

secured and tested at such times as the engineer may consider necessary. Samples shall weigh not less than 50 pounds.

3. GRADING

Coarse aggregate shall be uniformly graded between the limits specified and shall meet the following requirements:

	Per cent
Passing a - inch sieve	95-100
Passing a - inch sieve	95-100
Passing a No. 4 sieve	0-5

4. SOUNDNESS

Coarse aggregates shall pass the test for soundness. Samples showing disintegration shall be considered to have failed in this test.

American Association of State Highway Officials, standard specifications for highway bridges and incidental structures, 1928.

RUBBLE OR CYCLOPEAN AGGREGATE

One-man and derrick stone used in rubble or cyclopean concrete shall consist of tough, sound, and durable rock. The stone shall be free from coatings, drys, seams, or flaws of any character. In general, the percentage of wear shall be not greater than 6 per cent as determined by A. S. T. M. D2. (See 510, p. 182.)

Preferably stone shall be angular in shape and shall have a rough surface such as will thoroughly bond with the surrounding mortar.

American Concrete Institute, tentative purchase specifications for concrete aggregates, E-5A-29T, 1929.

(See 512.13, p. 236.)

American Railway Engineering Association, specifications for buildings for railway purposes, 1926.

Coarse aggregate. (See A. R. E. A. specification for concrete, 516.3, p. 303.)

American Society for Municipal Improvements, standard specifications for sewers, 1927.

Coarse aggregate. (See 518.67, p. 453.)

American Society for Municipal Improvements, standard specifications for fine aggregate asphaltic concrete paving, 1922.

Coarse aggregate for use in paving. (See A. S. M. I. specification, 518.37, p. 399.)

American Society for Testing Materials, tentative specifications for concrete aggregates, serial designation C33-28T, 1926.

Coarse aggregate. (See 512.13, p. 237.)

Federal Specifications Board, specification No. 454, United States Government master specification for coarse aggregate for Portland cement concrete pavement or base (stone, slag, or gravel).

The material covered by this specification shall be supplied in the particular size and type ordered, depending on the commercial sizes available.

GENERAL REQUIREMENTS

1. Broken stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft, or disintegrated pieces, dirt, or other objectionable matter.

2. Broken slag shall be air-cooled blast-furnace slag, and shall consist of angular fragments, reasonably uniform in density and quality, and reasonably free from thin, elongated, or glassy pieces, dirt, or other objectionable matter.

"It is understood that the gradation of the coarse aggregate will be limited by the insertion of a maximum and intermediate size sieve which will insure that aggregates of satisfactory grading will be provided for the work in hand. The maximum sizes of aggregates for different classes of construction shall be as specified under "Concrete masonry," Division III.

3. Gravel shall consist of clean, hard, tough, and durable particles of gravel, free from soft, thin, elongated, or laminated pieces, vegetable, or other extraneous deleterious matter.

DETAIL REQUIREMENTS

(a) The broken stone shall have a percentage of wear of not more than 7.0.

(This test value for quality of stone is suggested as the lowest safe requirement. With favorable conditions of available materials the maximum percentage of wear permitted should be reduced.)

(b) Broken slag of each size specified shall weigh not less than 70 pounds per cubic foot.

(c) The material shall be well graded between the limits specified, and when tested by means of laboratory screens and sieves shall meet the following requirements for size as designated in the following table:

Size type.....inches.	Broken stone		Broken slag		Gravel	
	1/4-2	1/4-2 1/2	1/4-1 1/2	1/4-2 1/2	1/4-1 1/2	1/4-2 1/2
No. 8 sieve...per cent.	0-5	0-5	0-5	0-5	0-5	0-5
1/4-inch screen...do...	0-10	0-10	0-10	0-10	0-10	0-10
1/2-inch screen...do...	5-25				5-25	
3/4-inch screen...do...		10-25	40-75	10-25	40-75	10-40
1-inch screen...do...	40-75				40-75	
1 1/4-inch screen...do...		40-75	95-100	40-75	95-100	40-75
1 1/2-inch...do...			100		100	
2-inch screen...do...	95-100				95-100	
2 1/2-inch screen...do...		100	95-100	95-100		100
3-inch screen...do...			100			100

For use in base only.

METHODS OF SAMPLING AND TESTING

1. Methods of sampling shall be in accordance with A. S. T. M. standard method D75. (See 510., p. 184.)

2. Tests of coarse aggregate shall be made in accordance with the following methods:

(a) Percentage of wear: A. S. T. M. standard method D2. (See 510., p. 182.)

(b) Weight per cubic foot: A. S. T. M. standard method C9. (See 516.11, p. 287.)

(c) Mechanical analysis: A. S. T. M. Standard method D18 (see 512.15, p. 250.), using a No. 8 sieve in addition to the screens specified in method D18. The No. 8 sieve shall be a United States standard sieve meeting the requirements of A. S. T. M. standard specification E11, (see 500.2, p. 1).

National Sand and Gravel Association, bulletin 3, representative specifications for different uses of sand and gravel, November, 1928.

(In this bulletin representative specifications, many of which are presented in this volume, and including specifications for coarse aggregate, have been summarized.)

United States Department of Agriculture, bulletin 1216, method of test for percentage of shale in aggregate, 1928.

It is suggested that for the separation of shale and other pieces having low specific gravity from concrete aggregate, a solution of zinc chloride (ZnCl₂) or some other satisfactory liquid having a specific gravity of approximately 1.95 be used. A sample of the pebbles should be first dried to constant weight at not over 110° C., then placed in a container partially filled with the solution. Agitate for five minutes, skim off the lighter materials, and then pour the solution through a sieve which will retain the pebbles. Repeat the operation until the entire sample has been separated. Dry to constant weight, measure the volume of retained material, and compute the percentage of volume of shale or other soft material.

NOTE.—Attention is called to the fact that this method of test is not applicable when the specific gravity of the shale exceeds the specific gravity of the solution. In cases where a solution of very high density is required, a mixture of bromoform and benzol may be employed.

United States Department of Agriculture, bulletin 1216, method of test for soundness of coarse aggregate, 1928.

1. Immerse 10 small pieces (total weight about 1,000 g.) of the rock in a saturated solution at 70° F. of sodium sulphate (Na₂SO₄) for 20 hours, after which place them for 4 hours in a drying oven maintained at 100° C. Repeat the treatment — times. The operation of immersing, heating, reimmersing, etc., shall be continuous. Note the condition of the rock as to soundness at the end of the test.

2. Samples which exhibit marked disintegration shall be considered to have failed in this test.⁴⁵

512.15 Broken Stone.

American Association of State Highway Officials, tentative standard specifications for highway materials, 1927.

MATERIAL

NO. 1. STONE FOR TELFORD BASE COURSE AND RECONSTRUCTED BASE COURSE

The material for this work shall consist of approved, sound, tough, durable stone, free from clay, loam, or other foreign substances. The pieces shall be approximately rectangular in section, having a depth equal to the thickness of the course, a width of from 2 to 6 inches, and a length of from 6 to 12 inches. The small stone for filling the voids in the large material shall consist of material at least equal in quality to that of the large stone.

NO. 2. BROKEN STONE FOR WATER-BOUND BASE

These specifications are substantially the same as A. S. T. M. D190. (See p. 250.)

NO. 3. BROKEN SLAG FOR WATER-BOUND BASE

1. This specification covers the quality and size of broken slag and slag screenings for use in a water-bound base course which is to be covered with any type of surface.

2. The broken slag shall be air-cooled, blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

3. The slag shall conform to the following requirements:

	Pounds
(a) Per cent of wear, not more than.....	20
(b) Weight per cubic foot, not less than.....	60

4. The coarse slag shall be of (a) the 1½ to 2½ inch size, or (b) the 2½ to 3½ inch size and shall be well graded between these limits. When tested by means of laboratory screens it shall conform to the following requirements:

	Per cent
(a) Passing 1¼-inch screen.....	0-15
Passing 2½-inch screen.....	95-100
Passing 3-inch screen.....	100
(b) Passing 2¼-inch screen.....	0-15
Passing 3½-inch screen.....	95-100
Passing 4-inch screen.....	100

Either of the above sizes or a combination thereof may be specified as desired.

5. The screenings shall be of either (a) the 0 to ¼ inch size, or (b) the 0 to ¾-inch size, well graded from coarse to fine and free from dirt or other foreign material. When tested by means of laboratory

⁴⁵ A correct interpretation of the results of the sodium-sulphate soundness test will be greatly assisted by a visual examination of the ledge from which the sample was obtained. Failure in the test, when accompanied by evidence of weathering of the exposed surface, may be considered sufficient ground for rejection.

screens it shall conform to one of the following requirements:

	Per cent
(a) Passing ¼-inch screen.....	85-100
(b) Passing ¼-inch screen.....	40-80
Passing ¾-inch screen.....	95-100
Passing 1-inch screen.....	100

Either of the above alternate sizes may be specified as desired.

6. *Sampling and testing methods.*—(a) *Wear.*—See 510, page 187, United States Department of Agriculture bulletin 1216, method of test for abrasion of broken stone and broken slag, 1928.

(b) *Weight.*—See 512.10, page 212, A. S. T. M. method C29.

(c) *Sampling.*—See 510., page 184, A. S. T. M. method D75.

NO. 4. BROKEN STONE FOR BITUMINOUS CONCRETE BASE

Sections 2 and 7 (a) of A. S. T. M. D190, (see p. 250) are part of this specification with the following additional:

1. This specification covers the quality and size of broken stone to be used in the construction of a bituminous concrete base.

2. The stone shall conform to the following requirements:

Percentage of wear, not more than.....	6
Toughness, not less than.....	6

3. The coarse aggregate shall consist either of (a) the ¼ to 1¼ inch size or (b) the ¼ to 2½ inch size as designated and shall be well graded between these limits. When tested by means of laboratory screens the size designated shall conform to the following requirements:

	Per cent
(a) Passing a ¼-inch screen.....	0- 5
Passing ¾-inch screen.....	30- 60
Passing 1¼-inch screen.....	95-100
Passing 1½-inch screen.....	100
(b) Passing ¼-inch screen.....	0- 5
Passing ¾-inch screen.....	10- 25
Passing 1¼-inch screen.....	40- 75
Passing 2-inch screen.....	95-100
Passing 2½-inch screen.....	100

4. *Test for toughness.*—See 510. A. S. T. M. method D3.

NO. 7. BROKEN STONE FOR PORTLAND CEMENT CONCRETE BASE COURSE

Section 6 (a) and (c) of No. 3 and section 4 of No. 4 (above) are part of this specification, with the following additional:

1. This specification covers the quality and size of broken stone for use as coarse aggregate in a Portland cement concrete base course.

2. The broken stone shall consist of uncoated particles of clean, hard, tough, durable rock. It shall contain no organic or other deleterious matter and shall be free from lumps of clay and soft pieces.

3. At least — per cent of the stone shall come from ledges conforming to the following requirements:

Per cent of wear, not more than.....	8
Toughness, not less than.....	5

4. The broken stone shall show no evidence of disintegration when subjected to note 1 alternations in the sodium sulphate test for soundness.

5. Coarse aggregate shall be uniformly graded between the limits specified and shall meet the following requirements:

	Per cent
Tr. { Passing 3-inch screen.....	100
Passing 2½-inch screen.....	95-100
Passing —inch screen (note 2).....	95-100
Passing ¼-inch screen.....	0- 5

NOTE 1.—Five alternations are specified ordinarily. Attention, however, is called to the fact that a greater number may be specified in the judgment of the engineer, local conditions as to character of materials, or kind of service required make it advisable to do so.

Table of materials for 1 cubic yard of compacted concrete

Class of concrete	Nominal proportions	Cement sacks	Weight of cement
			<i>Pounds</i>
A-----	1:2:4	6.3	592
B-----	1:2½:5	5.2	489
C-----	1:3:6	4.5	423
D-----	1:2:3	7.3	686

If the contract price for concrete includes the cost of cement and if the proportions as adopted for the work vary from those specified above, necessitating a change in the quantity of cement, the difference in the cost of the work, based upon the actual cost of the cement delivered at the bridge site, shall be adjusted for or against the contractor, as the case may be.

Changes in the proportion of fine to coarse aggregate shall not be cause for any adjustment in compensation except as such changes affect the quantity of cement required. However, changes made at the contractor's request to permit the use of inferior aggregates shall not involve additional compensation for cement used.

CONSISTENCY

The quantity of mixing water to be used shall be determined in each case by the engineer, and no changes shall be made without his consent. In general, a mixture shall be used which contains the minimum amount of water consistent with the required workability.

In general, the consistency of concrete mixtures shall be such that:

1. The mortar clings to the coarse aggregate.
2. The concrete is not sufficiently fluid to segregate when transported to the place of deposit.
3. The concrete, when dropped directly from the discharge chute of the mixer, shall flatten out at the center of the pile, but shall stand up and not flow at the edges.
4. The mortar shall show no free water when removed from the mixer.
5. The concrete shall settle into place when deposited in the forms and, when transported in metal chutes at an angle of 30° with the horizontal, it shall slide and not flow into place.
6. The upper layer of the set concrete shall show a cement film upon the surface, but shall be free from laitance.

RUBBLE OR CYCLOPEAN CONCRETE

Rubble or cyclopean concrete shall consist of either class B or class C concrete, as specified, in which is embedded large individual stones in accordance with the following requirements.

This class of concrete shall be used only in massive piers, gravity abutments, and heavy footings, and only with the approval of the engineer.

The stone shall be carefully placed (not dropped or cast) and the method of placing shall be such as to avoid injury to the forms or to the partially set adjacent masonry. Stratified stone shall be placed upon its natural bed. All stone shall be thoroughly washed and saturated with water before being placed.

The total volume of the stone used shall not be greater than one-third of the total volume of the portion of the work in which it is placed.

For walls or piers greater than 2 feet in thickness 1-man stone may be used. Each stone shall be completely surrounded by a layer of concrete not less than 6 inches in thickness. No stone shall

extend above a point 1 foot below the top surface of any wall or pier nor shall it extend within less than 6 inches of any coping.

For walls or piers greater than 4 feet in thickness derrick stone may be used. Each stone shall be completely surrounded by a layer of concrete not less than 1 foot in thickness. No stone shall extend above a point 2 feet below the top surface of any wall or pier nor shall it extend within less than 8 inches of any coping.

EXPANSION JOINTS

Expansion joints may be of the following types: Friction joints, open joints, filled compression joints, mortise joints, and special expansion joints.

Friction joints, when of metal, shall be composed of cast-iron or bronze plates, as noted on the plans. Sliding surfaces shall be planed true and smooth, the marks of the plane paralleling the movement of the joint. Expansion plates shall be well anchored, as shown on the plans. All sliding surfaces of expansion plates shall be thoroughly coated with graphite and grease just before being placed in position and special care taken to avoid placing concrete in such manner as to interfere with their free action.

Open joints shall be placed at locations designated on the plans and shall be formed by the insertion and subsequent removal of a templet of timber, metal, or other suitable material. The method of insertion and removal of joint templets shall be such as to avoid the possibility of chipping or breaking down at the edges, and the templets shall be so constructed that their removal may be readily accomplished without injury to the work.

Filled compression joints shall be made with an asphalt filler or premolded filler, the materials for which shall conform to "fillers," 505.15, American Association of State Highway Officials.

Mortise joints shall be as shown on the plans and, in general, shall consist of a tenon of concrete or metal sliding in a suitable concrete or metal socket or mortise. Concrete tenons in concrete mortise sockets, brass or bronze tenons sliding in concrete sockets, or metal tenons sliding in galvanized pipe sockets may be specified. In any case, the construction shall be such as to permit freedom of movement and such as to be, as far as possible, water-tight and rustproof.

Special types of expansion joints may be used when so specified on the plans or ordered in writing by the engineer.

Expansion joints through bridge floors preferably shall be constructed with a waterproof flashing of copper or zinc to prevent the entrance of water into the joint. Such flashing shall be so arranged as to lead all drainage water to a point of discharge such as will avoid any staining of the exposed concrete surfaces.

ORDINARY SURFACE FINISH

The external surface of all concrete masonry shall be thoroughly worked during the operation of placing by means of a broad-tined fork or a concrete spade of an approved type. The working shall be such as to force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish free from water and air pockets or honeycomb.

As soon as the concrete has set sufficiently to permit, the forms shall be carefully removed and all depressions resulting from the removal of metal ties and all other holes and rough places shall be carefully pointed with a mortar of sand and cement in the proportion which has been employed for the particular class of concrete treated. The surface film of all such pointed surfaces shall be carefully removed before setting occurs. The surface shall then be given one of the following finishes:

resistance to compression of the treated and the untreated pieces shall then be compared.

VI. PACKING, MARKING, AND SHIPMENT

Materials for integral waterproofing shall be packed in suitable containers that will preserve the materials in good condition. Each package shall be marked with the net weight or net liquid measure of the contents, and with the brand or trade name of the contents and the name of the manufacturer. Each order of the material shall be accompanied by printed directions for its use.

VII. NOTES

1. The integral waterproofing materials should be mixed with the mortar or concrete with which it is to be used in accordance with the printed directions of the manufacturer.

2. Treated mortar and concrete should be made with not more than 2 volumes of fine nor more than 4 volumes of coarse aggregate to each volume of cement. The aggregate should be so graded in size as to produce a mixture of maximum density. Only such a quantity of water should be used as necessary to make the completely mixed product sufficiently plastic for properly placing and finishing.

3. In addition to various makes of integral waterproofing material, there are in the market brands of Portland cement with which a waterproofing material has been combined in its manufacture.

Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.—This committee, consisting of affiliated committees of the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, American Concrete Institute and Portland Cement Association, submitted to constituent organizations August 14, 1924, a report on standard specifications for concrete and reinforced concrete.

The specifications are for the use of concrete in construction, including methods and materials under the chapter heads of (1) general instructions, (2) definitions, (3) quality of concrete, (4) materials, (5) proportioning and mixing concrete, (6) depositing concrete, (7) forms, (8) details of construction, (9) waterproofing and protective treatment, (10) surface finish, and (11) design.

The specifications given for materials include the following:

PORTLAND CEMENT

Portland cement shall conform to the standard specifications and tests for Portland cement of the American Society for Testing Materials, serial designation C9-26. (See 516.11, p. 294.)

FINE AND COARSE AGGREGATE

This specification is practically identical with American Society for Testing Materials, specification for aggregates, with the exception that in the A. S. T. M. specification for fine aggregate there is an added requirement that 100 per cent shall pass a $\frac{3}{8}$ -inch sieve. Since publication of the joint committee specifications, the American Society for Testing Materials has revised its specification, C33-28T. (See 512.13, p. 237.)

RUBBLE AND CYCLOPEAN AGGREGATE

Rubble aggregate shall consist of clean, hard, durable stone or gravel larger than 3 inches and weighing not more than 100 pounds.

Cyclopean aggregate shall consist of clean, hard, durable stone or gravel weighing more than 100 pounds.

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.

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

National Sand and Gravel Association, Bulletin 3, representative specifications for different uses of sand and gravel, November, 1928.

(In this bulletin representative specifications, many of which are presented in this volume and including specifications for sand for brick mortar, have been summarized.)

Portland Cement Association, specifications for making, placing, and curing concrete in cold weather.

(This association has prepared the above-entitled specification to supplement regular concrete specifications and to be added thereto.)

United States Department of Agriculture, Bulletin 1216, Method of Proportioning Natural Sand and Gravel for Concrete Construction, 1928.

(See 512.10, p. 216.)

516.4 CONCRETE BRICKS AND BLOCKS.

American Association of State Highway Officials, standard specifications for highway bridges and incidental structures, 1928.

CONCRETE CRIBBING

(The full text of this specification includes construction methods and requirements for measurement and payment.)

GENERAL

The construction of concrete cribbing shall consist of the furnishing and installation of reinforced concrete crib members and the placing of the interior filling materials. Drift bolts shall be of wrought iron or galvanized steel not less than 1 inch in diameter and of the required length.

Casings for drift bolts shall be of galvanized steel or iron pipe not less than $1\frac{1}{4}$ inches in diameter.

GENERAL REQUIREMENTS

The details of the crib members and their arrangement shall be as shown on the plans. If specific details for reinforcement are not shown on the plans, or if the contractor is permitted to purchase the crib members from manufacturers, he shall submit detailed specifications and plans for the approval of the engineer, and such plans must be approved before delivery of the material is begun.

All members shall be free from depressions and spalled, patched, or plastered surfaces or edges, or any other defect which may impair their strength or durability. Cracked or otherwise defective members will be rejected.

American Concrete Institute, standard specifications for concrete building block and concrete building tile, serial designation P-1A-29, 1929.

I. GENERAL

1. The purpose of these specifications is to define the requirements for concrete building block and concrete building tile to be used in construction.

2. The word "concrete" shall be understood to mean Portland-cement concrete.

3. The average compressive strength of three or more concrete block or concrete building tile in pounds per square inch of gross cross-sectional area as laid in the wall shall not be less than 700 pounds, no one unit falling below 600 pounds 28 days after being manufactured or when shipped.