DIVISION 700

STRUCTURES

SECTION 701

PORTLAND CEMENT AND PORTLAND CEMENT CONCRETE

701.01 Description. This work shall consist of furnishing, storing, and handling of the materials; and the proportioning, mixing, and delivery of portland cement concrete for structures.

Portland cement concrete for structures shall be composed of cement, fine aggregate, coarse aggregate, water, air-entraining admixture and other admixtures when permitted or required. Fly ash, water granulated blast-furnace slag, and silica fume may be added or used as a replacement portion of the portland cement and shall be considered as cement in the water cement ratio unless otherwise designated. The materials shall conform to the requirements hereinafter specified, and the mixture shall be prepared and delivered in accordance with these specifications.

The designation of the ten classes of concrete normally used by the Department are listed below:

New Designation	Previous Designation
Class 2500	Class B
Class 3000	Class A
Class 4000	Class D
Class 4000DS	--

Classes of Concrete (Continued)

New Designation	Previous Designation
Class 4000S	Class AA
Class 4000P	--
Class 5000	Class X
Class 6000	--
Class 6500	Class E
Class 7000	--

The following classes of concrete shall be air-entrained unless otherwise specified: Class 2500, Class 3000, Class 4000, Class 4000S, and Class 6500. The use of air-entrainment in Class 4000DS, Class 4000P, Class 5000, Class 6000, and Class 7000 concrete is left to the preference of the Contractor. When air-entrainment is used in these classes of concrete, the proportions of water, fine aggregate and coarse aggregate shall be varied from those specified to maintain the specified yield of concrete. The entrained air shall be obtained by using an approved admixture as specified in Subsection **701.06**.

All references to water cement ratio shall be the ratio of water to cementitious materials by weight.

MATERIALS

701.02 Portland Cement. Portland cement shall conform to the requirements of the following cited specifications for the type specified or permitted and with the additional requirements stated hereafter:

Compressive strength requirements will govern and the requirements for low-alkali cement (0.6 maximum) shall be met. The maximum limits of fineness of grind of AASHTO M 85 shall not apply for cement used in RC pipe, prestressed or precast products.

The maximum limits of fineness of grind in AASHTO M 85 for cement other than that used in RC pipe, prestressed or precast products will be controlled as follows:

1. The cement mill test reports furnished by the manufacturer shall comply with the maximum fineness (air permeability test) values as stated in AASHTO M 85.

2. Job control samples taken at random at the project sites and submitted to the Research and Materials Laboratory for testing shall have a maximum fineness limit (air permeability test) in conformance with the requirements of AASHTO M 85 with allowance for variations in sampling, presence of moisture in the sample, age of the cement production, and multi-laboratory coefficient of variation.

Type I(SM) Slag-Modified Portland Cement may be used instead of Type I and Type II cement. Type I(SM) cement shall conform to AASHTO M 240. It shall be an intimate and uniform blend of portland cement and granulated blast-furnace slag. In any case, the slag constituent shall be less than 25% of the total weight of the slag-modified portland cement.

The cement suppliers shall furnish certified mill test reports as outlined in the *Policy for Cement Inspection* adopted by the South Carolina Department of Transportation.

Incompatible brands of cement or different types of cement shall not be mixed in any continuous pour or be placed in the same cement storage bin.

The weighing and handling procedures of bulk cement shall be inspected and approved by the Engineer before use. Cement shipments shall be fully protected at all times. Questionable cement shall be inspected, sampled, and tested before being used. Cement that is lumpy, caked, discarded

from used bags, or otherwise damaged shall not be used.

Cement shall be measured by weight or by the bag as packed by the manufacturer. One bag of cement shall be based on a weight of 94 pounds.

Whenever it is determined by subsequent laboratory testing of mill or job control samples that a cement shipment does not comply with the above stated specifications, use of cement from that cement mill will be discontinued for Department use until testing reveals that the problem has been corrected. The Contractor will be held responsible for replacement or otherwise making satisfactory the concrete in which any defective cement is used.

701.03 Fly Ash. Fly Ash (Type C or Type F) shall conform to the requirements of AASHTO M 295 except that the supplementary optional physical requirements will not apply.

701.04 Water Granulated Blast-Furnace Slag. Water granulated blast-furnace slag shall be Class 100 or higher and shall conform to the requirements of ASTM C 989.

701.05 Silica Fume. Silica Fume shall meet the general requirements of ASTM C 1240. The raw silica fume shall meet the chemical requirements of Table 1 and Table 2 and the physical requirements of Table 3 in ASTM C 1240. The manufacturer's certification shall be furnished stating the results of tests made on samples of silica fume during production and that the applicable requirements of ASTM C 1240 have been met. A certification for each lot of each shipment shall be provided to the Engineer.

Silica Fume may be added to the mix in either dry (densified) form or a wet (slurry) form. The dry form is usually supplied in 50-pound bags. When a dry form is used, the mix design shall be adjusted to use whole bags of silica fume, (i.e., partial bag(s) shall not be used.) Silica fume in excess of the specified minimum is permitted, and to prevent overextending silica fume, a whole bag quantity that is as much

as 10 pound less than the specified minimum is also permitted. Guidelines regarding worker protection shall comply with current OSHA regulations.

When a wet (slurry) form is used, the water contained in the slurry shall be computed and deducted from the total water required in the mix. This shall be in accordance with the manufacturer's certified quality test report for the lot being used in the mix.

701.06 Air-Entraining Admixtures. Air-entraining admixtures shall comply with AASHTO M 154. A certified affidavit and test result evidence based on tests made in a recognized laboratory shall be submitted to the Engineer to show that the material conforms to the requirements of AASHTO M 154. Such affidavits and test results may be required every two years. Only those admixtures that appear on an approved list, published by the Research and Materials Laboratory of the Department, entitled *Approved Air Entraining and Chemical Admixtures for Concrete* or otherwise approved by the Engineer shall be used.

701.07 Accelerating, Retarding, and Water-Reducing Admixtures. In the event the Contractor or the Department, or both, elect to use a chemical admixture to produce concrete with characteristics more suitable to the placing conditions, such admixture shall comply with AASHTO M 194.

When a retarding admixture is desired, the Contractor may use a Type G high range water reducing retarding admixture, or a Type D water reducer retarder combined with a Type F high range water reducer as provided in Subsection **701.21**. The Type B retarding admixture will not be allowed.

A certified affidavit and test result evidence based on tests made in a recognized laboratory shall be submitted to the Engineer to show that the material conforms to the requirements of AASHTO M 194. Such affidavits and test results may be required every two years.

Only those admixtures that appear on an approved list, published by the Research and Materials Laboratory of the Department, entitled *Approved Air Entrainment and Chemical Admixtures for Concrete* or otherwise approved by the Engineer, shall be used.

When admixtures are used, the Contractor shall demonstrate that the admixtures are compatible, will not adversely extend normal setting time, and will not cause excessive bleeding.

701.08 Corrosion Inhibitor. One of the two alternates indicated below shall be used when a corrosion inhibitor is required in the concrete mix. The corrosion inhibitor shall be added to the concrete while it is being batched. The Contractor shall adhere to the manufacturer's written recommendations regarding the use of the admixture including storage, transportation, and method of mixing. The solution shall be added to the mix by a dispenser meeting the requirements of Subsection **701.19D**.

The Contractor shall furnish to the Engineer a copy of the manufacturer's certified test report showing the composition of the materials and the percent of solids for the alternate selected. Samples of the alternate selected may be taken and tested by the Department.

A. Alternate No. 1. Rheocrete 222, manufactured by Master Builders, Inc., Cleveland, Ohio, shall be added at the rate of 1.0 gallon per cubic yard.

Rheocrete 222 is a water-based organic material formulated to inhibit corrosion of steel in reinforced concrete that may be classified chemically as aqueous amines and esters. Rheocrete 222 does not accelerate the rate of hardening and has no effect on slump. The addition of Rheocrete 222 does require an increase in air-entraining admixture and an increase in mixing time to obtain the required air content. An additional 50 revolutions at mixing

speed (or 30 seconds in a central mix plant) may be expected to obtain required air. The manufacturer's certification of material shall be furnished to the Engineer. Rheocrete 222 shall not be considered in the water-cement ratio.

B. Alternate No. 2. Calcium nitrite, $Ca(NO_2)_2$ as manufactured by W. R. Grace and Co., Cambridge, Massachusetts, shall be added to the mix at a rate sufficient for the hardened concrete to contain no less than 4.5 pounds of nitrite (NO_2) per cubic yard of concrete. An application rate of two (2.0) gallons of 30% solids solution per cubic yard of concrete will comply with this specification.

Use of the material and application rate may be based on Department tests. Any air-entraining, water reducing, and/or set controlling admixture used in the production of concrete shall be compatible with the calcium nitrite solution being used.

The calcium nitrite, which acts as an accelerator, may be used in conjunction with a retarder to control the set of concrete, as per manufacturer's recommendation.

The non-solids portion of the calcium nitrite solution shall be considered as part of the total water in the mix. For a 30% solids solution, 7.58 pounds of water in a gallon of solution shall be considered in the water-cement ratio.

701.09 Calcium Chloride. Calcium chloride shall comply with the requirements of AASHTO M 144 for Type S or Type L. This material for cold weather work may be used in non-reinforced concrete in the maximum proportion of 2% by weight of cementitious material. Calcium chloride shall not be used in reinforced concrete structures unless quantity, type, grade, and class are approved by the Engineer.

701.10 Fine Aggregate for Portland Cement Concrete. The type of sand intended for use in concrete mix designs shall be submitted and approved by the Research and Mate-

rials Engineer. Fine aggregate shall consist of natural sand, manufactured sand or a combination of natural and manufactured sand meeting the following requirements:

A. Natural Sand. Natural sand shall be composed of clean, hard, durable, uncoated grains, free from lumps or flaky particles, organic matter, loam or other deleterious substances.

B. Manufactured Sand. Manufactured sand, FA-10M, shall be made from stone meeting all the quality requirements for coarse aggregates.

C. Mixtures of Sand. When a blend of sands is approved, the two materials shall be stored and batched separately unless otherwise approved by the Engineer.

D. Organic Impurities. All fine aggregate shall be free from injurious amounts of organic impurities. Fine aggregates subjected to the colorimetric test (AASHTO T 21) for organic impurities and producing a color darker than 3 shall not be used unless both of the following criteria are met:

1. Section 4.2 of AASHTO T 71 shall be revised to read as follows:

   Mix one batch of mortar with the aggregate treated in sodium hydroxide and one batch with untreated aggregate on the same day. Mold six 2-inch cubes from each batch. Test three of the cubes from each batch at the ages of seven (7) and twenty-eight (28) days.

2. A fine aggregate with the color darker than 3 may be used provided that the relative strength at seven (7) and twenty-eight (28) days is not less than 95% when tested in accordance with the revised AASHTO T 71.

E. Soundness. When the fine aggregate is subjected to five alternations of the sodium sulfate soundness test (AASHTO T 104) the weighted loss shall not exceed 10% by weight.

F. Approved Sources. Only those sand sources which appear on an approved list, published by the Research and Materials Laboratory of the Department, entitled *SCDOT Quality Approved Fine Aggregate Pits for Use in Portland Cement Concrete*, or otherwise approved by the Engineer shall be used.

G. Gradation of Fine Aggregate. Fine aggregate for all classes of portland cement concrete and concrete pavement shall conform to the following gradations of FA-10 or FA-10M:

	FA-10	**FA-10M**
Aggregate No. Sieve Designation	**Percentage by Weight Passing**	**Percentage by Weight Passing**
3/8"	100	100
No. 4	96 - 100	95 - 100
No.8	75 - 100	84 - 100
No. 16	55 - 98	45 - 95
No. 30	25 - 75	25 - 75
No. 50	5 - 30	8 - 30
No. 100	0 - 9	0.5 - 20
No. 200	0 - 3	0 - 10*

*Dust of fracture essentially free from clay or shale, final job site testing only.

701.11 Coarse Aggregate. Coarse aggregate for portland cement concrete shall conform to the following requirements:

A. General. Coarse aggregate shall be clean, tough, durable gravel, crushed gravel, or crushed stone. It shall be free from soft, thin, elongated or laminated pieces. It shall be sufficiently washed during production to produce a clean aggregate, free from lumps or coatings of clay, disintegrated particles, vegetation or deleterious substances and adherent coatings which may be considered injurious. The Los Angeles Abrasion loss as determined by AASHTO T 96 shall not exceed 60%. When the coarse aggregate is subjected to 5 alternations of the sodium sulfate soundness test conducted according to AASHTO T 104, the weighted loss shall not exceed 15%.

B. Slag. Crushed slag or other inert materials having similar characteristics and approved by the Engineer, shall consist of clean, tough, durable pieces of approved slag or other inert materials, reasonably uniform in density and quality and reasonably free from thin or elongated pieces. The slag or other inert material shall be air-cooled and shall have a weight of not less than 75 pounds per cubic foot and the Los Angeles Abrasion loss shall not exceed 40%. Slag shall not contain free lime in deleterious quantities as determined by laboratory tests and shall not contain more than 15% by weight of glassy pieces.

C. Approved Sources. Only those coarse aggregate sources that appear on an approved list and shown as approved for portland cement concrete, published by the Research and Materials Laboratory of the Department, entitled *Quality Tests on SC Coarse Aggregates*, or otherwise approved by the Engineer shall be used.

Aggregate from fossiliferous limestone quarries is permitted in all applications of non-reinforced concrete. When fossiliferous limestone coarse aggregate is subjected to five alternations of the sodium sulfate soundness test conducted according to AASHTO T 104, the weighted loss shall not exceed 25% when tested according to AASHTO T 96. When fossiliferous limestone aggregate is used, a sprinkler system shall be used to insure saturated

aggregate during concrete batching.

D. Gradation of Coarse Aggregate. Coarse aggregate for portland cement concrete shall be No. 56, No. 57 or No. 67. Aggregate No. 78 may be used in thin sections and prestressed panels when approved by the Engineer. No. 789 or other approved gradations may be used for blending if approved by the Research and Materials Engineer. Gradations shall be as follows:

Sieve Size or Designation	Percentage By Weight Passing for Aggregate				
	No. 56	**No. 57**	**No. 67**	**No. 78**	**No. 789**
1 1/2 "	100	100	--	--	--
1"	90 – 100	95 - 100	100	--	--
3/4"	40 – 85	90 - 100	100	100	100
1/2"	10 – 40	25 - 60	--	90 - 100	90 - 100
3/8"	0 – 15	--	20 - 55	40 - 75	80 - 100
No. 4	0 – 5	0 - 10	0 - 10	5 - 25	20 - 50
No. 8	0 – 5	0 - 5	0 - 5	--	--
No. 16	--	--	--	0 - 5	0 - 6
No. 100	--	--	--	0 - 2	0 - 2

701.12 Water. Water used in mixing, fogging, or curing of portland cement concrete shall be reasonably free from salt, oil, acid, alkali, organic matter, sewage or other substances injurious to the finished product.

A comparison of the water with distilled or other satisfactory water will be made by means of standard cement test for soundness, time of setting and 1:3 mortar strength with standard sand conforming to ASTM C 778, using the same cement with each water. Any indication of unsoundness, change in time of setting of plus or minus 30 minutes, or a reduction of more than 10% in strength from results at age seven (7) days, obtained with mixtures containing satisfactory water, shall be sufficient cause for rejection of the water un-

der test.

When required by the Engineer, the acidity or alkalinity of the water shall be determined in accordance with AASHTO T 26. Water from a public water supply may be accepted without being tested. Water from other sources shall not be used until tested and approved.

In the event an approved source reservoir is relatively shallow, the intake pipe shall be so enclosed and elevated so as to exclude silt, mud, grass or other foreign matter.

EQUIPMENT

701.13 Equipment, Inspection, and Approval. All equipment hereinafter specified shall be inspected and approved before use. Such inspections will also be conducted at least annually and at other times as considered necessary.

701.14 Weighing Equipment. The equipment used for weighing materials at all types of batch plants shall provide convenient and positive means of determining the quantities in each batch of concrete.

Individual cementitous materials shall be weighed to no less than 99% of the required weights.

The individual aggregates, as weighed, shall be within ±2% of the required weight and the total weight of aggregate shall be within ±2% of the total required weight. Scales for weighing aggregates and cement shall be of either the beam type or the springless-dial type, or the load cell type, and shall be accurate within 0.5% when used for cement and within 1.0% when used for aggregate under operating conditions throughout the range of use. When beam-type scales are used, provisions such as a “tell-tale” dial shall be made for indicating that the required load in the weighing hopper is being approached. Poises shall be designed to lock in any position to prevent accidental change of position.

Dial scales shall be in a dust tight enclosure. The chart shall be of durable material to insure good readability.

Scales used in batching portland cement concrete shall be periodically checked for accuracy by the Division of Weights and Measures of the State Department of Agriculture, or by other qualified scale service agents and a statement of the date of scale inspection and certifying as to their accuracy shall be posted on the scales or in the batching room. The interval between inspections shall not exceed twelve (12) months.

The cement-weighing hopper shall be properly sealed and vented to preclude dusting during weighing operations.

701.15 Central Mixing Plant. Concrete shall be thoroughly mixed in a batch mixer of an approved size and type that will insure a uniform distribution of the materials throughout the mass.

Adequate water storage shall be provided and the mixer shall be equipped with a device for accurately weighing or measuring and automatically controlling the quantity of water used in each batch. The device used shall be accurate and so calibrated that under all operating conditions it shall have an accuracy within one percent of the quantity of water required for the batch. The Contractor shall furnish the Engineer with facilities for checking the water measuring equipment whenever the Engineer deems it necessary. Scales or other means used for measuring water shall be clearly marked and accurately show the quantity used. The water measuring device shall be so arranged that there will be no loss of water from the time it is measured until it is deposited in the mixer drum and also, that the water supply will be automatically cut off while water is being discharged into the mixer. The mixer shall be equipped with an acceptable timing device capable of being locked, and shall not permit the batch to be discharged until the specified mixing time has elapsed.

Mixers shall be maintained and repaired if necessary so

that the concrete will be of uniform quality. Mixers shall be examined for changes in condition due to accumulation of hard concrete or mortar or to wear of blades. The pick-up and throw-over blades shall be replaced when any part or section is worn one inch or more below the original height of the manufacturer's design. A copy of the manufacturer's design, showing dimensions and arrangements of blades shall be available to the Engineer.

Mixers shall be equipped with a separate dispenser for each type of admixture. The dispensers may operate either automatically or manually and shall be capable of measuring and placing exactly and consistently the desired amount of the admixture in each batch.

701.16 Truck Mixers. All truck mixers shall have been pre-inspected by SCDOT and display the current unexpired SCDOT inspection sticker.

The truck mixer shall be capable of combining the ingredients of the concrete within the specified number of mixing revolutions into a thoroughly mixed and uniform mass and discharging the concrete with a satisfactory degree of uniformity.

The volume of mixed concrete permitted in the drum of truck mixers shall not exceed the manufacturer's rating on the capacity plate. The National Ready Mixed Concrete Association (NRMCA) plate shall, at all times, be accessible, clear, and legible. Agitators shall similarly be capable of producing concrete with a satisfactory degree of uniformity.

If the equipment does not have attached the rating plates referred to above, the approved capacity as a mixer and as an agitator will be based on the table shown below:

Maximum Gross Volume of Drum (cubic feet)	Maximum Capacity (cubic yards)	
	As Mixer	As Agitator
261	6	7.75
306	7	9.25
329	7.5	9.75
352	8	10.5
376	8.5	11.25
399	9	12
423	9.5	12.75
446	10	13.25
493	11	14.75
540	12	16
587	13	17.5
634	14	19
681	15	20.25

The Research and Materials Laboratory will provide a SCDOT decal to be used instead of the manufacturer's rating plate showing the mixing and agitating capacity if the volume can be determined.

The truck mixer shall be equipped with a water system and measuring device. The device shall permit ready access and ready determination of the quantity of water used. The water-measuring device shall be accurate to within one percent of the total water measuring capacity of the tank when the truck mixer is stationary and essentially level.

Truck mixers and agitators of the revolving drum type must be equipped with a hatch in the periphery of the drum shell of such design as to permit access to the inside of the

drum for inspection, cleaning and repair of the drum and blades.

Truck mixers shall be provided with an electrically or mechanically actuated revolution counter that can be reset to zero. This counter shall be mounted in such a position that it can be read from the ground by both the operator and the Engineer.

Truck mixers shall be maintained and repaired if necessary so that the concrete will be of uniform quality. Blades shall be replaced when any part or section is worn one inch or more below the original design. A copy of the manufacturer's design showing dimensions and arrangement of blades shall be available to the Engineer.

CONSTRUCTION REQUIREMENTS

701.17 Care and Storage of Concrete Aggregates. The handling and storage of concrete aggregates shall be such as to prevent intermixing, segregation, and contamination by foreign materials. Each separate aggregate component of different source or grading shall be separately handled and stockpiled. The stockpile sites that have natural ground bottoms shall be cleared of vegetation and other extraneous matter and shall be generally smooth, firm and well drained. The bottom one-foot of any natural ground stockpile shall not be used except under immediate supervision of the Engineer. Should excessive segregation occur as a result of the methods employed in the stockpiling of an aggregate, the stockpile shall be constructed in layers not to exceed three (3) feet in depth.

701.18 Storage of Cement. Bulk cement shall be stored in bins or silos of weatherproof construction that will protect the cement from dampness and provide for the free flow of the cement. If the Engineer authorizes the use of bagged cement, it shall be stored in weatherproof buildings or temporary storage in the open on a raised platform with ample waterproof flooring and covering.

At a batching plant with two (2) or more silos in which different types of cement or cementitious materials are stored, each silo shall have a sign at each fill inlet. It shall be made from a durable material, with minimum two (2) inch high by 1/4 inch thick letters that are raised, indented, or cut. The sign shall identify the material that is in the silo.

If concrete is to be proportioned at the work site and only for the Department, the Contractor shall keep accurate records of the deliveries of cement and of its use in the work. Copies of these records shall be supplied to the Engineer in such form as may be required.

701.19 Measuring Materials.

A. Portland Cement. Portland cement and other cementitious materials shall be measured by weight unless otherwise specified. The cementitious materials shall be weighed on scales meeting the requirements of Subsection **701.14** separate from those used for other materials. Should bagged cement be authorized, it shall be measured in bags as packed by the manufacturer. From time to time, full bags may be weighed as a check on the net weight. Batches shall be used which do not require fractional bags of cement unless all the cement for each batch is weighed.

B. Water. Water shall be measured by volume or by weight through an approved measuring system. The measuring system shall be capable of incorporating into the batch, through a metering or weighing device, the predetermined quantity of water, to an accuracy of one percent of the quantity of water required for the batch. Water shall be assumed to weigh 8.33 pounds per gallon.

C. Fine and Coarse Aggregate. Fine and coarse aggregates shall be measured separately by weight on scales meeting the requirements of Subsection **701.14**. In measuring aggregates, allowance shall be made for water

in the aggregates. For determinations of the moisture content of aggregates, automatic sensing devices shall be used if available; otherwise representative samples shall be taken and investigated individually or combined in a composite sample.

D. Admixture. Admixtures shall be dispensed into the batch as a solution of uniform concentration and in the amounts recommended by the manufacturer. The sight tube dispensers shall be properly equipped with a graduation strip or strips that are labeled in terms of ounces or ounces per hundred pounds of cement. Graduated strips shall be so identified as to the rate at which the admixture is being measured for the particular diameter of the tube being used.

Meter and timing dispensers shall be calibrated by obtaining a metered sample and checking the accuracy of the system. The equipment shall be checked and approved during the annual inspection and at other times when deemed necessary.

The accuracy of all systems shall be maintained within ±3%. The admixture shall be discharged into the stream of water entering the mixer drum or into the pre-measured or pre-weighed water for each batch. Precautions shall be taken to prevent the dilution of the admixture in storage by rain and condensation. For actual control, the air content will be measured with air meters only. Additional admixtures may be added at any time to achieve the proper amount of entrained air. Where more severe climate conditions occur, the minimum percent air may be increased by the Engineer.

When adding Types A, C, D, or E admixtures, the dispensing equipment and procedure shall be such that the admixture will be added after the dispensing of the air entraining agent is complete and some mixing of the concrete has occurred. When adding Types F or G admixture, the admixture agent will not be added until after all of

the materials are in the mixer and have been mixed for one minute if in a truck mixer, for 15 seconds if in a central-mix mixer, or at approximately midpoint of the primary mixing portion of the auger mixing chamber on a mobile concrete mixer unit.

701.20 Proportions.

A. General. The Contractor shall be responsible for designing the mixtures for all classes of concrete and determining the proportions of cement, fine aggregate, coarse aggregate, water, air-entraining admixture and water-reducing or water-reducing set retarding admixture (when used) which will produce a workable concrete mix meeting the criteria for the class of concrete specified in the **STRUCTURAL CONCRETE TABLE** including General Notes and Notes 1 through 7) found in Subsection **701.20C**. Consideration shall be given to the amount of any air-entrainment that must be incidentally afforded by the use of water-reducing or water-reducing set retarding admixture. The proportions of ingredients shall be determined in accordance with requirements for the particular type of work and with consideration of the specific gravities of the materials to provide the desired workability and consistency. At his own expense, the Contractor may retain an independent testing laboratory, accredited by AASHTO, to design the mix for the class of concrete specified or shall use a mix design previously reviewed and used by the Department. All design mixes shall be submitted to the Engineer for review.

The design of the concrete mix shall be established using Department approved ingredients that the Contractor intends to use for the project, and all trial batches shall be made using such materials. Trial mixes designed by the Contractor shall be tested for complete conformance to these specifications by the accredited laboratory engaged by the Contractor.

No separate payment will be made for the cost of the laboratory engaged by the Contractor; or for the materials furnished and used for trial batches; or for the preparation and testing of trial batches either by the Contractor or his laboratory; or for furnishing the Engineer with the mix data, the results of the cylinder tests, and yield to be tested. These costs will be considered incidental to the work of the applicable item and will be included in the contract unit prices for the pay items shown on the plans.

Upon review of a satisfactory design mix, the mix proportions shall be used without change for all concrete of that class, unless modifications are necessary.

B. Changes in Mix Design. When changes are made in the mix design, the Contractor shall furnish to the Engineer for review the new proportioning values as necessary for batching purposes over the range of quantities to be batched.

C. Structural Concrete Table.

General Notes:

Mix designs shall be based on 4 1/2% (± 1 1/2%) entrained air. Class 4000DS, Class 4000S, Class 5000, Class 6000, and Class 7000 have no target entrainment value, but shall not exceed 4 1/2% entrained air.

Mix designs shall be based on specific gravities and saturated surface dry moisture contents obtained from current Research and Materials Laboratory aggregate source approval sheets.

The sand to stone ratio is based on volume and may be varied to obtain good workability.

STRUCTURAL CONCRETE TABLE

Aggregate Type	Minimum Cement Content (lbs./CY)	Other Cement-itious Material (lbs./CY)	Min. 28 Day Mix Design (psi)	Percent Fine to Coarse Aggregate Ratio	Max. Water to Ce-ment Ratio
		Class 2500			
Crushed stone	494	--	2500	36:64	0.49
Gravel	494	--	2500	35:65	0.46
Fossil. Limestone	494	--	2500	40:60	0.50
		Class 3000			
Crushed stone	588	--	3000	35:65	0.46
Gravel	588	--	3000	34:66	0.44
Fossil. Limestone	588	--	3000	39:61	0.47
		Class 4000		(See Note 4)	
Crushed stone	611	--	4000	35:65	0.40
Gravel	611	--	4000	34:66	0.40
		Class 4000S			
Crushed stone	588	--	4000	38:62	0.45
Gravel	588	--	4000	38:62	0.45
		Class 4000DS		(See Notes 2 & 5)	
Crushed stone	625	--	4000	40:60	0.44
Gravel	625	--	4000	39.61	0.43

STRUCTURAL CONCRETE TABLE (Continued)

Aggregate Type	Minimum Cement Content (lbs./CY)	Other Cement-itious Material (lbs./CY)	Min. 28 Day Mix Design (psi)	Percent Fine to Coarse Aggregate Ratio	Max. Water to Ce-ment Ratio
		Class 4000P		(See Note 6)	
Crushed stone	682	--	4000	34:66	0.43
Gravel	682	--	4000	33:67	0.38
		Class 5000			
Crushed stone	705	--	5000	35:65	0.46
Gravel	705	--	5000	34:66	0.42
		Class 6000			
Crushed stone	750	--	6000	34:66	0.44
Gravel	750	--	6000	33:67	0.39
		Class 6500		(See Notes 1 & 3)	
Crushed stone	600	CF42, FA140	4000	35:65	0.37
Gravel	600	CF42, FA140	4000	36:64	0.37
		Class 7000		(See Note 7)	
Crushed stone	800	---	7000	35:65	0.37
Gravel	800	---	7000	34:66	0.37

STRUTURAL STEEL TABLE NOTES

Note 1:

The Laboratory 56 day mix design strength shall be a minimum of 6500 psi. Acceptance of in place concrete will be based on a minimum strength of 4000 psi compression strength at a maximum of 28 days or 6500 psi at 56 days.

Note 2:

Type G or Type D admixture is required.

Note 3:

Proportioning: The Class 6500 concrete shall be designed with the following ingredients per cubic yard:

Cement (min.)……600 lbs.
Fly Ash……140 lbs.
Silica Fume……..42 lbs.
Corrosion Inhibitor……(*See Subsection **701.08)***
Entrained Air (Range)……4.5(±1.5)%
Water Cement Ratio (max.)……..0.37
High Range Water Reducer……*Required*
Aggregates……..*Variable*

The total mix water content shall be based on the weight of cement, flyash, and silica fume multiplied by the water-cementitous ratio. Absorbed water in the aggregate shall not be included as mix water.

If a Type A or D admixture is used, the Contractor will demonstrate that the admixtures are compatible, will not adversely extend normal setting time, or cause excessive bleeding.

The slump of the concrete, at time of placement in the forms, shall be increased by the use of a High Range Water Reducer (HRWR). Either Type F or Type G admixture may be used. Slump shall not exceed 8 inches after addition of HRWR.

If silica fume slurry is used, it shall be added at a point that produces an acceptable mix.

The high range water reducer shall be added at the

job site. Additional mixing shall be the minimum specified in accordance with Subsection **701.21,** but may be increased in order to obtain the necessary entrained air.

Concrete Temperature. The temperature of Class 6500 concrete shall not exceed the maximum permitted in Subsection **701.22**.

Mix Design Review. The Contractor shall submit to the Engineer a proposed sequence of mixing and a proposed concrete mix design based on trial mixes by the concrete supplier. The Contractor shall perform the laboratory mix design with the observation and assistance from the SCDOT Research and Materials Laboratory.

There shall be no separate pay item for this mix design.

Class 6500 Trial Mix. Before placing Class 6500 concrete in the deck, the Contractor shall supply one or more small batches of Class 6500 concrete that may be used in a part of the structure as directed by the Engineer. Testing shall be performed and will include air content, slump, unit weight, temperature, cylinder for 28 day compressive strength, and time of set. The trial batch procedure shall be repeated until all desired mix properties are achieved.

No separate pay items shall be included for the trial batches. The Class 6500 concrete used in trial batches may be substituted for another class of concrete elsewhere in the project if it meets proper strength requirements. It will be paid for at the contract unit price of the concrete for which it is being substituted.

Mixing Sequence. The Contractor shall develop a proposed mixing sequence for review that will assure breakup and distribution of the dry densified silica fume. Generally, the addition of part of the water, aggregates, and silica fume along with some mixing at mixing speed will adequately disperse the silica fume. The remaining ingredients may then be added in a sequence to produce a desirable mix.

The Class 6500 concrete shall contain both silica

fume and fly ash as part of the cementitous material.

Note 4:

The water cementitous ratio for Class 4000 shall not exceed 0.40 or 244 pounds of water per cubic yard.

Note 5:

Concrete for drilled shaft construction shall be Class 4000DS.

The Contractor shall be responsible for designing the mixture for shaft concrete and determining the proportions of cement, fine aggregate, coarse aggregate, water, and water reducing retarding admixture which will produce a workable concrete mix meeting the following criteria:

Minimum cement per cubic yard……..625 lbs.
Slump……7-9 inches
Maximum water/cement ratio……..……(*See Table)*
28-day minimum compressive strength…4000 psi
Air entraining admixture……*Not Required*
Nominal coarse aggregate size……..3/4-inch
No. 67 aggregate gradation……..*Required*

The design concrete mix shall be established using approved ingredients that the Contractor intends to use for the project. A trial mix shall be tested for complete conformance to these specifications.

The proposed mix to be used, along with test results showing full compliance with the specifications, shall be submitted to the Engineer for review.

The Contractor may use a Type G high range water reducing retarding admixture, or a Type D water reducer retarder combined with a Type F high range water reducer.

Method of Measurement. No measurement will be made for concrete in drilled shafts or drilled pile foundations. Drilled shaft concrete shall be included in the contract unit price for the item Drilled Shafts. The quantity shown on the plans will be used for the item Drilled Pile Foundations Concrete unless directed otherwise by the

Engineer.

Basis of Payment. The cost of mix design, trial batches, and production concrete will be included in the contract unit price for Drilled Shafts or Drilled Pile Foundation Concrete as applicable.

Note 6:

Class 4000 concrete is preferred in non-prestressed precast items.

Note 7:

The water cementitous ratio for Class 7000 shall not exceed 0.37. The air entrainment for Class 7000 is optional, but shall not exceed 4 1/2%.

D. Nonconforming Concrete. If the 28 day compressive strength or tensile strength of the concrete test cylinders falls below the expected design strengths, the Contractor shall be subject to a strength/price reduction on the quantity of concrete represented by the nonconforming cylinders determined from the following table:

Cylinder Test Results: Percentage of Minimum Strength	Strength/Price Reduction (percent X contract unit price)	
	With Contract Unit Price	*Without Contract Unit Price
98 - 100	0	0
95 < 98	minus 5 percent	minus 17 percent
90 < 95	minus 10 percent	minus 33 percent

*If no contract unit price for concrete, use percent X supplier's invoice unit cost.

If the cylinder test result is below 90%, the Department will take cores from the concrete in structure that is represented by the nonconforming test cylinders and test the cores. The Contractor may elect to have the cores taken and tested by an independent accredited laboratory ac-

ceptable to the Department; however, this work shall be performed at the Contractor's expense. The following procedure will be used in obtaining and testing cores:

1. Applicability. When cylinder test results from structural concrete do not attain at least 90% of the minimum specified strength in twenty-eight (28) days, cores shall be obtained for testing in order to evaluate the strength of the concrete in place. Other methods may be used to give an indication of the limits of the concrete in question, but consideration for acceptance will be solely based on cores removed from the in-place concrete.

2. Obtaining Cores. Cores will be removed from the structure by the Department or an independent firm, accredited by AASHTO, in the presence of all parties. The location of the cores will be designated by the SCDOT representative to best represent the concrete in question. Three cores, 2 to 4 inches in diameter, shall be taken from each area of concrete that failed cylinder strength requirements. Care shall be taken to avoid damaging reinforcing steel.

3. Conditioning and Testing Cores. The cores shall be tested by the Department or an independent testing firm accredited by AASHTO in the testing of concrete.

Cores shall be tested in a wet condition after being subjected to a lime-saturated water soak for at least forty (40) hours before testing. The Department will not consider dry testing.

All conditioning and testing will be in accordance with AASHTO T 24. The testing laboratory shall provide a written report on the results to all parties.

4. Acceptance of Concrete. Acceptance of the concrete from which the cores are taken will be based on the test results. If access to the concrete is not practical

for obtaining cores or the taking of cores would result in irreversible damage to the structure, the Engineer will approve concrete test method ASTM C 803 or ASTM C 805 to determine if the concrete represents reasonably acceptable work.

If the core tests method or other approved method result is below 90% percent of the design strength, the Department will perform a design analysis of the structure to determine if the concrete can remain in place. In no case will the concrete remain in place if the test result does not meet at least 85% of the design strength.

If it is determined that the nonconforming concrete can remain in place, the Contractor shall be subject to a strength/price reduction on the quantity of concrete in question determined by the following table:

*Core Test Results: Percent of Minimum Strength	Strength/Price Reduction (percent X contract unit price)	
	With Contract Unit Price	**Without Contract Unit Price
98-100	0 percent	0 percent
95 < 98	minus 5 percent	minus 17 percent
90 < 95	minus 10 percent	minus 33 percent
85 < 90	***minus 15 percent	minus 50 percent

* Or other approved test method.
** If no contract unit price for concrete, use percentage x supplier's invoice unit cost.
*** Use 15% of contract unit price or 50% of supplier's invoice unit cost, whichever is less.

701.21 Consistency. The Contractor is responsible for obtaining the desired consistency of the concrete. The addition of pozzolans and/or admixtures may be necessary to obtain the appropriate workability and consistency. The Contractor

is responsible for providing additional pozzolans and/or admixtures as necessary. These items shall be provided at no additional cost to the Department.

Concrete shall be acceptable when the slump, when measured in accordance with AASHTO T 119, or SC-T-42, is 1 to 4 inches, unless otherwise specified, provided the specified strengths are obtained.

Loads of concrete with a mix design strength of 2500 psi that have a slump not exceeding 6 inches when sampled from the first part of the load, may be used provided additional cement is added at the job site at the rate of 20 pounds of cement per cubic yard of concrete per inch of slump in excess of 4 inches. Loads of concrete with slumps greater than 6 inches shall be rejected for Department use unless otherwise permitted by these specifications. The Contractor shall have on hand at the job site a suitable amount of cement in bags for drying up over-saturated concrete. In the event additional water is required to obtain the specified slump at the job site, the Engineer may approve adding water normally at the rate one gallon per cubic yard per inch of desired slump provided a maximum water cement ratio is not exceeded. Additional need for water may indicate flash setting of the concrete, and in this case, additional water shall not be added without specific approval of the Engineer. When additional cement or water is added, a minimum of 25 revolutions of the truck mixer drum at mixing speed shall be required before discharge of the concrete.

Type F or Type G admixtures may be added to concrete for additional workability and/or to reduce the water cement ratio. Type F is a high range water reducer and Type G is a high range water reducer-retarder. When these admixtures are used, they are usually added at the job site just before discharge. The slump of the concrete shall be measured before the addition of the high range admixture and shall not exceed the maximum slump limits described above for normal concrete. Slumps measured after adding the admixtures are not valid as the admixture causes increased flow charac-

teristic of the mixture. Instead of slump measurements, a mixture that demonstrates good workability without excessive flow, bleeding or segregation shall be produced. The admixture may be added a second or third time to re-establish mixture flow provided the maximum time for placing the concrete after the mix water is added has not expired. The addition of the admixture will require additional mixing. Minimum mixing time shall be based on 30 seconds per cubic yard of concrete in the mixer after each addition of admixture.

701.22 Concrete Batching and Mixing.

A. Batching and Mixing in Cold Weather. No concrete shall be batched when the atmospheric temperature is below 35°F unless specifically authorized by the Engineer upon the receipt of a written satisfactory *Cold Weather Batching and Mixing Plan* developed by the Contractor. The Plan shall include how the Contractor intends to meet the following requirements. No concrete shall be batched from aggregates that contain frozen particles. Mixing water may be heated to a temperature not to exceed 170°F; the aggregates may be heated by either steam or dry heat. The heating apparatus shall be such as to heat the aggregates uniformly and avoid hot spots. The temperature of the batched concrete shall be at least 50°F when placed in the forms. The Engineer may add other requirements to the Plan at his discretion.

B. Batching and Mixing in Hot Weather. The Contractor shall consider the applicable requirements of ACI Standard 305 and shall take necessary measures to prevent the concrete mix temperature from exceeding 90°F measured before placement in the forms unless specified otherwise. Such measures may include, but are not limited to, using chilled mixing water or shaved ice to replace part of the mixing water and considering the use of Type II cement. This requirement will not apply to concrete used in precast/prestressed members.

C. Batching. When concrete is furnished by a transit or

central-mix plant, the batching equipment shall be sufficient to weigh out a load of required size in not more than 15 minutes.

A competent, SCDOT-certified Batch Plant Inspector shall be present at the plant when material is being produced for SCDOT work. The Batch Plant Inspector may be an employee of the Contractor, the concrete supplier, or an independent testing laboratory. However, it is the Contractor's responsibility to ensure that appropriately trained personnel and equipment are present and available when required. While material is being produced for SCDOT work, the Batch Plant Inspectors sole, full-time responsibility shall be to maintain quality control records and conduct physical testing of concrete and its constituent materials as outlined in the publication entitled *SCDOT Concrete Batch Plant Inspector's Handbook*, current edition. No concrete will be accepted by the Department unless the appropriate documentation, as defined by the *SCDOT Portland Cement Concrete Inspector's Manual*, is signed and certified by the Batch Plant Inspector and accompanies its delivery.

The Contractor shall give advance notification to the Engineer the name of the plant supplying the concrete in order to permit the Engineer to make the necessary arrangements for inspection of equipment at the plant.

D. Central Plant Mixing. Concrete shall be thoroughly mixed in a central mixer of an approved plant. The period of mixing after all materials including water are in the drum shall be a minimum of 1 1/2 minutes. During the mixing period, the drum shall be operated at drum speeds specified by the mixer manufacturer and shown on the nameplate on the machine. The first batch of concrete material placed in the mixer shall contain an additional quantity of sand, cement, and water to coat the inside surface of the drum.

Concrete shall be mixed only in quantities required for

immediate use. The mixed concrete shall be transported to the site of the work in a truck mixer operating at agitating speed.

E. Truck Mixing. Each batch shall be mixed at not less than 70 revolutions at mixing speed, after all materials, including water, have been placed in the mixer. All rotation after mixing shall be at agitating speed of 2 to 6 rpm or at the speed designated by the manufacturer of the equipment as agitating speed. Mixing speed shall be at the speed designated by the mixer manufacturer as shown on the rating plate. Mixing shall be done at the batching plant or at the job site. When concrete is in transit, the mixing unit shall be operated at agitating speed between the plant and the job site.

F. Wash Water Stabilizers. Ready mix concrete producers may use mixer drum wash water stabilizer agents in truck and central mix drums. Only those products that appear on the most recent edition of the *Approval Sheet 32* as published by the SCDOT Research and Materials Laboratory shall be used. These products shall be used in accordance with the Department's policy entitled *Stabilizer Agents and Methods for Mixer Drum Wash Water.* Approved stabilizer agents and methods of use will be shown in the policy. Copies of the policy can be obtained from:

Research and Materials Engineer
South Carolina Department of Transportation
Post Office Box 191
Columbia, SC 29202

The Engineer may eliminate the use of mixer drum wash water stabilizers if the Department's policy is not strictly adhered to or technical problems are encountered as a result of using a stabilizer.

701.23 Mobile Concrete Mixing Plants. A truck mounted mobile portland cement concrete plant, designed for automatic volume proportioning of the concrete materials and for

mixing the concrete for immediate use at the site of the work, may be used for incidental construction when authorized by the Engineer. Such plant shall be able to provide a satisfactory rate of production and shall be capable of combining the concrete ingredients into a thoroughly mixed and uniform mass and of discharging the concrete without segregation.

701.24 Use of Retarders. A water-reducing admixture or water-reducing set retarding admixture may be added to the concrete mixes for the purposes of reducing the water content and shrinkage in the concrete, improving its workability, retarding the initial set of the concrete, and/or reducing the rate of internal heat development in concrete pours without sacrificing quality or strength.

A Water Reducer-Retarder, Type D or Type G complying with Subsection **701.07** shall be used in concrete deposited under water and also in concrete that is not likely to reach its final position in the forms before initial set takes place. The proportioning and dispensing of the admixture shall be as specified in Subsection **701.19D**.

701.25 Use of Fly Ash and Water-Granulated Blast-Furnace Slag. The Contractor will be allowed to incorporate fly ash or water granulated blast-furnace slag into the concrete mixture. The following requirements shall be complied with when using these materials:

1. Fly ash or water-granulated blast-furnace slag may replace allowable percentages of Type I, Type II, or Type III portland cement. Fly ash or slag replacement is not allowed for mixes using Type I (SM) or any other blended cement.

2. Form removal shall be in accordance with Subsection **702.21**.

3. Fly ash shall replace the removed portland cement by a ratio of not less than 1.2 to 1 by weight and shall not replace more than 20% of the cement originally

called for in the mixture.

4. Water-granulated blast-furnace slag shall replace the removed portland cement by a ratio of 1:1 by weight and shall not replace more than 50% of the cement originally called for in mixture.

5. The Contractor shall submit a mix design to the Engineer for review seven (7) calendar days in advance of batching. The submittal shall indicate the amount of cement to be removed, the material that will replace it and compressive strength results of the mix.

6. After batching begins and as concrete is delivered to the job site, the Contractor will be responsible for furnishing concrete that contains the specified air entrainment content at the time it is discharged from the transit mixer. Concrete with the nonconforming air content shall not be used in the work.

7. Storage bins, conveying devices, weighing equipment, and weighing procedures to assure accurate batching shall be provided for each material (fly ash or slag) to be used.

8. Fly ash will be accepted only from sources that provide quality control of the product at the source and furnish with each shipment certified mill test reports.

9. Fly ash and water-granulated blast furnace slag will be accepted only from sources approved by the Research and Materials Engineer. The fly ash suppliers shall furnish certified mill test reports and shipping tickets as outlined in the Department's adopted *Policy for Fly Ash Inspection.* Water-granulated slag suppliers shall furnish certified mill test reports and shipping tickets as outlined in the Department's adopted *Policy for Portland Cement Concrete and Water-Granulated Blast Furnace Slag Manufacturers.*

701.26 Method of Measurement. The quantity of concrete measured for payment shall be the number of cubic yards of concrete of each class within the neat lines of the structure as shown on the plans or revised by the authority of the Engineer except that deductions shall be made from this yardage for the volume of embedded items other than reinforcing steel, and no deduction shall be made for chamfers of 3/4 inch size or smaller.

All cost for concrete used in precast/prestressed members, bridge railing, and drilled shafts, including the cost of designing the mix, testing, engaging the laboratory and furnishing the Engineer materials for testing, shall be included in the unit price for the applicable pay item(s).

701.27 Basis of Payment. The quantity of each class of concrete, determined as provided above, will be paid for at the contract unit price, excluding precast/prestressed members, bridge railing, and drilled shaft concrete, for each class of concrete, which price and payment shall be full compensation for furnishing all equipment, tools, materials, admixtures, falsework, falsework piling, forms, bracing, labor, surface finish, curing materials and other items of expense required to complete the concrete work shown on the plans or otherwise described, with the exception of reinforcing steel.

Unless otherwise specified, payment for concrete shall also include the cost of pipe drains, French drains and weep holes, expansion joints, expansion joint materials, flashing, pipes, conduits, anchors and other similar material. Payment for concrete shall also include cost of removing and disposing of portions of existing structures as designated on the plans, where such structures are widened or reconstructed and also the costs of drilling for dowels or expansion bolts.

Payment for this item includes all direct and indirect costs and expenses required to complete the work.

Payment will be made under:

Item No.	Pay Item	Pay Unit
7011XXX	Concrete for Structures - Class *(class)*	Cubic Yard

SECTION 702

CONCRETE STRUCTURES

702.01 Description. This work shall consist of the construction of all types of structures involving the use of structural concrete, except where the requirements are specifically waived or revised by another governing section of the specification. All concrete structures shall be constructed in accordance with the design requirements and details shown on the plans and in conformity with the requirements of this specification and any special provisions pertaining thereto.

MATERIALS

702.02 Concrete. All concrete shall conform to the provisions of Section **701**. The class of concrete for each type of structure, structural element, or concrete item shall be as specified on the plans or in the special provisions.

702.03 Expansion Material. Expansion material shall comply with the following requirements for the material involved:

A. Preformed Joint Filler. Preformed joint filler shall consist of preformed material composed of cane or other fibers of a cellular nature, securely bound together and uniformly saturated with a suitable bituminous binder and shall comply with the requirements of AASHTO M 213, or a preformed material composed of 100% scrap tire rubber, shredded and fused into cohesion with a non-toxic, odorless and tasteless formulated polyurethane binder. The shreds shall be treated to resist most types of microbes,