46,400		
5 @ 12	2 1/4	0.45	49,650		
5 @ 12	2.0	0.40	51,450	11.13	146.4

SCS-ENG-29
(2-80)

Pile Driving Record
Bent #2
Cherry St Bridge
Station 10+7620

J.R. Smith
Inspector
5-20-64 7:00 am
4:00 pm
Fair, Warm

Cutoff elevation	Length of cutoff	Length in leads	Length in place	Diameter of pile Butt (in)	Tip (in)
		(18.2)		(10)	(8)
145.1	0.8	18.2	17.4	10	8
		(18.5)		(11)	(8 1/2)
145.10	1.3	18.5	17.2	11	8 1/2

Figure 4–8.—Engineering notes; example of field notes for pile driving.

Station	B.S.	H.I.	F.S. or grade rod	Elev. or planned elev.	Corrected elevation
B.M #2	4.98	157.52		152.54	152.54
BM #3			5.01	152.51	152.50
Pile # 3				(10:15 – 11:00 am)	
Average drop (ft)	Penetration (ft)	Total blows at each foot	Blows per foot	Elevation of pile tip	
	0			150.38	
	1	0			
	2	5	5		
	3	12	7		
	4	20	8		
	5	30	10		
	6	42	12		
	~	~	~		
	20	600	83		
	21	695	95		
	22	811	116		
	23	990	179	127.38	
	23.1	1,025		127.28	

SCS-ENG-29
(2-80)

Test Pile Driving Record — J. R. Smith, Inspector

Bent #2

Cherry St. Bridge — 5-26-64 7:00 am 4:00 pm

Station 10+76.20 — Cloudy, warm

Make/model of hammer: Vulcan-Model-1

Type of hammer: Single action-Steam-Air

Weight of hammer: 5,000 lb

Average blow per minute: 55 stroke or fall: 36 in

Manufacturer's rating "E" 15,000 ft-lb

Pile length-total: 28 ft. Diameter-butt: 13 in, Tip: 9 in

- after cut off: 24.5 ft
- in ground: 23.0 ft

Pile diameter @ cut off: 12 in @ ground: 11 3/4 in.

Kind/type of pile: Round creosote-treated fir timber straight, peeled, all knots smooth. Point steel driving shoe

Observations for 1 in penetration	
6 blows per inch @ 18 ft	14 blows per inch @ 22 ft + 9 in
7 blows per inch @ 19 ft 6 in	20 blows per inch @ 23 ft
9 blows per inch @ 21 ft	Driving stopped at
11 blows per inch	21 blows per inch
12 blows per inch @ 22 ft 6 in	

Figure 4–9.—Engineering notes; example of field notes for test pile driving.

Station	B.S.	H.I.	F.S. or grade rod	Elev. or planned elev.
Date and time	Elapsed time (hr-min)	Load (ton)	Settlement (in)	Remarks
5-28-64 8:00 am	0:00	0.0	0.000	
	0:02	12.5	0.000	
	:10	12.5	0.000	
	:20	12.5	0.000	
	:40	12.5	0.000	
	1:00	25.0	0.003	
	:01	25.0	0.003	
	:10	25.0	0.003	
	:20	25.0	0.003	
	:40	25.0	0.003	
	2:00	25.0	0.003	
	3:00	37.5	0.006	For illustration,
	4:00	50.0	0.008	time intervals
	5:00	62.5	0.011	:01, :10, :20, and
	6:00	75.0	0.013	:40 not shown
	7:00	100.0	0.018	
	30:00	100.0	0.018	No reading
	30:01	50.0	0.012	7-30 hours.
	32:00	25.0	0.010	Time intervals
	33:00	10.0	0.007	Not shown.
	34:00	0.0	0.005	Loading ended 5-29-64

SCS-ENG-29 (2-80)

Test Pile Loading Record
Bent #2
Cherry St Bridge
Station 10+76.20

J R Smith
R.W. Brown - Recorder
5-28-64
Clear, warm

Pile 3
Date pile driven: 5-26-64
Kind/Type of pile: Round, creosote-treated fir timber
Condition of Pile: Smooth and sound at cut-off
Elevation @ butt: 157.78 ft @ tip: 127.28
Ground elevation @ pile: 150.2 ft
Method of loading/equipment:
Reaction load consisting of box filled with sand, supported by timbers and steel I-beam crribing
Load applied to pile by calibrated hydraulic jack
Four black-and-white photos taken of test equipment
Method of measuring settlement: Engineers level and rod with Vernier.

Figure 4-10.—Engineering notes; example of field notes for test pile loading.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-522A
2-80

COMPUTATION SHEET

State _____ Project _____

By _____ Date _____ Checked by _____ Date _____ Job No. _____

Subject _____ Sheet _____ of _____

Figure 4–11.–Form SCS-ENG-522A, "Computation Sheet."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-528
2-80

EARTHWORK COMPUTATION SHEET

Location WINONA Oklahoma Owner WINONA Flood Control District Contractor Wilder Construction Company Contract No. WC-82-63

Watershed Washita River Item Embankment, Item #5 Computed by Joe Smith Date 1-22 19 63

Subwatershed WINONA Creek Site No. 5 Final quantity (yd³) Checked by M H. BROWN Date 1-25 19 63

Station	Lt [1]					℄ [1]			Rt [1]			Double end areas	Σ double end area	Distance	Volume in ft³ ÷ 4	Volume in yd³
5+00	0.0	0.3	20.0	20.0	30.4	32.0	38.0	38.0	32.4	-0.3	0.0					
	-0.0	-10.0	-60.0	-72.5	-98.5	-45.0	+0.0	+40.0	+91.0	+10.0	+0.0	7,693.3				
													16,089.5	50	804,475.0	7,448.8
5+50	0.0	0.3	20.0	20.0	36.0	36.1	37.5	35.7	34.6	-0.3	0.0	8,396.2				
	-0.0	-10.0	-60.0	-72.5	-112.5	-50.0	+0.0	+51.0	+96.5	+10.0	+0.0					

Sample CALCULATIONS:

Embankment Station 5+00

	+	−
0.3	[-60.0 - (-0.0)] =	
20.0	[-72.5 - (-10.0)] =	
20.0	[-98.5 - (60.0)] =	
30.4	[-45.0 - (-72.5)] = 30.4 x 27.5 = 836.0	
32.0	[-70.0 - (-98.5)] = 32.0 x 98.5 = 3,152.0	

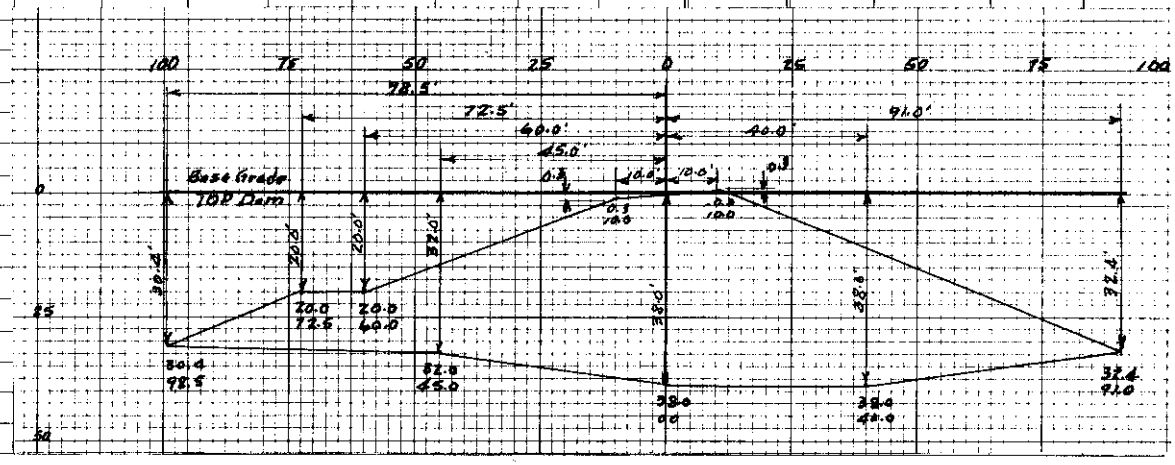
Station 5+00 (Continued)

	+	−
	38.0 [-40.0 - (-45.0)] = 38.0 x 85.0 = 3,230.0	
0.3 x (-60.0) = 18.0	38.0 [-91.0 (+0.0)] = 38.0 x 91.0 = 3,458.0	
20.0 x (-62.5) = 1,250.0	32.4 [+10.0 - (+40.0)] =	32.4 x (-30.0) = 972.0
20.0 x (-38.5) = 770.0	-0.3 [+0.0 - (+91.0)] = -0.3 x (-91.0) = 27.3	

Σ (+) = 10,703.3

Σ (−) = 3,010.0

E. A. x 2 = 7,693.3



[1] Provide appropriate headings for use of offset or ℄ baseline.

Figure 4–12.—Form SCS-ENG-528, "Earthwork Computation Sheet"; example *1*.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-528
2-80

EARTHWORK COMPUTATION SHEET

District

Location Winona Oklahoma Owner Winona Flood Control District Contractor Wilder Construction Company Contract No. WC-82-03

Watershed Washita River Item Access road Item # 13 Computed by Joe Smith Date 1-22 19 63

Subwatershed Winona Creek Site No. 5 Final quantity (yd³) ____ Checked by M. H. Brown Date 1-25 19 63

Station	Lt [1]					℄ [1]			Rt [1]				Double end areas	Σ double end area	Distance	Volume ft³ × d	Volume yd³
2+50		0.0	0.0	-1.0	9.0	11.0	9.0		5.4	-1.0	0.0	0.0					
		0.0	-16.0	-18.0	-38.0	-18.0	0.0		30.8	18.0	16.0	0.0	991.2				
														2,079.2	50	103,960.0	962.6
3+00			0.0	0.0	-1.0	10.0	10.5	6.2	-1.0	0.0	0.0		1,038.0				
			0.0	-16.0	-18.0	-40.0	0.0	32.4	-18.0	16.0	0.0						

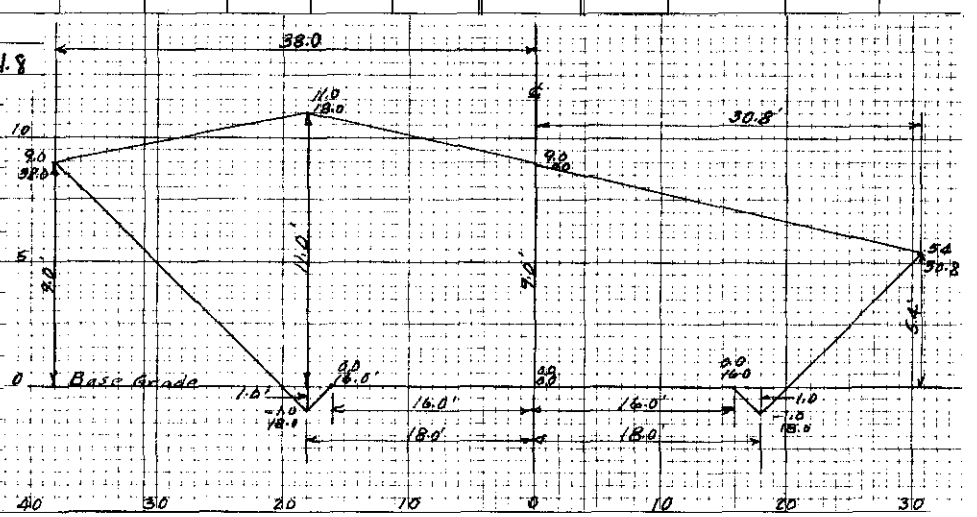
Sample Calculations:
Cut stations: 2+50

-1.0 [-38.0 - (-16.0)] = -1.0 x (-22.0) = 22.0
9.0 [-18.0 - (-18.0)] = 9.0 x 0.0 = —
11.0 [0.0 - (-38.0)] = 11.0 x 38.0 = 418.0
9.0 [+30.8 - (-18.0)] = 9.0 x 48.8 = 439.2
5.4 [+18.0 - (-0.0)] = 5.4 x 18.0 = 97.2
-1.0 [+16.0 - (+30.8)] = -1.0 x (-14.8) = 14.8

Σ(+) = 991.2

Σ(-) = 0

E.A. x 2 = 991.2



[1] Provide appropriate headings for use of offset or ℄ baseline.

Figure 4–13.—Form SCS-ENG-528; example 2.

U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS ENG 528
2-80

EARTHWORK COMPUTATION SHEET

Location Winona, Oklahoma Owner Winona Flood Control District Contractor Wilder Construction Company Contract No. We-82-63

Watershed Washita River Item Embankment, Item #5 Computed by Joe Smith Date 1-22 19 63

Subwatershed Winona Creek Site No. 5 Final quantity (yd³) ____ Checked by M. H. Brown Date 1-25 19 63

Station	Lt [1]				℄ [1]				Rt [1]			Double end areas	Σ double end areas	Distance	Volume in ft³ ×4	Volume in yd³
2+00 (1)	0.0	0.3	20.0	20.0	30.4	32.0	38.0	88.0	82.4	-0.3	0.0					
(2)	0.0	-10.0+	-60.0+	-72.5+	-98.5+	-45.0+	0.0	+40.0 -	+91.0 -	+10.0 -	0.0					
(3)	-10.0	-60.0	-62.5	-38.5	-27.5	+98.5	+85.0	+91.0	-80.0	-91.0	-10.0					
(4)	-0.0	-18.0	-1,250.0	-770.0	+836.0	3,157.0	+3,230.0	+3,458.0	-972.0	+27.3	-0.0	7,693.3				
													16,089.5	50	804,475.0	7,448.8
2+50	0.0 / 0.0	0.3 / 10.0	20.0 / 60.0	20.0 / 72.5	36.0 / 112.5	36.1 / 50.0	37.5 / 0.0	35.7 / 57.0	34.6 / 96.5	-0.3 / 10.0	0.0 / 0.0	8,396.2				

Procedure:

(1) Represents fill heights to construction grade (in feet). Record as minus (-) quantity when above or below base grade.

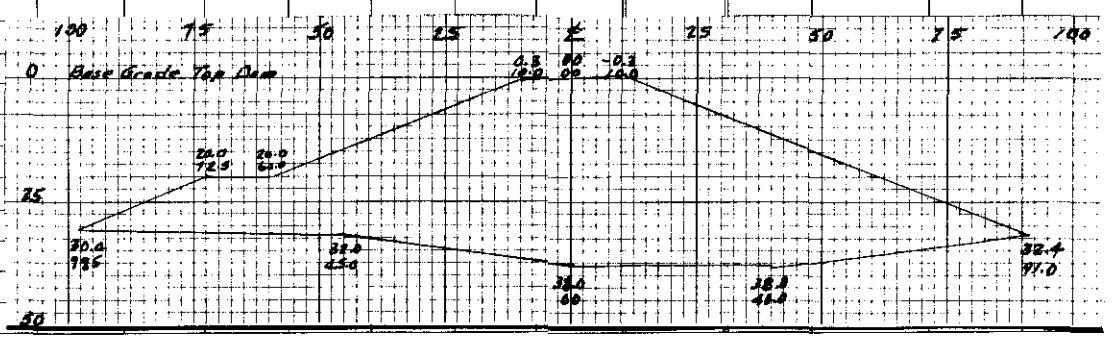
(2) Represents horizontal distances Rt and Lt of ℄ (in feet). For each point Lt of ℄ place a (-) sign preceding the number and a (+) sign immediately following the number. To the Rt of ℄ reverse the procedure: Place (+) sign as a prefix and (-) sign as a suffix. Include the 0.0 points, both extremities of the X-section.

(3) Represents the algebraic difference in distance between the point immediately ahead and point next back, using the signs adjacent to the point under consideration (see example in box below). The Σ (+) distance minus Σ (-) distance equals 0.

(4) Determined by multiplying (1) x (3) in each vertical column using the correct algebraic sign for each product.

Double E.A. = The difference between the Σ (+) products and the Σ (-) products for the X-section

(1)	0.3	20.0	20.0
(2)	-10.0	-60.0+	72.5+
(3)		-62.5	-72.5
			+10.0
			-62.5



[1] Provide appropriate headings for use of offset or ℄ baseline.

Figure 4-14.—Form SCS-ENG-528; example 3

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-528
2-80

EARTHWORK COMPUTATION SHEET

Location WINONA, OKLAHOMA Owner WINONA Flood Control District Contractor Wilder CONSTRUCTION Company Contract No. WC-82-63

Watershed WASHITA RIVER Item Emergency spillway, item #4 Computed by Joe Smith Date 1-22 19 63

Subwatershed WINONA CREEK Site No. 5 Final quantity (yd³) ____ Checked by M. H. BROWN Date 1-25 19 63

Station	Lt [1]			℄ [1]			Rt [1]			Double end areas	Σ double end area	Distance	Volume ft³ x 4	Volume in yd³
2+00	0.0	0.0	0.0	9.0	11.0	9.0	5.4	0.0	0.0					
	0.0	20.0	38.0	18.0	0.0	30.8	20.0	0.0		983.2				
											2,067.4	50	103,370.0	957.1
2+50	0.0	0.0	0.0	10.0	10.5	6.2	0.0	0.0		1,084.2				
	0.0	20.0	40.0	0.0	32.4	20.0	0.0							

Sample Calculations

Station 2+00

+			−		
9.0 x	20.0 =	180.0	9.0 x	18.0 =	162.0
11.0 x	38.0 =	418.0			
9.0 x	18.0 =	162.0			
9.0 x	30.8 =	277.2			
5.4 x	20.0 =	108.0			

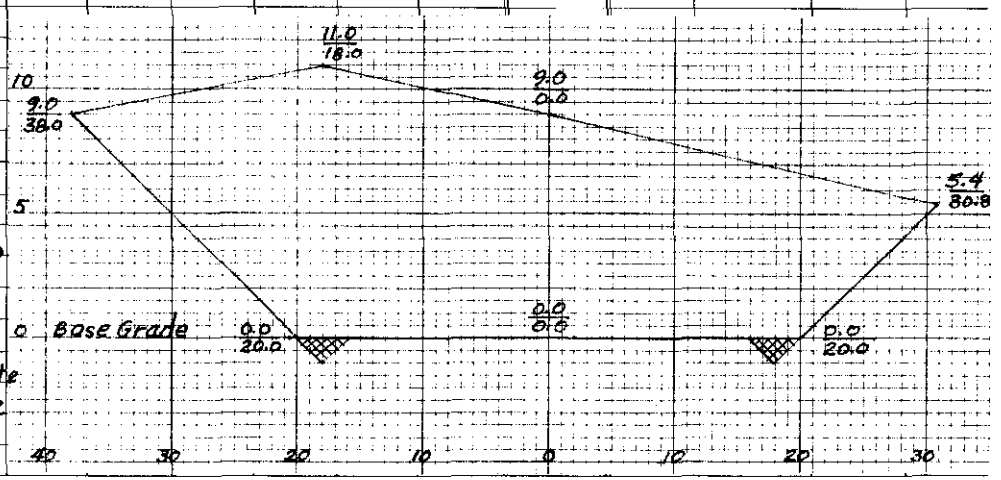
Procedure:
Multiply grade rod x adjacent distance from ℄ as indicated by the solid diagonal lines, and add the products - All positives (+). Multiply as shown by the opposite diagonal dashed line and add the products - All Negative (-) The difference gives the double end area.

Σ(+) = 1,145.2

Σ(-) = 162.0

E.A. x 2 = 983.2

Note:
Minor quantities of C or F that are performed to a uniform section and which normally would be represented by a (-) grade rod in the calculations may be computed as separate quantities to complete the total E. A. or volume; for example ditch sections this figure.



[1] Provide appropriate headings for use of offset or ℄ baseline.

Figure 4–15.—Form SCS-ENG-528; example 4.

Contractor UP HENRY ROE
Item Outlet channel excavation

Station	End area (in²)	End area (ft²)	Sum of end areas (ft²)	Distance (ft)	Section products (ft³)	(yd³)	Remarks
12+40	0.00	0					
13+00	2.45	245	245	60	14,700		
13+50	2.50	250	495	50	24,750		
14+00	2.57	257	507	50	25,350		
14+50	2.40	240	497	50	24,850		
15+50	0.76	76	316	100	31,600		
16+00	1.10	110	186	50	9,300		
17+00	0.54	54	164	100	16,400		
17+50	0.85	85	139	50	6,950		
18+00	1.02	102	187	50	9,350		
18+40	0.00	0	102	40	4,080		
				Total	167,330 / 2x27	= 3,099 yd³	
			Sample				
Cross section scale: 1 in. =			10 ft vertical. 10 ft horizontal.	(End area's by planimeter – machine constant 1.00 = 1 in.²)			

_____ sheets

Figure 4–16.—Form SCS-ENG.529, "Earthwork Computation Sheet."

TABULAR COMPUTATIONS

Fill in the proper headings; they are similar to headings on fig 4-16, Show project and Job site, computer and checked-by, names, dates, etc

Figure 4-17.—Form SCS-ENG-004, "Tabular Computations."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-546
2-80

BID ITEM RECORD SHEET

Contract No. 1 Item No. 3 Unit price 0.40 unit Cubic yard + 25% 7,500
Structure Dam No. 2 Description Excavation - common - 25% 4,500

Date 1961	Description of entry	Reference file supplement data	Authorized contract award Quantity	Authorized contract award Amount	Authorized change Quantity	Authorized change Amount	Authorized total Quantity	Authorized total Amount	Estimate this period Quantity	Estimate this period Amount	Estimate completed to date Quantity	Estimate completed to date Amount	Percentage completed Actual	Percentage completed Scheduled
5/1	Contract, estimate	Bid Schedule	6,000.0	2,400.00		-0-		-0-						
5/15	Stripping of foundation	Computation file/3							1,2100	484.00				
5/20	Contract modification #1, foundation principal S	contract modification file			+1,000.0	400.00	7000.0	2800.00						
5/31	Foundation principal spill way - complete	computation file/3							3,015.0	1,206.00				
5/31	Cut off treach	computation file/3							600.0	240.00				
5/31	Partial payment #1		6,000.00	2,400.00	+1,000.0	400.00	7,000.0	2,800.00	4,825.0	1,930.00	4,825.0	1,930.00	69	50
6/15	Tail ditch-complete	computation file/3							210.0	84.00				
6/25	Contract modification #2, cutoff treanch	contract modification			[over 25% at 0.50 yd³]									
6/29	Cutoff treach-complete	computation file/3			+500.0	+200.0	(+25%) 7,500.0	3,000.00	2,465.0	986.00				
6/30	Excess: 25% clause at 0.5°	cont. mod file/3			+410.0	+205.00	7,910.0	3,205.00	410.0	205.00				
6/30	Partial payment #2		6,000.0	2,400.00	+1,910.0	+805.00	7,910.0	3,205.00	3,085.0	1,275.00	7,910.0	3,205.00	100	85

Item 3: 100% complete, 6/30/61 partial payment #2

3 Item No

Figure 4–18.—Form SCS-ENG-546, "Bid Item Record Sheet"; example 1.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-546
2-80

BID ITEM RECORD SHEET

Contract No. 1 Item No. 4 Unit price 0.40 Unit Cubic Yard + 25% 85,125

Structure Dam No-2 Description Embankment - ZONE I 25% 51,075

Date 1961	Description of entry	Reference file supplement data	Authorized contract award Quantity	Authorized contract award Amount	Authorized change Quantity	Authorized change Amount	Authorized total Quantity	Authorized total Amount	Estimate this period Quantity	Estimate this period Amount	Estimate completed to date Quantity	Estimate completed to date Amount	Percentage completed Actual	Percentage completed Scheduled
5/1	Contract estimate	Bid schedule	68,100.0	27,240.00										
5/20	Principal spillway foundation	Computation file/4							3,015.0	1,206.00				
5/31	Cut off trench	Comp file 4							(1210.0)	484.00				
5/31	Partial payment #1		68,100.0	27,240.00		⊖		⊖	4225.0	1,690.0	4,225.0	1,690.00	6	10
6/17	Cut off trench	Comp file 4							2,275.0	910.00				
6/21	Foundation stripped area	Comp file 4							1210	484.00				
6/31	Dam-ZONE 1	Comp file 4							(4,200.0)	1,680.00				
6/31	Partial payment #2		68,100.0	27,240.00		⊖		⊖	7,685.0	3,074.00	11,910.0	4,764.00	18	25
7/31	DAM- ZONE 1	Comp file 4							(15,600.0)	6,240.00				
7/31	Partial payment #3		68,100.0	27,240.00					15,600.0	6,240.00	27,510.0	11,004.00	40	45
8/31	DAM-ZONE 1	Comp file 4							(22,400.0)	8,960.00				
8/31	Partial payment #4		68,100.0	27,240.00		⊖		⊖	22,400.0	8,960.00	49,900.0	19,964.00	73	75
9/20	Dam-ZONE 1-Complete	Comp file 4							15,800.0	6,320.00				
9/27	Contract modification #1, adjust to correct yards	Contract mod.			-2,400.0	-960.00	65,700.0	26,280.00	15,800.0	6,320.00	65,700.0	26,280.00		
9/30	Partial payment #5 (Item 4 — 100% complete 6/30/61)		68,100.0	27,240.00	-2,400.0	-960.00	65,700.0	26,280.00	15,800.0	6,320.00	65,700.0	26,280.00	100	100

4 Item No.

Figure 4-19.—Form SCS-ENG-546; example 2

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-546
2-80

BID ITEM RECORD SHEET

Contract No. 12-10-040-226 Item No. 5 Unit price 80.00 Unit Cubic yard + 25% 75.63

Structure Pine Creek Diversion Description Class "B" Concrete (diversion + headwork) – 25% 45.38

Date 1961	Description of entry	Reference file supplement data	Authorized contract award		Authorized change		Authorized total		Estimate this period		Estimate completed to date		Percentage completed	
			Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Actual	Scheduled
5/1	contract estimate	Bid schedule	60.5	4,840.00										
5/31	cut off walls and floor	comp files							(22.0)	1,760.00				
5/31	Partial Payment #1		60.5	4,840.00		-0-		-0-	22.0	1,760.00	22.0	1,760.00	36	30
6/20	contract modification #1 add downstream wing wall	contract modification file			+8.5	+680.00	69.0	5,520.00						
6/26	Total concrete in place	Comp file #5							45.6	3,648.00				
6/30	Partial payment #2		60.5	4,840.00	+8.5	+680.00	69.0	5,520.00	45.6	3,648.00	67.6	5,408.00	100	90
7/5	contract modification #2 adjust to correct yardage	contract modification file	60.5	4,840.00	-1.4	-112.00	67.6	5,408.00	-0-	-0-	67.6	5,408.00	100	
7/5	Partial Payment #2 - Final Status		60.5	4,840.00	+7.1	568.00	67.6	5,408.00	-0-	-0-	67.6	5,408.00	100	
	Assume cement a sperate bid item - Unit price 4.40/barrel - Example entry													
8/15	Sack count - 37 each	Inspector diary	150.00	660.00					9.25					
8/19	Sack count - 44 each	Inspector diary							11.00					
8/24	Sack count - 58 each	Inspector diary							14.50					
8/28	Sack count - 61 each total 200	Inspector diary							15.25					
8/31	Partial payment #1		150.00	660.00					50.00	220.00	50.00	220.00		

5 Item No.

Figure 4–20.—Form SCS-ENG-546; example 3

PROGRESS SHEET COMPUTATIONS OF CONTRACT PAY ITEMS

Location Putnam unty Georgia Owner – Luke Dunn
Watershed Rooty Creek Subwatershed —
Site No 25 Contract No 6-GA-SCD-5

Item No.	Work or material	Computed			Checked		
		Date	Name	Quantity	Date	Name	Quantity
1	Clearing	5/1/63	L.A.H	11.2 acres	5-4-63	W.J.P	11.2 acres
2	Clearing and grubbing						
	Embankment area	5/1/63	L.A.H.	1.6 acres	5-4-63	W.J.P.	1.6 acres
	Emergency spillway area	5/1/63	L.A.H.	2.5	5-4-63	W.J.P.	2.5
	Total	5/1/63	L.A.H.	4.1 acres	5-4-63	W.J.P.	4.1 acres
3	Excavation						
	Conduit strip out	5/1/63	L.A.H	1919 yd³	5-4-63	W.J.P.	1919 yd³
	Key way	5/1/63	L.A.H	2333	5-4-63	W.J.P	2333
	Old Channel	5/1/63	L.A.H.	1172	5-4-63	W.J.P.	1172
	Tail ditch	5/1/63	L.A.H	196	5-4-63	W.J.P.	196
	Total	5/1/63	L.A.H	5620 yd³	5-4-63	W.J.P.	5620 yd³
4	Earth fill						
	Embankment	5/11/63	L.A.H.	15,267 yd³	5/11/63	W.J.P.	15,267 yd³
	Conduit strip out	—	—	1919	—	—	1919
	Key way	—	—	2333	—	—	2333
	Old Channel	—	—	1172	—	—	1172
	Total	5/11/63	L.AH.	20,691 yd³	5/11/63	W.J.P.	20,691 yd³
5	Concrete-Class B						
	Riser	—	—	5.47 yd³	—	—	5.47 yd³
	Anti-seep Collars	—	—	3.15	—	—	3.15
	Anti-Vortex baffle	—	—	2.54	—	—	2.54
	Sill	5/11/63	L.A.H.	2.96	5/11/63	W.J.P.	2.96
	Total	5/11/63	L.A.H.	14.12 yd³	5/11/63	W.J.P.	14.12 yd³
	Drainage filter						
	Material	5/5/63	L.A.H.	178 yd³	5/5/63	W.J.P	178. yd³

Sheet _____ of _____ sheets

Figure 4-21.—Form SCS-ADS-53, "Progress Sheet Computations of Contract Pay Items."

Table 4-1.--Earthwork Computation Table

Feet between cross sections	Constant computing factor	Feet between cross sections	Constant computing factor	Feet between cross sections	Constant computing factor	Feet between cross sections	Constant computing factor
1	.01852	26	.48148	51	.94444	76	1.40741
2	.03704	27	.50000	52	.96296	77	1.42592
3	.05556	28	.51852	53	.98148	78	1.44444
4	.07407	29	.53704	54	1.00000	79	1.46296
5	.09259	30	.55555	55	1.01852	80	1.48148
6	.11111	31	.57407	56	1.03704	81	1.50000
7	.12963	32	.59259	57	1.05555	82	1.51852
8	.14815	33	.61111	58	1.07407	83	1.53704
9	.16667	34	.62963	59	1.09259	a4	1.55555
10	.18519	35	.64815	60	1.11111	85	1.57407
11	.20370	36	.66666	61	1.12463	86	1.59259
12	.22222	37	.68518	62	1.14815	87	1.61111
13	.24074	38	.70370	63	1.16667	88	1.62963
14	.25926	39	.72222	64	1.18518	89	1.64815
15	.27778	40	.74074	65	1.20370	90	1.66666
16	.29630	41	.75926	66	1.22222	91	1.68518
17	.31481	42	.77778	67	1.24074	92	1.70370
18	.33333	43	.79629	68	1.25926	93	1.72222
19	.35185	44	.81481	69	1.27777	94	1.74074
20	.37037	45	.83333	70	1.29630	95	1.75926
21	.38889	46	.85158	71	1.31481	96	1.77778
22	.40741	47	.87037	72	1.33333	97	1.79629
23	.42593	48	.88889	73	1.35185	98	1.8148 1
24	.44444	49	.90741	74	1.37037	99	1.83333
25	.46296	50	.92593	75	1.38889	100	1.85185

reas in s are feet t es a cons' nt equals bic yards er station.

the distance between the sections. The volume can be calculated by:

$$V = L\left[\frac{(A_1 + A_2)}{54}\right]$$

where

V = Volume in cubic yards of the prismoid (mass) between cross sections.

A,, A, = Areas in square feet of the cross-sectional ends.

L = Distance in feet between the cross sections.

The "Earthwork Computation Table" lists conversion factors in L distances from **1** to 100 ft that, when multiplied by the sum of the end areas, A, and A,, give volume (table **4–1).**

The planimeter can be used for measuring end areas. But cross sections must be plotted, and this is time consuming, laborious, and usually unjustified unless needed to visualize an intricate geometric configuration. If a planimeter is used, the following procedures must be followed

- Determine the correct constant reading for the instrument.
- Make at least three separate measurements for each section.
- Use the average of the three readings.
- Have all area calculations checked by a second party to verify the measurement accuracy.

Formula for Computing **End** Areas

Level cross sections.—The end area can be calculated by:

$$A = C\left(d + \frac{W}{2}\right)$$

where

A = End area in square feet.

C = Center cut *or* fill in feet.

W = Width in feet on a level section of the top of the fill or the bottom of the channel.

d = Distance in feet from the centerline to either slope stake.

Three-level sections.—The end area can be calculated by:

$$A = \frac{W}{4}(h_1 + h_2) + \frac{C}{2}(d_1 + d_2)$$

(see sketch below)

where

A = End area in square feet.

C = Cut or fill in feet at centerline.

W = Width of top of embankment or bottom of cut in feet (level section).

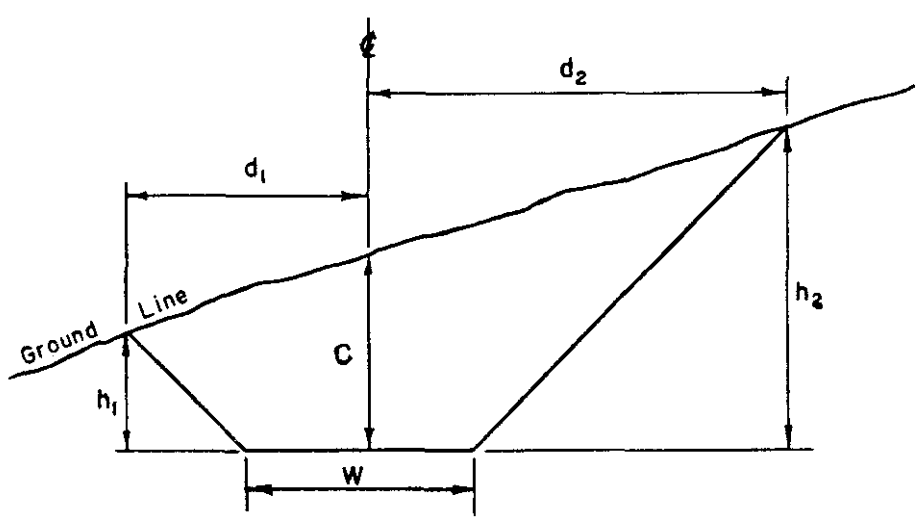
d_1 = Distance in feet to the slope stake left of centerline.

d_2 = Distance in feet to the slope stake right of centerline.

h_1 = Cut or fill in feet left of centerline.

h_2 = Cut or fill in feet right of centerline.

Computation (methods **1** or **2)** are recorded on SCS-ENG-522A and SCS-ENG-004 (fig. **4–11** and **4–17).**



Irregular cross sections.—The following procedure, often referred to as the double end area method, is adapted from the coordinate system of computing areas. Slope stake and elevation data for either the channels or embankments are recorded in the usual manner. The end area of the cross section in square feet is determined as follows:

- Use minus signs for distances to the left of center and use plus signs for distances to the right of center.
- Use minus signs for any vertical distance below base grades in the cuts or above base grades in the fills.
- Starting at any point, use every value of the numerator (cut, fill) in order, proceeding clockwise or counterclockwise around the area.
- Multiply each value of the numerator by the difference (algebraically) between the "distance" from the centerline of the point ahead and the "distance" from the centerline of the point behind.
- Find the algebraic sum of all these quantities and divide by 2.

This procedure applies to all cross sections. If a centerline does not exist as such, a reference line must be established for denoting distances left and right.

This method, along with some of the variations used to compute areas of irregular sections, is shown on SCS-ENG-528 (fig. 4–12 to 4–15). Headings for the last four vertical columns of this form must be filled in properly to identify the method used to determine volume quantities.

Figure 4–12 shows a cross section of an embankment, and figure 4–13 shows a cross section of an excavation. Both figures include grade rod and distance data for each elevation point and sample calculations to illustrate the procedural steps above. Figure 4–14, although similar in format and content to figure 4–12, shows an alternative procedure to use.

Figure 4–15 is similar in format and content to figure **4–13.** The procedure illustrated, often referred to as the criss-cross or diagonal method, is used because of its simplicity. The method is also well adapted for use with a calculator having memory-plus, memory-minus, and memory-recall capabilities. The positive products (considering data along solid lines) can be accumulated in the memory-plus system, while the negative products (considering data along dashed lines) can be accumulated in the memory-minus system. Pressing memory-recall yields the net total; this is the double end area of the cross section.

This method is used only on sections that are represented by a negative grade rod. They can be computed separately and included in the final quantity, thus increasing the adaptability of this method.

For sections entirely in cut or in fill, axes are usually the centerline, and the finished elevation is the top of the embankment or the bottom of the cut. For sidehill sections involving cut-and-fill quantities, it may be advantageous for calculation purposes to shift the vertical axis to the point of zero cut-fill (correcting the horizontal field note data accordingly), since cut-and-fill quantities usually accumulate separately.

The headings for each computation sheet must be properly filled in. Complete identification of the structural feature for which quantities have been computed must be added to the heading. Separate computation sheets are needed for each bid item or element of a bid item as required.

Borrow Areas

Quantities of the material excavated from the borrow areas can be computed by dividing the surface area into squares, rectangles, or triangles by using level elevations for each corner of the original face and the elevation of the same point after excavation. A before-and-after cross section can be used to compute end areas and volumes by using the same procedures outlined for other earthwork computations. Sometimes it is desirable to use a combination of both methods. For the normal conditions of excavation and finish of completed borrow areas, the cross section method should give adequate accuracy for the quantity determination.

Concrete

Final quantities of the inplace concrete are computed to the limits shown in the drawings or as staked. Calculations can often be simplified by subdividing structural elements into components of geometrical shape that can be computed mathematically. Each segment is computed to hun-

dredths, and the total quantity is rounded off to the nearest tenth of a cubic yard, unless specified otherwise.

All sketches, formulas, and calculations are recorded on SCS-ENG-522A (fig. 4–11).

Steel

Final weights or quantities for the steel can be determined by carefully verifying the size, length, and total weight recorded on the invoices with those on the drawings and placement records. Quantities can also be computed by using unit-weight tables for the shape furnished—table values are multiplied by the actual lengths placed and measured in accordance with the specifications and drawings.

All computations and records for steel quantities must be properly identified and documented on SCS-ENG-522A. Properly approved invoices or delivery slips can be filed as supporting data.

Other Items

Quantities of other contract items, such as pipe, timber and lumber, revetment, and asphalt concrete, must be carefully measured in the units specified in the contract. All calculations required for determining quantity or supporting data required for the estimates or the final payment must be recorded on SCS-ENG-522A or other approved SCS forms.

Completion of Contract

When construction operations are completed or nearing completion, the project engineer is to prepare job records for submission to the state office.

All quantities should be checked by a second party, and field notebooks must be carefully indexed. The as-built set of construction drawings must be carefully reviewed and checked against the engineering notes to verify that all required changes, permanent markers, boundaries, ties, and other pertinent data have been accurately recorded (see as-built drawings).

The final construction report, if required, and all correspondence and records dealing with the contract should be sent to the state office within 90 days after completion of the contract. Field office material can include, but is not limited to: the working agreement with the local organization, the contract docket, correspondence, contract modifications, stop orders, resume-work orders, claims for extra work, material certifications, partial and final pay estimates, material test reports, material delivery slips or invoices, field diaries, engineering field notebooks, as-built drawings, and all supporting notes, calculations, or forms pertaining to quantities, quality of materials, or workmanship.

As-Built Drawings

Procedures and requirements for the preparation of as-built drawings are in National Engineering Manual, **Part 512,** Subpart F.

The engineer is responsible for seeing that one set of the contract plans (large size, black-and-white prints) are labeled "AS-BUILT." These drawings must be kept at the worksite construction office.

All changes should be recorded in red ink on the as-built prints or be drafted on properly identified standard drawing sheets with adequate reference on the new as-built drawings and as-built prints to define changes made. Work deleted from the contract must be shown on the as-built drawings. A contrasting color, crosshatch, notes, or other identification should be used to show items or limits of deleted work.

The detail in which specific changes are recorded depends on (1) the effect of the change on the functioning of the structure and (2) whether the change is made on a part of the structure that will remain visible after completion. Each sheet of the original set of drawings and all detailed drawings prepared as supplements to the original drawings must be clearly stamped "AS-BUILT."

Changes in elements of the structure that are visible after construction need not be redrafted. Changes can be shown on the as-built drawings by redlines, dimensions, angles, stations, or as notes. For example, for a change in location of the emergency spillway of a dam, the new location of the centerline is plotted with a new stationing on the plan view, then shown by a note indicating

that the cross sections of the channel and proposed structures will remain the same.

Structural or dimensional changes in any nonvisible portion of a structure, such as in the drainage systems, cutoffs, principal spillway conduits, pipelines, piling, and reinforcing steel, must be redrafted in the detail needed to present a complete, readable record.

When construction has been completed, all as-built drawings and prints must be carefully checked. All field notes, diaries, and other records must be carefully reviewed to ascertain that all changes have been properly recorded. These drawings are sent to the state office with other records of the complete project within 90 days after work is accepted.

The following changes and additions must be recorded on the as-built drawings:

- Additional permanent monuments and points established during construction, including angles or bearings, reference points, stationing, kind of material, and identification.
- Location, elevation, description, and identification of new bench marks, and corrections in elevation, location, or description of old bench marks.
- Name, location, owner, kind of material, and size of any utilities.
- New locations, stationing, equations, bearings, and angles of base lines or centerlines used for control, and references to the old lines.
- Additions, deletions, and changes in the location and design of the structure, and in the dimensions and kinds of material in it. Complete, detailed drawings are needed for major changes *in* existing structures or for additional structures.
- Changes in the right-of-way or easement limits (properly identified) that were made a matter of record before the construction drawings were prepared.

Construction Completion Report

The preparation of a completion report covering highlights of the construction operations and contract administration for a project is optional but very desirable. When all the pertinent facts and data are readily available, it may appear to be an unjustifiable effort. But in subsequent years when all the records have been removed from the local files and personnel connected with the construction are not readily available, it is conceivable that questions may arise within SCS or in its contracts with local people that could be simply resolved by reference to a properly documented final construction report.

The completion report should be concise. It must represent the thinking of the construction force, revealing problems during construction, their impressions of the contractor and his operations, and the effectiveness and quality of the completed project. Report content will vary, depending on the type and magnitude of the work.

Content

If a report is prepared, the following material is suggested for inclusion:

- Brief description of the project can include: scope, location, and purposes of the project; and names of cooperating agencies, contracting officers, and local organization board members.
- Dates and facts can include: number of bidders, date of the award, names and addresses of the contractor and any subcontractors, dates and 'reasons for any major shutdowns required, revisions of the contract time (amount, days of liquidated damage), and date of formal acceptance.
- Installation services can include: names of those responsible for engineering and inspection (SCS or others); names, titles, and duties of the personnel assigned to the project; commentary on the adequacy of the engineering force; and suggestions for improving the organization.
- Installation can include: types of equipment and methods used for the major items of work; comments on new or special types of equipment or techniques and ,their adaptability for other types of work and comments on exceptionally high or low rates of production, indicating the average production rates per hour or day for the larger items.

- Problems can include: comments on site or material conditions that varied from the design or plan; how any problems were resolved; comments on the quality of materials and workmanship and the completeness and accuracy of the specifications and drawings, being specific as to omissions, errors, or weak points; suggestions for improvements; and other situations that were unusual or affected operations, such as weather, labor, and relations with local organizations or the public.
- Materials can include: a list of manufacturers producing major items used in the project, such as concrete products, metal, and fabricated assemblies; comments on the quality and workmanship; and problems with earthwork, borrow, rock riprap, or other materials.
- Evaluation of the contractor's performance can include: comments on his experience, equipment, financial problems, integrity, organization, and supervision; evaluation of the production and quality of the finished product; comments on his attitude and relations toward the general public, local contracting organization, and engineering installation force, including his willingness to comply with instructions or orders; and the desirability of awarding him future contracts (if the rating is unfavorable, specific reasons or examples must be given to support this rating).
- Modifications and claims can include: comments on contract modifications; comments on the negotiation of prices, extras, liquidated damages, and other items that changed the value of the contract; reasons for these value changes; and suggestions how they might have been avoided.
- Costs can include: a report of the original and final values of the contract and the percentage of the overrun or underrun, and a report of the original and final costs to the government and to the local contracting organization.
- Pictures can include: available photographs to show major construction operations and the finished project, including foundations, latent conditions, special equipment, and unusual methods. Select pictures carefully to show the intended information and the highlights and scope of the project.

"Form" Completion Report (SCS-ENG-547, SCS-ENG-548)

Forms SCS-ENG-547, "Construction Completion Report," and SCS-ENG-548, "Summary of Construction Quantities and Costs," can be used in lieu of a narrative (fig. 4–22 and 4–23). If any unusual features including changes or additions are thought to be significant, they should be written up as a supplement. This report can also include a limited number of well-captioned photographs to show construction features and the scope of the project.

Distribution

The construction completion report is transmitted to the SCS state office with the other job records.

Table of Forms Used by Field Construction Offices (SCS-ENG-549)

Before starting a new construction contract, the engineer must know what records and reports will be required, the distribution and number of copies, and the due date for each report.

Form SCS-ENG-549, "Table of Forms Used by Field Construction Office," is primarily for project office use to serve as a reminder for timely preparation of required forms (fig. 4–24).

Preparation of Form

Form number—List correct prefix letters and the number for each form.

Title of form—Enter opposite the form number, the correct title or heading as it appears on the form.

Offices—Indicate in each of the eight columns the number of copies needed (use figures or checkmarks). Enter the letter O as a suffix to indicate the distribution of the original copy or the letter S for signed copies.

Due date—Indicate the completion date for filing in the office or for mailing to the receiving office.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-547
2-80

CONSTRUCTION COMPLETION REPORT

To _____ _____ Date _____
(contracting officer)

Address _____

1. Contract No. _____ for construction of _____
_____
in _____ Watershed, State of _____

2. Name of contractor

3. Address of contractor

4. Original amount of contract:
(federal share) $ _____
(local share) $ _____

Total $ _____

5. Revised amount of contract:
$ _____
$ _____

$ _____

6. Location of work
_____
_____

7. Description of work
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Complete in accordance with contract specifications and drawings together with such additional work as required or ordered in writing by the contracting officer

8. Dates:
Contract date _____ Original date for completion _____
Notice to proceed _____ Revised date for completion _____
Work started _____ Work completed _____

9. Time allowed for completion: _____ calendar days after receipt of notice to proceed.

Extended _____ calendar days by Modifications No. _____

10. Liquidated damages: contract provided that $ _____ per calendar day would be assessed for each day of delay. Number of days charged _____

Figure 4-22.—Form SCS-ENG-547, "Construction Completion Report."

11. Plans and specifications—the following plans and specifications were used (specify by construction site)

_____

12. Contractor performance rating:

Performance Chart (check below)

Factors considered					
Success in meeting scheduled completion dates					
Quality of work performed					
Organizational ability and efficiency					
Cooperative attitude of contractor					
Cooperative attitude of superintendents and foremen					
Effectiveness of supervision (contractor's)					
Effective use of equipment and manpower					
Adherence to safety regulations					

Overall adjective rating to be entered in appropriate space below and signed by the rating and review officials

Rating official	Reviewing official
Rating _____	Rating _____
Signature _____ (government representative)	Signature _____
	Title _____

13. Give a brief summary of major points concerning the contract, such as weather conditions, labor problems, material shortages, etc.

_____

Figure 4–22 (cont).—Form SCS-ENG-547; second page.

14. Principal construction inspection by:

Name	Duties	Representing
	Resident engineer	
	Chief inspector	

15. Recommendations (suggested improvements—plans, specifications, field staff organization, construction materials, installation methods, etc.)

16. Final inspection: Date held

Attended by

17. Report prepared:

By

Title

Date

Approval recommended:

BY
(government representative)

Date

Figure 4–22 (cont).—Form SCS-ENG-547; third page.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-548
2-80

SUMMARY OF CONSTRUCTION QUANTITIES AND COSTS

Site No. _____ Watershed _____ Contract No. _____ Contractor _____

Item No.	Item description	Total quantity		Unit	Unit price	Total amount		Modification	
		Original	Revised			Original	Revised or final	No.	Date

Totals for site No. ____ 5 _____ $ _____ Net (decrease) (increase) $ _____ Total for contract (decrease) (increase) 5 _____

Figure 4–23.—Form SCS-ENG-548, "Summary of Construction Quantities and Costs."

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-549
2-80

TABLE OF FORMS USED BY FIELD CONSTRUCTION OFFICE
Distribution & Number of Copies

Form No.	Title of form	Offices						Contracting local organization	Contractor	Due date or frequency
		Washington		State		Field				
		Administrative services	TSC unit	Administrative officer	Conservation engineer	Area conservationist	Government representative			

Figure 4-24.—Form SCS-ENG-549, "Table of Forms Used by Field Construction Office."

United States
Department of
Agriculture

Soil
Conservation
Service

National Engineering Handbook

Section 19

Construction Inspection

Chapter 5

Technical References

Chapter 5 Contents

	Page
Field engineering and surveying	5–1
Concrete	5–1
Soil mechanics	5–1
General construction	5–2

CHAPTER 5—Technical References

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