

## SECTION 55

### CAST IN PLACE CONCRETE STRUCTURES

#### 55.1 DESCRIPTION

**A. General:** This work consists of false work and form construction and the furnishing, handling, placing, curing, and finishing of concrete for structures.

**B. Related Work:**

Section 57	Reinforcing Steel
Section 100	Portland Cement
Section 101	Air-Entraining Admixtures
Section 102	Chemical Admixtures for Concrete
Section 103	Fly Ash
Section 104	Water for Use in Portland Cement Concrete
Section 105	Fine Aggregate for Use in Portland Cement Concrete
Section 106	Masonry Mortar Sand Section
Section 107	Coarse Aggregate for Use in Portland Cement Concrete
Section 108	Concrete Curing Materials
Section 113	Preformed Expansion Joint Filler for Concrete
Section 114	Concrete Joint Sealer
Section 123	Concrete Reinforcement
Section 203	Submittals

#### 55.2 MATERIALS

**A. Cement:** Shall conform to the requirements of Section 100. Type II cement shall be used for all concrete.

**B. Fine Aggregate:** Shall conform to the requirements of Section 105.

**C. Coarse Aggregate:** Shall conform to the requirements of Section 107.

**D. Water:** Shall conform to the requirements of Section 104.

**E. Admixtures:** Shall conform to the requirements of Section 101 and 102.

**F. Reinforcing Steel:** Shall conform to the requirements of Sections 57 and 123. Epoxy coated rebar is not required unless otherwise specified in detailed plans and specifications, or per standard details.

**G. Curing Materials:** Shall conform to the requirements of Section 108.

**H. Preformed Expansion Joint Filler:** Shall conform to the requirements of Section 113.

- I. **Joint Sealer:** Shall conform to the requirements of Section 114.
- J. **Fly Ash:** Shall be per Section 103.
- K. **Grout:** Shall be a commercially available non-metallic, non-shrink grout capable of attaining a minimum compressive strength of 4500 psi and shall conform to the requirements of ASTM C1107.

### 55.3 CONSTRUCTION REQUIREMENTS

- A. **Quality and Proportion:** The Contractor shall design and be responsible for the performance of all concrete mixes used in structures. Mix designs shall be modified during the course of the work when necessary to assure compliance with the requirements for strength and consistency. All mix designs and any modification thereto, including changes in admixtures, shall be approved by the Engineer prior to use. The mix design shall produce a concrete conforming to the following requirements:

- Minimum cementitious material: 585 lbs/CY
- Maximum water cementitious material ratio: 0.45
- Slump Range at time of placement: 1 - 4½ inches
- Entrained air content range: 5.0 to 7.5 percent
- Minimum course aggregate content: 55 percent
- Minimum 28 day compressive strength: 4000 PSI

If contractor proposed using a well graded concrete mix design, the design shall be per SDDOT Standard Specification for Roads and Bridges Section 460.

The absolute volume method as described in the American Concrete Institute Publication 211.1 shall be used in selecting mix proportions. The mix design shall be based upon obtaining an average concrete compressive strength 1200 psi above the specified minimum 28 day compressive strength.

- 1. **Concrete Mix Design Performance:** When the Contractor proposes to use materials for concrete structures from sources not previously accepted by the City, the Contractor shall obtain independent, certified laboratory tests that verify that the materials meet the requirements in this section. Minimum number of tests is once each year per source unless otherwise ordered by the Engineer.

Satisfactory performance of the proposed concrete mix design shall be verified by laboratory tests on trial batches. The trial batches must be performed by a testing facility that also performs SDDOT trial batch testing. Trial batches shall be conducted in accordance with the American Concrete Institute Publication ACI 211.1, ACI 318, ASTM C192 and the following:

- a) A minimum of three trial batches shall be performed.
- b) The slump of each trial batch shall be within  $\pm 3/4$  inch of the maximum specified.
- c) The air content of each trial batch shall be +0.5% to -1.0% of the maximum specified.

The results of each trial batch test shall be furnished by the Contractor to the Engineer at the time the proposed mix design is submitted. The as-batched results shall include the following: material weights, aggregate moistures, fresh concrete test results (slump, air content, unit weight, and mix temperature), water cementitious material ratios, aggregate gradations, compressive strengths, and aggregate qualities. In addition, aggregate supplier production test results shall be provided.

- 2. **Alternate Concrete Mix Design:** A concrete mix design previously approved will be considered in compliance with the mix design requirements provided all of the following conditions are met:

- a) The concrete mix proportions are in accordance with this section.
- b) The mix design, including all material and admixtures, are identical to those previously used and tested.
- c) The average 28 day compressive strength of 10 or more test results from an approved testing facility is at least 1.34 standard deviations above the specified strength. These test results and associated batch tickets shall be submitted to the Engineer. No more than 1 in 10 compressive strength test results may be below specified strength.
- d) The Contractor submits all supporting information for the mix design, including but not limited to, fresh concrete tests and material properties.

- B. **Determination of 28 Day Compressive Strength and Acceptance Criteria:** The Contractor will be responsible for the sampling, preparing, properly curing, and breaking of all concrete cylinders for concrete compressive strength in accordance with the SDDOT Materials Manual. The 28 day compressive strength shall be determined in accordance with SDDOT test SD 420. Results from concrete testing shall be provided to the Engineer within three (3) days of the test being performed.

The 28 day compressive strength acceptance criteria shall be as follows:

- 1. **Concrete Cylinder Testing:** If the 28 day cylinder compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinder shall be accepted.

If the 28 day cylinder compressive strength is less than the specified 28 day compressive strength, the backup cylinder shall be broken as soon as possible after breaking the 28 day cylinder. The compressive strength for the backup cylinder will be the strength at the time it was broken and will not be corrected back to a 28 day strength.

- 2. Backup Concrete Cylinder Testing:** If the backup cylinder compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinder shall be accepted.

If the backup cylinder compressive strength is less than the specified 28 day compressive strength by no more than 500 psi, the Engineer will determine if the unit is structurally adequate at the average compressive strength of the 28 day and the backup cylinder. If structurally adequate, the concrete will be allowed to remain in place and will be subject to price adjustment based on the average compressive strength of the two cylinders. If the analysis shows the average cylinder compressive strength is not structurally adequate, the concrete will be removed and replaced at the Contractor's expense.

If the average compressive strength of the 28 day and the backup cylinder compressive strength is more than 500 psi, below the specified 28 day compressive strength, the concrete represented by the cylinders shall be removed and replaced.

- 3. Suspect Test Results:** If there is some reason to suspect that the compressive strength test results are not valid due to a damaged concrete cylinder, malfunction of testing equipment, etc., or if the City or Contractor believes that the test results are not representative of the in place concrete, the City may require the Contractor to core the concrete represented by the cylinders. When cores are deemed necessary the additional testing and all costs will be borne by the Contractor. The coring and compressive testing shall be in accordance with the current edition of AASHTO T 24.

If the average core compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinders shall be accepted.

If the average core compressive strength is less than the specified 28 day compressive strength by no more than 500 psi, the Engineer will determine if the unit is structurally adequate at the lower compressive strength. If structurally adequate, the concrete will be allowed to remain in place and will be subject to price adjustment. If the analysis shows the average core compressive strength is not structurally adequate, the concrete will be removed and replaced at the Contractor's expense.

- 4. Coring & Compressive Testing:** If coring is directed by the City or chosen by Contractor as specified in this section, the Contractor shall arrange for an independent testing laboratory to perform the coring and compressive testing

within 14 calendar days of notification. The independent testing laboratory must be approved by the Engineer prior to starting the coring and compressive testing. The coring and compressive testing shall be in accordance with the current edition of AASHTO T 24.

The independent testing laboratory will take three (3) cores of the area representing the cylinders in which the compressive strength is in question and test them for compressive strength. The coring and compressive testing shall be witnessed by the Engineer.

The Contractor will be responsible to locate the reinforcing steel prior to coring. It is critical that the coring operation avoids all reinforcing steel. The core holes shall be grouted with a grout that conforms to Section 55.2.K

The average compressive strength of three (3) cores will be used for the determination of acceptance of concrete represented by each set of 28 day cylinders. One core's compressive strength may be 15% below the specified strength if the average of the 3 core's compressive strength is above the specified strength. ASTM E178 (Standard Practice for Dealing With Outlying Observations) will be used with the 10% significance level to deal with excessively high or low core strengths. If a core compressive strength is an outlier, then the set of cores will be averaged using the 2 remaining cores.

The average compressive strength of the cores will prevail over all other compressive strength determination methods.

If it is determined by the additional testing that the 28 day compressive strength is less than that specified, all costs for the coring and compressive testing will be borne by the Contractor and the concrete shall be either accepted or rejected as per this section.

The following information shall be provided for each core taken:

- Include City project number and project name.
- Core identification number & location of each core (representing cylinder number, structure number, location of cores sketch, date concrete was cast, date cores taken, date cores tested)
- Age of the concrete at the time of testing.
- Length & diameter of each core tested.
- Unit weight of each core.
- End preparation (capped or neoprene).
- Date of last calibration of the compression machine.
- What, if any, correction factor was used to compute the compressive strength.
- Actual calculations including load & cross-sectional area.
- Type of fracture as per ASTM C39. Note if the bond to the coarse aggregate is not adequate due to cement adhesion.
- Any defects in either the core or the cap.

**C. Equipment:** Shall be available in advance of the start of construction operations to allow for thorough examination by the Engineer.

**1. Batching Equipment:** Shall be automatic or previously approved by the Engineer.

The Contractor shall provide satisfactory means for obtaining material samples from the batching plant.

Batching plant structures shall be leveled so the accuracy of the weighing mechanism is maintained.

Hoppers shall fully discharge without jarring the scales.

Clearances between scale parts, hoppers, and bin structure shall be maintained to avoid displacement of, or friction between, parts due to materials accumulations, vibration, or other cause. Exposed fulcrums, clevises, and similar working parts shall be kept clean.

To maintain accuracy, weighing hoppers and other parts which are affected by wind action shall be protected by shelters or wind breaks.

The scale display shall be completely enclosed in weather proof cases and provided with glass opening to permit observation and reading.

The equipment for weighing aggregates, cement, water, and admixtures shall be an integral part of the batching equipment. The scales/load cells shall be accurate within 0.5% at any point throughout the range of the scale/load cell. Graduations shall be not greater than 0.1% of the capacity of the scale/load cell. The scales/load cells shall be sensitive to the weight indicated by one graduation.

The following controls shall apply to the aggregate batching equipment:

- The batching equipment shall operate within a delivery tolerance of 1.5% of the net weight for each aggregate weighed.
- The hopper inlet mechanism shall be interlocked against opening when the discharge gate is open.
- The hopper discharge mechanism shall be interlocked against opening while the hopper is being charged.

The hopper discharge mechanism shall be interlocked against opening if any material in the hopper is either overweight or underweight by more than 1.5% of the specified weight.

The cement batching equipment shall operate within a delivery tolerance of 1% of the net weight of the cement per batch. The cementitious material (cement and fly ash) batching equipment shall also operate within a delivery tolerance of 1% of the net weight of the total cementitious material per batch.

Water may be measured by volume or weight. The measuring equipment shall operate within a delivery tolerance of 1% of the net weight or volume of water.

When water is measured by volume, means for determining the accuracy of the measuring device shall be provided.

Air-entraining or other admixtures may be measured by volume or by weight. The measuring equipment shall operate within a delivery tolerance of 3% of the net weight or volume per batch.

**2. Computerized Batching Equipment:** The following provisions shall apply to all Class A or Class M concrete batched by computerized batching equipment:

A printed, computer generated, ticket shall be automatically produced for each load of concrete batched. The printed computer ticket shall accompany each load of concrete to the project and shall be presented to the Engineer prior to discharging the load at the project site unless the Engineer approves an alternate procedure.

The printed ticket must contain the following minimum information:

- Truck Number
- Date and Time batched
- Total volume of the load, in cubic yards
- Mix Design Number or Mix Type
- Actual weight (mass) or volume of each component of the mix:
  - Coarse Aggregate
  - Fine Aggregate Cement
  - Fly ash
  - Water (batch water)
  - Admixtures
    - Air Entraining
    - Water Reducers
    - Retarders
    - Accelerators
    - Others
- % Moisture in Aggregate (either % free moisture or % total moisture)
- Maximum Water Allowed  
(maximum water allowed = weight of mix design water - weight of free water)
- W/C ratio (as-batched)

The final W/C ratio, for acceptance, shall be calculated using the following formula and rounded to the nearest 0.01:

$$\text{W/C ratio} = \left( \frac{\text{weight of free water} + \text{weight of batch water} + \text{weight of added water}}{\text{weight of cement} + \text{weight of supplementary cementitious material}} \right)$$

% free moisture =	% total moisture in aggregate - % absorption of aggregate
weight of free water =	% free moisture x weight of aggregate
weight of batch water =	total weight of water added to the batch either at the plant or in the truck
weight of added water =	total weight of water added after batching process (typically added at point of delivery)

The weight of free water shall be calculated for both the fine aggregate and the coarse aggregate.

The above information must be automatically printed in such a manner that the Engineer may verify the mix adheres to the proportions specified by the design mix.

- 3. Mixing and Hauling Equipment:** Mixers and agitators shall have attached in a prominent place, a manufacturer plate or plates showing the various uses for which the equipment is designed and the capacity of the drum or container in terms of volume of mixed concrete.

The pick-up and throw-over blades in the drum shall be restored or replaced when any part or section is worn 3/4 inch or more below the original height of the manufacturer's design. The Contractor shall maintain a copy of the manufacturer's design, showing original dimensions and arrangement of blades. Mixers that have an accumulation of hard concrete or mortar shall not be used.

Mixers, except truck mixers, shall be equipped with an approved timing device to track the total mixing time of the concrete batch.

Truck mixers shall be equipped with counters to record the number of revolutions of the drum or blades. The revolution counter on the truck mixers shall be set to zero as each new load is batched.

Mixers shall be capable of combining the concrete ingredients into a thoroughly mixed and uniform mass and shall uniformly discharge the concrete.

The hauling bodies of non-agitating equipment shall be smooth, mortar-tight metal containers equipped with gates and vibrators that will permit uniform control of the discharge of the concrete.

- 4. Wood Forms:** Forms shall be designed, built, and maintained to sustain the pressure and weight of the concrete and construction loads. The design of the forms shall consider the effect of vibration of the concrete as it is placed.

Forms and form lumber shall be clean and in good condition. Lumber that is split, warped, bulged, marred, or that has other defects shall not be used.

Forms for concrete surfaces shall be constructed to produce mortar tight joints with smooth even concrete surfaces. Forms shall be filleted at all sharp corners and shall be given a bevel or draft in all projections, such as girders and copings.



Metal ties and anchorages within the forms shall be constructed to permit placement without injury to the concrete. Ties used in the presence of epoxy coated reinforcement shall be epoxy coated or made of other corrosion resistant material. If ordinary or epoxy coated wire ties are permitted, all wires shall be cut back at least 1/4 inch from the face of the concrete after the forms are removed. Fittings for metal ties shall be designed so on removal the resulting cavities will be the smallest practical size.

Forms shall be set and maintained true to the line designated. When forms appear to be unsatisfactory, either before or during the placing of concrete, the Engineer may order the work to be stopped until the defects have been corrected.

Forms shall be surface treated with an approved form oil or saturated with water immediately before placing the concrete. For members with exposed faces, the forms shall be surface treated with an approved form oil to prevent the adherence of concrete. Material which will adhere to or discolor the concrete shall not be used.

5. **Metal Forms:** The requirements for wood forms in regards to design, mortar tightness, filleted corners, beveled projections, bracing, alignment, reuse, and oiling shall apply to metal forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. Bolt and rivet heads shall be countersunk. Clamps, pins, and other connecting devices shall hold the forms rigidly together and allow removal without injury to the concrete. Metal forms, which do not present a smooth surface or line up properly, shall not be used. Special care shall be exercised to keep metal forms free from rust, grease, and other foreign matter, which will discolor and contaminate the concrete.
  6. **False Work:** False work associated with bridge construction shall require structural engineering design calculations and shall be in accordance with SDDOT Standard specifications for Roads and Bridges.
- D. Handling, Measuring, and Batching Materials:** The separate aggregate components shall not become intermixed prior to being weighed and the weigh hopper or hoppers shall be charged so the batched weights are within the tolerances of this section.
1. Cement shall be measured by the sack or by weight. When cement is weighed, separate scales and hoppers shall be used with a device to indicate positively the complete discharge of the batch of cement into the mixing drum.
  2. Admixtures shall be used in accordance with the manufacturer's recommendations. When multiple types of admixtures are being used, the admixtures shall be individually dispensed. Compatibility of the admixtures shall be verified prior to use.
  3. The amount of batch water and aggregates added to the mix shall be adjusted accordingly using the results of the most recent moisture tests. Moisture shall be

measured by the supplier at regular intervals. Automatic moisture sensing equipment may be used, and shall be properly calibrated.

- E. Mixing Concrete:** Concrete shall be mixed at a central stationary plant site or in truck mixers.

Mixing and agitating speeds shall be as designated by the manufacturer of the equipment. Mixers shall not be charged in excess of the rated capacity.

When a concrete batch is transported in a truck mixer or agitator and the batch is smaller than 60% of the rated capacity of the truck mixer or agitator, the following percentage of additional cementitious material at the same proportions as listed on the mix design shall be added to the batch:

Percent of Rated Capacity	Additional Cementitious Material Required
40% to 60%	5%
20% to 39%	10%
10% to 19%	15%
0% to 9%	20%

The above provisions regarding additional cementitious material shall also apply to the mixing of small batches in central plants. Additional cementitious material will not be required when the small batch is mixed in a drum that is sufficiently coated with mortar to withstand the loss of cementitious material. Sufficient mortar coating, as determined by the Engineer, may include mortar coating the drum from a previously mixed batch during continuous mixing operations. Additional cementitious material will be required if more than 30 minutes has passed from the mixing of the previous batch, if the drum has been cleaned following the previous batch, or if the mortar coating the drum has been disturbed following the previous batch.

- 1. Central Plant Mixing:** The batch shall be charged in the drum so a portion of the mixing water enters in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period.

Concrete shall be mixed for a period of not less than one minute after all materials, are in the mixer.

Concrete mixed less than the specified mixing time shall be discarded and disposed of.

- 2. Truck Mixing:** Original mixing time for truck mixed concrete shall be not less than 70 or more than 100 revolutions of the drum at mixing speed after all ingredients, including water, are in the drum. Additional revolutions beyond 100 shall be done at agitating speed.

The mixing water shall be added at the time of batching. Additional water, cement, or admixtures may be added to the full load after completion of the original mixing, provided that slump, entrained air, and water cement specifications are adhered to. Addition of water, cement, or admixtures to partial loads is not allowed (partial loads of concrete are defined as loads that have been partially discharged). Admixtures shall be added in accordance with the manufacturer's recommendations. When additional water, cement, or admixture is added, the batch shall be mixed an additional 30 revolutions at mixing speed. The Contractor shall provide means to accurately measure the amount of additional materials added.

- 3. Water/Cementitious Material Ratio:** The water/cementitious material ratio of the concrete placed shall not exceed the maximum water/cementitious ratio established for the mix design.
- F. Limitations of Mixing:** Concrete shall be mixed in the quantities required for immediate use and shall be placed before initial set has occurred. Concrete in which initial set has begun prior to beginning placement shall be wasted at the Contractor's expense. Retempering of concrete after initial set has occurred will not be allowed.

Concrete shall not be mixed and placed unless the natural light is sufficient for finishing operations, or an adequate artificial lighting system is provided.

Mixing water shall not be heated above 160°F. Aggregates shall not be heated above 100°F and shall be free of frozen lumps, ice, and snow.

- G. Delivery Requirements:** When concrete is continuously agitated in the hauling unit, the concrete shall be discharged within 90 minutes after the cement has been placed in contact with the aggregates and discharged and screeded within 105 minutes after the cement has been placed in contact with the aggregates. When the concrete temperature is 80°F or above, the time limitation shall be reduced to discharged within 45 minutes and discharged and screeded within 60 minutes.

When concrete is not continuously agitated in the hauling unit, the concrete shall be discharged within 45 minutes after the cement has been placed in contact with the aggregates and discharged and screeded within 60 minutes. When the concrete temperature is 80°F or above, the time limitation shall be reduced to discharged within 30 minutes and discharged and screeded within 45 minutes.

The rate of delivery of concrete shall be uniform. The interval between batches shall not exceed 30 minutes.

For delivery of concrete in remote locations where the preceding concrete delivery requirements will be difficult to meet, the Contractor may be allowed to use a set retarding admixture to control initial set when approved by the Engineer. When set retarding admixtures are allowed, the concrete delivery requirements may be adjusted with approval from the Engineer.

- H. Construction Tolerances:** Construction tolerances shall be in accordance with the latest edition of ACI 117, Standard Tolerances for Concrete Construction and Materials.
- I. Placing Concrete:** The Contractor shall give sufficient notice before starting to place concrete to permit inspection of forms, reinforcing steel, and preparation for placing. Concrete shall not be placed without approval of the Engineer.

Placement of concrete on a frozen foundation will not be permitted. The surface temperature of forms, steel, and adjacent concrete which will come in contact with the concrete being placed shall be raised to a temperature above freezing prior to placement.

The temperature of concrete immediately after placing shall not be less than 50°F or more than 90°F. The top limit for bridge deck concrete shall be 80°F except as indicated below.

The slope of chutes for concrete placement shall allow the concrete to flow slowly without segregation. The delivery point of the chute shall be as close as possible to the point of deposit. Chutes and spouts shall be kept clean and shall be thoroughly flushed with water before and after each run. The flush water shall be discharged outside the forms.

Free fall of concrete shall not exceed five (5) feet. In thin walls or columns where the reinforcement prohibits the use of chutes the method of placement shall prevent objectionable separation of coarse aggregate.

The sequence of placing concrete, including the location of construction joints, shall be as specified. Concrete shall be placed in continuous horizontal layers. Each subsequent layer shall be placed before the preceding layer has attained its initial set.

The concrete shall be consolidated by vibrating internally, externally, or both without displacement of reinforcing or forms. The vibration shall be of sufficient duration and intensity to thoroughly consolidate the concrete without causing segregation; localized areas of grout; or damage to concrete, forms, and reinforcement.

Vibration shall not be applied directly to reinforcement which extends into sections or layers of concrete which are not plastic under vibration. Vibrators shall not be used to move concrete over distances or to transport concrete in the forms.

Accumulations of mortar splashed upon the reinforcing steel and the surfaces of forms shall be satisfactorily removed. Care shall be exercised not to injure or break the concrete to steel bond at and near the surface of the concrete while cleaning the reinforcing steel.

- J. Surface Finish:** The surfaces of all structural concrete shall be worked during placing. The working shall force all coarse aggregate from the surface and thoroughly work the

mortar against the forms to produce a smooth finish relatively free of water, air pockets, and honeycombing.

As soon as the concrete has set in accordance with Section this section the forms on all exposed surfaces shall be carefully removed and all depressions resulting from the removal of metal ties or other causes shall be carefully pointed with a mortar of sand and cement in the same proportions as the concrete being treated. All fins and rough corners on the surfaces shall be removed to present a neat and uniform appearance.

Concrete flatwork shall be finished per appropriate section of these Standard Specifications.

Additional finishing will be required as follows:

**Rubbed, Brushed, and Commercial Texture Finishes:** One of these three finishes will be required for all railing, curbs, parapets, wing walls, Type "C" walls, and other surfaces not subject to wear which are visible to the traveling public unless otherwise designated in the plans. The selected finish shall be used throughout the entire structure, except the finish for the top and inside of the curb may be different than that used for the other parts of the structure. These finishes will not be required on surfaces which are not visible to the traveling public such as box culvert wing walls, box culvert parapets, bridge wing walls, and backsides of curbs on bridges, provided the forms result in a smooth unblemished surface.

Begin finishing as soon as the forms are removed. Remove fins and irregular projections from surfaces that are exposed or will be waterproofed. Remove bulges and offsets with carborundum stones or discs. Remove localized, poorly bonded rock pockets or honeycombed concrete, and replace with sound concrete or packed mortar in an approved manner.

Clean and point form tie cavities, holes, broken comers and edges, and other defects. Saturate the area with water. Finish the area with mortar that is less than 1-hour old. After the mortar is set, rub it (if required) and continue curing. Match exposed surfaces to surrounding concrete.

Carefully tool and remove free mortar and concrete from construction and expansion joints. Leave joint filler exposed for its full length with clean, true edges.

**1. Rubbed Finish:** As soon as the pointing has set sufficiently, the surfaces to receive a rubbed finish shall be thoroughly wetted with a brush and rubbed with a medium coarse carborundum stone or an abrasive of equal quality using a small amount of mortar on stone face. The rubbing shall be continued until all form marks and projections are removed, producing a relatively smooth clean surface free from pits or irregularities.

The final finish shall be obtained by rubbing with a fine carborundum stone or an abrasive of equal quality. This rubbing shall continue until the entire surface has a smooth texture and a uniform color.

Unless otherwise specified in plans, Type "C" walls shall receive a rubbed finish.

2. **Brushed Finish:** This finish will be permitted only if it is accomplished within 12 hours of concrete placement. The forms shall be removed as soon as the concrete is able to stand firm without slumping. The surface shall be worked with a rubber float which may be dipped in a very wet three parts sand to one part cement grout mixture. Immediately after the surface is worked into a lather, a soft bristle brush shall be used to smooth the surface, leaving a fine grained, smooth but sanded texture. A "plastering" job resulting from the use of an excess of grout on the surface will not be permitted. Linseed oil cure shall be added immediately after the brushed finish operation, and shall be maintained for the remainder of the curing period.
3. **Commercial Texture Finish:** The objective is to obtain a surface that is reasonably smooth and uniform in texture and appearance. Repairing surface blemishes (bug holes, form lines, etc.) to prevent "show through" prior to application of the commercial texture finish is required. The commercial texture finish shall be performed using an approved system listed in the detailed plans and specifications and approved by the Engineer. The Contractor is required to provide a copy of the manufacturer's recommendations to the Engineer prior to performing any commercial texture finish work.

Unless otherwise noted in the manufacturer's recommendations, commercial texture finish shall not be applied to any surface until the concrete is a minimum of 28 days old. The surfaces to receive commercial texture finish shall be abrasive blast cleaned to break the surface film, to remove all laitance and other foreign material, and to provide an absorptive surface. When allowed in the manufacturer's recommendations, pressure washing may be used to prepare the surface in lieu of abrasive blast cleaning.

The commercial texture finish mixture shall be mixed in accordance with the method specified in the approved list for the system being used. The same materials and application method shall be used for all surfaces on any one structure.

Commercial texture finish mixtures may be applied by a brushing, rolling, or by spraying, as per the manufacturer's recommendations. The mixture shall cover the original surface with a one coat application. The one coat application shall not be too thick to cause runs, sags, or a plastered effect. After drying, the final surface shall be uniform in color and texture with no laps or breaks in continuity. The color of the system shall closely simulate the color of the original concrete, unless otherwise specified on the plans.

The application of the commercial texture finish shall not be started until all other work that could damage the finish has been completed. The finishing operations shall be continuous until completion of the finish application on any one surface. Corrective work, at the Contractors expense, will be required on any surfaces

which have not been satisfactorily finished or on finished surfaces that have been damaged during subsequent work. The repair work will include as much adjacent surface area as necessary to achieve a uniform appearance.

**K. Curing Concrete:** Begin curing immediately after the free surface water has evaporated and the finishing is complete. If the surface of the concrete begins to dry before the selected cure method can be implemented, keep concrete surface moist using a fog spray without damaging the surface.

- 1. Forms In-Place Method:** Forms remaining in place shall be considered as adequate cover for curing for the number of days such forms remain in place, providing all exposed concrete surfaces are so covered. Curing shall continue for a period of not less than seven (7) days after placing the concrete. Other precautions to insure development of strength shall be taken as the Engineer may direct.
- 2. Liquid Membrane Curing Compound Method (Linseed Oil Cure):** White pigmented linseed oil-based emulsion compound shall be used. The compound shall be uniformly applied after the final finishing operations are completed and immediately after the free water has left the surface.

The curing compound may be applied in either one or two applications in accordance with the direction of the manufacturer. If applied in two coatings, the second shall not be applied later than 30 minutes after the first.

Equipment, workmen, and materials will not be allowed on the surface for a minimum of seven days after application of the curing compound, unless the surface is adequately protected with an approved material. This protection shall not be applied for at least eight hours after application of the curing compound. If the membrane film is broken or damaged within the seven (7) day curing period, the areas affected shall be given a duplicate treatment of the curing material, at the same application rate as the first treatment.

Application of linseed oil base emulsion curing compound shall conform to the following requirements:

- a)** Prior to application, the material shall be mixed to a uniform consistency without the use of air, violent agitation, or thinning.
- b)** The material shall be maintained above 50°F during application.
- c)** The material shall be spray applied with an applicator of sufficient capacity and spray nozzles of proper size and design to provide a uniform application at the specified rate immediately after the concrete has received the final finish.
- d)** Unless otherwise provided on the plans or ordered by the Engineer, minimum application rate shall be as follows:

- 1) Carpet drag or broom finish - one gallon/150 square feet
  - 2) Steel tine finish - one gallon/125 square feet
- 3. Curing for Special Surface Finish:** For surfaces that are not to be cured with linseed oil curing compound, such as Type "C" walls, forms shall remain in place for minimum 72 hours. Keep surfaces to be rubbed moist after forms are removed. Cure immediately with linseed oil curing compound following the first rub. For formed surfaces, leave the forms in-place without loosening. If forms are removed during the curing period to facilitate rubbing, only strip forms from those areas able to be rubbed during the same shift.

Surfaces, which are to receive a rubbed finish or a brush finish, shall be cured by a method other than linseed oil cure until the rubbing or brushing has been completed, after which the linseed oil cure shall be used as directed above, and maintained for the duration of the cure period.

Surfaces which are to receive a commercial texture finish, or colored concrete, shall be cured by a method other than linseed oil cure. Linseed oil curing compound will not be allowed on any surface to which concrete is to be bonded.

- L. Protection of Concrete:** The following provisions apply to all type of concrete except PCC concrete pavement.

Vibrations caused by any work activities that may be detrimental to the freshly placed concrete will not be allowed for at least 72 hours after placement or until the concrete has attained a minimum compressive strength of 1600 psi. If the Engineer suspects that construction activities may be causing excessive vibration, a 2 inch x 4 inch stake shall be driven solidly into the ground adjacent to the freshly placed concrete. A small container of water shall then be placed on top of the stake. If the water surface remains calm, the construction activity will be allowed to continue. When the water surface shows any movement, vibrations are reaching the freshly placed concrete and the construction activities shall be either stopped or altered such that vibrations at the freshly placed concrete are eliminated.

Enclosures for protection of concrete shall be capable of maintaining the temperature specified and permit free circulation of artificial heat. Open flame type heating units are prohibited.

Form insulation shall be bats of fiberglass, rockwool, balsam wool, or similar commercial insulation material. Insulation shall remain in place for the full protection period. The forms may be loosened slightly to control the temperature of the concrete below the maximum value specified.

The Contractor shall install a min-max (a.k.a. high-low) thermometer at locations determined by the Engineer, to determine the concrete temperature when the forecasted air temperature will drop below 40°F.



1. Concrete for sidewalks, curb and gutter, fillets, drop inlets, manholes, pipe headwalls, driveway pavement, etc. shall be maintained above 35°F until it has attained 1500 psi compressive strength.
2. Concrete for box culverts, retaining walls, anchor blocks, median barriers, light and signal footings, and other structures shall be maintained at a temperature of 50°F or above for the first 72 hours after the concrete has been placed. The concrete shall be maintained at a temperature of 40°F or above for the next 48 hour period. If low temperatures are recorded during this protection period, one extra day of protection time above 40°F shall be added to the original five days of protection for each day that the minimum concrete temperature falls below the specified temperature.

If an additional bag of cement per cubic yard is used, or if high early strength cement is permitted, the concrete shall be maintained at a temperature of 60°F or above for 72 hours. If temperatures less than 60°F are recorded during this protection period, the protection time required shall revert back to that in the preceding paragraph with its provision for low temperatures also being applicable.

Until one of the protection periods have been satisfied, cold weather protection shall continue, falsework shall remain in place, live loads shall not be applied, and the concrete temperature shall be maintained above 35°F.

At the end of the protection period, the concrete temperature shall not be permitted to fall more than 40°F in each subsequent 24 hour period.

The surface temperature of concrete protected by housing and heating or insulated forms shall not exceed 100°F during the protection period.

It will be permissible to flood concrete with water to a minimum depth of 1 foot for 10 calendar days after the concrete is placed maintaining a water temperature which prevents freezing of the water in contact with the concrete.

- M. Removal of Formwork and Construction of Superimposed Elements:** In the determination of the time for the removal of false work and forms, consideration shall be given to the location and character of the structure, the weather, and any other conditions influencing the setting of the concrete.

Methods of removal of temporary works likely to cause overstressing of the concrete shall not be used. Temporary works shall be removed such that the concrete gradually and uniformly takes stresses due to its own weight.

Falsework, forms and other temporary works shall not be removed and superimposed elements shall not be placed without the approval of the Engineer. Falsework and forms may be removed from the affected concrete and placement of superimposed elements may proceed when the concrete reaches the strength specified in Table 1. Concrete compressive strength shall be used as the basis for falsework removal, form removal, and placement of superimposed elements whenever possible. Falsework

removal, form removal, and superimposed element placement may be allowed on the basis of time only when concrete compressive strength is not able to be determined and shall not include periods of time when the temperature is below 40°F.

**Table 2**

Structural Elements	Formwork/Form Removal		Placement of Superimposed Elements	
	Concrete Strength psi	Time	Concrete Strength psi	Time
Footings/Sleeper Slabs	800	24 hrs.	1600	72 hrs.
Box Culvert:				
Floor, Wing Wall Footings	800	24 hrs.	1600	72 hrs.
Walls	800	24 hrs.	3000	20 days
Top Slab	2000	12 days	1200	48 hrs.
Other Vertical Surfaces not Carrying Load	800	24 hrs.		

For removal of formwork associated with structures not listed in Table 1 refer to SDDOT Standard Specifications.

- N. Backfilling and Application of Liveload:** All concrete shall attain full design strength and all falsework shall be removed prior to backfilling and applying highway live loads to the structure. Construction vehicles, materials, and equipment weighing less than 4,000 pounds in total will be allowed on any span, provided the most recently placed concrete has attained a compressive strength of 2,400 psi. Loads over 4,000 pounds will not be allowed until the concrete has attained design strength and all falsework has been removed.

The only exceptions are that footings, curb and gutter, and sidewalks shall not be backfilled until permission has been given by the Engineer.

Backfill material shall be placed in accordance with the associated specification section.

Luminaires, sign poles, and signals shall not be installed on their footings until the concrete has reached full design strength.

- O. Joints:** Shall be constructed at the locations and of the dimensions shown on the plans or as directed by the Engineer. In joining fresh concrete to that which has already set at a construction joint, the concrete in place shall have all loose material removed.
- P. Concrete Quality Tests:** The Contractor is to be responsible for slump, air content, seven (7) and twenty-eight (28) day compressive strength test sets unless otherwise indicated in detailed plans and specifications. All sampling and testing shall be done by certified testing laboratory and American Concrete Institute (ACI) certified personnel.

Testing shall be done at the rate of one test set per maximum 30 cubic yards of concrete placed. All test results shall be submitted to the Engineer prior to final payment. The Engineer or his representative shall be present for all field sampling.

**55.4 METHOD OF MEASUREMENT**

Measurement of concrete structures shall be per the associated specification section.

**55.5 BASIS OF PAYMENT**

Payment for concrete structures shall be per the associated specification section.

Payment will be full compensation for materials, labor, equipment and tools necessary, concrete, reinforcing steel, joint sealer, plastic sheeting, preformed expansion joint material, sawing, testing, curing, finishing, and incidentals.

**END OF SECTION**