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A23—1929

CANADIAN ENGINEERING STANDARDS
ASSOCIATION

(INCORPORATED 1919)

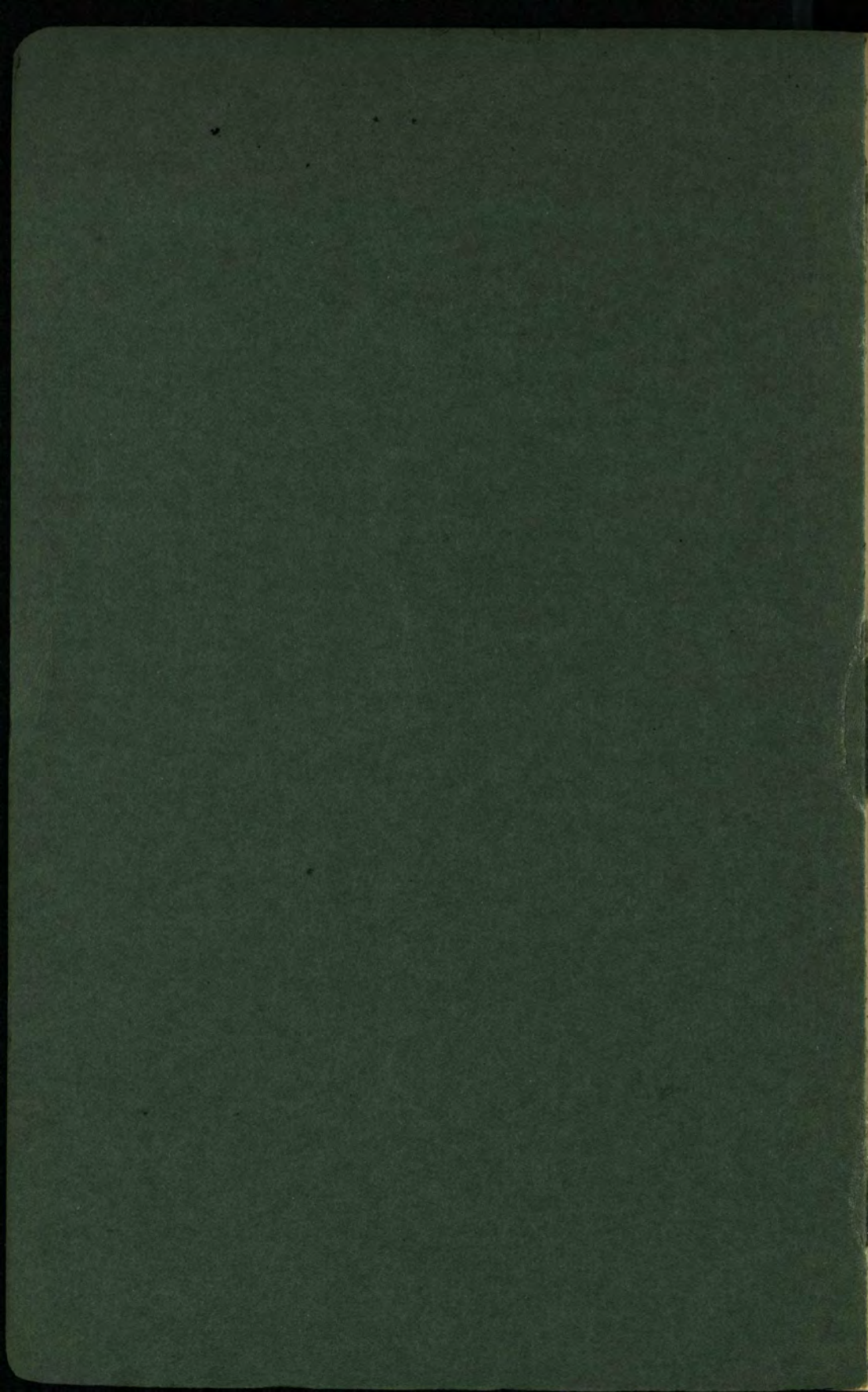
STANDARD SPECIFICATION
FOR
CONCRETE AND REINFORCED CONCRETE



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CANADIAN ENGINEERING STANDARDS ASSOCIATION

— : —
OTTAWA, MAY 1929

PRICE \$1.00



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OTTAWA, MAY 1929

Don Rial Bélanger
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LIST OF PUBLICATIONS

- No. A 1 —1928 Standard Specification for Steel Railway Bridges (third edition). Price 50c.
 A 1a—1928 Material Specifications, Steel Railway Bridges (second reprint). Price 15c.
 C 2 —1920 Standard Requirements for Distribution Type Transformers.
 C 3 —1924 Standard Specification for Galvanized Telegraph and Telephone Wire (reprint).
 B 4 —1921 Standard Specification for Wire Rope for Mining, Dredging and Steam Shovel Purposes.
 A 5 —1927 Standard Specification for Portland Cement (second edition).
 A 6 —1929 Standard Specification for Steel Highway Bridges. (second edition). Price 50c.
 D 7 —1922 Standard Specification for Flexible Steel Wire Rope and Flexible Strand for Aircraft Purposes.
 G 8 —1923 Replaced by G26-1929 and G27-1929 (see below).
 A 9 —1923 Standard Specifications for Reinforcing Materials for Concrete.
 C10 —1923 Standard Specification for Tungsten Incandescent Lamps.
 D11 —1924 Interim Report on the Manufacture, Testing and Use of Gasoline.
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 G24 —1929 Standard Specification for Sampling for Check Analysis of Steel Billets, Bars and Shapes.
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 *G26 —1929 Standard Specification for Commercial Quality Hot-Rolled Bar Steels.
 *G27 —1929 Standard Specification for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting.
 G28 —1929 Standard Specification for Carbon Steel Castings.

*NOTE:—G26-1929 and G27-1929 are published in one volume.

The above are on sale at 25 cents per copy, *except as noted*, and may be obtained from:—

The Secretary,

Canadian Engineering Standards Association,

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Ottawa.

NOTE:—*In order to keep abreast of progress in the industries concerned, C.E.S.A. Publications are subjected to periodical review.*

Suggestions for improvement, addressed to the Secretary, will be welcomed at all times. They will be recorded, and in due course brought to the notice of the Committee charged with the revision of the documents to which they refer.

A23—1929

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PREFACE

THE specification for Concrete and Reinforced Concrete herewith has been prepared by a Committee of the Canadian Engineering Standards Association appointed by that body in 1921. It is divided into three parts, the first intended primarily for the use of the constructor and the second mainly for the guidance of the designer. A number of related specifications respecting materials, methods of test, etc., supplemented by drawings, a glossary and a list of algebraic symbols, comprise Part III.

In Part I, no attempt to prepare a treatise on the various subjects dealt with has been made, only sufficient material having been included to afford a guide to good workmanship. When additional detailed information is required, text books may be consulted. In Part II, an attempt was also made to exclude purely text-book material. The formulae reproduced are generally those that have been accepted by conservative designers. Arbitrary rulings are endorsed only where they have a rational basis or have been approved by competent authorities. It has been assumed that the user of this part of the specification possesses sufficient knowledge of structural mechanics to employ it with understanding and discretion and to cope with situations distinctly outside the compass of a working specification. Special attention is called to established list of bar sizes P.107.

To those familiar with the Progress and Final Reports of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete published in 1921 and 1924 respectively, and with the tentative Building Regulations for Reinforced Concrete issued by the American Concrete Institute in February, 1928, the influence herein of American practice will be apparent. Because of the contiguity of the United States and Canada and the similarity of the practice of building construction in the two countries, a measure of agreement in the building specifications of these nations is both inevitable and desirable. This circumstance has been kept constantly in mind by the Committee and hence in its major features the later specification of the Joint Committee has been followed. But where changes in practice seemed desirable, or where in the interest either of clarity or style alterations seemed advisable, departures therefrom have been freely made. Notwithstanding this, the debt which the present Committee owes to American workers, particularly to the American Society for Testing Materials for permission to use material from the Joint Report, is gratefully acknowledged.

In the Appendices of Part III will be found several well-known specifications having sufficiently close relation to the work in hand to be incorporated *in toto*. Others have been included but with modifications. Some of these are Canadian Engineering Standards Association specifications previously issued; others are of American Society for Testing Materials origin.

Preliminary draft of this Specification was considered at a meeting of the Committee on Concrete and Reinforced Concrete, held in Toronto on March 26th and 27th, 1928, and revised draft, at a meeting of the same committee held in Toronto on July 23rd, 1928. Final approval was received by letter ballot from the Committee on Concrete and Reinforced Concrete in February, 1929, from the Sectional Committee on Civil Engineering and Construction in April, 1929, and from the Main Committee of the Association, with authority to publish in May, 1929.

May, 1929.

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NOTE:—*The Association desires to call attention to the fact that this Specification is intended to include the technical provisions necessary for the supply of the material herein referred to, but does not purport to comprise all the necessary provisions of a Contract.*

C. E. S. A.
STANDARD SPECIFICATION
FOR
CONCRETE AND REINFORCED CONCRETE

PART I.

Note:—The requirements of Part I of this Specification shall be followed unless modified by the plans.

MATERIALS

PORTLAND CEMENT

Quality
of Cement

1. Portland cement shall conform to the "Standard Specification for Portland Cement" (A5-1927) of the Canadian Engineering Standards Association and subsequent revisions thereof. (See Appendix IV).

AGGREGATE*†

Quality
of Aggregate

2. Concrete aggregate shall consist of natural sands and gravels, crushed rock, crushed air-cooled blast furnace slag, or other inert materials having clean, uncoated grains of strong and durable minerals.

Aggregate shall be free from alkali, organic matter or other deleterious substances, and shall not contain soft, friable, thin, flaky, elongated or laminated particles totaling more than 3 per cent, or containing shale in excess of $1\frac{1}{2}$ per cent, or silt and crusher dust finer than the No. 100 sieve in excess of 2 per cent. These percentages shall be based on the weight of the combined aggregate as used in the concrete. When all three groups of these deleterious materials are present, the combined amounts shall not exceed 5 per cent by weight of the combined aggregate.

Fine
Aggregate
Grading

3. Fine aggregate shall range in size from fine to coarse within the limits indicated in Table I.

Table I.—Grading of Fine Aggregate

	Per Cent by Weight
Passing through $\frac{3}{8}$ inch sieve.....	100
Passing through No. 4 sieve.....	Not less than 90
Passing through No. 50 sieve.....	8 to 30
Weight removed by decantation...	Not more than 3

Fine aggregates that do not comply with the above requirements shall be used only with the special permission of the Engineer and under his direction.

* These specifications cover the usual requirements for aggregate. Where concrete having special properties is essential, the specifications should make clear the characteristics of the aggregate to be used.

Where several suitable aggregates are available, an investigation of the relative economy of each is advisable.

Fine
Aggregate
Mortar

4. Fine aggregate shall be of such quality that mortar briquettes, cylinders or prisms, consisting of one part by weight of Portland cement, and three parts by weight of fine aggregate,* mixed and tested in accordance with the methods described in Appendix IX, will show a tensile or compressive strength at ages of 7 and 28 days not less than † per cent of that of 1 : 3 Standard Ottawa sand mortar of the same plasticity made with the same cement.

Organic
Impurities

5. Sand, when tested in accordance with the "Method of Test for Organic Impurities in Sand for Concrete" given in Appendix X, shall show a colour not darker than the standard colour unless it complies with the foregoing requirement for mortar strength.

Coarse
Aggregate
Grading

6. Coarse aggregate shall range in size from fine to coarse within the limits given in Table II.

Table II.—Size and Grading of Coarse Aggregate

Passing	Per Cent by Weight
— (a) in. sieve (Maximum size) ..not less than	95
— (a) in. sieve (Intermediate size)	to —
No. 4 sieve	Not more than 10
No. 8 sieve	Not more than 5

Sieve
Analysis

7. The sieves and method of making sieve analyses shall conform to the "Method for Sieve Analysis of Aggregates for Concrete" given in Appendix VII.

Decantation
Test

8. The decantation test shall be made in accordance with the "Method of Decantation Test for Sand and Other Fine Aggregates" given in Appendix VIII.

Permissible
Variations

9. Aggregate that does not conform to the above requirements for quality, grading, mortar strength or colour, may be used only when approved by the Engineer and then in such proportion as he may require.

* In testing aggregate, fine aggregate that shows a color when tested in accordance with clause (5), should not be dried by heating before being made into mortar.

† This percentage must be inserted by the Engineer; it should preferably be 100.

(a) The Engineer must insert in these blanks the size and percentage required with regard to materials available. The following table indicates desirable gradings for coarse aggregates of certain nominal maximum sizes. Requirements for the quality of coarse aggregate for special purposes should be inserted.

Nominal Maximum Size of Aggregate in.	Percentage by Weight Passing Through Standard Sieves with Square Openings						Percentage passing, not more than:	
	3 in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	No. 4 Sieve	No. 8 sieve
3	95	..	40-75	..	..	..	10	5
2	..	95	..	40-75	..	..	10	5
1½	..	..	95	..	40-75	..	10	5
1	..	..	..	95	..	..	10	5
¾	..	..	..	..	95	..	10	5
½	..	..	..	..	..	95	10	5

Pre-Mixed or
Pit-Run
Aggregate

10. Pre-mixed or pit-run aggregate shall not be used except when approved by the Engineer, and in accordance with his instructions. If pit-run or pre-mixed aggregates are allowed, when screened on a No. 4 sieve, the portion retained shall meet the requirements of clause 6, and the portions passing shall meet the requirements of clauses 3, 4 and 5.

Rubble
Aggregate

11. Rubble aggregate shall consist of clean, hard, durable stone or gravel larger than 3 in., no piece of which weighs more than 100 lb.

Cyclopean
Aggregate

12. Cyclopean aggregate shall consist of clean, hard, durable stone or gravel, no piece of which weighs less than 100 lb.

REINFORCEMENT

Quality of
Reinforcement

13. Reinforcement shall conform to the "Standard Specification for Reinforcing Materials for Concrete" (A9-1923) of the Canadian Engineering Standards Association and subsequent revisions thereof (Appendix V).

WATER

Quality of
Water

14. Water for concrete shall be clean and free from injurious amounts of oil, acid, alkali, organic matter, or other deleterious substance.

STORAGE OF MATERIALS

Storage
of Cement
and Aggregate

15. Cement shall be stored in a weather-tight building. The floor of the building shall be raised above the ground to ensure dryness. When required by the Engineer, the cement shall be stored in such a manner as to permit ready identification of the various lots for test purposes.

Aggregate shall be so stored as to avoid the inclusion of foreign materials. Frozen aggregate or aggregate containing lumps of frozen material shall be thawed before using.

PROPORTIONING, CONSISTENCY AND MIXING PROPORTIONING

Unit of
Measurement
—Cement

16. The unit of measurement for cement shall be the cubic foot and for the purpose of this specification 94 lb. of cement shall be taken as equivalent to one cubic foot.*

Unit of
Measurement
—Water

17. The unit of measurement for water shall be the Imperial gallon, and for the purpose of this specification, 10 lb. of water shall be taken as the equivalent of one Imperial gallon.

Measurement
of Aggregate

18. The aggregate shall be measured by volume or weight, as may be directed by the Engineer. The method of measurement shall be such as to secure the specified proportions in each batch, due allowance being made for free moisture and bulking effect.

* The Canadian sack of cement, weighing at the present time $87\frac{1}{2}$ lb. gross, will, for the purpose of this Specification, be regarded as the equivalent of 0.9 cubic foot.

Measurement of Water

19. The water shall be measured by a device such that the quantity of water in each batch can be regulated to give concrete of uniform consistency in successive batches, due allowance being made for free moisture in the aggregate.

Proportions

20. The proportions of cement, aggregate and water* for each section of the work shall be decided by the Engineer and shall be expressed in terms of cubic feet or pounds of cement, cubic feet or pounds of aggregate, and Imperial gallons of water.

* For those who wish to specify concrete mixtures in terms of their resultant compressive strength at 28-days, the following information has been prepared:

The compressive strength of a concrete mixture can be controlled by regulating the quantity of water contained by it and usually this is done by maintaining that ratio of water to cement which corresponds to the compressive strength that the concrete is required to have.

For important structures, or where large quantities of concrete are involved, accuracy and economy require that the water-cement ratio relationship should be determined experimentally for the particular cement and aggregates to be used, but for lesser works, where materials of good quality, meeting these specifications, are being used, the water cement ratio relationship can be taken from tables that are derived from established results on average materials.

The following conditions should govern where concretes are specified by strength.

The working stresses for the design of concrete structures should be based upon the minimum ultimate 28-day strength of the concrete to be used in the work and all plans used on the structure should clearly show the strength of concrete for which the parts of the structure were designed.

The strength of the concrete should be given in terms of the water-cement ratio. By water-cement ratio is meant the total quantity of water entering the mixture, including the surface water carried by the aggregate, expressed in terms of the quantity of cement. The water-cement ratio may be stated as a ratio of volumes or weights: the latter method is simpler, although the former is more commonly used. In the accompanying table, the units adopted are the Imperial gallon of 10 lb., the standard sack of cement of 94 lb. net, and the more commonly used sack of cement of 87½ lb. gross.

Where no preliminary tests of the materials used are made, the water-cement ratio should not exceed the values in Table III. The mixture shown in the Table are approximate only, and may require adjustment to give proper workability.

Where the water-cement ratios for the various strengths of concrete are to be established by test, these tests should be made in advance of the beginning of operations using the materials proposed and consistencies suitable for the work and in accordance with the "Method of Making Compression Tests of Concrete," Appendix XII, including the provisions for curing in a moist room at 70 deg. F. and testing wet. From these tests, a curve representing the relation between the average 28-day strength of the concrete and water-cement ratio should be established for a range of values including all of the strengths called for in the plans. The tests should include at least four different water-cement ratios and at least four specimens for each. The water-cement ratio to be used in the structure should be that corresponding to a point on the curve established by these tests representing a strength of concrete 15 per cent higher than the minimum ultimate strength called for on the plans. No substitution should be made in the materials used on the work without additional tests in accordance herewith, to show the new water-cement ratios to be used.

During the progress of the work a reasonable number of compression tests should be made as may be required by the Engineer, but at least one specimen should be tested for each 100 cu. yd. of concrete of any one strength, and not less than 2 specimens of each strength of concrete for any one day's operation.

Such tests should be made in accordance with the "Method of Making and Storing Specimens in the Field," Appendix XIII. Should the average strength of the cylinders shown by these tests for any portion of the structure fall below the minimum ultimate 28-day strength called for on the plan, the Engineer should have the right to order a change in the mixtures or the water-cement ratios for the remaining portion of the structure and to require load tests on the portions of the structure affected to prove their adequacy.

All specimens or tests should be made by a properly qualified person or testing laboratory.

The proportions of aggregates to cement for concrete of any water-cement ratio, should be such as to produce concrete of a consistency that will comply with the requirements of Clause 21, and the mixture should work readily into the corners and angles of the forms, and around the reinforcement without excessive puddling or spading and without permitting the materials to segregate or free water to collect on the surface. The combined aggregate should be of such composition of sizes that when separated by the No. 4 sieve, the weight retained on the sieve shall be not less than one-third nor more than two-thirds of the total, nor shall the amount of coarse aggregate be such as to produce harshness in placing or any honeycombing in the structure. When forms are removed, the faces and corners of the members should show smooth and sound throughout.

TABLE III

Water-Cement Ratio Imperial Gallons per 94-lb. sack of cement	Water-Cement Ratio Imperial Gallons per 87½-lb. sack of cement	Approximate Mix. Volume of Portland Cement to sum of separate volumes of fine and coarse aggregate as measured dry	Assumed Compressive Strength at 28 Days in pounds per square inch.
PLASTIC CONCRETE			
6.87	6.19	1:7	1,500
6.25	5.63	1:6	2,000
5.62	5.07	1:5.25	2,500
5.0	4.5	1:4.5	3,000
MODERATELY WET CONCRETE			
6.87	6.19	1:6.5	1,500
6.25	5.63	1:5.5	2,000
5.62	5.07	1:4.75	2,500
5.0	4.5	1:4	3,000

CONSISTENCY OF CONCRETE

Consistency

21. The Engineer shall determine and specify the consistency of the concrete on the various sections of the work. The consistency* should be such that the concrete can be placed in the forms satisfactorily but should not be so wet that it will segregate in handling or placing.

MIXING

Machine
Mixing

22. The mixing of concrete, unless otherwise authorized by the Engineer, shall be done in a batch mixer of a type approved by him. The mixer shall be equipped with a suitable charging hopper, water storage and water measuring device. It shall be cleaned at frequent intervals when in use and maintained in such a condition that the mixing action will be unimpaired.

Duration of
Mixing

23. The mixing of each batch shall continue not less than one minute after all the materials are in the mixer, during which time the mixer shall rotate at a speed of from 14 to 20 revolutions per minute, unless otherwise rated by the manufacturer.

Hand
Mixing

24. When hand mixing is authorized by the Engineer, it shall be done on a water-tight platform. The fine aggregate shall be spread on the platform and the cement spread evenly over the fine aggregate. The material shall then be shoveled into a cone-shaped pile by casting centrally on the pile. This pile shall then be divided by casting into two or more cone-shaped piles and the operation of dividing and reuniting continued until the batch is uniform in colour. Only sufficient water to produce the desired consistency shall then be added by sprinkling as the batch is turned. The coarse aggregate previously moistened shall then be mixed with the mortar in the manner specified for mixing fine aggregate and cement.

Retempering

25. The rettempering of concrete or mortar which has partially hardened, that is, remixing with or without additional cement, aggregate, or water, will not be permitted.

FORMS AND PLACING

FORMS

Design

26. Forms shall be of such strength and rigidity and so supported that they will not deflect under the weight or pressure of the wet concrete. They shall be properly braced and tied together, so as to maintain position and shape, and prevent leakage of mortar.

Construction

27. Forms shall be so constructed that the finished concrete will conform to the shapes, lines, grades and dimensions indicated on the plans.

*The Engineer who wishes to employ the slump test for maintaining consistency is referred to Appendix XI.

Forms for beams, girders, arch ribs and lintels shall be so constructed that at least one side may be removed without disturbing the bottom portion of the form and its support.

- Approval** 28. All forms shall be of a type approved by the Engineer.
- Materials** 29. Lumber used in forms shall be free from warp. For exposed surfaces it shall be dressed to a uniform width and thickness, and be free from loose knots, decay or other defects. For unexposed surfaces and rough work, undressed lumber may be used if means be taken to prevent leakage of mortar.
- Internal Ties** 30. For internal ties, bolts and rods shall preferably be used. They shall be so arranged that when the forms are removed no metal shall be within one inch of any exposed surface. Wire ties may be permitted, but preferably only on light and unimportant work. They shall not be used through surfaces where discoloration will be objectionable.
- Cleaning** 31. Lumber once used in forms shall have nails withdrawn and surfaces to be in contact with concrete thoroughly cleaned before being used again.
- Treatment** 32. The inside of forms shall be coated with non-staining mineral oil or other approved liquid, or thoroughly wetted, (except in freezing weather). Where oil is used it shall be applied before the reinforcement is placed.
Care shall be taken to ensure that forms do not become dried and warped before concrete is deposited.
- Inspection** 33. Temporary openings shall be provided at the base of column and wall forms, and other places where necessary, to facilitate cleaning and inspection. These openings shall be so placed that water for removing debris shall have a clear run to the outside of the forms.
Immediately before concrete is placed, all forms shall be carefully inspected to ensure that they are properly placed, sufficiently rigid and tight, thoroughly clean, properly treated, and free from snow, ice or other foreign materials.
- Centres** 34. Supports for forms shall be so constructed that they will not deflect under the weight of wet concrete or other loads incident to construction. Shores supporting forms for slabs, beams, girders or arches, shall be set on wedges or other approved supports in order that they may be removed without producing undue strains or shock in the superstructure.
Where adequate foundation cannot be secured, forms shall be supported on trusses.
Shores supporting successive storeys shall be placed directly above those below, or so designed that the load will be transmitted directly to those below.

Form
Removal

35. Forms shall not be disturbed until the concrete has adequately hardened. The proper time for removal of forms shall be determined by the Engineer. Shoring shall not be removed until the member has acquired sufficient strength to support safely its weight and the load on it.

Members subject to additional loads during construction shall be adequately shored to support safely both their own weight and such construction loads. This shoring shall not be removed until the member has acquired sufficient strength to support safely its own weight and the load on it.

A set of drawings shall be filed on the work, upon which shall be marked by the superintendent, the progress, indicating the time and dates on which the concrete was deposited, and the date on which forms may be removed.

Mouldings

36. Unless otherwise specified, suitable mouldings or bevels shall be placed at the angles of forms to round or bevel the edges and re-entrant angles of the concrete.

PLACING

Approval

37. Before depositing concrete, forms and reinforcement shall be checked and approved by the Engineer.

Depositing

38. Concrete shall be deposited in forms as nearly as practicable in its final position to avoid re-handling, and in approximately uniform horizontal layers. Depositing shall be continuous until the unit of operation, as approved by the Engineer, is complete, and as rapid as practicable to ensure bonding of the successive layers.

In walls and columns, puddling shall be carried on constantly to bring air bubbles to the top, and precautions shall be taken that forms do not bulge or burst under the pressure of wet concrete.

The piling up of concrete in the forms in such a manner as to permit the escape of mortar from the coarse aggregate shall not be permitted.

In walls or deep girders, separators where employed shall not be removed until the concrete has reached their level. Suitable tools shall be provided for their recovery. Where spandril walls adjoin and rise above slabs, precautions shall be taken to ensure that the bond is not broken.

Chuting

39. When concrete is conveyed by chuting, the plant shall be of such size and design as to ensure a practically continuous flow in the chute. The angle of the chute with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients, but in no case shall the slope be less than 1 vertical to 2 horizontal. The delivery end of the chute shall be as close as possible to the point of deposit. When the operation is intermittent, the spout shall discharge into a hopper. The chute shall be thoroughly flushed with water before and after each run;

the water used for this purpose shall be discharged outside the forms.

Depositing in
Cold
Weather

40. Concrete mixed and deposited when the temperature of the surrounding atmosphere is 40 degrees F. or lower, shall have a temperature of not less than 50 degrees F. nor more than 120 degrees F. Suitable means shall be provided for maintaining a temperature of at least 50 degrees F. for not less than 72 hours after placing, or until the concrete has sufficiently hardened. The methods of heating the material and protecting the concrete shall be approved by the Engineer.

Salt, chemicals or other materials shall not be employed to prevent freezing, except by the express permission of the Engineer.

Depositing
under
Water

41. Concrete shall not be deposited in water which has a temperature below 35 degrees F.

It shall be deposited continuously, keeping the top surface as nearly level as possible until it is brought above water, or to the required level. (See Clause 52).

The methods, equipment and materials to be used shall be submitted to, and approved by, the Engineer before the work is commenced. Methods shall be such as to prevent the washing of the cement from the mixture, minimize the formation of laitance and the segregation of materials and avoid flow of water until the concrete has hardened.

Where a tremie is employed it shall be watertight and of sufficient dimension to permit a free flow of concrete. It shall be kept filled at all times during the depositing of the concrete and be discharged by raising it in such manner as to maintain as nearly as possible a uniform flow.

Where a drop-bottom bucket is employed it shall be of a type which cannot be discharged until it rests on the surface on which the concrete is to be deposited. The bottom doors when tripped shall open freely downward and outward. The top shall be open. The bucket shall be completely filled and slowly lowered and raised to avoid disturbance of the mixture.

Where bags of jute or other coarse cloth are used, they shall be filled two-thirds full and built by hand in a header and stretcher system so that the whole mass is interlocked.

Proportions
For Sub-
Aqueous Work

42. Concrete to be deposited under water shall contain not less than 658 pounds of Portland cement per cubic yard in place.

Compacting

43. Concrete, during and immediately after depositing, shall be thoroughly compacted by suitable means. For thin walls or inaccessible portions of the forms, where the use of tools is impracticable, the concrete shall be assisted into place by tapping or hammering the forms opposite the freshly deposited mixture. Concrete shall be thoroughly

worked around reinforcement and embedded fixtures, and into all parts of the forms. Coarser particles shall be worked back from the face of the forms.

Bonding

44. On recommencing placing after previous work has partially set, the forms shall be retightened if necessary. The surface of the hardened concrete shall be roughened, thoroughly cleaned of foreign matter and laitance, saturated with water and sprinkled with dry cement or covered with a thin layer of neat cement paste, which shall not be allowed to dry out. The surface shall then be covered with mortar to a depth of 2 in. or the super-imposed concrete shall be placed in such a manner as will ensure an excess of mortar over the entire surface of the joint.

Curing

45. After concrete has set sufficiently, its exposed surfaces shall be kept continuously wet. This shall continue for a period of at least 7 days after the concrete was deposited.

WATERPROOFING AND PROTECTIVE TREATMENT

WATERPROOFING

General

46. By careful attention to the quality and proportioning of ingredients and the manipulation of the mixture prior to and during placing, concrete can be produced that for all practical purposes is water-tight. A plaster coat of 1 : 1½ mix using a well graded sand will ensure water-tightness.

Integral Compounds

47. No integral compounds can be recommended.

Membrane Waterproofing

48. Where added protection is desired for basements, pits, shafts, tunnels, retaining walls and similar structures, membrane waterproofing may be used. The membrane should be protected from puncture by brick, tile or concrete or by a cement mortar coat.

Water-Tight Joints

49. See Clause 94.

OIL PROOFING

Oil Proofing

50. The use of concrete in structures for containing light mineral oils, animal oils, certain vegetable oils and other commercial liquids cannot be recommended unless protected. For floors or other surfaces exposed to heavy concentrations of such oils or liquids, concrete, if used, must be protected. The treatment to be applied shall also be approved by the Engineer.

CONCRETE IN SEA WATER

Proportions

51. Plain concrete in sea water or exposed directly along the sea coast, shall contain not less than 658 pounds of Portland cement per cubic yard in place. Slag, broken brick, soft limestone, soft sandstone or other porous or weak aggregates shall not be used.

Depositing

52. Concrete shall not be deposited under sea water unless this is unavoidable in which case it shall be placed in accordance with the methods described in Clause 41. Sea water, as far as possible, shall not be allowed to come in contact with the concrete until it has hardened for at least 4 days. Concrete shall be placed in such a manner as to avoid horizontal or inclined seams or work planes. The placing of concrete between tides shall be a continuous operation. Where it is impossible to avoid seams or joints proceed as in Clause 44.

Protection of Reinforcement and Concrete

53. Metal reinforcement shall be placed at least 3 in. from any plane or curved surface, and at corners at least 4 in. from all adjacent surfaces. Metal chairs, supports, or ties shall not extend to the surface of the concrete. Where unusually severe conditions or abrasion are anticipated, the face of the concrete from 2 ft. below low water to 2 ft. above high water or from a plane below to a plane above wave action, shall be protected by creosoted timber, stone of suitable quality or other materials as designated on the plans.

Consistency

54. The consistency of the concrete shall be the stiffest that will allow placing with a reasonable amount of labour, and shall be established by the Engineer according to conditions on the work. The Engineer may use the slump test or any other satisfactory method to check the consistency during the progress of the work.*

CONCRETE IN ALKALI SOILS AND WATER**General**

55. The destructive action of alkali waters on concrete is progressive. The rate of deterioration increases as the concentration of the sulphate content of the water increases and, for cement contents as great as are commonly used in structural work, decreases for any given cement as the concrete is made stronger.

High Concentration

56. Where structures are to be directly exposed to waters of high alkali concentration, the use of Portland cement concrete can not be recommended. At sites where the alkali concentration in the ground water is high, if concrete is to be used, the ground water should be lowered by drainage so that it will not come into contact with the structure. Additional protection may be obtained by the use of membrane waterproofing.

Integral Compounds

57. No integral compounds or alkali-proof products can be recommended.

Low Concentration

58. Where the alkali concentration is not great (under 0.1% concentration) concrete, if used, shall contain not less than 658 pounds of Portland cement per cubic yard in place and Clauses 38 to 45 inclusive should be carefully observed.

*The Engineer who wishes to employ the slump test for maintaining consistency is referred to Appendix XI.

SURFACE FINISH

PRECAUTIONS

General

59. The entire showing face between prescribed construction joints shall be cast in one continuous operation.

One brand of cement, and one kind and size of aggregate shall be used throughout the whole of any showing face.

For showing faces the forms shall be smooth and water-tight and if of wood, shall meet the requirements of Clause 29. Forms shall be so constructed as to be removable in sections by unscrewing or otherwise loosening without hammering or prying against the face. Any offsets in the forms that may occur shall be smoothly dressed and any openings pointed flush with stiff clay or plaster of Paris in order to prevent leakage or the formation of fins.

Placing
Material

60. Concrete that is to have a showing face, whether any particular finish is called for or not, shall be mixed, placed and worked as may be necessary to secure at the face a uniform distribution of the aggregates, freedom from void spaces, and uniform texture. If the finish is required to be one that will expose the coarse aggregate, by scrubbing, tooling, sand-blasting, or acid treatment, the concrete shall be thoroughly spaded, care being taken to avoid working the aggregate away from the forms. The coarse aggregate shall then be pressed against the form in order to secure uniform distribution at the face and a uniform texture after the aggregate is exposed.

Securing
Surface
Texture

61. Where a surface of mortar is to be the basis of the finish the coarse aggregate shall be worked back from the form with a suitable tool, so as to bring a full surface of mortar against the form, care being taken to prevent the formation of voids and air pockets.

Form
Removal

62. Care shall be taken when removing forms to avoid roughening or injuring corners, and to keep edges sharp.

Whenever forms are removed from showing faces before the concrete has become hard and dry, the surface of the concrete shall be immediately wetted and kept wet for at least three days.

Surface
Repairs

63. As soon as the face forms are removed all fins or other projections shall be carefully removed, and offsets levelled. All defective places shall be thoroughly cleaned of dust, laitance and foreign particles. Voids or damaged places shall immediately be saturated with water and filled with a mixture of the same composition as that used in the surface, and brought even with the surface by means of a wooden spatula or float. A steel trowel shall not be used to finish the surface. The face shall be finished free from streaks, discolourations or other imperfections. Plastering will not be permitted, except when ordered by the Engineer.

All nails, wires and bolts shall be removed or cut back to a depth of at least one inch from the surface of the concrete. Bolt holes shall be filled with corks or wooden plugs driven into the holes until the head is one inch back from the surface. The spot to be patched and the concrete immediately around it shall be saturated with water. A mortar composed of the same materials as in the surface concrete shall be forced into all parts of the cavity and the surface rubbed with a cork or wooden float. Any mortar that may work out and run over sound concrete shall be removed with a clean brush or cloth.

Patching in hot sunshine or quick drying wind should be avoided unless it is feasible to protect the fresh mortar with wet burlap.

SURFACES SUBJECT TO WEAR

Top Surfaces Subject to Wear

64. Aggregates for the wearing surface shall have a high resistance to abrasion, and shall be screened and, when necessary, thoroughly washed. The least quantity of mixing water that will produce a dense concrete shall be used. The mix shall not be leaner than 1 part of Portland cement and $2\frac{1}{2}$ parts of aggregate. The surface shall be screeded even and finished with a wood float. Excess water shall be promptly drained or otherwise removed. Overtrowelling shall be avoided.

The wearing surface in two-course work shall, when practicable, be placed within one-half hour after the base course. Where such surface is to be applied to a hardened course, the latter shall be prepared as indicated in Clause 44. The wearing course shall not be thinner than 1 in.

Concrete wearing surfaces shall be kept wet* for at least 10 days in the case of floors and 21 days in the case of roads and pavements.

Terrazzo

65. (a) Terrazzo finish† shall be made by mixing 1 part of cement, $2\frac{1}{2}$ parts of crushed marble, or other stone or crushed pebbles, as may be called for by the plans, and sufficient water to produce a dense concrete. The concrete shall be spread on the base course and worked down to a thickness of 1 in. by patting or rolling and trowelling. The marble shall pass a $\frac{1}{2}$ in. screen and be free from dust. The surface shall be kept wet for not less than 10 days and after curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Clause 44.

* Prevention of premature drying during the early hardening of concrete is essential to the development of high resistance to abrasion. The surface may be covered with a layer of burlap, earth or sand, kept wet, or it may be divided into small areas by dikes and flooded with water to a depth of 2 or 3 in.

† The Engineer must strike out one of the Clauses 65 (a) or 65 (b).

(b) Terrazzo finish* shall be made by mixing 1 part of cement, 2 parts of sand and sufficient water to produce a plastic mortar, which shall be spread on the base course to a depth of 1 in. Crushed marble, free from dust and passing a $\frac{1}{4}$ in. screen, shall be sprinkled over the surface of the fresh mortar and pressed or rolled in. The surface shall be kept wet for not less than 10 days and after curing shall be rubbed to a plane surface with a stone or surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Clause 44.

SURFACES NOT SUBJECT TO WEAR

Top
Surfaces

66. Top surfaces not subject to wear shall be smoothed with a wood float and kept wet for at least 7 days. Care shall be taken to avoid an excess of water in the concrete, and to drain or otherwise promptly remove any water that comes to the surface. Dry cement, or a dry mixture of cement and sand, shall not be sprinkled directly on the surface.

Granolithic
Surfaces

67. Granolithic surfaces shall be made by placing against the face form, in advance of the body concrete, facing concrete of such consistency and in such a manner as will ensure its bonding with the body concrete.

The facing concrete shall not be leaner than 1 part Portland cement, $1\frac{1}{2}$ parts fine aggregate, and 3 parts coarse aggregate made up of pebbles, crushed granite, or other stone as called for.

If iron or wooden moulds are used to retain the facing against the forms while placing body concrete, care should be taken that these moulds are not permitted to remain until initial setting occurs. The moulds shall be jarred frequently and raised at short intervals to prevent formation of seams and air spaces between the facing and the body concrete.

Rubbed
Surfaces

68. Surfaces to be finished shall be wetted and rubbed with a carborundum brick or other abrasive until even and smooth and of uniform appearance, without applying any cement or other coating. No finishing shall be done before concrete is 7 days old, or until the concrete is thoroughly hardened, or until after all repairs and pointing are complete and the mortar used for such repairs is firmly set.

Scrubbed
Surfaces

69. The forms shall be removed and the scrubbing done before the concrete has hardened.† The surface shall be scrubbed with fibre or wire brushes using water freely, until

* The Engineer must strike out one of the Clauses 65 (a) or 65 (b).

† In warm weather this will require from 6 to 24 hours, and in cold weather from 1 to 3 days. In either case, the concrete shall be protected from drying.

the surface film of mortar is removed and the aggregate uniformly exposed. It shall then be rinsed with clean water. If portions of the surface have become too hard to scrub in equal relief, dilute hydrochloric acid (1 part acid to 4 parts water) may be used to facilitate the scrubbing. The remaining acid shall be thoroughly removed with clean water.

Should any pointing be required, it shall be done immediately after scrubbing. After the patches have hardened sufficiently they shall be scrubbed to the same texture as the general surface, rinsed clean and kept moist for several days.

Sand
Blasted
Surfaces

70. The concrete face shall be permitted to attain an intermediate degree of hardness; it shall then be air-blasted with hard sand until the aggregate is in uniform relief. Any necessary pointing shall be done while the concrete is still green.

Tooled
Surfaces

71. The surface shall be permitted to become dry and hard and then dressed with tools to a uniform texture and even face as called for, by axing, rough or fine pointing, or bush-hammering.

Should any pointing be required on a surface to be tooled, the tooling shall precede the patching. The patching shall be done by first pointing and then embedding selected pieces of large aggregate in the mortar bed so as to match the surrounding tooled area. After the patches have thoroughly hardened they shall be carefully dressed.

Sand
Floated
Finish

72. The forms shall be removed before the surface has fully hardened; the surface shall be rubbed with a wooden float by a uniform circular motion, fine sand being rubbed into the surface until the resulting finish is even and uniform.

Any necessary pointing shall be done previous to rubbing.

Coloured
Aggregate

73. Coloured or other special aggregate used for finish shall be exposed by scrubbing as provided in Clause 69. Facing mortar, made from this special aggregate, proportioned not leaner than 1 part of cement, $1\frac{1}{2}$ parts of sand and 3 parts of clean and dust-free pebbles or screenings, shall be placed against the face forms to a thickness of about 1 in. sufficiently in advance of the concrete to prevent the latter coming in contact with the form.

Mineral
Pigment

74. Mineral pigment shall be thoroughly mixed dry with the cement and fine aggregate; care shall be taken to secure a uniform tint throughout.

Cement
Wash

75. Cement washes of practically any colour from white or cream to cement gray can be prepared by varying the proportions of white or gray cement and light or dark sand. Before applying the wash, all pointing and patching should be completed as indicated in Clauses 63, 68, 69 and 71.

A mixture of 1 part white cement and 1 part finely screened yellow sand, with 5 per cent. of hydrated lime will give a serviceable colour just off the white, and will serve as an example of a typical dry mixture.

The cement, sand and lime in the desired proportions shall be thoroughly mixed in the dry state. The mixture shall then be slowly added to water, stirring vigorously until the consistency is that of a stiff oil paint. The dry batch shall be large enough for a full day's work, but only enough of the wash shall be prepared to last one hour. The wash shall be stirred before each application to the concrete surface, and when refilling the container, all the old wash shall be cleaned out and discarded.

The area to be coated shall first be thoroughly wet, and then a full brush coat of the wash applied. This coat shall be rubbed in with a cork float, the surface being sprinkled with a little additional water if necessary. The surface shall then be gone over with a clean, damp brush, brushing in the direction of the board marks, so as to remove all excess material, and the remaining coat shall be as thin as will permit the surface to be entirely covered.

In coating adjacent areas the brush marks shall be carefully blended to avoid a line between the two areas. The sequence of the work shall be so planned that joinings occur at natural breaks in the surface.

In warm or drying weather the finished surface shall be sprinkled with water once a day for 3 days, and in cool, damp weather, shall be sprinkled at least once within 24 hours after finishing.

76. Proprietary cement paints or coatings shall be applied as directed.

DETAILS OF CONSTRUCTION

METAL REINFORCEMENT

77. Metal reinforcement, before being placed, shall be thoroughly cleaned of mill and rust scale and of coatings that will destroy or reduce the bond. Reinforcement appreciably reduced in section shall be rejected. Where there is delay in depositing concrete, reinforcement shall be re-inspected and, when necessary, cleaned.

78. Reinforcement shall be carefully formed to the dimensions indicated on the plans, or as provided in the specifications. Cold bends for steel of structural grade shall have an inside radius at least twice the dimension of the reinforcement in the plane of bending, and for steel of intermediate or hard grade an inside radius at least four times that dimension.

Proprietary
Coatings

Cleaning

Bending

Straightening

79. Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks, or bends not shown on the plans, shall not be used. Heating of reinforcement will be permitted only when the entire operation is approved by the Engineer.

Placing

80. Metal reinforcement shall be accurately placed, and secured against displacement by using annealed iron wire of not less than No. 18 gauge or suitable clips at intersections, and shall be supported by concrete or metal chairs or spacers, or metal hangers. The minimum clear distance in the plane of the reinforcement between parallel bars shall be $1\frac{1}{2}$ times the diameter of round bars or $1\frac{1}{2}$ times the diagonal of square bars; if the ends of bars are anchored as specified in Clause 133, this clear spacing may be made equal to the diameter of round bars or to the diagonal of square bars, but in no case shall the spacing between parallel bars measured in any direction be less than 1 in., nor less than $1\frac{1}{4}$ times the maximum size of the coarse aggregate. Bars parallel to the face of any member shall be embedded a clear distance not less than one diameter from the face. (See Clauses 84 and 85).

Splicing

81. In slabs, beams and girders, splices of reinforcement shall not be made at points of maximum stress without the approval of the Engineer. Splices, where permitted, shall provide sufficient lap to transfer the stress by bond. In such splices the bars shall be placed at the minimum distance specified in Clause 80; splices in adjacent bars shall be staggered.

Splices in the longitudinal reinforcement of columns, piers and struts shall provide sufficient lap to transfer the stress by bond. The clear distance between adjacent bars in such cases shall be not less than the nominal size of the coarse aggregate.

**Offsets in
Column
Reinforcement**

82. Where changes in the cross section of a compression member occur, the longitudinal reinforcement bars shall be sloped for the full length of the member or offset in a region where lateral support is afforded. Where offset, the slope of the inclined portion from the axis of the member shall be not more than 1 in 6.

**Future
Bonding**

83. Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion.

PROTECTIVE CONCRETE COVERING

**Moisture
Protection**

84. Metal reinforcement in wall and column footings and other members in contact with the ground shall have a minimum covering of 3 in. of concrete except in the case of precast members, for which the covering may be reduced to

1½ in. At surfaces of concrete exposed directly to water or rainfall, metal reinforcement shall be protected by a thickness of concrete not less than 2 inches.

**Fire
Protection**

85. Metal reinforcement in fire-resistive construction shall be protected by not less than 1 in. of concrete in slabs, except where reinforcement is ½ in. or less in diameter, in which case it may be ¾ in.; 1 in. in walls; 1 in. in beams or girders carrying less than 150 sq. ft. of loaded area; 2 in. in beams or girders carrying more than 150 sq. ft. of loaded area, and in columns, with the exception that for square columns, spirally reinforced, the protection shall be 1½ in.

In structures where the fire hazard is limited, the metal reinforcement shall be protected by not less than ¾ in. in slabs and walls or 1½ in. in beams, girders and columns.

Plaster

86. Cement or gypsum plaster adequately bonded to a concrete surface may be considered as reducing the thickness of concrete protection required in Clause 85 by one-half of the thickness of the plaster.

JOINTS

General

87. Joints not indicated on the plans shall be so designed and located as least to impair the strength and appearance of the structure. To prevent laitance in horizontal joints, excess water shall be removed from the surface forming the joint after depositing the concrete. Surfaces of contact shall be cleaned and wetted before depositing is resumed, and any laitance shall be removed. Where additional resistance to horizontal shear is required, stones shall be partially embedded in such a manner as to key with the adjoining concrete; or mortises or keys shall be formed in the concrete. (See Clause 44).

**Joints in
Columns**

88. Joints in columns shall be made at the underside of the floor. Haunches, column capitals, girders and beams shall be considered as part of the floor construction, and shall be built to act integrally therewith. At least 2 hours must elapse after depositing concrete in columns or walls before depositing in beams, girders or slabs.

**Joints in
Floors**

89. Construction joints in floors shall be located near the middle of spans of slabs, beams or girders. If a beam intersect a girder at midspan, the joint in the girder shall be offset a distance equal to twice the width of the beam. Provision shall be made for shear at the joint.

**Construction
Joints in
Long
Structures**

90. Special reinforcement shall be placed in construction joints which extend across a structure 100 ft. or more in length. The reinforcement shall be placed at right angles to the joint and shall extend a sufficient distance on each side of the joint to develop the strength of the reinforcement

by bond. This reinforcement shall be placed near the face of the member remote from the main tension reinforcement; the cross-sectional area of such reinforcement shall be not less than 0.5 per cent of the section of the members cut by the joint.

Expansion
Joints

91. Expansion joints shall be so detailed that the necessary movement may occur with a minimum of resistance at the joint. The structure adjacent to the joint shall preferably be supported on separate columns or walls. Reinforcement shall not extend across an expansion joint; the break between the two sections shall be complete.

Expansion
Joints in
Long
Structures

92. Unless otherwise specified structures exceeding 200 ft. in length and of width less than about one-half the length, shall be divided by means of expansion joints not more than 200 ft. apart. Structures in which marked changes in plan dimensions take place abruptly shall be provided with expansion joints at the sections where such changes occur.

Sliding
Joints

93. The seat of a sliding joint shall be finished to a smooth surface and the concrete shall not be placed upon it until the surface has set hard. Provision shall be made to facilitate sliding.

Water-tight
Joints

94. Where water-tight construction is required and it is not possible to finish a section of the structure in one continuous operation, the joint shall be made as specified by the Engineer.

Cutting Holes
in Floors

95. Where holes for the accommodation of pipes, conduits, etc., have to be cut through reinforced concrete floors after the concrete has hardened, one-third at least of the depth of the cutting shall be made from the under-side. The remainder may be cut from above.

PART II.

DESIGN

GENERAL ASSUMPTIONS

General Assumptions

96. The design of reinforced concrete members shall be based on the following assumptions:

(a) That for stresses due to bending, a transverse section plane before bending remains plane after bending.

(b) That the modulus of elasticity of concrete in compression is constant within the limits of working stresses.

(c) That the ratio of the modulus of elasticity of the steel to that of the concrete is

$$n = \frac{30,000}{f'_c}$$

in which f'_c is the ultimate compressive strength of the concrete in pounds per square inch at the age of 28 days.

(d) That in calculating the moment of resistance to bending, the tensile resistance of the concrete is neglected.

(e) That the bond between the concrete and the reinforcement remains unbroken throughout the range of working stresses.

(f) That initial stress due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.

FLEXURE OF RECTANGULAR REINFORCED
CONCRETE BEAMS AND SLABS

Notation

97. The symbols used in Formulae 1 to 29 are defined as follows:

A_s = effective cross-sectional area of metal reinforcement in tension in beams or slabs;

b = width of rectangular beam or width of flange of T-beam;

b' = width of stem of T-beam;

d = depth from compression surface of beam or structural slab to centre of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to centre of compression reinforcement;

f_c = unit compressive stress in extreme fibre of concrete;

- f_s = unit tensile stress in longitudinal reinforcement;
 f'_s = unit compressive stress in longitudinal reinforcement;
 h = unsupported length of column;
 I = gross moment of inertia of a section about the neutral axis for bending;
 j = ratio of lever arm of resisting couple to depth d ;
 k = ratio of depth of neutral axis to depth d ;
 l = span length of beam or slab (See Clause 99);
 M = bending moment or moment of resistance in general;
 n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;
 p = ratio of effective area of tension reinforcement to area of concrete in beams = A_s/bd ;
 p' = ratio of effective area of compression reinforcement to area of concrete in beams;
 t = thickness of flange of T-beam;
 V = total transverse shear;
 w = uniformly distributed dead and live load per unit of length of beam or slab;
 z = depth from compression surface of beam or slab to resultant of compressive stresses.

Flexure
Formulae—
Rectangular
Girders, Beams
and Slabs

98. The following formulae apply to computations for flexure in rectangular reinforced concrete girders, beams and slabs:

(a) REINFORCED FOR TENSION ONLY.

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn \dots \dots \dots (1)$$

Arm of resisting couple,

$$jd = \left\{ 1 - \frac{k}{3} \right\} d \dots \dots \dots (2)$$

Unit compressive stress in extreme fibre of concrete,

$$f_c = \frac{2M}{jkb d^2} = \frac{2pf_s}{k} \dots \dots \dots (3)$$

Unit tensile stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s j d} = \frac{M}{p j b d^2} \dots \dots \dots (4)$$

Steel ratio for balanced reinforcement,

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c} \left\{ \frac{f_s}{n f_c} + 1 \right\}} \dots \dots \dots (5)$$

For formulae on shear, bond and anchorage see Clauses 116, 121, 128 and 130.

(b) REINFORCED FOR BOTH TENSION AND COMPRESSION.

Position of neutral axis,

$$k = \sqrt{2n(p + p' \frac{d'}{d}) + n^2(p + p')^2} - n(p + p') \dots (6)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3} k^3 d + 2p' n d' (k - \frac{d'}{d})}{k^2 + 2p' n (k - \frac{d'}{d})} \dots \dots \dots (7)$$

Arm of resisting couple,

$$j d = d - z \dots \dots \dots (8)$$

Unit compressive stress in extreme fibre of concrete,

$$f_c = \frac{6M}{b d^2 \left\{ 3k - k^2 + \frac{6p' n}{k} (k - \frac{d'}{d}) (1 - \frac{d'}{d}) \right\}} \dots \dots (9)$$

Unit tensile stress in longitudinal reinforcement,

$$f_s = \frac{M}{p j b d^2} = n f_c \frac{1 - k}{k} \dots \dots \dots (10)$$

Unit compressive stress in longitudinal reinforcement,

$$f'_s = n f_c \frac{k - \frac{d'}{d}}{k} \dots \dots \dots (11)$$

Span
Length

99. The span length, l , of freely supported girders, beams and slabs, whether single or continuous, shall be either the distance between centres of supports or the clear span plus the depth of the beam or slab whichever is the less. The span length for girders, beams and slabs built to act integrally with supports shall be the clear distance between

faces of supports. Where a bracket having a width not less than the width of a restrained beam and making an angle of 45 degrees, or more, with the axis of the beam, is built to act integrally with the beam and support, the span shall be measured from the section where the combined depth of the beam and bracket is one-third more than the depth d of the beam. No portion of a bracket shall be considered as adding to the effective depth of the beam, unless the inclination of the bracket with the axis of the beam is less than 45 degrees. Maximum negative moments are to be considered as existing at the ends of the span as defined above.

**Lateral
Support**

100. Where the distance, l , between points of lateral support of an isolated beam exceeds 10 times the width, b , of the compression area, the permissible flexural stress in the concrete shall not exceed

$$f_{c_l} = f_c \left(1.20 - \frac{l}{50b} \right) \dots \dots \dots (12)$$

where f_c is the permissible flexural stress in beams continuously supported laterally.

The distance between lateral supports shall not exceed 24 times b , unless reinforcement in the compression area is provided to resist buckling.

**Slightly
Restrained
Beams of
Equal Span**

101. Beams and slabs of equal spans built to act integrally with beams, girders, or other slightly restraining supports and assumed to carry uniformly distributed loads shall be designed for the following moments at critical sections:

(a) Beams and slabs of one span,

Maximum positive moment near centre,

$$M = \frac{wl^2}{8} \dots \dots \dots (13)$$

(b) Beams and slabs continuous for two spans only.

(1) Maximum positive moment near centre,

$$M = \frac{wl^2}{10} \dots \dots \dots (14)$$

(2) Negative moment over interior support,

$$M = \frac{wl^2}{8} \dots \dots \dots (15)$$

(c) Beams and slabs continuous for more than two spans,

(1) Maximum positive moment near centre and negative moment at support of intermediate spans,

$$M = \frac{wl^2}{12} \dots \dots \dots (16)$$

- (2) Maximum positive moment near centres of end spans and negative moment at first interior support,

$$M = \frac{wl^2}{10} \dots\dots\dots (17)$$

- (d) Negative moment at end supports for cases (a), (b) and (c), of this clause,

$$M = \text{not less than } \frac{wl^2}{24} \dots\dots\dots (18)$$

Freely
Supported
Continuous
Beams of
Equal Span

102. Beams and slabs of equal spans freely supported and assumed to carry uniformly distributed loads shall be designed for the moments specified in Clause 101, except that no reinforcement for negative moment need be provided at end supports where effective measures are taken to prevent end restraint. The span shall be taken as defined in Clause 99 for freely supported beams.

Restrained
Beams of
Equal Span

103. Beams and slabs of equal span built to act integrally with columns, walls or other restraining supports and assumed to carry uniformly distributed loads, shall (except as provided in Clause 101) be designed for the following moments at critical sections, provided that the supports are reinforced to resist the moment due to such integral action.

- (a) Intermediate spans;

- (1) Negative moment at interior supports except the first,

$$M = \frac{wl^2}{12} \dots\dots\dots (19)$$

- (2) Maximum positive moment near centres of intermediate spans;

$$M = \frac{wl^2}{16} \dots\dots\dots (20)$$

- (b) End spans of continuous beams and beams of one span in which l/h is less than twice the sum of the values of l/h for the exterior columns immediately above and below;

- (1) Maximum positive moment near centre of span and negative moment at first interior support,

$$M = \frac{wl^2}{12} \dots\dots\dots (21)$$

- (2) Negative moment at exterior support,

$$M = \frac{wl^2}{12} \dots\dots\dots (22)$$

- (c) End spans of continuous beams, and beams of one span, in which I/l is equal to or greater than twice the sum of the values of I/h for the exterior columns immediately above and below;

- (1) Maximum positive moment near centre of span and negative moment at first interior support,

$$M = \frac{wl^2}{10} \dots\dots\dots (23)$$

- (2) Negative moment at exterior support,

$$M = \frac{wl^2}{16} \dots\dots\dots (24)$$

(d) The distribution of moments in beams prescribed in (b) and (c) above shall be based on moments of inertia of beams and columns computed from the gross section of the concrete including fireproofing but neglecting reinforcement, but the stresses in beams shall be computed in accordance with Clauses 98 and 106.

Moment
Coefficients
for Special
Beams

104. Where the spans are of unequal lengths or where special cases of loading occur, the moment shall be determined for all applicable conditions of loading and restraint. Provision shall be made for negative moment wherever it occurs.

Moments in
Statically
Indeterminate
Structures

105. In determining the distribution of moments in structures which are statically indeterminate, the moments of inertia of the members of the system as defined in Clause 103 (d) shall be used.

FLEXURE OF REINFORCED CONCRETE T-BEAMS

Flexure
Formulae
T-Beams

106. The following formulae apply to computations for flexure in reinforced concrete T-beams:

- (a) Neutral Axis in the Flange;

Use formulae for rectangular beams and slabs in Clause 98.

- (b) Neutral Axis below the Flange;

Position of neutral axis,

$$kd = \frac{2ndA_s + bf^2}{2nA_s + 2bt} \dots\dots\dots (25)$$

Position of resultant compression,

$$z = \left\{ \frac{3kd - 2t}{2kd - t} \right\} \frac{t}{3} \dots\dots\dots (26)$$

Arm of resisting couple,

$$jd = d - z \dots\dots\dots (27)$$

Unit compressive stress in extreme fibre of concrete,

$$f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n} \left\{ \frac{k}{1-k} \right\} \dots\dots\dots (28)$$

Unit tensile stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \dots\dots\dots (29)$$

Formulae 25, 26, 27, 28 and 29 neglect compression in the stem. In cases where the thickness of the slab is small in relation to kd , the compression in the stem should not be neglected.

107. Adequate shear resistance shall be provided in beam-and-slab construction at the junction of the slab with the stem of the beam. The slab shall be built and considered as an integral part of the beam; the effective flange width to be used in the design of symmetrical T-beams shall not exceed one-fourth of the span length of the beam, and the over-hanging part on either side of the stem shall not exceed 8 times the thickness of the slab nor one-half the clear distance to the next beam, where the beams involved are of equal size.

For beams having a flange on one side only, the effective overhanging flange width shall not exceed one-twelfth of the span length of the beam nor shall it exceed 6 times the thickness of the slab nor one-half the clear distance to the next beam.

108. Where the principal reinforcement in a slab which is considered as the flange of a T-beam (not a rib in ribbed floors) is parallel to the beam, transverse reinforcement shall be provided in the top of the slab. This reinforcement shall be designed to carry the load on the portion of the slab assumed as the flange of the T-beam. The spacing of the bars shall not exceed 5 times the thickness of the flange, nor in any case 18 in.

109. Provision shall be made for both compressive and tensile stress at the support in continuous T-beam construction.

110. In beam-and-tile construction when the tiles are so placed that the joints in alternate rows are staggered, the webs of the tile in contact with ribs or stems may be included in calculations involving shear and negative bending moment. (See Clause 119).

Flange
Width

Transverse
Reinforcement

Stress at
Supports

Beam-and-Tile
Construction

**Isolated
Beams**

111. Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the thickness of the stem and a total flange width not more than 4 times the stem thickness. The conditions set forth in Clause 100 shall apply.

**REINFORCEMENT FOR COMPRESSION, SHRINKAGE AND
TEMPERATURE CHANGES**

**Compression
Steel in
Flexural
Members**

112. Where it is necessary to introduce steel in compression in girders, beams or slabs, such steel shall be thoroughly anchored by ties or stirrups not less than one-quarter inch in size, which shall be spaced not more than 8 inches apart over the distance where the compression steel is required.

**Shrinkage and
Temperature
Reinforcement**

113. Reinforcement for shrinkage and temperature stresses shall be provided in floor and roof slabs where the principal reinforcement extends in one direction only. In no case shall reinforcing bars be placed farther apart than 5 times the slab thickness, nor more than 18 in. The following shall be minimum ratios of reinforcement area to concrete area:

Floor slabs where plain bars are used	0.0025
Floor slabs where deformed bars are used	0.002
Roof slabs where plain bars are used	0.003
Roof slabs where deformed bars are used	0.0025

FLOORS REINFORCED IN TWO DIRECTIONS

**Rules for
Design**

114. Concrete floors supported on four sides by beams, girders or walls, and reinforced in two directions shall be designed as follows, using moment coefficients given in Clauses 101, 103 and 104 as required, except as indicated under (d) below:

(a) If the length of the slab exceed one and one-half times its width, the entire load shall be carried in the short direction.

(b) In case of a square panel with uniformly distributed load, one-half of the live and dead load may be assumed as being resisted by each cross band.

(c) In rectangular panels of length L and breadth B , the portion of the load which shall be assumed as being supported by the slab in the short direction shall be equal to $\left\{ \frac{L}{B} - \frac{1}{2} \right\}$ times the total load. The remainder of the load shall be assumed as being supported by the slab in the long direction. The reinforcement in the long direction shall in no case be less than that specified in Clause 113, for shrinkage and temperature reinforcement.

(d) In placing the reinforcement, account may be taken of the fact that the moment is less in the portions of the band which are adjacent and parallel to the supporting beams. In the one-quarter width of band parallel and adjacent to the beams, the computed moment may be reduced 50 per cent. In no case shall the spacing of bars exceed twice the effective depth of the slab.

(e) Beams supporting such slabs shall be assumed to take the portion of the load as determined in (a), (b), or (c), above.

SHEAR

Notation

115. The symbols used in Formulae 30 to 33 are defined in Clause 97, except as follows:

- A_v = total area of web reinforcement in tension within a distance s , that is $s_1, s_2, s_3, \dots, s_n$, or the total area of all stirrups or all bars bent up in any one plane;
- α = angle between web bars and longitudinal bars;
- f'_c = ultimate compressive strength of concrete at age of 28 days based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the "Method of Making Compression Tests of Concrete" (Appendix XII) and the "Method of Making and Storing Specimens of Concrete in the Field" (Appendix XIII);
- f_v = unit tensile stress in web reinforcement;
- Σo = sum of perimeters of bars in one set;
- s = spacing of web bars or stirrups from each other or from the edge of the support measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam;
- t_1 = thickness of flat slab without dropped panels or total thickness of a dropped panel (See Appendix II, Fig. 14);
- t_2 = thickness of flat slab with dropped panels at points away from the dropped panel (See Appendix II, Fig. 14);
- u = unit bond stress;
- v = unit shear stress;
- V = total shear.

Formula for
Shear

116. The unit shear stress, v , in rectangular prismatic reinforced concrete beams shall be that computed by Formula 30.

$$v = \frac{V}{bjd} \dots \dots \dots (30)$$

For T-beams, b in Formula (30) is to be replaced by the stem width b' .

Shear for
Beams Wedge-
Shaped in
Profile

117. For beams wedge-shaped in profile, the shear, V , used in Formula 30, shall be replaced by V_1 , in which the effect of the inclination of the resultant compression or the resultant tension, or both, to a normal to the cross-section, is taken into account.

Variation of
Shear in
Beams with
Uniform Load

118. For purpose of design of simple or continuous beams carrying uniform loads not less than one-fourth of the total shearing resistance required at either end of the span shall be provided at the section where the computed shear stress is zero; from that section to the ends of the span the required shearing resistance shall be assumed to vary uniformly.

Shear in Beam-
and-Tile
Construction

119. The width of the effective section for shear in beam-and-tile construction shall be assumed as the thickness of the concrete web plus the thickness of the vertical webs of the concrete or clay tile in contact with the beam. (For typical design see Appendix II, Fig. 13.).

Types and
Spacing of Web
Reinforcement

120. Web reinforcement may consist of:

(a) Stirrups, or web bars forming an angle of 30 degrees or more with the longitudinal bars;

(b) Longitudinal bars bent up or bent down at an angle of 15 degrees or more with the direction of the longitudinal bars;

(c) A combination of (a) and (b).

Where, in the judgment of the Engineer, vertical cracks are likely to occur in beams at or near the face of supports, due to a combination of shrinkage or temperature effects with flexure, the vertical shear shall be wholly provided for by bent-up or bent-down longitudinal bars adequately anchored.

Stirrups, or bent-up bars which are not anchored at both ends, according to the provisions of Clause 134, shall not be considered effective as web reinforcement.

When the shear stress is not greater than $0.06f'_c$, the distance, s , shall not be greater than

$$s = \frac{45d}{\alpha + 10} \dots \dots \dots (31)$$

where the angle α is in degrees.

When the shear stress is greater than $0.06f'_c$, the distance, s , shall not be greater than two-thirds of the value given by Formula 31.

Except for hooks, the inside radius of curvature of a bent bar shall not be less than 12 times the dimension of the bar in the plane of bending.

Beams without
Special Anchor-
age of Longitu-
dinal Reinforce-
ment, or Beams
with Bars Bent
Up in a Single
Inclined Plane

121. The unit shear stress computed by Formula 30 in beams in which the longitudinal reinforcement is without special anchorage, or in beams with bars bent up in a single inclined plane, shall not exceed the value given by Formula 32 and in no case shall it exceed $0.06f'_c$.

$$v = 0.02f'_c + \frac{f_v A_v}{bs} (\sin \alpha + \cos \alpha) \dots \dots \dots (32)$$

When bars are bent up in a single inclined plane, the horizontal distance over which they are to be considered as effective in resisting web stresses shall not be greater than $s/2$ on either side of the point where the bent-up bars cross the mid depth of the beam, s being as indicated in Formula 31.

Beams with
Special Anchor-
age for
Longitudinal
Reinforcement

122. The unit shear stress computed by Formula 30 in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in Clause 133, shall not exceed the value given by Formula 32, when $0.03f'_c$ is substituted for $0.02f'_c$ in that formula, nor shall it exceed $0.09f'_c$ except as immediately below. (See Clause 182).

In cases where the design of unusual members involves the use of unit shear stresses in excess of $0.09f'_c$, values up to but not exceeding $0.12f'_c$ may be used, providing the requirements of this clause are fully met, that the members in which these stresses are used shall be specially designated on the plans and that these members shall be constructed under the personal supervision of the designing Engineer.

Shear
Stress in
Flat Slabs

123. (a) In flat slabs, the unit shear stress on a vertical section which lies at a distance $t_1 - 1\frac{1}{2}$ in. outside the edge of the column capital and parallel with it, shall not exceed the following values when computed by Formula 30, in which d shall be taken as $t_1 - 1\frac{1}{2}$ in:

(1) $0.03f'_c$ when at least 50 per cent of the total negative reinforcement in the two column strips passes directly over the column capital;

(2) $0.025f'_c$ when 25 per cent of the total negative reinforcement in two column strips passes directly over the column capital (which is the least that shall be permitted);

(3) For intermediate percentages, intermediate values of the unit shear stress shall be used.

(b) In flat slabs, the unit shear stress on a vertical section which lies at a distance of $t_2 - 1\frac{1}{2}$ in. outside the edge of the dropped panel and parallel with it shall not exceed $0.03f'_c$ when computed by Formula 30, in which d shall be taken as $t_2 - 1\frac{1}{2}$ in. At least 50 per cent of the cross-sectional area of the negative reinforcement in two column strips must be within the width of strip directly over the dropped panel.

Shear
Stress in
Footings

124. The shear stress shall be that computed by Formula 30. The stress on the critical section shall not exceed $0.02f'_c$ for footings with straight reinforcement bars, nor $0.03f'_c$ for footings in which the reinforcement bars are anchored at both ends by adequate hooks, as specified in Clause 133.

Critical
Section for
Soil Footings

125. The critical section for shear in footings on soil shall be a vertical section through the perimeter of the base of a frustum of a cone or pyramid having a base angle of 45 degrees and having, for its top, the bottom of the column or pedestal, and for its base the plane of longitudinal reinforcement.

Critical
Section for
Pile Footings

126. The critical section for shear in footings on piles shall be a vertical section at the inner edge of the first row of piles entirely outside a section midway between the face of the column or pedestal and the section described in Clause 125 for soil footings, but in no case shall it be outside the section defined in Clause 125. The critical section for piles not arranged in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum defined in Clause 125.

127. Footings having sloping top surfaces shall be considered as beams wedge-shaped in profile.

BOND AND ANCHORAGE

Bond
Stresses
by Beam Action

128. Where bar reinforcement is used to resist tensile stresses developed by beam action, the bond stress for prismatic beams shall be computed by Formula 33.

$$u = \frac{V}{\sum ojd} \dots \dots \dots (33)$$

For beams wedge-shaped in profile, V in Formula 33 is to be replaced by V_1 as defined in Clause 117. For a simple beam or the freely supported end of a continuous beam, the critical section for bond shall be assumed to be at the face of the support. For a continuous or a restrained beam, the critical section for bond for the positive reinforcement shall be assumed to be at the point of inflection, or at sections where bars not required for moment have been bent up; for the negative reinforcement it shall be assumed as at the face of the support or at sections where bars not required for moment have been bent down.

In a footing, only the bars specified in Clause 169 as effective in resisting bending moment shall be considered as resisting bond stresses. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surfaces.

Bond Stress
for Ordinary
Anchorage

129. In beams where the ordinary anchorage described in Clause 132 is provided, the bond stress computed by Formula 33 at any section shall not exceed the following values:

For plain bars..... $u = 0.04f'_c$

For deformed bars as defined in

Appendix III..... $u = 0.05f'_c$

Bond Stresses
for Special
Anchorage

130. In beams where special anchorage of the bars is provided as specified in Clause 133, apparent bond stresses as computed by Formula 33 exceeding those specified in Clause 129, but in no case more than $2\frac{1}{2}$ times the latter, may be used; provided, however, that sufficient length of bar is added beyond the point of beginning of anchorage defined below and indicated in Appendix II, Figure 7, to justify the use of the higher apparent bond stress. It may be computed by Formula 34.

$$x = \frac{F - Q' \Sigma (u' \Delta y \Sigma o)}{u \Sigma o} \dots \dots \dots (34)$$

where

F = total maximum tension in the bar or bars under consideration;

u = permissible bond stress specified in Clause 129;

u' = apparent mean bond stress for any portion, Δy , of the bars as determined by Formula 33;

Q' = ratio of u to the maximum apparent bond stress as determined by Formula 33, anywhere in the distance y ;

Σo = perimeter of the bar or bars under consideration;

x = length of the bar added for anchorage, including the hook, if any;

y = distance from the point of maximum tension in the bar to the point of beginning of anchorage;

Δy = any portion of the distance y .

The point of beginning of anchorage shall, in freely supported beams, be the edge of the support for straight bars, and the point of bending for bent bars. For straight bars in restrained or continuous beams, it shall be the point of inflection for the loading under consideration. For bent-up or bent-down bars in restrained or continuous beams it shall be

the point of bending. For straight bars in cantilever beams it shall be the beginning of the hook, if any, while for bent bars it shall be the point of bending.

The inside radius of bend of any portion of a bar included in the length added for anchorage shall not be less than 4 bar diameters.

**Bond Stress
for Reinforce-
ment in Two or
More Directions**

131. The permissible bond stress for footings and similar members in which reinforcement is placed in more than one direction, shall not exceed 75 per cent of the values specified in Clauses 129 and 130.

**Ordinary
Anchorage
Requirements**

132. For a continuous, restrained or cantilever beam, negative tension reinforcement shall be carried on both sides of the face of the support, a distance sufficient to develop by bond stress in accordance with Clause 129, the maximum tension in the reinforcement. Not less than one-fourth of the area of the positive reinforcement shall extend without change of alignment to provide an embedment of 10 or more bar diameters beyond the face of the support.

In a simple beam or at the freely supported end of a continuous beam, at least one-half of the area of the tensile reinforcement shall extend along the tension side of the beam to provide an embedment of 10 or more bar diameters beyond the face of the support.

**Special
Anchorage
Minimum
Requirements**

133. Where increased shearing stresses are used as provided in Clauses 122 and 124, or increased bond stresses as provided in Clause 130, special anchorage of reinforcement, in addition to that required in Clause 132, but not less than that required in Clause 130, shall be provided as follows:

(a) In a continuous or restrained beam, anchorage beyond points of inflection of one-third the area of the negative reinforcement and beyond the face of the support of one-third the area of the positive reinforcement shall be provided to develop one-third of the maximum working stress in tension, with bond stresses not greater than those specified in Clause 129.

(b) In footings, all bars shall be anchored by means of end hooks. The total length of bar shall be the width of the footing plus 20 bar diameters. The outer face of the hook shall be not less than 3 inches nor more than 4 inches from the face of the footing.

(c) In a simple beam or at the freely supported end of a continuous beam, at least one-half of the tensile reinforcement shall extend along the tension side of the beam to provide at a bond stress as specified in Clause 129, an anchorage beyond the face of the support for one-third of the maximum unit stress in tension.

Anchorage of
Web
Reinforcement

134. Web bars shall be anchored at both ends by:

- (a) providing continuity with the longitudinal reinforcement; or
- (b) bending around the longitudinal bar; or
- (c) a semi-circular hook which has an inside radius not less than four times the diameter of the web bar.

Stirrup anchorage shall be so provided in the compression and tension regions of a beam as to permit the development of safe working tensile stress in the stirrup at a point $0.3d$ from either face.

The end anchorage of a web member not in bearing on the longitudinal reinforcement shall be such as to engage an amount of concrete sufficient to prevent the bar from pulling out. (For typical designs see Appendix II, Figs. 8 and 11).

Hooks shall not be considered as effective if employed in situations where there is danger of splitting the concrete, unless this danger has been met by wrapping or other effective measures.

FLAT SLABS

Two-Way and Four-Way Systems with Rectangular Panels.

135. The moment coefficients, moment distribution and slab thicknesses specified herein are for a series of slabs of approximately uniform size arranged in three or more rows of panels in each direction, and in which the ratio of length to width of panel does not exceed 1.33. Slabs with paneled ceiling or with depressed paneling in the floor shall be considered as coming under the requirements herein given. The symbols used in Formulae 35 to 37 are defined herewith and in Clauses 138 and 139. (See also Appendix II, Figs. 13 and 14).

In flat slabs in which the ratio of reinforcement for negative moment in the column strip is not greater than 0.01, the numerical sum of the positive and negative moments in the direction of either side of the panel shall be assumed as not less than that given by Formula 35.

$$M_0 = 0.09 Wl \left\{ 1 - \frac{2c}{3l} \right\}^2 \dots \dots \dots (35)$$

where

M_0 = sum of positive and negative bending moments in either rectangular direction at the principal design sections of a panel of a flat slab.

c = base diameter of the largest right circular cone, which lies entirely within the column, (including

Moments in
Interior
Panels

the capital), the vertex angle of which is 90 deg. and the base of which is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (See Appendix II, Fig. 13). For wall columns with brackets, the value of c in the direction of the bracket may be taken as twice the distance from the centre of the column to a point where the bracket is $1\frac{1}{2}$ in. thick, provided the face of the bracket makes an angle with the vertical not over 45 degrees. In the direction of the wall, c may be taken as the width of the column plus twice the depth from the bottom of the slab or the dropped panel, if one is provided, to the bottom of the marginal beam.

- l = span length (See Appendix II, Fig. 14) of flat slab, centre to centre of columns in the rectangular direction in which moments are considered.
- l_1 = span length of flat slab, centre to centre of columns perpendicular to the rectangular direction in which moments are considered.
- W = total dead and live load uniformly distributed over a single panel area.

Table IV.—Moments to be Used in Design of Flat Slabs
ASSUMED TO CARRY UNIFORMLY DISTRIBUTED LOADS

Strip	Flat Slabs without Dropped Panels		Flat Slabs with Dropped Panels	
	Negative	Positive	Negative	Positive
Slabs with 2-way Reinforcement				
Column Strip.....	$0.23M_o$	$0.11M_o$	$0.25M_o$	$0.10M_o$
2 Column Strips....	$0.46M_o$	$0.22M_o$	$0.50M_o$	$0.20M_o$
Middle Strip.....	$0.16M_o$	$0.16M_o$	$0.15M_o$	$0.15M_o$
Slabs with 4-way Reinforcement				
Column Strip.....	$0.25M_o$	$0.10M_o$	$0.27M_o$	$0.095M_o$
2 Column Strips....	$0.50M_o$	$0.20M_o$	$0.54M_o$	$0.190M_o$
Middle Strip.....	$0.10M_o$	$0.20M_o$	$0.08M_o$	$0.190M_o$

**Principal
Design
Sections**

136. In computing the critical moments in flat slabs subjected to uniform load, the following principal design sections shall be used:

(a) Section for Negative Moment in Middle Strip.

The section extends over the central half of l_1 (See Appendix II, Fig. 14).

(b) Section for Negative Moment in Column Strip.

The section begins at a point on the edge of the panel $l_1/4$ from the centre of a column and extends in a rectangular direction towards the column to a point $c/2$ therefrom and thence along a one-quarter circumference about the column centre to the adjacent edge of the panel.

(c) Section for Positive Moment in Middle Strip.

The section extends over the central half of l_1 .

(d) Section for Positive Moment in Column Strip.

The section extends a length of $l_1/4$ in a rectangular direction across the centre of the column strip.

Moments in
Principal
Design
Sections

137. Provided that their sum remains equal to M_0 , the moments at the principal design sections may be varied from the values given in Table IV as follows:

(a) The sum of the maximum negative moments in the two column strips may be greater or less than the values given in Table IV by not more than $0.03M_0$.

(b) The maximum negative moment and the maximum positive moment in the middle strip and the sum of the maximum positive moments in the two column strips may each be less or greater than the values given in Table IV by not more than $0.01M_0$.

Thickness of
Flat Slabs

138. The total thickness t_1 , in inches, of slabs without dropped panels shall be not less than:

$$t_1 = \left\{ 0.038 \left(1 - 1.44 \frac{c}{l} \right) l \sqrt{w' + 1\frac{1}{2}} \right\} \sqrt[3]{\frac{2000}{f'_c}} \dots (36)$$

where w' = uniformly distributed dead and live load in lb. per sq. ft.

For slabs with dropped panels the total thickness in inches at points beyond the dropped panel shall be not less than

$$t_2 = \left\{ 0.02 l \sqrt{w' + 1} \right\} \sqrt[3]{\frac{2000}{f'_c}} \dots (37)$$

For the purpose of Formulae 36 and 37, c and l are in feet and are as defined in Clause 135.

The slab thickness t_1 or t_2 shall in no case be less than $l/32$ for floor slabs, and not less than $l/40$ for roof slabs.

Dimensions of
Dropped Panels

139. The dropped panel shall have a length or diameter in each rectangular direction of not less than one-third the panel length in that direction and a thickness not greater than $1.5t_2$ nor less than $1.25t_2$.

**Wall and Other
Irregular Panels**

140. In wall panels and other panels in which the slab is non-continuous on one edge, the maximum positive moments on the principal design sections parallel to the discontinuous edge (reinforcement perpendicular to that edge) shall be increased by 25 per cent.

The positive moment reinforcement perpendicular to the discontinuous edge shall extend to this edge and have an embedment of at least 6 in. in spandrel beams or columns. All negative moment reinforcement shall be bent or hooked at spandrel beams or columns to provide adequate bond resistance.

At the wall or discontinuous edge the negative moment in the column strip shall be taken as not less than 90 per cent and in the middle strip not less than $62\frac{1}{2}$ per cent. of the corresponding moments for a normal interior panel as given in Table IV.

**Panels with
Discontinuous
Edges**

141. In panels having a beam on one discontinuous edge, or on each of two intersecting discontinuous edges, the beam shall be designed to carry at least the load superimposed directly upon it, exclusive of the panel load. A beam which has a depth greater than $1\frac{1}{2}$ times the minimum slab thickness shall be designed to carry, in addition to the load superimposed upon it, at least one-fourth of the distributed load for which the adjacent panel is designed, and each column strip adjacent and parallel to the beam shall be designed to resist a moment at least one-half as great as that specified in Table IV for a column strip.

Each column strip adjacent and parallel to a marginal beam which has a depth equal to or less than $1\frac{1}{2}$ times the minimum slab thickness, shall be designed to resist the moments specified in Table IV for a column strip. Beams on opposite discontinuous edges of a panel and the slab between them shall be designed for the entire load and the slab shall be designed as a simple span.

**Flat Slabs
on Bearing
Walls**

142. Where there is a beam or a bearing wall on the centre line of columns in the interior portion of a continuous flat slab, the negative moment at the beam or wall line in the middle strip perpendicular to the beam or wall shall be taken as 30 per cent. greater than the moment specified in Table IV for a middle strip. The column strip adjacent to and lying on either side of the beam or wall shall be designed to resist a moment at least one-half of that specified in Table IV for a column strip.

**Line of
Inflection**

143. In the middle strip the line of inflection for slabs without dropped panels shall be assumed to be 0.33/ distant from the centre of the span and for slabs with dropped panels, 0.30/ distant from the centre of the span.

In the column strip, the line of inflection for slabs without dropped panels shall be assumed to be $0.33(l-c)$ distant from the centre of the panel and $0.30(l-c)$ for slabs with dropped panels.

Limitations
Respecting
Reinforcement

144. The ratio of flat slab reinforcement in any strip shall be not less than 0.0025. Bars shall be spaced not farther apart than $1\frac{1}{2}$ times the total slab thickness.

Effective
Reinforcement

145. The reinforcement bars which cross any section and which fulfil the requirements given in Clause 146, may be considered as effective in resisting the moment at the section. The sectional area of a bar multiplied by the cosine of the angle between the direction of the axis of the bar and any other direction may be considered effective as reinforcement in the latter direction.

Reinforcement
at Column
Heads

146. In both two-way and four-way systems provision shall be made for securing the reinforcement in place so as to resist properly not only the critical moments, but also the moments at intermediate sections. The full area of steel required for negative moment at the column head shall be continued in the same plane close to the upper surface of the slab as detailed in Clause 149. Lapped splices shall not be permitted at or near regions of maximum stress without the approval of the Engineer.

Bends in
Reinforcement

147. Bends in continuous bars shall be staggered within a zone extending on each side of the assumed line of inflection, which zone shall cover a width of at least $1/15$ of the panel length. Mere sagging of the bars shall not be accepted as the equivalent of bending.

Computing
Stress in
Concrete

148. The compressive stress in the concrete shall be computed on the following widths: for negative moments in column strips where dropped panels are used, the width of the dropped panel; for negative and positive moments in all other cases, one-half the width of the panel.

Arrangement
of Reinforce-
ment, Two-Way
System

149. For column strips at least four-tenths of the area of steel required at the section for positive moment in the column strip shall be of such length and so placed as to reinforce the negative moment section at the two adjacent column heads. These bars and any other bars for negative reinforcement shall extend into the adjacent panel to a point at least 0.05 l beyond the line of inflection. Not less than one-third of the bars used for positive reinforcement in the column strip shall extend into the dropped panel at least 20 diameters of the bar, but not less than 12 in., or in case no dropped panel is used shall extend to within 0.125 l of the centre line of the columns or the supports. The remainder of the bars for positive reinforcement in the column strip shall extend at least 0.33 l on either side of the centre line of panel.

For the middle strip at least one-half of the bars for positive moment shall be bent up and extend over the main bands at both sides of the panel to a point at least 0.25ℓ beyond the centre line of columns. The location of the bends shall be such that for a distance 0.15ℓ for slabs with dropped panels (or 0.125ℓ for slabs without dropped panels), on each side of the centre line of columns, the full reinforcement required for negative moment will be provided in the top face of the slab. The full reinforcement for positive moment in the middle strip shall extend in the bottom face of the slab to a point at least 0.30ℓ on either side of the panel centre line, and at least 50 per cent. of it shall extend to points 0.325ℓ on either side of the panel centre line for slabs with dropped panels, or 0.35ℓ for slabs without dropped panels.

**Arrangement of
Reinforcement,
Four-Way
System**

150. All provisions governing the placing of steel in column strips in two-way systems apply as well to the direct bands in four-way systems.

For diagonal bands, at least four-tenths of the area of steel required at the section for positive moment shall be of such length and so placed as to reinforce the negative moment section at the two diagonally opposite column heads. These bars and any other bars for negative reinforcement shall extend into the adjoining panel to points at least 0.40ℓ beyond a line drawn through the column centre perpendicular to the direction of the band. The straight bars for positive moment in the diagonal bands shall be not shorter than the longer straight bars in the direct bands.

For negative moment in the middle strip, the required steel shall extend not less than 0.25ℓ on either side of the column centre line.

**Unusual
Panels**

151. For structures having a width of one or two panels and also for slabs having panels of markedly different sizes, an analysis shall be made of the moments developed in both slabs and columns, and the values given in Clause 135 modified accordingly.

**REINFORCED CONCRETE, COMPOSITE AND STRUCTURAL
STEEL COLUMNS**

**Limiting
Dimensions**

152. The following clauses on reinforced concrete columns with the exception of Clause 161, are based on the assumption of a short column. Where the unsupported length of a reinforced concrete column is greater than 15 times the least lateral dimension of the area *A*, the safe load shall be determined by Formula 42. Principal columns in buildings shall have a minimum diameter or thickness of 8 in. Minor columns or struts shall have a minimum diameter or thickness of 6 in.

Unsupported
Length

153. The unsupported length of a column shall be taken as:

(a) In flat slab construction the clear distance between the floor and under side of the capital;

(b) In beam-and-slab construction, the clear distance between the floor and the under side of the shallowest beam framing into the column at the next higher floor level;

(c) In floor construction with beams in one direction only, the clear distance between floor slabs;

(d) In a column supported laterally by struts or beams only, the clear distance between consecutive pairs (or groups) of struts or beams, provided that to be considered an adequate support, two such struts or beams shall meet the column at approximately the same level and the angle between the two planes formed by the axis of the column and the axis of each strut respectively, is not less than 75 deg. nor more than 105 deg.

When reinforced-concrete brackets are used at the junction of beams or struts with columns, the clear distance between supports may be considered as reduced by the depth of the bracket, provided the width of the bracket is not less than one-half the width of the column.

Safe Load
on Columns
with Spirals

154. The safe axial load on a short column reinforced with longitudinal bars and closely spaced spirals shall be not greater than that determined by Formula 38.

The symbols used in Formulae 38 to 44 are defined in Clauses 96 and 97, except as indicated in Clauses 154, 156, 159, 161, 167 and 173.

$$P = f_c A \left\{ 1 + p (n - 1) \right\} \dots \dots \dots (38)$$

where

P = total safe axial load on column the h/D of which is not greater than 15;

A = area within the outer circumference of the spiral reinforcement;

D = outer diameter of spiral reinforcement;

p = ratio of area of longitudinal reinforcement to area A ;

f_c = permissible compressive stress in concrete
 $= 300 + (0.10 + 4p) f_c' \dots \dots \dots (39)$

The longitudinal reinforcement shall consist of at least 6 bars of minimum diameter of $\frac{1}{2}$ in. and its cross-sectional area shall be not less than 1 per cent. nor more than 6 per cent. of the area A (See Clause 81 regarding splices).

Spiral
Reinforcement

155. The volume of the spiral reinforcement shall be not less than one-fourth the volume of the longitudinal reinforcement. It shall consist of evenly-spaced continuous spirals held firmly in place and true to line by at least 3 vertical spacer bars. The pitch of the spirals shall be not greater than one-sixth of D and in no case more than 3 in. The ends of spirals shall be anchored, or shall be lapped for a length at least 20 times the diameter of the material. The spiral reinforcement shall meet the requirements of the C.E.S.A. "Standard Specification for Cold-Drawn Steel Wire for Concrete Reinforcement". (Appendix V).

Safe Load
on Columns
with Lateral
Ties

156. The safe axial load on a short column reinforced with longitudinal bars and separate lateral ties shall be determined by Formula 38,

where

A = area within the protective envelope which shall be not less than 1 inch thick;

p = ratio of area of longitudinal reinforcement to the area A .

The value of f_c shall not exceed $0.25 f'_c$. The amount of longitudinal reinforcement shall be not more than 2 per cent nor less than 0.5 per cent of the area A . The longitudinal reinforcement shall consist of not less than 4 bars of a minimum diameter of $\frac{1}{2}$ in.

Lateral
Ties

157. Lateral ties shall be not less than $\frac{1}{4}$ in. in diameter, spaced not farther apart than 15 times the diameter of the reinforcement, nor more than 12 inches in any case.

Bending in
Columns

158. The bending moments in interior and exterior columns shall be determined by the conditions of loading and end restraint, and shall be provided for in the design. The following provisions shall apply to reinforced concrete columns subjected to bending:

(a) With Spiral Reinforcement. The unit compressive stress on the concrete within the area A under combined axial load and bending shall not exceed by more than 20 per cent the value given for axial load by Formula 39.

(b) With Lateral Ties. Longitudinal reinforcement additional to that specified in Clause 156, but not to exceed 2% of the area A , may be used if required and the unit compressive stress on the concrete under combined axial load and bending may be increased to $0.30 f'_c$.

Composite
Columns

159. The safe load on a composite column in which a structural steel or cast-iron section is thoroughly encased in a circumferentially reinforced concrete core, shall be based on a certain unit stress for the steel or cast-iron section plus a unit stress of $0.25 f'_c$ on the area of concrete

within the outer circumference of the spiral. Longitudinal rods may be used up to 4% of the area A and shall be figured for a compressive stress of $0.25nf'_c$.

The unit compressive stress on the steel section shall be not greater than that determined by Formula 40,

$$f_r = 18,000 - 70h/R \dots\dots\dots (40)$$

but shall not exceed 15,000 lb. per sq. in.

The unit compressive stress on the cast-iron section shall be not greater than that determined by Formula 41,

$$f_r = 12,000 - 60 h/R \dots\dots\dots (41)$$

but shall not exceed 9,000 lb. per sq. in.

In Formulae 40 and 41,

f_r = unit compressive stress in metal section;

R = least radius of gyration of composite column.
For approximate design this may be taken as the least radius of gyration of metal section.

The diameter of the cast-iron section shall not exceed one-half of the diameter of the core within the outer diameter of the spiral. The spiral reinforcement shall be not less than 0.5 per cent. of the volume of this core and shall conform in quality, spacing and other requirements to the provisions for spirals in Clause 155.

The area of the concrete between the spiral and the metal section shall be not less than that required to carry the total floor load of the story above on the basis of a stress in the concrete of $0.35f'_c$, unless special brackets are arranged on the metal section to receive directly the beam or slab load.

160. The safe load on a structural steel column of a section which fully encases an area of concrete and which is protected by an outside shell of concrete at least 3 in. thick, shall be computed in the same manner as for the composite column in Clause 159, allowing $0.25f'_c$ only on the area of the concrete enclosed by the steel section. The outside shell shall be reinforced by wire mesh, ties or spiral hoops, weighing not less than 0.2 lb. per sq. ft. and with a maximum spacing of 6 in. between strands or hoops. Steel brackets shall be used to receive the entire floor load at each story.

161. The permissible working load on columns reinforced with longitudinal bars and closely spaced spirals, or with longitudinal bars and lateral ties, referred to in Clauses

Structural
Steel
Columns

Long
Columns

154 and 156 respectively, and which have an unsupported length greater than 15 times D , shall be not greater than that determined by Formula 42,

$$\frac{P'}{P} = 1.47 - \frac{h}{32D} \dots\dots\dots (42)$$

where

P' = total safe axial load on long column;

P = total safe axial load on column of the same section in which the h/D is not greater than 15, determined as in Clauses 154 and 156;

D = least lateral dimension of the area A .

FOOTINGS

General

162. The requirements for tension, compression, shear and bond in Clauses 96 to 134 inclusive, shall govern the design of footings, except as hereinafter provided. Provision shall be made for possible flexure and uplift in columns.

Loads

163. Footings resting directly on soil or on piles shall be proportioned as to area or number of piles on the basis of the total column load plus the weight of the footing itself. For computations of moments and shears the upward reaction per unit area or per pile shall be the total column load (not including the weight of the footing itself) divided by the area or by the number of piles.

Sloped or Stepped Footings

164. Footings in which the thickness has been determined by the requirements for shear as specified in Clauses 125 and 126 may be sloped or stepped, provided that the shear on no section exceeds the value specified, and provided further that the thickness of the footing above the reinforcement at the edge shall be not less than 6 in. for footings on soil nor less than 12 in. for footings on piles. The shear stress in a footing with sloping top surface shall be computed as for a beam wedge-shaped in profile. Sloped or stepped footings shall be cast as a unit.

Critical Section for Bending

165. The critical section for bending in a concrete footing which supports a column or pedestal, shall be considered to be at the face of the column or pedestal.

Plain Concrete Footings

166. In a plain concrete footing computed as in Clause 165, the flexural stress shall not exceed $0.02f'_c$.

Square Column on Square Footing

167. In a square footing supporting a concentric square column, the bending moment at the critical section shall be computed by the formula,

$$M = \frac{w}{2} (a_1 + 1.2c)c^2 \dots\dots\dots (43)$$

where

M = bending moment at critical section of footing;

a_1 = width of loaded area of footing;

c = projection of footing from face of column;

w = upward reaction per unit of area of base of footing.

(For typical footing designs, see Appendix II, Figs. 15 and 16).

Round Column
on Square
Footing

168. For a round or an octagonal column, the distance a_1 shall be taken as the side of a square having an area equal to the area of the column.

Reinforcement

169. The reinforcement in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth shall be the distance from the top of the footing to the plane of the reinforcement. The sectional area of reinforcement shall be distributed uniformly across the footing unless the width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is uniformly spread may be increased to include one-half the remaining width of the footing. In order that no considerable width of the footing shall remain unreinforced, additional reinforcement shall be placed outside of the width specified, but such reinforcements shall not be considered as effective in resisting the calculated bending moment. For the extra reinforcement a spacing double that within the effective belt may be used.

Concrete
Stress

170. The extreme fibre stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

Transfer
of Stress from
Column

171. The compressive stress in longitudinal reinforcement in columns or pedestals shall be transferred to the footing by distributing bases or dowels. Where dowels are used, there shall be at least one for each bar and their total sectional area shall be not less than the area of the longitudinal reinforcement in the column or pedestal. The dowels shall project into the column or pedestal and into the footing a distance sufficient to develop the working stress in the dowels by bond.

Pedestals
without
Reinforcement

172. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal without reinforcement shall be $0.25f'_c$.

**Bearing
Stress on
Pedestals**

173. On the loaded area under a column resting on such a pedestal with or without a distributing base for the longitudinal reinforcement, the permissible unit compressive stress may be determined by the following formula, but in no case shall it exceed $0.50f'_c$:

$$r_a = 0.25f'_c \left\{ \frac{a_1 + a_2}{2a_1} \right\} \dots\dots\dots (44)$$

where

r_a = permissible working stress over the loaded area;

a_1 = width of loaded area of pedestal;

a_2 = twice the distance from centre line of load to nearest side of pedestal.

In sloped or stepped footings, concentrically loaded, a_2 may be taken as the width of the top horizontal surface of the footing or the width of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for the width of its upper base the diameter of the column, and having side slopes of 1 vertical to 2 horizontal. If these widths differ, the greater shall be used.

**Pedestals with
Reinforcement**

174. When lateral reinforcement in the form of spirals or hoops is provided, the value of r_a in Formula 44 may be multiplied by $(1+2.5 np_s)$, but no area outside the outer diameter of the spiral shall be considered. The ratio of the volume of the spiral reinforcement to the volume within the outer diameter of such reinforcement is denoted by p_s . In no case shall r_a exceed $0.50 f'_c$.

Where lateral reinforcement is provided it shall extend to within 3 in. of the top of the pedestal, pier or footing and to a depth equal to the diameter of the spiral. The spiral hooping shall be concentric with the column. The pitch of the spiral or the spacing of the hoops in the clear shall be not less than 2 in. nor more than 5 in. The designed pitch shall be maintained by at least four spacers securely fastened to each spiral turn or hoop. The value of p_s shall not exceed 0.015.

**Pedestals
without
Reinforcement**

175. The depth of a pedestal or pedestal footing with vertical sides shall be not greater than 3 times its least width. The depth of a pedestal whose sides are sloped or stepped shall not exceed 3 times the least width or diameter of the section midway between the top and bottom. A pedestal footing supported directly on piles shall have a mat of reinforcing bars having a cross-sectional area of not less than 0.20 sq. in. per foot in each direction, placed 3 in. above the top of the piles.

REINFORCED CONCRETE RETAINING WALLS

Details of
Design

176. The following principles shall be followed in the design of reinforced concrete retaining walls:

(a) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the faces of the vertical stem.

(b) The vertical stem of a cantilever wall shall be considered a cantilever beam fixed at the top of the base.

(c) In counterforted or buttressed walls those portions of face walls and base slabs lying between, and supported by, counterforts or buttresses shall be designed in accordance with the requirements for continuous slabs in Clause 103.

(d) Counterforts shall be designed in accordance with the requirements for T-beams in Clauses 106 and 107. They shall be considered as beams wedge-shaped in profile. Stirrups shall be provided in counterforts to take the reaction when face walls and heels are designed to span between counterforts. Stirrups shall be anchored as near the exposed face of the longitudinal wall and as close to the lower face of the base as the requirements for protective covering permit.

(e) Buttresses shall be designed in accordance with the requirements for beams rectangular in cross section and wedge-shaped in profile.

(f) The shear stress at the junction of the base with counterforts or buttresses shall be governed generally by the conditions of Clauses 115 to 122.

(g) Horizontal metal reinforcement shall be of such form and so distributed as to develop the required bond. To prevent temperature and shrinkage cracks in exposed surfaces not less than 0.25 sq. in. of horizontal metal reinforcement per foot of height shall be provided.

(h) Provision for temperature changes shall be made at suitable joints at sections not over 60 ft. apart.

(i) Counterforts and buttresses shall be located under points of concentrated loading, and at intermediate points, as may be required by the design.

(j) The walls shall be cast as a unit between expansion joints unless construction joints, formed in accordance with Clauses 87 and 91, are provided.

(k) Suitable weep holes not less than 4 in. in diameter and not more than 10 ft. apart, or drains, shall be provided. In counterforted walls each pocket formed by the counterforts shall be drained.

SUMMARY OF WORKING STRESSES

General

177. The following are the working stresses on which this specification is based:
where

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12 in. or 8 by 16 in. cylinders made and tested in accordance with the "Method of Making Compression Tests of Concrete" (Appendix XII), and the "Method of Making and Storing Specimens of Concrete in the Field" (Appendix XIII).

DIRECT STRESS IN CONCRETE

Direct
Compression

178. (a) Columns of which the length does not exceed 15 times the least lateral dimension:
- (1) With spirals it varies with amount of longitudinal reinforcement (See Clause 154);
 - (2) With longitudinal reinforcement and lateral ties (See Clause 156).
- (b) Long Columns.... (See Clauses 159 and 161).
- (c) Piers and Pedestals..... $0.25 f'_c$
(See Clause 172).

Compression
in Extreme
Fibre.

179. (a) Extreme fibre stress in flexure $*0.40 f'_c$
- (b) Extreme fibre stress in flexure adjacent to supports of continuous or fixed beams, or at joints of rigid frames..... $*0.45 f'_c$

Tension

180. (a) In reinforced concrete members..... none
- (b) In plain concrete members in flexure... $0.02 f'_c$

SHEARING STRESS IN CONCRETE

Longitudinal
Bars without
Special
Anchorage

181. (a) Beams without web reinforcement..... $0.02 f'_c$
- (b) Beams with stirrups or bent-up bars or combination of the two..... $0.06 f'_c$

Longitudinal
Bars having
Special
Anchorage

182. (a) Beams without web reinforcement..... $0.03 f'_c$
- (b) Beams with stirrups or bent-up bars or combination of the two..... $*0.09 f'_c$
- (See Clause 122 for conditions determining the use of greater shear stresses).

**For minor structures on which competent supervision and inspection may not be provided, it is recommended that these stresses be reduced by 20 per cent.*

Flat Slabs

183. Shear at distance d from capital or dropped panel..... $0.25 f'_c$ to $0.03 f'_c$
(See Clause 123).

Footings

184. (a) Longitudinal bars without special anchorage..... $0.02 f'_c$
(b) Longitudinal bars having special anchorage..... $0.03 f'_c$

STRESS IN REINFORCEMENT

Tension in Steel

185. (a) Billet-steel bars:
(1) Structural Steel grade 18,000 lb. per sq. in.
(2) Intermediate grade... 20,000 lb. per sq. in.
(3) Hard grade..... 20,000 lb. per sq. in.
(b) Rail-steel bars..... 20,000 lb. per sq. in.
(c) Structural Steel..... 18,000 lb. per sq. in.
(d) Web reinforcement, hangers or other direct tension members, (all qualities of steel)..... 16,000 lb. per sq. in.
(e) Other steel reinforcements 50 per cent. of yield point stress.

Compression in Steel

186. (a) Bars: n times stress in adjacent concrete.
(b) Structural steel columns, or structural steel core of composite columns..... 18,000 lb. per sq. in. reduced for slenderness ratio with maximum of... 15,000 lb. per sq. in.
(See Clauses 159 and 160).

Compression in Cast Iron

187. Composite cast-iron columns... 12,000 lb. per sq. in. reduced for slenderness ratio with a maximum of..... 9,000 lb. per sq. in.
(See Clause 159).

Bond between Concrete and Reinforcement

188. (a) Beams and slabs, plain bars..... $0.04 f'_c$
(b) Beams and slabs, deformed bars..... $0.05 f'_c$
(c) Footings, plain bars, one-way..... $0.04 f'_c$
(d) Footings, deformed bars, one-way..... $0.05 f'_c$
(e) Footings, bars in more than one direction, (c) or (d) reduced by 25 per cent.

PART III

APPENDIX I

STANDARD NOTATION

All symbols used in this Specification for Concrete and Reinforced Concrete have been collected here for convenience of reference. The symbols are in general defined in the text near the formulae in which they are used. In a few instances the same symbol is used in two distinct senses; however, there is little danger of confusion from this source.

- a_1 = width of loaded area of pedestal, pier or footing;
- a_2 = twice the distance from centre line of load to nearest side of pedestal;
- α = angle between web bars and longitudinal bars;
- A = area within outer circumference of a column spiral, or in the case of a column with lateral ties, the area within the protective envelope;
- A_s = effective cross-sectional area of metal reinforcement in tension in beams or slabs or in compression in columns; and the effective cross-sectional area of metal reinforcement which crosses any of the principal design sections of a flat slab and which meets the requirements of Clause 146;
- A_v = total area of web reinforcement in tension within a distance of s (s_1, s_2, s_3 , etc.) or the total area of all bars bent up in any one plane (See Appendix II, Fig. 9);
- b = width of rectangular beam or width of flange of T-beam;
- b' = width of stem of T-beam;
- b_1 = dimension of the dropped panel of a flat slab in the direction parallel to l_1 (See Appendix II, Fig. 14);
- c = base diameter of the largest right circular cone which lies entirely within the column (including the capital), the vertex angle of which is 90 deg. and the base of which is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (See Appendix II, Fig. 13);
- c = projection of footing from face of column;
- C = total compressive stress in concrete;
- C' = total compressive stress in reinforcement;
- d = depth from compression surface of beam or structural slab to centre of longitudinal tension reinforcement;
- d' = depth from compression surface of beam or slab to centre of compression reinforcement;
- D = least lateral dimension of the area A ;

- E_c = modulus of elasticity of concrete in compression;
 E_s = modulus of elasticity of steel in tension = 30,000,000 lb. per sq. in.;
 f_c = unit compressive stress in extreme fibre of concrete;
 f_{c1} = permissible unit flexural stress in extreme fibre of concrete for a beam without continuous lateral support;
 f'_c = ultimate compressive strength of concrete at age of 28 days based on tests of 6 by 12 in., or 8 by 16 in. cylinders made and tested in accordance with the "Method of Making Compression Tests of Concrete" (Appendix XII), and the "Method of Making and Storing Specimens of Concrete in the Field" (Appendix XIII);
 f_r = unit compressive stress in metal section of column;
 f_s = unit tensile stress in longitudinal reinforcement;
 f'_s = unit compressive stress in longitudinal reinforcement;
 f_v = unit tensile stress in web reinforcement;
 F = total maximum tension in a bar or set of bars;
 h = unsupported length of column;
 I = gross moment of inertia of a section about the neutral axis for bending;
 j = ratio of lever arm of resisting couple to depth d ;
 jd = $d - z$ = arm of resisting couple;
 k = ratio of depth of neutral axis to depth d ;
 l = span length of beam or slab (generally distance from centre to centre of supports; for special cases, see Clauses 99 and 135);
 l_1 = span length of flat slab, centre to centre of columns, perpendicular to the rectangular direction in which moments are considered;
 l = span length of flat slab, centre to centre of columns, in the rectangular direction in which moments are considered;
 M = bending moment or moment of resistance in general;
 M_o = sum of positive and negative bending moments in either rectangular direction, at the principal design sections of a panel of a flat slab;
 n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;
 o = perimeter of bar;
 Σo = sum of perimeters of bars in one set;
 p = ratio of effective area of tension reinforcement to area of concrete in beams = A_s/bd ; and the ratio of area of longitudinal reinforcement to the area A in columns;
 p' = ratio of effective area of compression reinforcement to area of concrete in beams;

- p_s = the ratio of the volume of the spiral reinforcement in a column or pedestal to the volume within the outer diameter of such reinforcement;
- P = total safe axial load on column whose h/D is not greater than 15;
- P' = total safe axial load on long column;
- Q' = ratio of permissible bond stress u to the maximum apparent bond stress as determined by Formula 33, anywhere in the distance y ;
- r_a = permissible working stress in concrete over the loaded area of a pedestal, pier or footing;
- R = ratio to M_0 , of positive or negative moment in two column strips, or one middle strip of a flat slab;
- R = least radius of gyration of a composite column;
- s = spacing of web bars or stirrups from each other or from the edge of the support, measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam;
- t = thickness of flange of T-beam;
- t_1 = thickness of flat slab without dropped panels or total thickness of a dropped panel (See Appendix II, Fig. 13);
- t_2 = thickness of flat slab with dropped panels at points away from the dropped panel (See Appendix II, Fig. 13);
- T = total tensile stress in longitudinal reinforcement;
- u = bond stress per unit of area of surface of bar;
- u' = apparent existing mean bond stress for any portion, Δy , of the bars as computed by Formula 33;
- v = unit shear stress;
- V = total transverse shear;
- V_1 = total shear to be taken by concrete and web reinforcement in wedge-shaped beams;
- w = uniformly distributed dead and live load per unit of length of beam or slab;
- w = upward reaction per unit of area of base of footing;
- w' = uniformly distributed dead and live load per unit of area of a floor or roof;
- W = total dead and live load uniformly distributed over a single panel area;
- x = length of bar added for anchorage, including the hook, if any;
- y = distance from the point of maximum tension in the bar to the point of beginning of anchorage;
- Δy = any portion of the distance y ;
- z = depth from compression surface of beam or slab to resultant of compressive stresses.

APPENDIX II

DRAWINGS ILLUSTRATING DESIGN

Note—See Appendix I for explanation of symbols used in drawings.

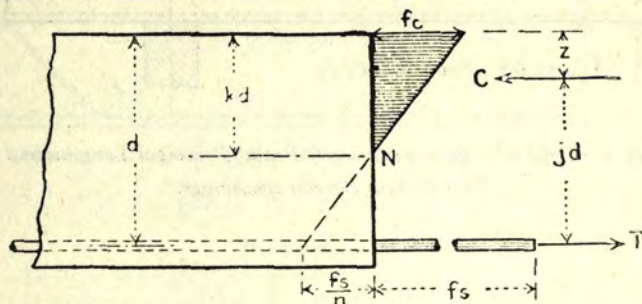


Fig.1— Nomenclature for Concrete Beam Reinforced for Tension.

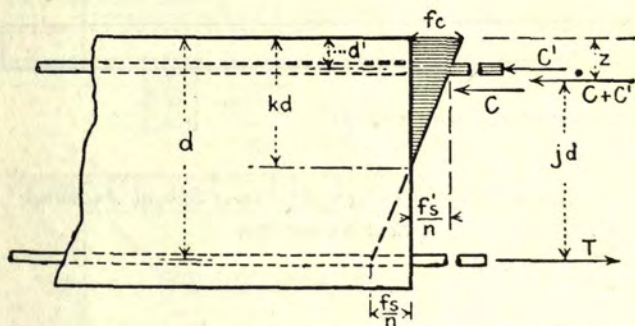


Fig. 2—Nomenclature for Concrete Beam Reinforced for Tension and Compression.

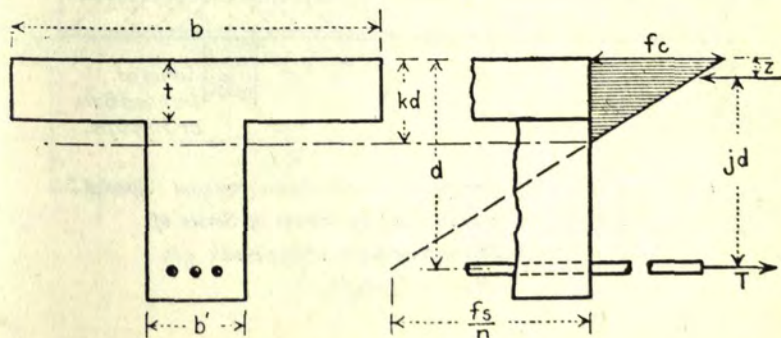


Fig. 3—Nomenclature for Reinforced Concrete T-Beam.

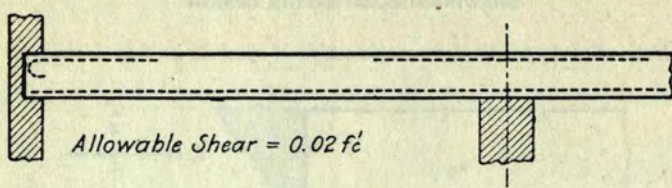


Fig. 4—Typical Reinforced Concrete Beam; Principal Longitudinal Bars without Special Anchorage.

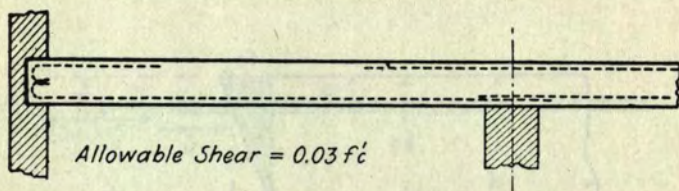


Fig. 5—Typical Reinforced Concrete Beam; Special Anchorage of Longitudinal Bars.

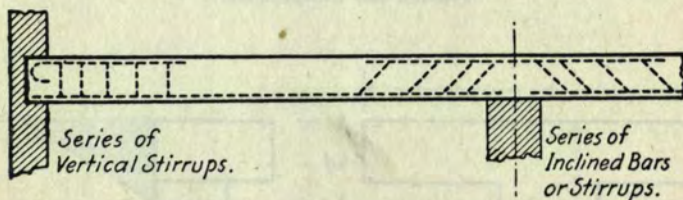


Fig. 6—Typical Reinforced Concrete Beam without Special Anchorage; Web Reinforced by Means of Series of Vertical Stirrups or Series of Inclined Bars or Stirrups.

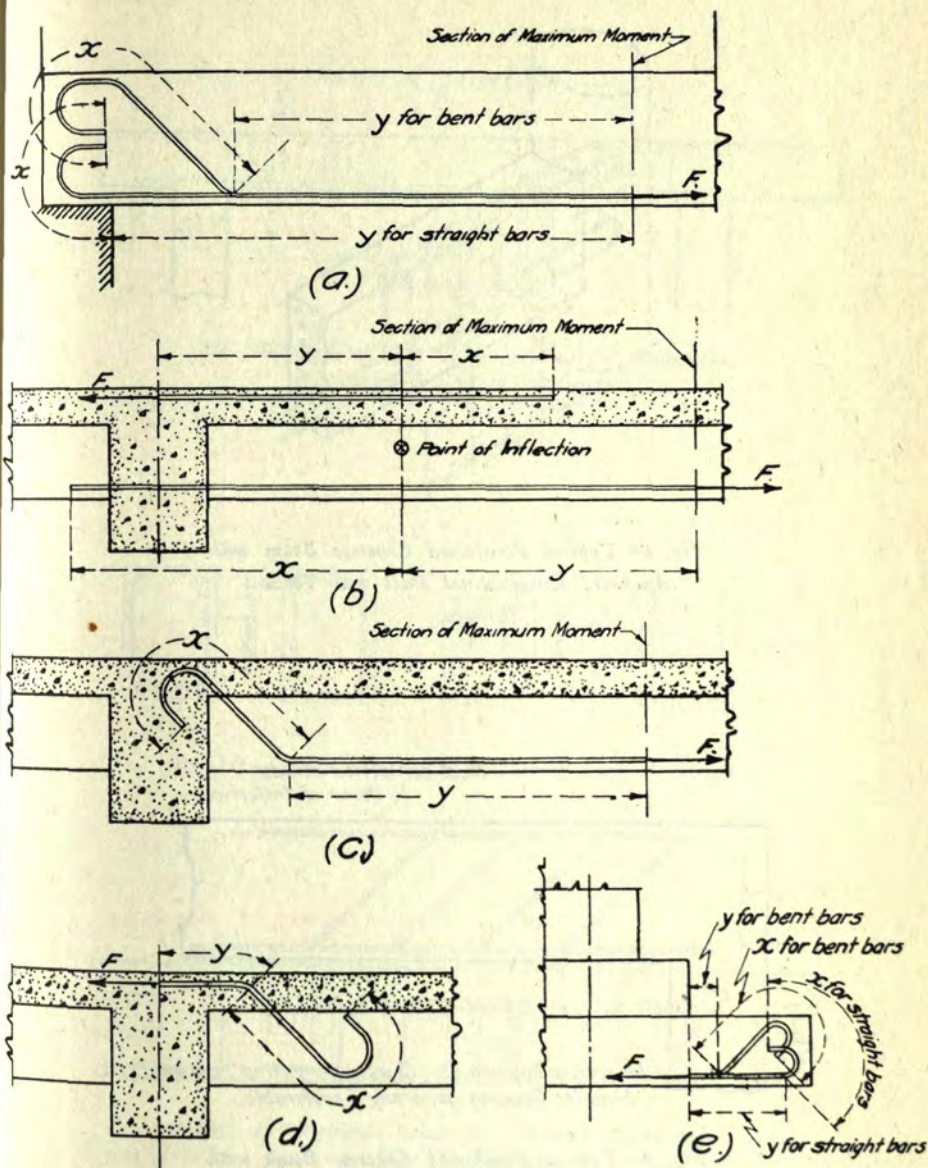


Fig. 7—Lengths of Anchorages (See Clause 130).

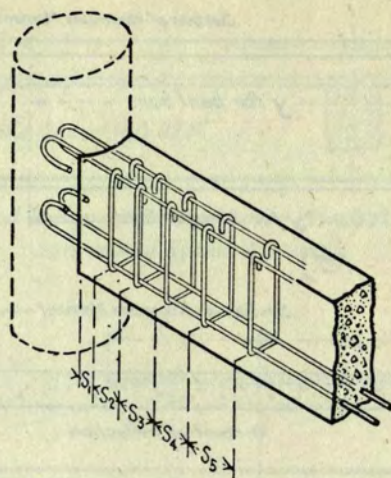


Fig. 8—Typical Reinforced Concrete Beam with Anchored Longitudinal Bars and Vertical Stirrups.

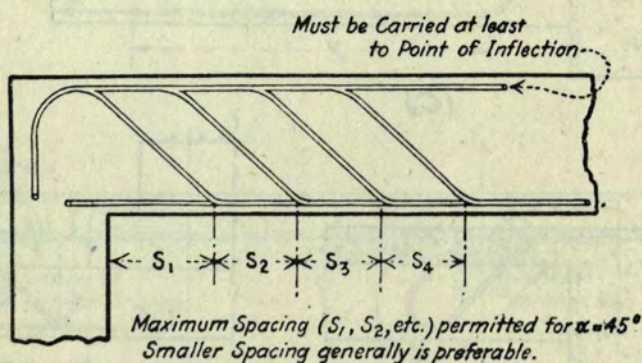


Fig. 9—Typical Reinforced Concrete Beam with Web Reinforced by Means of Series of Inclined Bars.

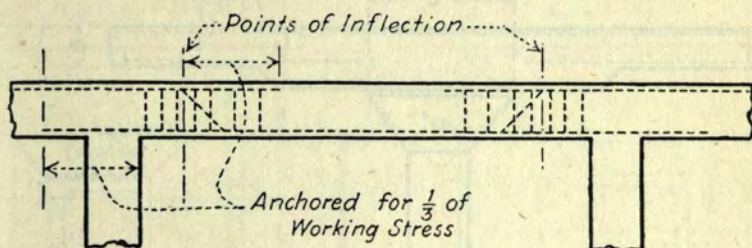


Fig. 10—Typical Web Reinforcement for Continuous Beams with Special Anchorage.

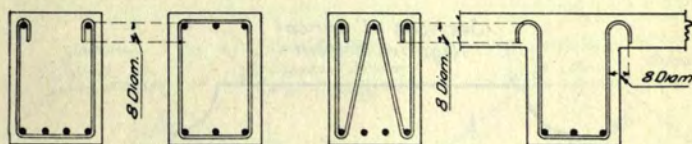


Fig. 11—Typical Methods of Anchoring Vertical Stirrups.

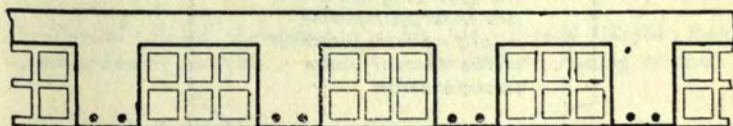


Fig. 12—Typical Reinforced Concrete Beam-and-Tile Construction.

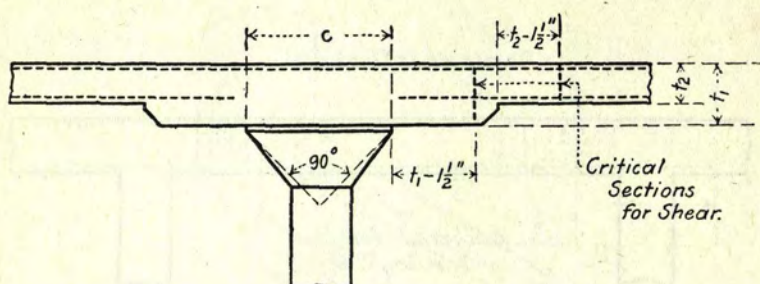


Fig. 13—Typical Column Capital and Sections of Flat Slab with Dropped Panel.

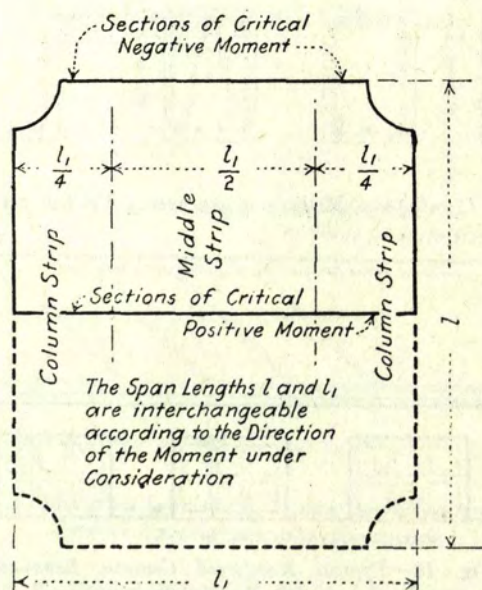


Fig. 14—Principal Design Sections of a Flat Slab.

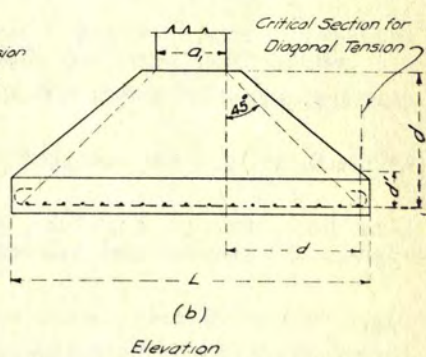
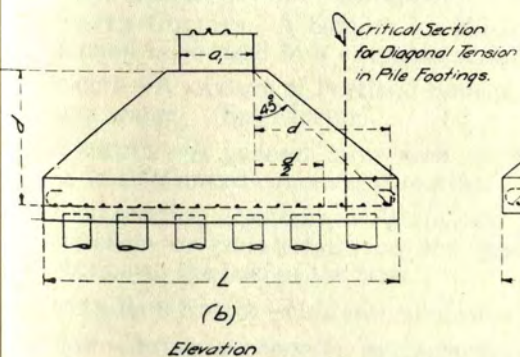
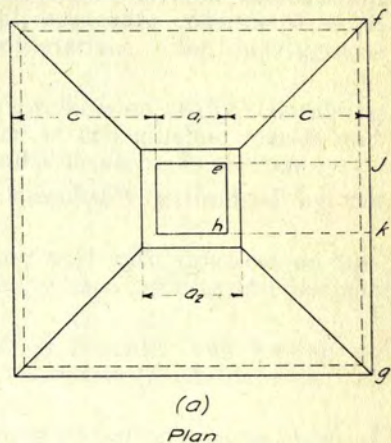
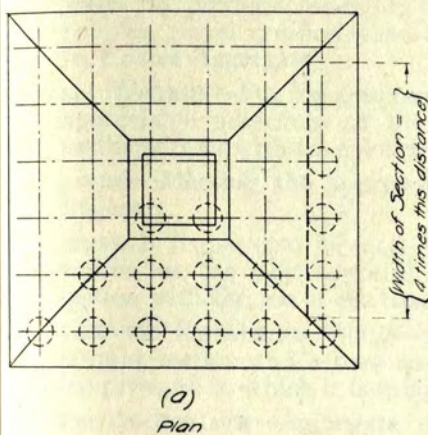


Fig. 15—Typical Sloped Reinforced Concrete Footing on Piles.

Fig. 16—Typical Sloped Reinforced Concrete Footing on Soil.

APPENDIX III

GENERAL GLOSSARY

- AGGREGATE**—Inert material which is mixed with Portland cement and water to produce concrete; in general, aggregate consists of sand, pebbles, gravel, crushed stone, or similar materials. (See Fine Aggregate, Coarse Aggregate).
- ALKALI WATERS**—For the purposes of this specification, waters containing appreciable quantities of the sulphates of the alkaline metals and earths with or without chlorides of the alkaline earths in solution.
- APPROVED**—Meeting the approval of, or specifically authorized by, the Engineer.
- BUTTRESSED RETAINING WALL**—A retaining wall with brackets or buttresses on the side opposite the pressure face uniting the upright section with the toe of the base.
- CANTILEVER RETAINING WALL**—A reinforced concrete wall having an upright section and a base each of which resists, by cantilever action, the pressure to which it is subjected.
- COARSE AGGREGATE**—Aggregate, subject to specified tolerances retained on a No. 4 sieve and of a maximum size generally not larger than 3 in. (See Aggregate, Fine Aggregate).
- COMPOSITE COLUMN**—A column in which a structural steel or cast iron section is encased in a circumferentially reinforced concrete core.
- CONCRETE**—A mixture of Portland cement, fine aggregate, coarse aggregate and water. (See Mortar).
- CONSISTENCY**—A general term used to designate the relative plasticity of freshly mixed concrete or mortar.
- COUNTERFORTED RETAINING WALL**—A reinforced concrete wall with brackets or counterforts on the pressure face uniting the upright section to the heel of the base.
- CRUSHER-RUN STONE**—Unscreened crushed stone. (See Stone Screenings).
- CURING**—Curing of concrete, as distinguished from drying, is the continued chemical reaction which takes place between the water and the cement. This reaction is assisted by the maintenance of proper temperature and moisture conditions, the resulting strength and wearing qualities of the concrete increasing with the length of the period during which these conditions are maintained.
- CYCLOPEAN CONCRETE**—Concrete in which stones weighing more than 100 lb. are individually embedded.
- DEFORMED BAR**—Reinforcement bar with closely spaced shoulders, lugs, or projections formed integrally with the bar during rolling so as to engage firmly the surrounding concrete. Wire mesh, with welded intersections not farther apart than twelve inches in the direction of the principal reinforcing and with cross wires not smaller than No. 10, may be rated as a deformed bar.
- ENGINEER**—The Engineer in responsible charge of the work.

- FINE AGGREGATE**—Aggregate, subject to specified tolerances, passing through a No. 4 sieve. (See Aggregate, Coarse Aggregate).
- FLAT SLAB**—A concrete slab having reinforcement bars extending in two or more directions without beams or girders to carry the load to supporting members.
- GRAVEL**—Rounded particles larger than sand resulting from the natural disintegration of rocks. (See Sand).
- LAITANCE**—Extremely fine material of little or no hardness which may collect on the surface of freshly deposited concrete or mortar, resulting from the use of excess mixing water, and usually recognized by its relatively light colour.
- MEMBRANE WATERPROOFING**—A coating reinforced by fabric, felt or similar toughening material and applied to structures to prevent contact of moisture.
- MORTAR**—A mixture of Portland cement, fine aggregate, and water. (See Concrete).
- OILPROOFING**—Treatment of a concrete surface to resist the action of mineral, vegetable or animal oils.
- PEDESTAL**—An upright compression member whose height does not exceed 3 times its least lateral dimension.
- PEDESTAL FOOTING**—A column footing projecting less than one-half its depth from the faces of the column on all sides and having a depth not more than 3 times its least width.
- PIT-RUN AGGREGATE**—A natural mixture of sand and gravel which has not been screened or otherwise treated to make it suitable for concrete.
- PORTLAND CEMENT**—The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions, subsequent to calcination, excepting water and calcined or uncalcined gypsum.
- PRE-MIXED AGGREGATE**—A mixture of fine and coarse aggregate that has been combined in some predetermined proportion before delivering to the work.
- REINFORCED CONCRETE**—Concrete in which metal is embedded in such a manner that the two materials act together in resisting forces.
- REINFORCED CONCRETE COLUMN**—A column reinforced with longitudinal bars and closely spaced spirals, or with longitudinal bars and separate lateral ties.
- RUBBLE AGGREGATE**—Stone or gravel larger than 3 in. in diameter and weighing not more than 100 lb. (See Rubble Concrete).
- RUBBLE CONCRETE**—Concrete in which pieces of rubble aggregate are individually embedded. (See Rubble Aggregate).
- SAND**—Small grains resulting from the natural disintegration of rocks. (See Gravel).

SCREEN—A metal plate with closely spaced circular perforations. (See Sieve).

SHORT COLUMN—A column in which the ratio of unsupported length to the dimension D is not greater than 15.

SIEVE—Woven wire cloth with square openings. (See Screen).

STANDARD SAND—Natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve, used as the fine aggregate in standard strength tests of Portland cement. (For specifications see Appendix IV).

STONE SCREENINGS—Crushed stone, subject to specified tolerances, passing through a No. 4 sieve. (See Crusher-Run Stone).

TREMIE—A water-tight pipe of suitable dimensions, generally used in a vertical position, for depositing concrete.

APPENDIX IV

STANDARD SPECIFICATION FOR PORTLAND CEMENT

C. E. S. A. Specification A5—1927

MATERIAL COVERED

Definition.

1. Portland Cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

MANUFACTURE

Methods.

2. Methods of manufacture shall be such as to ensure that the finished cement will conform to the requirements hereinafter specified, when subjected to the tests enumerated below and carried out in accordance with the methods and with the apparatus described in Appendix I.

CHEMICAL PROPERTIES

Require-
ments.

3. The following limits shall not be exceeded:—

Loss on ignition per cent.....	4.00
Insoluble residue per cent.....	0.75
Sulphuric Anhydride ($S O_2$) per cent.....	2.00
Magnesia (MgO) per cent.....	4.00

PHYSICAL PROPERTIES

Fineness.

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent.

Soundness.

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of
Setting.

6. The cement shall not develop initial set in less than thirty minutes and final set shall develop within ten hours.

Tensile
Strength.

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes composed of one part cement and three parts standard sand, by weight, shall be equal to, or higher than, the following:

Age at Test Days	Storage of Briquettes	Tensile Strength lbs. per sq. inch
7	1 day in moist air, 6 days in water	225
28	1 day in moist air, 27 days in water.....	325

8. The average tensile strength of standard mortar briquettes at 28 days shall be higher than that at 7 days.

9. Tests shall be made with a testing machine satisfactory to both the Vendor and the Purchaser.

PACKING AND MARKING

Packages.

10. Cement covered by this Specification shall be sold by weight, and, unless otherwise provided by agreement between the Vendor and the Purchaser, shall be delivered in bags, each containing 94 lbs. net weight. Four bags shall constitute a barrel.

Bags.

11. All bags in which cement is delivered shall be made of substantial material and shall be in good repair when filled. The following information shall be plainly marked on each bag:

- (a) Name of manufacturer;
- (b) The brand of cement, and preferably the name of the mill in which it was manufactured.

INSPECTION

Sampling.

12. Cement shall be sampled without undue delay in accordance with the methods described in Appendix II.

Inspection.

13. It shall be subject to inspection and testing either at the place of manufacture, at the point of shipment, or on delivery, as may be specified by the Purchaser.

Facilities.

14. The Vendor shall afford every facility for sampling and inspection, for taking and packing the samples either at the mill, or at the point of delivery, as the case may be, and for subsequently identifying the cement, and a reasonable period shall be allowed for inspection and the completion of tests.

Cost of Tests.

15. The cost of inspection and tests shall be borne by the Purchaser unless otherwise provided by agreement between the Vendor and the Purchaser.

Copies and
Certificates
of Tests.

16. The Vendor shall, if required, furnish free of cost a copy of any document in his possession showing the result of any tests or analyses made for him, or for any other person, of any cement sold or offered for sale to the Purchaser, or of the lot from which the cement so sold or offered for sale has been or is to be taken.

17. He shall also, if required at the time of purchase, furnish, free of cost, a certificate that the cement so sold or offered for sale has been tested and analysed, and that such tests and analyses comply in all respects with this Specification.

18. The furnishing of such copies of documents or the giving of such certificate shall not preclude the Purchaser from rejecting any cement which does not comply with this Specification.

Vendor.

19. The term "Vendor" throughout this Specification shall mean the seller of the cement, whether he be the manufacturer of the cement or not.

REJECTION

Rejection.

20. The cement may be rejected if it fails to meet any of the requirements of this Specification.

21. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

22. Cement failing to meet the test for soundness in steam, but complying in all other respects with the Specification, may be resampled and re-submitted for test at any time within 28 days thereafter.

23. Packages varying more than three per cent. from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

APPENDIX I

STANDARD METHODS AND APPARATUS FOR TESTING CEMENT

CHEMICAL METHODS

**Loss on
Ignition.**

24. The loss on ignition shall be determined as follows, by heating one gram of cement in a weighed covered platinum crucible, of 20 to 25 cc. capacity, using either method (a) or (b) as ordered:

(a) Place the crucible in a hole in an asbestos board, clamped horizontally, so that about three-fifths of the crucible projects below, and blast at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disc of sheet platinum and placing this disc over a somewhat larger hole in an asbestos board.

(b) Place the crucible in a muffle at any temperature between 900 and 1000° C. for 15 minutes, and check the loss in weight by a second heating for 5 minutes.

25. A permissible variation of 0.25 above the specified limit will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be accepted as meeting the specification of 4.00 per cent.

**Insoluble
Residue.**

26. The insoluble residue shall be determined as follows: Weigh one gram of cement into a porcelain dish, add 10 cc. of water and 5 cc. of concentrated hydrochloric acid; warm the liquid until effervescence ceases. Dilute the solution to 50 cc. and digest on a steam bath or hot plate until it is evident that decomposition of the cement is complete. Filter the residue, wash with cold water, and digest the filter paper and contents in about 30 cc. of a 5 per cent. solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. Filter the remaining residue, wash with cold water, then with a few drops of hot hydrochloric acid (1:9) and finally with hot water. Ignite at a red heat and weigh as the insoluble residue.

27. A permissible variation of 0.15 above the specified limit will be allowed, and all results in excess of the specified limit but within this permissible variation shall be accepted as meeting the specification of 0.75 per cent.

**Sulphuric
Anhydride.**

28. The determination of sulphuric anhydride shall be carried out as follows:—

Weigh one gram of the finely powdered cement into a suitable dish, moisten and stir with 10 cc. of water to prevent lumping, add 10 cc. of hydrochloric acid and digest at a gentle heat. When solution is complete, add 50 cc. of hot water and filter. Dilute the filtrate to 250 cc., boil, add 10 cc. of a hot 10 per cent. solution of barium chloride, drop by drop, while stirring, and continue boiling until the precipitate is well formed (15 to 20 minutes). Set aside in a warm place for several hours, or over night, filter, wash, dry, place the dry filter paper and precipitate in a weighed platinum crucible, burn off the paper at a low heat, ignite at a temperature not higher than 1000° C. for a few minutes, and weigh. The weight of the ignited precipitate in grams multiplied by 0.3430 gives the weight of sulphuric anhydride.

The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride, instead of using a separate sample.

29. A permissible variation of 0.10 above the specified limit will be allowed, and all results in excess of the specified limit but within this permissible variation shall be accepted as meeting the specification of 2.00 per cent.

Magnesia.

30. The determination of magnesia shall be carried out as follows:—

Weigh 0.5 gram of the cement into an evaporating dish. Stir with about 10 cc. of cold water and add from 5 to 10 cc. of concentrated hydrochloric acid. Heat gently, while stirring, till the chemical reaction is finished, and then evaporate the solution on a steam bath or hot plate to complete dryness. Cool, add from 10 to 20 cc. of hydrochloric acid (1:1) and digest the sample on a steam bath or hot plate for a few minutes to dissolve the soluble parts. Pour the contents of the evaporating dish into a 250 cc. beaker, wash well, and dilute to about 100 cc. Add enough bromine water to precipitate any manganese that may be present, heat to boiling, add ammonia in slight excess while stirring, boil for a minute or two, filter into a 400 cc. beaker, and wash well with hot water three times. Wash the precipitate back into the beaker used for the precipitation, and if anything remains on the filter, dissolve it with a few drops of hydrochloric acid and wash into the beaker with the precipitate. Dissolve the precipitate with a small excess of hydrochloric acid, add bromine water, and dilute to about 100 cc., heat to boiling, and precipitate again with ammonia as described before. Filter through

the same filter that was used the first time into the beaker which contains the first filtrate and wash well. Make the filtrates slightly acid with hydrochloric acid, heat to boiling, while stirring, add 40 cc. of a boiling 4 per cent. solution of ammonium oxalate and then a small excess of ammonia. Continue the boiling for two or three minutes, while stirring, and set aside the covered beaker on a warm plate for from half an hour to one hour to allow the precipitate to settle. Filter and wash well. Acidify the filtrate with hydrochloric acid and concentrate to about 150 cc. Cool the filtrate, add 10 cc. of saturated sodium phosphate while stirring constantly; then add ammonia in moderate excess. Allow to stand for about 5 hours, filter and wash well with water containing 2.5 per cent. ammonia. Wrap the filter paper, dry between filter paper, and ignite in a weighed platinum crucible. In doing this use at first gentle heat to char the paper, then increase the heat until the carbon is burned and the phosphate changed into pyro-phosphate. Cool the crucible in a desiccator and weigh. The weight of the ignited precipitate in grams multiplied by 0.3621 gives the weight of magnesia.

31. A permissible variation of 0.4 above the specified limit will be allowed, and all results in excess of the specified limit but within this permissible variation shall be accepted as meeting the specification of 4.00 per cent.

**Check
Analysis.**

32. If the proportion of magnesia does not fall within the prescribed limit of 4.00 per cent., a complete analysis of the cement may be made as a check, following the methods and using the apparatus described in Appendix III.

The results of such a check analysis as regards magnesia shall be taken as conclusive.

DETERMINATION OF FINENESS

**Standard
Sieves.**

33. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire and mounted without distortion on frames not less than $1\frac{1}{2}$ inch below the top of the frame. The sieve frames shall be circular, approximately 8 inches in diameter, and may be provided with a pan and cover.

34. A standard No. 200 sieve is one having nominally an opening of 0.0029 inch and 200 wires per inch, and shall be certified by the Surveys Laboratory of the Department of the Interior (Ottawa) as free from major defects and conforming to the following requirements:—

The number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between

adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 inch, and the average diameter shall not be outside the limits 0.0019 to 0.0023 inch.

35. For the purpose of enabling users themselves to judge from time to time as to the correct condition of standard sieves in their possession, the Department of Public Works (Ottawa) will furnish on payment a standardized sample of cement or other similarly graded material which gives a residue of 20 to 25 per cent. on a standard No. 200 sieve, and which may be used as follows:—

A sieve shall be regarded as satisfactory which, when tested with such standardized cement or material in conformity with the method specified below under "Manipulation," shall give an amount of residue which does not differ from that obtained in the Department's Laboratory, with the same sample, by more than 1.5 per cent., above or below.

Manipulation.

36. The test shall be made with 50 grams of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve should be turned every 20 or 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 gram passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

37. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method.

MIXING CEMENT PASTES

Manipulation.

38. The quantity of dry material to be mixed at one time shall not be less than 500 grams. The dry cement shall be weighed, placed upon a non-absorbent surface, and a crater formed in the centre, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of one-half minute for the absorption of the water, the operation shall be completed by continuous vigorous mixing, squeezing and kneading with the hands for at least $1\frac{1}{2}$ minutes.

During the operation of mixing, the hands should be protected by rubber gloves or rubber finger cots.

The temperature of the room shall be maintained above a minimum of 18° C., and that of the mixing water shall be between 20° C. and 22° C.

MIXING STANDARD CEMENT MORTARS FOR TENSILE TESTS

Quantities.

39. The quantity of dry material to be mixed at one time shall not exceed 1000 grams or be less than 500 grams. The quantities of cement and sand shall be stated by weight in grams of the dry materials, the quantity of water shall be expressed in cc.

Mixing.

40. The dry materials shall be weighed out, placed in a suitable metal mixing bowl (preferably enamelled) and intimately mixed dry with a steel spatula to a uniform colour. The bowl and spatula shall be similar in form to those shown in Fig. 1, the edges of the bent spatula blade being formed to fit the curved side of the bowl. The proper percentage of clean water of the specified temperature shall then be added. After an interval of one-half minute for the absorption of the water, the process shall be completed by vigorous stirring with the spatula, working the material back from time to time in the reverse direction by pressure between the back of the spatula and the side of the bowl. During these operations the bowl can with advantage be revolved if tilted slightly and held in the left hand. The mixing processes shall be continued for at least 1½ minutes.

The temperature of the room shall be maintained above a minimum of 18° C., and that of the mixing water shall be between 20° C. and 22° C.

Percentage of Water.

41. The proportion of water to be used for a standard mortar shall depend on the amount of water required with the same sample of cement to produce a paste of normal consistency as specified below, and shall be determined in accordance with Table I as there given.

DETERMINATION OF NORMAL CONSISTENCY

Normal Consistency.

42. A cement paste is said to have normal consistency when the proportion of water in the freshly mixed paste is such as to give a plasticity corresponding to a settlement of the Vicat rod (1 cm. diameter) to a point 10 mm. below the original surface in ½ minute after being released, when the paste is tested as described below.

43. Paste of normal consistency is to be used in the tests for soundness and time of setting.

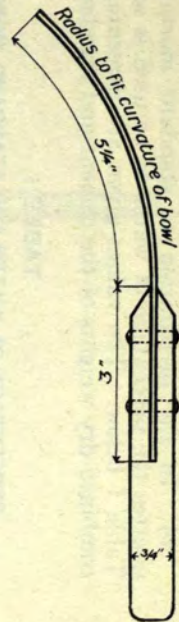
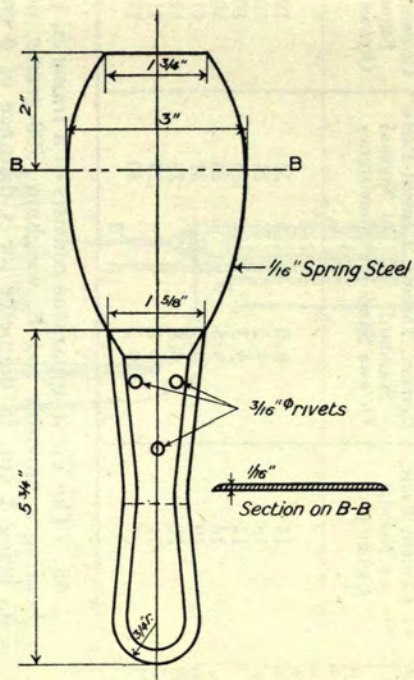
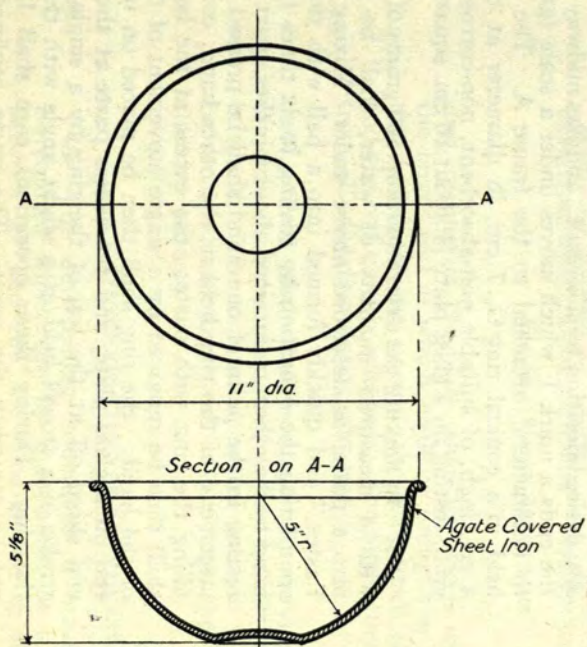


Fig. 1. Mixing Bowl and Spatula

Water in
Standard
Mortar.

44. In the preparation of standard mortar for briquettes the percentage of water to be used is set forth in Table I below. The values given are percentages of the combined dry weights of the cement and standard sand.

TABLE I
PERCENTAGE OF WATER FOR STANDARD MORTARS

Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement, Three Standard Ottawa Sand.	Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement, Three Standard Ottawa Sand.
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

Vicat
Apparatus.

45. The Vicat apparatus consists of a frame A, (Fig. 2) bearing a movable rod B, weighing 300 grams, one end C being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle D, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw E, and has midway between the ends a mark F which moves under a scale (graduated to millimeters) attached to the frame A. The paste is held in a conical ring G, 7 cm. in diameter at the base, 4 cm. high, of suitable non-absorbent, non-corrosive material, resting on a glass plate H about 10 cm. square.

Method
for Normal
Consistency.

46. In making the determination, 500 grams of cement, with a measured quantity of water, shall be kneaded into a paste, as described above under "Mixing Cement Pastes," and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 inches apart; the ball resting in the palm of one hand shall be pressed into the larger end of the ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate, and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the

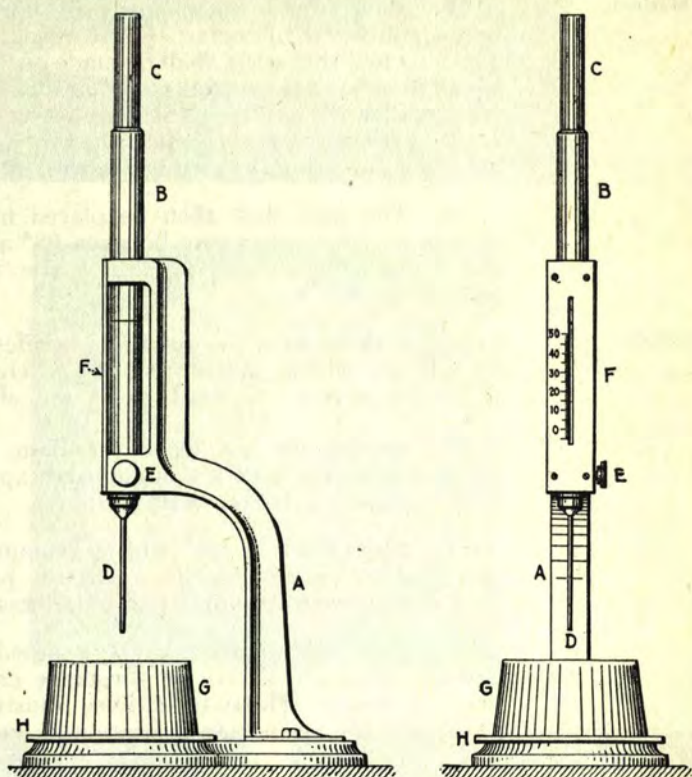


Fig. 2. Vicat Apparatus

ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall then be read, and the rod quickly released. The apparatus shall be free from all vibration during the test.

47. Trial pastes shall be made with varying percentages of water until the amount necessary for normal consistency is found. The amount of water used in each trial shall be recorded and expressed as a percentage by weight of the dry cement.

DETERMINATION OF SOUNDNESS

Apparatus.

48. For determining soundness a steam apparatus is required which can be maintained at a temperature between 98° and 100° C. One similar to that shown in Fig. 3 is recommended.

Method.

49. Pats from cement paste of normal consistency, about 3 inches in diameter, $\frac{1}{2}$ inch thick at the centre, and tapering to a thin edge, shall be made on clean glass plates about 4 inches square, and stored in moist air for 24 hours. In moulding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the centre.

50. The pats shall then be placed in an atmosphere of steam at a temperature between 98° and 100° C. upon a suitable support above boiling water where they shall remain for five hours.

Defects.

51. Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration. Typical cases are shown in Fig. 4.

52. Should the pat leave the plate, distortion may be best detected with a straight edge applied to the surface which was in contact with the plate.

53. The failure of the pats to remain on the glass, or the cracking of the glass to which the pats are attached, does not necessarily indicate unsoundness.

54. Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours. These conditions, illustrated in Fig. 5, at (c) and (d), are not an indication of unsoundness.

DETERMINATION OF TIME OF SETTING

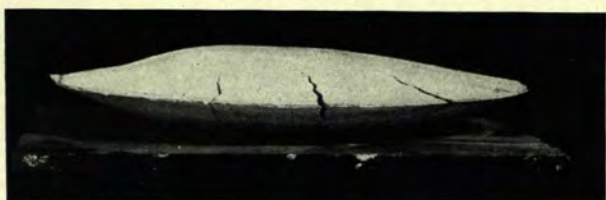
Apparatus.

55. The time of setting shall be determined with the Vicat apparatus described above under "Determination of Normal Consistency" (See Fig. 2).

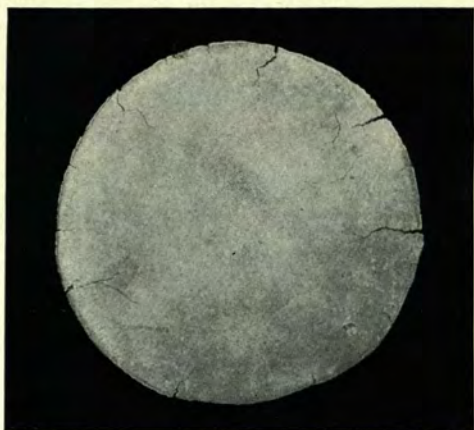
**Method
for Time
of Setting.**

56. A paste of normal consistency shall be moulded in the ring G as described above, and placed under the rod B, the needle end of which (1 mm. diameter) shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in one half minute after being released; and the final set, when the needle does not sink visibly into the paste. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration.

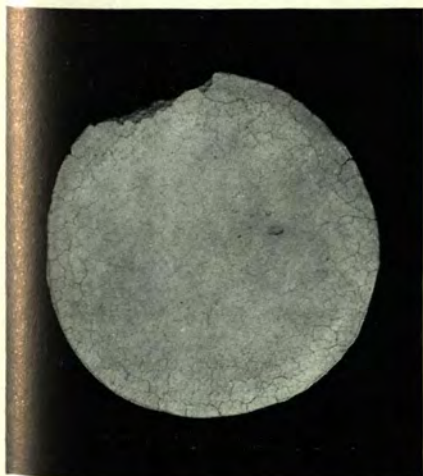
57. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature



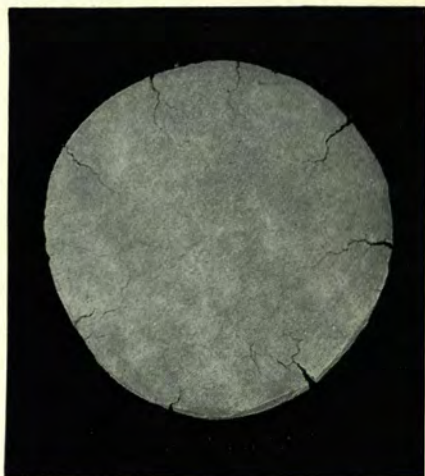
Distortion.



Radial Expansion cracks.



Checking and Distortion.

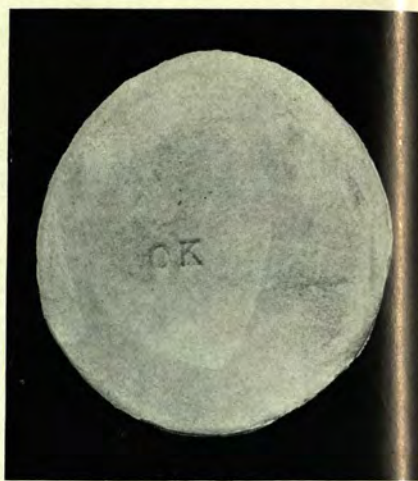


Expansion and Distortion.

Fig. 4. Typical Failures in Soundness Test



a



b

Pats of sound cement after steam test.



c



d

Shrinkage cracks due to exposure to dry air during setting.

Fig. 5. Pats of Sound Cement Properly and Improperly Treated

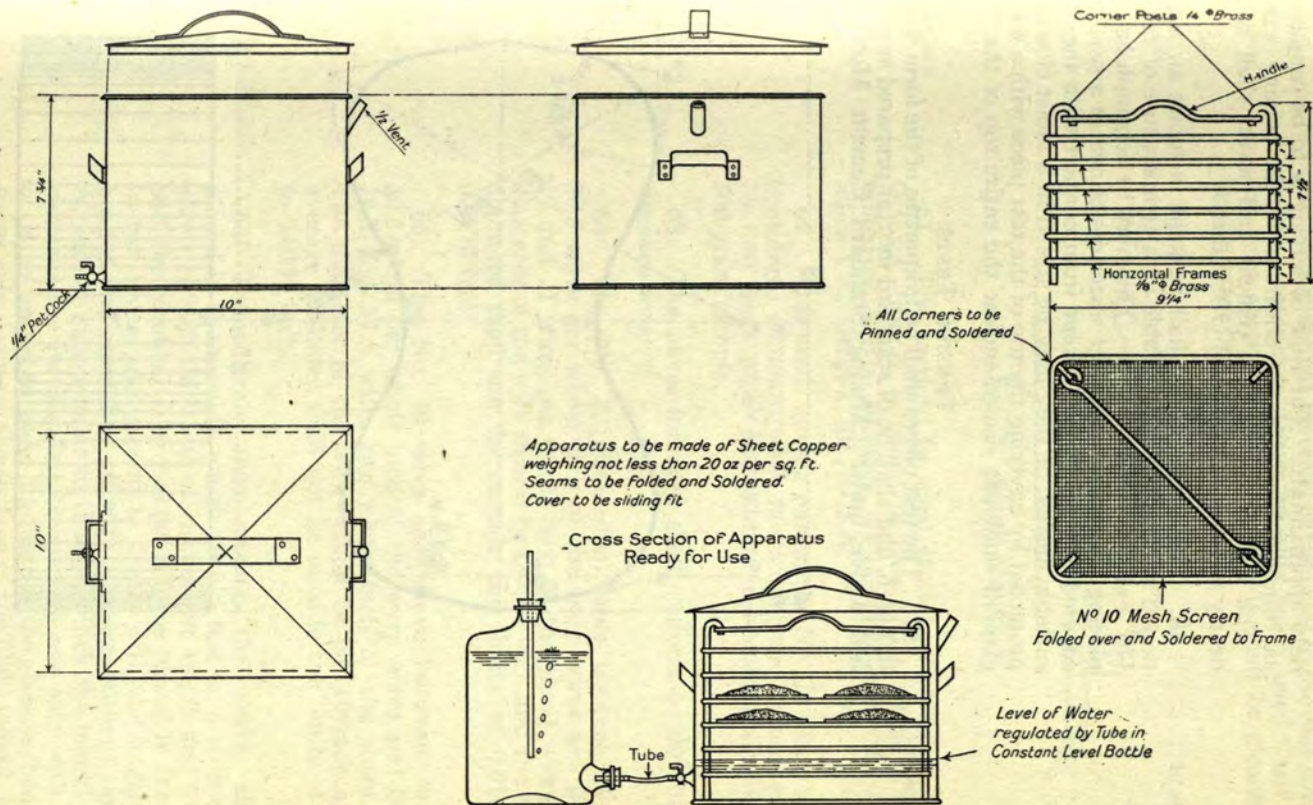


Fig. 3. Steam Test Apparatus

and humidity of the air, and its determination is therefore only approximate. The time of setting is to be considered as commencing with the addition of the mixing water.

The temperature of the cement and water shall be as nearly as practicable 21° C. (70° Fahr.).

**Storage of
Test
Pieces.**

58. These test pieces shall be kept in moist air maintained as nearly as practicable at a temperature of 21° C. (70° Fahr.) during the test. This may be accomplished by placing them on a rack over water contained in a pan, and covered by a damp cloth kept from contact with them by suitable means; or they may be stored in a moist closet, or protected by covering the top of the test piece with a watch glass of sufficient size to enclose the entire top of the ring.

TENSILE TESTS

Test Pieces.

59. The test pieces shall be briquettes of the form shown in Fig. 6, and shall be of standard mortar prepared as specified above under "Mixing Standard Cement Mortars."

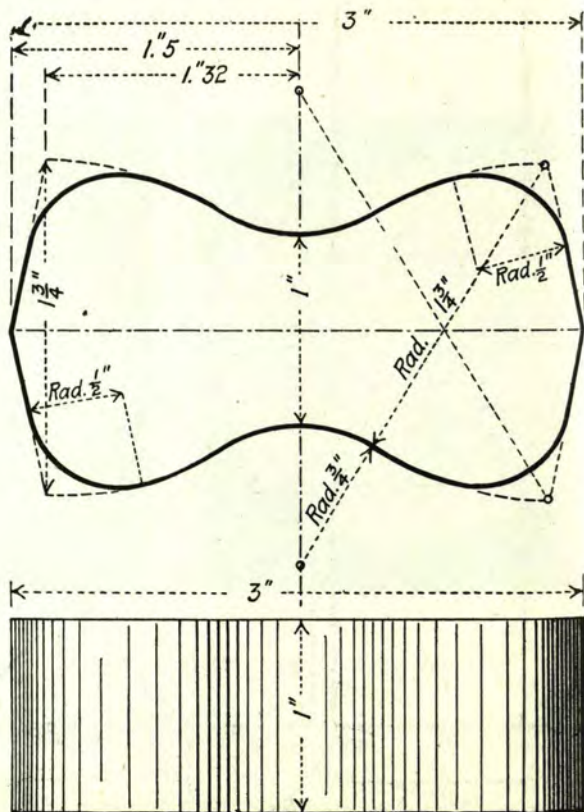


Fig. 6. Details for Briquette

Moulds.

60. The moulds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during moulding. Gang moulds when used shall be of the type shown in Fig. 7. Moulds shall be cleaned and lightly oiled before using.

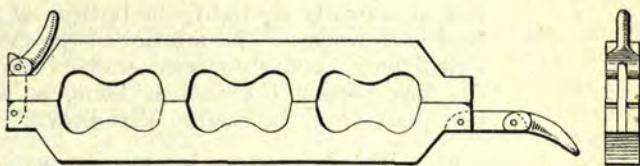


Fig. 7. Gang Mould

Standard Sand.

61. The sand to be used shall be natural sand from Ottawa, Illinois, screened to pass a No. 20 sieve and retained on a No. 30 sieve, as obtained from the Ottawa Silica Co., Ottawa, Ill., U.S.A.

62. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 grams pass the No. 30 sieve after one minute continuous sieving of a 500-gram sample.

Sieves for Sand.

63. The sieves for sand shall conform to the following specifications:—

64. The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 inch and the average diameter shall not be outside the limits of 0.0160 and 0.0170 inch.

65. The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 inch and the average diameter shall not be outside the limits of 0.0105 to 0.0115 inch.

Method of Filling Moulds.

66. Immediately after mixing, the mortar shall be placed in the moulds, which should rest on a strip of glass about $\frac{1}{4}$ inch thick and of convenient length and width to suit the moulds. The mortar is to be placed in the mould in two layers and pressed in firmly with the fingers, then heaped and smoothed off with a trowel without ramming. A piece of glass similar to that on which the mould and its contents are resting, but covered on one side with a strip of paper wetted to make it adhere to the glass, is then placed paper side down on the surface of the filled mould, and the

two pieces of glass, with the filled mould between them, are picked up and turned over. The operation of heaping and smoothing off is then to be repeated on the reverse surface.

Moist Closet.

67. The moist closet shall consist of a substantial box, practically air-tight, the bottom of which is kept covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that the test pieces may be readily withdrawn.

**Storage of
Briquettes.**

68. The briquettes for tensile tests shall be kept in moulds on glass plates in the moist closet for 24 hours, when they shall be removed from the moulds, immediately submerged in clean fresh water in a tank of non-corroding material, and left there till taken out for breaking.

Temperatures.

69. The moist closet shall be maintained as nearly as practicable at a temperature of 21° C. (70° Fahr.).

70. The water storage tanks shall be maintained above a minimum of 18° C. (64° Fahr.) and below a maximum of 25° C. (77° Fahr.), and as nearly as possible at a temperature of 21° C. (70° Fahr.).

Testing.

71. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centred and the load applied continuously at the rate of 600 pounds per minute.

72. Testing machines should be calibrated frequently in order to determine their accuracy.

73. Briquettes which give strengths differing more than 15 per cent., from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

APPENDIX II

RECOMMENDED METHODS FOR SAMPLING CEMENT

SAMPLES

Definitions.

74. Individual samples are separate portions of material taken at random from packages, conveyors, or bulk. They are as a rule not subjected separately to test or examination; but are taken, combined, and thoroughly blended, in order to obtain a composite Test-sample, i. e., a quantity of cement whose composition is as nearly as possible the same as the average of the lot or shipment of cement from which the various Individual samples have been taken. Each Test-sample is thus considered as representing a certain shipment or lot of cement.

Test-samples.

75. Portions of cement are taken from the Test-samples as required for the purpose of the various prescribed tests (chemical, mechanical or otherwise).

76. The weight of a Test-sample should not be less than 8 pounds, however small the quantity of cement which it represents.

Individual Samples.

77. Each Test-sample should be made up of at least 16 Individual samples, which, if the cement is not sampled in bulk or from a conveyor or spout, should each be taken from a separate bag or package.

78. The weight to be taken for an Individual sample depends on circumstances; but should as a rule be from $\frac{1}{4}$ to $\frac{1}{2}$ pound.

METHODS OF SAMPLING

Samples from Bags stowed in Cars, Steamers, or Warehouses.

79. One Individual sample should be taken from every fiftieth bag, preferably at the point of loading, and after loading has been completed. Unless otherwise specified by the Purchaser, Individual samples should be so combined for the tests, other than soundness and time of setting, that one Test-sample shall represent each car-load of not more than 1000 bags.

Sampling Tube.

80. Individual samples from bags should be taken from the surface of the cement to the centre of the bag. If the bags be equipped with valves, samples may be taken through the valves by a suitable sampling tube, inclining the tube to the centre of the bag. If the cement be piled samples should not be taken from the top row unless the top row of bags has only just been placed in position.

81. A sampling tube suitable for use when sampling from bags is shown in Fig. 8.

Material Sheet Brass or Galvanized Iron about 0.05" thick

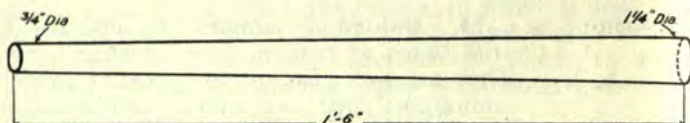


Fig. 8. Tube for Sampling Cement in Bags

Samples from
Bulk in Bins
or Cars.

82. Unless otherwise specified by the Purchaser, Individual samples taken from bulk should be so combined for the tests, other than soundness and time of setting, that one Test-sample shall represent not more than 94,000 lbs. of cement (say 250 barrels or 1000 bags).

83. Individual samples from bulk should be taken from points well distributed under the surface or sides by inserting the sampling tube vertically or horizontally.

84. Such samples should not, as a rule, be taken from a greater depth than 6 feet, on account of the difficulty experienced in obtaining a representative sample when the sampling tube is driven to any considerable depth in the cement.

Samples
from
Conveyors.

85. When sampling from a conveyor delivering to a bin, it is recommended that one Test-sample be taken to represent from 4 to 6 hours run of the plant. In cases where satisfactory automatic sampling machines are not provided, the Test-samples should be made up of Individual samples taken by a scoop at equal intervals of time, at least hourly, and preferably more frequently.

86. When cement is being discharged from a bin, and loaded in bulk, samples should be taken by a scoop from the conveyor or spout at equal intervals of time in such a way that at least sixteen Individual samples will be taken from each 1000 bags.

87. When the cement is being discharged from a bin, and bagged by a bagging machine, it is recommended that the cement be sampled from the bags after piling or loading in cars, in the same manner as for carload lots in bags.

Samples for
Soundness and
Time of Sett-
ing.

88. In cases where cement from two or more bins has been loaded into the same car, or where there is reason to believe that one portion of a shipment may differ in quality from the rest, it is recommended that, unless otherwise required by the Purchaser, the tests for soundness and time of setting should be made on some or all of the Individual samples before combining them. For this purpose one Individual sample may be taken to represent 50 to 100 bags.

TREATMENT, SHIPMENT, AND STORAGE

Treatment,
Shipment and
Storage of
Test-samples.

89. As soon as the Individual samples have been combined, the resulting Test-sample should be intimately mixed, preferably by coning, or by placing it on a suitable impervious cloth measuring about 6 feet square, and rolling the cement back and forth by raising alternate sides of the cloth.

90. Each Test-sample after mixing should be immediately placed in a suitable air-tight container or containers, and, if not to be tested at the place of sampling, sealed in such a manner as to preclude tampering.

Containers.

91. Care should be taken that Test-samples are shipped and stored in the original air-tight containers.

Identifying
Samples.

92. Each container should have securely attached to, or enclosed in it, a card giving the following information:

- Car number and initials (if shipped by rail);
- Test-sample number;
- Place of sampling;
- Date of sampling, and signature of person taking the sample;
- Name of manufacturer;
- Brand of cement;
- Place of manufacture.

Sieving.

93. Before removing any portion of a Test-sample for testing, the Test-sample should be passed through a sieve having 20 meshes per lineal inch in order to break up lumps and remove foreign material.

APPENDIX III

STANDARD METHODS FOR THE COMPLETE CHEMICAL
ANALYSIS OF CEMENT

DETERMINATION OF SILICA

Silica.

94. Weigh one-half gram of finely powdered cement into a 300 cc. porcelain casserole, or preferably a platinum dish for the sake of greater accuracy. Moisten and stir with 10 cc. of water to prevent lumping, and add 10 cc. of hydrochloric acid. Digest with the aid of gentle heat and agitation until the solution is complete. (Solution may be aided by light pressure on any hard, dark particles with the flattened end of a glass rod). Filter off the silica, which contains any material that may remain undecomposed, wash, dry, ignite gently to burn off all carbon, and fuse with 1 gram of sodium carbonate; dissolve in dilute hydrochloric acid and add this solution to the first filtrate. Evaporate to dryness on a hot-plate or steam-bath at a temperature of 100° to 110° C. Treat the dry residue, without further heating, with 10 cc. of 1 to 1 hydrochloric acid, cover the dish with a watch glass and digest for ten minutes at a gentle heat; filter and wash the separated silica thoroughly with hot water. Evaporate the filtrate to dryness for a second time at 110° C. without baking, cool, add to the dry residue 25 cc. of 1 to 1 hydrochloric acid to bring all the bases into solution, and to afford excess hydrochloric acid to form sufficient ammonium chloride (when the solution is made ammoniacal in the determination of ferric oxide and alumina) to prevent the precipitation of magnesium hydroxide, digest for a few minutes, add 50 cc. of water and maintain at a gentle heat for about 30 minutes to separate the small amount of silica in the solution. Filter and wash the silica on a second paper, and receive the filtrate in a 250 cc. beaker, reserving it for the determination of ferric oxide and alumina, lime, and magnesia. Transfer the wet papers containing the silica to a weighed platinum crucible, dry thoroughly, ignite at a low temperature until the carbon of the filter is completely consumed, and blast at 1200° C. for 15 to 20 minutes to constant weight. It is to be remembered that a small amount of additional silica can always be recovered from the ferric oxide and alumina, as described under that head, and its weight is to be added to the two silica precipitates to obtain the total silica in the sample.

95. Treat the silica in the crucible, if greater accuracy is desired, with 10 cc. of hydrofluoric acid and 4

drops of sulphuric acid; evaporate on a hot-plate to fumes of sulphuric anhydride. Repeat the treatment with hydrofluoric acid, and evaporate carefully to the complete expulsion of sulphuric acid, ignite gently at first and then apply the blast to the crucible for a minute or two, cool, and weigh. (The expulsion of sulphuric acid during evaporation can be accomplished without spattering by applying the heat of a pin-hole burner to the crucible, or crucibles, supported on a gauze at an elevation of 2 to 4 inches above the adjusted flame). The loss in weight after treatment with hydrofluoric acid represents the amount of silica. The residue, after fusion with sodium bisulphate and solution in water, is added to the two filtrates from the silica.

96. If there is any doubt as to the silica being completely volatilized by the double hydrofluoric acid treatment described above, the operation may be repeated a third time in the manner already set forth. For ordinary commercial analysis the hydrofluoric acid treatment of the silica may, perhaps, be neglected; but the double evaporation should never be omitted. 

DETERMINATION OF FERRIC OXIDE PLUS ALUMINA

Ferric
Oxide plus
Alumina.

97. Add to the filtrate from the second evaporation for silica, which should be made up to about 150 cc., a few drops of bromine water or a small quantity of sodium peroxide or hydrogen peroxide, boil, and add a very slight excess of ammonium hydroxide, boil for a few minutes or until only a faint odour of ammonia is perceptible; allow to settle for about five minutes, filter, and wash the precipitate two or three times with hot water. Set aside the filtrate, remove the precipitate from the filter paper into the original beaker with the aid of a jet of hot water, and dissolve by the addition of a few cc. of concentrated nitric acid, taking care that any precipitate attached to the sides of the beaker is also dissolved. The volume of this solution should be about 50 cc. Reprecipitate the iron and aluminium as hydroxides with ammonium hydroxide, boil and settle as before; decant the almost clear solution on to the original filter, then transfer the precipitate and wash well with a hot solution of ammonium nitrate (10 grams to the litre) made slightly alkaline with a few drops of ammonium hydroxide. The addition of the ammonium nitrate to the wash water assists in the washing, and also in preventing, to a great extent, the solution of the colloidal iron and aluminium hydroxides, which are slightly dissolved by pure water.

98. This is the main iron-and-aluminium-hydroxide precipitate; however, on concentrating the two filtrates from this precipitate a little iron and aluminium hydroxide will separate, and is to be filtered, washed, and added to the main precipitate. Dry the two precipitates, ignite in a weighed platinum crucible at a white heat (1100° to 1200° C.) for about ten minutes, cool, and weigh.

99. The weight gives the amount of mixed oxides, namely, ferric oxide, alumina, phosphorus pentoxide, titanium dioxide, and manganese monoxide (in part), together with a few milligrams of silica. This small amount of silica is separated later by fusion of the above mixed oxides with sodium bisulphate, as described in the determination of ferric oxide; its weight can be determined and subtracted to obtain the actual weight of the iron and aluminium oxides. When manganese is present in the sample, a small amount is precipitated with the iron and aluminium hydroxides, and later with the calcium oxalate, while the remainder will be found with the magnesium phosphate, especially when double precipitations have been employed in the separations.

DETERMINATION OF FERRIC OXIDE

Ferric
Oxide alone.

100. The separate estimation of ferric oxide in the mixed oxides determined above is not generally required for cement analysis, but if it is desired, proceed as follows:

Fuse the mixed oxides obtained above, in a covered platinum, or transparent quartz crucible, with three or four grams of fused sodium bisulphate. Heat gently at first, and gradually increase the temperature to a full red heat. When a quiet fusion is reached and no dark specks are apparent, remove from the source of heat, give the crucible a rotary motion with the aid of the tongs, so that the fused mass is spread up the sides, giving extended surface to effect ready solution, and cool. Place the crucible and contents in a beaker containing 5 cc. of concentrated sulphuric acid and 50 cc. of water, digest until solution is complete. Or, to effect the same result, the fusion may be quickly poured into a clean dry platinum dish floating in cold water, and brought into solution as above by treatment with the dilute acid. Evaporate the solution so obtained to fumes of sulphuric anhydride, cool, add 50 cc. of cold water, and heat to effect complete solution. Filter out the small amount of silica, wash, ignite, weigh, and add its weight to that of the original silica. Reduce the solution by means of zinc in a Jones' Reductor, and titrate with standard potassium permanganate. Or, neutralize the solution with ammonium hy-

droxide, add 1 to 2 cc. of sulphuric acid, and pass hydrogen sulphide gas through the hot liquid for about ten minutes. When reduction is complete pass in carbon dioxide gas and boil to expel the hydrogen sulphide, remove from the source of heat, and continue passing carbon dioxide until the solution has cooled. Dilute with freshly boiled distilled water, add a few cc. of sulphuric acid, and titrate with standard potassium permanganate, the strength of which should not exceed 0.0040 grams of ferric oxide per cc.

DETERMINATION OF CALCIUM OXIDE

Calcium
Oxide.

101. Heat the solution, freed from all ferric and aluminium hydroxides, to boiling, add gradually, while stirring, 20 cc. of a hot saturated solution of ammonium oxalate, and maintain near the boiling point until the precipitated calcium oxalate assumes a well defined granular form (five to ten minutes). Allow the solution to stand until the precipitate has settled (about fifteen minutes), filter, and wash the calcium oxalate, with small amounts of warm (not *hot*) water, two or three times on the filter. Remove the precipitate from the filter paper into the original beaker with the assistance of a jet of hot water, dissolve by the addition of a few cc. of hydrochloric acid, dilute to 100 cc. with hot water, add 1 or 2 cc. of the ammonium oxalate solution, and make alkaline with ammonium hydroxide in slight excess. Boil, filter, and wash thoroughly with the smallest necessary amount of water. Place the filter paper and precipitate in a weighed platinum crucible, dry, burn off the paper at a low heat, and blast at 1200° C. to constant weight. Weigh as calcium oxide.

102. Instead of following the above procedure, the calcium oxalate may be dissolved and determined volumetrically with standard potassium permanganate, though this method is not generally considered to be so accurate as the gravimetric method.

103. The filtrates from the two calcium oxalate precipitations are to be combined and reserved for the magnesia determination.

104. If extreme accuracy is desired, a third calcium oxalate precipitation may be employed. In this case acidify, with a small excess of hydrochloric acid, the combined filtrates from the previous calcium oxalate precipitations, concentrate on a steam-bath to about 200 cc., add ammonium hydroxide in slight excess, boil,

and allow to settle. If any precipitate forms, filter, wash, and add to the calcium oxalate previously precipitated. The filtrate is to be reserved for the magnesia determination.

DETERMINATION OF MAGNESIA

Magnesia.

105. Acidify, with a small excess of hydrochloric acid, the combined filtrates from the calcium oxalate precipitations, concentrate on the steam-bath to about 200 cc., add 10 cc. of a 10 per cent. solution of sodium-ammonium phosphate, and boil for several minutes. Cool, add ammonium hydroxide, drop by drop, while vigorously stirring, until the crystalline magnesium-ammonium ortho-phosphate begins to form, and then in moderate excess (about 20 cc. in all); continue the stirring for several minutes. Set aside for several hours, or over night, in a cool place, filter and wash with 2½ per cent. solution of ammonium hydroxide (1 part of ammonium hydroxide to 10 parts of water+100 grams of ammonium nitrate per litre). If greater accuracy is desired, dissolve the precipitate in hot 1 to 1 hydrochloric acid, make up the solution to 100 cc., add 1 or 2 cc., of the 10 per cent. solution of sodium-ammonium phosphate, cool, and reprecipitate as before. Allow to stand in a cool place for about two hours, filter, wash well with the 2½ per cent. ammonium hydroxide solution, transfer the filter and precipitate to a weighed platinum crucible, dry to incipient charring, burn off the paper at a low heat, ignite at 1000° C., cool, and weigh as magnesium pyrophosphate. The weight of the ignited precipitate in grams multiplied by 0.3621 gives the weight of magnesia.

DETERMINATION OF SULPHURIC ANHYDRIDE

Sulphuric Anhydride.

106. Weigh one gram of the finely-powdered cement into a suitable dish, moisten and stir with 10 cc. of water to prevent lumping, add 10 cc. of hydrochloric acid, and digest at a gentle heat. When solution is complete, add 50 cc. of hot water and filter. Dilute the filtrate to 250 cc., boil, add 10 cc. of a hot 10 per cent. solution of barium chloride, drop by drop, while stirring, and continue boiling until the precipitate is well formed (15 to 20 minutes). Set aside in a warm place for several hours, or over night, filter, wash, dry, place the dry filter paper and precipitate in a weighed platinum crucible, burn off the paper at a low heat, ignite at a temperature not higher than 1000° C. for a few minutes, and weigh. The weight of the ignited precipitate in grams multiplied by 0.3430 gives the weight of sulphuric anhydride.

DETERMINATION OF TOTAL SULPHUR AS SULPHURIC ANHYDRIDE

Total Sulphur.

107. Weigh one gram of the cement into a large platinum crucible, fuse with 10 grams of sodium carbonate and 1 gram of ammonium nitrate over a suitable burner, being careful to prevent contamination by sulphur derived from the source of heat. Dissolve the melt by first pouring the fusion into a platinum dish as described under the iron and aluminium oxide fusion, add boiling water, heat until the fusion is disintegrated and all sodium salts are in solution, filter, acidulate with hydrochloric acid to ensure 1 or 2 cc. excess of acid, and make up to 250 cc. with hot water. Boil, add 10 cc. of the 10 per cent. barium chloride solution, and proceed as in the determination of sulphuric anhydride given above.

DETERMINATION OF THE ALKALIES

Sodium
and Potass-
ium Oxides.

108. This determination is seldom required for cement; but if needed, the following modified method of J. Lawrence Smith is recommended, recent investigations by M. F. Connor having shown that the "double fusion" is indispensable for the complete extraction of the alkalies.

109. Weigh one gram of very finely ground cement into a porcelain or agate mortar, add one gram of alkali-free ammonium chloride, and grind until the two are thoroughly mixed. Then add 8 grams of alkali-free calcium carbonate, and continue the grinding to obtain an intimate mixture of the whole. Take a platinum crucible of such a size that the mixture will not occupy more than about three-quarters of its capacity, place a layer about one-quarter inch thick of the dry calcium carbonate on the bottom to prevent the semi-fused mass adhering persistently to the bottom during the leaching operation, and then carefully transfer the mixture, and gently tap it down, finally covering with a thin layer of the dry calcium carbonate. Cover with a close-fitting lid, heat carefully for a few minutes with a small Bunsen flame placed 3 or 4 inches below the crucible to transform the calcium carbonate to calcium chloride and volatilize ammonium salts, then gradually raise the heat to redness, maintaining this temperature for $\frac{3}{4}$ hour. Allow the crucible and contents to cool until they are just warm, and then add distilled water drop by drop, until the lime is thoroughly slaked. The mass may now easily be detached from the crucible and transferred to a platinum dish with about 80 cc. of water. Wash the crucible and cover with hot water directly in-

to the platinum dish. Cover the dish with a watch glass and boil carefully for at least 15 minutes, as magnesia is precipitated by the boiling solution containing excess of hydroxide of lime. Pour off the solution and finely disintegrated residue on to a filter, then with a little water crush the residue in a dish to reduce any lumps, boil for a few minutes, and then pour on to the filter as before. Continue this operation until the whole mass is reduced to extreme fineness and has been washed on to the filter. Wash with boiling water until but a slight cloudiness is shown when silver nitrate is added to a drop or two of the washing. The filtrate will then be about 450 cc.; dry and reserve the residue for a second fusion, as it still contains a small percentage of the alkalies which must be recovered, and treat the filtrate as follows:—

110. Heat to boiling and make decidedly ammoniacal, then add, while stirring, a strongly ammoniacal solution of one to ten ammonium carbonate until all lime is precipitated, and digest on a water-bath a few minutes until the voluminous precipitate settles. Filter off the precipitated calcium carbonate and wash six or seven times with hot water. Place the filtrate on the water-bath for evaporation.

111. It is now necessary to recover some alkalies held by occlusion in the calcium carbonate just precipitated. For this purpose redissolve in the least possible amount of hydrochloric acid and reprecipitate as before with ammonium carbonate, filter, and add filtrate to the main filtrate which has been evaporating. Any excess of acid used in the solution of the calcium carbonate precipitate forms ammonium chloride when the solution is made ammoniacal; this ammonium chloride helps to retain some lime in solution when precipitating with ammonium carbonate, and increases the amount of ammonium salts to be volatilized later in the operation.

112. For the second fusion to recover the remaining alkalies, use the dry residue from the first fusion, adding thereto the washed and dried calcium carbonate precipitate obtained from the main filtrate containing the alkalies, also 1 to 2 grams of fresh calcium carbonate and 1 gram of ammonium chloride; mix intimately in a mortar and repeat the operation as given above.

113. The final filtrates from this second set of operations are added to those from the first, which have been evaporating on a water-bath, and the whole solution is evaporated to dryness in a large platinum or quartz dish. Dry the residue at 115° C. in an air oven for about $\frac{1}{2}$ hour.

and then heat at as low a temperature as possible below redness to volatilize the ammonium salts. After all the ammonium salts have been driven off, dissolve the residue in the smallest possible amount of water, and add a little ammonia and ammonium carbonate solution to remove any lime held in solution by the ammonium chloride just removed by volatilization. Filter, wash, evaporate the filtrate to small volume, and acidify with a drop or two of hydrochloric acid in order to have sufficient chlorine present to combine with all the alkali bases from the final weighing as chlorides, whenever this last stage is reached.

114. Add about one or two cc. of barium chloride solution to the hot solution, filter off the barium sulphate, and add to the filtrate a slight excess of ammonium carbonate with a small amount of ammonium oxalate. Filter off the precipitate, which contains the remaining barium together with any residual calcium, evaporate the filtrate to dryness, and ignite gently to drive off ammonium salts.

115. Finally heat the alkali chlorides to incipient fusion, cool, and obtain the weight of the dish plus the potassium and sodium chlorides. Dissolve the alkali chlorides in a few cc. of hot water. A slight residue consisting of traces of lime and magnesia will be left, adhering mostly to the platinum dish. Filter the solution through a small filter to catch any loose particles of this residue, and after washing well place the filter paper in the platinum dish with the adhering residue, ignite, weigh, and deduct this combined weight from the weight of the dish and alkalies already noted, thus obtaining the correct weight of the potassium and sodium chlorides.

116. To determine the potash in the mixed chlorides, add to the aqueous solution of the pure alkali chlorides just obtained, preferably in a small porcelain casserole (30 to 40 cc. capacity), a solution of platinic chloride, sufficient to combine with all the potassium and sodium salts and leave a considerable excess. Evaporate on a water-bath maintained at a temperature a little below the boiling-point of water, until the residue solidifies on cooling. Add sufficient water (about 2 or 3 cc.), while stirring, to dissolve the excess of platinic chloride, follow at once with about 5 cc. of 95 per cent. alcohol, stir well with a glass rod and cover with a watch glass. Stir a few times at intervals, and filter after one hour's time through a Gooch crucible, wash with alcohol until the filtrate runs through perfectly colorless, dry at 100° C. and weigh as potassium-platinic chloride. This weight multiplied by

0.19376 gives the weight of potash (potassium oxide), or multiplied by 0.30673 gives the weight of potassium chloride. This latter weight subtracted from the weight of the mixed potassium and sodium chlorides previously obtained gives the weight of the sodium chloride, which, multiplied by 0.53028, gives the weight of soda (sodium oxide).

117. Although it is generally possible to obtain relatively alkali-free reagents, it is preferable to prepare them in the laboratory. In any case a blank test for alkali content should be made on the thoroughly-sampled reagents used.

APPENDIX V

STANDARD SPECIFICATION FOR BILLET STEEL REINFORCING BARS*

C.E.S.A. Specification A9A-1923†

The provisions of this Specification are in substantial agreement with those of Specification A15-14† of the American Society for Testing Materials.

MATERIAL

Material
Covered

1. This Specification covers three classes of billet-steel reinforcing bars, namely: plain, deformed, and cold-twisted.

2. Plain and deformed bars are of three grades, namely: structural-steel, intermediate and hard.

Basis of
Purchase

3. If desired, cold twisted bars may be purchased on the basis of tests of the hot-rolled bars before twisting, in which case such tests shall govern and shall conform to the requirements specified for plain bars of structural steel grade.

MANUFACTURE

Processes

4. The steel shall be made by either the Bessemer or open-hearth process.

5. The bars shall be rolled from new billets. No re-rolled material will be accepted.

Cold-twisted
Bars

6. Cold-twisted bars shall be twisted cold with one complete twist in a length not over 12 times the thickness of the bar.

CHEMICAL PROPERTIES AND TESTS

Chemical
Composition

7. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	{ Bessemer	not over 0.10 per cent.
	{ Open-hearth Basic " " "	0.05 " "
	{ Open-hearth Acid " " "	0.08 " "

Ladle
Analyses

8. An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the Manufacturer from a test ingot taken during the pouring of the heat, a copy of which shall be given to the Purchaser or his representative. This analysis shall conform to the requirements specified above.

Check
Analyses

9. Check analyses may be made by the Purchaser from finished bars representing each heat of open-hearth steel, and each heat, or lot of ten tons, of Bessemer steel, in which case an excess of 25 per cent. above the requirements specified above under "Chemical Composition" shall be allowed.

*In the next edition, this Specification will be given a distinctive number.

†Revised to date.

PHYSICAL PROPERTIES AND TESTS

Tension
Tests

10. The bars shall conform to the following requirements as to tensile properties, except as modified herein after:

TENSILE PROPERTIES

Properties Considered	PLAIN BARS			DEFORMED BARS			Cold-twisted Bars
	Structural Steel Grade.	Intermediate Grade.	Hard Grade.	Structural Steel Grade.	Intermediate Grade.	Hard Grade.	
Tensile strength, lb. per sq. inch.	55 000 to 70 000	70 000 to 90 000	80 000 min.	55 000 to 70 000	70 000 to 90 000	80 000 min.	Recorded only
Yield point, lb. per sq. inch	33 000	40 000	50 000	33 000	40 000	50 000	55 000
Elongation in 8 inches, min. per cent.	1 400 000	1 300 000	1 200 000	1 250 000	1 125 000	1 000 000	5
	Tens. str.	Tens. str. but in no case less than 16 per cent.	Tens. str.	Tens. str.	Tens. str. but in no case less than 14 per cent.	Tens. str.	

Yield
Point

11. The yield point shall be determined by the drop of the beam of the testing machine.

Modifications
in
Elongation

12. For plain and deformed bars over 3/4 inch in thickness or diameter, a deduction of 1.0 from the percentages of elongation specified above under "Tension Tests" shall be made for each increase of 1/8 inch in thickness or diameter above 3/4 inch.

13. For plain and deformed bars under 7/16 inch in thickness or diameter, a deduction of 1.0 from the percentages of elongation specified above under "Tension Tests" shall be made for each decrease of 1/16 inch in thickness or diameter below 7/16 inch.

Bend Tests

14. The test specimens shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

BEND-TEST REQUIREMENTS

Thickness or Diameter of Bar	PLAIN BARS			DEFORMED BARS			
	Structural Steel Grade.	Inter- mediate Grade.	Hard Grade.	Structural Steel Grade.	Inter- mediate Grade.	Hard Grade.	Cold Twisted Bars
Under $\frac{3}{4}$ inch..	180 deg. $d = t$	180 deg. $d = 2t$	180 deg. $d = 3t$	180 deg. $d = t$	180 deg. $d = 3t$	180 deg. $d = 4t$	180 deg. $d = 2t$
$\frac{3}{4}$ inch or over.	180 deg. $d = t$	90 deg. $d = 2t$	90 deg. $d = 3t$	180 deg. $d = 2t$	90 deg. $d = 3t$	90 deg. $d = 4t$	90 deg. $d = 3t$

NOTE:— d = diameter of pin about which the specimen is bent;
 t = thickness or diameter of the specimen.

Test
Specimens

15. Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 inches if deemed necessary by the Manufacturer to obtain uniform cross-section.

16. Tension and bend test specimens for cold-twisted bars shall be taken from the finished bars without further treatment, unless otherwise specified by the Purchaser.

Number of
Tests

17. One tension and one bend test shall be made from each heat of open-hearth steel, and from each heat, or lot of ten tons, of Bessemer steel; except that if material rolled from one heat differs $\frac{3}{8}$ inch or more in thickness or diameter, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

18. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Re-tests

19. If the percentage of elongation of any tension test specimen is less than that specified above under "Tension Tests" and any part of the fracture is outside the middle third of the gauge length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT

Permissible
Variations

20. The weight of any lot of bars shall not vary more than 5 per cent. from the computed weight of that lot, based on an assumed weight of 0.2833 per cubic inch.

Finish

21. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION**Inspection**

22. The Inspector representing the Purchaser shall have free entry, at all times while work on the contract of the Purchaser is being performed, to all parts of the Manufacturer's works which concern the manufacture of the bars ordered.

23. The Manufacturer shall afford the Inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with this Specification.

24. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

25. Unless otherwise specified, any rejection based on results of check analyses shall be reported within five working days from the receipt of samples.

26. Bars which show injurious defects subsequent to their acceptance at the Manufacturer's works will be rejected, and the Manufacturer shall be notified.

Rehearing

27. Samples on which check analyses have been made which represent rejected bars shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the check analyses, the Manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATION FOR RAIL-STEEL REINFORCING BARS*

C.E.S.A. Specification A9B-1923

The provisions of this Specification are in substantial agreement with those of Specification A16-14 of the American Society for Testing Materials.

MATERIAL

Material
Covered

1. This Specification covers three classes of rail-steel reinforcing bars, namely: plain, deformed and hot-twisted.

MANUFACTURE

Process

2. The bars shall be rolled from standard section Tee rails.

Hot-twisted
Bars

3. Hot-twisted bars shall have one complete twist in a length not over 12 times the thickness of the bar.

PHYSICAL PROPERTIES AND TESTS

Tension
Tests

4. The bars shall conform to the following minimum requirements as to tensile properties except as modified hereinafter:

Properties Considered	Plain Bars	Deformed and Hot-twisted Bars
Tensile strength, lb. per sq. inch.....	80 000	80 000
Yield Point, lb. per sq. inch.....	50 000	50 000
Elongation in 8 inches, per cent.....	1 200 000	1 000 000
	Tens. str.	Tens. str.

Yield
Point

5. The yield point shall be determined by the drop of the beam of the testing machine.

Modifications
in
Elongation

6. For bars over 3/4 inch in thickness or diameter, a deduction of 0.25 from the percentages of elongation specified above under "Tension Tests," shall be made for each increase of 1/32 inch in thickness or diameter above 3/4 inch.

*In the next edition this Specification will be given a distinctive number.

7. For bars under 7/16 inch in thickness or diameter, a deduction of 0.5 from the percentages of elongation specified above under "Tension Tests," shall be made for each decrease of 1/32 inch in thickness or diameter below 7/16 inch.

Bend Tests

8. The test specimens shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

Thickness or Diameter of Bar	Plain Bars	Deformed and Hot-twisted Bars
Under $\frac{3}{4}$ inch.....	180 deg. $d = 3t$	180 deg. $d = 4t$
$\frac{3}{4}$ inch or over.....	90 deg. $d = 3t$	90 deg. $d = 4t$

NOTE:— d = diameter of pin about which the specimen is bent;

t = thickness or diameter of the specimen.

Test Specimens

9. Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 inches if deemed necessary by the Manufacturer to obtain uniform cross-section.

10. Tension and bend test specimens for hot-twisted bars shall be taken from the finished bars without further treatment.

Number of Tests

11. One tension and one bend test shall be made from each lot of ten tons or less of each size of bar rolled from rails varying not more than 10 lbs. per yard in nominal weight.

12. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Re-tests

13. If the percentage of elongation of any tension test specimen is less than that specified above under "Tension Tests" and any part of the fracture is outside the middle third of the gauge length, as indicated by scribe scratches marked on the specimen before testing, a re-test shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT

Permissible
Variations

14. The weight of any lot of bars shall not vary more than 5 per cent. from the computed weight of that lot based on an assumed weight of 0.2833 lb. per cubic inch.

FINISH

Finish

15. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

Inspection

16. The Inspector representing the Purchaser shall have free entry, at all times while work on the contract of the Purchaser is being performed, to all parts of the Manufacturer's works which concern the Manufacture of the bars ordered.

17. The Manufacturer shall afford the Inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with this Specification.

18. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

19. Bars which show injurious defects subsequent to their acceptance at the Manufacturer's works will be rejected, and the Manufacturer shall be notified.

ESTABLISHED SIZES FOR ROUND AND SQUARE
REINFORCING BARS*

Size in Inches	Area in Square Inches
$\frac{1}{4}$ Round.....	.049
$\frac{3}{8}$ ".....	.110
$\frac{1}{2}$ ".....	.196
$\frac{5}{8}$ Square.....	.250
$\frac{3}{4}$ Round.....	.307
$\frac{7}{8}$ ".....	.442
1 ".....	.601
1 ".....	.785
1 Square.....	1.000
$1\frac{1}{8}$ ".....	1.266
$1\frac{1}{4}$ ".....	1.563

*Billet-Steel or Rail-Steel.

STANDARD SPECIFICATION FOR COLD-DRAWN STEEL WIRE
FOR CONCRETE REINFORCEMENT*

C.E.S.A. Specification A9C-1923†

The provisions of this Specification are in substantial agreement with those of Specification A82-27 of the American Society for Testing Materials.

MATERIAL

Material
Covered

1. This Specification covers cold-drawn steel wire to be used as such, or in fabricated form, for the reinforcement of concrete, in diameters not less than 0.080 inch nor greater than 0.625 inch.

Basis of
Purchase

2. When wire is ordered by gauge number the following relation between number and diameter, in inches, shall apply unless otherwise specified.

Gauge Number	Equivalent Diameter, Inch	Gauge Number	Equivalent Diameter, Inch
0000000	0.4900	5	0.2070
000000	0.4615	6	0.1920
00000	0.4305	7	0.1770
0000	0.3938	8	0.1620
000	0.3625	9	0.1483
00	0.3310	10	0.1350
0	0.3065	11	0.1205
1	0.2830	12	0.1055
2	0.2625	13	0.0915
3	0.2437	14	0.0800
4	0.2253		

MANUFACTURE

Process

3. The steel shall be made by either or both the following processes: Bessemer or open-hearth.

Drawing

4. The wire shall be cold-drawn from rods hot-rolled from billets.

PHYSICAL PROPERTIES AND TESTS

Tension
Tests

5. The wire, except as modified hereinafter, shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. inch.....	80 000
Reduction of area, per cent.....	30

*In the next edition this Specification will be given a distinctive number.

†Revised to date.

6. For wire to be used in the fabrication of mesh a minimum tensile strength of 70 000 lb. per sq. inch shall be permitted.

7. For wire testing over 100 000 lb. per sq. inch tensile strength, the reduction of area shall be not less than 25 per cent.

Bend Tests

8. The test specimens shall withstand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows:

For wire 0.3 inch in diameter or under, around a pin the diameter of which is equal to the diameter of the specimen.

For wire over 0.3 inch in diameter, around a pin the diameter of which is equal to twice the diameter of the specimen.

Test Specimens

9. Tension and bend test specimens shall be of the full-size section of the wire as drawn.

Number of Tests

10. One tension and one bend test shall be made for each 10 tons or less of each size of wire.

11. If any test specimen shows defects or flaws, it may be discarded and another specimen substituted.

PERMISSIBLE VARIATIONS IN DIAMETER

Variations in Diameter

12. The diameter of the wire shall not vary more than 0.003 inch from the size ordered.

WORKMANSHIP AND FINISH

Finish

13. The finished wire shall be free from injurious defects and shall have a workmanlike finish with smooth surface.

INSPECTION AND REJECTION

Inspection

14. The Manufacturer shall afford the Inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with this Specification.

15. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

16. Wire which shows injurious defects subsequent to its acceptance at the Manufacturer's works will be rejected, and the Manufacturer shall be notified.

1. The first thing I noticed when I stepped out of the plane was the cold air. It was a sharp contrast to the warm, humid air of the tropics. I shivered slightly, but then I remembered that this was just the beginning of my journey. I took a deep breath and stepped forward, ready to face whatever came my way.

2. The next thing I noticed was the sound of the engine. It was a low, steady hum that seemed to fill the entire cabin. I looked around and saw that everyone else was also looking out the windows. The pilot's voice came over the intercom, telling us that we were about to take off. I felt a sense of anticipation as the plane began to move forward.

3. The third thing I noticed was the view. The landscape below was a mix of green fields and brown hills. The sky was a pale blue, and the sun was shining brightly. I felt a sense of wonder as I looked out at the world from above. The plane took off smoothly, and I felt a sense of freedom as it soared into the sky.

4. The fourth thing I noticed was the smell. It was a mix of the fresh air outside and the stale air inside the cabin. I took a deep breath and tried to ignore it. I knew that this was just a small part of the journey, and I was determined to make the most of it.

5. The fifth thing I noticed was the people. There were about twenty people on the plane, including the pilot, the co-pilot, and the flight attendants. I looked around and saw that everyone was looking at me with curiosity. I felt a sense of nervousness as I realized that I was the only one on the plane who was not a local.

6. The sixth thing I noticed was the time. It was about 10:00 AM, and the sun was high in the sky. I looked at my watch and saw that I had been on the plane for about an hour. I felt a sense of accomplishment as I realized that I had made it to the other side of the world.

7. The seventh thing I noticed was the food. The flight attendant brought me a tray with a sandwich, some fruit, and a glass of juice. I took a bite of the sandwich and felt a sense of satisfaction. I knew that this was just the beginning of my journey, and I was determined to make the most of it.

8. The eighth thing I noticed was the music. The flight attendant played a mix of pop and rock music. I listened to it and felt a sense of joy. I knew that this was just the beginning of my journey, and I was determined to make the most of it.

9. The ninth thing I noticed was the scenery. The landscape below was a mix of green fields and brown hills. The sky was a pale blue, and the sun was shining brightly. I felt a sense of wonder as I looked out at the world from above. The plane took off smoothly, and I felt a sense of freedom as it soared into the sky.

10. The tenth thing I noticed was the people. There were about twenty people on the plane, including the pilot, the co-pilot, and the flight attendants. I looked around and saw that everyone was looking at me with curiosity. I felt a sense of nervousness as I realized that I was the only one on the plane who was not a local.

APPENDIX VI

SPECIFICATION FOR STRUCTURAL CARBON STEEL

C.E.S.A. Specification A6-1929—Appendix V*

(In substantial agreement with A.S.T.M. Specification A7—24)

MANUFACTURE

Process

1. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical
Composition

2. The steel shall conform to the following requirements as to chemical composition:

	Structural Steel			Rivet Steel		
Phosphorus	{ Acid.....	not over	0.06	not over	0.04	per cent.
	{ Basic.....	" "	0.04	" "	0.04	" "
Sulphur.....	" "	" "	0.05	" "	0.045	" "

Ladle
Analyses

3. An analysis of each heat of steel shall be made by the Manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the Purchaser or his representative and shall conform to the requirements specified above.

Check
Analyses

4. Analyses may be made by the Purchaser from finished material representing each heat. The phosphorus and sulphur content thus determined shall not exceed that specified above by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension
Tests

5. The material shall conform to the following requirements as to tensile properties, except as modified herein-after:

Properties Considered	Structural Carbon Steel	Rivet Carbon Steel
Tensile strength, lbs. per sq. inch.....	55 000—65 000	46 000—56 000
Yield Point, min., lbs. per sq. inch.....	0.5 tens. str.	0.5 tens. str.
but in no case less than.....	30,000	25 000
	1 500 000	1 500 000
Elongation in 8 ins., min., per cent.....	(a)	
	Tens. str.	Tens. str.
Elongation in 2 ins., min., per cent.....	22	

*NOTE:—Committee has decided to re-insert Clauses 28, 29 and 30 and Tables I and II in App. V of 1922 edition, covering variations in weight and thickness of steel plates.

(a) See Modifications on next page.

Yield Point

6. The yield point shall be determined by the drop of the beam of the testing machine.

**Modifications
in Elongation**

7. For structural carbon steel over $3/4$ inch in thickness, or diameter, a deduction, from the percentage of elongation in 8 inches specified above, of 0.25 per cent shall be made for each increase of $1/32$ inch in thickness or diameter above $3/4$ inch, to a minimum of 18 per cent.

8. For structural carbon steel under $5/16$ inch in thickness or diameter, a deduction, from the percentage of elongation in 8 inches specified above, of 1.25 per cent shall be made for each decrease of $1/32$ inch in thickness or diameter below $5/16$ inch.

Bend Tests

9. Bend test specimens for plates, shapes and bars (except those for pins, rollers and other bars when $1 \times 1/2$ inch in section, and for rivet steel) shall stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows; for material $3/4$ inch or under in thickness, flat on themselves; for material over $3/4$ inch to and including $1 1/4$ inches in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1 1/4$ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

10. The test specimens for pins, rollers and other bars when $1 \times 1/2$ inch in section, when prepared as specified below under "Test Specimens", shall stand being bent cold through 180 degrees around a pin one inch in diameter without cracking on the outside of the bent portion.

11. The test specimens for rivet carbon steel shall stand being bent cold through 180 degrees flat on themselves without cracking on the outside of the bent portion.

TEST SPECIMENS**Test Specimens**

12. Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

13. Test specimens shall be taken longitudinally, and, except as otherwise specified herein, shall be of the full thickness or diameter of material as rolled.

14. Test specimens for plates, shapes, and flats may be machined to the form and dimensions shewn in Fig. 1, or with both edges parallel.

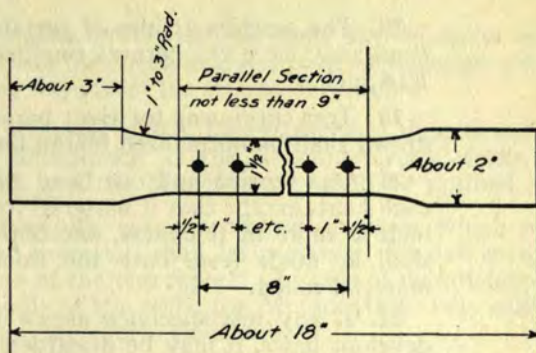


FIG. 1

15. Tension test specimens for plates over $1\frac{1}{2}$ inches in thickness, and bend test specimens for plates over $1\frac{1}{2}$ inches in thickness, may be machined to a thickness or diameter of at least $\frac{3}{4}$ inch for a length of at least 9 inches.

16. Test specimens for bars over $1\frac{1}{2}$ inches in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ inch for a length of at least 9 inches; or tension test specimens may conform to the dimensions shewn in Fig. 2., in which case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be $1 \times \frac{1}{2}$ inch in section.

17. Tension test specimens for pins and rollers shall conform to the dimensions shewn in Fig. 2. In this case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be $1 \times \frac{1}{2}$ inch in section.

18. The tension test specimens shewn in Fig. 2 and the $1 \times \frac{1}{2}$ inch bend test specimens for pins and rollers shall be taken so that the axis is 1 inch from the surface; and for other bars over $1\frac{1}{2}$ inches in thickness or diameter, midway between the centre and surface.

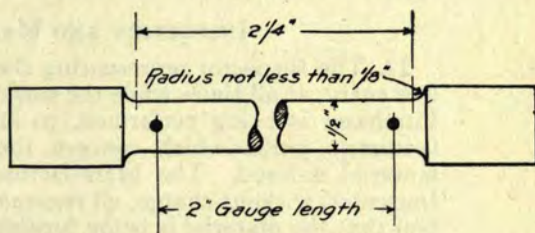


FIG. 2

NOTE:—The gauge-length, parallel portions and fillets shall be as shewn; but the ends may be of any form which will fit the holders of the testing-machine.

19. The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over 1/16 inch.

20. Test specimens for rivet bars which have been cold drawn shall be normalized before testing.

Number
of tests

21. One tension and one bend test shall be made from each heat; except that if material from one heat differs 3/8 inch or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

22. If any test specimen shews defective machining or develops flaws, it may be discarded and another specimen substituted.

Retests

23. If the percentage of elongation of any tension test specimen is less than that specified under "Tension Tests" and any part of the fracture is more than 3/4 inch from the centre of the gauge length of a 2-inch specimen or is outside the middle third of the gauge length of an 8-inch specimen, as indicated by scribe-scratches marked on the specimen before testing, a retest shall be allowed.

Character
of Fracture

24. Test specimens of structural or rivet carbon steel shall shew a fracture of uniform, silky appearance; of bluish grey or dove color and generally free from granular, black and brilliant specks.

FINISH

Defects

25. Finished rolled material shall be free from cracks, flaws, injurious seams, blisters, ragged and imperfect edges, and other surface defects. It shall have a smooth finish, and shall be straightened in the mill before shipment.

Permissible
Variations

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

26. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

INSPECTION AND MARKING

Inspection

27. The Inspector representing the Purchaser shall have free entry, at all times while the work on the contract of the Purchaser is being performed, to all parts of the Manufacturer's works which concern the manufacture of the material ordered. The Manufacturer shall afford to the Inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejecting

28. Unless otherwise specified, any rejection based on tests made for check analysis shall be reported within five working days from the receipt of samples.

29. Material which shews injurious defects subsequent to its acceptance at the Manufacturer's works will be rejected, and the Manufacturer shall be notified.

Rehearing

30. Samples, tested for check analysis, which represent rejected material, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the Manufacturer may make claim for rehearing within that time.

MARKING**Marking**

31. The name or brand of the Manufacturer and the heat number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The heat number shall be legibly marked, by stamping, if practicable, on each test specimen.

The first of these is the fact that the United States is a young nation, and that its history is a history of growth and expansion. The second is the fact that the United States is a nation of immigrants, and that its history is a history of the struggle for a common identity. The third is the fact that the United States is a nation of free men, and that its history is a history of the struggle for freedom.

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APPENDIX VII

METHOD FOR SIEVE ANALYSIS OF AGGREGATES FOR CONCRETE

Based on A.S.T.M. Specification C41-24

- Sample**
1. A representative sample of the aggregate shall be selected by quartering or by use of a sampler, which after drying, will give not less than the following:
 - (a) Fine aggregate—500 grams.
 - (b) Coarse aggregate or a mixture of fine and coarse aggregates all of which will pass a $\frac{3}{4}$ inch sieve—25 lb.
- Aggregates coarser than the above—50 lb.
2. Whenever possible, quartering shall be done with the aggregate containing its natural moisture.
 3. The sample shall be dried at not over 110°C (230°F) to constant weight.
- Sieves**
4. (a) The sieves shall be of square-mesh wire-cloth and shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sifting.
 - (b) The size of wire and sieve openings shall be as given in Table I below.
- Sifting**
5. (a) The sample shall be separated into a series of sizes by means of the sieves specified in Clause 4. Sifting shall be continued until not more than 1 per cent of the weight retained on each sieve passes the sieve during 1 minute.
 - (b) Each size shall be weighed on a balance or scale which is sensitive to 1/1000 of the weight of the test sample.
 - (c) The percentage by weight of the total sample which is finer than each of the sieves shall be computed.
- Reporting**
6. (a) The percentage in sieve analysis shall be reported to the nearest whole number.
 - (b) If more than 10 per cent of a fine aggregate is coarser than the No. 4 sieve, or more than 10 per cent of a coarse aggregate is finer than a No. 4 sieve, the above analysis of the portions finer and coarser than this sieve shall be reported separately.

TABLE I

Sieve No. or Size * in inches	Sieve Opening		Wire Diameter		Tolerance, per cent.			
	mm.	in.	mm.	in.	Aver. Open- ing	Wire Diameter		Max- imum Open- ing
						Under	Over	
No. 100	0.149	0.0059	0.102	0.0040	6	15	35	40
No. 50	0.297	0.0117	0.188	0.0074	6	15	35	40
No. 30	0.59	0.0232	0.33	0.0130	5	15	30	25
No. 16	1.19	0.0469	0.54	0.0213	3	15	30	10
No. 8	2.38	0.0937	0.84	0.0331	3	15	30	10
No. 4	4.76	0.187	1.27	0.050	3	15	30	10
$\frac{3}{8}$ in.	9.5	0.375	2.33	0.092	3	10	10	10
$\frac{3}{4}$ in.	19.0	0.75	3.42	0.135	3	10	10	10
1 in.	25.4	1.00	4.12	0.162	3	10	10	10
$1\frac{1}{2}$ in.	38.0	1.50	4.50	0.177	3	10	10	10
2 in.	50.8	2.00	4.88	0.192	3	10	10	10
3 in.	76.0	3.00	6.3	0.25	3	10	10	10

* The requirements for sieves No. 100 to No. 4 conform to the requirements of the U.S. Standard Sieve Series, as given in U.S. Bureau of Standards Letter Circular No. 74. The liberal tolerance will permit the use of certain sieves which do not exactly correspond to the number given in table.

APPENDIX VIII

METHOD OF DECANTATION TEST FOR SAND AND OTHER FINE AGGREGATES

Based on A.S.T.M. Specification D136-28

- Scope** 1. This method of test covers the determination of the total quantity of silt, loam, clay etc., in sand and other fine aggregates.*
- Apparatus** 2. The pan or vessel to be used in the determination shall be approximately 9 in. (230 mm) in diameter, and not less than 4 in. (102 mm) in depth.
- Treatment of Sample** 3. The sample must contain sufficient moisture to prevent segregation and shall be thoroughly mixed. A representative portion of the sample sufficient to yield approximately 500 g. of dried material, shall then be dried to a constant weight at a temperature not exceeding 110 deg. C. (230 deg. F.)
- Procedure** 4. The dried material shall be placed in the pan and sufficient water added to cover the sample (about 225 c.c.) The contents of the pan shall be agitated vigorously for 15 seconds, and then be allowed to settle for 15 seconds, after which the water shall be poured off, care being taken not to pour off any sand. This operation shall be repeated until the wash water is clear. As a precaution, the wash water shall be poured through a 200-mesh sieve and any material retained thereon returned to the washed sample. The washed sand shall be dried to a constant weight at a temperature not exceeding 110 deg. C. (230 deg. F.) and weighed.
- Calculation of Results** 5. The results shall be calculated from the formula:
 Percentage of silt, clay, loam, etc. =
$$\frac{\text{Original dry weight} - \text{weight after washing}}{\text{Original dry weight}} \times 100$$
- Check Determination** 6. When check determinations are desired, the wash water shall be evaporated to dryness, the residue weighed and the percentage calculated from the formula:
 Percentage of silt, loam, clay, etc. =
$$\frac{\text{Weight of residue}}{\text{Original dry weight}} \times 100.$$

* This determination of the percentage of silt, clay, loam, etc. will include all water-soluble material present, the percentage of which may be determined separately if desired.

APPENDIX VII

THE RESULTS OF THE INVESTIGATION INTO THE CAUSES OF THE ACCIDENTS WHICH OCCURRED IN THE

NAVY OF THE UNITED STATES DURING THE YEAR 1897

IN THE MONTHS OF JANUARY, FEBRUARY, MARCH, APRIL, MAY, JUNE, JULY, AUGUST, SEPTEMBER, OCTOBER, NOVEMBER, AND DECEMBER

OF THE YEAR 1897

AS REPORTED BY THE COMMISSIONERS OF THE NAVY

IN THEIR REPORT TO THE HOUSE OF REPRESENTATIVES

IN JANUARY, 1898

AND IN THE REPORT OF THE COMMISSIONERS OF THE NAVY

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APPENDIX IX

METHOD OF TEST FOR COMPRESSIVE STRENGTH OF PORTLAND CEMENT MORTARS

*Adapted in part from A.S.T.M. Specification C9-16T*Tension
Tests

1. Tension tests of mortar shall be made in accordance with the requirements governing the preparation and testing of standard sand mortars of the "Standard Specification for Portland Cement" (No.A5-1927) of the Canadian Engineering Standards Association."

Compression
Tests

2. Compression tests of mortar shall comply with the same requirements except in the following particulars.

The dry material shall be weighed out, placed upon a non-absorbent surface and thoroughly mixed dry with a trowel, to a uniform colour. A crater shall then be formed in the centre into which the proper percentage of clean water shall be poured; the material on the outer edge being turned into the centre by the aid of the trowel. After an interval of $\frac{1}{2}$ minute for the absorption of the water, the operation shall be completed by vigorous mixing by trowel, or preferably by squeezing and kneading with the hands, for at least $1\frac{1}{2}$ minutes. During the operation of mixing, the hands shall be protected by rubber gloves or rubber finger cots. The temperature of the room shall be maintained above a minimum of 18°C and that of the mixing water shall be between 20°C and 22°C .

Form of
Test Piece

3. Cylindrical test specimens, either 2 in. in diameter and 4 in. in length or 2 in. cubes, are recommended in making compression tests of mortar.

Moulding
Cylindrical
Specimens

4. The mortar shall be placed in the mould in layers about $1\frac{1}{2}$ in. in thickness, each layer being tamped 15 times by means of the steel tamper having a bottom diameter of 1 in. and weighing approximately $\frac{3}{4}$ lb. In finishing the test piece, the mortar shall be heaped above the mould and smoothed off with a trowel. As soon as the test pieces from one sample are moulded, the top of each test piece shall be covered with a piece of glass, which is brought to a firm bearing on the fresh mortar. The cover glasses shall remain in place until the moulds are removed.

Prism
Specimens

5. Prism specimens are made similarly to the briquettes except that the mould is not turned.

Testing

6. Tests of standard mortar cylinders and prisms shall be made in any testing machine that is adapted to meet the specified requirements. The ends of the cylindrical

specimens should be smooth and plane. Cube specimens shall be tested on their sides, that is perpendicular to the direction of the moulding. The test pieces shall be tested as soon as removed from the water. The metal bearing plates of the testing machine shall be placed in direct contact with the test piece. During the test a spherical bearing block shall be used on top of the specimen. In order to secure a uniform distribution of the load over the test specimen, the spherical bearing block must be accurately centered. The diameter of the spherical bearing block should be only a little greater than that of the test piece. The test piece shall be loaded continuously to failure. The moving head of the testing machine shall travel at the rate of not less than 0.05 or more than 0.10 in. per minute.

Faulty
Specimens

7. Specimens that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces tested at the same period and made from the same sample, shall not be considered in determining the compressive strength.

APPENDIX X

METHOD OF TEST FOR ORGANIC IMPURITIES IN SAND FOR CONCRETE

Based on A.S.T.M. Specification C40-27

Scope

1. The test herein specified is an approximate test for the presence of injurious organic compounds in natural sand for cement mortar or concrete. The principal value of the test is in furnishing a warning that further tests of the sand are necessary before they may be used in concrete. Sands which produce a colour in the sodium hydroxide solution darker than the standard colour should be subjected to strength tests in mortar or concrete before use.

Procedure

2. (a) A representative test sample of sand of about 1 lb. shall be obtained by quartering or by use of a sampler.

(b) A 12-oz. graduated glass prescription bottle shall be filled to the $4\frac{1}{2}$ oz. mark with the sand to be tested.

(c) A 3 per cent solution on the basis of chemically pure sodium hydroxide ($Na OH$) in water shall be added until the sand and liquid after shaking gives a total volume of 7 liquid ounces.

(d) The bottle shall be stoppered and shaken thoroughly and then allowed to stand for 24 hours.

(e) A standard colour solution shall be prepared by adding 2.5 c.c. of a 2 per cent. solution of tannic acid in 10 per cent alcohol to 22.5 c.c. of a 3 per cent sodium hydroxide solution. This shall be placed in a 12 oz. prescription bottle, stoppered and allowed to stand for 24 hours, then 25cc of water added.

(f) The colour of the clear liquid above the sand shall be compared with the standard colour solution prepared in Clause (e) or with a glass of colour similar to the standard solution.

Colour
Value

3. Solutions darker in colour than the standard colour have a "colour value" higher than 250 parts per million in terms of tannic acid.

Crusher
Dust

4. In cases where no sand can be obtained in the vicinity of the work which gives a satisfactory result on the colourimetric test and the crushed stone coarse aggregate contains a proportion of fine aggregate free of organic impurities, the test may be applied to the fine aggregate portion of the composite aggregate. When this is done the composite aggregate should be subjected to strength tests if the solution is equal in colour to the standard colour.

1. Preparation of the standard solution

1.1. Weigh accurately about 0.5 g of the substance to be determined, and dissolve it in a small volume of water in a 100 ml volumetric flask.

1.2. Add a few drops of a 1% solution of potassium dichromate as an indicator, and dilute to the mark with water. The solution should be a pale yellow color.

1.3. The standard solution is now ready for use.

1.4. The standard solution should be stored in a dark bottle, and its concentration should be checked periodically by titrating a known amount of a standard solution of ferrous sulfate.

1.5. The standard solution should be standardized immediately before use.

1.6. A standard solution of ferrous sulfate should be prepared by dissolving 10 g of ferrous sulfate in 100 ml of water, and adding a few drops of a 1% solution of hydrochloric acid.

1.7. The standard solution of ferrous sulfate should be standardized by titrating a known amount of a standard solution of potassium dichromate.

1.8. The standard solution of ferrous sulfate should be stored in a dark bottle, and its concentration should be checked periodically by titrating a known amount of a standard solution of potassium dichromate.

1.9. In cases where the substance to be determined is a solid, it should be weighed accurately, and dissolved in a small volume of water in a 100 ml volumetric flask. The solution should be a pale yellow color.

APPENDIX XI

TENTATIVE METHOD OF TEST FOR CONSISTENCY OF PORTLAND CEMENT CONCRETE

Based on A.S.T.M. Specification D138-26T

Scope

1. This test covers the method to be used in the field for maintaining consistency of concrete*.

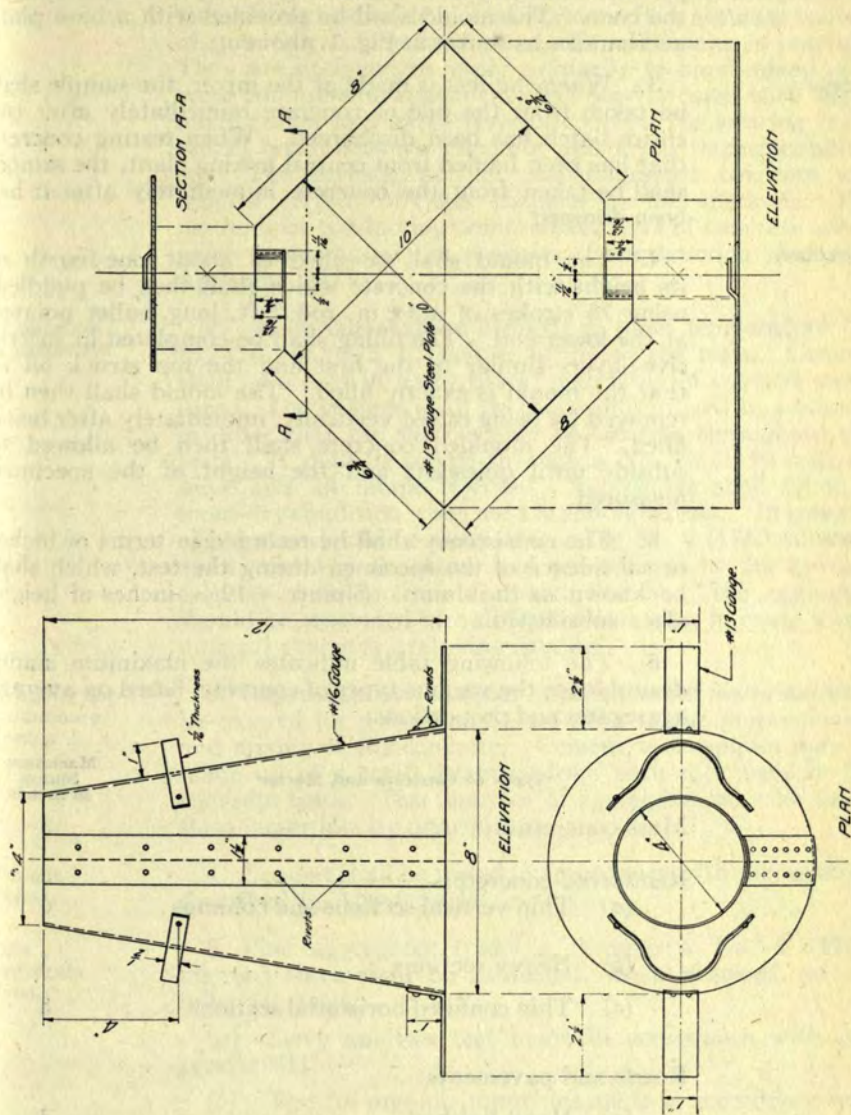


Figure 1

* This test is not considered applicable when there is a considerable amount of coarse aggregate over 2 in. in size in the concrete.

Apparatus

2. The test specimen shall be formed in a mould of No. 16 gauge galvanized metal in the form of the lateral surface of the frustum of a cone with the base, 8 in. in diameter, the upper surface, 4 in. in diameter, and the altitude, 12 in. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with a base plate and handles as shown in Fig. 1. above.

Sample

3. When the test is made at the mixer, the sample shall be taken from the pile of concrete immediately after the entire batch has been discharged. When testing concrete that has been hauled from central mixing plant, the sample shall be taken from the concrete immediately after it has been dumped.

Procedure

4. The mould shall be filled to about one-fourth of its height with the concrete which shall then be puddled, using 25 strokes of a $\frac{5}{8}$ in. rod 2 ft. long, bullet pointed at the lower end. The filling shall be completed in successive layers similar to the first and the top struck off so that the mould is exactly filled. The mould shall then be removed by being raised vertically, immediately after being filled. The moulded concrete shall then be allowed to subside until quiescent and the height of the specimen measured.

Slump

5. The consistency shall be recorded in terms of inches or subsidence of the specimen during the test, which shall be known as the slump. Slump = 12 — inches of height after subsidence.

6. The following table indicates the maximum slump desirable for the various types of concrete, based on average aggregates and proportions:

Types of Concrete and Mortar	Maximum Slump in inches
Mass concrete	3
Reinforced concrete:	
(a) Thin vertical sections and columns	6
(b) Heavy sections	3
(c) Thin confined horizontal sections	8
Roads and pavements:	
(a) Hand-finished	3
(b) Machine-finished	1
Mortar for floor finish	2

APPENDIX XII

METHOD OF MAKING COMPRESSION TESTS OF CONCRETE

(In substantial agreement with Specification A.S.T.M. C39-27)

Scope

1. These methods are intended to cover compression tests of concrete made in a laboratory where accurate control of quantities of materials and test conditions is possible. They are designed to apply primarily to hand-mixed concrete compression specimens, but may be used with slight modification in making tests of concrete for wearing resistance, bond between concrete and steel, impermeability, etc. The investigation of machine-mixed concrete will require certain obvious changes in the methods. For methods of conducting compression tests of concrete specimens made during the progress of construction work, see Appendix XIII.

Preparation
of Materials

2. Materials shall be brought to room temperature (18 to 24° C., 65 to 75° F.) before beginning the tests. Cement shall be stored in a dry place; preferably in covered metal cans. The cement shall be thoroughly mixed in advance, in order that the sample may be uniform throughout the tests. It shall be sieved through a No. 16 (1190 micron) sieve and all lumps rejected. Aggregates shall be in a room-dry condition when used in concrete tests. In general, aggregates should be separated on the No. 4 (4760-micron), $\frac{3}{8}$ -in. and 1½ in. sieves and recombined to the average original sieve analysis for each batch. Fine aggregate should be separated into different sizes also, in cases where unusual gradings are being studied.

Sampling for
Preliminary
Tests

3. Representative samples of all concrete materials shall be secured for preliminary tests prior to the proportioning and mixing of the concrete. Cement test samples may be made up of a small quantity from each sack used in the concrete tests. Test samples of aggregates may be taken from larger lots by quartering.

Cement
Tests

4. Cement shall be tested in accordance with the methods described in Appendix IV.

Fine
Aggregate
Tests

5. Fine aggregates (passing through a No. 4 (4760-micron) sieve shall be subjected, when required, to the following tests:

(a) Sieve analysis test made in accordance with Appendix VII.

(b) Test for organic impurities made in accordance with Appendix X.

(c) Test for quantity of silt, clay and dust made in accordance with Appendix VIII.

(d) Test for unit weight made in accordance with Appendix XIV.

(e) Strength test of 1:3 mortar by weight at 7 and 28 days in comparison with standard sand mortar in accordance with Appendix IV.

**Coarse
Aggregate
Tests**

6. Coarse aggregates (retained on a No. 4 (4760-micron) sieve) shall be subjected when required to the following tests:

(a) Sieve analysis test as specified in Clause 5 (a);

(b) Test for quantity of silt, clay and dust made generally in accordance with Appendix VIII.

(c) Test for unit weight as specified in Clause 5 (d).

**Mixed
Aggregate
Tests**

7. The unit weight of mixed fine and coarse aggregates as used in concrete tests shall be determined in accordance with the method specified in Clause 5 (d).

Proportioning

8. The quantities of each size of aggregate to be used in each batch shall be determined on the basis of the sieve analysis and the unit weight of the mixed aggregate. The exact quantities of cement and of each size of aggregate for each batch shall be determined by weight. The quantity of water for each batch shall be accurately measured. The quantities of materials may be expressed as (a) 1 volume of cement to . . volumes of total aggregate mixed as used, or (b) 1 volume of cement, . . volumes of fine aggregate, and . . volumes of coarse aggregate, or (c) 1 part by weight of cement . . parts by weight of fine aggregate, and . . parts by weight of coarse aggregate.

NOTE.—It is impracticable to give a general method for proportioning concrete for experimental purposes; the details will necessarily vary widely with the purpose for which the tests are made. The following procedure is suggested for specific cases:.

(a) Vary the cement content by 10-per-cent intervals above and below assumed quantity.

(b) Vary the proportions of fine to coarse aggregate, measured separately, at intervals of 10 per cent.

(c) Vary the quantity of mixing water by intervals of 10 per cent.

**Size and
Shape of
Specimens**

9. Compression tests of concrete shall be made on cylinders of diameter equal to one-half the length. The standard shall be 6 by 12-in. cylinders where the coarse aggregate does not exceed 2-in. in size; for aggregates larger than 2 in., 8 by 16-in. cylinders shall be used; 2 by 4-in. cylinders may be used for mixtures without coarse aggregate.

**Mixing
Concrete**

10. (a) Concrete shall be mixed by hand in batches of such size as to leave a small quantity of concrete after molding a single test specimen. The batch shall preferably be mixed in a shallow metal pan with a 10-in. bricklayer's trowel which has been blunted by cutting off about $2\frac{1}{2}$ in. of the point, as follows:

(b) The cement and fine aggregate shall be mixed dry until the mixture is homogeneous in color;

(c) The coarse aggregate shall be added and mixed dry;

(d) Sufficient water shall be added to produce concrete of the required workability;

NOTE.—Concrete tests should be made on plastic mixtures. It is of the utmost importance that a uniform degree of workability be secured in tests involving comparisons of different materials and methods.

(e) The mass shall be mixed thoroughly until the resulting concrete is homogeneous in appearance.

Workability

11. The workability or plasticity of each batch of concrete shall be measured immediately after mixing by one of the following methods:

(a) Slump test made in accordance with Appendix XI.

(b) Flow test made by placing a metal mold in the shape of a frustum of a cone $6\frac{3}{4}$ in. in top diameter, 10 in. in bottom diameter, 5 in. in depth, on the table of the flow apparatus. The fresh concrete shall be placed in the mold in two layers. Each layer shall be puddled as described in Section 13. Immediately after molding, the surplus concrete shall be struck off with a trowel and the mold shall be removed by a steady upward pull; the table raised $\frac{1}{2}$ in. and dropped 15 times in about 10 seconds by means of a suitable cam and crank. The spread of the fresh concrete due to this treatment expressed as a percentage of the original bottom diameter of the cone is the "flow."

Molds

12. The molds shall preferably be of metal. Each mold shall be provided with a machined metal base plate, and shall be oiled with a heavy mineral oil before using. Particular care shall be taken to obtain tight molds so that the mixing water will not escape during molding.

NOTE.—The best type of mold consists of lengths of cold-drawn steel tubing, split along one element and closed by means of a circumferential band and bolt. Satisfactory molds can be made from lengths of steel water-pipe machined on the inside, from rolled metal plates, from galvanized steel, machined iron or steel castings. Paraffined cardboard molds will give good results under expert supervision.

Molding Test Specimens

13. Concrete test specimens shall be molded by placing the fresh concrete in the mold in layers 3 to 4 in. in thickness. Each layer shall be puddled with 25 strokes with a $\frac{5}{8}$ -in. rod 24 in. in length, bullet-pointed at the lower end. After the top layer has been puddled, the surplus concrete shall be struck off with a trowel, and the mold covered with a piece of plate glass at least $\frac{1}{4}$ in. in thickness or a machined metal plate which will be used later in capping the test specimen.

**Capping
Specimens**

14. Two to four hours after molding, the test specimens shall be capped with a thin layer of stiff neat-cement paste in order that the cylinder may present a smooth end for testing. The cap shall be formed by means of a piece of plate glass $\frac{1}{4}$ in. in thickness or machined metal plate $\frac{1}{2}$ -in. in thickness and of a diameter 2 or 3 in. larger than that of the mold. The plate shall be worked on the fresh cement paste until it rests on top of the mold. The cement for capping should be mixed to a stiff paste 2 to 4 hours before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of the concrete to the top and bottom plates may be avoided by oiling the plates or by inserting a sheet of paraffined paper.

**Curing Test
Specimens**

15. Concrete test specimens shall be removed from the molds 20 to 48 hours after molding, marked, weighed and stored in damp sand, under damp cloths or in a moist chamber until the date of test. The temperature of the curing room should not fall outside the range of 18 to 24° C. (60 to 75° F.).

Age at Test

16. Tests shall be made at the age of 7 and 28 days; ages of 3 months and 1 year are recommended, if longer-time tests are required.

**Sequence of
Tests**

17. Three to five test specimens should be made on different days on investigations in which accurate comparisons are desired.

**Preparation
of Tests**

18. Compression tests shall be made immediately upon removal of the concrete test specimens from the curing room; that is, the test specimens shall be loaded in a damp condition. The length and average diameter of the test specimen shall be measured in inches and hundredths; two diameters shall be measured at right angles near the mid-length. The test specimen shall be weighed immediately before testing.

**Method of
Testing**

19. In general, only the ultimate compressive strength of the cylinders need be observed. The metal bearing plates of the testing machine shall be placed in contact with the ends of the test specimen; cushioning materials shall not be used. An adjustable bearing block shall be used to transmit the load to the test specimen. The bearing block shall be used on *top* of the specimen in vertical testing machines. The diameter of the bearing block shall be the same or slightly larger than that of the test specimen. The upper or lower section of the bearing block shall be kept in motion as the head of the testing machine is brought to a bearing on the test specimen.

**Application
of Load**

20. The load shall be applied uniformly and without shock. The moving head of the testing machine should travel at the rate of about 0.05 in. per minute when the machine is running idle.

Record of
Tests

21. The total load indicated by the testing machine at failure of the test specimen shall be recorded and the unit compressive strength calculated in pounds per square inch, the area computed from the average diameter of the cylinder being used. The type of failure and appearance of the concrete shall be noted.

Weight of
Concrete

22. The weight of the concrete in pounds per cubic foot shall be determined from the weight of the specimens and their dimensions.

Density and
Yield

23. Density and yield of concrete when required shall be calculated from the unit volumes of the constituent materials and the volume of the fresh or set concrete as desired. Density is here understood to be the ratio of solids in the concrete to the total volume of the mass. Yield is the volume of concrete resulting from the volume of aggregate mixed as used.

Report

24. The report shall include the following:

- (a) The kind and origin of concrete materials;
- (b) Complete data on all tests of cement and aggregates;
- (c) A description of methods of making and testing the concrete, where methods deviate from the proposed standards;
- (d) The quantities of cement, aggregates and water in each batch;
- (e) The method of measuring workability or plasticity with "slump" or "flow" of concrete;
- (f) The quantity of water expressed as a ratio to volume of cement;
- (g) The age at test;
- (h) The size of test specimens;
- (i) The date of moulding and testing each cylinder;
- (j) The compressive strength in pounds per square inch of each test specimen and the average of tests in a set;
- (k) A description of failure and appearance of concrete on each test specimen;
- (l) The unit weight, density and yield of the concrete.

The first of these is the fact that the United States is a young nation, and that its history is a history of growth and development. It is a history of a people who have been able to overcome many difficulties and to build a great nation out of a small colony.

The second of these is the fact that the United States is a nation of immigrants. It is a nation of people who have come from many different parts of the world, and who have brought with them their own customs and traditions. This has made the United States a melting pot of different cultures and peoples.

The third of these is the fact that the United States is a nation of pioneers. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony.

The fourth of these is the fact that the United States is a nation of freedom. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony.

The fifth of these is the fact that the United States is a nation of progress. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony.

The sixth of these is the fact that the United States is a nation of peace. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony. It is a nation of people who have been able to overcome many difficulties and to build a great nation out of a small colony.

APPENDIX XIII

METHOD OF MAKING AND STORING SPECIMENS OF CONCRETE IN THE FIELD

(In substantial agreement with Specification A.S.T.M. C31-27)

Scope. 1. This method is intended to apply to the molding and storing of test specimens of concrete sampled from concrete being used in construction.

Size and
Shape of
Specimens.

2. The test specimens shall be cylindrical in form with the length twice the diameter. The standard shall be 6 by 12-in. cylinders where the coarse aggregate does not exceed 2 in. in size; for aggregates larger than 2 in., 8 by 16-in. cylinders shall be used; 2 by 4-in. cylinders may be used for mixtures without coarse aggregate.

Molds.

3. (a) The molds shall be cylindrical in form, made of non-absorbent material, and shall be substantial enough to hold their form during the molding of the test specimens. They shall not vary in diameter more than $\frac{1}{16}$ in. in any direction, nor shall they vary in height more than $\frac{1}{16}$ in. from the height required. They shall be substantially water tight so that there will be no leakage of water from the test specimen during molding.

NOTE—The best type of mold consists of lengths of cold-drawn steel tubing, split along one element and closed by means of a circumferential band and bolt. Satisfactory molds can be made from lengths of steel water pipe machined on the inside, from rolled metal plates, from galvanized steel, machined iron or steel castings. Paraffined carboard molds will give good results under expert supervision.

(b) Each mold shall be provided with a base plate having a plane surface and made of non-absorbent material. This plate shall be large enough in diameter to properly support the mold without leakage. Plate glass or planed metal are satisfactory for this purpose. A similar plate should be provided for covering the top surface of the test specimen when molded.

(c) Suggestions for suitable molds are shown in Figs. 1, 2, and 3.

Sampling of
Concrete.

4. (a) Concrete for the test specimens shall be taken immediately after it has been placed in the work. All the concrete for each sample shall be taken from one place. A sufficient number of samples—each large enough to make one test specimen—shall be taken at different points so that the test specimens made from them will give a fair

average of the concrete placed in that portion of the structure selected for tests. The location from which each sample is taken shall be noted clearly for future reference.

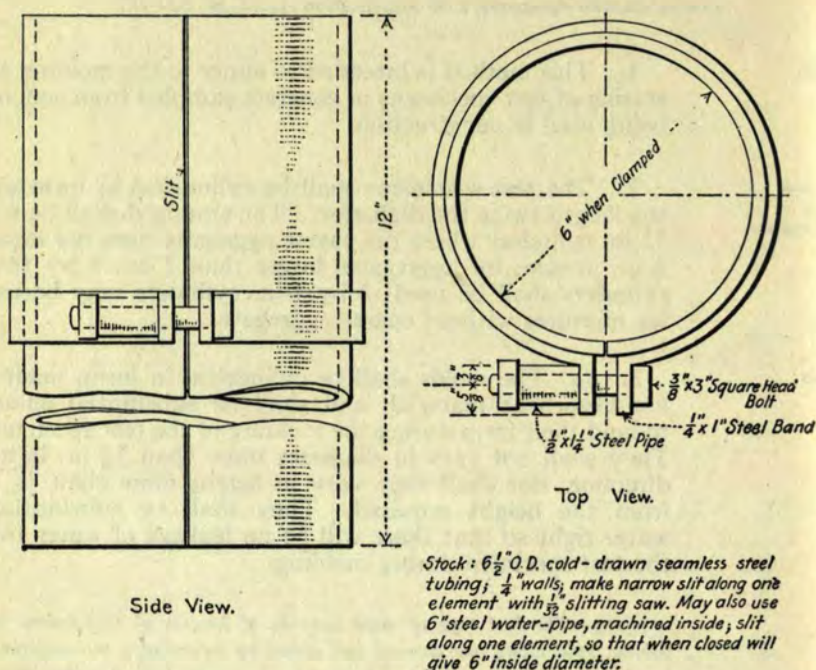


FIG. 1.

(b) In securing samples, the concrete shall be taken from the mass by a shovel or similar implement and placed in a large pail or other receptacle, for transporting to the place of molding. Care shall be taken to see that each test specimen represents the total mixture of the concrete from a given place. Different samples shall not be mixed together but each sample shall make one specimen.

Molding Test Specimens.

5. (a) The pails or other receptacles containing the samples of concrete shall be taken as quickly as possible to the place selected for molding test specimens. To offset segregation of the concrete occurring during transportation, each sample shall be dumped into a non-absorbent water-tight receptacle and, after slight mixing, immediately placed in the mold.

(b) The test specimens shall be molded by placing the concrete in the mold in layers 3 to 4 in. in thickness. Each layer shall be puddled with 25 strokes with a $\frac{5}{8}$ -in. rod 24 in. in length bullet-pointed at the lower end. After

puddling the top layer, the surface concrete shall be struck off with a trowel and covered with the top cover plate which may later be used in capping the test specimen.

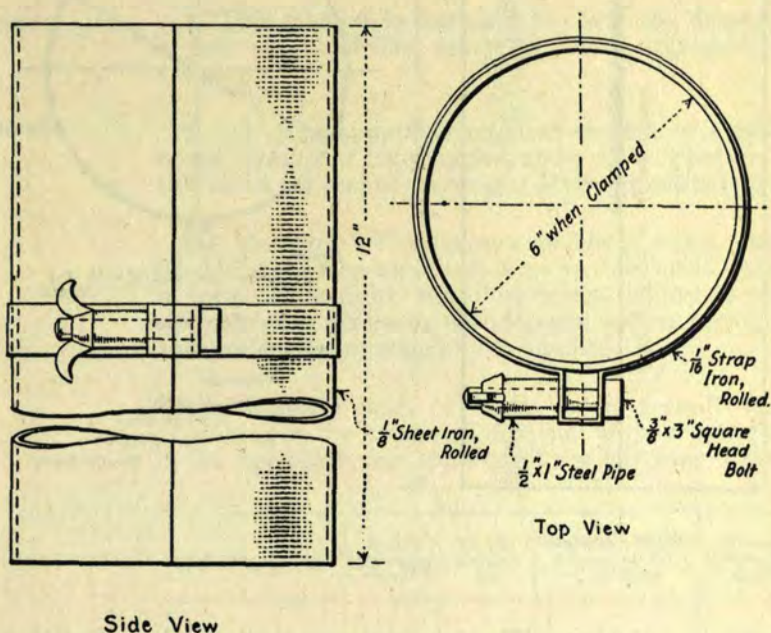


FIG. 2.

Capping Specimens.

6. Two to four hours after molding, the test specimens shall be capped with a thin layer of stiff neat-cement paste in order that the cylinder may present a smooth end for testing. The cap shall be formed by means of a piece of plate glass $\frac{1}{4}$ in. in thickness or a machined metal plate $\frac{1}{2}$ in. in thickness and of a diameter 2 or 3 in. larger than that of the mold. The plate shall be worked on the fresh cement paste until it rests on top of the mold. The cement for capping should be mixed to a stiff paste 2 to 4 hours before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of the concrete to the top and bottom plates may be avoided by oiling the plates or by inserting a sheet of paraffined paper.

Removal of Specimens from Molds.

7. At the end of 48 hours the test specimens shall be removed from the molds and buried in damp sand except in case the molds shown in Fig. 3 are used, when they may be buried in damp sand without removal of the mold, thus permitting shipping in the molds.

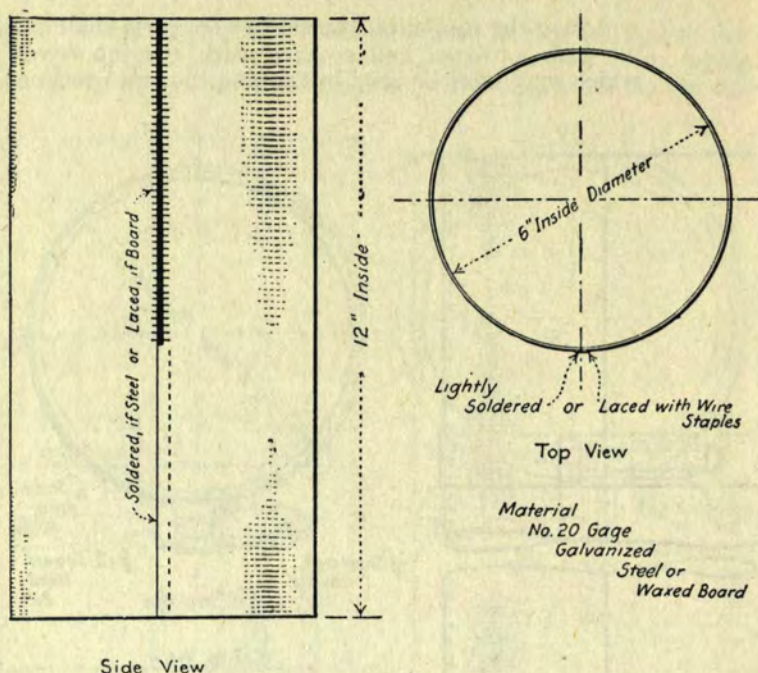


FIG. 3.

Storage of Specimens.

8. (a) The test specimens shall remain buried in damp sand until 10 days prior to the date of test. They shall then be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they shall be stored either in a moist room or in damp sand until the date of test.

(b) Should a 7-day test be required, the test specimens shall remain at the work as long as possible to harden and then shall be shipped so as to arrive at the laboratory in time for test on the required date.

(c) Test specimens shall be protected from drying after removal from damp storage and before testing.

APPENDIX XIV

METHOD OF TEST FOR UNIT WEIGHT OF AGGREGATE FOR CONCRETE

(In substantial agreement with Specification A.S.T.M. C29-27)

Scope 1. This method is intended to cover the determination of unit weight of fine, coarse, or mixed aggregate for concrete.

Apparatus 2. (a) The apparatus required consists of a cylindrical metal measure, a tamping rod, and a scale or balance, sensitive to 0.5 per cent of the weight of the sample to be weighed.

(b) *Measures.*—The measure shall be of metal, preferably machined to accurate dimensions on the inside, cylindrical in form, water-tight, and of sufficient rigidity to retain its form under rough usage, with top and bottom true and even, and preferably provided with handles.

The measure shall be of $\frac{1}{10}$ or $\frac{1}{2}$ 1-cu.-ft. capacity, depending on the maximum diameter of the coarsest particle in the aggregate, and shall be of the following dimensions:

Capacity, cu. ft.	Inside Diameter, in.	Inside Height, in.	Minimum Thickness of Metal, U. S. Gage	Diameter of Largest Particles of Aggregate, in.
$\frac{1}{10}$	6.00	6.10	No. 11	Under $\frac{1}{2}$
$\frac{1}{2}$	10.00	11.00	No. 8	Under $1\frac{1}{2}$
1.....	14.00	11.23	No. 5	Over $1\frac{1}{2}$

(c) *Tamping Rod.*—The tamping rod shall be a straight metal rod $\frac{5}{8}$ in. in diameter and 24 in. in length, with one end tapered for a distance of 1 in. to a blunt bullet-shaped point.

Calibrating the Measure

3. The measure shall be calibrated by accurately determining the weight of water at 16.7° C. (62° F.) required to fill it. The factor for any unit shall be obtained by dividing the unit weight of water at 16.7° F. (62° C.) (62.355 lb. per cu. ft.) by the weight of water at 16.7° C. (62° F.) required to fill the measure.

Condition of Sample

4. The sample of aggregate shall be room-dry and thoroughly mixed.

Method

5. (a) The measure shall be filled one-third full and the top levelled off with the fingers. The mass shall be puddled

with the tamping rod with 25 strokes evenly distributed over the surface. The measure shall be filled two-thirds full and again puddled with 25 strokes as before. The measure shall then be filled to overflowing, puddled 25 times, and the surplus aggregate struck off, using the tamping rod as a straight edge.

In puddling the first layer the rod should not be permitted to forcibly strike the bottom of the measure. In puddling the second and final layers, only enough force to cause the tamping rod to penetrate the last layer of aggregate placed in the measure should be used.

(b) The net weight of the aggregate in the measure shall be determined. The unit weight of the aggregate shall then be obtained by multiplying the net weight of the aggregate by the factor found as described in Section 3.

Accuracy

6. Results with the same sample should check within 1 per cent.

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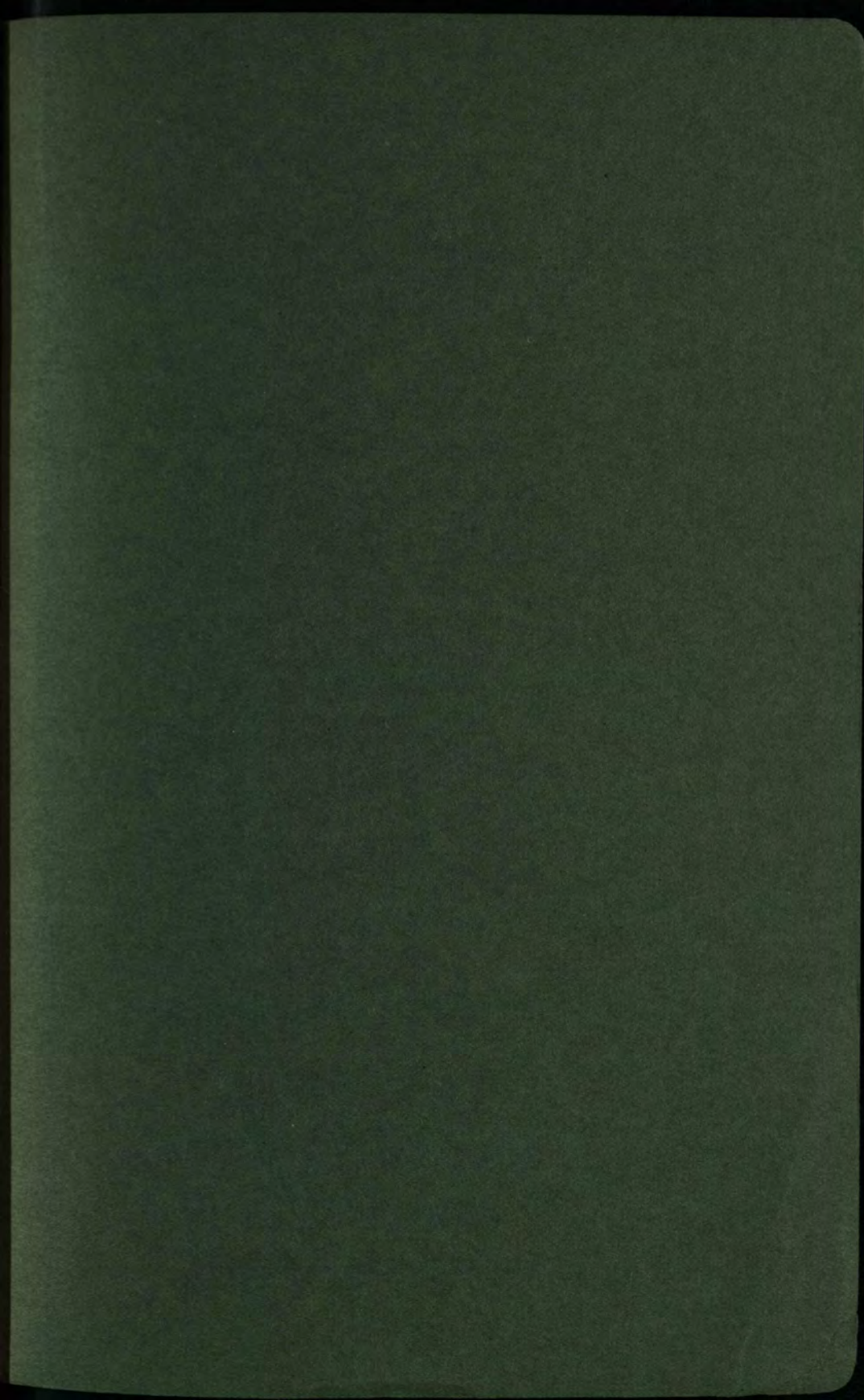
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Babcock-Wilcox Co.
Bell Telephone Co. of Canada.
John Bertram & Sons Co. Ltd.
British American Oil Co. Ltd.
British Columbia Cement Co. Ltd.
Burlington Steel Co. Ltd.
Canada Wire & Cable Co. Ltd.
Canadian Acme Screw & Gear Ltd.
Canadian Bridge Co. Ltd.
Canadian Car & Foundry C. Ltd.
Canada Cement Company Ltd.
Canadian Drawn Steel Co. Ltd.
Canadian General Electric Co. Ltd.
Canadian Inspection & Testing Co. Ltd.
*Canadian International Paper Co.
Canadian Laco Lamps Ltd.
Canadian National Railways.
Canadian Pacific Railway Co.
Canadian Steel & Wire Co. Ltd.
Canadian Tube & Steel Products Co. Ltd.
Canadian Westinghouse Co. Ltd.
B. J. Coghlin Co. Ltd.
*Consolidated Mining & Smelting Co. Ltd.
Crane Limited.
Dominion Bridge Co. Ltd.
*Dominion Engineering Works Ltd.
*Dominion Forge & Stamping Co. Ltd.
Dominion Foundries & Steel Ltd.
Dominion Iron & Steel Co. Ltd.
*English Electric Co. of Canada Ltd.
Ferranti Electric Limited.
Foundation Co. of Canada Ltd.
Frost Steel & Wire Company Ltd.
*Gartshore-Thomson Pipe & Foundry Co. Ltd.
Goldie & McCulloch Co. Ltd.
Hamilton Bridge Works Co. Ltd.
Robert W. Hunt & Co. Ltd.
Imperial Oil Ltd.
E. Leonard & Sons Ltd.
*Lincoln Meter Co. Ltd.
Manitoba Rolling Mill Co. Ltd.
Maritime Telegraph & Telephone Co. Ltd.
Massey Harris Co. Ltd.
Milton Hersey Co. Ltd.
Robert Mitchell Co. Ltd.
*Moffats Limited.
Montreal Light Heat & Power Consolidated
Montreal Locomotive Works Ltd.
New Brunswick Telephone Co. Ltd.
Northern Bolt Screw & Wire Co. Ltd.
Northern Electric Co. Ltd.
Ottawa Electric & Ottawa Gas Companies
Page Hersey Tubes Ltd.
Eugene F. Phillips Electrical Works Ltd.
Pratt & Whitney Co. of Canada Ltd.
Price Brothers & Co. Ltd.
St. Mary's Cement Co. Ltd.
Sangamo Electric Co. of Canada Ltd.
*Seton Engineering-Inspection Co.
Shawinigan Water & Power Co.
*Shell Company of Canada Ltd.
Solex Co. Ltd.
Steel Co. of Canada Ltd.
Stowell Screw Co. Ltd.
*Toronto Hydro-Electric Commission.
*Union Drawn Steel Co. Ltd.
*Chas. Warnock & Co. Ltd.
Willys-Overland Ltd.

*Indicates New Member.

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