MATERIAL SPECIFICATION FOR CONCRETE - MATERIALS AND PRODUCTION

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1350.01 SCOPE

This specification covers the requirements for materials and methods for proportioning, mixing and transporting concrete.
1350.02 REFERENCES

This specification refers to the following standards, specifications or publications:

**Ontario Provincial Standard Specifications, Construction:**

OPSS 904  Concrete Structures
OPSS 930  Structure Rehabilitation - Concrete Patches and Overlays

**Ontario Provincial Standard Specifications, Material:**

OPSS 1001  Aggregates - General
OPSS 1002  Aggregates - Concrete
OPSS 1301  Cementing Materials
OPSS 1302  Water
OPSS 1303  Air Entraining and Chemical Admixtures for Concrete

**Canadian Standards Association Standards:**

CAN/CSA A23.2-M90 - Methods of Test for Concrete
CAN/CSA A5-93 - Portland Cement

**American Society for Testing and Materials Standards:**

ASTM C457-90 - Practice for Microscopical Determination of Air Void Content and Parameters of the Air Void System in Hardened Concrete
ASTM C496-90 - Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
ASTM C684-89 - Method of Making, Accelerated Curing, and Testing of Concrete Compression Test Specimens

**American Concrete Institute:**

ACI 211.1-91 - Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete

1350.03 DEFINITIONS

For the purposes of this specification the following definitions apply:

**Cold Weather:** means those conditions when the air temperature is at or below 5°C. It is also considered to exist when the air temperature is at or is likely to fall below 5°C within 96 h after concrete placement. Temperature refers to shade temperature.

**Continuous Concrete Mixing Plant - Mobile Mixer Truck:** means a plant that has materials, cement and aggregates stored individually and which batches through a volumetric calibrated system to a discharging auger mixing chute.

**Hot Weather:** means those conditions when the air temperature is at or above 28°C. It is also considered to exist when the air temperature is at or is likely to rise above 28°C within 24 h. Temperature refers to shade temperature.

**Inspector:** means a representative of the Owner of the contract to which the concrete is being supplied.
Mobile Mix Concrete: means concrete that is completely batched and mixed by a mobile mixer truck at the site.

Non-Structural Concrete: means concrete that is non-reinforced, and used in components that are not designed to withstand heavy loads or that is used as fill material in excavations.

Portland Cement: means the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates to which calcium sulphate, limestone, water and processing additions may be added at the option of the manufacturer.

Ready Mixed Concrete: means concrete that is completely batched at the plant and completely mixed in a truck at the plant, or while in transit.

Stationary Mixer: means a non-mobile mixer installed at a plant for the purpose of mixing concrete.

Tremie Concrete: means concrete placed by means of a tremie.

Truck Mixer: means a concrete mixer mounted on a truck or other vehicle used for the complete mixing of concrete ingredients after they have been batched at the plant.

1350.04 SUBMISSION AND DESIGN REQUIREMENTS

1350.04.01 Submissions

1350.04.01.01 Concrete Mix Data

At least two weeks prior to the delivery of concrete, the concrete supplier shall submit, to the concrete purchaser, a statement detailing the material, sources and proportions of materials to be used for each class of concrete including the fineness modulus of the fine aggregate.

The statement shall include the purchaser's name, contract number, concrete supplier's name, supplier's mix design number, primary plant location and back-up plant, intended mix use, air and slump range for each intended use.

The quantity of chemical admixtures shall be at least the specified minimum dose in conformance with OPSS 128.

1350.04.01.02 Ready Mix Concrete Operation or Mobile Mix Concrete Operation

At least one week prior to the delivery of concrete to the site, the concrete supplier shall submit to the concrete purchaser a currently valid Certificate of Ready Mixed Concrete Production Facilities or a currently valid Certificate of Mobile Mix Concrete Production Facilities as issued by the Ready Mixed Concrete Association of Ontario to the plant being used.

1350.04.01.03 Mix Design Materials

Samples of aggregates, cementing materials, water, chemical admixtures and air entraining admixtures, representative of the materials to be used in the work shall be provided when requested by the concrete purchaser.

1350.04.01.04 Concrete Delivery Ticket

Two copies of the delivery ticket shall be supplied to the concrete purchaser prior to unloading at the site.
1350.04.02 Design

The concrete mix shall be designed in conformance with the general requirements of ACI 211.1.

1350.05 MATERIALS

1350.05.01 Materials for Concrete

1350.05.01.01 Cementing Materials

Cementing materials shall conform to OPSS 1301.

When concrete is produced by a mobile mixer truck or when non-agitating trucks are used, the cement shall be certified as being free from early stiffening tendencies when tested in conformance with CAN/CSA A5 Appendix A, early stiffening of cement paste.

Portland Cement shall be used, however, a portion of it may be replaced by supplementary cementing material. The supplementary cementing material shall be a ground granulated blast furnace slag or fly ash or a combination of the two materials.

The supplementary cementing materials shall be restricted to the following proportions by mass of the total cementing material:

a. Slag up to 25%;
b. Fly ash up to 10%;
c. A mixture of slag and fly ash up to 25% except that the amount of fly ash shall not exceed 10% by mass of the total cementing materials.

Neither slag nor fly ash shall be used for lean concrete base.

Except when the Portland Cement and supplementary cementing materials are supplied blended, the supplementary cementing material shall be weighed separately from the Portland Cement. In the concrete materials weighing process the Portland Cement shall be weighed prior to the supplementary cementing material. Supplementary cementing materials may be weighed on the same scale with the Portland Cement.

1350.05.01.02 Aggregates

Aggregates shall conform to OPSS 1001 and OPSS 1002.

The maximum nominal size of aggregate shall not exceed 19.0 mm.

1350.05.01.03 Water

Water for concrete shall conform to OPSS 1302.

1350.05.01.04 Air Entraining and Chemical Admixtures

Air entraining and chemical admixtures shall conform to OPSS 1303.
1350.05.02 Physical Requirements for Concrete

1350.05.02.01 Strength

The concrete strength shall be as specified in the Contract.

1350.05.02.02 Cementing Materials Content

The minimum cementing materials content of the concrete shall be as shown in Table 1.

**TABLE 1**
CEMENTING MATERIALS CONTENT

<table>
<thead>
<tr>
<th>CLASS OF CONCRETE</th>
<th>MINIMUM CEMENTING MATERIALS CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum 28 d Strength in MPa</td>
<td>kilograms per Cubic metre Concrete</td>
</tr>
<tr>
<td>15</td>
<td>250</td>
</tr>
<tr>
<td>20</td>
<td>310</td>
</tr>
<tr>
<td>30</td>
<td>355</td>
</tr>
<tr>
<td>≥ 35</td>
<td>&gt; 355 *</td>
</tr>
<tr>
<td>Tremie Concrete</td>
<td>415</td>
</tr>
</tbody>
</table>

* The cementing materials content shall be determined from tests, and shall be sufficient to produce durable concrete.

1350.05.02.03 Air Content

The total air content of the concrete, measured with an air meter, immediately prior to placing shall be as shown in Table 2.

**TABLE 2**
AIR CONTENT

<table>
<thead>
<tr>
<th>Nominal Max Size of Coarse Aggregate in Concrete (mm)</th>
<th>Air Content Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0</td>
<td>7.0 ± 1.5</td>
</tr>
<tr>
<td>13.2</td>
<td>8.0 ± 1.5</td>
</tr>
<tr>
<td>9.5</td>
<td>8.0 ± 1.5</td>
</tr>
<tr>
<td>* Precast Beams</td>
<td>4.0 ± 1.0</td>
</tr>
<tr>
<td>* Precast Concrete Facing</td>
<td></td>
</tr>
<tr>
<td>* Permanent Precast Barriers</td>
<td></td>
</tr>
<tr>
<td>Tremie Concrete</td>
<td>when required</td>
</tr>
<tr>
<td>Sand-Cement Mortar</td>
<td>12.0 ± 1.5</td>
</tr>
</tbody>
</table>

* The air void system will be measured in hardened concrete in conformance with the method specified in Quality Assurance.
1350.05.02.04 Slump

Slump shall be as specified in Table 3 prior to the addition of superplasticizer.

TABLE 3
SLUMP

<table>
<thead>
<tr>
<th>COMPONENTS</th>
<th>SLUMP mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced concrete within vertical formwork such as abutments, columns, piers, walls and beams and footings.</td>
<td>80 ± 20</td>
</tr>
<tr>
<td>Reinforced or plain concrete in flat sections such as bridge decks, and approach slabs.</td>
<td>70 ± 20</td>
</tr>
<tr>
<td>Slipformed barrier walls.</td>
<td>15 ± 10</td>
</tr>
<tr>
<td>Tremie Concrete</td>
<td>150 ± 20</td>
</tr>
</tbody>
</table>

Slump will be measured in conformance with CAN/CSA A23.2-5C. Maximum slump for concrete to which superplasticizer has been added is 180 mm.

1350.05.02.05 Within Batch Uniformity of Concrete

The within batch uniformity of concrete shall meet the requirements shown in Table 6.

1350.05.03 Chemical Admixtures

1350.05.03.01 Type

One of the first six chemical admixtures listed in Table 4 shall be used in the concrete.

Accelerators shall only be used when specified in the Contract.

TABLE 4
CHEMICAL ADMIXTURES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>WATER REDUCING</th>
<th>HIGH RANGE WATER REDUCER</th>
<th>STRENGTH INCREASING</th>
<th>SET RETARDING</th>
<th>EXTENDED RETARDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>WN</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WR</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RX</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SP</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1350.06 EQUIPMENT

1350.06.01 Batching Plant

The batching plant and equipment shall conform to the certification requirements of the Ready Mixed Concrete Association of Ontario.

The batching plant shall have either a radio or telephone communication with the placement operation.

1350.06.02 Mixing Equipment

All mixers shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass, and of discharging the concrete so that the uniformity requirements of Table 6 are met.

1350.07 PRODUCTION

1350.07.01 General

Concrete shall be produced at a plant certified by Ready Mixed Concrete Association of Ontario.

The entire contents of the mixer shall be discharged before recharging.

When any ingredient is added after initial batching the volume of material in the drum shall not exceed the mixing capacity of the drum.

Proper facilities shall be provided to enable inspection of the materials, both as to quality and quantity, and the processes used in the manufacture and delivery of the concrete. The inspector shall be provided with all reasonable facilities for securing samples to determine whether the concrete and its materials are being supplied in conformance with the specification.

Where there is evidence of inaccurately batched loads of concrete, recalibration of the scales or weighing devices may be required.

1350.07.02 Measurement of Materials

When ice is used as part of the mixing water the ice shall be measured by mass.

Mixers shall be completely emptied of wash water prior to the loading of a concrete batch.

When concrete is mixed in a truck mixer and more than 10 percent of the required mix water is added from the truck water system such water shall be measured with a water meter, or other approved device, to an accuracy of 1 percent.

1350.07.03 Continuous Concrete Mixing Plant - Mobile Mixer Truck

Concrete produced by a mobile continuous concrete mixing plant will only be allowed when,

1. The concrete is non structural concrete.

2. The required concrete strength at 28 d is 30 MPa or less.

3. The plant is certified and calibrated in conformance with the certification requirements of Ready Mixed Concrete Association of Ontario and the calibration is done within four months of use.
An aggregate discharge test shall be made in conformance with OPSS 930 whenever the aggregate sources are changed or when proportions appear suspect.

Concrete produced prior to an acceptable initial air and slump test will not be accepted.

1350.07.04 Mixing Time and Mixing Rate

Mixers shall be rotated at the speed recommended by the manufacturer of the mixer.

Mixing time shall be measured from the time that all cementitious materials, cement and aggregates are in the drum.

The minimum mixing time for concrete shall be as recommended by the equipment manufacturer or the minimum time required to produce concrete meeting the acceptance criteria of Table 6 whichever is greater.

When a truck mixer is used for complete mixing and is loaded to its rated maximum mixing capacity, each batch of concrete shall be mixed for not less than 70 nor more than 100 revolutions of the drum.

After completion of mixing, the truck mixer drum shall be rotated at the designed agitating speed until discharge of concrete commences.

When a stationary mixer is used for partial mixing of concrete prior to transferring to a truck mixer, the mixing time shall be no more than is required to intermingle the ingredients. After transfer to a truck mixer further mixing at the designated mixing speed shall be carried out.

1350.07.05 Temperature Control

1350.07.05.01 General

The concrete temperature at the time of discharge from the truck shall be at or between 10°C and 28°C.

The temperature of the cementing materials shall be less than 65°C immediately prior to batching.

1350.07.05.02 Cold Weather Concrete

Water brought into direct contact with the cementing materials shall have a temperature less than 40°C.

The plant shall have a water temperature indicator so installed that the batch operator can ensure that the temperature restrictions for water are being met for each batch.

The method of heating aggregate stockpiles shall be such as to produce uniform conditions without local hot spots. Provision shall be made for heating aggregates in the batch plant storage bins.

Frozen lumps of aggregate shall not be added to the concrete.

1350.07.05.03 Hot Weather Concrete

Any method to be used to control the concrete temperature shall be submitted to the concrete purchaser.

When ice is added to the concrete it shall be completely melted by the time concrete mixing is completed.

When the air temperature exceeds 28°C, and the concrete temperature exceeds 25°C, the concrete delivered by means of agitators or truck mixers shall be discharged within 1 h after the introduction of the mixing water.
Concrete Strengths 35 MPa or Greater

1350.07.06.01 Trial Batch

The concrete mix proportions for concrete with strengths of 35 MPa or greater shall be confirmed by means of test cylinders.

The testing of the field trial batch of concrete shall be the responsibility of the Contractor.

At least 30 d prior to placing concrete of 35 MPa strength, or greater, the concrete supplier shall mix a full size trial batch of concrete in the proportions designed.

When the concrete is mixed within a ready mixed truck, the volume of the trial batch shall be the volume of concrete normally mixed in the truck.

When the source of concrete is a ready mix plant a trial batch of concrete shall originate from each plant that will be used for the supply of the concrete and the trial batch shall be delivered to the site of the work or as directed by the concrete purchaser.

When an approved ready mixed concrete operation is currently supplying or has supplied a class of concrete to another of the Owner’s contracts, within the last 12 months, that requires tests in conformance with this clause, permission may be given to use concrete from that operation without the need for full size field trial batches, providing that:

a. There is no change in the source of any material.

b. The quality and grading of the aggregates have not changed significantly.

c. The concrete mix designated and previously used meets the specified requirements.

d. Documentation of this prior approval is submitted to the concrete purchaser.

1350.07.06.02 Early Strength Determination of Mix Design

When agreed upon with the concrete purchaser accelerated tests may be used to predict the 28 d strength of the proposed concrete mix.

The cylinders shall be tested in conformance with the autogenous curing test procedure C of ASTM C684.

Table 5 lists the 2 d accelerated strengths and the usually accepted corresponding 28 d strengths of standard cured cylinders.
### TABLE 5

**2 DAY ACCELERATED STRENGTHS**

<table>
<thead>
<tr>
<th>Minimum 28 d Strength in MPa</th>
<th>Corresponding 2 d Accelerated Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>8.4</td>
</tr>
<tr>
<td>25</td>
<td>12.9</td>
</tr>
<tr>
<td>30</td>
<td>17.4</td>
</tr>
<tr>
<td>35</td>
<td>21.9</td>
</tr>
<tr>
<td>40</td>
<td>26.4</td>
</tr>
</tbody>
</table>

---

1350.07.07  Ready Mix Concrete

1350.07.07.01  Delivery of Ready Mix Concrete

1. **Delivery with Non-agitating Equipment**

Concrete that is completely mixed in a stationary mixer may be transported in non-agitating equipment. The bodies of such equipment shall be smooth, water tight, steel containers equipped with gates that will permit control of the discharge of the concrete.

Covers shall be used to provide protection during inclement weather. The concrete shall be delivered to the site, without segregation, in a thoroughly mixed and uniform mass, and discharged with the uniformity required in Table 6.

Discharge of concrete shall be complete within 30 min after introduction of the mixing water to the cement and aggregates.

2. **Delivery with Agitators or Truck Mixers**

After completion of mixing, concrete shall be transported to the site by means of agitator trucks or truck mixers. The equipment shall be operated at the speed of rotation designated by the manufacturers of the truck as the agitating speed.

The concrete shall be delivered to the site, in a thoroughly mixed and uniform mass, and discharged with the uniformity required in Table 6.

Except as specified for Hot Weather Concrete, when concrete is transported to the site by means of agitating or mixing equipment, discharge of the concrete shall be completed within 1.5 h after introduction of the mixing water to the cement and aggregates.

1350.07.07.02  Site Addition of Materials

When a truck mixer is used at agitating capacity no adjustment shall be made to the load of concrete.

When a truck mixer is used for mixing of the concrete, no water from the truck water system shall be added after the initial introduction of the mixing water to the load of concrete except when, at the start of discharge, the measured slump of the concrete is less than that specified.
Water shall not be added to the load of concrete at any later time.

Air entraining admixture may be added to the load of concrete prior to discharge to increase the air content to that specified. The use of detraining admixtures to lower the air content of concrete is prohibited.

When any material is added to the concrete, the load of concrete shall be mixed for an additional 30 revolutions or more if necessary, at the designated mixing speed, so that the uniformity requirements of Table 6 are complied with.

1350.07.08 Delivery Tickets

The concrete supplier shall provide to the concrete purchaser, with each load of concrete, two copies of the delivery ticket on which shall be printed, stamped or written the following information:

a. name and location of plant

b. time of batching concrete which shall be stamped, by time clock, within five minutes of batching

c. mix proportions of concrete or the concrete supplier's mix design number.

d. specified minimum 28 d compressive strength of concrete.

1350.08 QUALITY ASSURANCE

1350.08.01 Sampling and Testing

1350.08.01.01 General

Tests to determine the quality of the plastic concrete will be made at the work site.

Testing for slump, air content, compressive strength, yield and temperature will be done in conformance with the following:

Slump: CAN/CSA A23.2-5C, Slump of Concrete

Air Content: CAN/CSA A23.2-4C, Air Content of Plastic Concrete by the Pressure Method

Compressive Strength: CAN/CSA A23.2-9C, Compressive Strength of Cylindrical Concrete Specimens and CAN/CSA A23.2-3C, Making and Curing Concrete Compression and Flexure Test Specimens

Accelerating the Cure of Concrete Cylinders and Determining their Compressive Strength (Accelerated Cured): CAN/CSA A23.2-10C, Methods of Making, Curing and Determining the Compressive Strength of Accelerated Cured Concrete Test Specimens in the Field

Yield: CAN/CSA A23.2-6C, Density, Yield and Cement Materials Factor of Plastic Concrete
1350.08.01.02 Air Content in Hardened Concrete

The air void system in the hardened concrete will be tested in conformance with ASTM C457, using magnification not less than 100 x and shall be:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Content Percent</td>
<td>3.0 minimum</td>
</tr>
<tr>
<td>Spacing Factor</td>
<td>0.2 mm maximum</td>
</tr>
<tr>
<td>Specific Surface</td>
<td>25.0 mm$^{-1}$ minimum</td>
</tr>
</tbody>
</table>

1350.08.01.03 Testing for Uniformity of Mixed Concrete

When required, tests to determine the within batch uniformity of mixed concrete as specified in Table 6, will be done in conformance with OPSS 904.

1350.08.01.04 Strength Tests and Requirements

Compressive Strength

For the purpose of acceptance on the basis of concrete strength, cylinders shall be made and cured in conformance with CAN/CSA A23.2-3C under standard moisture and temperature conditions and tested in conformance with CAN/CSA A23.2-9C.

To conform to the specified nominal minimum 28 d strength requirements:

a. The average of all groups of three consecutive strength tests shall be equal to or greater than the specified strength.

b. No individual strength test shall be more than 3.5 MPa below the specified strength.

A compressive strength test result is the average strength of two standard 150 x 300 mm concrete cylinders.

Flexural Strength

Concrete for pavement and base shall meet the requirements for compressive strength and also flexural strength as stated here. The minimum flexural strength shall be 3.8 MPa at 10 d.

A flexural strength test is the average of two breaks on a 150 x 150 x 900 mm long beam representative of concrete taken from one batch of concrete.

Flexural strength test beams shall be made and cured in conformance with CAN/CSA A23.2-3C depending on the particular circumstances. The method of testing shall be as specified in CAN/CSA A23.2-8C.

Alternatively a splitting tensile test may be carried out instead of the flexural strength test. One splitting tensile test shall be considered to be the average of two standard 150 x 300 mm cylinders representative of concrete taken from one batch of concrete. The splitting tensile test cylinders shall be made in conformance with CAN/CSA A23.2-3C. The method of testing shall be in conformance with CAN/CSA A23.2-13C or ASTM Standard C496. The minimum splitting tensile strength shall be 2.8 MPa at 10 d.

To conform to the specified nominal minimum 10 d strength requirements, the average of all sets of three consecutive strength tests shall be equal to or greater than the specified strength.
<table>
<thead>
<tr>
<th>TEST</th>
<th>RANGE BETWEEN HIGHEST &amp; LOWEST VALUES OF 3 TEST SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accept if equal to or less than</td>
</tr>
<tr>
<td>Density kg/m$^3$</td>
<td>32</td>
</tr>
<tr>
<td>Air Content (%) in Plastic Concrete</td>
<td>0.7</td>
</tr>
<tr>
<td>Slump (mm)</td>
<td>30</td>
</tr>
<tr>
<td>7 d Compressive Strength (%)</td>
<td>14</td>
</tr>
</tbody>
</table>