

Section 701. PORTLAND CEMENT CONCRETE FOR STRUCTURES

701.01 Description. Concrete shall consist of a mixture of Portland cement or blended Portland cement substitutes, fine aggregate, coarse aggregate, water, and admixtures when required or permitted, combined in the proportions for the various grades of concrete required.

Unless otherwise specified, air-entrained concrete will be required.

Where the term "sack" is used in this specification in relation to cement, it shall be interpreted as meaning a 94 pound sack of cement.

701.02 Materials. The materials shall meet the following requirements.

Cement	901
Fly Ash	901
Ground Granulated Blast-Furnace Slag	901
Coarse Aggregate 6A, 6AA	902
Fine Aggregate 2NS, 2SS	902
Concrete Admixtures	903
Water	911

The particular coarse aggregate required will be that specified in Table 701-1 for the grade of concrete specified.

Stone sand 2SS will be permitted only in concrete to be used in structure concrete not exposed to vehicular traffic.

Ground granulated blast-furnace slag may be used as a portion of the cementing material with Type IA or Type I Portland cement.

Concrete Accelerators. Accelerators containing calcium chloride shall not be used in concrete for bridges or where the concrete will contain embedded aluminum or galvanized steel.

701.03 General Requirements.

A. **Equipment.** All equipment shall be according to subsection 601.03.

B. **Mixing Concrete:**

1. **General.** Ready mixed concrete is produced and delivered as central mixed or truck mixed concrete. Central mixed concrete is concrete completely mixed in a central mixer and transported to the project site in a truck agitator, a truck mixer, or in approved non-agitating equipment. Truck mixed concrete is concrete completely mixed in a truck mixer with an approved revolution counter, at the plant site.

The Contractor shall provide communication service from the project to the batching plant which shall be available to the Engineer at all times during the concreting operations.

The mixer drum, and truck mixers, shall be entirely emptied after each batch before recharging.

The maximum batch size shall not exceed the capacity of the mixer as shown on the metal plate attached to the truck. Batch sizes for agitating units and truck mixers used to transport central mixed concrete shall not exceed the manufacturer's recommendation for maximum agitating capacity.

2. **Batch Mixing.** The drum or blades shall revolve at the speed or within the speed range recommended by the manufacturer and shown on the metal plate attached to the mixer.

The mixing time is measured from the time all cement and aggregates are in the drum until the beginning of discharge of the concrete. For multi-compartment mixers the mixing time includes the transfer time between drums. The ingredients shall be charged into the mixer so that some of the water will enter in advance of cement and aggregate, and substantially all the water is in the drum before one-third of the specified mixing time has elapsed.

- a. **Central Mixed Concrete.** The minimum time required for mixing each batch of central mixed concrete shall be 45 seconds for turbine mixers and 60 seconds for revolving drum and pugmill mixers, except that, for revolving drum and pugmill mixers having a capacity of one cubic yard or less, the minimum mixing time shall be 90 seconds.
 - b. **Truck Mixed Concrete.** Each batch of truck mixed concrete shall be mixed for more than 70 revolutions at mixing speed.
3. **Elapsed Time.** The time from charging of the mixer until complete discharge of the concrete into the work shall not exceed that specified in Table 701-2.

The time of charging is defined as the time the cement comes in contact with the mixing water or damp aggregates.

When it is anticipated that the time interval between charging and completion of discharge may exceed 30 minutes, the concrete shall be continuously agitated.

4. **Additional Water at Placement Site.** For concrete transported in truck mixers, if additional mixing water is required to obtain the specified slump, and the truck mixer is not loaded in excess of its rated mixing capacity, water may be added. After all water is added, a minimum of 30 revolutions of the truck mixer drum at mixing speed will be required before discharge of any concrete. The additional water shall be added and the additional mixing completed at the project site within the maximum time interval specified in Table 701-2. Except for fog curing, no water shall be added to the concrete during discharge or placement. In particular, no water shall be added in truck chutes or in pump or slipform hoppers.

Table 701-1 Concrete Structure Mixtures

Cement Content cu yd(b)(c) (1)=IA (3)=IP-A,(PM)-A (2)=IS-A,(SM)-A				Slump, inches				Minimum Strength of Concrete (f)					
Grade of Concrete (e)	Cement Content (b) (c)		Fly Ash cu yd	Type A, D or no Admixtures	Type MR (g), or F, G Admixtures			Flexural psi			Compressive, psi		
	lb/cyd	Sacks			Before Admixture	After Admixture (Type MR) Mid-Range	After Admixtures (Type F or G)	At 7 Days	At 14 Days	At 28 Days (Design Strength)	At 7 Days	At 14 Days	At 28 Days (Design Strength)
D(a)	658(d)(1) (2)(3)	7.0	0	0-3½	0-3	0-6	0-7	625	700	725	3200	4000	4500
S1	610 (1)(2)(3)	6.5	0	3-5	0-3	3-6	3-7	600	650	700	3000	3500	4000
	545 (d)(1)	5.8	92										
T	610 (1)(2)(3)	6.5	0	3 -7	0-4	3 -7	3-8	550	600	650	2600	3000	3500
	545 (d)(1)	5.8	92										
S2(a)	565 (1)(2)(3)	6.0	0	0-3	0-3	0-6	0-7	550	600	650	2600	3000	3500
	526(d)(1) (2)(3)	5.6	0										
	518 (1)	5.5	78										
	481 (d)(1)	5.1	72										
S3	518 (1)(2)(3)	5.5	0	0-3	0-3	0-6	0-7	500	550	600	2200	2600	3000
	489(d)(1) (2)(3)	5.2	0										
	470 (1)	5.0	71										
	452 (d)(1)	4.8	68										

a. Unless otherwise specified, Coarse Aggregate 6AA shall be used for exposed structural concrete used in bridges, retaining walls, and pumphouses.

b. Concrete mixtures containing Type IS-A, I(SM)-A, IP-A, or I(PM)-A cement, or containing ground granulated blast-furnace slag or fly ash, shall not be used on projects in the Lower Peninsula between October 15 and April 1 nor in the Upper Peninsula between October 1 and April 15, except this restriction does not apply to Grade S1 concrete used in foundation piling below ground level, and Grade T concrete used in tremie construction.

c. Non-air-entraining cement corresponding to the types of air-entraining cement listed may be used with an approved air-entraining admixture to produce the specified air content.

d. The quantity of admixture shall be as indicated in the *Materials Source Guide* to provide reduction in mixing water and is required for Grade D concrete and Grades S1, S2, S3 and T having reduced cement content. The admixture used in Grade D concrete shall be a water-reducing retarding admixture and shall be used in such amounts to provide the necessary retardation of setting. When the air temperature is not expected to exceed 60 °F for the day, the Contractor shall have the option of using a water-reducing admixture or a water-reducing retarding admixture. Grade D concrete used in concrete diaphragms shall contain either a water-reducing admixture or a water-reducing retarding admixture.

e. The mix design basis for bulk volume (dry, loose) of coarse aggregate per unit volume of concrete is 68% for Grade S1; 70% for Grades D, S2, T, and S3.

f. Flexural strength may be used for determining when to remove forms. Compressive strength shall be used for acceptance in all other situations.

g. Mid-range.

**Table 701-2 Maximum Time Interval Between Charging Mixer
and Placing Structural Concrete**

Type of Unit	Temperature of Concrete (ASTM C1064)		
	Below 60 °F	60 °F to 85 °F	Above 85 °F
Closed Top Agitating Units and Truck Mixers	90	60	45
Closed Top Agitating Units and Truck Mixers with Concrete Containing Water Reducing Retarding Admixture (a)	120	90	70
a. Does not apply to superstructure concrete. (Superstructure concrete shall meet the time limits for closed top agitating units and truck mixers.)			

5. **Volumetric Batching and Continuous Mixing.** Where volumetric batching and continuous mixing methods are used, concrete shall be proportioned, mixed, and discharged according to ASTM C 685.

C. Cold Weather Requirements:

1. **Heating of Ingredients for Concrete.** The ingredients for concrete shall be heated whenever necessary to produce concrete having a temperature of not less than 45 °F. When the concrete ingredients are heated, the concrete temperature shall not exceed 80 °F, except that when concrete is placed in insulated forms, the temperature shall not exceed 70 °F.

Heated concrete shall be obtained by heating the water or aggregates, or both. Aggregates shall not be heated over 150 °F. The water shall be mixed with the aggregates before the cement is added.

The aggregates shall be free of ice and frozen lumps at time of batching. Aggregates in stockpiles or bins shall be heated by steam or hot water coils, live steam, or by indirect hot air. Heating by direct flame will not be permitted for coarse aggregate. Accumulated condensation from heating shall be compensated for during batching operations to maintain slump within allowable limits.

- D. **Concrete Temperature Limitations.** The concrete temperature shall be between 45 °F and 90 °F at the time of placement.

- E. **Determining Volume of Concrete Used.** The Engineer will determine the volume of concrete used each day or fraction thereof, or for each individual pour based on the number of batches placed in the work and the nominal volume of concrete per batch.

This quantity will be compared with the estimated plan quantities of concrete required. If the volume of concrete used overruns the plan quantity by 6 percent or more, or underruns the plan quantity, all factors which may affect the quantity of concrete shall be checked and all irregularities corrected.

F. Concrete Mixture Requirements.

1. **General.** The Contractor is responsible for quality control for concrete according to subsection 604.

The Contractor is responsible for concrete quality assurance according to subsection 605, when the corresponding pay items are shown on the plans.

The Engineer will provide the mix design requirements on all other projects based on the Contractor's choice of materials from approved sources. Mixture proportions will be designed to provide concrete that meets the requirements in Table 701-1, however, the Contractor must immediately correct concrete production and placement methods should the requirements not be met.

Mix designs will designate the amounts of cementitious materials, fine aggregate, coarse aggregate, and the amount of water required per cubic meter of concrete. Contractor modifications to the Department's mix design are restricted to, increased coarse aggregate content, or decreased water content, at no cost to the Department.

2. **Mixes Using Additional Fly Ash or Ground Granulated Blast Furnace Slag (GGBFS).** Fly ash may be used in the concrete mixture according to Table 701-1. A greater quantity of fly ash may be used, subject to the following requirements.
 - a. A Contractor mix design by a testing laboratory conforming to ASTM C 1077, and verification by the laboratory that the mix design produces concrete with 28-day compressive strength in excess of the requirements in Table 701-1 by at least 500 psi, must be submitted for approval by the Engineer. Concrete shall be made and cured according to ASTM C 192, with a minimum of three batches made and tested according to the grade of concrete. Any subsequent change in any of the mixture constituents will require that new laboratory data be submitted for reapproval by the Engineer.
 - b. Type I or IA Portland cement must be used.
 - c. The cement quantity for Type I or Type IA shown in Table 701-1 may be reduced up to a maximum of 25 percent for fly ash substitution or up to a maximum of 40 percent GGBFS substitutions.
 - d. The fly ash or GGBFS weights shall be equal to the weight of the cement reduction.
 - e. If fly ash and GGBFS are used in the same mixture, the cement quantity shown in Table 701-1 may be reduced up to a maximum of 40 percent of which the fly ash quantity shall not exceed 15 percent.
3. **Air Content.** The use of defoaming (air-detraining) admixtures will not be permitted. All concrete shall be air-entrained and shall contain 6.5 ± 1.5 percent entrained air, except as follows.

For concrete containing Type F or Type G admixtures, the air content shall be 7.0 ± 1.5 percent.

For concrete furnished for placement by slipform methods and having a slump of $1\frac{1}{2}$ inches or less, the minimum entrained-air content permitted will be 4.5 percent.

Concrete to be used for cast-in-place concrete slope paving and related headers shall contain 6.5 ± 3.0 percent entrained air.

For all concrete that lies in the finished work at least 3 feet below the surface of the ground or entirely under water, an air content of less than 5 percent will not be cause for rejection.

For concrete placed in steel shell piles, non-air-entrained concrete will be permitted in piles not subject to freezing.

The air content of freshly mixed concrete will be determined by the Department's modification of ASTM C 231 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method or by ASTM C 173 Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method. Samples will be taken according to MTM 207.

The air content of freshly mixed concrete containing slag or other highly porous coarse aggregate will be determined by the volumetric method, ASTM C 173. Samples will be taken according to MTM 207.

When the Contractor adjusts the amount of air-entraining admixture used, the actual amount used per sack of cement or per batch of concrete shall be recorded on the first delivery ticket following the adjustment.

When concrete having low air content is received at the project site in truck mixers, the Contractor may add additional air-entraining admixture at the site, with additional mixing as necessary, until adjustments can be made at the batching plant.

4. **Water-Reducing Admixtures.** Concrete mixtures containing an admixture shall meet the requirements for strength, slump, and air content required for the respective grade of concrete without an admixture.

When a water reducing admixture is used, it shall be added according to the manufacturer's recommendations. The dosage used shall not be less than the amount indicated on the Qualified Products List. Admixture dosage rates shall be based on the total cementitious material (cement plus fly ash or ground granulated blast-furnace slag when used) in the concrete.

When a concrete mixture containing a Type A, D or mid-range (MR) admixture requires retempering due to loss of slump, the consistency may be restored according to subsection 701.03.B.4.

When a concrete mixture containing a Type F or G admixture requires retempering due to loss of slump, the consistency shall be restored only by the further addition of Type F or G admixture. This additional admixture may be added manually. The mixing drum must be turned a minimum of 45 revolutions at mixing speed after addition of the admixture.

5. **Slump.** The slump of concrete mixes will be determined by the ASTM C 143 slump cone test, except that the samples will be taken according to MTM 207 at the project site.

The slump of the concrete shall not exceed the limits shown in Table 701-1, for the grade and usage specified.

G. **Strength of Concrete.**

1. **Quality Assurance** - Refer to section 605.
2. **Non Quality Assurance - Strength of Concrete.** Concrete test specimens will be made at frequent intervals from the concrete being incorporated in the work. Concrete for test specimens and labor for making and transporting them to the designated testing laboratory shall be furnished without charge by the Contractor. Molds and testing equipment for specimens will be furnished by the Department. Removal of forms may be based on flexural strength. Compressive strength shall be used for acceptance in all other situations.

The Contractor's personnel performing designated sampling and testing shall be a certified concrete technician(s) (Michigan Level I or II) through a program certified by the Michigan Concrete Association or through the Michigan Concrete Paving Association (Level I - three year certification). The Contractor shall furnish the name(s) and credentials of the concrete technician(s) to the Engineer prior to sampling and testing.

Test specimens will be made according to AASHTO T 23, Method of Making and Curing Concrete Compressive and Flexural Strength Test Specimens in the Field. Test specimens for determining conformance to the strengths shown in Table 701-1 shall be cured according to Section 9.2 of T 23, Curing Specimens as the Basis for Acceptance or Section 9.3 of T 23, Curing Specimens as the Basis for Acceptance at Remote Sites.

Concrete cylinders shall be compression tested according to AASHTO T 22, Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens. Unbonded caps allowed by the annex of AASHTO T 22 are acceptable. Use unbonded caps according to MTM 206, Test Method for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders.

Flexural strength will be determined according to Department procedures which are based on a modification of ASTM C 293, Test Method for Flexural Strength of Concrete (Using Simple Beams with Center-Point Loading). If compressive strength is determined on beam ends according to ASTM C 116, that strength will be reduced by

20 percent to provide results comparable to results which would be obtained on a cylinder having a height-to-diameter ratio of two.

If the average strength from compression tests on two companion cylinders is less than the 28-day strength shown in Table 701-1, then the Engineer may:

- a. Require the Contractor to remove and replace the concrete at no cost to the Department.
- b. Determine if the concrete has sufficient structural strength; if so, prorate the unit price for affected pay items and quantity represented based on the following formula:

$$\text{Adj. Unit Price} = \frac{\text{Tested Strength}}{\text{Strength}^*} \times (\text{Unit Price})$$

*Minimum Strength of Concrete shown in Table 701-1

- c. Allow the Contractor to submit a plan, for approval for corrective action to be performed at no cost to the Department. If the plan for corrective action is not approved, either option (a) or (b) may be applied.
3. **Work Progress Specimens.** The strength of structure concrete for opening to construction traffic or regular traffic, for removing shoring and forms, or for other similar purposes will be determined by one or more of the following methods, deemed appropriate by the Engineer. Refer to subsection 104.11 for requirement for opening to construction traffic.

Concrete containing ground granulated blast-furnace slag or fly ash may gain strength at a slower rate during early stages (prior to 28 days) than if only Portland cement was used. The Contractor shall adjust operations as necessary for staging activities to conform with the actual strength gained by the concrete.

- a. **Test Cylinders or Beams.** A series of test cylinders or beams may be made and cured under environmental conditions similar to the pavement or structure.
- b. **Non-Destructive Tests.** Non-destructive test equipment will be calibrated between the strength level of flexure or compression test specimens at various stages of curing, and rebound number measured by a concrete test hammer, or penetration resistance. The calibration shall be for a given instrument and for the specific materials and concrete mix used in the work. Occasional cylinders or beams will be made and tested during the course of the work to verify the calibration. Testing for calibration and for determination of strength shall be performed in the presence of the Engineer. Non-destructive tests on the structure shall be made by the Contractor at locations designated or approved by the Engineer. Non-destructive tests shall be performed according to ASTM C 803 or C 805.

- H. **Furnishing and Handling Aggregates.** The fine and coarse aggregates shall be furnished, stocked and handled in a manner to prevent segregation. Fine aggregates, coarse aggregates and aggregates secured from different sources shall be placed in separate bins or stockpiles. The ground area for stockpiles shall be firm, reasonably level, and thoroughly cleaned of all foreign materials. If paved areas are not used, the bottom one foot of the stockpile will not be used. Frozen aggregate lumps shall not be used. Equipment that causes contamination or degradation will not be permitted. The aggregate moisture content will be kept uniform for each day's run without evidence of any surplus water. Stockpiles of slag or other highly absorptive aggregates shall be kept continuously wet to maintain a uniform moisture content.

The fine and coarse aggregates to be used in work for the Department shall be stocked in separate piles or bins apart from aggregates to be used in other work. When the coarse aggregate consists of a blend of two more gradations, each gradation shall be stockpiled separately.

- I. **Furnishing and Handling Cement, Ground Blast-Furnace Slag, and Fly Ash.** Cement, ground granulated blast-furnace slag, and fly ash furnished to the project in bulk form shall be stored in separate weatherproof bins. Wet or contaminated material will not be used.

If the Contractor changes source or type of cement, source or class of fly ash, or source or grade of ground granulated blast-furnace slag, the bin shall be emptied to within the quantity used for two batches of concrete before refilling with new material. Notice of the material change shall be recorded on the first ticket (see subsection 601.03.4) for concrete delivered to each project.

The Contractor shall furnish the Engineer with a copy of the shipment notice showing the quantity of cement, ground granulated blast-furnace slag, or fly ash in each shipment and containing a certification that the material meets Department requirements.

701.04 Measurement and Payment. Not directly specified. Structure concrete mixtures, associated materials, equipment and labor are included in other contract items (pay items).