SECTION 550 BRIDGE CONSTRUCTION

Section 551 - Piling

DESCRIPTION

551.01 Work

This work shall consist of furnishing and driving or placing piling.

The contractor shall furnish the piles in accordance with an itemized list that will be furnished by the Engineer, showing the number and lengths of all piles. No list will be furnished when cast-in-place concrete piles are specified. When test piles and load tests are required in accordance with Subsections 551.02 and 551.03, respectively, the data obtained from driving test piles and making load tests will be used in conjunction with other available subsoil information to determine the number and lengths of piles to be furnished. The Engineer will not prepare the itemized list of piles for any portion of the foundation area until all required load tests and test pile driving in that portion have been completed.

Lengths of piles given in the order list will be based on the lengths that are assumed to remain in the completed structure. The contractor shall, without added compensation, increase the lengths to provide for fresh heading and for such additional length as might be necessary to suit the contractor's method of operation.

551.02 Test Piles

For information, the contractor may drive as many test piles as necessary. When called for in the SCHEDULE OF ITEMS or when needed for calibrating hammers in accordance with Subsection 551.03, the contractor shall furnish and drive test piles of the dimensions and at the locations SHOWN ON THE DRAWINGS or ordered by the Engineer. They shall be of the material shown in the SCHEDULE OF ITEMS and shall be driven to refusal or to such tip elevation or approximate bearing value SHOWN ON THE DRAWINGS or ordered by the Engineer. When test piles are to be incorporated in the completed structure, they shall be driven with the same type of hammer that will be used for driving the contract piles.

When the Engineer requests a load test to determine a bearing value, the first load test pile shall be driven to the specified bearing value as determined by the applicable formula indicated in Subsection 551.04. Subsequent test piles to be load tested shall be driven to the specified bearing values as determined by the applicable formula modified by the results of prior load tests and foundation data. It is the intent of these specifications that test piles to be load tested shall fail between two and three times the specified bearing value except for piles driven to refusal, rock, or a specified tip elevation. The ground at each test pile shall be excavated to the elevation at the bottom of the footing before the pile is driven. The hammer used shall meet the requirements of Subsection 551.16.

551.03 Load Tests

When called for in the SCHEDULE OF ITEMS, load tests shall be made where SHOWN ON THE DRAWINGS or required in the SPECIAL PROJECT SPECIFICATIONS. When diesel or other types of hammers requiring calibration are to be used, the contractor shall make load tests even though no load tests are called for in the SCHEDULE OF ITEMS, except that load tests will not be required when the hammer is to be used only for driving piles to refusal, rock, or a fixed tip elevation, or when the hammer is of a type and model that has been previously calibrated for similar type, size, and length of pile, and foundation material. Calibration data must have been obtained from sources acceptable to the Engineer.

Load tests shall be made by methods approved by the Engineer. The contractor shall submit to the Engineer for approval detailed drawings of the loading apparatus he intends to use. The apparatus shall be constructed to allow the various increments of

the load to be placed gradually without causing vibration to the test piles. If the approved method requires the use of tension (anchor) piles, such tension piles shall be of the same type and size as the permanent piles and shall be driven in the location of permanent piles when feasible. Permanent piling used as anchor piling that is raised during the load test shall be redriven to original grade and bearing.

After the completion of load tests, the load used shall be removed, and the piles, including tension piles, shall be used in the structure if they are found by the Engineer to be satisfactory for such use. Test piles not loaded shall be used similarly. If any pile, after serving its purpose as a test or tension pile, is found unsatisfactory for use in the structure, it shall be removed or cut off at least 1 foot below the ground line or footings, whichever is applicable.

551.04 Timber Pile Bearing Values by Formula

When load tests are called for in the SCHEDULE OF ITEMS, and when diesel or other hammers to be calibrated are used, the minimum number of hammer blows per unit of pile penetration needed to obtain the specified bearing value of piles will be determined by load tests in accordance with Subsections 551.02 and 551.03. In the absence of load tests, the safe bearing value of each timber pile will be determined by whichever of the following approximate formulas is applicable.

For gravity hammers:

$$P = \frac{2WH}{S + 1}$$

For single-acting steam or air hammers and for diesel hammers having unrestricted rebound of ram:

$$P = \frac{2WH}{S + 0.1}$$

For double-acting steam or air hammers and diesel hammers having enclosed rams:

$$P = \frac{2E}{S + 0.1}$$

where

P = *safe load per pile in pounds;*

W = *weight of the striking part of the hammer in pounds;*

H = *height of fall in feet for gravity, steam, and air hammers; and observed average height of fall, in feet, of blows used to determine penetration for diesel hammers with unrestricted rebound of ram;*

S = *average penetration per blow in inches for the last 5 to 10 blows of a gravity hammer or the last 10 to 20 blows of a steam, air, or diesel hammer; and*

E = *the manufacturer's rating for foot-pounds of energy developed by double-acting steam or air hammers, and*

= *90 percent of the average equivalent energy in foot-pounds as determined by gauge attached to the pile hammer and recorded during the period when the average penetration per blow is recorded for diesel hammers having enclosed rams. Hammers of this type shall be equipped with a gauge, and applicable charts shall be supplied that will evaluate the equivalent energy being produced under any driving condition.*

The above formulas are applicable only when:

(a) The hammer has a free fall.

(b) The head of the pile is free from broomed or crushed wood fiber or other serious impairment.

(c) The penetration is at a reasonably quick and uniform rate.

(d) There is no measurable bounce after the blow.

(e) If a gravity hammer is used, its weight shall be at least 3,000 pounds and equal to or greater than the weight of the pile plus the weight of the driving head, but shall not be greater than three times the weight of the pile.

(f) A follower is not used.

If there is a measurable bounce, twice the height of bounce shall be deducted from H to determine the value in the formula. The bearing power as determined by the appropriate formula in the foregoing list will be considered effective only when it is less than the crushing strength of the pile.

In all cases, when bearing power is determined by a formula, timber piles shall be driven until the computed safe bearing power of each is not less than the design value SHOWN ON THE DRAWINGS. Piles shall be driven to a pile tip elevation at least as low as SHOWN ON THE DRAWINGS.

551.05 Concrete & Steel Pile Bearing Values

The formulas specified above for timber piling may be used to approximate the bearing value of precast concrete piles, cast-in-place concrete piles, and structural steel piles.

Wave Equation Analysis. Wave Equation Analysis shall be used to determine pile bearing values when specified in the SPECIAL PROJECT SPECIFICATIONS or SHOWN ON THE DRAWINGS. When wave equation analysis is specified, all pile driving equipment to be used in the work shall be subject to approval by the Engineer. Prerequisite to the Engineer's approval, the contractor shall submit the following:

(a) The pile hammer operating specifications. The specifications shall include the weight, diameter, and length of the ram; drive head and anvil (if applicable) dimensions and weights; capblock and cushion data (such as material thickness, area, modulus of elasticity, and coefficient of restitution); net weight of hammer, net weight of cylinder, and piston areas for doubleacting or differential acting air or steam hammers; bounce chamber pressure versus equivalent energy graphs for closed-end diesel hammers; and mandrel type and weight, when applicable.

(b) A wave equation analysis bearing the approval of a registered professional engineer for each hammer proposed for use to determine the soil resistance value SHOWN ON THE DRAWINGS unless otherwise provided in the SPECIAL PROJECT SPECIFICATIONS.

The pile hammer operating specifications and wave equation analysis shall be submitted to the Engineer at least 21 days prior to commencing pile driving operations. The Engineer will approve or deny the submittal within 7 days of receipt from the contractor.

Approval of the proposed pile hammer shall not relieve the contractor of responsibility for stress-damaged piles due to misalignment of the leads, failure of capblock or cushion material, failure of splices, malfunctioning of the pile hammer, or other improper construction methods. Piles damaged for such reasons shall be rejected if the damage impairs the strength of the pile as determined by the Engineer.

In all cases where the bearing value of concrete and steel piles is determined by formula, the piles shall be driven until the safe bearing value of each is computed to be not less than the design value SHOWN ON THE DRAWINGS. Piles shall be driven to a tip elevation at least as low as SHOWN ON THE DRAWINGS.

551.06 Minimum Penetration

All piles shall penetrate at least 10 feet into the natural ground, and when a pile tip elevation is specified shall penetrate at least to the specified tip elevation. When the blow count approaches refusal without reaching the required penetration, additional aids shall be used to obtain the specified penetration, unless otherwise permitted in writing by the Engineer. These aids may include the use of waterjets or larger hammer and ram striking with low velocity. Driving equipment that damages the pile shall not be used.

551.07 Jetted Piles

The safe bearing value of jetted piles will be determined by actual tests or by the appropriate method and formulas given above. No jet shall be used during the test blows.

MATERIALS

551.08 Requirements

Materials for piling shall meet the requirements of the following Subsections:

Untreated Timber Piles	715.01
Treated Timber Piles	715.02
Concrete Piles	552.03-04
Steel Shells	715.04
Steel Pipes	715.05
Steel H-Piles	715.06
Sheet Piles	715.07
Pile Shoes	715.08
Paint	708.03
Reinforcing Steel	709.01
Prestessing Reinforcing Steel	709.03

CONSTRUCTION

551.09 Precast Concrete Piles

Precast concrete piles shall be of the design or designs SHOWN ON THE DRAWINGS. They shall be constructed of Portland cement concrete meeting the requirements of Section 552. Prestressed concrete piles shall be prestressed in accordance with Section 553.

The piles shall be cast separately or if alternate piles are cast in a tier, the intermediate piles shall not be cast until 4 days after the adjacent piles have been poured. Piles cast in tiers shall be separated by tar paper or other suitable separating materials. The concrete in each pile shall be placed continuously. The completed piles shall be free from stone pockets, honeycombs, or other defects, and shall be straight and true to the form specified. The forms shall be true to line and built of metal, plywood, or dressed lumber. A 1-inch chamfer strip shall be used in all corners unless otherwise SHOWN ON THE DRAWINGS. Forms shall be watertight and shall not be removed until at least 24 hours after the concrete is placed. Exposed surfaces of piles shall be given a Class 1 ordinary surface finish. Piles shall be cured and finished in accordance with the applicable requirements of Section 552 or 553.

Test cylinders shall be made in accordance with AASHTO T 23 and tested for compressive strength in accordance with AASHTO T 22.

Piles shall not be moved until the tests indicate a compressive strength of 80 percent of the required 28-day compressive stength, and they shall not be transported or driven until the tests indicate a compressive strength of the required 28-day compressive strength.

When concrete piles are lifted or removed, they shall be supported at the points SHOWN ON THE DRAWINGS or, if not so shown, they shall be supported at the quarter points.

551.10 Cast-In-Place Concrete Piles

Cast-in-place concrete piles shall be of the design or designs SHOWN ON THE DRAWINGS. They shall consist of concrete cast-in-steel shells or pipes driven to the required bearing. Concrete shall meet the requirements of Section 552.

The inside of shells and pipes shall be cleaned and all loose material removed before concrete is placed. The concrete shall be placed in one continuous operation from tip to cutoff elevation avoiding segregation. The top 15 feet of concrete-filled shells shall be consolidated by vibratory equipment.

Pipes shall be of the diameter SHOWN ON THE DRAWINGS. The wall thickness for shell pipes shall not be less than that SHOWN ON THE DRAWINGS but in no case less than 16 gauge (0.064 inch). The pipe, including end closures, shall be of sufficient strength to be driven by the specified methods without distortion.

Closure plates and connecting welds shall not project more than 1/2 inch beyond the perimeter of the pile tips.

Shells or pipes shall not be filled with concrete until all adjacent shells, pipes, or piles within a radius of 15 feet have been driven to the required resistance, or until all shells or pipes for any one bent or abutment have been completely driven.

No shell, pipe, or pile shall be driven within 20 feet of a shell or pipe that has been filled with concrete until at least seven days have elapsed.

551.11 Steel H-Piles

Steel H-piles shall consist of structural steel shapes of the sections SHOWN ON THE DRAWINGS.

When placed in the leads, the pile shall not exceed the camber and sweep permitted by allowable mill tolerance. Piles bent or otherwise damaged will be rejected.

The loading, transporting, unloading, storing, and handling of steel H-pile shall be conducted so that the metal will be kept free from damage.

551.12 Open End Tubular Steel Piles

Piles with an outside diameter of less than 14 inches shall have a minimum wall thickness of 1/4 inch. Piles with an outside diameter of 14 inches and greater shall have a minimum wall thickness of 3/8 inch. The pipe shall be of sufficient strength to be driven by the specified methods without distortion.

551.13 Timber Piles

(a) General. The heads of treated timber piles shall be shaped to fit the driving head.

(b) Strapping. Treated timber piles shall be strapped with a minimum of three straps: one approximately 18 inches from the butt, one approximately 24 inches from the butt, and one approximately 12 inches from the tip. In addition, piles shall be strapped at an interval not to exceed 15 feet. Straps shall be approximately 1.25 inches wide, 0.03 inch thick, and manufactured from cold-rolled, heat-treated steel. The strap shall have an ultimate tensile strength of 5,100 pounds. The strap shall encircle the pile once and shall be fastened with a clip so crimped that the joint will have a minimum tensile strength of 80 percent of the tensile strength of the strap. The strap shall be installed after pressure treating of the pile.

(c) Storage and Handling of Timber Piles. The method of storage and handling shall be such as to avoid injury to the piles. Special care shall be taken to avoid breaking of the surface of treated piles. Cuts or breaks in the surface of treated piles

shall be protected in accordance with AWPA Standard M-4. If the treatment is damaged so that the integrity of the pile is in jeopardy, the pile will be rejected and a replacement pile shall be furnished by the contractor at no expense to the Government.

(d) Minimum Diameter. The minimum diameter of timber piling shall be as SHOWN ON THE DRAWINGS.

551.14 Extensions

Extensions, when approved by the Engineer, shall be made in accordance with this Subsection.

(a) Precast Concrete Piles. Extensions of precast concrete piles shall be made by cutting away the concrete at the end of the pile, leaving the reinforcement steel exposed for a length of 40 diameters. The final cut of the concrete shall be perpendicular to the axis of the pile. Reinforcement of the same size as used in the pile shall be fastened securely to the projecting steel and the necessary form work shall be placed. Care shall be taken to prevent leakage along the pile. Just prior to placing concrete, the top of the pile shall be wetted thoroughly and covered with a thin coating of neat cement, or other bonding material. The forms shall remain in place until the concrete has attained at least two-thirds of its required strength. If tests are not available, forms shall remain in place until the concrete is set and will not be damaged, but not less than 7 days. Curing and finishing operations shall be in accordance with Sections 552 and 553.

(b) Prestressed Piles. Extensions of prestressed precast piles will generally not be permitted, but when permitted they shall be made in accordance with (a) above, but only after driving has been completed. Reinforcement bars shall be included in the pile head for splicing to the extension bars. No additional driving will be permitted. The contractor has the option of submitting alternative plans of extensions for approval by the Engineer.

(c) Steel H-Piles, Pipes, Shells, and Open-End Tubular Steel Pipes. If the ordered length of a steel H-pile, pipe, or open-end tubular steel pile shell is insufficient to obtain the specified bearing value, an extension of the same cross section shall be spliced to it. Unless otherwise SHOWN ON THE DRAWINGS, splices shall be made by butt-welding the entire cross section, using the electric arc method in accordance with current AWS specifications. Butt-welded surfaces shall be flat or concave. Every effort shall be made to have welds below ground. Where exposed in pile bents, welds exceeding 1/16 inch in thickness above the base metal shall be ground off.

551.15 Timber Pile Bents

Piles for any one bent shall be carefully selected as to size, to avoid undue bending or distortion of the sway bracing. However, care shall be exercised in the distribution of piles of various sizes to obtain uniform strength and rigidity in the bents of any given structure.

Cutoffs shall be made accurately to ensure full bearing between caps and piles of bents.

551.16 Driving Piles

At least 21 days before first use of any pile hammer, the contractor shall furnish the Engineer two copies of the manufacturer's specifications on the hammer. The specifications shall include all information necessary to properly use the appropriate bearing value formula in Subsection 551.04 and to verify that the hammer meets the other requirements of this Section. All piles shall be driven at locations SHOWN ON THE DRAWINGS. They shall be driven within an allowed variation of 1/4 inch per foot of pile length above the ground from the vertical or batter SHOWN ON THE DRAWINGS. The maximum allowable variation from the pile design location and batter shall be as SHOWN ON THE DRAWINGS.

Prior to driving piles, all structure excavation shall have been performed in accordance with Sections 203 and 206.

Predrilled holes to facilitate pile-driving operations shall be provided to the diameter and depths SHOWN ON THE DRAWINGS when required by the SPECIAL PROJECT SPECIFICATIONS. The diameter of the holes shall not be greater than 0.8 times the diameter of the piles unless permitted by the Engineer.

The heads of all piles shall be protected by caps of approved design, having a rope or other suitable cushion next to the pile head and fitting into a casting, which in turn supports a timber shock block.

For special types of piling, driving heads, mandrels, or other devices meeting the manufacturers' recommendations shall be provided so the pile can be driven without damage.

For steel piling, the heads shall be cut squarely and a driving cap shall be provided to hold the axis of the pile in line with the axis of the hammer.

Full-length piles shall be used except when splices are permitted as provided by Subsection 551.14.

Piles shall be driven with steam, air, diesel hammers, or a combination of hammers with water jets. Gravity or drop hammers are permitted when driving timber piles unless excluded ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS.

The plant and equipment furnished for steam and air hammers shall have sufficient capacity to maintain, under working conditions, the pressure at the hammer specified by the manufacturer. The boiler or tank shall be equipped with an accurate pressure gauge, and another gauge shall be supplied at the hammer intake to determine the drop in pressure between the gauges.

Gravity hammers permitted for driving timber piling shall weigh not less than the combined weight of the driving head and pile, nor less than 3,000 pounds. When gravity hammers are permitted for driving timber piles, the drop of the hammer should be regulated to avoid damage to the pile.

Pile hammers, except gravity or drop hammers, shall be steam, air, or diesel hammers that develop sufficient energy to drive the piles at a penetration rate of not less than 1/8 inch per blow at the required bearing value. When steam, air, or diesel hammers are used, the total energy developed by the hammer shall be not less than 7,000 foot-pounds per blow, except as specified below for concrete piles.

Diesel hammers shall be operated with wide-open throttles when blows are being counted for determination of penetration for use in the safe load formula, except that in the case of diesel hammers with enclosed rams, the throttle settings shall be just short of the settings that would cause nonstriking parts of the hammers to rise off the piles as the ram piston travels upward.

Piles shall be supported in line and position with leads while being driven. Pile driver leads shall be constructed to afford freedom of movement of the hammer, and they shall be held in position by guys or steel braces to ensure rigid lateral support to the pile during driving. Except where piles are driven through water, the leads shall be of sufficient length to make the use of a follower unnecessary and shall be designed to permit proper placing of batter piles. The driving of piles with followers shall be allowed only with written approval from the Engineer.

Steam, diesel, or air hammers used for driving concrete piles shall develop an energy per blow at each full stroke of the piston of not less than 3,500 foot-pounds per cubic yard of concrete in the pile driven.

No driving of piles shall be done within 20 feet of concrete less than 7 days old.

551.17
Defective Piles

The method used in driving piles shall not produce crushing and spalling of the concrete, injurious splitting, splintering, and brooming of the wood, or deformation of the steel. Excessive manipulation of piles to force them into proper position will not be permitted. Any pile damaged by reason of internal defects, or by improper driving, or driven out of its proper location, or driven below the elevations SHOWN ON THE DRAWINGS or set by the Engineer, shall be corrected by the contractor, without added compensation, by one of the following methods approved by the Engineer for the pile in question:

(a) The pile shall be withdrawn and replaced by a new and, when necessary, longer pile.

(b) A second pile shall be driven adjacent to the defective pile.

(c) The pile shall be spliced or built up as otherwise provided herein or a sufficient portion of the footing extended to properly embed the pile. Piles shall not be spliced unless approved by the Engineer. All piles pushed up by the driving of adjacent piles or by any other cause shall be driven down again.

A concrete pile will be considered defective if it has a visible crack, or cracks, extending around the entire periphery of the pile or any defect that affects the strength or life of the pile.

551.18
Cutting Off & Capping Piles

Piles shall be cut off level at the elevation SHOWN ON THE DRAWINGS. The length of pile cutoff shall be sufficient to permit the removal of all injured material. The distance from the side of any pile to the nearest edge of the footing shall be a minimum of 9 inches.

When the cutoff elevation for a precast concrete pile or for the steel shell or concrete casing for a cast-in-place concrete pile is below the elevation of the bottom of the cap, the pile shall be built up from the butt of the pile to the elevation of the bottom of the cap by means of a reinforced concrete extension as approved by the Engineer. Steel shells or concrete casings for cast-in-place concrete piles shall be cut off at the DESIGNATED elevation before being filled with concrete.

Cutoffs of steel bearing piles shall be made at right angles to the axis of the pile. The cuts shall be made in clean, straight lines.

Cutoffs of treated timber piles shall be protected in accordance with AWPA Standard M-4.

At the completion of the work, all unused pile cutoff lengths not included in the itemized order list furnished by the Engineer shall become the property of the contractor and shall be removed or disposed of by the contractor.

551.19
Protecting Untreated Timber Trestle Piles

The sawed surface of the heads of untreated piles shall be thoroughly brush coated with two applications of hot creosote oil or other approved preservative.

551.20
Painting Steel Piles

When steel piles extend above the ground surface or water surface, they shall be protected by three coats of paint in accordance with the systems for cleaning and painting metal surfaces in Section 555 as SHOWN ON THE DRAWINGS. This protection shall extend from the elevation SHOWN ON THE DRAWINGS to the top of the exposed steel.

MEASUREMENT

551.21 Method

The method of measurement, as described in Section 106, will be DESIGNATED in the SCHEDULE OF ITEMS.

551.22 Timber, Steel, & Precast Concrete Piles

(a) Piles Furnished. Measurement (in feet) will be the sum of the lengths, measured to the nearest foot, of the several types and lengths of piles furnished and stockpiled in good condition at the site of the work by the contractor and accepted by the Engineer. The number of feet to be measured will include the lengths of test and tension piles required, but not the lengths of those furnished at the contractor's option. No measurement will be made for footage of piles, including test piles, furnished by the contractor to replace piles previously accepted by the Engineer that are lost or damaged while in stockpile or during handling or driving, prior to completion of the contract and which are subsequently removed from the site of the work or disposed of otherwise.

If case extensions of piles are necessary, the extension length will be included in the linear footage of piling furnished, except for cutoff lengths used for extensions and otherwise measured for payment.

(b) Piles Driven. Driving of timber, steel, and precast concrete piles will be measured to the nearest foot of piling in place between the actual tip elevation and the elevation of the ground existing at the pile immediately prior to driving. Structure excavation, if required, shall have been performed prior to this measurement. Test piles driven at the option of the contractor will not be included unless they comply fully with the requirements specified herein and are accepted by the Engineer to become part of the completed structure.

Drilled or jetted holes for facilitating pile driving procedures will not be measured directly, but will be considered incidental to pay items on the SCHEDULE OF ITEMS.

551.23 Cast-In-Place Concrete Piles

Cast-in-place piles will be measured by the actual number of feet of piles cast and left in place in the completed and accepted work. Measurement to the nearest foot will be made from the point of the tip of the pile to the bottom of the cap or bottom of the footing, as the case may be. Portions of piles cast deeper than required will not be measured.

551.24 Pile Shoes

Pile shoes, including test pile shoes, will be measured as the number of pile shoes SHOWN ON THE DRAWINGS or ordered in writing by the Engineer, furnished and stockpiled by the contractor in good condition at the site of the work, and accepted by the Engineer. Pile shoes furnished at the contractor's option will not be included. No allowance will be made for pile shoes furnished by the contractor to replace pile shoes previously furnished and accepted by the Engineer that are lost or damaged while in stockpile or during handling prior to completion of the contract and which are subsequently removed from the site of the work or disposed of otherwise.

551.25 Load Tests

Load tests will be measured by the number of load tests completed and accepted. Load tests made at the option of the contractor and load tests made to calibrate diesel or other designated types of hammers will not be included in the quantity measured.

551.26 Splices

Splices for pipes, shells, or H-piles will be measured by the number of splices ordered and accepted by the Engineer. Splices made for the convenience of the contractor will not be measured.

PAYMENT

551.27 Basis

The accepted quantities will be paid for at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS.

Payment will be made under:

Pay Item		Pay Unit
551(01)	Untreated Timber Piles, Furnished	L.F.
551(02)	Treated Timber Piles, _____ Preservative, Furnished	L.F.
551(03)	Steel H-Piles, Furnished	L.F.
551(04)	Precast Concrete Piles, Furnished	L.F.
551(05)	Precast Prestressed Concrete Piles, Furnished .	L.F.
551(06)	Untreated Timber Sheet Piles, Furnished	L.F.
551(07)	Treated Timber Sheet Piles, _____ Preservative, Furnished	L.F.
551(08)	Precast Concrete Sheet Piles, Furnished	L.F.
551(09)	Steel Shells for Concrete Piles, Furnished . . .	L.F.
551(10)	Steel Pipes for Concrete Piles, Furnished . . .	L.F.
551(11)	Untreated Timber Piles, Driven	L.F.
551(12)	Treated Timber Piles, Driven	L.F.
551(13)	Steel H-Piles, Driven	L.F.
551(14)	Precast Concrete Piles, Driven	L.F.
551(15)	Untreated Timber Sheet Piles, Driven	L.F.
551(16)	Treated Timber Sheet Piles, Driven	L.F.
551(17)	Precast Concrete Sheet Piles, Driven	L.F.
551(18)	Precast Prestressed Concrete Piles, Driven . . .	L.F.
551(19)	Test Piles, _____, Driven	L.F.
551(20)	Concrete Piles Cast in Steel Shells, Driven . .	L.F.
551(21)	Concrete Piles Cast in Steel Pipes, Driven . . .	L.F.
551(22)	Pile Shoes	EA.
551(23)	Splices	EA.
551(24)	Load Tests	EA.

Section 552 - Structural Concrete

DESCRIPTION

552.01 Work

This work shall consist of furnishing, placing, and finishing concrete in major structures. Concrete shall consist of a mixture of Portland cement or fly ash modified Portland cement, fine aggregate, coarse aggregate, admixtures when required, and water mixed in the proportions approved by the Engineer.

552.02 Classes, Composition, & Testing of Concrete

(a) Classes of Concrete. The class of concrete used in each part of the structure shall be as SHOWN ON THE DRAWINGS or approved by the Engineer.

Prestressed concrete shall be Class P. Concrete deposited under water shall be seal concrete. All other concrete shall be Class A and shall be air entrained.

(b) Composition of Concrete. The contractor, through an approved testing laboratory, shall design the mix for each class of concrete. The mix design proposed by the contractor shall meet the requirements in table 552-1 and the minimum strength requirements SHOWN IN THE DRAWINGS, in the SPECIAL PROJECT SPECIFICATIONS, or in Subsection 552.02(c). The testing laboratory engaged by the contractor shall be fully equipped and capable of performing the required tests and services. The mix design shall be based on representative samples of aggregates, cement, water, and admixtures to be used on the project. Aggregate samples shall be taken in accordance with AASHTO T 2 and reduced to testing size in accordance with AASHTO T 248. A separate proposed mix design for each class of concrete shall be submitted to the Engineer for review at least 21 days prior to placement of the concrete in the work. If the contractor elects to change aggregate source during the progress of work, new mix designs meeting these requirements shall be submitted to the Engineer at least 21 days before such material is to be placed in the work.

Where fly ash modified concrete is used, the water/cement ratio in table 552-1 shall be computed as the ratio of the weight of water to the combined weights of Portland cement and 60 percent of the weight of the fly ash.

Current mix designs for other projects may be acceptable provided all items required herein are covered by certified submittals. Mix-design and aggregate quality tests from other projects shall have been run within 12 months of the date of submittal, and the aggregate source must be the same.

Table 552-1.--Classes of structural concrete--requirements.

Class of Concrete	Method of Placing	Minimum Cement Content Required (Pounds per cu yd)	Maximum Water/ Cement Ratio Allowed (Pounds per Pound)	Required Slump (Range) (Inches)	Required Entrained Air (Range) (Percent)
A[b]	Vibrated	611	0.49	2-1/2 (±1)	5(±1)
pb	Vibrated	658	0.44	2(±1)	-- --[a]
Seal	Nonvibrated	658	0.54	6(±2)	-- --

[a]Designated by 28-day compressive strength SHOWN ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS. See Subsection 552.02(c) for minimum strength requirements.

[b]Concrete used in prestressed concrete sections shall not be air-entrained unless SHOWN ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS.

Each mix design shall include the following items:

(1) Location and identification of aggregate source.

(2) Batch quantities for 1 cubic yard of concrete, including:

a. Weight in pounds of fine aggregate in the saturated surface dry condition.

b. Weight in pounds of each coarse aggregate size in the saturated surface dry condition.

c. Weight in pounds of cement.

d. Weight in pounds and volume in gallons of water and the water/cement ratio in pounds per pound.

e. Amount and description (include manufacturer, specific product name, and number) of all admixtures, including fly ash.

(3) Test results on the proposed mix design, including the following:

a. Cement factor in pounds per cubic yard based on yield test.

b. Water/cement ratio expressed in pounds of water per pound of cement (aggregates in saturated surface dry condition).

c. Percent entrained air by volume.

d. Consistency in inches of slump.

e. At least three 7-day and three 28-day compressive strength tests.

(4) Brand, type, and place of manufacture of cement.

(5) Aggregate test results for grading, deleterious substances, and physical properties shall be in accordance with Section 703. In addition to the requirements of Section 703, bulk specific gravity and absorption of coarse and fine aggregate shall be given. Unless waived in writing by the Engineer, the following test results shall be submitted.

Fine Aggregate

a.	Sieve analysis	AASHTO T 27
b.	Fineness modulus	AASHTO M 6
c.	Deleterious substances	
	Clay lumps and friable particles	AASHTO T 112
	Material finer than the No. 200 Sieve . . .	AASHTO T 11
	Coal and lignite, as defined in 7.1.6 of AASHTO M 80	AASHTO T 113
	Organic impurities	AASHTO T 21
d.	Evaluation of potential aggregate reactivity	AASHTO M 80
e.	Bulk specific gravity and absorption capacity	AASHTO T 84
f.	Sand Equivalent (min. 75)	AASHTO T 176

Coarse Aggregate

a.	Sieve analysis	AASHTO T 27
b.	Deleterious substances	
	Clay lumps and friable particles	AASHTO T 112
	Chert--less than 2.4 sp. gr. SSD	AASHTO T 113
	Material finer than the No. 200 sieve . .	AASHTO T 11
	Coal and lignite, as defined in 7.1.6 of AASHTO M 80	AASHTO T 113
c.	Evaluation of potential aggregate reactivity	AASHTO M 80
d.	Percentage of wear (L.A.R.)	AASHTO T 96
e.	Unit weight of aggregate	AASHTO T 19
f.	Bulk specific gravity and absorption capacity	AASHTO T 85

(c) Concrete Compressive Strength. Unless otherwise SHOWN ON THE DRAWINGS, the specified minimum 28-day compressive strength in pounds per square inch for the given classes of concrete shall be the following:

	Specified Strength		
Class	At Time of Transfer of Prestress Force (Minimum)	7-Day (Minimum)	28-Day (Minimum)
A	-----	2,300	3,500
P	4,500	-----	5,500
P (air-entrained)	4,500	-----	5,000
Seal	-----	2,000	3,000

For a strength test, two standard test specimens shall be made. For each structural element, enough specimens shall be taken to make at least one 7-day strength test and one 28-day strength test (total four specimens, minimum). The test result shall be the average of the strengths of the two specimens, except that if any specimen shows definite evidence, other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded, and the strength of the remaining cylinder shall be considered the test result.

The standard 28-day curing period for compressive strength tests shall be extended for fly ash modified concrete by 1 day (rounded to the nearest whole day) for each 1.5 percent of Portland cement replaced with fly ash at the selected rate. (Example: If the maximum of 20 percent cement is replaced, the curing period for cylinders would be 41 days.)

Prior to approval of the contractor's mix design, or approval of subsequent revised mix design(s), sampling and testing shall be the responsibility of the contractor. Field sampling and testing on the concrete being placed in the work will be made by the Engineer.

The average of all the strength tests representing the concrete in each structural element shall meet the following requirements:

(1) If seven or more strength tests are available, not more than 20 percent of the strength tests shall have values less than the specified strength, and the average of any six consecutive strength tests shall be equal to or greater than the specified strength.

(2) If six or fewer strength tests are available, the average of all the tests shall be equal to or greater than those shown in the following table:

Number of Strength Tests	Required Average Strength (Percent of Specified Strength)	
	Class A & Seal	Class P
1	79	86
2	90	97
3	94	102
4	97	105
5	99	107
6	100	108

(3) If the concrete strength tests fail to meet the requirements of this specification, the Engineer may order the contractor to have a testing laboratory, acceptable to the Forest Service, take and test core samples of questionable concrete. The Engineer may order all low-strength concrete removed and replaced if core strengths are below specified strengths. All costs connected with concrete coring and removal and replacement of concrete that fails to meet these requirements shall be borne by the contractor.

(d) Field Adjustment of Concrete Mix. Field adjustment of the concrete mix designs will be necessary to compensate for the free water content in the aggregates.

After initial mixing, if the consistency (slump) is outside the specification limits (table 552-1) by less than 1 inch, the Engineer may approve the addition of water or cement provided all the following conditions are met:

(1) Addition of Water.

a. The maximum allowable water content in pounds per cubic yard of concrete (table 552-1) is not exceeded.

b. The maximum allowable mixing time (or number of drum revolutions) is not exceeded.

c. Concrete is remixed for at least half of the minimum mixing time (or number of drum revolutions).

(2) Addition of Cement.

a. Amount of cement added does not exceed 94 pounds per cubic yard more than the mix design or a total of 705 pounds per cubic yard, unless otherwise specified in the SPECIAL PROJECT SPECIFICATIONS.

b. The maximum allowable mixing time (or number of drum revolutions) is not exceeded.

c. Concrete is remixed for at least half of the minimum mixing time (or number of drum revolutions).

d. Cement may not be added to Class P concrete.

(3) Adjustment for Variation in Yield. If the cement content of the concrete varies more than 19 pounds per cubic yard over the value in the approved mix design, the proportions may be adjusted at the request of the contractor. If the cement content varies more than 19 pounds per cubic yard below the value in the approved mix design, the proportions shall be adjusted. Adjustment of aggregate weights within the 2 percent allowed by the specification is the only adjustment of the proportions that shall be carried out in the field. Other adjustments of proportions shall be effected by the contractor obtaining a new mix design and securing approval of the new mix design from the Engineer.

(4) Adjustment for Percent Entrained Air. The amount of air-entraining admixture used in each batch will be varied as necessary from that given in the approved mix design to produce concrete having the percent entrained air specified in table 552-1.

(5) Concrete Test Methods. The following methods shall be used in making the indicated tests on concrete:

Making and curing concrete compression test specimens in the laboratory	AASHTO T 126
Sampling fresh concrete	AASHTO T 141
Coring concrete and testing drilled concrete cores	AASHTO T 24
Yield, cubic feet per batch; and cement content, pounds per cubic yard	AASHTO T 121
Percent entrained air (pressure method)	AASHTO T 152
(volume measure)	AASHTO T 196
Compressive strength of concrete cylinders	AASHTO T 22
Flexural strength of concrete	AASHTO T 97
Consistency (slump) of concrete	AASHTO T 119
Making and curing concrete compressive and flexural strength test specimens in the field	AASHTO T 23

MATERIALS

552.03 Requirements

Materials shall meet the requirements of the following Subsections:

Portland Cement	701.01
Fine Aggregate	703.01
Coarse Aggregate	703.02
Joint Fillers	705.01
Curing Materials	711.01
Air-Entraining Admixtures	711.02
Chemical Admixtures	711.03
Water	712.01
Fly Ash	712.14
Epoxy Resin Adhesives	712.10
Bonding Agents	712.12
Elastomeric Bearing Pads	717.13
Elastomeric Compression Joint Seals	717.18

552.04 Cement

Type II cement shall be used for all classes of concrete with the following exceptions:

(a) Type III cement may be used.

(b) When concrete work is permitted by the Engineer in air temperatures below 35 °F, Type III cement shall be used.

(c) Type I cement may be used if SHOWN ON THE DRAWINGS or specified in the SPECIAL PROJECT SPECIFICATIONS.

(d) Pozzolan (fly ash) concrete may be proposed for any mix design except for prestressed concrete, either pretensioned or posttensioned. If fly ash is proposed as an additive to a mix design containing Type I, II, or III cement, the fly ash shall be substituted for cement at a rate of 1.2 pounds of fly ash for 1.0 pounds of Portland cement. After substitution, design aggregate volumes shall be reduced by an amount equal to the net increase in volume of the combined cement and fly ash. Not less than 10 percent nor more than 20 percent of the minimum weight of Portland cement required by table 552-1 may be replaced with fly ash at the above rate.

An air-entraining admixture shall be used to obtain the specified air entrainment.

Cement acceptance may be based on mill certification as well as from pretested and approved bins.

The cement and fly ash shall be well protected from rain and moisture, and any cement or fly ash damaged by moisture or which fails to meet any of the specified requirements shall be rejected and removed from the work. Cement stored by the contractor for a period longer than 60 days shall require the Engineer's approval before being used on the work. Cement of different brands, types, or from different mills shall be stored separately.

CONSTRUCTION

552.05 Performance

The contractor shall submit a written schedule of concreting operations, including personnel and equipment, when requested by the Engineer. The contractor shall give the Engineer 24-hour notice prior to placing any segment of the concrete work.

552.06 Batching

Measuring and batching of materials shall be done at a batching plant.

(a) Portland Cement. Either bagged or bulk cement may be used. No fraction of a bag of cement shall be used in a batch of concrete unless the cement is weighed.

All bulk cement shall be weighed on an approved weighing device. The bulk cement weighing hopper shall be properly sealed and vented to preclude dusting during operation. The discharge chute shall not be suspended from the weighing hopper and shall be so arranged that cement will not lodge in it nor leak from it.

Accuracy of batching shall be within 1 percent of the required weight.

(b) Water. Water shall be measured by volume or by weight. The device for the measurement of the water shall be readily adjustable and shall be capable of being set to deliver the required amount and to cut off the flow automatically when this amount has been discharged. Under all operating conditions, the device shall have an accuracy within 1 percent of the quantity of water required for the batch. The device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be of adequate capacity to furnish the maximum mixing water required and shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank. Wash water is not permitted to be used as a portion of the mixing water for succeeding batches.

(c) Aggregates. Stockpiles of aggregates shall be built up in layers of not more than 3 feet in thickness. Each layer shall be completely in place before beginning the next and shall not be allowed to side cast down over the previous layer. Aggregates from different sources and of different gradings shall not be stockpiled together.

Aggregates shall be handled from stockpiles or other sources to the batching plant in a manner that secures a uniform grading of material.

Aggregates that have become segregated or mixed with earth or foreign material shall not be used. All aggregates produced or handled by hydraulic methods and washed aggregates shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipment requiring more than 12 hours will be accepted as adequate binning if the car bodies permit free drainage. If the aggregates contain high or nonuniform moisture content, storage or stockpile periods in excess of 12 hours may be required.

Accuracy of aggregate batching shall be plus or minus 2 percent of each aggregate's required weight, and plus or minus 2 percent of the total required aggregate weight.

(d) Bins and Scales. The batching plant shall include separate bins for the bulk cements, for fine aggregate, and for each size of coarse aggregate; a weighing hopper; and scales capable of determining accurately the weight of each component of the batch.

Scales shall be accurate to 0.5 percent throughout the range of use. To ensure continued accuracy, the contractor shall have scales inspected, tested, sealed, and certified by a representative of the State agency responsible for weights and measures or a qualified manufacturer's representative, as often as necessary.

(e) Batching. When batches are hauled to a jobsite stationary mixer, cement shall be transported either in bags, or in bulk in a separate waterproof compartment. When bulk cement is transported in contact with aggregates, mixing shall commence within one-half hour of such contact.

Truck mixers may be used to haul unmixed concrete batches to the construction site only when cement is hauled separately in bags or waterproof compartments.

Batches shall be delivered to the mixer separate and intact. Each batch shall be dumped cleanly into the mixer without loss.

(f) Admixtures. The contractor shall submit to the Engineer, for approval, a written procedure for adding the specified amount of admixture. He shall provide separate scales for the admixtures that are to be proportioned by weight and accurate measures for those to be proportioned by volume. All admixtures shall be measured into the mixer with an accuracy of plus or minus 3 percent.

Set retarding and/or water reducing admixture may be used provided they conform to the requirements of Type B or Type D of AASHTO M 194 or ASTM C 494. The type and quantity of the admixture to be used must be included in the mix design submitted to the Engineer. The use of the admixture shall conform to the manufacturer's recommendations.

When an air-entraining agent is being added at the mixer, the quantity or the strength of solution shall be varied as might be necessary to ensure full compliance with the requirements for air content of the concrete given in table 552-1.

The air-entraining agent may be introduced by means of an automatic dispensing device approved by the Engineer, or it may be introduced manually by pouring it on the aggregates in the skip of the mixer. When added manually, a quantity shall first be diluted with water, in the proportions specified, so that a volume of not less than 1 quart of the diluted solution is measured and added to each batch of concrete.

Admixtures, including fly ash, shall not be used to reduce the cement content below the minimum shown in the table 552-1. Admixtures containing chlorides as Cl in excess of 1 percent by weight shall not be used.

552.07 Mixing & Delivery

Concrete may be mixed at the site of construction, at a central point, by a combination of central point and truck mixing, or by a combination of central point mixing and truck agitating.

When concrete is delivered to the work site, a ticket showing dispatch time and mix design identification shall be supplied by the contractor.

Mixing and delivery of concrete shall be in accordance with the appropriate requirements of AASHTO M 157, Sections 8 and 9 with the following modifications:

(a) In addition to the requirement of Section 9.4 regarding number of truck mixer drum revolutions, the sum of all drum revolutions at both mixing and agitating speeds shall not exceed 300 before all concrete has been discharged from the drum, except that the sum of all drum revolutions shall not exceed 200 if the outside air temperature is over 85 °F. If mixing is done before arrival of the truck at the point of delivery, the drum shall again be rotated at mixing speed for 10 to 15 revolutions to reblend possible stagnant spots.

(b) If set retarding admixture is used, the sum of all drum revolutions at both mixing and agitating speeds shall not exceed 550 before all concrete has been discharged from the drum, except that the sum of all drum revolutions shall not exceed 450 if the outside air temperature is over 85 °F. In addition, the time limits specified in Subsection 9.6 may be extended up to an additional 2 hours by the Engineer.

(c) The last sentence of Subsection 9.6.1 is deleted.

(d) Subsection 9.9 is replaced by the following:

(1) Concrete delivered in outdoor temperatures of 35 °F or below shall meet the requirements of Subsection 552.08 of this specification.

(2) At the time of placement, concrete temperature shall be as specified in Subsection 552.08.

(e) Delivery of concrete shall be so regulated that placing is at a continuous rate unless delayed by the placing operations. The intervals between delivery of batches shall not be so great as to allow the concrete in place to harden partially, and in no case shall such an interval exceed 30 minutes.

(f) The first batch of concrete materials placed in the mixer shall contain a sufficient excess of cement, sand, and water to coat the inside of the drum without reducing the required mortar content of the mix.

(g) Handmixing shall not be permitted, except in case of emergency and with written approval from the Engineer. When permitted, it shall be performed only on watertight platforms. Handmixed batches shall not exceed 1/12 cubic yard volume. Handmixing shall not be permitted for concrete that is to be placed under water.

(h) Mixers and agitators shall meet the requirements of Subsections 8.1 and 8.1.1, except 8.1.1 is modified to allow the use of mechanically operated counters, and 8.1.3 is deleted.

(i) Truck-mixed concrete shall have the cement transported separately from the aggregate and water. Cement shall be added to the mixer at the project site.

For batch mixing at the site of construction or at a central point, a batch mixer of an approved type shall be used. No mixer having a rated capacity of less than a one-bag batch shall be used. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity as shown on the manufacturer's standard rating plate on the mixer. The batch shall be so charged into the drum that a portion of the water shall enter 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. Mixing time shall be measured from the time all materials, except water, are in the drum. Mixing time shall be not less than 60 seconds for mixers having a capacity of 2 cubic yards or less. For mixers having a capacity greater than 2 cubic yards, the mixing time shall be not less than 90 seconds. If timing starts the instant the skip reaches its maximum raised position, 4 seconds shall be added to the specified mixing time. Mixing time ends when the discharge chute opens.

The mixer shall be operated at the drum speed shown on the manufacturer's name plate on the mixer. Any concrete mixed less than the specified time shall be discarded and disposed of by the contractor without compensation.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the contractor will be permitted to continue operations while it is being repaired, provided an approved timepiece equipped with minute and second hands is furnished. If the timing device is not repaired within 24 hours, further use of the mixer will be prohibited until repairs are made.

552.08
Adverse Weather
Concrete

(a) Cold Weather. The contractor shall furnish the Engineer with a detailed plan of equipment and material to be used for protection of the concrete during the curing period.

When the air temperature is 35 °F or less at the time of mixing or placing, or an air temperature of 35 °F or less can be expected in the 24-hour period immediately following the concrete placing, the mixing water or aggregates, or both, shall be heated. The temperature of water and aggregate, and the resulting batch of mixed concrete shall be within the temperature ranges specified below.

Aggregates that contain frozen lumps shall not be used. If either the aggregates or water is heated to a temperature in excess of 100 °F, the water and aggregates shall be premixed so that the resulting temperature of the combined water and aggregates is not in excess of 100 °F when the cement is added to the batch.

Heating equipment or methods that cause uneven heating or alter or prevent the entrainment of the required amount of air in the concrete shall not be used. Aggregates may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or oil flame or on sheet metal over fire.

When aggregates are heated in bins, steam-coil or water-coil heating or other methods that will not be detrimental to the aggregates may be used. The use of live steam on or through binned aggregates shall not be permitted.

Heating of the cement or the adding of salt or other chemicals to the mix to prevent freezing will not be permitted.

Forms and reinforcement shall be free of ice, snow, and frost at the time of concrete placement. When the atmospheric temperature is below 40 °F the interior surfaces of forms, all reinforcement, and the surface of the concrete adjacent to the pour shall be preheated to 40 °F or higher.

When placed in the forms, the mixed concrete shall have a temperature of not less than 50 °F nor more than 80 °F for concrete in deck slabs, girders, and sections less than 24 inches thick; and not less than 50 °F nor more than 90 °F for concrete in sections 24 inches or more in thickness. Where insulated forms are used for protecting the concrete, the allowable temperature range of all concrete placed shall be from 50 °F to 90 °F.

When the air temperature is 35 °F or less, or when an air temperature of 35 °F or less can be expected within a period of 6 days following placing of the concrete, the work shall be protected by insulated forms or blankets or heated housing.

(1) Insulated Forms and Blankets. The contractor may protect structural concrete by the use of insulated forms or blankets as hereafter described.

When housing of the structure or section thereof can be delayed, but is subsequently required in accordance with the specifications, the contractor may protect structural concrete in bridge decks or similar sections with insulating blankets instead of housing, heating, and curing for the remainder of the protection period. The curing method shall prevent moisture loss on all exposed surfaces protected by insulating blankets.

Insulation shall consist of bats or blankets of fiberglass, rock wool, balsam wool, insulation boards, or other approved material. Insulation used on placements having a thickness of 24 inches or less shall have an insulation value of not less than 7.0, and insulation used on placements having a thickness greater than 24 inches shall have an insulation value of not less than 5.0, based on the following formula:

$$R = \frac{T}{K}$$

where

R = *Insulation value*
T = *Thickness in inches*
K = *Thermal conductivity in Btus per hour per square foot for a temperature gradient of 1 °F per inch of thickness.*

Upon the Engineer's request, the contractor shall furnish the K value, as determined by the manufacturer, for the type of insulation proposed for use in protecting the work.

The bats or blankets shall be completely encased in suitable wind- and water-resistant covers that shall be fastened securely to wood forms between the studs and wales, with edges and ends sealed to the framing to minimize heat loss. The insulation shall be attached to steel forms by adhesive or other approved methods. Ribs and flanges of steel forms shall be covered by the insulating blankets, or separate strips of insulation shall be applied to them. The edges and corners of concrete shall be well insulated. Horizontal surfaces of concrete shall be protected by a layer of the insulating material securely fastened in place. The tops of placements, such as bridge decks and similar flat slab sections, shall be protected by tarpaulins over the insulation. Large insulating blankets may be wrapped around and securely fastened in place for curing concrete columns cast in prefabricated forms and similar concrete items. All joints in the blankets shall be sealed with tape.

Any tears in the cover shall be repaired. Where tie rods extend through the insulated form, a suitable washer shall be placed over the hole outside of the insulation and fastened to the form.

When insulating blankets are applied directly to concrete masonry, the methods of applying and securing the insulation shall be approved in advance by the Engineer. All joints shall be sealed.

The insulated forms or blankets shall remain in place for a protection period of at least 6 days (4 days when Type III cement is used) after placement of the concrete.

The contractor shall provide approved facilities and shall measure the temperatures inside and outside of the insulation and within the mass of the concrete at various locations in the unit. Frequent thermometer readings shall be taken and recorded and shall be available to the Engineer at all times. Approved recording thermometers may be used to obtain temperature records. Forms or insulation shall be loosened as required to control the temperature of the concrete. The temperature of the concrete shall not be allowed to exceed 120 °F nor fall below 45 °F during the protection period. In addition, the temperature at the surface of the concrete shall not be allowed to exceed 90 °F.

At the close of the protection period, the temperature of the concrete shall be gradually decreased to the temperature of the outside air at a rate not to exceed 40 °F per 24-hour period or 5 °F in any hour by loosening the forms or blankets.

Electric heating blankets and other suitable materials may be used instead of insulated blankets or bats when specifically approved by the Engineer for each application.

The contractor shall assume entire responsibility for the proper protection and final satisfactory condition of all concrete placed during cold weather or exposed to cold weather within the required protection period. This responsibility shall extend to the adequacy of all equipment and methods necessary to conform to the requirements of the contract. Any concrete that has been frozen or damaged by other causes shall, upon order of the Engineer, be removed and replaced with satisfactory concrete at the contractor's expense.

(2) Housing, Heating, and Curing. If the concrete temperatures cannot be maintained within the limits specified above by insulated forms or blankets, adequate housing shall enclose each section of a structure before placing the concrete in such section, except as follows:

a. The contractor may delay the erection of such housing if the air temperature is not expected to fall to 35 °F or below during the 24 hours immediately following placement of the concrete. Housing may be delayed until the temperature is expected to fall to 35 °F or below during any 24 hours of the succeeding 5-day period, provided that an adequate supply of housing material is maintained at the site and sufficient men and equipment are available to ensure the erection of suitable housing before the temperature falls to 35 °F.

b. The protective housing shall be of sufficient size to allow all concrete placing and finishing operations for any one placement to proceed under cover without hindrance. However, to facilitate the placement of concrete, the covering material may be installed immediately following the depositing of the concrete. The housing shall be constructed weather-tight in a manner that will ensure that specified temperatures will be maintained uniformly throughout the enclosure during the protection period.

c. Before starting concreting operations, the contractor shall have available ample and suitable equipment, for heating, curing, and protecting the concrete during the protection period. Heating may be by steam or hot air. A humid condition must be maintained within the housing during the heating period. Stoves or open-burning salamanders will not be permitted within the housing.

d. Application of heat that will endanger forms, falsework, or any part of the structure, or that will subject the concrete to drying out or other injury due to excessive temperatures, will not be permitted. The concrete surface shall be heated to maintain a temperature between 50 °F and 90 °F.

e. When housing is required prior to placement of concrete, heat shall be admitted to the housing sufficiently in advance of placing the concrete to ensure that the temperature of the forms and reinforcing steel will not be less than 40 °F. Within the enclosure or housing, a temperature not less than 45 °F nor more than 70 °F shall be maintained during placing of the concrete and for a protection period of at least 6 days thereafter or for the remaining number of days of such 6-day period that housing is required. The temperature within the enclosure shall be reasonably uniform throughout.

f. The contractor shall provide adequate fire protection when heating is in progress and shall maintain watchmen or other attendants to keep heating units in continuous operation.

g. The contractor shall provide reliable thermometers and take temperature readings within the enclosure at such points and at such times as are necessary to show the true temperature conditions to which the concrete is subjected. Outside air temperature recordings shall be made at the time of making the recordings within the enclosure. A copy of the temperature records shall be available to the Engineer at all times. Approved recording thermometers may be used to obtain all temperature records at the contractor's option.

h. At the close of the heating period, the temperature within the enclosure shall be reduced in a manner that will avoid a sudden temperature change to the new concrete. The average rate of decrease shall not exceed 40 °F per 24-hour period until the outside air temperature is reached. The surface of the concrete shall be permitted to dry while temperatures are being equalized.

i. When pozzolan or fly ash cement is used, the required period of controlled temperature and moisture shall be:

Percentage of Cement Replaced by Weight	Required Period of Controlled Temperature and Moisture
10%	9 days
10-15%	10 days
16-20%	11 days

The above requirement for an extended period of controlled temperature and/or moisture may be waived if a compressive strength of 65 percent of the specified 28-day strength is achieved in 6 days.

(b) Hot Weather. Immediately prior to being placed, the temperature of plastic concrete shall not exceed 90 °F, except that bridge superstructure concrete shall not exceed 80 °F. Chipped or

crushed ice may be used in the mix as a portion of the mixing water on a pound-for-pound basis. If ice is used, all ice shall be entirely melted at the completion of the mixing period.

When placing concrete deck slabs, if the air temperature near the slab's surface is expected to rise above 80 °F, the contractor shall schedule his operations so that finishing of the top of the slab is completed before this occurs or use hot weather concreting practices to maintain the slab surface temperature 80 °F or less until finishing is completed. An evaporation rate in excess of 0.1 pound per square foot per hour (as determined by Portland Cement Association Bulletin "Design and Control of Concrete Mixtures," current edition) will be considered cause for requiring the use of a protective housing when making bridge deck placements.

The protective housing shall be covered by waterproof material and shall be of sufficient size to allow the concrete placing and finishing operations for any one pour to proceed under the housing without hindrance until final set. However, to facilitate the placement of concrete, the covering material may be installed immediately following the depositing of the concrete and shall remain in place for a period of 12 hours following the completion of the deck pour or until the adverse weather has passed, whichever is less.

Fogging equipment shall be capable of applying water to the concrete in the form of a fine mist in sufficient quantity to curb the effects of rapid evaporation of mixing water from the concrete on the deck. Fogging nozzles and water supply methods shall be approved by the Engineer in advance. Nozzles shall produce a true mist that will not harm the surface finish of fresh concrete. The mist shall be applied at the times and in the manner approved by the Engineer.

When pozzolan or fly ash modified cement is used, the required period of controlled moisture shall be as shown above in 552.08 (a)(2)i.

552.09 Consistency

Slump will be measured in accordance with AASHTO T 119 and shall meet the requirements shown in table 552-1.

552.10 Foundations, Falsework, & Forms

Preparation of foundations shall meet the requirements in Section 206. The elevations of the bottoms of footings as SHOWN ON THE DRAWINGS are approximate, and changes in dimensions or elevations of footings may be ordered by the Engineer.

Two weeks prior to placement of the concrete supported by falsework, three copies of detailed drawings of the falsework and/or formwork for cast-in-place concrete decks and superstructure shall be submitted to the Engineer for approval.

Falsework shall be built on foundations of sufficient strength to carry the loads, without appreciable settlement. Falsework that cannot be founded on solid footings must be supported by ample falsework piling. Forms for cast-in-place concrete bridge decks supported on girders shall be completely supported by the girders upon which the deck is to be cast; shoring to the ground or substructures is not permitted.

Falsework shall be built on foundations of sufficient strength to carry the loads with a deflection not to exceed 1/500 of the falsework span and shall be set to give the finished structure the lines and grades SHOWN ON THE DRAWINGS. Suitable screw jacks or wedges shall be incorporated into the falsework and adjusted to take up any settlement in the formwork either before or during the placing of concrete. An arch centering shall be so constructed as to permit its being lowered gradually and uniformly.

Forms shall meet the requirements below:

(a) General. Forms shall be rigid enough to prevent distortion and deflection due to the pressure of the concrete and other loads including vibration, incident to the construction operations. Forms shall be so constructed and maintained as to prevent the opening of joints due to shrinkage of the lumber. Deflection of forms shall not exceed 1/360 of the span under full load.

Forms for concrete containing a retarding admixture, fly ash, or other pozzolan replacement for cement, shall be designed to contain the lateral pressure exerted by the full anticipated height of fluidized concrete, unless documented information on initial set is provided by the manufacturer.

(b) Forms. Forms for all exposed concrete surfaces shall be one of the following:

(1) Faced with exterior-type plywood with the face grain running perpendicular to the supports.

(2) Lumber dressed at least on one side and two edges.

(3) Metal.

(4) Fiberglass.

In all cases, forms shall be so constructed as to produce mortar-tight joints and smooth, even concrete surfaces. Forms shall be filleted and chamfered 3/4 inch or as SHOWN ON THE DRAWINGS, and they shall be given a bevel or draft in the case of all projections, such as girders and copings, to ensure easy removal.

Form sheets shall not be permitted to rest directly on the top of the stringer or floor beam flanges. Sheets shall be securely fastened to form supports and shall have a minimum bearing length of 1 inch at each end. Form supports shall be placed in direct contact with the flange of stringer or floor beam. All attachments shall be made by permissible welds, bolts, clips, or other means approved by the Engineer. However, welding of form supports to flanges of steel not considered weldable and to portions of flange subject to tensile stresses shall not be permitted. Welding and welds shall be in accordance with the provisions of AWS D1.1, Structural Welding Code, pertaining to fillet welds, except that 1/8 inch fillet welds will be permitted.

(c) Metal Ties. Metal ties or anchorages within the forms shall be constructed to permit their removal to a depth of at least 1 inch from the face without injury to the concrete. In case wire ties are permitted, suitable cones shall be provided. The cavities shall be filled with cement mortar and the surface left sound, smooth, even, and uniform in color.

(d) Walls. Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so extraneous material may be removed from the forms immediately before placing the concrete.

(e) Surface Treatment. All forms shall be treated with form-release agent prior to placing reinforcement; and, in addition, woodforms shall be moistened with water immediately before placing concrete. No material or treatment that will be detrimental to, adhere to, or discolor concrete shall be used.

(f) Metal Forms. The specifications for forms, including design, mortar-tightness, filleted corners, beveled projections, bracing, alinement, removal, reuse, and oiling, apply to metal forms.

(g) Permanent Steel Bridge Deck Forms. Permanent or stay-in-place metal forms will not be permitted under deck slabs unless SHOWN ON THE DRAWINGS.

All forms shall be installed in accordance with approved fabrication and erection drawings.

Form support provisions in Subsection 552.10(b) shall apply to permanent steel deck forms.

Where the galvanized coating of any permanently exposed form metal has been damaged, it shall be thoroughly cleaned, wire brushed, and painted with two coats of zinc oxide-zinc dust primer (Fed. Spec.-TT-P-641 Type II, no color added). Minor heat discoloration in areas of welds need not be touched up.

Transverse construction joints shall be located at the bottom of a flute and 1/4-inch weep holes shall be field drilled at approximately 12 inches on center along the line of the joint.

552.11 Placing Concrete

(a) General. Concrete shall not be placed until forms and reinforcing steel have been checked and approved by the Engineer. The forms shall be cleaned of all debris before concrete is placed. The method and sequence of placing concrete shall be as approved by the Engineer.

Concrete shall be placed and consolidated by methods that will not cause segregation of the aggregates and will result in a dense homogeneous concrete that is free of voids and rock pockets. All concrete shall be used while fresh and before it has taken an initial set. Retempering any partially hardened concrete shall not be permitted. No pumping lines, pipes, chutes, conveyors, etc., containing aluminum, which may be in contact with the mixed concrete, shall be permitted.

Surfaces on which concrete is to be placed shall be thoroughly moistened with water immediately before placing concrete.

Mixed concrete, after being deposited, shall be consolidated until all voids are filled and free mortar appears on the surface.

Placing of concrete for roadway deck shall be commenced at a time that will permit all required finishing operations to be conducted during daylight hours; however, upon prior written approval of the Engineer, night finishing operations may be performed under artificial illumination of suitable character, distribution, and intensity.

(b) Chutes and Troughs. Concrete shall be so placed as to avoid segregation of the materials and the displacement of the reinforcement.

Where steep slopes are required, the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of movement.

All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

Concrete shall not be dropped into the forms a distance of more than 5 feet, unless confined by closed chutes or pipes. Care shall be taken to fill each part of the form by depositing the concrete as near final position as possible. The coarse aggregate shall be worked back from the forms and worked around the reinforcement without displacing the bars. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of projecting reinforcement.

In thin sections where there is not sufficient space inside the form to place by chute, concrete shall be placed through form windows, or the Engineer may permit dropping more than 5 feet, provided that the placing is so controlled by short chutes, baffles, or other means that the concrete will be placed without segregation, and mortar splatter on reinforcing steel will be minimized.

(c) Pneumatic Placing. The equipment shall be so arranged that no vibrations result that might damage freshly placed concrete. Where concrete is conveyed and placed by pneumatic means, the equipment shall be suitable in kind and adequate in capacity for the work. The machine shall be located as close as practicable to the place of deposit. The position of the discharge end of the line shall not be more than 10 feet from the point of deposit. The discharge lines shall be horizontal or incline upwards from the machine.

(d) Pumping. The equipment shall be so arranged that no vibrations result that might damage freshly placed concrete. Where concrete is conveyed and placed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work. The operation of the pump shall produce a continuous stream of concrete without air pockets. When pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected so that there will be no contamination of the concrete or separation of the ingredients.

(e) Vibrating. All concrete, except seal concrete, shall be consolidated with approved mechanical vibrators operating within the concrete. When required, vibrating shall be supplemented by hand spading with suitable tools to ensure proper and adequate compaction.

Vibrators shall be capable of transmitting vibration to the concrete at frequencies of not less than 7,000 impulses per minute and visibly affecting a properly designed mixture with 1-inch slump for a distance of at least 8 inches from the vibrator.

Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and imbedded fixtures and into corners and angles of the forms. The concrete shall be placed as nearly as possible in its final position and the use of vibrators for extensive shifting of the mass of fresh concrete will not be permitted. The vibration at any point shall be of sufficient duration to accomplish consolidation, but shall not be prolonged to the point where segregation occurs.

The contractor shall have a back-up vibrator at the site of the work.

(f) Depositing Concrete Under Water. Concrete shall be deposited under water only in the presence of the Engineer and by the method described in the following paragraphs:

Only seal concrete shall be deposited under water. The concrete shall be placed carefully in a compact mass in its final position by means of a tremie or by other approved means, and the concrete shall not be disturbed after being deposited. Special care must be exercised to maintain still water at the point of deposit. Concrete shall not be placed in running water. The method of depositing concrete shall be so regulated as to produce approximately horizontal surfaces.

Concrete seals shall be placed in one continuous operation.

When a tremie is used, it shall consist of a steel tube not less than 10 inches in diameter constructed in sections having flanged couplings fitted with gaskets. The means of supporting the tremie shall be designed to permit free movement of the discharge end over

the entire top of the concrete and to permit its being lowered rapidly when necessary to choke off or retard the flow. The tremie shall be filled by a method that will prevent washing of the concrete. The discharge end shall be completely submerged in concrete at all times.

The tremie tube shall be kept full to the top. When placing concrete through a tremie, two distinct handling devices shall be used; one to raise, lower, and place the tremie; the other to deliver concrete to the tremie. When a batch is dumped into the hopper at the top, the tremie shall be raised slightly, but not out of the concrete at the bottom, until the batch discharges to the bottom of the hopper at the top of the tremie tube. The flow shall then be stopped by lowering the tremie.

When concrete is placed under water by pumping, the pump pipe shall be equipped with a bottom valve or other approved device to prevent mixing of water with the concrete in the pipe. The pump pipe shall be withdrawn as the concrete rises but the end shall, at all times, be below the surface of the concrete.

(g) Concrete Columns. Concrete in columns shall be placed in one continuous operation unless otherwise permitted by the Engineer. The concrete shall be allowed to set at least 12 hours before caps are placed, unless otherwise SHOWN ON THE DRAWINGS.

(h) Concrete Slab and Girder Spans. Slabs and girders having lengths of 30 feet or less shall be placed in one continuous operation.

Girders spanning more than 30 feet may be placed in two operations, the first operation being the placement of the girder stems to the bottom of the slab haunches. Adequate shear resistance shall be obtained by using a broom finish with 1/4-inch grooves on the surface of the first concrete pour.

The period between the first or girder placement and the second or slab placement shall be at least 24 hours. Immediately before the second placement, the contractor shall check all falsework for shrinkage and settlement and shall tighten all wedges to ensure minimum deflection of the stems due to the added weight of the slab.

The undersurface of cantilever brackets and overhanging slabs shall be provided with a drip groove, 1/2 inch in depth at a point not more than 6 inches from the outside face, to arrest the flow of moisture.

(i) Arches. Arch centering shall be constructed in accordance with construction drawings approved by the Engineer. Centering shall be lowered gradually and symmetrically to avoid overstresses in the arch.

Centering shall be placed upon approved jacks to provide means of correcting any slight settlement that may occur after concrete placement has begun. Any adjustments made necessary by settlement shall be made before the concrete has taken its initial set.

Railings and copings shall not be constructed until centering has been struck and the arch made self-supporting.

For closed-spandrel arches, portions of the spandrel walls necessary to avoid jamming of the expansion joints shall be left for construction subsequent to the striking of centers.

For filled-spandrel arches, the filling shall be placed as provided in Section 206, care being taken to load the ring uniformly and symmetrically. The filling material shall be acceptable to the Engineer and shall be placed in horizontal layers, carefully tamped, and brought up simultaneously from both haunches.

Wedge-shaped sections of filling material against spandrels, wings, or abutments will not be permitted.

(j) Concrete Railings, Parapets, and Curbs. Special care shall be exercised to obtain smooth, tight-fitting forms that can be held rigidly to line and grade and can be removed without injury to the concrete. All moldings, panel work, and bevel strips shall be constructed as SHOWN ON THE DRAWINGS, with neatly mitered joints. All corners in the finished work shall be true, sharp, clean-cut, and shall be free from cracks, spalls, or other defects.

Precast railing members shall be cast in mortar-tight forms. The precast members shall be removed from the molds as soon as the concrete is sufficiently hard and shall then be kept covered with water-saturated burlap or a tarpaulin for at least 3 days. After this treatment, the curing shall be completed by immersion in water or by spraying not less than twice a day for a period of not less than 7 days.

The method of storage and handling shall preserve the edges and corners true and even. Any precast members that become chipped, marred, or cracked before or during the process of placing shall be rejected and removed from the work.

In the construction of cast-in-place railing caps and copings built in connection with precast balusters, the balusters shall be protected from staining and disfigurement during the process of placing and finishing the concrete.

(k) Construction Joints. Construction joints shall be located where SHOWN ON THE DRAWINGS. Additional construction joints shall require written approval by the Engineer.

At all construction joints, gauge strips 1-1/2 inches thick shall be placed inside the forms along all exposed faces to give the joints straight lines. Before placing fresh concrete, the surfaces of construction joints shall be sandblasted or washed and scrubbed with a wire broom, drenched with water until saturated, and kept saturated until the new concrete is placed.

Immediately prior to placing new concrete, the forms shall be drawn tight against the concrete already in place and the old surface shall be coated thoroughly with a very thin coating of neat cement mortar. Concrete in substructures shall be placed so that all horizontal construction joints will be truly horizontal and, if possible, in locations so that they will not be exposed to view in the finished structure. Where vertical construction joints are necessary, reinforcing bars shall extend across the joint to make the structure monolithic.

Dowels, load-transfer devices, and bonding devices shall be placed as SHOWN ON THE DRAWINGS.

(l) Expansion Joints. Expansion joints shall be located and formed as SHOWN ON THE DRAWINGS.

(1) Open Joints. Open joints shall be constructed by insertion and subsequent removal of a wooden strip, metal plate, or other approved material. The insertion and removal of the template shall be accomplished without chipping or breaking the corners of the concrete.

(2) Filled Joints. Poured expansion joints shall be constructed similarly to open joints.

When premolded expansion joints are specified, the thickness of the filler installed shall be as SHOWN ON THE DRAWINGS. The joint filler shall be cut to the same shape and size as that of the surfaces being joined. It shall be fixed firmly against the surface of the concrete already in place so that it will not be

displaced when concrete is deposited against it. Where it is necessary to use more than one piece of filler to cover any surface, the abutting pieces shall be placed in close contact, and the joint between them shall be covered with a layer of asphalt-saturated roofing felt of not less than 40-pound grade, one side of which shall be covered with hot asphalt to ensure proper retention. Immediately after the forms are removed, the expansion joints shall be inspected carefully. Any concrete or mortar that has sealed across the joint shall be cut neatly and removed. When, during construction, an opening of 1/8 inch or more appears in any joint over which any traffic will occur, the opening shall be completely filled with asphalt.

Dowels, load-transfer devices, and other devices shall be placed as SHOWN ON THE DRAWINGS.

(3) Steel Joints. The plates, angles, or other structural shapes shall be accurately shaped at the shop to conform to the section of the concrete floor. Care shall be taken to ensure that the surface in the finished plane is true and free of warping. Positive methods shall be employed in placing the joints to keep them in correct position during the placing of the concrete. The opening at expansion joints shall be adjusted to compensate for the actual temperature of the structure at the time of concrete placement, and care shall be taken to avoid impairment of the clearance in any manner.

(4) Water Stops. Water stops shall be placed in accordance with Section 616.

(5) Compression Joint Seals. Compression joint seals shall be in one piece for the full length of transverse joints and in the longest practicable lengths for longitudinal joints. Joints shall be clean and dry and shall be made free of spalls and irregularities that would impair a tight seal in service. Seals shall be placed in the joint under compression, as recommended by the manufacturer, using the lubricant-adhesive as a covering film applied to both sides of the seal just prior to its installation. The top edges of the seal shall be set below the adjacent surfaces of the concrete, as SHOWN ON THE DRAWINGS, and the seal shall contact the walls of the joint throughout its length. Longitudinal elongation of an installed seal by 5 percent or more of its original length will be cause for its removal and reinstallation.

All lubricant-adhesive that comes to the top of an installed seal shall be removed before it dries, and all seals that show twist, curl, nicks, or other malformations as installed, shall be removed and replaced by a new seal.

(6) Elastomeric Expansion Joint Seal. The joint shall be furnished and installed in accordance with the details SHOWN ON THE DRAWINGS and with the manufacturer's recommendations.

(m) Anchor Bolts. All necessary anchor bolts in piers, abutments, or pedestals shall be accurately set either in the concrete as it is being placed, in holes formed while the concrete is being placed, or in holes drilled after the concrete has set, unless a specific method is SHOWN ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS. If a bolt is to be set in the concrete as it is being placed, the bolt shall be placed in a section of standard black pipe at least 2 inches larger in diameter than the bolt and shall be anchored by passing it through a heavy steel washer at the bottom of the pipe. Holes may be formed by inserting oiled wooden plugs, metal pipe sleeves, or other devices approved by the Engineer, into the fresh concrete and withdrawing them after the concrete has partially set. Holes so formed shall be at least 4 inches in diameter. If drilled, holes shall be at least 1 inch larger in diameter than the bolts used. During freezing conditions, anchor bolt holes shall be protected from water

accumulations at all times. Bolts shall be set accurately and fixed with grout completely filling the holes. A nonshrink grout approved by the Engineer shall be used.

Anchor bolts used in connection with expansion shoes, rollers, and rockers shall be located with due regard to the temperature at the time of erection. The nuts on anchor bolts at the expansion end of a span shall be adjusted to permit free movement of the span and then burred to prevent further tightening by vibration unless otherwise SHOWN ON THE DRAWINGS.

(n) Shoes and Bearing Plates. Preferably, bridge seat bearing areas shall be finished high and rubbed to grade. Shoes and bearing plates shall be set in accordance with Section 555.

(o) Drainage Holes and Weep Holes. Drainage holes and weep holes shall be constructed in the manner and at the locations SHOWN ON THE DRAWINGS. Ports or vents for equalizing hydrostatic pressure shall be placed below low water.

Forms for weep holes through concrete may be clay pipe, plastic pipe, concrete drain pipe, wooden boxes, or metal. If wooden forms are used, they shall be removed after the concrete is placed. Exposed surfaces of metal drains shall be coated or uncoated as SHOWN ON THE DRAWINGS.

(p) Pipes, Conduits, and Ducts. Pipes, conduits, and ducts that are to be encased in concrete shall be installed before the concrete is placed. Unless otherwise SHOWN ON THE DRAWINGS, pipes embedded in concrete shall be standard, lightweight galvanized steel or plastic pipes. Pipes shall be held or braced rigidly during concrete placement in order to prevent their displacement.

(q) Loads on New Concrete Structures. No load shall be placed upon new concrete structural elements until tests on concrete cylinders cast from the same concrete and cured under the same conditions as the structural element indicate that all concrete has attained a minimum of 80 percent of the specified 28-day design strength.

Traffic will not be permitted on concrete bridges until the concrete has attained the design strength SHOWN ON THE DRAWINGS.

In lieu of the above requirements, the minimum required time before a load may be placed on a new concrete structural element shall be 7 days after placement for concrete made with Type I or II cement or 3 days after placement for concrete made with Type III cement. However, when pozzolan or fly ash modified concrete is used, the placement of additional loads shall be based solely upon 80 percent of required 28-day compressive strength.

552.12 Removal of Forms & Falsework

Forms and falsework shall not be removed without approval of the Engineer. The Engineer's approval shall not relieve the contractor of responsibility for safety and protection of the work. Blocks and bracing shall be removed at the time the forms are removed, and in no case shall any portion of the wood forms be left in the concrete.

Falsework removal for continuous or cantilevered structures shall be performed so that the structure is gradually subjected to its working stress.

When concrete strength tests are used for removal of forms and supports, removal should not begin until the concrete has attained the percentage of the specified 28-day compressive strength shown in Column 3 below.

When fly ash modified concrete is used, removal of forms shall be based solely upon criteria shown in Column 3 below.

If field operations are not controlled by beam or cylinder tests, the forms and falsework for various parts of the structure shall not be removed before the number of days specified in Columns 1 and 2 of the following table have elapsed after the placing of the concrete, exclusive of days when the temperature is below 50 °F.

Forms and falsework shall not be released from under concrete that has been cured at a temperature continuously under 50 °F without first determining if the concrete has gained the specified strength, no matter how much time has passed.

Unless approved otherwise by the Engineer, substructure concrete shall reach the required 28-day compressive strength prior to erecting any superstructure or additional substructure elements.

Concrete Structure	Column 1 Standard Concrete	Column 2 Early Strength Concrete (Type III Cement)	Column 3 Percent of Required 28-Day Comprehensive Strength
Columns and wall faces (not yet supporting loads)	3 days	2 days	50%
Mass piers and mass abutments (not yet supporting loads) except pier caps	3 days	N/A[b]	50%
Sidewalk on bridges; sidewalk forms shall, in all cases, be released before the main girder and slab forms are released[a]	10 days	4 days	70%
Box girders	14 days	7 days	80%
T-beam girders, slabs, crossbeams, caps, pier caps not continuously supported, struts, and top slabs on concrete box culverts[a]	14 days	7 days	80%
Trestle slabs, when supported on wood stringers[a]	10 days	4 days	70%
Slabs, when supported on steel stringers or prestressed concrete girders[a]	10 days	4 days	70%
Pier caps continuously supported[a]	7 days	3 days	60%
Arches[a]	21 days	10 days	95%
Rail bases, traffic railings, and median barriers	3 days	2 days	50%

[a]Items apply to falsework and forms supporting the full load of the concrete.
[b]Not applicable.

In continuous structures, falsework shall not be released in any span until the first and second adjoining spans on each side have reached the strength specified herein or in the SPECIAL PROJECT SPECIFICATIONS. When cast-in-place post-tensioned bridges are constructed, falsework shall remain in place until all post tensioning has been accomplished.

Falsework under all spans of continuous structures shall be completely released before concrete is placed in curbs, railings, and parapets.

In order to determine the condition of column concrete, forms shall be removed from columns before releasing supports from beneath beams and girders.

The forms for footings constructed within cofferdams or cribs may be left in place when their removal would endanger the safety of the cofferdam or crib, and when the form so left intact will not be exposed to view in the finished structure. All other forms shall be removed whether above or below the ground line or water level.

All removable forms shall be removed from the cells of concrete box girders unless otherwise SHOWN ON THE DRAWINGS or permitted by the Engineer. No forms shall be left that might jeopardize drainage or enclosed utilities.

To facilitate finishing, forms on exposed surfaces not supporting loads may be removed earlier than that specified above, when approved by the Engineer.

Falsework and centering for spandrel-filled arches shall not be struck until fills behind abutments have been placed up to the spring line. Falsework supporting the deck of rigid frame structures shall not be removed until fills have been placed behind the vertical legs.

552.13 Finishing Concrete Surfaces

Unless otherwise authorized, the formed surface of the concrete shall be finished immediately after form removal.

All formed concrete surfaces shall be given a Class 1 finish. If further finishing is required, exposed surfaces SHOWN ON THE DRAWINGS or DESIGNATED in the SPECIAL PROJECT SPECIFICATIONS shall be given a Class 2 finish. Other finish classes may be SHOWN ON THE DRAWINGS for DESIGNATED surfaces. All roadway and sidewalk surfaces shall be given a float finish in accordance with paragraph (c) below.

(a) Class 1, Ordinary Surface Finish. As soon as the forms are removed, all projecting wire or metal devices that have been used for holding the forms in place and that pass through the body of the concrete shall be removed or cut back at least 1 inch beneath the surface of the concrete. Lips of mortar and all irregularities caused by form joints shall be removed.

All small holes, depressions, and voids that show upon the removal of forms shall be filled with cement mortar mixed in the same proportions as that used in the body of the work. In patching larger holes and honeycombs, all coarse or broken materials shall be chipped away until a dense uniform surface of concrete exposing solid coarse aggregate is obtained. Feathered edges shall be cut away to form faces perpendicular to the surface. All surfaces of the cavity shall be saturated thoroughly with water, after which a thin layer of neat cement mortar shall be applied. The cavity shall then be filled with stiff mortar, composed of one part of Portland cement to two parts of sand, that shall be thoroughly tamped into place. The mortar shall be preshrunk by mixing it approximately 30 minutes before using. The length of time may be varied in accordance with the brand of cement used, temperature, humidity, and other local conditions. The surface of this mortar shall be floated with a wooden float before initial set takes place and shall be neat and workmanlike in appearance.

For patching large or deep areas, coarse aggregate shall be added to the patching material and special precautions shall be taken to ensure a dense, well-bonded, and properly cured patch.

Areas of honeycomb that exceed 2 percent of the surface area of a structural element may be considered sufficient cause for rejection of the structural element.

The mortar patches shall be cured in accordance with Subsection 552.14. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

All surfaces that cannot be repaired satisfactorily shall be rubbed as specified for a Class 2 finish.

(b) Class 2, Rubbed Finish. After removal of forms, the rubbing of concrete shall be started as soon as its condition will permit. Immediately before starting this work, the concrete shall be thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the patch to thoroughly set. Surfaces to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in the proportions used in the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

After the final rubbing is complete and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

(c) Float Finish.

(1) General. Immediately after the concrete has been struck off to the required grade, the horizontal surface shall be hand finished to smooth even surfaces by both longitudinal and transverse movement of wooden floats, or other suitable means.

After floating has been completed, but while the concrete is still plastic, the surface of the concrete shall be tested for trueness with a 10-foot straightedge. The straightedge shall be held in contact with the surface in successive positions parallel to the slab centerline and the whole area gone over from one side of the slab to the other. Advancement along the slab shall be in successive stages of not more than one-half the length of the straightedge. Any depressions found shall be filled immediately with freshly mixed concrete, and any high areas shall be cut down. The surface shall be struck off, consolidated, and refinished. Special attention shall be given to ensure that the surface across joints fully meets the requirements for smoothness. The straightedge testing and refloating shall continue until the entire surface is found to be free from observable departures from the straightedge and the slab has the required grade and crown.

As soon as the concrete has hardened sufficiently, the surfaces shall be given a further test for trueness using a 10-foot straightedge or other specified device. Areas showing high spots of more than 1/8 inch shall be marked and immediately ground down with a diamond-faced, saw-type cutting machine, capable of cutting through mortar and aggregate without breaking or dislodging the aggregate or causing spalls, to an elevation where the area or spot will not show surface deviations in excess of 1/8 inch when tested with a 10-foot straightedge.

The 10-foot straightedge shall be provided by the contractor and the straightedge testing shall be performed by contractor personnel while the Engineer is present.

(2) Bridge Decks. On bridge decks, a smooth riding surface of uniform texture, true to the required grade and cross section, shall be obtained. The contractor shall use finishing machines meeting the requirements specified herein for finishing bridge roadway deck concrete. Hand-operated strike-off devices may be used for small areas or under special conditions when approved by the Engineer.

Finishing of concrete placed in bridge decks shall consist essentially of striking off the surface of the concrete as placed and floating the surface so struck off.

The placing of concrete in bridge decks will not be permitted unless the rate of producing and placing concrete will be sufficient to complete the proposed placing and finishing operations within the scheduled time, unless experienced finishing machine operators and concrete finishers are employed to finish the deck, and unless the fogging equipment and all necessary finishing tools and equipment are on hand at the site of the work and in satisfactory condition for use. Finishing machines shall be set up sufficiently in advance of use to permit inspection by the Engineer during the daylight hours before each placement.

The placing of concrete in bridge decks shall cease early enough to permit completion of finishing operations during daylight hours, unless night finishing operations have been approved in advance by the Engineer as specified in Subsection 552.05.

Rails for the support and operation of finishing machines and headers for hand-operated strike-off devices shall be completely in place and firmly secured for the scheduled length for concrete placement before placing of concrete will be permitted. Rails for finishing machines shall extend sufficient distance beyond both ends of the scheduled length for concrete placement to permit the float of the finishing machine to fully clear the concrete to be placed, unless otherwise approved by the Engineer. Rails or headers shall be adjustable for elevation and shall be set to elevations, with allowance for anticipated settlement, camber, and deflection of falsework, as required to obtain a bridge deck true to the required grade and cross section. Rails or headers shall be of a type and shall be so installed that no springing or deflection will occur under the weight of the finishing equipment and shall be so located that finishing equipment can operate without interruption over the entire bridge deck being finished. Rails or headers shall be adjusted as necessary to correct any unanticipated settlement or deflection that may occur during finishing operations.

Immediately prior to placing bridge deck concrete, the contractor shall check all falsework and wedges and shall make all necessary adjustments. Care shall be exercised to ensure that settlement and deflection due to the added weight of the bridge deck concrete will be at a minimum. Suitable means, such as telltales, shall be provided by the contractor to readily permit measurement of settlement and deflection by the Engineer as it occurs.

Should settlement or other unanticipated events occur that would prevent obtaining a bridge deck meeting the requirements of this specification, placing of deck concrete shall be discontinued until corrective measures are provided. If satisfactory measures are not provided prior to initial set of the concrete in the affected area, the placing of concrete shall be discontinued and a bulkhead installed at a location approved by the Engineer. All concrete in place beyond the bulkhead shall be removed.

Concrete for bridge decks shall be placed in a uniform heading approximately normal to the structure centerline. The rate of placing concrete shall be limited to that which can be finished before the beginning of initial set, but in no case shall concrete be placed more than 8 feet ahead of the finishing machine.

All concrete bridge decks shall be placed continuously full length of the structure or superstructure unit unless otherwise SHOWN ON THE DRAWINGS or approved in writing by the Engineer. The contractor shall provide sufficient material, equipment, and manpower to complete a finished bridge deck at a minimum rate of 20 linear feet per hour unless otherwise SHOWN ON THE DRAWINGS.

Immediately after the concrete has been placed and consolidated, the surface shall be struck off with the finishing machine or hand-operated screed until the required surface is obtained. The use of "jitterbugs" or similar devices will not be permitted. The strike-off method and equipment shall be subject to approval by the Engineer. Approval shall be withdrawn if performance is not satisfactory. The equipment shall be capable of finishing roadway decks within the surface tolerances set forth in these specifications. Improper adjustment and operation that results in unsatisfactory consolidation and smoothness shall be corrected immediately. Unsatisfactory performance may be cause for rejection of the equipment and removal of the in-place concrete. Following the completion of the strike-off, the roadway slab surface shall be floated to a smooth, uniform surface by means of floats 10 feet or more in length. Adequate floats shall be used to remove roughness and minor irregularities left by the strike board or finishing machine and to seal the concrete surface. Excessive working of the concrete surface will not be permitted. All floats shall be used so that each transverse pass overlaps the previous pass by a distance equal to at least one-half the length of the float.

When hand-operated float boards are used, they shall be from 12 feet to 16 feet long, ribbed and trussed as necessary to provide a rigid float, and equipped with adjustable handles at each end. The float shall be wood not less than 1 inch thick and a minimum of 8 inches wide. Adjusting screws, spaced not to exceed 24 inches on centers, shall be provided between the float and the rib. The float board shall be maintained free of twist and true at all times.

Hand-operated float boards shall be operated from transverse finishing bridges. The finishing bridges shall completely span the roadway area being floated, and a sufficient number of finishing bridges shall be provided to permit operation of the floats without undue delay. Not less than two transverse finishing bridges shall be provided when hand-operated float boards are used. When a finishing machine is used for longitudinal floating, one finishing bridge equivalent to the transverse finishing bridge specified herein shall be furnished for use by the Engineer.

All finishing bridges shall be of rigid construction, free of wobble and spring when used by the operators of longitudinal floats, and easily moved.

In advance of curing operations, the surface of the concrete shall be textured with metal tines to produce grooving 3/16 inch deep on 1/2-inch centers unless otherwise SHOWN ON THE DRAWINGS. The grooving shall be transverse unless otherwise SHOWN ON THE DRAWINGS. The operation shall produce a hardened surface having a uniform texture. Sidewalks and tops of curbs shall be given a fine broom or brush finish, unless otherwise SHOWN ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS.

(d) Special Finishes. Details for special finishes SHOWN ON THE DRAWINGS will be given in the SPECIAL PROJECT SPECIFICATIONS.

552.14
Curing of Concrete

(a) General. All newly placed concrete shall be cured, and curing shall begin immediately after finishing and continue for at least 7 days. For fly ash or pozzolan modified concrete, the curing period shall be as shown in Subsection 552.08(a)(2)i. Curing shall be done so that moisture is always present and shall be an integral part of the concreting operations. Improperly cured concrete will be considered defective and placing operations shall be suspended until proper procedures are put into effect.

If a formed surface is to be rubbed, the concrete shall be kept moist before and during the rubbing, and the curing shall be initiated immediately following the first rub, while the concrete surface is still moist.

When the air temperature is expected to fall below 35 °F, the contractor shall provide suitable measures to maintain the concrete surface temperature between 50 °F and 90 °F and comply with all other applicable provisions of Subsection 552.08. The contractor shall furnish recording thermometers with a range of 0 °F to 212 °F and a recording capability of at least 24 hours. If the structure is enclosed, combustion heaters shall not contact the concrete surface and shall be vented to the outside of the enclosure.

(b) Methods. Concrete shall be cured by any one method or combination of methods listed below, consistent with any limitations given within a particular method.

The top surface of bridge decks, approach slabs, sidewalks, and curbs shall be cured by the method of supplying additional moisture, by the curing compound method of preventing moisture loss, or by the method of water curing.

(1) Supplying Additional Moisture. This method shall include supplying additional moisture by ponding, sprinkling, or fogging. Coverings such as burlap shall be used to retain water. The use of sawdust will not be allowed, and coverings that cause unsightly discoloration of concrete shall not be used. Any method that results in the concrete being alternately wet and dry will be considered an improper curing procedure. Coverings shall be placed as soon as possible after finishing operations have been completed and there is no danger of surface damage. They shall be kept continuously moist. This method shall also be used for curing all construction joints.

Fogging equipment shall be approved by the Engineer in advance and shall be capable of applying water to the concrete in the form of a fine mist in sufficient quantity to curb the effects of rapid evaporation of mixing water from the concrete on the deck resulting from wind, high temperature, low humidity, or a combination of these factors.

(2) Preventing Moisture Loss. This method shall consist of preventing moisture loss from the concrete. It may be done with the use of approved waterproof paper, plastic sheets, or liquid-membrane curing compound, except where other requirements prohibit the use of these compounds. If a formed surface is to be rubbed, the concrete shall be kept moist before and during the rubbing, and the curing shall be initiated immediately following the rubbing while the concrete surface is still moist. Unless a curing compound is used, bridge decks, approach slabs, sidewalks, and curbs shall be covered with burlap or sand blankets as soon as the concrete is sufficiently set to support this material without damage to the finish. This moisture-retaining material shall then be saturated with water and the entire area covered with waterproof paper or plastic sheeting.

a. Waterproof Paper. The paper shall be the widest practicable width, and adjacent sheets shall overlap a minimum of 6 inches and shall be tightly sealed with pressure-sensitive tape,

mastic, glue, or other methods approved by the Engineer to form a complete waterproof cover of the entire concrete surface. The paper shall be secured so wind will not displace it. Should any portion of the sheets be broken or damaged before expiration of the curing period, the broken or damaged portions shall be immediately repaired. Sections that have lost their waterproof qualities shall not be used.

b. Plastic Sheets. The sheets shall be used in the same manner as required above for waterproof paper. Care shall be taken not to exceed the maximum temperature requirements when nontransparent sheets are used.

c. Curing Compounds. Type 1-D or Type 2 liquid membrane curing compounds may be used as the initial and final curing agents on structural concrete subject to the following limitations:

1. If the membrane film is broken or damaged at any time during the curing period, the area or areas shall be recoated to the original requirements.

2. Curing compounds shall be applied to unformed areas as soon as the water sheen has practically disappeared from the finished concrete or as soon as the forms have been removed from surfaces not to be rubbed.

3. Areas receiving a rubbed finish shall be cured with Type 1-D curing compound only.

4. If there is any delay in applying curing compound, the surface shall be protected by supplying additional moisture until compound can be applied.

5. Curing compound shall be applied with equipment that will produce a fine spray, and all compounds shall be thoroughly agitated just prior to use. The surface shall be sprayed again immediately at right angles to the first application. The rate of each application shall be not less than 1 gallon for each 150 square feet of surface. Care shall be taken to prevent application to joints where concrete is required to be bonded to reinforcement steel and to joints where joint sealer is to be placed.

(3) Steam and Radiant Head Curing Methods. Steam and radiant heat curing methods may be used for Class P and precast concrete. The methods shall meet the requirements of Section 553.

(4) Water Curing. Concrete may be cured under water if the temperature of the water does not fall below 35 °F.

552.15
Opening to Traffic

No traffic shall be permitted on concrete bridge decks until:

(a) Curbs, bridge railing, guardrail, and object markers SHOWN ON THE DRAWINGS or in the SPECIAL PROJECT SPECIFICATIONS are completely in place.

(b) The compressive strength of concrete in the deck reaches the specified 28-day strength, as determined by compressive strength tests on cylinders cured with the deck.

(c) In the absence of compressive tests specified in (b), no traffic shall be permitted on concrete bridge decks for at least 28 days after placement of all deck concrete, or longer if determined necessary by the Engineer.

Upon completion of placement of all bridge deck concrete, the contractor shall erect barricades at each end of the bridge if the road approaches have been constructed to the point the vehicles

could drive onto the bridge deck. Barricades shall be located to physically prevent vehicular access to the bridge deck. Barricades shall not be removed until the bridge deck is open to traffic.

552.16
(Reserved)

MEASUREMENT

552.17
Method

The method of measurement, as described in Section 106, will be DESIGNATED in the SCHEDULE OF ITEMS.

No deduction will be made for the volume occupied by pipes less than 8 inches in diameter nor for reinforcing steel, anchors, conduits, weep holes, piling, or chamfers less than 6 inches on a side. The volume of fillets less than 6 inches on a side and of varying thickness haunches between prefabricated girders and bridge decks shall not be included.

The quantity shall include Type III cement when used in place of Type I or II; furnishing mix designs and materials for testing; furnishing and placing joint fillers, sealers, and waterstops; and all formwork, falsework, finishing and curing, admixtures, and increased cement content.

Class A concrete placed where seal concrete was specified will be considered seal concrete.

PAYMENT

552.18
Basis

The accepted quantities will be paid for at the contract unit price for each pay item shown in the SCHEDULE OF ITEMS.

Payment will be made under:

Pay Item		Pay Unit
552(01)	Structural Concrete, Class ____	C.Y.
552(02)	Structural Concrete, Class ____, _____ . . .	C.Y.
552(03)	Structural Concrete, Class ____	L.S.
552(04)	Structural Concrete, Class ____, _____ . . .	L.S.
552(05)	Seal Concrete	C.Y.

The following percentages of the price will be allowed for progress payments as the work progresses:

Portion of Work Completed	Percent of Price
Formwork and Falsework in Place	50
Reinforcing Steel in Place	65
Concrete Placed, Finished, and Cured	90
Forms Removed and Cleanup Completed	100