

## CHAPTER 9 - PORTLAND CEMENT CONCRETE

### 9.1 GENERAL

The work shall consist of furnishing, forming, placing, finishing, and curing Portland Cement concrete, as required.

### 9.2 MATERIALS

#### 9.2.1 Portland Cement:

Portland cement shall be Type II and shall comply with the Standard Specification for Portland Cement, ASTM C150.

If air-entraining cement is to be used, the Developer/Contractor shall furnish the manufacturers written statement giving the source, amount and brand name of the air-entraining addition.

Cement shall be stored in such a manner as to be protected from weather, dampness or other destructive agents. Cement that is partially hydrated or otherwise damaged will be rejected.

#### 9.2.2 Aggregate:

Aggregates shall conform to Tentative Specifications for Concrete Aggregates, ASTM C33 for the specified sizes. Aggregates that fail to meet any requirement may be accepted only when: (1) the specified alternate conditions of acceptance can be proved prior to the use of the aggregates on the job and within a period of time such that no work under the contract will be delayed by the requirements of such proof; or, (2) the specification for concrete expressly contains a provision of special mix requirements to compensate for the effects of the deficiencies.

The potential reactivity of aggregates with the alkalis in cement shall be evaluated by petrographic examination and, where applicable, the chemical method of test, ASTM Designation C289, or by the results of previous tests or service records of concrete made from similar aggregates from the same source. The standards for evaluating potential reactivity shall be as described in ASTM Specification C33, Appendix A1.

Aggregates indicated by any of the above to be potentially reactive shall not be used, except under one of the following conditions:

- 1) Applicable test results of mortar bar tests, made according to ASTM Method C227, are available which indicate an expansion of less than 0.10 per cent at six months in mortar bars made with cement containing not less than 0.8 per cent alkalis expressed as sodium oxide; or
- 2) Concrete made from similar aggregates from the same source has been demonstrated to be sound after 3 years or more of service under conditions of exposure to moisture and weather similar to those anticipated for the concrete under these specifications.

Aggregates indicated to be potentially reactive, but within acceptable limits as determined by mortar bar test results or service records, shall be used only with "low alkali" cement, containing less than 0.60 per cent alkalis expressed as sodium oxide.

Aggregate of each class and size shall be stored and handled by methods that prevent segregation of particle sizes or contamination by intermixing with other materials.

### 9.2.3 Water:

Water shall be cleaned and free from injurious amounts of oil, salt, acid, alkali, organic matter or other deleterious substances and shall meet the requirements of ACI Standard Code (ACI 318 latest edition), paragraph 3.4.

### 9.2.4 Air-Entraining Agent:

Air-entraining agent shall be used in all concrete exposed to the weather. The agent shall conform to ASTM Designation C150 and C260, except that the relative durability factor in the freezing and thawing test shall be not less than 95.

### 9.2.5 Water-Reducing and Set-Retarding Admixtures:

Water-reducing and set-retarding admixtures shall conform to the requirements of ASTM Specification C494, except that resistance to freezing and thawing shall be determined in all cases, and the minimum relative durability factor shall be 95.

Admixtures shall be Type A, Water-Reducing or Type D, Water-Reducing and Retarding, as defined in ASTM Specification C494.

When added, in the manner and amount recommended by the manufacturer, to the concrete used on the job, with no change in the cement content or proportions of the aggregates, admixtures shall have the following effects:

Type A or Type D: The water content at the required slump shall be at least 5 percent less with the admixture than without. The air content shall remain within the range specified, but shall not exceed 8 per-cent in any case.

Type D: The time of initial setting, determined as prescribed in ASTM C494, shall be from 1 to 3 hours longer with the admixture than without.

### 9.2.6 Curing compound:

Curing compound for concrete shall meet the requirements of ASTM Specification C309.

Unless otherwise specified, the compound shall be Type 2.

All curing compound shall be delivered to the site of the work in the original container bearing the name of the manufacturer and the brand name. The compound shall be stored in a manner to prevent damage to the containers and to protect water-emulsion types from freezing.

## 9.3 CLASS OF CONCRETE

Concrete used within the City Right-of-Way shall have the following properties:

- Minimum 28 day compressive strength of 5000 psi
- Minimum cement content of 7.5 bags
- Maximum water-cement ratio of 0.44

## 9.4 COMPOSITION OF CONCRETE

### 9.4.1 Aggregate:

Aggregates maximum size shall be not larger than one-fifth (1/5) of the narrowest dimension between forms within which the concrete is to be cast, nor larger than three-fourths (3/4) of the minimum clear spacing

between reinforcing bars or between reinforcing bars and forms. For un-reinforced concrete slabs, the maximum size of aggregates shall not be larger than one-fourth (1/4) the slab thickness.

**9.4.2 Water:**

Water shall be added to the mix to produce concrete with the minimum practicable slump. The slump of mechanically vibrated concrete shall not exceed four-inch (4"). No concrete shall be placed with a slump in excess of five-inch (5").

**9.4.3 Air-Content:**

Air-Content for air-entrained concrete shall comply with the following:

Course Aggregate Size (in.)	Air Content (percent)
1 1/2 to 2 1/2	5 ± 1
3/4 or 1	6 ± 1
3/8 or 1/2	7 ± 1

The air-entraining agent shall be added as liquid to the mixing water by means of mechanical equipment capable of accurate measurement and control.

**9.4.4 Admixtures:**

Water Reducing and/or Set Retarding admixtures shall not be used except with previous approval from the City Engineer / Public Works Representative and shall in such a case, conform to the standards of materials set forth in the specification.

**9.5 DESIGN OF THE CONCRETE MIX**

The proportions of the aggregates shall be such as to produce a concrete mixture that will work readily into the corners and angles of the forms and around reinforcement when consolidated, but will not segregate or exclude free water during consolidation.

Prior to placement of concrete, the Developer/Contractor shall furnish the City Engineer / Public Works Representative, for approval, a statement of the materials and mix proportions (including admixtures, if any) it intends to use. The statement shall include evidence satisfactory to the City Engineer / Public Works Representative that the materials and proportions will produce concrete conforming to this specification. The materials and proportions so stated shall constitute the "job mix." After the job mix has been reviewed for conformance to specification by the City Engineer / Public Works Representative, neither the source, character, grading of the aggregates, the type and brand of cement, nor admixture shall be changed without prior notice to the City Engineer / Public Works Representative. If such changes are necessary, no concrete containing such new or altered materials shall be placed until the City Engineer / Public Works Representative has approved a revised job mix.

**9.6 OBSERVATION AND TESTING**

The City Engineer / Public Works Representative shall have free entry to the plant and equipment furnishing concrete under the contract. Proper facilities shall be provided for the City Engineer / Public Works Representative to observe the materials, equipment and processes and to obtain samples of the concrete. All tests and observations will be conducted so as not to interfere unnecessarily with manufacture and delivery of the concrete.

**9.6.1 Concrete Testing Requirements:**

- 1) Review and/or test materials in conformance with specifications. Concrete material shall conform to Section 9.2. Flowable Fill shall conform to Chapter 16.
- 2) Conduct strength tests of concrete used in conformance with the following procedures:
  - a. Secure composite samples in conformance with ASTM C 172. Obtain samples from different batches of concrete on a random basis. When testing concrete from a concrete pump, take the sample from the hose after all the priming grout has been wasted.
  - b. Take four specimens per sample in conformance with ASTM C31. Report deviations from requirements.
  - c. Test specimens per sample in conformance with ASTM C39. Make at least one strength test for each 50 CY, or fraction thereof, of each mix design of concrete placed in any one day. When total quantity of concrete with a given mix design is less than 50 CY, strength tests may be waived by Engineer if, in his judgment, adequate evidence of satisfactory strength is provided.
- 3) Perform slump tests with each strength test in conformance with ASTM C143. Reject concrete failing slump test.
- 4) Determine normal weight concrete air content with each strength test in conformance with ASTM C231.
  - a. If an air test fails, immediately terminate concrete discharge and retest the same load.
  - b. The concrete will be rejected if the second air test does not meet the specification.
  - c. If the second air test meets the specification, a third test will be performed to establish concrete acceptance or rejection.
- 5) Determine air content and unit weight of lightweight concrete test with each strength test in conformance with ASTM C173 and C567.
- 6) Determine temperature of concrete for each strength test.
- 7) Identify on testing reports, location of placement of tested concrete.

#### **9.6.2 Evaluation of Test Results:**

Concrete strength: As long as averages of all sets of three consecutive strength test results equal or exceed specified strength ( $f_c$ ) and no individual strength test result falls below specified strength ( $f_c$ ) by more than 500 psi, concrete strength is considered satisfactory.

#### **9.6.3 Acceptance:**

- 1) The strength will be determined by the average of the test lot cylinders taken on a specific pour. The test lot will consist of four (4) cylinders, one broken at 7 days and three broken at 28 days. The last three will be used for determining the average strength.
- 2) Concrete with compressive strength below the required specified strength shall be evaluated by the Engineer for capabilities necessary to the integrity of the structure. The City Engineer / Public Works Representative may accept this concrete, or require that it be replaced with acceptable material. The City Engineer / Public Works Representative shall make the final decision.

## **9.7 HANDLING AND MEASUREMENT OF MATERIALS**

Materials shall be stockpiled and batched by methods that will prevent segregation or contamination of aggregates and insure accurate proportioning of the ingredients of the mix.

Except as otherwise provided in Division 8, cement and aggregates shall be measured as follows:

- 1) Cement shall be measured by weight or in bags of 94 pounds each. When cement is measured in bags, no fraction of a bag shall be used unless weighed.
- 2) Aggregates shall be measured by weight. Mix proportions shall be based on saturated, surface-dry weights. The batch weight of each aggregate shall be the required saturated, surface-dry weight plus the weight of surface moisture it contains.
- 3) Water shall be measured by weight, to accuracy within one per cent of the total quantity of water required for the batch.
- 4) Admixtures shall be measured within a limit of accuracy of 3 percent (3%).

## 9.8 MIXERS AND MIXING

Concrete shall be uniform and thoroughly mixed when delivered to the work. Variations in slump of more than one inch (1") within a batch will be considered evidence of inadequate mixing and shall be corrected by increasing mixing time or other means. For stationary mixers, the mixing time after all cement and aggregates are in the mixer drum shall be not less than one and one-half (1-1/2) minutes. When concrete is mixed in a truck mixer, the number of revolutions of the drum or blades at mixing speed shall be not less than 70 or more than 100.

Unless otherwise specified, volumetric batching and continuous mixing at the construction site will be permitted if approved by City Engineer / Public Works Representative. The batching and mixing equipment shall conform to the requirements of ASTM Specification C685 and shall be demonstrated prior to placement of concrete, by tests with the job mix, to produce concrete meeting the specified proportioning and uniformity requirements. Concrete made by this method shall be produced, inspected, and certified in conformance with Sections 6, 7, 8, 13, and 14 of ASTM Specification C685.

No mixing water in excess of the amount called for by the job mix shall be added to the concrete during mixing or hauling or after arrival at the delivery point.

## 9.9 FORMS

Forms shall be of steel or other approved material and shall be mortar tight. The forms and associated falsework shall be substantial and unyielding and shall be constructed so that the finished concrete will conform to the specified dimensions and contours. Form surfaces shall be smooth and free from holes, dents, sags or other irregularities. Forms shall be coated with a non-staining form oil before being set into place.

Metal ties or anchors within the forms shall be equipped with cones, she-bolts or other devices that permit their removal to a depth of at least one inch without injury to the concrete.

All edges that will be exposed to view when the structure is completed shall be chamfered by placing molding in the forms, unless finishing with molding tools.

## 9.10 PREPARATION OF FORMS AND SUBGRADE

Prior to placement of concrete the forms and subgrade shall be free of chips, sawdust, debris, water, ice, snow, extraneous oil, mortar, or other harmful substances or coatings. Any oil on the reinforcing steel or other surfaces required to be bonded to the concrete shall be removed. Rock surfaces shall be cleaned by air-water cutting, wet sandblasting or wire brush scrubbing, as necessary, and shall be wetted immediately prior to placement of concrete. Earth surfaces shall be firm and damp. Placement of concrete on mud, dried earth or uncompacted fill or frozen subgrade will not be permitted.

Unless otherwise specified, when concrete is to be placed over drain fill, the contact surface of the drain fill shall be covered with a layer of asphalt-impregnated building paper or polyvinyl sheeting prior to placement of the concrete. Forms for weepholes shall extend through this layer into the drain fill.

Items to be embedded in the concrete shall be positioned accurately and anchored firmly.

Weepholes in walls or slabs shall be formed with nonferrous materials.

## **9.11 CONVEYING**

Concrete shall be delivered to the site and discharged into the forms within 90 minutes after the introduction of the cement to the aggregates. In hot weather or under conditions contributing to quick stiffening of the concrete, the time between the introduction of the cement to the aggregates and discharge shall not exceed 45 minutes. The City Engineer / Public Works Representative may allow a longer time, provided the setting time of the concrete is increased a corresponding amount by the addition of an approved set-retarding admixture. In any case, concrete shall be conveyed from the mixer to the forms as rapidly as practicable by methods that will prevent segregation of the aggregates or loss of mortar.

Concrete shall not be dropped more than five feet (5') vertically unless suitable equipment is used to prevent segregation.

## **9.12 PLACING**

Concrete shall not be placed until the subgrade, forms and steel reinforcement have been inspected and approved. No concrete shall be placed except in the presence of the City Engineer / Public Works Representative. The Developer/Contractor shall give 48-hour notice to the City Engineer / Public Works Representative each time it intends to place concrete. Such notice will give the City Engineer / Public Works Representative adequate time to inspect the subgrade, forms, steel reinforcement and other preparations for compliance with the specifications before concrete is delivered for placing.

The concrete shall be deposited as closely as possible to its final position in the forms and shall be worked into the corners and angles of the forms and around all reinforcements and embedded items in a manner to prevent segregation of aggregates or excessive laitance. Unless otherwise specified, slab concrete shall be placed to design thickness in one continuous layer. Formed concrete shall be placed in horizontal layers not more than 20 inches thick. Hoppers and chutes, pipes or "elephant trunks" shall be used as necessary to prevent splashing of mortar on the forms and reinforcing steel above the layers being placed.

Immediately after the concrete is placed in the forms, it shall be consolidated by spading, hand tramping or vibration as necessary to insure smooth surfaces and dense concrete. Each layer shall be consolidated to insure monolithic bond with the preceding layer. If the surface of a layer of concrete in place sets to the degree that it will not flow and merge with the succeeding layer when spaded or vibrated, the Developer/Contractor shall discontinue placing concrete and shall make a construction joint according to the procedure specified.

If placing is discontinued when an incomplete horizontal layer is in place, the unfinished end of the layer shall be formed by a vertical bulkhead.

## **9.13 CONSTRUCTION JOINTS**

If construction joints are needed they shall be placed in locations approved by the City Engineer / Public Works Representative.

Where a featheredge would be produced at a construction joint, as in the top surface of a sloping wall, an inset form shall be used so that the resulting edge thickness on either side of the joint is not less than six inches (6").

In walls and columns, as each lift is completed, the top surfaces shall be immediately and carefully protected from any condition that might adversely affect the hardening of the concrete.

Steel tying and form construction adjacent to concrete in place shall not be started until the concrete has cured at least 12 hours. Before new concrete is deposited on or against concrete that has hardened, the forms shall be retightened. New concrete shall not be placed until the hardening concrete has cured at least 12 hours.

Surfaces of construction joints shall be cleaned of all unsatisfactory concrete, laitance, coatings or debris by washing and scrubbing with a wire brush or wire broom or by other means approved by the City Engineer / Public Works Representative. The surfaces shall be kept moist for at least one (1) hour prior to placement of the new concrete.

**9.14 EXPANSION AND CONTRACTION JOINTS**

**Maximum Joint Spacing**

	<b>Expansion Joints</b>	<b>Contraction Joint</b>
<b>Sidewalk</b>	50 LF	5 LF
<b>Curb and Gutter</b>	At Construction (Cold) Joints	10 LF
<b>Cross Gutter</b>	At Construction (Cold) Joints	10 LF

Contraction joints shall be a minimum of T/4 where T is the thickness of the concrete.

Exposed concrete edges at expansion and contraction joints shall be carefully tooled or chamfered, and the joints shall be free of mortar and concrete. Joint filler shall be left exposed for its full length with clean and true edges.

Preformed expansion joint filler shall be held firmly in the correct position as the concrete is placed.

Open joints, when specified, shall be constructed by the insertion and subsequent removal of a wooden strip, metal plate or other suitable template in such a manner that the corners of the concrete will not be chipped or broken. The edges of open joints shall be finished with an edging tool prior to removal of the joint strips.

**9.15 WATERSTOP**

Waterstops shall be held firmly in the correct position as the concrete is placed. Joints in metal waterstops shall be soldered, brazed or welded. Joints in rubber or plastic waterstops shall be cemented, welded or vulcanized as recommended by the manufacturer.

**9.16 REMOVAL OF FORMS**

Forms shall not be removed without the approval of the City Engineer / Public Works Representative. Forms shall be removed in such a way as to prevent damage to the concrete. Supports shall be removed in a manner that will permit the concrete to take the stresses due to its own weight uniformly and gradually.

**9.17 FINISHING FORMED SURFACES**

Immediately after the removal of the forms:

- 1) All fins and irregular projections shall be removed from exposed surfaces.
- 2) On all surfaces, the holes produced by the removal of form ties, cone-bolts, and she-bolts shall be cleaned, wetted and filled with a dry-pack mortar consisting of one part Portland cement, three parts sand that will pass a No. 16 sieve, and water just sufficient to produce a consistency such that the filling is at the point of becoming rubbery when the material is solidly packed.

## 9.18 FINISHING UNFORMED SURFACES

All exposed surfaces on the concrete shall be accurately screeded to grade and then float finished, unless specified otherwise.

Excessive floating or troweling of surfaces while the concrete is soft will not be permitted.

The addition of dry cement or water to the surface of the screeded concrete to expedite finishing will not be allowed.

Joints and edges on unformed surfaces that will be exposed to view shall be chamfered or finished with molding tools.

## 9.19 CURING AND PROTECTION

Concrete shall be prevented from drying for a curing period of at least 7 days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period, or until curing compound is applied as specified below. Sprinkling, flooding or fog spraying shall maintain moisture or by covering with continuously moistened canvas, cloth mats, straw, sand or other approved material. Wood forms (except plywood) left in place during the curing period shall be kept wet. Formed surfaces shall be thoroughly wetted immediately after forms are removed and shall be kept wet until patching and repairs are completed. Water or covering shall be applied in such a way that the concrete surface is not eroded or otherwise damaged.

As soon as the concrete has hardened sufficiently to prevent damage, the finished surface shall be protected for curing in one of the following ways:

- 1) Ponding of water on the surface or continuous sprinkling.
- 2) Application of absorptive mats such as three-inches (3") of cured hay, clean straw or fabric kept continuously wet.
- 3) Application of two-inches (2") of moist earth or sand uniformly distributed on the surface and kept saturated by spraying with water.
- 4) Application of light colored waterproof plastic materials, conforming to "Specifications for Waterproof Sheet Materials for Curing Concrete" ASTM C171, placed and maintained in contact with the surface of the concrete.
- 5) Application of a curing compound, conforming to "Specifications for Liquid Membrane - Forming Compounds for Curing Concrete" ASTM C309. The compound shall be light in color and shall be applied in accordance with the manufacturer's recommendations immediately after any water sheen, which may develop after finishing, has disappeared from the concrete surface.

Curing compound shall not be applied to surfaces requiring bond to subsequently placed concrete, such as construction joints, shear plates, reinforcing steel and other embedded items. If the membrane is damaged during the curing period, the damaged area shall be re-sprayed at the rate of application specified above.

## 9.20 REMOVAL OR REPAIR

When concrete is honey combed, damaged or otherwise defective, the Developer/Contractor shall remove and replace the structure or structural member containing the defective concrete or, where feasible, correct or repair the defective concrete. Prior to starting repair work the Developer/Contractor shall obtain the City Engineer / Public Works Representative's approval of its plan for affecting the repair. The Developer/Contractor shall perform all repair work in the presence of the City Engineer / Public Works Representative.



**9.21 CONCRETING IN COLD WEATHER**

Concrete shall not be mixed nor placed when the daily minimum atmospheric temperature is less than 40° F unless facilities are provided to prevent the concrete from freezing. (Below 25° F heating blankets alone will not be allowed and must be supplemented with an additional heat source.) The use of accelerators or antifreeze compounds will not be allowed. The contractor shall be responsible to insure the protection of the concrete regarding these requirements.

**9.22 CONCRETING IN HOT WEATHER**

The Developer/Contractor shall apply effective means to maintain the temperature of the concrete below 90° F during mixing, conveying and placing. The contractor shall be responsible to insure the protection of the concrete regarding these requirements.