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2401
Concrete Bridge Construction

2401.1 DESCRIPTION

This work shall consist of constructing those portions of bridges that are made of concrete, except for concrete piling, special wearing courses, and precast concrete members.

Reference to the "Bridge Deck Slab" means the complete structural slab and wearing course constructed monolithically. Reference to the "Bridge Structural Slab" means only the structural unit upon which will be constructed a separately poured wearing course. "Bridge Slab" means either "Bridge Deck Slab" or "Bridge Structural Slab."

2401.2 MATERIALS

A Concrete 2461

Mix designations shall be as indicated in the Plans for the specific item of work.

Class A coarse aggregate, as defined in 3137.2B, shall be used in all concrete for bridge railings, posts, curbs, sidewalks, and median strips that are poured separately from the bridge deck.

B Reinforcement Bars 3301
C Steel Fabric 3303
D Spiral Reinforcement 3305
E Preformed Joint Filler 3702
F Concrete Joint Sealer, Hot Poured Type 3723
G Concrete Joint Sealer, Preformed Type 3721
H Concrete Treating Oil 3917

2401.3 CONSTRUCTION REQUIREMENTS

A General

The construction requirements for concrete bridges are those specified for the component items of work, subsidiary to the completed structure, contained elsewhere in these Specifications, as well as those herein specified.

Foundation preparations and piling shall be subject to 2451 and 2452, respectively. Metal reinforcement shall be placed in accordance with 2472.

B Falsework and Forms

Whenever "Manual" is referred to in falsework, form, or falsework and form construction, "Manual" means the Falsework and Form section of the Mn/DOT Bridge Construction Manual.

Forms shall be used for all concrete except portions of footings that extend into solid rock. Casting concrete against the side of an earth excavation in lieu of forming will not be permitted. Cofferdam sheets

will be considered as forms for footings when the Special Provisions permit the sheets to be driven along the neat line of a footing.

B1 Material Requirements, with Allowable Stresses or Loads

B1a Falsework Piling

All falsework piles shall have a size, soundness, straightness, and absence of structural defects that allows driving to the required bearing without damage to the piles. Falsework piles shall be capable of carrying the design loads without over stressing.

Safe pile-bearing capacities shall be determined from the appropriate formulas in 2452.

Regardless of computed bearing, timber piles shall not be designed to more than 700 N per millimeter (**2 tons per inch**) of average diameter (of an individual pile) at cutoff. Timber piles with an average diameter of less than 200 mm (**8 inches**) at cut-off shall not be used.

Piles shall not be loaded to more than the maximum design loads specified in the Manual for the size and type of pile and under the conditions of use.

B1b Structural Shapes and Fabricated Assemblies

Steel or aluminum shapes shall be straight and shall have a shape suitable for the proposed use. A reduction in safe load capacity, as determined by the Engineer, shall be made for any material or fabricated assembly that has a loss of section due to corrosion, damage, or previous fabrication. In general, shapes used as beams shall not be spliced at points of maximum bending stress. All splices shall develop the net section.

The design of trusses or other fabricated sections and of steel beams shall conform to the applicable design provisions of AASHTO Standard Specifications for Highway Bridges, with the modification that the allowable stresses given in this publication may be increased by not more than one-third.

Form ties and other steel devices, portions of which must be cast into the concrete, shall be designed and used so as to permit the major part or all of the device to remain permanently in the concrete. When any device passes through a concrete surface exposed to view in the completed structure, the device shall be so designed that all material in the device to a depth of at least 25 mm (**1 inch**) back of the concrete face can be disengaged and removed without spalling or damaging the concrete.

B1c Lumber

All lumber shall be sound, seasoned wood. The timber species and grade of the lumber used, together with the dimensions and surfacing of the pieces, shall be suitable for the proposed use. Individual pieces shall be free of defects including crook, twist, warp, and variations in dimensions that may adversely affect the strength of the piece or the

appearance of exposed concrete lines and surfaces. The side of all lumber pieces that will contact concrete shall be surfaced and, when form lining is not used, the two edges shall be surfaced or dressed and matched as required to prevent mortar leakage.

Working stresses for lumber shall not exceed the maximums specified in the Manual.

Sheathing lumber, either with or without form lining, shall have a minimum thickness of 25 mm (**1 inch**) nominal and maximum width of 200 mm (**8 inches**) for exposed concrete surfaces, except that wider lumber may be used when a single piece will completely cover a concrete surface and adequate provisions are made to prevent cupping and warping of the piece. For special curved surfaces, sheathing may have a thickness less than 25 mm (**1 inch**) nominal, when approved by the Engineer.

B1d Plywood Sheathing

Plywood used as form sheathing shall have five or more plies and a nominal thickness of not less than 20 mm (**3/4 inch**), and shall be of a concrete form grade (with sanded or overlaid surfaces) specially manufactured for the purpose. Plywood meeting these requirements may be used without backing. For special curved surfaces, and for slab sections between girders or beams, sheathing may have a thickness less than 20 mm (**3/4 inch**) nominal, subject to approval by the Engineer.

B1e Form Lining

When form lining is specified, the form backing shall consist of plywood sheathing in good condition, or the form backing used shall be lined with smooth surfaced material (including plywood of a lesser thickness) that will produce a concrete surface substantially as smooth and uniform as would be obtained by the use of sanded or overlaid plywood sheathing in good condition. The same kind of form lining material shall be used throughout on any exposed concrete face. In any event, the contact surface of the form lining shall be so smooth and free of defects that any irregularities produced by the form face will be obliterated by the specified concrete finishing operations.

Form lining material shall have a uniform thickness. The edge finish and dimensions of form lining sheets or sections, either new or used, shall permit tight and smooth joints between adjacent sheets or sections and joints that will be mortar tight.

Bolt, nail, or rivet heads and weld deposits shall be flush with the form lining face in contact with concrete.

In general, the size of form lining sheets or sections shall be such as to reduce the number of joints required to substantially the same as if 1220 x 2440 mm (**4 x 8 foot**) plywood sheets had been used for the form lining.

B1f Forms For Circular Columns

Molds of fiber or other material that are used for forming circular columns shall be capable of withstanding the design concrete pressures without distortion. The concrete surface produced by the use of these forms shall be free of conspicuous ridges and depressions. Fiber molds meeting these requirements may be used when form lining is required. For brands that have not been used, but are proposed for use, the Contractor shall furnish manufacturers' data showing that the product will produce the required results.

When the performance of any brand produces unsatisfactory results, the use of such brand shall be discontinued, and the Contractor shall make such corrections to the concrete surface as the Engineer may direct.

B1g Chamfer Strips

The chamfer strips shall be uniform in cross section dimensions without rounded corners and shall be smooth on all sides. When wood strips are used, they shall be made of straight grain soft wood, preferably white pine.

B2 Design of Falsework and Forms

Unless otherwise provided, detailed plans for falsework and forms shall be supplied to the Engineer on request, but in no case shall the Contractor be relieved of responsibility for results obtained by the use of these plans.

Falsework members shall be designed to safely carry the following forces:

(1) Its own deadload.
(2) The deadload of the green concrete, computed at 23.6 kN/m^3 (**150 pounds per cubic foot**).
(3) A vertical live load of 2.4 kN (**50 pounds**) per square meter (**foot**), applied on the upper concrete surface.
(4) The deadload of the forms and other falsework members supported by the members.

The specified live load shall be considered a minimum and shall be adjusted where known concentrated loads may produce higher live loads on a member.

The design of falsework and forms shall conform to the Manual with respect to the determination of concrete pressures; standard formulas to be used; and allowable stresses, deflections, and deviations of alignment. Reliable information as to the performance of the proposed falsework and forms under concrete load may be required for any type of construction not included in the Manual.

Prior to use, the Engineer may require full scale field testing or testing by a reputable laboratory, without cost to the Department, for

certain devices or fabrications for which insufficient performance information is available.

B3 Form Lining Requirements

Form lining backed by sheathing shall be nailed sufficiently to prevent bulging of the lining. Plywood 20 mm (**3/4 inch**) or more in thickness shall be fastened to its supports with sufficient nails to ensure stiffness and close contact between the plywood and supports. Edges of sheets and form panels shall be tightly butted without offset and shall be mortar tight. Any open joints shall be patched or sealed with cold water putty or an approved equal. Joints in form lining sections or between adjacent form panels shall follow the same horizontal line whenever practical. When a horizontal joint in form lining is required on all four sides of a square or rectangular column that does not receive a rubbed finish, the joint shall extend on the same level around the column without vertical offset between joints on the four faces. Horizontal joints on all columns of a unit shall be as near to the same level as may be visible to the eye. Joints in form lining shall be truly vertical and horizontal. Pressed wood and hard board shall be prepared for use as recommended by the manufacturer. The screen side shall be in contact with the concrete when a rubbed finish is required, and the smooth side shall be in contact with the concrete when a rubbed finish is not required.

On forms for concrete faces exposed to view, holes for form bolts shall be drilled through sheathing or form lining in a manner that will avoid splintering the face of the form that will be in contact with the concrete. When sheathing may be reversed, splintering shall be avoided on both faces.

Form lining, as defined in 2401.3B1e, shall be used for all formed surfaces except those that will be buried or otherwise hidden from view in the completed structure, such as the back face of abutments, the sides of footings, and the interior surfaces of concrete box beams.

When the Plans require that a concrete surface be divided into panels formed by recessed rustication strips, the joints in the form lining shall be set so as to be covered by the rustications, except when a rubbed surface finish or a special surface finish is specified or is substituted therefor at no additional cost to the Department.

B4 Falsework Requirements

Falsework shall be supported on piling, on ledge rock, on parts of the structure, or on temporary footings.

No welding will be permitted on the primary stress-carrying steel members of the bridge superstructure except as specifically provided for under 2402.

Falsework piling shall be driven to a bearing capacity and penetration that will adequately support the superimposed loads without settlement.

If authorized by the Engineer, temporary footings may be used to support falsework for the structure. Temporary footings will only be authorized when the supporting soil will carry superimposed load without detrimental settlement and the footings are protected from disturbance, freezing, and inundation. Authorization will not be given unless the Contractor submits borings, testing, analysis and calculations for proposed footings which show that detrimental settlement will not occur under maximum construction loads and conditions anticipated at the site. Analysis and calculations shall include soil bearing capacity, anticipated settlement, and sliding resistance. If use of temporary footings is not authorized by the Engineer, falsework shall be supported on piling.

All falsework piling in a bent shall be cut off so as to provide uniform bearing for the pile cap. Caps shall be securely fastened to the pile heads or posts. Each falsework bent shall be securely braced with timber of adequate size, and the bents shall be securely braced to adjacent bents.

The width of falsework for superstructures shall be greater than the overall width of the superstructure by an amount that will permit side forms to be braced to the falsework.

On bridges with separate roadways, the form and falsework supports for each roadway slab shall be supported entirely by the beams or girders under that roadway.

Primary supports for concrete slab spans and the bottom slab for concrete box girders shall be located near enough to the construction joints in these slabs so as to preclude conspicuous offsets resulting from differential deflections between adjacent slab sections. In general, the distance from the joint to the nearest primary support shall not be greater than 0.6 m (**2 feet**).

Falsework for the floor slab overhang for steel beam spans shall be capable of resisting torsional stresses that are particularly critical at the midpoint between diaphragms when the length of overhang is greater than the depth of the fascia beam. Pronounced irregularities caused by these stresses shall be prevented by the use of knee bracing, cross bracing, struts, ties, or other methods acceptable to the Engineer.

B5 Removal Of Falsework

Falsework supporting concrete structures and concrete members shall not be released until the curing period plus 1 day of drying out time has been completed. Curing time shall be as defined in these Specifications under Concrete Curing and Protection.

No loads shall be placed on concrete members until the curing has been completed and the falsework has been released, except as may be permitted by the Engineer.

Adequate strength for the complete structure will be determined for the last concrete cast that will be affected by the release of falsework.

Supporting falsework shall be loosened and removed in a manner that will permit the concrete to uniformly and gradually take the stresses due to its own mass. Methods of falsework removal likely to cause over stressing of the concrete shall not be used.

The release of falsework shall start at or near the center of a span for the full width of the span and progress simultaneously toward both ends of the span unless otherwise authorized. On continuous span concrete superstructures, with or without cantilevers and hinges, release of falsework shall progress simultaneously and uniformly in all spans unless otherwise authorized.

Falsework piles located within the roadbed shall be removed to an elevation at least 1.2 m (**4 feet**) below the subgrade. Those located in a stream or lake bed and within the limits of low water shall be removed to the stream or lake bed, except that in established navigation channels, they shall be removed to an elevation at least 0.6 m (**2 feet**) below the established bottom of the channel. Those located outside the above defined limits shall be removed to an elevation at least 0.6 m (**2 feet**) below ground elevation.

All lumber and timber (except timber piles) used for falsework and forms under abutment floor slabs shall be removed. Falsework piles for abutment floor slabs may be left in place. Falsework supports for the top slab of concrete box girder spans shall be completely removed.

Unless otherwise authorized by the Engineer, temporary footings shall be entirely removed, unless their top surfaces are at least 1.2 m (**4 feet**) below the grading grade or at least 0.6 m (**2 feet**) under other ground surfaces.

All open excavations resulting from the removal of falsework shall, at the Contractor's expense, be backfilled with suitable material and compacted in accordance with 2451.

B6 Form Construction

Forms shall be designed and constructed to safely resist the pressure of fluid concrete under vibration and of other loads incidental to the construction operations. They shall be constructed and erected so as to be mortar tight, so that the finished concrete conforms to the proper dimensions and contours, and so that undulations and waves on exposed finished concrete surface do not exceed the maximum shown in the Manual. The forms shall be set true to the designated lines and be rigidly maintained in this position until the concrete has sufficiently hardened.

When vertical construction joints are required in a concrete unit for which a rubbed surface finish is specified, joints in form sections shall be so located that the major part of the forms for any previously cast part of the unit may be removed to permit the initial rubbed surface finish to be performed independent of progress on adjacent concrete casts.

Vertical forms shall be constructed in a manner that will permit their removal independent of any overhead falsework.

Rustication strips and other forms for small recesses on exposed concrete surfaces shall be fastened to forms in a manner that will permit them to remain in place when the form is removed.

Sheathing lumber shall be placed horizontally, except where otherwise authorized by the Engineer.

Splices in wales shall be so constructed that the wale will be effective continuously for its entire length. Splices in each member of a double wale shall be staggered at least one stud space. Splices in studs, when required, shall be so constructed that the stud will be continuous between plates and will meet design requirements.

Openings may be left in the forms for cleaning out extraneous matter or facilitating the placement of concrete, but the number and location of openings shall be first approved. Closures for openings shall be carefully constructed to ensure a tight fit flush with the adjoining surfaces.

Unless otherwise specified, chamfer strips having 20 mm (**3/4 inch**) sides shall be used to form chamfered corners where exposed intersecting concrete surfaces meet at an angle of 90 degrees or less. Chamfered corners will not be required at the corners of beam stools under decks if the corner is formed mortar tight. Similar moldings with 15 mm (**½ inch**) sides shall be used at all joints that will be exposed to view and are not required to be edged. Moldings shall be securely fastened at intervals not to exceed 150 mm (**6 inches**).

The method of setting chamfer strips at the tops of pier caps supported on falsework shall provide for adjustment to true bridge seat elevation after the bulk of the cap concrete is in place.

Forms for keyways at construction joints in concrete may be constructed to nominal lumber dimensions and with side bevels of not more than 1:10.

Forms for open joints shall be made readily removable to preclude damage to the joint when the form is removed.

When a construction joint is required between the bridge slab and superimposed concrete casts, the forms for the superimposed concrete casts (including any forms for offsets at the top edge of the slab) shall not be set to proper elevation and alignment in a span until the bridge slab has been placed in all spans that will appreciably alter the deflection in the span being formed.

Concrete box girder spans and concrete slab spans shall be freed of all temporary supports before grade elevations are set for the curbs, sidewalks, and median.

Forms for the roadway faces of curbs, sidewalks, and medians cast separately from the slab shall be set and maintained to proper alignment

and batter. Nails of any type driven into the hardened concrete shall not be used. A sufficient number of braces and struts shall be used to rigidly maintain the forms to proper line and batter during concrete casting without the use of internal spreaders. Bolts and pins, set or drilled into the slab, shall be removed to a depth of at least 40 mm (**1-1/2 inches**) without spalling or damaging the concrete, after which the holes shall be filled flush with mortar.

When the Plans indicate that a bridge (or portions thereof) is to be constructed to a horizontal curve, the forms for edges of slab, curbs, copings, medians, and railings shall be constructed to their proper degree of curvature within a tolerance of 3 mm in 3 m (**1/8 inch in 10 feet**).

B7 Treatment of Forms

The contact faces of all forms shall be treated with an approved form coating material meeting 3902 prior to placing the reinforcement.

Form lining treated before erection shall be protected from accumulations of dust and dirt.

All faces of forms that will be in contact with concrete shall be thoroughly flushed with water immediately prior to the placement of concrete.

B8 Removal of Forms

Removal of forms, including removal of form ties, shall be carefully done in a manner that will not spall or mar concrete surfaces or break off concrete corners.

Forms for the roadway face of curbs, sidewalks, and medians may be removed as soon as the concrete can retain its molded shape provided weather conditions permit the specified concrete finish to be started immediately after the forms are removed. All other forms shall remain in place for at least 12 hours after the concrete is cast or for a longer time if stripping of the forms would damage the concrete or prevent disengaging the form ties.

Column and wall forms shall be removed before the falsework supports are released from any concrete that will be supported by the column or wall.

When a surface finishing operation is specified to be completed within a definite period of time after casting, the forms on the surface shall be removed as necessary to permit completion of the finishing operation within the specified time, but not sooner than the specified minimum period of time after casting. Forms for rustication, fluting strips, and drain recesses shall not be removed with the face forms but shall remain in place until they can be removed without spalling, chipping, or marring of concrete corners or edges.

Forms for the webs of concrete box girder spans shall be removed, and the web concrete shall be given ordinary surface finish before the forms for the top slab are set in place at that location.

All interior forms in concrete box girder spans shall be completely removed, and the inside of the concrete box girders cleared of all loose material and swept clean.

B9 Re-Use of Forms

The re-use of forms or form materials will be restricted to members or materials that are unimpaired in strength, rigidity, or condition. Conspicuous permanent set of form lining between supports will require removal of the form lining and correction before reuse.

Any open holes in sheathing shall be plugged or covered. All open holes in form lining shall be plugged flush, and blemishes on the form lining surface shall be repaired to a smooth and even surface. Form surfaces in contact with concrete shall be cleaned of all adhering concrete and extraneous matter before reuse.

C Placement of Concrete

C1 General Requirements

Forms, falsework, bracing, and reinforcement bars for the entire concrete cast shall be properly in place, and all necessary concrete placement equipment, finishing equipment, and curing media shall be on hand before concrete placement is started.

The Engineer shall be notified well in advance of the casting of concrete in order to make proper arrangements for the inspection of forms, reinforcement bars, materials, and equipment. No concrete shall be placed until this inspection has been made and the work approved. Such approval shall not relieve the Contractor of full responsibility for satisfactory results.

Mixing, placing, and finishing of concrete shall be done under adequate lighting conditions.

Concrete shall be transported to and placed in the work in a manner and with equipment that will avoid segregation of the batch materials. Concrete shall be placed in or near its final position in a manner that will avoid displacement of reinforcement and to ensure complete enveloping of the reinforcement in the concrete.

All equipment for transporting, placing, and finishing concrete shall be kept free of foreign matter and coatings of hardened concrete. Water for cleaning the equipment shall be wasted outside the forms.

Forms and reinforcement bars shall be clean, and all debris shall be removed from within the forms before concrete is placed.

Concrete shall be placed under water only when it is used for a cofferdam seal, and then only as provided in the Special Provisions or as specifically permitted by the Engineer.

Earth and porous rock foundations shall be moist at the time concrete is placed on or against them.

When casting footings in solid rock, the rock trench shall be completely filled with the grade of concrete specified for the footing, without the use of side forms.

Concrete between required or permissible joints shall be placed in a continuous operation. In the event of a breakdown, during which time the concrete sets to a degree that it cannot be effectively revibrated, the surface of the concrete that will be covered by fresh concrete shall first be covered with an approved bonding agent or mortar, as determined by the Engineer. Concrete placement shall be so regulated that the pressures caused by the fluid concrete shall not exceed those for which the forms were designed. If, during the placement of concrete, the forms or falsework show signs of overstress or excessive deflection, the casting operations shall be stopped until corrective measures have been taken. Any section of concrete found to be defective or disturbed will be subject to 1512.

Concrete, except for seals, shall be deposited and compacted in continuous horizontal layers. The thickness of each layer placed shall not exceed 0.3 m (**1 foot**), except that in columns and thin walls the thickness may be increased to not more than 1.0 m (**3 feet**). Concrete placement operations shall be planned and carried on so that concrete may be deposited and compacted before the concrete in the preceding layer (directly below) has taken initial set. Not more than 1 hour shall elapse from the time of placement of concrete at a point in a layer to the time the concrete in the next overlaying layer is placed at that point. Some modification to these time requirements will be made when it is determined by the Engineer that the concrete mix, admixtures, concrete, air temperature, or humidity conditions may advance or retard the normal time of initial set.

Concrete shall not be dropped from a height of more than 1.2 m (**4 feet**) unless confined in a vertical mortar-tight, sheet metal down spout or other approved type of pipe or unless another placement method is approved by the Engineer. Down spouts shall be equipped with suitable hoppers at their inlet end and shall be made in sectional lengths that will permit adjustment of the level of the outlet during concrete placement. The number of down spouts used shall be sufficient to ensure concrete placement at a fairly horizontal level.

Pipes, belts, or chutes that are inclined may be used only when approved means of preventing segregation are provided. Inclined pipes and chutes, and belts either inclined or horizontal, shall discharge into hoppers with vertical down spouts.

Concrete buckets and hoppers shall be so constructed as to permit concrete with the specified slump to be readily discharged at a regulated rate. Concrete buckets shall be placed as close as practical to the point of deposit before discharging. When concrete buckets discharge the

concrete directly into or on the forms, the rate of discharge and movement of the bucket shall be controlled, and discharging excess concrete in a pile for rehandling shall be avoided.

Laitance and foreign matter of any nature shall not be permitted to accumulate at any point inside the forms.

Dried or hardened mortar accumulations shall not be mixed with fresh concrete. As the concrete rises in the forms, the form surfaces and reinforcement bars shall be kept reasonably free of mortar spatters that may harden before being incorporated in the mix. Removal of mortar shall be done by methods that are not detrimental to the concrete. Dried mortar and dust accumulations on the form surfaces and reinforcement bars above construction joints shall be removed before placing the next concrete lift, by methods that will not damage the form surfaces or the steel-to-concrete bond at and near the surface of the joint.

Special care shall be exercised to work the coarse aggregate back from the forms and to force the concrete under and around the reinforcement bars without displacing them.

When a wall or column more than 1.5 m (**5 feet**) tall is cast integrally with a beam, strut, or slab, a time lapse of 30 to 90 minutes, as determined by the Engineer, shall elapse between placement of the concrete to the level of the bottom of the beam, strut, or slab and placement of the concrete above this level.

For caps supported by more than one column, casting of the columns shall proceed uniformly, to provide a similar time delay at all columns before placement of the cap is started.

Before fresh concrete is placed against concrete that has set, the surface of the set concrete shall be thoroughly cleaned of all loose material, laitance, dirt, and other foreign matter. For superstructure concrete, the set concrete shall be cleaned by sandblasting, water blasting, or other approved methods. Care shall be taken during blasting operations to prevent damage to epoxy coating on reinforcement bars. Immediately prior to placing the fresh concrete, the forms for the fresh concrete shall be drawn tight against the set concrete. The contact surfaces of the set concrete shall be kept thoroughly wet until the fresh concrete is deposited.

When the Engineer determines that shock waves from pile driving, blasting, or other operations will be detrimental to concrete, these operations shall either be completed in advance of concrete placement or they shall be suspended until adequate concrete strength is gained.

Runways for concrete transportation shall not be supported by the forms unless authorized.

Concrete railings shall not be placed, without authorization from the Engineer, until the span falsework has been removed and an acceptable bridge slab cure has been obtained.

C2 Cold Weather Protection of Concrete

The Contractor shall place concrete according to the following requirements when placement is before April 15th and after:

(a) October 1st for Projects north of the 46th parallel.

(b) October 15th for Projects south of the 46th parallel.

C2a Cold Weather Protection Plan

The Contractor shall submit for the Engineer's approval a proposed time schedule and plans for cold weather protection of concrete, including maintenance of acceptable temperatures during placement and curing. The Contractor shall not place concrete until the Contractor's cold weather protection plans have been approved by the Engineer.

C2b General

The Contractor shall:

(1) Preheat the forms, in-place concrete, and items such as the top flanges of beams prior to placing concrete when their surface temperatures are below freezing. The Contractor shall not apply flames directly to concrete or steel.

(2) Provide insulated forms, insulation, or heating and housing facilities as necessary to maintain a minimum concrete temperature of 15^0C (**60^0F**) during the curing period. The heated enclosures shall be vented to prevent the buildup of carbon dioxide.

(3) Keep the forms, insulation, and housing enclosure in place until the cold weather protection needs have been fulfilled as determined by the Engineer.

The Engineer will base anticipated concrete placement and curing temperatures on weather forecasts. If weather forecasts are not considered adequate, the Engineer will base the anticipated temperatures on typical temperature data for the time of year at the locality of the structure.

C2c Bridge Slabs, Box Girder Bottom Slabs, and Box Girder Webs

The Contractor shall meet the following requirements regarding the placement and curing of concrete in bridge slabs, box girder bottom slabs, and box girder webs.

C2c1 Air Temperatures Below 2^0C (**36^0F**)

When the air temperature is anticipated to be below 2^0C (**36^0F**) the Contractor shall not place concrete until housing is in place and is sufficient to protect the entire area to be poured.

C2c2 Air Temperatures Above 2^0C (**36^0F**) During Placement But Below 1^0C (**34^0F**) During Curing

When the air temperature is above 2^0C (**36^0F**) during placement but anticipated to fall below 1^0C (**34^0F**) during curing, the Contractor shall not place concrete until insulation or housing and heating are in

place and are sufficient to protect the concrete from freezing. The Contractor may install insulation and housing upon completion of concrete finishing as provided in the approved cold weather protection plan if it hinders concrete placement.

C2d Bridge Deck Slab

If a bridge deck slab is to be opened to traffic before April 15th, the Contractor shall remove the conventional wet curing media from the slab surface at the end of the curing period. For the next 25 calendar days or until April 15th, whichever comes first, the Contractor shall heat and provide suitable housing to ensure free air circulation above the concrete surface to dry the concrete and prevent the temperature of the concrete from falling below 5^0C (**40^0F**) .

D Compaction of Concrete

Concrete, except for cofferdam seals, shall be thoroughly compacted by mechanical vibration applied internally. Vibrators shall be operated at a frequency of not less than 75 Hz (**4500 impulses per minute**). A sufficient number of vibrators shall be used to properly compact each batch, or part thereof, immediately after it is deposited.

The application of a vibrator or vibrators shall be at points uniformly spaced and not farther apart than twice the radius over which the vibration is visibly effective. Vibrators shall be manipulated so as to thoroughly work the concrete around the reinforcement and imbedded fixtures and into the corners and angles of the forms. Vibration shall be supplemented by as much spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with vibrators.

Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be methodically inserted and withdrawn from the concrete. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete, but vibrators shall be withdrawn before segregation and localized areas of grout result.

Vibration shall not be applied directly or through reinforcement to sections or layers of concrete that have hardened to the degree that the concrete ceases to be plastic under vibration. Vibrators shall not be used to make concrete flow in the forms over distances so great as to cause segregation.

E Joint Construction

Joint construction shall be in accordance with the details and at the locations shown in the Plans or as otherwise provided for hereinbefore, subject to the additional requirements set forth herein.

E1 Transverse Construction Joints

Saw cuts shall be made at transverse construction joints in the bridge slab unless otherwise directed by the Engineer. The saw cuts shall be 10 mm (**3/8 inch**) wide by 25 mm (**1 inch**) deep for the full width of the roadway between gutter lines, and the cut shall be made directly over the construction joint before the curb forms are placed.

E2 Weakened Plane Joints

When the bridge slab is supported by prestressed I-beams and is designed so as to be continuous over a pier, a 10 mm (**3/8 inch**) wide by 25 mm (**1 inch**) deep saw cut shall be made in the slab from gutter to gutter directly over the pier along its centerline.

Under sidewalks and at other locations where a saw cut cannot be made in the slab, a weakened plane shall be extended and formed using a removable insert at the time the slab is cast. The insert shall cut the fresh concrete on a straight and true line to a depth of 25 mm (**1 inch**). The insert shall be coated with oil or grease before being placed and shall be withdrawn when the concrete has set sufficiently to retain its shape.

The weakened plane shall be accurately located so as to fall vertically below the proposed sidewalk, curb, or median joint at that location, with the following exception: skewed bridges on which the exterior girders or beams are under the curbs, sidewalks, or medians, and on which the curb, sidewalk, or median joints are normal to the longitudinal axis of the bridge, shall have the weakened plane extended by using a removable insert placed as a continuation of the line to be saw cut, extending to the centerline of the exterior girders or beams. Outward from the centerline of the exterior girders or beams, the weakened plane shall be common to the joint to be placed in the curb, sidewalk, or median, thus forming an angle in the alignment of the weakened plane. A vertical 13 mm (**½ inch**) vee shall be formed into the edge of the slab at the end of the weakened plane at that location.

E3 Open or Filled Joints

The concrete faces or armored edges against which preformed filler or sealer material is to be placed shall be constructed truly vertical, straight, and parallel. Where open joints are to be constructed, the distance between faces shall be accurately formed with removable inserts, headers, or templates to provide the required opening for the temperature range prevailing at the time of concrete placement. A tabulation will be included in the Plans or Shop Drawings showing the required openings at various temperatures.

The tabulated joint openings are those required at the time the elastomeric seals are installed. The temperatures listed are those anticipated at the time the slab is to be cast. The Contractor is advised that the joint may widen due to concrete shrinkage.

After the bridge slab adjacent to an elastomeric seal expansion joint is in place and after allowing sufficient time for drying of the concrete

subsequent to completion of the curing, the Engineer will measure the constructed joint openings for conformance with the sizes specified in the Plans. Any openings that deviate from the specified size by more than 5 mm (**3/16 inch**) will be considered unacceptable work. No offsets at joints between segments will be permitted.

Where preformed joint filler is used to form vertical joints, the filler material shall be placed and secured in proper position by methods that will provide adequate anchorage without detrimental effects, such as by using copper nails, copper wire, or other approved means. Cork joint filler shall be anchored with 65 mm (**2-1/2 inch**) long copper nails at about 0.5 m (**20 inch**) centers. Where chamfered corners are required at joints to be filled with preformed material, the filler shall be trimmed back to the inside of the vee formed by the chamfer strip.

E4 Expansion Joint Devices

Bridge slab expansion joint devices shall be furnished and installed according to the details and at the locations indicated in the Plans. Field assembly and erection of the expansion devices shall be in accordance with 2402.3K.

F Finish of Concrete

F1 General

Surface finishing shall be done only on properly set concrete and (unless protection for the work is provided) only under approved weather conditions. When the finishing must be done under adverse weather conditions, protection for the work shall be furnished.

F2 Formed Surfaces

F2a Ordinary Surface Finish

All formed surfaces of concrete structures shall receive ordinary surface finish. The term "exposed surfaces," as used hereinafter, means exposed to view in the completed structure, above low water and above the final ground line.

Immediately after removal of the forms, the concrete surfaces shall be examined for areas of unsound concrete and defective surfaces due to improper concrete placement, faulty form work, faulty form removal, and other causes. Concrete with porosity, honey comb, or segregated materials shall be removed and replaced, but the ordinary surface finish shall not be started until the Engineer has viewed the extent of the defective concrete and has approved the time and method of repair and the materials to be used. In general, small areas may be repaired with mortar as specified for surface cavities; large areas may require concrete with formed surfaces. A bonding agent, mechanical bonds, or both may be required, and all repair work shall be cured in an approved manner. When defects in a concrete section are so extensive that satisfactory repairs cannot be made, that section will be subject to the Unacceptable Work provisions of 1512.

All fins and irregular projections shall be removed from exposed surfaces and from surfaces that will be waterproofed.

All surface cavities produced by form ties and, on exposed surfaces, any surface cavities (bug holes) with a diameter of 10 mm (**3/8 inch**) and larger and smaller surface cavities so closely spaced as to be conspicuous shall be thoroughly cleaned, saturated with water, and filled with mortar.

The mortar shall consist of 1 part white cement, 2 parts standard Portland cement, 6 parts mortar sand, and water. For surfaces that will not be exposed to view, standard Portland cement may be substituted for the white cement. The quantity of water used shall produce a mortar consistency as dry as possible to use effectively and, to further reduce plastic shrinkage, the mortar shall be mixed about 1 hour in advance of use.

An approved latex or acrylic-based bonding agent shall be incorporated into the mortar used for performing the ordinary surface finish on all areas that will subsequently receive a special surface finish. The bonding agent shall be added to the mixing water at an ratio of 1 part bonding agent to 3 parts water.

The cavities shall be completely filled with mortar, thoroughly compacted into place, pointed, and trimmed flush with the concrete surface. On exposed surfaces, mortar stains or streaks outside the area of the filled cavity shall be avoided and, if they should occur, they shall be removed.

When the Special Provisions do not specify additional surface finishing on an exposed surface, at the time of completion of all concrete work on the structure, all conspicuous streaks, stains, and blemishes shall be removed from the surface. Additional surface finishing shall also be done on an exposed surface that requires only ordinary surface finish when adjoining form lining sheets present sharply contrasting colors or textures. A modification of sack rubbed surface finish may be required as a corrective measure when the surface appearance remains objectionable after the ordinary surface finish has been completed.

When the ordinary surface finish is performed before the completion of the curing period for the concrete being finished, the finishing shall be done with a minimum of interruption to the curing.

F2b Sack Rubbed Surface Finish

Where numerous surface voids are present on an exposed surface, the sack rubbed finish may be used to fill the smaller voids in lieu of the method described under ordinary surface finish. However, the filling of form tie holes and other large cavities shall be done as specified under ordinary surface finish.

As a preparatory operation, the entire surface shall be ground with a high speed electric disk-type grinder or sandblasted until blemishes,

discolorations, and thin mortar films covering surface voids have been removed.

When the structure has been completed to the extent that further blemishes and discolorations on the surface will not result from any remaining construction, the final operations shall be performed as follows:

(1) The surface shall be thoroughly saturated with water and, while the surface is still moist, a mortar mixture (consisting of 1 part white cement, 1 part standard Portland cement and 2 parts mortar sand, with sufficient water added to produce a moderately thick paste) shall be applied to the wetted area with a rubber float, starting at the top. All voids shall be completely filled during this operation. If any portion of the surface shows evidence of becoming dry before the mortar is applied, it shall be rewetted.

(2) After the mortar has set sufficiently to be retained within the voids and before it has become completely dry, the entire surface that has been floated with mortar shall be rubbed with a small burlap sack filled with a dry mix (sand and cement only) of the mortar described above. All mortar in excess of that required to fill the voids shall be removed during the dry mortar sack rubbing operations. In lieu of the dry mix filled burlap sack, any equally effective means of removing the excess mortar will be approved.

(3) The completed surface shall be free of blemishes, discolorations, surface voids, and conspicuous form marks. The surface shall be uniform in texture and appearance except for the difference in texture between filled voids and the remainder of the surface. Surfaces that do not meet these requirements shall be corrected to the satisfaction of the Engineer.

F2c Special Surface Finish

A special surface finish will be required for only those bridges and on those surfaces designated in the Contract. The objective of this operation is to obtain a surface that is reasonably smooth and uniform in texture and appearance.

The special surface finishing shall be performed using a department approved system of commercially packaged mortar, bonding agent, and 100% acrylic paint. The mortar, bonding agent, and water shall be blended in proportions specified by the manufacturer. The 100% acrylic paint shall be blended in at a rate of 3.8 L/22.7 kg (**1 gallon/50 pound**) of dry mortar mix. The 100% acrylic paint shall meet the requirements of 3584. The approval requirements for the special surface finish system along with the approved list are on file in the Concrete Engineering Unit. The materials used for the system shall produce a mixture suitable for spray application to vertical concrete surfaces at the specified coverage rate.

Unless the system proposed for use has been previously approved by the department, the contractor shall have the system tested in a recognized commercial independent testing laboratory in accordance with procedures prescribed by the department. The time required for the testing is approximately 90 days. No work in conjunction with the surface finish shall be started until the system has been approved. The same materials and application method shall be used for the entire surface specified to be given a special surface finish.

The special surface finish shall not relieve the contractor of full responsibility for performing the ordinary surface finish operations as specified. All conventionally formed concrete surfaces that are to receive the special surface finish, shall be sandblasted or water-sandblasted prior to the ordinary surface finish to break the surface film and to remove all laitance, form release agent, dirt and other foreign matter that may impede adhesion of the special surface finish.

The approved materials shall be thoroughly mixed in accordance with the manufacturer's recommendations. Setting times and re-mixing shall be in accordance with the manufacturer's requirements. The manufacturer's technical representative shall be available for recommendations to the contractor prior to and during the work.

The mixture shall be applied in a minimum of two coats by spraying. The initial coat shall cover the entire surface; it shall not be so thick as to cause runs, sags or a "plastered" effect. Follow all other manufacturer recommended application procedures. The total coverage rate for the two coats shall be 0.4 m^2 per L (**16 square feet per gallon)** of material.

Special surface finishing operations including any topcoat applications may commence when air temperature is at least 4^0C (**39^0F**) with the temperature rising, and shall be suspended when the air temperature is falling and reaches 7^0C (**45^0F**).

Application of the special surface finish and any required topcoat application shall not be started until all other work that might mar the special surface finish has been completed, nor until the finishing operations can be carried on continuously from beginning to completion on any one bridge.

The final surface after drying shall be uniform in color and texture, with no evidence of laps or breaks in continuity. Corrective work, as directed by the engineer, will be required over any areas that have not been satisfactorily finished, including as much adjacent area as may be necessary to achieve uniform appearance, and all at the contractor's expense. This requirement is for all specified special finish operations including both the special surface finishing and any required topcoat application.

F2d Curb, Sidewalk, and Median Finish

The surface finish of formed surfaces of medians, delineator curbs, and the roadway face of curbs and sidewalks shall be as follows:

(1) Ordinary surface finish operations shall be started immediately after removal of the forms and shall be carried on continuously to completion. As the ordinary surface finish progresses, it shall be followed by immediately rubbing the surface with a cork float or fine carborundum stone (depending on the set of the concrete) to produce a paste on the surface and to expose and fill all depressions and all surface cavities. The paste shall be floated to a smooth surface free of coarse texture, swirls, and ridges and, before it is set, shall be brushed lightly with a fine bristled brush until all cement films present are removed and the surface has a uniform, fine grained, sanded texture.

(2) Concrete placement, form removal, and finishing operations shall be planned and carried out so that the surface finishing of the formed surface can be completed within 48 hours after concrete placement of that section has been completed.

F2e Railing Finish

Irregularities in any 3 m (**10 foot**) length of the finished concrete railing shall not exceed 6 mm (**1/4 inch**) (horizontal and vertical). Surfaces and edges not meeting this tolerance shall be considered to be unacceptable work. Unacceptable Work shall be removed and replaced with acceptable work when so ordered by the Engineer. Extensive areas with deviations greater than 15 mm (**½ inch**) shall be removed and replaced. In the absence of an order to remove and replace, the unacceptable work may be left in place with the following price adjustments:

(1) For 7 to 15 mm (**5/16 to ½ inch**) deviation, payment at 75 percent of the Contract price.

(2) For minor areas with deviations over 15 mm (**½ inch**), payment at 50 percent of the Contract price.

F3 Unformed Surfaces

F3a Miscellaneous Unformed Surfaces

All upper horizontal and inclined surfaces that are not formed, except for the surface of bridge slabs and the surface at horizontal construction joints, shall be finished as follows:

Steel trowels and steel shod floats shall not be used. Templates and strike-offs shall be wood, or wood shod, accurately made to fit the required surface contour. Contact surfaces of hand floats and darbies may be of wood, canvas, rubber, or cork. Edgers shall be made of metal, accurately shaped to fit the specified radius and included angle. The metal at the lower lip of the edger (in contact with the form) shall not be so thick as to form any appreciable offset in the surface when the form is stripped. The edger shall be of sufficient length to prevent waves in the surface resulting from slight variations in pressure at the

time the final tooling is done. In lieu of tooling with an edger, an approved type of cove strip, so milled as to leave no appreciable offset with adjacent concrete surfaces, may be used to form rounded corners.

An excess of concrete shall be placed in the forms and compacted by internal vibration. After a delay of about 30 minutes (due consideration being given to weather conditions) the surface shall be struck off and screeded with an accurate template in a manner that will force the coarse aggregate below the finished surface and will leave the surface slightly above finished elevation. The screeding and strike-off operation shall be repeated as necessary to obtain the required elevation and contour (except for edging). Laitance and excess mortar shall be wasted outside of the forms. After the final strike off and screeding, the surface shall be hand floated as necessary to correct irregularities and seal surface tears and, immediately after the water sheen leaves the surface, the surface shall be lightly reworked with a float to a uniform texture, and rounded corners and edges shall be tooled to final radius in a manner that will force the coarse aggregate beneath the finished radius. Trails left by the edging tools shall be removed with the float.

Final texture and finish to the surface shall then be applied as follows: Bridge curbs and sidewalks and the floor slabs, ramps, landings, and stair treads for pedestrian bridges and tunnels shall be brushed (broomed) in a transverse direction, using a fairly stiff bristled brush or broom, so as to produce a slightly serrated surface finish that will not be slippery when wet and a surface that will be uniform throughout in texture and appearance. The final finish on other upper surfaces shall be obtained by brushing the cement film from the surface with a fine bristled brush, and leaving a uniform, fine grained, sanded texture on the surface.

The finished surface shall not vary more than 3 mm (**1/8 inch**) from a 3 m (**10 foot**) straightedge laid longitudinally on the surface, with transverse surfaces substantially as specified in the Plans.

F3b Bridge Slabs

F3b(1) General

Prior to starting concrete placement for a section of bridge slab, and after the strike-off rails or guides have been set to correct elevation, the top reinforcement shall be checked for vertical position by the Contractor in the presence of an inspector by operating the strike-off on the rails or guides. A filler strip, 6 mm (**1/4 inch**) less in thickness than the minimum concrete cover requirements, shall be attached to the bottom of the strike-off during this check as a means of detecting reinforcement bars that may encroach on the required clearance.

Each bridge slab section between joints, between an end bulk-head and a joint, or the entire slab when no joints are specified, shall be placed in a continuous operation proceeding uniformly from edge to edge of the slab or from end to end of the section.

When the sequence of casting the slab sections and the direction in which the slab sections are to be cast is not specified, plans for the proposed casting procedures shall be submitted for approval. Construction that may be affected by alterations to the proposed plans shall not be started until the plans, as submitted, or with required alterations, have been approved.

The entire operation of bridge slab placement and finishing, including the rate of concrete delivery and placement, the placement and finishing equipment used, and the personnel provided for the work shall be so scheduled and the work so performed that the bridge slab section can be placed and properly finished during daylight hours.

When a bridge slab section is supported by two or more spans of continuous beams or girders, the following shall apply:

The rate of concrete placement for continuous pours of two or more spans shall be adequate to ensure that the concrete will remain plastic for at least one-half a span length back of an intermediate support, until placement has proceeded to a point one-half the span length ahead of that support. Approved admixtures, which retard the setting time of the concrete, may be required in order to provide the necessary plasticity.

F3b(2) Roadway Finish of Bridge Slabs

On bridge slabs, concrete placement and compaction shall be closely followed by the striking off and screeding of the roadway surface. The roadway surface shall then be rescreeded until the surface of the plastic concrete has the required cross-slope and longitudinal profile.

Bleed water or laitance that rises to the surface shall be removed and wasted outside the forms and, except for this removal and wasting operation, the concrete surface shall not be worked, smoothed, or otherwise disturbed while bleed water and laitance are present on the surface.

Advancement of the concrete placement and the initial strike-off shall be coordinated so that the initial strike-off is never more than 3 m (**10 feet**) behind the concrete placement. The head of concrete shall be maintained parallel with the initially screeded surface. Any excess concrete carried in front of the screed when the head of the concrete is reached shall be left on the concrete surface and mixed with freshly deposited concrete before the fresh concrete is compacted. As the concrete is deposited and compacted it shall be roughly leveled off slightly above finished surface contour. When low areas are revealed as the initial strike-off operation proceeds, the strike-off operation shall be delayed to permit filling these areas with additional concrete (not mortar). Walking in the concrete after the initial pass of the screed shall be avoided.

Strike-off and screeding of the surface shall be accomplished by a combined longitudinal and transverse motion of an accurate template

while the template is supported on or suspended from suitable rigid guides. Approved mechanically rotated templates may be used in lieu of one of the screeding motions. Screed guides for manual strike-off may be rails, bulk-heads, or the side forms. Guides for power-operated strike-offs (screeds) shall be rails, with provisions for vertical adjustment. Screed guides and screed guide supports shall be so rigid that deflection and settlement under the mass of the equipment operated thereon is negligible. Unless other locations are approved by the Engineer, the screed guides for power-operated screeds shall be supported on the exterior beams, girders, or webs of the structure. Approval for support of screed guides on the side forms or on any falsework independent of the superstructure will only be given when the relative deflection of the supports is negligible and when undesirable conditions are not introduced. The elevation and longitudinal profile (including any allowance for residual camber and deflection under load) to which the screed guides are set, together with the shape of the screed, shall permit the surface of the plastic concrete to be cut and molded to the required cross-slope, longitudinal profile, and elevation under the strike-off and screeding operations.

On concrete deck girder and concrete slab span bridges, the screed guides shall be constructed so that vertical adjustment of the guides can be made after the concrete is in place. After the concrete is in place over a portion of the falsework, and when the elevations may be affected by the concrete load, the elevations of the screed guides shall be checked and, when necessary, readjusted to the required elevations before the final screeding of the roadway surface is done.

Screed mounted vibrators, when approved, shall not be used on the initial strike-off and screeding of the surface, and vibration shall be reduced to a minimum during the final screeding of the surface.

A self propelled power-operated strike-off machine shall be used for screeding the roadway surface of all bridge slabs unless another type of machine is approved for use by the Engineer.

When an outside webwall of a box girder is under a sidewalk or curb, the Contractor may modify the sidewalk or curb reinforcement in order to accommodate the running rail system for the power strike-off machine. However, any modifications of the reinforcement shall be subject to the approval of the Engineer. Any additional costs involved in reinforcement bars due to the modification shall be at the Contractor's expense.

When the use of a power-operated strike-off (screed) is specified, the screeding motion shall be done mechanically and the equipment shall move on flanged or grooved wheels resting on the screed guides. When the running rails are supported by exterior beams or girders that lie under the roadway slab, the area between the rail and the gutter may be finished without the use of the power-operated screed. In this area suitable guides shall be used to determine the required gutter profile

and, after plastic shrinkage has taken place, the area shall be straightened and trued to the required profile and cross-slope.

The screed shall carry a surplus of concrete in front of it during all screeding operations, and rescreeding operations shall be discontinued when no surplus concrete is present.

Manual screeds and reciprocating power-operated screeds shall be operated slowly, with uniform forward travel, and the final screeding shall cover as long a section as practicable without stopping.

After the concrete has been consolidated, screeded and floated the roadway surface of bridge deck slabs shall be given a final finish texture. This final finish shall be obtained by drawing a carpet drag longitudinally along the bridge slab before the concrete has attained its initial set. The drag shall be mounted on a bridge. The dimensions of the drag shall be the width of the concrete placed by a longitudinal length of 1 m (**3 feet**). The carpet drag shall be adjusted as necessary to produce a texture satisfactory to the Engineer.

The carpeting drag shall be an artificial grass type having a molded polyethylene pile face with a blade length of from 15 to 25 mm **(5/8 to 1 inch)** and a total minimum weight of 2.37 kg/m^2 (**70 ounces per square yard**). The backing shall be a strong durable material not subject to rot, that shall be adequately bonded to the facing to withstand use as specified. In lieu of the carpet drag texturing, a coarse broom texturing may be used subject to approval by the Engineer.

In addition to and immediately following the carpet drag, the bridge slab surface shall be given a transverse metal-tine texture. The device used for this operation shall be equipped with 100 to 150 mm (**4 to 6 inch**) steel tines, 2 to 3 mm (**1/12 to 1/8 inch**) thick, arranged so as to obtain randomized grooves approximately 3 to 8 mm (**1/8 to 5/16 inch**) deep, with a variable spacing between tines of approximately 16 to 25 mm (**5/8 to 1 inch**). The Engineer may approve other texturing equipment provided an equivalent texture is obtained. Tining shall not extend into the areas within 300 mm (**1 foot**) of curbs.

The roadway surface of bridge structural slabs shall be hand floated only to the extent necessary to close up areas of exposed aggregate. It shall then be textured by methods and equipment approved by the Engineer so as to produce a final surface that is serrated, grooved, or roughened to a greater degree than that normally produced by conventional brooming, but not to the extent of tearing out or loosening particles of coarse aggregate.

Movement and storage of equipment, vehicles, and materials on bridge structural slabs prior to placement of the wearing course shall be kept to a practical minimum. All foreign matter that may have accumulated on the bridge structural slab surface shall be completely

removed, to the satisfaction of the Engineer, prior to placement of the wearing course.

The final surface shall have the required crown and shall be free of porous spots and irregularities. When checked with a 3 m (**10 foot**) straightedge placed longitudinally thereon, the surface shall not vary from the straightedge more than 10 mm (**3/8 inch**) on a bridge structural slab nor more than 3 mm (**1/8 inch**) on a bridge deck slab. Corrective measures required to meet this tolerance shall also provide comparable appearance and texture.

F3b(3) Bridge Slab Finish Under Curbs, Sidewalks, and Medians

The top surface of the bridge slab under curbs, sidewalks, and medians shall be floated to grade, leaving a rough surface but with the coarse aggregate embedded in mortar. At the edge of the slab and under the roadway face of curbs, sidewalks, and medians, a strip 50 mm (**2 inches**) wide shall be given a smooth finish.

F3b(4) Bridge Slab Finish for Bottom Slab Concrete Box Girders

The top surface of the concrete in the bottom slab of concrete box girders shall be struck off to the required grade, and finished to within a 5 mm (**1/4 inch**) tolerance when checked with a 3 m (**10 foot**) straightedge. No further finishing of this surface will be required.

F3b(5) Surface Smoothness Check

After completion of the curing period, the Engineer will check the bridge slab surface for trueness, using a 3 m (**10 foot**) straightedge for transverse checks and a 3 m (**10 foot**) rolling straightedge of the design used by the Department for longitudinal checks. At least two longitudinal checks will be made in each traffic lane and one check near each gutter. These checks will be made after the floor is swept clean and when it is free of all debris. The protective oil treatment, if required, shall not be applied until the trueness checks have been made.

If, as a result of the trueness checks, it is determined that corrective measures will be required, then the oil treatment shall not be applied until the corrective measures have been completed.

Surfaces that are outside of the specified tolerance in a 3 m (**10 foot**) straightedge shall be corrected as required by the following and to the extent approved by the Engineer. High spots shall be milled to the required grade. Concrete in low spots that has been designated for removal shall be removed a minimum of 50 mm (**2 inches**) below required grade and recast to the proper grade with an approved concrete mixture. In addition, any tining that has been removed shall be restored. Nonconforming areas that are not satisfactorily corrected as provided for herein shall be subject to 1503 and 1512.

Correction by surface grinding or filling will not be permitted where unsatisfactory results are anticipated, nor will such corrective

work be allowed to continue when unsatisfactory results are being obtained. Surface grinding and filling, and the preparation of the surface prior to filling, shall be done in a manner approved by the Engineer, with the high spots being removed to the extent approved before any depressions remaining adjacent thereto are filled. Areas corrected by surface grinding to acceptable surface and thickness tolerances shall be coated with an approved surface sealer if a wearing course is not to be placed. Upon completion of the corrective work, the areas shall be acceptable in appearance or they will not be considered as being corrected satisfactorily.

F3b(6) Preparation of Bridge Seats

The bearing areas of bridge seats shall be power ground as necessary to produce a surface that does not vary more than 1.6 mm (**1/16 inch**) from the required plane.

G Concrete Curing and Protection

Newly placed concrete shall be properly cured by providing protection against rapid loss of moisture, freezing temperatures, high temperatures, abrupt temperature changes, vibrations, shock waves, and prematurely applied loads. This protection shall be provided when directed by the Engineer and for a period of time not less than that specified hereinafter, except as may be otherwise determined and permitted by the Engineer.

The curing time shall be that period of time starting with the completion of concrete placement for a specific section or unit and continuing without interruption until the Engineer has determined that the curing has been satisfactorily completed. For cast-in-place concrete the curing shall continue until the Engineer has determined that the concrete has attained a strength based upon a percentage of anticipated compressive strength given in 2461.3B2. This percentage shall not be less than that shown below for the specified sections or units to which it corresponds:

Section or Unit	**Percent**
Bridge superstructures, except as otherwise specified	65
Diaphragms and end webs that are not a part of box girders and are cast in advance of the bridge slab	45
Railing	45
All sections not included in superstructures	45

Railing concrete shall not be subjected to loading (supporting screed rails, light standards, etc.) until the Engineer has determined that the concrete has attained a strength not less than 60 percent of the anticipated compressive strength.

Heavy equipment (such as ready-mix trucks) will not be permitted on the bridge slab until after completion of the curing period. Then the equipment operation shall be in a manner that will minimize shock

waves. Mixer revolution shall be restricted to agitation speed. Equipment with gross mass exceeding 14 t (**15 tons**) will not be permitted on the bridge slab for box girder and slab span bridges until one week after completion of the curing period.

Some modification of the requirement for continuous curing without interruption may be permitted by the Engineer for the purpose of setting wall or column forms on footings, but only when adequate provisions are made to protect the concrete from freezing or excessive drying during the interruption period. Curing shall be resumed at the earliest opportunity, and shall then be continuous until completion. When heated enclosures are used during the curing period, heaters and other equipment operated within the enclosure shall be vented to prevent the buildup of carbon dioxide.

In the event the curing period terminates during a time of the year when low temperatures will prevent additional strength gain before opening a bridge to traffic, the curing time for bridge superstructure concrete shall be extended to provide for strength gain equal to 70 percent of its anticipated compressive strength.

Strength gain percentages shall be computed from the Strength Gain Chart in Table 2401-1, except that during freezing or anticipated freezing temperatures, the Engineer may require that the computed strength gain be verified by casting and breaking control cylinders in accordance with 2461.4A5. In the event of discrepancy between these two methods, the Concrete Engineer may be called upon for determination of curing adequacy.

When control cylinders are used to determine if the minimum strength has been attained, in no case shall curing for cast-in-place concrete be considered completed in less than 96 hours for sections or units requiring a minimum of 65 percent of anticipated compressive strength or in less than 72 hours for sections or units requiring a minimum of 45 percent of anticipated compressive strength.

TABLE 2401-1

DETERMINATION OF STRENGTH GAIN OF STRUCTURAL CONCRETE *(A)*
Percent per 24 HOURS

Concrete Surface Temp. *(B)* °C (°F)	Previously Accumulated Strength Gain *(C)* % of 28 Day Value													
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
24 (**75**)	15	15	15	15	14	13	12	11	10	9	8	7	6	6
21 (**70**)	15	15	15	15	14	13	12	11	10	9	8	7	6	6
18 (**65**)	14	14	14	14	13	12	11	10	9	8	7	6	6	5
16 (**60**)	12	12	12	12	11	10	9	9	9	8	7	6	6	4
13 (**55**)	10	11	11	10	9	8	8	8	8	7	6	5	5	3
10 (**50**)				8	7	7	7	7	7	6	5	4	4	3
7 (**45**)	6	8	7	6	6	6	6	5	5	4	4	3	3	2
4 (**40**)	5	6	6	6	5	5	5	4	4	3	3	3	2	2

(A) Table values indicate incremental strength gain for 24-hour periods at temperatures ranging from 4°C (**40°F**) to 25°C (**75°F**) when the concrete has previously accumulated a specific strength gain (percent).

(B) Represents temperature at the surface of the concrete for the section (or part section) being cured.

(C) Represents accumulative strength gain of structural grade concrete made with type I cement as a percentage of its compressive strength if cured 28 days at 24°C (**75°F**). Strength gain for concrete with cement substitutions shall be determined by control cylinders.

EXAMPLE --- Average surface temperature for 24-hour period = 16°C (**60°F**). Previously recorded strength gain = 36 percent. Therefore, incremental strength gain = 9 percent; new accumulative total = 45 percent.

Strength gain shall not be credited for any period of time during which the concrete does not indicated the presence of a surface-moist condition, nor for any period of time when the temperature at the concrete surface is less than 5°C (**40°F**). In the event of exposure of the concrete to freezing temperatures or excessive drying during the curing period, the Engineer will declare the affected section, or partial section,

to be defective. Depending on the extent of the damage caused by exposure, as determined by the Engineer, the affected section shall be:

(1) Removed and replaced,
(2) Removed to a depth specified by the Engineer and be replaced as directed,
(3) Sandblasted and overlaid with epoxy mortar or epoxy with sand broadcast,
(4) Covered by an epoxy seal coat,
(5) Subject to a reduction in payment as determined equitable by the Engineer, or
(6) Subjected to any combination of these remedies.

Anchor bolt holes and other depressions that may collect water shall, during periods of freezing temperature, be sealed or temporarily filled with closed cell polystyrene or other satisfactory material.

After completion of tine texturing for bridge deck slabs and after free water has disappeared from the surface, the Contractor shall apply a linseed oil curing emulsion that has been approved by the Materials Engineer. The rate of application shall be approximately 4 m^2 per liter (**150 square feet per gallon**) unless otherwise directed by the Engineer. The curing compound or emulsion shall be applied with approved power-operated spray equipment. The curing compound or emulsion is not a substitute for the cure specified below, but is required for moisture retention until the conventional curing material can be placed. The conventional curing shall be in place by 12:00 noon on the day following concrete placement.

Bridge structural slabs shall have the conventional wet curing applied as soon as possible after texturing.

Concrete exposed to condition causing surface drying during the curing period shall be protected by a west covering as soon as the set of the concrete will permit. Membrane curing compound will not be considered as an acceptable alternative for wet curing, except for such items as slope paving, footings and other section s that are to be covered with backfill material. Membrane curing compound shall not be used on an area that is to be covered by and bonded to subsequent concrete construction. The preferred method of we curing is with commercially available blankets of burlap and plastic bonded together.

Regardless of the method used, a moist surface condition must be maintained. Plywood forms left in place during the curing period shall not be permitted to become excessively dry.

Materials used as an aid to the retention of moisture on the surface of the concrete shall conform to the appropriate material requirements of these Specifications. However, when two or more materials (such as burlene over curing compound) are used in combination, some deviation from the material requirements may be allowed, subject to

approval of the Engineer. (N no event shall the sue of an approved curing system relieve the Contractor of responsibility for maintaining a moist surface condition throughout the curing period.

Only when all requirements specified herein have been fulfilled, as determined by the Engineer, shall the during period be considered as having been completed. When cold weather protection has been provided, its discontinuance shall be gradual and in a manner such that the rate of temperature reduction adjacent to the concrete surfaces will not be more than 11°C (**20°F**) during any 12-hour period until the surface temperature reaches that of the atmosphere.

H Slipforming of Bridge Railing

The Contractor may slipform Type F railing using the following requirements, instead of using conventional forming methods.

H1 Reinforcement Bars

The Contractor shall not tack weld reinforcement bars but shall use additional tying to maintain the rigidity of the reinforcement bar cage. The Contractor shall use plastic coated tie wires when the bars are epoxy coated.

H2 Concrete Mix

The Contractor shall use 3Y16 concrete mix design in the slipformed railing. The Engineer will reject concrete with a slump of more than 300 mm (**1-1/4 inches**).

H3 Construction Requirements

The Contractor shall:

(a) Set the slipformer to the proper garde and alignment.

(b) Verify that the concrete placing equipment is operating properly.

(c) Check the clear distance from the slipform forms to the reinforcement bars in the presence of the inspector. Attache the fill strips or other approved devices to the slipformer during this check as a means of detecting areas of reinforcement bars that might encroach on the required concrete cover. Make this check for the full distance that is anticipated to be placed in the subsequent pour, less any areas of exceptions.

(d) Blank

(e) Edge the joints with a small radius edger prior to placing the curing materials.

(f) Saw-cutting the top portion of the joint to the full depth within 24 hours of the concrete placement to a wide of 10 mm (**3/8 inch**) with power saws mounted on a frame with guidance provisions.

(g) Seal the joint with an approved silicone sealer. The saw-cut portion of the joint shall be sealed to a minimum depth of 25 mm (**1 inch**).

(h) Form the ends of the railing with securely braced conventional forms with the guardrail plate securely bolted in place.

(i) Blank

(j) Conventionally form the railing sections at exceptions (such as deck drain box outs, light standards, and expansion joint devices) for a minimum distance of 1.2 m (**4 feet**) on each side of the exception.

(k) Maintain the Plan location of the gutter line or face of railing. However, the Contract may increase the slab overhangs up to 25 mm (**1 inch**) and batter the outside of the barrier or railing up to 25 mm (**1 inch**).

(l) Use either chamfer or radii strips at horizontal and vertical edges.

(m) Restrict the time interval for delivery of ready-mix concrete to no greater than 1 hour when the air-entraining agent is added to the mix at the central plant.

(n) Wet cure the railing in accordance with 2401.3G using commercially available blankets of wet burlap and plastic bonded together.

(o) Blank.

(p) Positively secure the curing material to the railing to prevent moisture loss.

I Blank

J Joint and Crack Sealing

J1 Joint Sealing

Joint sealer material of the type specified in the Plans or Special Provisions shall be placed in accordance with the applicable requirements of 2301.3N. Furnishing and placing joint sealers shall be incidental work for which no direct compensation will be made.

All construction joints and saw cuts in the deck, curb face, sidewalk, and median shall be sealed with concrete joint sealer.

J2 Crack Sealing

The Engineer will make a visual inspection of the bridge deck slab, including decks of pedestrian bridges, and will mark all cracks appearing on the top surface of the slabs. All cracks so marked shall be filled with an approved epoxy penetrant sealer prior to application of the treating oil. Application of the epoxy penetrant sealer shall be in accordance with the manufacturer's recommendations except when otherwise directed by the Engineer.

Furnishing and placing the epoxy penetrant sealer as specified above will be considered to be incidental work for which no direct compensation will be made.

K Protective Oil Treatment

A protective oil treatment will be required on the upper surface of bridge deck slabs, including pedestrian bridges, medians and sidewalks, but will not be required on a separately poured concrete wearing course placed on a bridge structural slab. The treatment of medians and

sidewalks shall include the roadway face of the curb. , if a curb section is required. Unless other types of treating oil are specified or permitted by Plan or Special Provision, the treating oil shall meet the requirements of 3917, Type II. The treatment shall be made in two equal applications, totaling not less than 3 m^2 per liter (**0.07 gallons per square yard**), as soon as conditions permit and when the concrete is clean and dry. The second application shall not be made until the first has been absorbed by the concrete. Drains shall be plugged when so directed.

Joint sealers shall be in place prior to treating with oil in these areas, and shall be protected during the applications.

2401.4 METHOD OF MEASUREMENT

A Structural Concrete

Measurement of structural concrete will be based on Plan dimensions with each grade or mix measured separately, and with no allowance made for excess quantity beyond the minimum dimensions specified.

Bridge slab concrete, when measured by area, will be based on end-of-slab stationing and out-to-out transverse dimensions of the slab. Sidewalk concrete, when measured by area, will be based on the end-to-end bridge dimension along the centerline of the sidewalk and the overall width of the sidewalk block. Raised median concrete, when measured by area, will be based on the end-to-end slab dimension and overall width of the median. Median barrier concrete measurement will be based on the end-to-end slab dimensions. Measurement of concrete railings or concrete bases for metal railing will be the horizontal lengths between the outside faces of railings or end posts, whichever is applicable.

No deduction will be made in concrete quantities for the volumes displaced by metal reinforcement, structural steel sections, floor drains, conduits, pile headers, chamfer strips with side dimensions of 50mm (**2 inches**) of less, or for variations in camber and deflections for that indicated in the Plans. No increase will be allowed for any extra concrete used to secure true conformity to the Plan requirements of the elevation profile and cross section in the finished roadway slab. Floor thickness shall be considered to be the thickness show in the Plans as minimum thickness unless other dimensions are shown. Keyways shall not be considered when making quantity computations.

B Metal Reinforcement..... 2472.4

C Blank

D Structure Excavation

When separate items are provided in the Proposal for one or more classes of structure excavation under this Specification, the excavation will be classified in accordance with the definitions given in 2451.3B2

and measured in accordance with 2451.4A, which apply to "cast-in-place" structures.

E Granular Material 2451.4B

F Soil Bearing Tests 2451.4C

2401.5 BASIS OF PAYMENT

Payment for structural concrete o f each grade mix designated at the Contract prices per unit of measure will be compensation in full for all costs of constructing the bridge structure complete in place as specified, except for those costs that the Contract specifically designates as having been included for payment under separate items for which the Proposal contains specific unit prices.

If the Contractor elects to pour the concrete end diaphragms with the bridge slab, the concrete mix for the diaphragms may be the same as used for the slab, and payment will be made at the Contract bid price for end diaphragm concrete.

Payment for reinforcement bars, steel fabric, and spiral reinforcement, at the Contract prices per unit of measure, will be compensation in full for all costs of furnishing, fabricating, delivering, and placing the metal reinforcement as specified. When the Proposal contains separate items for "delivering" and "placing" reinforcement bars, payment at the delivered price will be compensation in full for all costs of furnishing, fabricating, and delivering the material to the job site, and payment at the placed price will be compensation in full for all costs of placing the material in the structure as specified.

Payment for structure excavation, soil bearing tests, and backfill materials will be made as provided in 2451.5.

Payment for concrete bridge construction will be made on the basis of the following schedule:

Item No.		Item Unit
2401.501	Structural Concrete (Grade/Mix No.)	cubic meter (**cubic yard**)
2401.511	Structural Concrete (Grade/Mix No.)	square meter (**square foot**)
2401.512	Bridge Slab Concrete (Mix No.)	square meter (**square foot**)
2401.513	Type ____ Railing Concrete (Mix No.).....	meter (**foot**)
2401.514	Median Barrier Concrete (Mix No.)	meter (**foot**)
2401.515	Sidewalk Concrete (Mix No.)	square meter (**square foot)**
2401.516	Raised Median Concrete (Mix No.)	square meter (**square foot)**

2401.5

2401.521	Structure Concrete, Class ____	cubic meter (**cubic yard**)
2401.539	Reinforcement Bars Delivered	kilogram (**pound**)
2401.540	Reinforcement Bars Placed	kilogram (**pound**)
2401.541	Reinforcement Bars	kilogram (**pound**)
2401.542	Steel Fabric	kilogram (**pound**)
2401.453	Spiral Reinforcement	kilogram (**pound**)

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2402
Steel Bridge Construction

2402.1 DESCRIPTION

This work shall consist of the erection of those portions of bridges and structures that are made of structural steel and miscellaneous metals.

2402.2 MATERIALS

A Structural Metals 2471

B High Strength Bolts, Direct Tension Indicators, and Pin Bolts 3391

C Elastomeric Bearing Pads 3741

2402.3 CONSTRUCTION REQUIREMENTS

A General

A1 Structural Steel Components of Concrete Bridges 2401

A2 Steel Piling 2452

A3 Assembly

The Contractor shall assemble all bridge components according to the erection Plans and match markings. Assembly shall be in accordance with the procedures outlined in the Contract. Where no specific procedures are specified, assembly shall be in accordance with recognized practices and as indicated on the approved shop detail drawings.

B Handling and Storage of Materials

Girders and beams shall be stored in an upright position, and all materials shall be kept clean and properly drained. Members stored for long periods shall be covered or sheltered, with provisions for air circulation, in a manner that will protect them from the elements.

C Straightening Bent Materials

The straightening of plates and angles or other shapes shall be done by methods not likely to produce fracture or other damage. The metal shall be heated only when permitted by the Engineer, in which case the heating shall not be to a higher temperature than 650°C (**1200°F**).

After heating and straightening, the metal shall be slowly cooled and be inspected for evidence of fracture or other damage. Galvanized and metallized coating shall be repaired as provided in 2471. The Engineer will reject any members not satisfactorily repaired.

D Falsework Design and Construction

The falsework shall be properly designed and substantially constructed and maintained to safely support the loads to which it will be subjected. Detailed falsework plans shall be supplied to the Engineer upon request, but in no case shall the Contractor be relieved of

responsibility for the results obtained by use of these plans. Adequate provisions shall be made for jacking when necessary.

Timber used for falsework piles or members shall be of sound wood, straight, and in good condition. Steel members shall be straight and of adequate strength for the use intended.

Falsework shall remain in place until the field connections have been riveted or bolted to the extent that release of falsework supports is approved by the Engineer, and the removal of falsework shall be governed by the applicable provisions of 2401.

Except for attachment of screed rail support pipes, no welding will be permitted on primary stress-carrying members of the bridge structure for the purposes of fastening any appurtenances not shown in the Plans or on the approved detail drawings. Screed rail support pipes may be welded to the top flange with 6 mm (**1/4 inch**) longitudinal fillet welds not exceeding 50 mm (**2 inches**) in length. No welding of any kind will be permitted in the negative moment area (designated in the Plans as Area "A") of the top flange of primary stress-carrying members of the bridge structure.

Base metal preparation and ambient weather conditions during welding shall conform to 2471.3F.

E Preparation and Erection

Before bearing plates and shoes are placed, the concrete surfaces upon which they will rest shall be prepared by methods acceptable to the Engineer, so as to provide uniform bearing surface.

Immediately before assembly, all temporary protective coatings shall be removed from pins and pin holes, and the contact surfaces at connections shall be cleaned of all foreign matter. Where pin holes are provided with bronze bushings, the areas of contact between the pins and bushings shall be cleaned to bare metal before assembly.

The required painting on surfaces that will be inaccessible after erection shall be completed before fit-up.

F Field Fit-up

Structural steel members shall be erected in a manner that will provide safety to the workers, inspectors, and the public at all times, as well as reasonable assurance against damage to the members. The primary members, such as beams and girders, shall be temporarily anchored and braced as they are erected, so as to preclude movement or creep in any direction, and so as to prevent tipping and buckling. Struts, bracing, tie cables, and other devices used for temporary restraint shall be of a size and strength that will ensure their adequacy.

Simple spans shall be "fully assembled" before starting permanent bolting. On continuous spans, permanent bolting on a span in the continuous series shall not be started until the immediately adjacent spans in the same series have been "fully assembled". The term "fully

assembled" means assembly of all transversely interconnected beams and girders, diaphragms, and floor beams, but not necessarily stringers, expansion devices, or other members that have no significant effect on the main structural members or that have independent means for adjustment. The Engineer may allow permanent bolting of field splices in beams for continuous spans on the ground prior to "full assembly" of adjacent spans, provided beams to be spliced are positioned on firm supports adjusted to provide the correct alignment, camber, grade, and skew shown in the Plans.

Splices in primary stress-carrying members shall have one-half of the holes filled with erection pins and bolts (half bolts and half pins with balanced distribution) prior to placing the permanent connectors. When live loads are to be carried by these members during erection, additional bolts and erection pins shall be used as required to compensate for the additional loads. Connections for diaphragms and other secondary members shall have a sufficient number of holes filled with erection pins and bolts so that the plates are drawn into full contact and so that the holes are properly matched prior to placing the permanent connectors.

Pins and pinholes, including pinholes having bronze bushings, shall be coated with an approved heavy duty grease prior to assembly.

Erection bolts shall be of the same diameter as the permanent connectors. Erection pins shall not be larger than the diameter of the hole and in no case shall they be smaller than the hole diameter minus 1 mm (**1/32 inch**). Erection washers shall generally be used with erection bolts.

Pin nuts shall be drawn tight, except those with cotter keys, and the exposed thread at the face of the nut shall be upset by centerpunching to prevent backoff. Pin nuts with cotter keys shall be tightened only to the extent that the cotter key can be freely inserted and the pin is free to turn without binding under the Lomas nut.

When the required section has been fully assembled, it shall be referred to the Engineer for approval before proceeding with placement of permanent connectors. Vertical adjustments shall be made at splice points as directed by the Engineer, based on elevations taken at these points. Shifting of the spans may be required to provide for proper anchorage and expansion device locations.

Bearing plates and assemblies shall be checked for contact prior to placement of the permanent connectors, and any deviations from full bearing between parts, or between the bridge seat and the bearing plates, shall be corrected in a manner satisfactory to the Engineer. Major deviations may require readjustment of diaphragms, cross frames, splice plates, recambering, or other refabrication procedures. Minor deviations may, with approval by the Engineer, be corrected by the use of properly shaped and sized fills or shims.

G Permanent Connections

Permanent field connections shall, unless otherwise specified in the Contract or permitted by the Engineer, be made using high strength bolts, or pin bolts, at the Contractor's option. The same type fastener shall be used throughout the structure except as otherwise permitted by the Engineer.

G1 Welded Connections

All field connections to be made by welding shall be done in conformance with the quality requirements of 2471.3F. All welders must have proof in their possession that they have passed the required qualification test as described in 2471.3F for the type of welding work performed. For field welding on primary stress-carrying members, the Engineer may require additional welding procedure tests of the welders. Tests of welders who have previously passed the required qualification tests may be required at any time by the Engineer.

G2 Connections Using High Strength Bolts

G2a General

Bolts shall be installed with their heads outward for the webs of fascia girders, and with their heads downward for the flanges of beams and girders spanning highways, streets, roadways, and walkways.

G2b Bolted Parts

The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled, and shall not be separated by gaskets or any other interposed compressible material.

When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts, or washers, shall be free of scale, except tight mill scale, and shall also be free of dirt, loose scale, burrs, other foreign material, and other defects that would prevent solid seating of the parts. In addition, contact surfaces of friction-type joints shall also be free of coating materials such as oil, galvanizing, and rust inhibitors.

G2c Installation

G2c(1) Bolt Tension

At the time of installation, threaded portions of bolts and nuts shall be free of dirt and corrosion and shall be lubricated. If dirty or corroded, threads shall be cleaned prior to installation. Lubrication of threaded portions of bolts and nuts with an approved lubricant will be required after cleaning and when, during calibration or installation, a substantial variation in torque is necessary to achieve minimum bolt tension.

Threaded bolts shall be tightened by the turn-of-nut or direct tension indicator methods. If required because of bolt entering and

wrench operation clearances, tightening by either procedure may be done by turning the bolt while the nut is prevented from rotating.

Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately 10 seconds.

Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum bolt tension shown in the following tabulation for the size of fastener used:

TABLE 2402-1
BOLT TENSION

Bolt Size mm (inches)	**Minimum Tension *(A)* kN (Kips)**
19 (**3/4**)	125 (**28**)
22 (**7/8**)	173 (**39**)
25 (**1**)	227 (**51**)
29 (**1-1/8**)	249 (**56**)
32 (**1-1/4**)	316 (**71**)

(A) Equal to the proof load (length measurement method) given in ASTM A 325.

G2c(2) Washers

All fasteners shall have a hardened washer under the element (nut or bolt head) turned in tightening.

High strength bolts used in conjunction with full sized punched holes shall have one hardened washer under both the bolt head and the nut.

Where an outer face of the bolted parts has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

G2c(3) Direct Tension Indicator Tightening

When direct tension indicators are used to provide the required bolt tension, installation of the indicators shall be in accordance with the manufacturer's recommendations. Compressible washer-type indicators shall meet the requirements of ASTM F 959. Inspection shall be in accordance with 2402.3G2d, except that a device that can accurately measure deformation of the direct tension indicator shall be used instead of the inspection wrench.

G2c(4) Turn-of-Nut Tightening

When the turn-of-nut method is used to provide the required bolt tension, there shall first be enough bolts brought to a "snug tight" condition to ensure that all parts of the joint are brought into full contact with each other. "Snug tight" is defined as the tightness

attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified hereinafter, with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.

For coarse thread heavy hexagon structural bolts and heavy hexagon semi-finished nuts, nut rotation from snug-tight condition shall be in accordance with the following:

(a) When both faces are normal to bolt axis (with or without use of beveled washers), nut rotation shall be one-third turn for bolt lengths equal to 4 diameters or less, one-half turn for bolt lengths greater than 4 diameters but not exceeding 8 diameters, and 2/3 turn for bolt lengths exceeding 8 diameters but not exceeding 12 diameters.

(b) When one face is normal and the other is sloped not more than 1:20 (beveled washers not used), nut rotation shall be one-half turn for bolt lengths equal to 4 diameters or less, two-thirds turn for bolt lengths greater than 4 diameters but not exceeding 8 diameters, and 5/6 turn for bolt lengths exceeding 8 diameters but not exceeding 12 diameters.

(c) When both faces are sloped not more than 1:20 (beveled washers not used), nut rotation shall be two-thirds turn for bolt lengths equal to 4 diameters or less, five-sixths turn for bolt diameters greater than 4 diameters, but not exceeding 8 diameters and, one turn for bolt lengths exceeding 8 diameters but not exceeding than 12 diameters.

Bolt length shall be measured from underside of head to extreme end of the bolt. Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned. Allowable tolerance in nut rotation shall be one-sixth turn over and nothing under.

G2d Inspection

The Engineer will observe the installation and tightening of bolts to determine that the selected tightening procedure is properly used and will determine that all bolts are tightened to the specified tension. The following inspection procedure will be used in testing bolt tension unless a more extensive or different procedure is specified.

G2d(1) Calibration of Inspection Wrench

The inspection wrench may be either a torque or a power wrench that shall be accurately calibrated as follows:

Three bolts of the same grade, size, and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the part turned

in tightening each bolt. These three test bolts may be any length representative of the bolts used in the structure.

When the inspecting wrench is a torque wrench, each test bolt shall be tightened in the calibration device by any convenient means to an initial condition equal to approximately 15 percent of the specified bolt tension and then to the minimum tension specified for its size as given in 2402.3G2c(1). The inspecting wrench shall then be applied to the tightened bolt and the torque necessary to turn the nut or head five degrees (approximately 25 mm at 300 mm (**1 inch at 12 inch**) radius) in tightening direction shall be determined. The average torque measured in the tests of three bolts shall be taken as the "job-inspecting torque" to be used in the manner specified in 2402.3G2d(2). If the turn-of-nut method is used and tightening results in nut rotation beyond the amount permitted in 2402.3G2c(4), the torque at minimum tension requirements specified for the bolt size plus 5 percent shall be used for computation of "job-inspecting torque."

When the inspecting wrench is a power wrench, it shall be adjusted so that it will tighten each test bolt to a tension 5 to 10 percent greater than the minimum tension specified for its size as given in 2402.3G2c(1); however, if this adjustment results in greater nut rotation than allowed by 2402.3G2c(4), the wrench shall be readjusted to meet both nut rotation and minimum tension requirements, or, if it is not possible to meet both requirements, the torque at minimum tension requirements plus 5 percent shall be used.

Inspection wrenches and bolt tension-indicating devices required by these Specifications shall be furnished by the Contractor. The Engineer shall have full opportunity to witness the prescribed calibration tests.

During the calibration procedure specified in 2402.3G2d(1), the bolt and nut shall withstand rotation to two times the required number of turns required by 2402.3G2c(4) without visible stripping of threads or failure of either bolt or nut.

G2d(2) Inspection Procedure

Either the Engineer, or the Contractor in the presence of the Engineer, at the Engineer's option, shall operate the inspecting wrench as follows:

(a) The tightened bolts in the structure shall be inspected by applying, in the tightened direction, the inspecting wrench and its job-inspecting torque to 10 percent of the bolts, but not less than two bolts, selected at random in each connection.

(b) If no nut or bolt head is turned by this application of the job-inspecting torque, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the job-inspecting torque, this torque shall be applied to all bolts in the connection, and all bolts whose nut or head is turned by the job-inspecting torque shall be tightened and reinspected; or

alternatively, the Contractor may retighten all of the bolts in the connection and then resubmit the connection for the specified inspection.

G3 Connections Using Pin Bolts

Pin bolts shall be installed in conformance with 2402.3G2a and 2402.3G2b, together with the following requirements:

The driving of the pin bolts shall be done by the use of a special driving tool capable of partial swaging of the collars to allow for some adjustment during erection when the pinning and bolting work is performed. The tool shall be capable of producing the required tension in the bolt, and shall be capable of swaging the collar into the annular locking grooves, forming the collar into the proper size and shape as recommended by the manufacturer, before the pin tail breaks.

The pin bolts will be tested prior to use in a device (furnished by the Contractor) capable of indicating actual bolt tension. Not less than three typical bolts of each size and length shall be furnished for tests from the supply of bolts that will subsequently be used in the work. Other bolts may be tested during the bolting operation as directed by the Engineer. The same installation tool that will subsequently be used for tightening and swaging the bolts for the field connections shall also be used for applying tension in the bolts during the testing procedure.

The expendable pin tails shall be recovered from the driving tool as it breaks from the bolt, and shall not be permitted to drop in such a manner as to create a hazard.

The procedure for testing and the installation of pin bolts shall meet with the approval of the Engineer.

H Setting Anchor Bolts

Holes for anchor bolts shall be drilled, except when the Contract specifies otherwise. The bolts shall be accurately set and fixed with Portland cement grout completely filling the holes, except that during freezing weather other products approved by the Engineer may be used.

Nuts for anchor bolts shall be set as indicated in the Plans, providing for clearance where required. The bolt thread at the face of the nuts shall be upset by center punching to prevent back-off.

Anchor bolts that are cast in the concrete shall be accurately set to proper location and elevation with templates.

I Blank

J Bearing Assemblies and Hangers

Rocker bearings and hangers shall be plumb at 7ºC (**45ºF**). Elongation resulting from total load deflection shall be considered when setting these devices.

K Expansion Joint Devices

Expansion joint devices will be designated by type as given in the item name. The type number denotes the minimum movement capability, in millimeters (**inches**), required of the device to be installed at a given location. Maximum movement capability may range up to 50 percent greater than the minimum specified.

Shop detail drawings shall be furnished for all expansion joint devices in accordance with 2471.3B. The drawings shall include detailed instructions for installation and tabulated joint openings for various temperatures.

Joint devices having movement capability exceeding 50 percent of the specified minimum may be approved for use provided that functional requirements are met and the shop drawings indicate the sizes being proposed.

Steel components of expansion devices shall be furnished in lengths that will facilitate installation under roadway and traffic conditions existing at the time of placement. Splices in the gland will not be permitted except where necessary at "tee" intersections where vulcanized splices are required. Welded gutter sections shall be smooth faced at the grip surface.

All structural steel surfaces of the expansion devices, including anchorages, shall be galvanized after fabrication in accordance with 3394. Bolts for roadway sections of the expansion devices shall meet the requirements of 3391.2E, Type 316. Bolts for curb, sidewalk, median, and barrier cover plates shall be stainless steel conforming to 3391.2E, Type 316, or shall be galvanized in accordance with 3392. Steel extrusions and roadway plates shall be straightened after galvanizing to meet a tolerance of 3 mm in 3 m (**1/8 inch in 10 feet**).

Expansion devices shall be installed in accordance with the details and instructions provided by the shop drawings and as directed by the Engineer. All joint-forming material shall be removed from the joint opening.

The complete expansion joint installation shall be watertight at all points and shall be so tested by filling the joint opening, or portions thereof, as designated by the Engineer, with water and observing the results over a period of not less than 1 hour.

L Field Painting

After all erection work has been completed, structural metals shall be cleaned and painted in accordance with 2476 or 2478, whichever is applicable.

2402.4 METHOD OF MEASUREMENT

Structural metals placed in bridges or other structures will be measured by mass, length, area, or unit complete in place.

A Mass

The mass of all structural steel shapes and plates and of all steel sheets and bars will be computed on the basis of the net finished dimensions shown in the Plans using the theoretical density of 7849 kg/m^3 (**490 lbs/ft^3**). No allowance will be made for the fabrication of girder cambers, haunches, and sweeps, nor for the machining of surfaces. No deductions will be made for open holes and incidental bevels or chamfers. The summation of these masses, exclusive of steel piling, will be increased by 1.5 percent to compensate for incidental metal items such as: permanent bolts 150 mm (**6 inches**) or less in length, shop or field high strength bolts, field shims, weld metal deposits, extra material used to make weld procedure tests, shop galvanizing, metallizing, overruns, etc., for which no direct mass measurements are made.

The mass of bolts over 150 mm (**6 inches**) long and tie rods that are used for connecting structural steel parts, including nuts and washers, will be computed from the nominal mass as given in the AISC Manual of Steel Construction and will be included in the mass of structural steel.

The mass of non-incidental metals other than steel will be computed from the theoretical densities as given in the AISC Manual of Steel Construction using the above measurement limitations, except that no measurement will be made of any bolts, nuts, rivets, washers, or shims used in the fabrication and erection, and that a percentage increase in mass therefor shall not apply.

B Length

B1 Metal Railing

Unless other limits are shown in the Plans, the length will be the summation of the lengths of the various sections shown in the Plans, measured at the base of the rail.

B2 Pipe

Unless other limits are shown in the Plans, the length will be the summation of the lengths of all the runs, measured on the centerline of the pipe and fittings.

B3 Expansion Joint Devices

Expansion joint devices of each type will be measured separately by length based on the out-to-out distance along the centerline of each expansion device.

B4 Other Items

Linear measurement of other items not specifically covered herein will be made between the limits shown in the Plans.

C Area

Unless other limits are shown in the Plans, the area will be computed on the basis of net finished dimensions. No deduction will be made for open holes.

D Complete Unit

The unit will be construed to be the complete assembly of all its component parts.

2402.5 BASIS OF PAYMENT

The cost of providing temporary support and restraint, as specified in 2402.3F, shall be included in the Contract unit price bid for the particular structural steel item.

Payment for structural metals at the Contract price per unit of measure will include the mass of all structural metals in a single total.

Payment for item 2402.532, furnishing structural steel, (Spec. No.) at the Contract price therefor, will be compensation in full for all costs of: (a) furnishing and fabricating, in accordance with 2471; (b) surface preparation and shop coat painting, unless otherwise specified in the Contract, in accordance with 2476 or 2478, whichever is applicable; and (c) delivering, in accordance with the Contract, the materials included in this item.

Payment for item 2402.533, erecting structural metals, at the Contract price therefor, will be compensation in full for all costs of erecting the structural metals complete in place as specified, and for all required field coat painting in the absence of a Contract item therefore.

Payment for item 2402.521, structural steel (and other ferrous metals included therein), at the Contract price therefore, will be compensation in full for all costs of: (a) furnishing and fabricating, in accordance with 2471; (b) surface preparation and shop coat painting, unless otherwise specified in the Contract, in accordance with 2476 or 2478, whichever is applicable; and (c) delivering and erecting, in accordance with the provisions herein, all materials included in this item.

Payment for metal railings at the Contract price per unit of measure will be considered to include compensation for painting, metal posts, fittings, castings, anchor bolts, and all other accessories required for the erection.

Payment for expansion joint devices of each type at the Contract price per unit of measure will be compensation in full for all costs of furnishing and installing the devices complete in place as specified, including curb, sidewalk, median, and barrier sections, together with all required coverplates.

Payment for elastomeric bearing pads or assemblies of each type specified at the Contract prices therefor will be compensation in full for all costs of furnishing and installing the pads or assemblies complete in place.

Payment for structural metals will be made on the basis of the following schedule:

Item No.	Item	Unit
2402.504	Sheet Metal, (Spec. No.)	kilogram (**pound**)
2402.521	Structural Steel, (Spec. No.)	kilogram (**pound**)
2402.532	Furnishing Structural Steel, (Spec. No.)	kilogram (**pound**)
2402.533	Erecting Structural Metals	kilogram (**pound**)
2402.546	Floor Drain, Type ___	each
2402.555	Rigid Steel Conduit	kilogram (**pound**)
2402.560	Metal Pipe (Spec. No.)	kilogram (**pound**)
2402.583	Ornamental Metal Railing	meter (**linear foot**)
2402.585	Pipe Railing	meter (**foot**)
2402.586	Plate Railing	meter (**linear foot**)
2402.590	Elastomeric Bearing Pad, Type ___	each
2402.591	Expansion Joint Devices, Type ___	meter (**linear foot**)
2402.592	Elastomeric Bearing Assembly, Type ___	each
2402.595	Bearing Assembly	each
2402.599	Structural Metals	kilogram (**pound**)

2403
Timber Bridge Construction

2403.1 DESCRIPTION

This work shall consist of the construction of those portions of bridge structures that are made of timber.

2403.2 MATERIALS

A Timber

A1 Stress-rated Timber and Lumber

The Contractor shall use stress-rated timber and lumber meeting 3426 for the grade specified.

The Contractor shall use lumber for laminating that is graded according to 3426 with allowable working stress values as shown in the Contract, and which conforms to ANSI/AITC A190.1

A2 Timber Piling 3471

A3 Other Lumber 3457

B Preservative Treatment

All timber shall be preservative treated in accordance with 3491 unless untreated timber is specified in the Contract.

C Adhesives

The Contractor shall use adhesives that meet the requirements for wet-use (waterproof) according to ANSI/AITC A 190.1.

D Dowels

The Contractor shall use hot rolled 3306 steel that is galvanized according to 3394.

E Blank

F Plank for Laminated Floors

The strips shall be surfaced on one side (SIS) to a uniform thickness of not more than 75 mm (**3 inches**). Unless so specified in the Plans, surfacing to uniform width will not be required.

At least 50 percent of the strips shall be 5 m (**16 feet**) or more in length. No strips, except as may be necessary to fill skews, shall be less than 2 m (**6 feet**) long. Other lengths shall be such that no joints will occur over any one stringer closer than each third strip.

G Blank

H Railings

Timber and lumber for railings shall be especially selected to secure material free from blemishes that detract from the appearance of the finished work, and shall be surfaced on 4 sides (S4S).

I Blank

J Hardware

All hardware, including nails, spikes, and timber connectors, shall be galvanized after fabrication in accordance with 3392.

Bolts shall conform to 3391.2C unless otherwise shown or noted in the Plans.

Driftbolts, lag screws, and rods shall conform to 3306 for incidental items. Driftbolts shall have counter-sunk heads and chisel points.

Plate washers shall be properly proportioned to develop the full strength of the bolt. Unless otherwise shown in the Plans, the diameter of the washer or the minimum side dimension of a square washer shall be at least 3.5 times the diameter of the bolt, and its minimum thickness shall be equal to 0.5 of the diameter of the bolt. Washers for bolts less than 12 mm (**1/2 inch**) in diameter may be cut from medium steel plate.

Timber connectors shall be standard manufactured products, of the size and type specified in the Plans.

2403.3 CONSTRUCTION REQUIREMENTS

A General

A1 Cutting and Framing

All cutting, framing, and boring of treated timber shall, so far as possible, be done before treatment.

Nails and spikes shall be driven with just sufficient force to set the heads flush with the surface of the wood. Deep or frequent hammer marks in exposed wood surfaces shall be considered evidence of poor work quality and may be cause for rejection of the piece or member.

B Blank

C Handling and Storage

Timber shall be handled, transported, and stored by methods that will not be detrimental to any portion that will remain in the completed structure. Care shall be exercised to avoid splitting or damaging the surfaces and edges, and in the case of treated timber, to avoid puncturing the treated surface by the use of pointed tools, temporary bolts, or spikes.

D Framing

D1 General

Lumber and timber shall be accurately cut and framed, true and exact to a close fit, in such a manner that the joints will have even bearing over the entire contact surfaces. No shimming will be permitted in making joints, nor will open joints be accepted.

D2 Holes in Untreated Timber

Holes for the following types of hardware shall be bored and shall have the diameters specified below:

For round driftbolts and dowels, 2 mm (**1/16 inch**) less than the diameter of the bolt or dowel; for square driftbolts or dowels, equal to the least dimension of the bolt or dowel; for machine bolts, the same diameter as the bolt; for rods, 2 mm (**1/16 inch**) greater than the diameter of the rod; for lag screws, not larger than the body of the screw at the root of the thread.

D3 Holes in Treated Timber

All holes bored in timber after treatment shall be 2 mm (**1/16 inch**) larger than specified above for holes in untreated timber.

E Field Treatment

All field cuts (except pile cut-offs), daps, field bored holes, and abrasions in treated piles and timbers shall be carefully trimmed and coated with at least two applications of copper naphthenate or another compatible preservative material meeting AWPA Standard M4, with a minimum time lapse of 2 hours between application.

After cut-off, the tops of all treated timber piles used in timber bridge construction shall be treated in accordance with 2452.3F.

F Piling 2452

G Sills

Concrete pedestals, where required for the support of framed bents, shall be carefully finished so that the sills or posts will take even bearing on them. Dowels for anchoring the sills shall project not less than 225 mm (**9 inches**) above the tops of pedestals and shall be set during the casting of pedestals.

Sills shall have true and even bearing on piles or pedestals. They shall be drift-bolted to the piles, with the bolts extending into the piles not less than 225 mm (**9 inches**). When possible, all earth shall be removed from around the sills so that there will be free air circulation around them.

Posts shall be fastened to sills by dowels extending not less than 150 mm (**6 inches**) into the posts and sills.

H Caps

Timber caps shall be placed so as to obtain an even and uniform bearing over the tops of the supporting posts or piles and to secure an even alignment of their ends. All caps, except wing pile caps, shall be secured by driftbolts extending not less than 225 mm (**9 inches**) into the posts or piles. The driftbolts shall be located approximately in the center of each post or pile.

I Blank

J Bracing

The ends of bracing shall be fastened to the pile or post and cap with bolts of not less than 20 mm (**3/4 inch**) diameter and split or tooth ring connectors. Intermediate intersections shall be bolted and spiked with wire spikes, boat spikes, or spike grid connectors, as indicated in the Plans.

K Stringers and Bridging

Stringers shall be sized at bearings. Stringers that are one panel in length shall be so placed that knots near the edges will be in the top portion of the stringers. Stringers that are two panels in length shall be so placed that knots near the edges will be in the compression edges and that lapped joints will be staggered over the supports.

Outside stringers shall have butt joints, but interior stringers shall be lapped to take bearing over the full width of the floor beam or cap at each end. The lapped ends of stringers shall be securely fastened by toenailing or bolting, as specified.

Cross bridging members shall be neatly and accurately framed with bevel cut ends. When placed, they shall have full bearing at each end against the sides of stringers and shall be securely held by at least two nails at each end. The cross bridging shall be set before placing the

floor. The top ends shall be tightly set and the nails driven "home," the lower ends being nailed only enough to hold the bridging in place. After all the floor and wearing surface is in place, the lower ends of cross bridging shall be readjusted, drawn tight to the face of the stringers, and fully nailed as required.

Block or header bridging shall be placed before laying the subfloor. The blocks shall be fully nailed at the top and only temporarily nailed at the bottom. After the entire floor is in place, the nailing of the bridging shall be completed. When the Plans require bolts or lag screws to fasten block bridging, the final tightening of the bolts or lag screws shall be deferred until the entire floor is placed. Block bridging shall be cut square and to accurate length to avoid need for shims. If end shims are necessary, they shall be of zinc or galvanized sheet metal. Shims shall be of the size of the end of the block, with sufficient additional width to permit nailing along one side of block. Shims shall be held in place by means of galvanized roofing nails.

Unless otherwise indicated in the Plans, cross bridging shall be placed at the center of each span.

L Blank

M Blank

N Prefabricated Timber Panels

The Contractor shall ensure that nail or glue laminated timber panels for use in bridge superstructures are fabricated and installed in accordance with the following:

N1 Nail Laminated Panels

The Contractor shall ensure that the following sequence is followed:

(1) Cut individual timber members for use in the panels to proper length and drill all dowel holes.

(2) Treat members with preservative.

(3) Fabricate members into panels.

The Contractor shall have the panels fabricated according to Plan details and fully assembled at the fabrication plant before delivery to the Project. The panels shall be match-marked before shipment. Tolerance on panel length shall be 3 mm (**1/8 inch**) and on width shall be such that when installed the overall deck width is within 6 mm (**1/4 inch**) of Panels Plan dimension.

N2 Glued Laminated Deck Panels

The Contractor shall ensure that glued laminated deck panels are fabricated and installed in accordance to these requirements, the Plans, and ANSI/AITC A 190.1, American National Standards for Wood Products - Structural Glued Laminated Timber. Shop details shall be furnished and approved in conformance to 2471.3B before fabrication work is begun.

N2a Appearance Grades

The panels shall be surface finished to the AITC Industrial Appearance Grade except that the roadway surface of the panels need not be finished. Individual planks shall be placed in a manner that will achieve the maximum corrugation on the roadway surface.

N2b Dowel Holes

All dowel holes shall be drilled 2 mm (**1/16 inch**) greater in diameter than the dowel and 12 mm (**1/2 inch**) deeper than necessary to provide the planned dowel projection before the preservative treatment process.

N2c Marking and Protection

The panels shall be match-marked before shipment. The panels shall not be end sealed, surface sealed, or wrapped.

N2d Preservative Treatment

The Contractor shall ensure that the following sequence is followed:

(1) Fabricate the panels.

(2) Thoroughly remove all excess glue from all surfaces of the panels, except on the roadway surfaces.

(3) Treat with preservative.

N2e Inspection 3491.3

The Contractor shall have the independent commercial inspection agency verify conformance with the above requirements by providing an approval certification mark on each panel and a Certificate of Compliance including the test results.

N2f Assembly

The contractor shall verify dowel projection and conformance with plan dimensions at the project site prior to assembly.

O Blank

P Blank

Q Blank

R Railings

Railings shall be accurately framed in accordance with the Plans, and special care shall be used in erection to secure true lines.

S Hardware

Driftbolts shall be placed in the structure with the chisel point at right angles to the grain of the unbored section of the timbers connected.

Plate washers shall be used for all bolts 12 mm (**1/2 inch**) in diameter or larger, unless special bolt heads and nuts that provide equivalent bearing surface and strength are used.

Timber connectors shall be of the type specified in the Plans. The split ring and the shear plate shall be installed in precut grooves of the dimensions as shown in the Plans or as recommended by the manufacturer. The toothed ring and the spike grid shall be forced into the contact surfaces of the timber joint by means of pressure equipment. All connectors of this type at a joint shall be imbedded simultaneously and uniformly. The claw plate shall be installed by a combination of both methods, partially by precut grooving and partially by pressure.

2403.4 METHOD OF MEASUREMENT

A Treated or Untreated Timber

The Department will measure treated timber and lumber and untreated timber and lumber separately by the unit of measure based on nominal sizes and lengths incorporated in the structure. No allowance will be made for waste except beveled ends.

The Department will measure panels by the number of acceptable units of each type furnished and installed. Panel hardware is included in this item.

B Hardware

The Department will measure hardware by mass only if a pay item for hardware is included in the Contract. The Department will not include the mass of nails, dowels, or panel hardware in quantities for payment.

2403.5 BASIS OF PAYMENT

The Department will make payment for each item at the Contract price per unit of measure as full compensation for all costs of manufacturing, transporting, and installing the item.

Item No.	Item	Unit
2403.501	Untreated Timber	cubic meter (**Mbm***)
2403.502	Treated Timber	cubic meter (**Mbm***)
2403.506	Hardware	kilogram (**pound**)
2403.508	Prefabricated Timber Panels, Type ___	each
2403.510	Glued Laminated Deck Panels, Type __	each

*** Means 1,000 Board-Feet Measure**

2404
Concrete Wearing Course for Bridges

2404. 1 DESCRIPTION

The work shall consist of constructing a Portland cement concrete wearing course on a bridge structural slab or approach panel.

2404.2 MATERIALS

The wearing course shall be composed of a 50 mm (**2 inch**) minimum depth low slump concrete course produced in accordance with the following unless the plan requires or allows a latex modified concrete wearing course:

A Latex Modified Concrete

A1 Portland Cement, Type I or Type IA 3101

The Portland cement shall be of recent manufacture and free of lumps. When mixed with the other ingredients, the mixture shall have between 3.5 and 6.5 percent entrained air as determined in accordance with AASHTO T 152.

A2 Fine Aggregate 3126

A3 Coarse Aggregate, Class A, Gradation CA70..... 3137

A4 Formulated Latex Modifier

The formulated latex modifier shall be a nontoxic, film forming, polymeric emulsion to which all stabilizers have been added at the point of manufacture, and shall be homogeneous and uniform in composition. The latex modifier shall be of approved manufacture as listed in the Special Provisions.

The latex modifier shall conform to the following requirements:

Polymer Type ..... Styrene Butadiene

Stabilizers, Latex..... Nonionic Surfactants

Portland Cement Composition ..... Poly Dimethyl Siloxane

Percent Solids..... 46.0 - 49.0

Density at -4°C (**25°F**) ..... 1.0 kg/L (**8.4 pounds per gallon**)

Shelf Life..... 2 years minimum

Color..... White

Suitable precautions shall be taken to protect latex modifier from extreme heat or cold. Latex modifier shall be stored in suitable enclosures that will protect it from prolonged exposure to temperatures above 29°C (**85°F**). Drums of latex modifier may be stored at the bridge site in direct sunlight for a period not to exceed 10 days if covered on top and all sides with a suitable insulating blanket material.

A5 Mixing Requirements

Latex modified concrete shall be mixed according to the following proportions:

Portland Cement ....392 kg/m^3 (**658 pounds/cubic yards**) of concrete

Latex Modifier ..... 0.3 L /kg (**22.4 ounce/pound**) of cement

Water ..... As required for slump control

Slump: 140 mm with a tolerance of 25 mm (**5-1/2 inch ±1 inch**) when tested 4 to 5 minutes after discharge from the mixer. A minimum quantity of water shall be used sufficient to provide a mixture that can be placed and finished in accordance with these Specifications.

Approximate Ratio of Dry Ingredients by Mass:

Cement - 1 part;

Fine aggregate - 2.5 parts;

Coarse aggregate 2.0 parts; based on 2.65 specific gravity aggregates.

B Low Slump Concrete

Low slump concrete shall be produced in accordance with 2461 as modified by the following:

B1 Mix Requirements

The concrete mix shall be No. 3U17A, using the maximum quantity of water-reducer permitted by the Mn/DOT Concrete Manual.

Concrete slump shall be maintained at 20 mm (**3/4 inch**) within a tolerance of 6 mm (**1/4 inch**).

Air content shall be maintained within the range of 6 to 7 percent whenever possible, and it shall not be less than 5 percent nor more than 8 percent of the measured volume of freshly mixed concrete.

B2 Air Content Provisions

Low slump concrete (Mix No. 3U17A) having an air content less than 4.8 percent or more than 8.2 percent, when tested in accordance with the prescribed procedures and excluding permissible deviations, will not be accepted for payment at Contract prices, but shall be subject to the following:

(a) Concrete having an air content of more than 8.2 percent will be paid for at an adjusted unit price equal to 95 percent of the Contract bid price for the item involved.

(b) Concrete having an air content less than 4.8 percent but not less than 4.0 percent will be paid for at an adjusted unit price equal to 75 percent of the Contract bid price for the item involved.

(c) Concrete having an air content less than 4.0 percent but not less than 3.5 percent may be left in place without any payment being made therefor.

(d) Concrete having an air content less than 3.5 percent shall be removed and replaced.

When air-entraining cement is used and it is found that the air content of the concrete is less than 6 percent or more than 7 percent, the use of that particular brand of cement shall be discontinued as provided in 2461.4A4b.

C Bonding Grout

Grout for bonding the new concrete to the structural slab shall consist of equal parts, by mass, of Portland cement and sand mixed with sufficient water to form a slurry having the consistency of thick cream. The grout should not be self-leveling but will require brushing or scrubbing with stiff bristle brooms to completely coat the in-place concrete immediately before placing the concrete wearing course. For sealing vertical joints, this grout shall be thinned with additional water to a paint-like consistency.

D Membrane Curing Compound, Type 2, Class B 3754

2404.3 CONSTRUCTION REQUIREMENTS

A General

All equipment used for proportioning, mixing, placing, and finishing the concrete shall be subject to the approval of the Engineer. This approval will be contingent upon satisfactory performance and will be rescinded in the event that such performance is not being achieved.

Concrete shall be mixed in accordance with the specified requirements for the equipment used. The concrete, as discharged from the mixer, shall be uniform in composition and consistency. Mixing capacity shall be such that finishing operations can proceed at a steady pace, with final finishing being completed within the times specified herein. Placing and finishing equipment shall include adequate hand tools for placement of the concrete and for working the concrete down to approximately the correct level for strike-off.

An approved power-operated finishing machine shall be used. The finishing machine shall be so designed that, under normal operating conditions, the elapsed time between depositing the concrete on the bridge deck and the final screeding shall be minimal but in no case exceed 15 minutes.

Design of the finishing machine, together with appurtenant equipment, shall be such that positive machine screeding of the plastic concrete will be obtained. The length of the screed shall be sufficient to extend at least 150 mm (**6 inches**) beyond the edge of a subsequently placed section, and to overlap the edge of a previously placed section at least 150 mm (**6 inches**).

The finishing machine shall be capable of forward and reverse motion under positive control. Provisions shall be made for raising the screeds to clear the screeded surface for traveling in reverse.

Unless otherwise directed by the Engineer, the Contractor will be required to demonstrate that the finishing machine proposed for use will

produce the required results (placement rate, concrete density, surface finish, etc.) under the conditions to be encountered.

Rails will be required for the finishing machine to travel on and they shall be placed outside of the wearing course area. Rail anchorages shall provide horizontal and vertical stability and shall not be ballistically shot into concrete that will not be overlaid.

After the rails have been set to proper grade and elevation, and prior to starting the concrete placement, the clear distance from the bottom of the screed to the top of the prepared concrete surface shall be checked by the Contractor in the presence of the inspector. A fill strip or other approved device shall be attached to the bottom of the screed during this check as a means of detecting any areas encroaching on the required wearing course thickness. Sufficient screed rails shall be set to allow the clearance check to be made in one continuous run for a complete day's placement. Corrections shall be made as directed by the Engineer so as to obtain the specified thickness.

The location of longitudinal joints shall be subject to the approval of the Engineer and shall be located at the edges of traffic lanes.

Immediately before placing the concrete wearing course, the slab surface shall be thoroughly cleaned, and the entire surface shall be sandblasted. After sandblasting, the resulting debris shall be removed by sweeping or other approved method, after which surface dust shall be removed by airblasting. The air supply system must be provided with a suitable oil trap between the storage tank and air nozzle.

All sandblasting, sweeping, and cleaning of the bridge structural slab shall be completed prior to placing the concrete so that surface inspection can be accomplished during the daylight hours when natural light is sufficient for visual inspection.

After the surface to be overlaid has been cleaned, and immediately before placing the wearing course, the entire surface shall be sandblasted.

Concrete placement and finishing shall proceed at a linear rate, measured parallel to the centerline of the bridge, of not less than 12 m (**40 feet**) per hour under normal working conditions. Unless otherwise authorized, pours shall not exceed 7.3 m (**24 feet**) in width.

Joints shall be made in the concrete wearing course in accordance with the applicable requirements of 2401.3E, and shall be located directly above the original joints constructed in the bridge deck slab. Saw cuts shall be made as soon as the concrete can be cut without raveling. This work shall be performed in a manner that will expose the uncured concrete to surface drying for the shortest time practicable. Saw cuts shall be sealed with joint sealer conforming to 3723.

After the concrete has been consolidated, screeded and floated, the Contractor shall texture the surface of the wearing course by drawing a carpet drag longitudinally along the pavement before the concrete has

attained its initial set. The drag shall be mounted on a bridge. The dimensions of the drag shall be the width of the concrete placed by a longitudinal length of 1.2 meters (**4 feet)**. The carpet drag shall be adjusted as necessary to produce a texture satisfactory to the Engineer.

The carpeting for the drag shall be an artificial grass type having a molded polyethylene pile face with a blade length of 16 to 25 mm (**5/8 to 1 inch**) and a total minimum mass of 2.35 kg (**70 ounces**) per square meter (**yard**). The backing shall be of a strong, durable material not subject to rot, that shall be adequately bonded to the facing to withstand use as specified. In lieu of the carpet drag texturing, a coarse broom texturing may be used subject to approval by the Engineer.

In addition to and immediately following the carpet drag, the bridge slab shall be given a transverse metal-tine texture. The device used for this operation shall be equipped with 100 to 150 mm (**4 to 6 inch**) steel tines approximately 1 by 2 mm (**1/12 by 1/8 inch**) thick (cross section) arranged so as to obtain randomized grooves approximately 3 to 8 mm (**1/8 to 5/16 inch**) deep with a variable spacing of 15 to 25 mm (**5/8 to one inch**). The Engineer may approve other texturing equipment provided an equivalent texture is obtained. Tining shall not extend into areas within 0.3 m (**1 foot**) of curbs.

The final surface shall not vary more than 3 mm (**1/8 inch**) from a 3 m (**10 foot**) straightedge laid longitudinally thereon. Special care shall be taken in the areas of expansion devices and other breaks in the continuity of the wearing course to ensure that this tolerance is met.

Surface areas not meeting the specified tolerances shall be corrected by removal and replacement or by grinding the high spots to the extent directed by the Engineer. Nonconforming areas that are not satisfactorily corrected shall be subject to 1503 and 1512.

The provisions of 2401.3J shall be complied with in performing the sealing operations.

If the daytime temperature for a scheduled concrete placement is predicted by the National Weather Service to reach or exceed 27°C (**80° F**), the placement shall either be rescheduled or it shall be started between the hours of 7:00 p.m. and 5:00 a.m. Pours started after 7:00 p.m. but not completed by 5:00 a.m. shall be terminated at 5:00 a.m. if the air temperature is at or above 27°C (**80°F**). If the air temperature is below 27°C (**80°F**) at 5:00 a.m., the pour may continue until such time as the temperature reaches 27°C (**80°F**). No concrete wearing course shall be placed when the air temperature is below 5°C (**40°F**) nor when the slab surface shows signs of frost.

The Contractor shall notify the Engineer a reasonable length of time in advance of scheduling a night operation, and shall provide artificial lighting as necessary for quality workmanship and adequate inspection.

Concrete for wearing courses shall not be placed before April 15th, or after September l5th, north of the 46th parallel, or after October 1st,

south of the 46th parallel, unless the deck is heated and housed in accordance with the following:

(1) The Contractor shall submit, for the Engineer's approval, a plan and proposed time schedule for cold weather protection and maintenance of acceptable curing temperatures. No work shall be commenced until all necessary provisions have been made to the satisfaction of the Engineer.

(2) The concrete shall be provided with suitable housing immediately after placement, such as will provide free air circulation above the surface and protect against freezing rain or snow.

(3) Pre-heating of the structural slab may be required prior to concrete placement. Insulation blankets or heating facilities shall be provided as necessary to maintain the specified curing temperatures.

(4) For the first 96 hours after concrete placement, the concrete surface or enclosure temperature shall be maintained at a minimum temperature of 16°C (**60°F**) for low slump concrete and 13°C (**55°F**) for latex modified concrete. Thereafter, for the next 26 calendar days, insulation or heating shall be provided as necessary to ensure that the concrete will not be exposed to temperatures below 5°C (**40°F**).

(5) The housing enclosure shall not be removed until the cold weather protection needs have been fulfilled, as determined by the Engineer.

B Latex Modified Concrete

B1 Mixer Requirements

Proportioning and mixing equipment shall be of an approved stationary batch or self-contained mobile type. Conventional ready-mix truck mixers shall not be used.

Self-contained mobile type mixers shall comply with the following requirements:

(a) The mixer shall be self-propelled and be capable of carrying sufficient unmixed materials for the latex composition.

(b) The mixer shall be capable of positive measurement of the cement being introduced into the mix. A recording device, visible at all times, and equipped with ticket print-out shall indicate this quantity.

(c) The mixer shall provide positive control of the flow rate of water and latex emulsion into the mixing chamber. Water flow shall be indicated by a flow measuring device and be readily adjustable to compensate for minor variations in aggregate moisture.

(d) The mixer shall be capable of being calibrated to automatically proportion and blend all components of the indicated composition on a continuous or intermittent basis, as required by the finishing operations, and shall discharge the mixed material through a conventional chute directly in front of the finishing machine.

(e) The mixer shall be capable of adequately blending the latex composition so that the freshly consolidated material contains no more than 6.5 percent entrained air.

Stationary batch type mixers shall be capable of producing a latex composition that is equal in all respects to that produced by the mobile mixer unit.

B2 Concrete Placement

Bulkheads shall be installed to the required grade and profile and they shall not be treated with a parting compound to facilitate removal.

The surface to be overlaid shall be dampened with water immediately prior to placement of the latex composition. No puddles or standing water will be permitted on the surface at the time of placing the latex composition.

Latex composition shall not be placed at air temperatures lower than 7^0C (**45^0 F**) and may be placed at 7^0C (**45^0 F**) only when rising temperature is predicted.

Properly mixed latex composition shall be promptly delivered to and be deposited on the dampened surface, where it shall be brushed out carefully to ensure uniform coating of all vertical as well as horizontal surfaces. Spent aggregate from the brushing operations shall be disposed of in an approved manner. The rate of progress in placing the latex composition shall be so controlled that it does not become dry before being covered with the wearing course.

A surplus of mortar shall be maintained in front of the leading edge of the finishing machine screed during all operations. Hand finishing with a wood or magnesium float will be required as necessary to produce a dense, uniform surface.

Bulkheads shall be separated from the newly placed concrete by passing a pointing trowel along the inside face. Care shall be exercised to ensure that the trowel cut is made for the entire depth and length of the bulkheads after the concrete has set sufficiently so it will not flow back.

B3 Curing Requirements

A single layer of wet burlap or approved equal shall be placed on the surface as soon as the concrete has set sufficiently to support it without deformation. Care shall be exercised to ensure that the burlap is well drained. It is the nature of the latex modifier to form a plastic film at the surface upon drying, usually within 25 minutes in hot dry

weather. The burlap covering must be placed prior to formation of this film, to ensure against premature drying and cracking.

A layer of polyethylene film shall be placed on the wet burlap and remain in place for a period of not less than 48 hours. If the ambient temperature falls below 13°C (**55°F**) during this period, the duration of the wet cure shall be extended as directed by the Engineer.

No traffic shall be permitted on the concrete wearing course until it has had 72 hours of drying time after removal of the curing media.

C Low Slump Concrete

C1 Mixer Requirements

Mixing equipment shall conform to 2461, modified to the extent that a continuous mixer used in conjunction with metered proportioning will be required. This mixer shall be calibrated by the Department for the specific materials to be used. A minimum of 7 days lead time will be required to establish mix settings. All concrete shall be mixed at the job site.

The finishing machine shall have at least one oscillating screed and be designed to consolidate the concrete to 98 percent of rodded density by vibration. Either a sufficient number of identical vibrators, or pillow blocks with eccentric cams, shall be installed so that effectively at least one vibrator (or source of vibration) is provided for each 1.5 m (**5 feet**) of screed length. If only one screed is vibrated, it shall be the front screed. The bottom face of this screed shall be at least 125 mm (**5 inches**) wide and have a turned-up or rounded leading edge to minimize surface tearing. Each screed shall produce a pressure of at least 366 kg per square meter (**75 pounds per square foot**) of screed area of bottom face. Each screed shall be provided with positive control of the vertical position, angle of tilt, and shape of the crown. The finishing machine shall be equipped with an adjustable power-operated paddle or auger to strike off concrete in front of the first screed.

C2 Concrete Placement

The prepared deck surface shall not be presaturated, but shall be dry so as to allow absorption of bonding grout. The bonding grout shall be thoroughly scrubbed into the deck surface at a rigidly controlled rate as will not allow the bonding grout to become dry before it is covered with the concrete wearing course.

The concrete shall be mechanically struck off slightly above final grade before being consolidated and screeded to final grade.

At transverse and longitudinal joints, the course previously placed shall be sawn to a straight, vertical edge, and the trimmings shall be completely removed before the adjacent course is placed. No impact equipment shall be operated in the adjacent lane during the first 72 hours after concrete placement without specific authorization from the Engineer.

As soon as finishing and texturing have been completed, all vertical joints with adjacent concrete shall be sealed by painting with thinned bonding grout.

C3 Curing Requirements

The concrete shall be coated with membrane curing compound within 30 minutes after depositing the concrete on a given area. The compound shall be applied by an approved airless spraying machine at the approximate rate of 1 liter per 4 m^2 (**1 gallon per 150 square feet**) of curing area.

The spraying machine shall have as essential elements:

(a) A recirculating bypass system that provides for continuous agitation of the reservoir material.

(b) Separate hose and nozzle filters.

(c) A multiple or adjustable nozzle system that will provide for variable spray patterns.

Before application, the curing compound as received in the shipping containers shall be agitated until a homogeneous mixture is obtained. Application shall be such that a uniform coating is obtained. Any areas that appear to have too light a coating shall be resprayed immediately. Also, should the membrane film become damaged at any time prior to placement of the wet cure, the damaged areas shall be repaired immediately by respraying.

Failure to apply membrane curing in a given area within 30 minutes after depositing concrete thereon shall be subject to 1512. However, if the Engineer determines that revibration of the concrete is necessary, this time limit will be extended 15 minutes. Concrete in areas not coated with membrane curing compound within the stated time limits shall be removed and replaced at no additional cost to the Department.

As soon as the concrete can be walked on without damage, conventional curing media (wet burlap or curing blankets) shall be placed in accordance with 2401.3G for a minimum curing period of 96 hours.

No vehicular traffic shall be permitted on the concrete wearing course during the 96 hour curing period. If the daily mean temperatures have been below 15^0C (**60^0F**) during this 96 hour period, additional curing time will be required by the Engineer before traffic will be permitted.

2404.4 METHOD OF MEASUREMENT

The concrete wearing course will be measured by surface area as computed from specified dimensions. No deduction will be made for the surface area of expansion devices or other miscellaneous appurtenances.

2404.5 BASIS OF PAYMENT

Payment for the concrete wearing course at the Contract price per unit of measure will be compensation in full for all costs of constructing the wearing course complete as specified, except for those costs that the Contract specifically designates as having been included for payment under separate items for which the Proposal contains specific unit prices.

Payment for concrete wearing course will be made on the basis of the following schedule:

Item No.	Item	Unit
2404.501	Concrete Wearing Course..... (Type or Mix No.)	square meter **(square foot)**

2405
Prestressed Concrete Beams

2405.1 DESCRIPTION

This work shall consist of the fabrication and installation of prestressed concrete I-beams and double Tee-beams for use in bridge superstructures.

2405.2 MATERIALS

A Concrete 2461

The concrete shall be produced in a central-mix plant meeting 2461.4D4. Generally, Portland cement, Types I, II, or III may be used at the Contractor's option.

Concrete for prestressed I-beams shall be Mix No. 1W36 or 3W36. When the minimum required concrete strength for I-beams, as shown in the Plans, is greater than 35 Mpa (**5,000 psi**) but does not exceed 42 Mpa (**6,000 psi**), the concrete shall be concrete Mix No. 1W36 and an approved water reducing admixture shall be added. The quantity of admixture shall be sufficient to reduce the water content of the concrete by not less than 5 percent when compared with concrete that does not contain the admixture. When the minimum required concrete strength for concrete I-beams, as shown in the Plans, is greater than 42 MPa (**6,000 psi**), the concrete shall be Mix No. 1W36 modified to give the required concrete strength or an approved alternate mix. This may require the use of a super water reducer under procedures approved by the Concrete Engineer.

Concrete for double Tee-beams shall be Concrete Mix No. 3W36.

B Reinforcement Bars 3301

C Structural Steel 3306

D Corrosion-Resistant High Strength Steel 3307

E Prestressing Tendons Seven Wire Strand 3348

F Structural Steel Pipe..... 3362
G Galvanized Structural Shapes 3394
H Curing Paper..... 3752
I Blank
J Plastic Curing Blankets..... 3756

2405.3 CONSTRUCTION REQUIREMENTS

The Contractor shall fabricate the beams in a precast/prestressed concrete fabrication plant that has been granted Certification by the Precast/Prestressed Concrete Institute, or by an organization approved by the Materials Engineer.

The prestressed concrete beams shall be fabricated in accordance with the applicable sections of 2401, 2471, and 2472, and the PCI Manual for Quality Control: Precast and Prestressed Concrete except as modified hereinafter.

A General

The State Materials Engineer is the Engineer with authority concerning all matters of plant fabrication and inspection prior to delivery of the material to the Project. The Project Engineer is the Engineer with authority concerning all matters of fabrication at the Project site.

The Contractor shall notify the Department, in writing, immediately after placing orders for prestressed concrete beams. This notification shall be directed to the Engineer, with a copy to the Project Engineer, and shall include the name and address of the supplier and the location at which the beams will be manufactured. This information is required so that proper arrangements can be made for inspection at the place of manufacture.

The Fabricator shall notify the Engineer at least 7 days prior to starting manufacturing operations, except that if the beams are cast at the site of the bridge, the Engineer shall be notified a sufficient time in advance of casting to permit inspection of the forms and reinforcement.

When the beams are cast at a plant away from the bridge site, and if, on any day on which the services of the Department inspector are required, less than 2 beams are cast, the Department will deduct from any moneys due or becoming due to the Contractor the total cost of such inspection for that day. This policy may be modified by the Materials Engineer to suit the particular circumstances. However, in any case, after informing the Fabricator, inspection costs deemed excessive by the Engineer will be deducted from the total cost for the product paid to the Contractor.

The Fabricator shall have a PCI Level II, Certified Technician, available at the start of fabrication and throughout fabrication of the prestressed beams. All technician's performing quality control

functions will be Mn/DOT - PCI Level I Certified. The supervisor of the quality control staff will be PCI Level II Certified.

The Fabricator shall take precautions to prevent damage to prestressing steel that may result in weakening the prestressing steel or that may result in its failure under stress. Nicking or kinking of the prestressing steel may result in rejection of the material. Sparks or pieces of molten metal from welding or burning equipment shall not be permitted to contact any prestressing steel, and the use of prestressing steel as a ground for welding equipment will not be permitted. The cutting off of surplus tendon ends by burning will be permitted, provided the burning is done rapidly and neatly.

During the tensioning of the tendons, and until such time as the stress has been transferred from the jacks to permanent anchors or temporary grips, special precautions shall be taken by the Fabricator to prevent accidents that may result from failure of the equipment or materials.

Shop drawings for all structural metals shall be prepared in accordance with 2471.3B.

B Forms

Forms shall be designed to withstand the pressure due to concrete, vibration, and impact without distortion. They shall be set and maintained mortar tight, free of warp, and on a rigid foundation. The soffit form shall be at right angles to the vertical axis of the beams, with the plane of bearing surfaces flat and true. Side and soffit forms shall be true to Plan dimensions and shall be so set and maintained during casting and until the concrete has set. Joints in sectional forms shall have a tight fit without offset.

Forms for prestressed concrete beams shall be so set that the dimensions of the beam after prestress transfer will conform to the Plan dimensions within the tolerances specified in 2405.3J.

The face of the forms in contact with the concrete shall be treated with form coating material meeting 3902 before the form is set in position. Forms shall be thoroughly cleaned of accumulations of oil or other substances prior to use.

When beam end blocks are required, the length of the end block shown in the Plans is a minimum and may be increased as much as 300 mm (**12 inches**) to accommodate sectional forms. The length of the end blocks for all beams of the same length in any one span shall be the same.

C Steel Units

Reinforcement bars for prestressed concrete beams shall be placed, supported, and tied in accordance with the applicable provisions of 2472, except that welded ties will be permitted at bar intersections that are to be contained within the top flange of the beams, provided that no

welding is performed in the vicinity of the prestressing strands. This is the only exception to the requirements for using wire ties.

When the top flange transverse stirrup reinforcement bars are tack welded to the vertical web reinforcement bars in fabricating the reinforcement bars into cages, additional U-shaped No. 13 vertical reinforcement bars will be required at the top flange. The bar details shall be the same as the vertical web reinforcement bars, except that the length of the bars from the top of the curve to the ends of the legs shall be 450 mm (**18 inches**). These bars shall be located at the vertical web reinforcement bars at each end of the beam and at the intermittent bars at a spacing that does not exceed 600 mm (**24 inches**). The bars shall be placed to match the projection of the vertical web reinforcement bars from the top of the beam and shall be held in place to them with wire ties. Tack welding will not be permitted. Where two vertical web reinforcement bars are used in end blocks, and where half vertical web reinforcement bars are used in end block tapers, one bar is required and may be located with either bar or half bar.

The concrete cover on reinforcement bars shall not be less than 25 mm (**1 inch**) at any point.

Sole plates for prestressed beams shall be so set that after prestress transfer, the location of the sole plates will conform to the Plans within the tolerance specified for the length of pretensioned beams. The sole plates shall be in close contact with the soffit forms and shall be so maintained during placement of concrete.

Floor drains shall be placed in the position shown in the Plans and securely fastened to the forms in such a manner that the placing of the concrete will not alter their alignment or location.

All loose rust and all dirt, oil, and other foreign substances shall be removed from prestressing tendons before the side forms are erected for the beams.

The construction of hold-down devices for deflected strands may be such that the device can be removed for a distance of 25 mm (**1 inch**) or more from the face of the concrete and the hole plugged with mortar, or the device may rest on the bottom form and remain in-place, in which case that part in contact with and for a distance of at least 25 mm (**1 inch**) from the form shall be galvanized.

D Placement of Concrete

The beams shall be cast in an upright position and the concrete in each beam shall be placed without interruption, except that for prestressed I-beams, the concrete shall be placed in continuous lifts of approximately 35 percent of the beam depth. The casting procedure shall be modified when the length of the beams and placement conditions are such that a cold joint may result if each lift is continued full length before another lift is placed.

The concrete in each beam shall be vibrated internally, externally, or both, as required to produce uniformly dense concrete, and in such a manner as to avoid displacement of enclosures or steel units. Internal vibration shall conform with 2401.3D, except that internal vibrators shall have a vibrating head not greater than 32 mm (**1-1/4 inch**) in diameter and shall operate at a frequency of not less than 100 Hz (**100 cps**).

After the top surface of the beams has been struck off to the required level, it shall be worked and hand floated sufficiently to seal open tears in the surface and depress all coarse aggregate, and the surface shall then be roughened by transverse brooming.

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F Concrete Curing

F1 General

The curing operations shall begin immediately after the concrete has taken its initial set and shall be continued until the concrete, as evidenced by the strength of control test cylinders cured with the beams, has reached a compressive strength not less than the minimum required for prestress transfer.

When cold weather protection is required, the temperature inside the housing shall, after the expiration of the curing period, be reduced at a rate not exceeding 22^0C (**40^0F**) per hour until the temperatures inside and outside the housing are equal.

F2 Curing Methods

The beams shall be cured by any of the following methods or combinations thereof:

(a) A covering of burlap or canvas kept continuously wet,

(b) A continuous water spray or mist,

(c) A complete airtight seal using curing paper or plastic curing blankets,

(d) Submersion of the unit in water, or

(e) The moist air or steam method of curing, subject to the requirements set forth below.

F3 Steam Curing

The introduction of steam into the curing chamber, for curing purposes, shall be delayed until the concrete has taken its initial set and in any event until at least 3 hours after the concrete is placed. During the delay period, the minimum temperature within the curing chamber shall be not less than 10ºC (**50ºF**), and the maximum temperature shall not exceed the temperature of the concrete at the time of placement by more than 5ºC (**9ºF**). Steam may be used only to maintain the curing chamber temperature within these limits.

Steam jets shall not impinge directly on the concrete or on the forms. The rate of rise in temperature adjacent to the concrete shall not exceed 15ºC (**27ºF**) per hour. There shall be free circulation around the top, sides, and ends of the concrete units. The temperature adjacent to the concrete shall not exceed 70ºC (**158ºF**) at any time. The steam within the curing chamber shall be thoroughly saturated at all times. The temperature of the concrete unit shall be kept above 10ºC (**50ºF**) during the entire curing period. The difference in temperature adjacent to the concrete at different locations within the chamber shall not exceed 5ºC (**9ºF**) at any one time.

After the expiration of the steam curing period, the temperature inside the chamber shall be reduced at a rate of not more than 22ºC (**40ºF**) per hour until the temperature inside and outside of the chamber are equal; and, after being removed from the chamber, the beams shall be protected as may be necessary to avoid cooling at a rate greater than 22^0C ($\mathbf{40^0F}$) per hour until the air temperature at the storage site is reached.

When side forms are removed from the curing chamber before the steam curing cycle (including temperature taper off process) is completed, only the minimum area of the curing chamber enclosure that is necessary to remove each individual form section shall be removed and remain uncovered at any one time. The open area in the enclosure shall be immediately closed as each form section is removed, and in any event, within 15 minutes of the time the area was first uncovered.

When the Fabricator elects to remove the beams from the casting bed during the cooling-off process, the Fabricator shall take appropriate measures to keep the beams warm during the moving operations, and shall immediately resume the cooling-off process at the storage area.

Two continuous recording thermometers shall be provided for each casting chamber having a casting bed length of 30 m (**100 feet**) or less and, for each additional 30 m (**100 feet**) or fraction thereof in the length of the casting bed within each chamber, one additional thermometer shall be provided. Thermometers shall be located in each enclosure or curing chamber as directed by the Engineer. Complete temperature recording charts for all cures shall be submitted to the Engineer for review.

When the records indicate that the temperature and time element Specifications pertaining to the steam curing are not being complied with, the use of steam curing shall be discontinued and other approved cured methods shall be used.

G Tensioning

G1 Equipment

Prestressing tendons shall be tensioned with hydraulic jacks or dynamometers and hydraulic jacks. Each jack pump shall be equipped with a hydraulic pressure gauge. Jacks, gauges, and pumps shall be

calibrated as a unit under conditions as nearly similar to operating conditions as practicable, and a dated, certified calibration curve shall be furnished for each combination used. Recalibration will be required for equipment that gives erratic results during tensioning operations.

The sensitivity and accuracy of hydraulic pressure gauges shall be such that at final elongation of the prestressing tendons, the actual stress on the jacks can be accurately determined within a tolerance of 2 percent of the total indicated stress at that time.

The dynamometer that is used to measure an initial tension shall be calibrated, and the sensitivity and accuracy of the dynamometer shall be such that the initial tension can be accurately determined within a tolerance of 5 percent.

G2 General Procedures

The tensioning procedure shall be so conducted that the indicated stress on the tendons based on gauge pressures and the indicated stress based on the corresponding elongation of the tendons may be measured and compared at any time. When the two indicated stresses, corrected for friction loss, differ by 5 percent or less, the tendons shall be so stressed that the lower of the two indicated stresses is equal to the required tension in the tendon, except that in no case shall any tendon be tensioned to an indicated stress in excess of 85 percent of its specified yield point strength. If the difference exceeds 5 percent, tensioning operations shall cease until the source of the discrepancy has been determined and corrected.

Tensioning of prestressing strands in the bundled position with direct contact between adjacent strands will not be permitted. A minimum of 6 mm (**1/4 inch**) clear space shall be maintained between adjacent strands during tensioning. However, tensioned strands may be depressed into a bundled position with contact between adjacent strands after all tensioning has been completed.

The Contractor shall keep a record of gauge pressures, indicated stresses, and elongations and shall submit the record to the Engineer.

Each strand shall be given an initial tension of such magnitude and be supported at such intervals that the strand is straightened and the slack partially removed before jacking is started. Strands tensioned as a group shall have the same initial tension, and all strands in the group shall be from the same manufacturer. When the required initial tension is 650 N (**150 pounds**) per strand or less, it shall be considered zero tension. When the required initial tension exceeds 650 N (**150 pounds**) per strand, it shall be measured with a dynamometer or an equally accurate device, and the elongation due to the initial tension applied shall be added to the final elongation measurement.

The tensioning of deflected strands shall be done in a manner that the final tension in all parts of the strand is uniform, and means shall be provided to reduce frictional forces at the bend points to a minimum.

Tension-elongation measurements shall be corrected for losses, as determined by the Engineer in the field, due to slippage of grips or anchorages, and friction, to obtain the required prestress force in the strands after anchorages are set.

When there will be an appreciable change in elongation of the strands due to a temperature differential in the strands at the time of tensioning and time of concrete placement, the change shall be considered in the final elongation measurements to obtain the required prestress force at the time of casting. The change in elongation due to temperature shall be based on 1 mm per 10 m (**1/8 inch per 100 feet**) of strand length for each 8ºC (**15ºF**) variation in temperature. Tensioning of prestressing tendons shall only be allowed if the ambient air temperature is above 0ºC (**32ºF**) and rising.

H Prestress Transfer

Beams shall not be removed from their casting beds until the prestressed transfer has been made. When not otherwise noted in the Plans, the prestress transfer shall not be made until the control cylinders indicate the concrete has reached a compressive strength of at least 31 Mpa (**4500 psi**) when a steam cure is used, the prestress transfer shall be made while the concrete is still warm and moist.

Prestress transfer sequence shall be such as to keep the lateral eccentricity of the prestress to a minimum and prevent cracking in the top flange of the beams. The prestress transfer may be made by the gradual release of hydraulic jacks, by heating exposed portions of individual strands to failure, or by a combination of these two methods. When heating of individual strands is employed, it shall be subject to the following:

(1) Heating of each individual strand shall be done simultaneously on the strand at a minimum of two locations along the casting bed. The sequence of heating each strand along the bed and the sequence of prestress transfer between individual strands shall be such that no detrimental effect will result.

(2) Heating shall be done with a large, low oxygen flame played along the strand for a minimum distance of 125 mm (**5 inches**) The application of heat shall be so controlled that failure of the first wire in the strand does not occur for at least 5 seconds after heat is applied, followed by gradual elongation and failure of the remaining wires.

Prestress transfer shall not begin until the forms are completely stripped from the beams.

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J Tolerances

The dimensions of the prestressed concrete beam after prestress transfer shall conform to the Plan dimensions within the tolerances

specified in the "Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products" prepared by the Prestressed Concrete Institute except as modified by the appropriate Mn/DOT Prestressed Concrete Beam Inspection form. Tolerances for double Tee-beams shall be in accordance with Section 5.5.2. Tolerances for I-beams shall be in accordance with Section 5.5.8.

Differential camber between adjacent members of the same design, if applicable, will be measured with the beams erected to their final position.

Any member that does not conform to the plan dimensions within the specified tolerances shall be subject to 1503.

K Rejection

Beams shall be subject to rejection because of failure to meet any of the requirements specified above, or if, upon removal of the forms, there is evidence of honeycombing, stone pockets, sand streaks, or imperfect mixing and casting.

Minor surface cavities or irregularities that do not impair the service value of the beams and that are satisfactorily repaired shall not constitute cause for rejection. Repairs shall not be made until the Engineer has inspected the extent of the irregularities and has determined whether or not the beam will be rejected. All grout used shall meet the approval of the Engineer.

L Marking, Handling, Storage, and Transportation

Beams may be moved from the casting bed to a nearby storage area upon attaining the minimum compressive strength for prestress transfer; however, no beam shall be transported or installed until the minimum compressive strength specified for transportation has been attained, as evidenced by control cylinders. If not otherwise specified, the minimum strength for transportation shall be 35 Mpa (**5000 psi**).

Each beam shall be marked showing casting date and piecemark. Beams cast away from the bridge site shall bear the name or trademark of the manufacturer and the bridge number. Prior to shipment, the beams will be stamped with the official mark of the Department.

All markings shall be placed in such a manner as to remain in evidence after erection, but not readily visible in the completed structure. No beam shall be transported or installed unless it bears all of the required markings.

Prestressed beams shall remain in an upright position at all times and shall be supported during storage, lifting, and transportation at two points only. The location of the support points shall be determined by the Contractor in accordance with standard Prestressed Concrete Institute methods and shall include consideration of beam stresses and stability, subject to final approval by the Engineer.

Permits may be required from road authorities.

M Installation

After each prestressed beam has been erected, it shall be temporarily braced and tied in a manner satisfactory to the Project Engineer so as to preclude sliding, tipping, or other movement that may otherwise occur prior to placement of the diaphragms and the slab. The Contractor shall arrange the work schedule so that at least two adjacent I-beams will be erected and braced in any one span before operations are suspended.

The prestressed concrete beams shall be installed and permanently fastened in accordance with the details shown in the Plans.

Intermediate diaphragms for prestressed concrete I-beams shall be in accordance with the Plans.

All structural steel shapes and plates for the steel intermediate diaphragm option shall comply with either 3306 or 3309. Steel plates and shapes complying with 3306 or 3309 shall be galvanized in accordance with 3394.

Fasteners, including washers, for the intermediate steel option shall be in accordance with 3391. Fasteners for use with galvanized structural steel shall meet the requirements of ASTM A 325, Type 1 or 3, and shall be galvanized in accordance with 3392.

Cast-in-place anchorages shall be used to connect the steel intermediate diaphragms to the fascia beams. The anchorages shall provide an ultimate pull-out strength of at least 65 kN (**15 kips**) per anchorage.

Material used to form holes in beam webs for connection bolts for steel intermediate diaphragms shall be either plastic or galvanized steel.

In addition to the ordinary surface finish, a special surface finish conforming to 2401.3F will be required on the outer face of the exterior beams of a bridge. The special surface finish shall be done with the beams in place and in conjunction with the final finish of the remainder of the structure.

2405.4 METHOD OF MEASUREMENT

Item 2405.501, Prestressed Concrete Beams Type ___, will be measured separately as individual units regardless of minor variations in Plan details between beams of the same type.

Item 2405.502, Prestressed Concrete Beams ___, will be measured by summation of the individual lengths, out to out, along the centerlines of beams.

Intermediate diaphragms for prestressed concrete I-beams will be measured by length based on the horizontal distance from centerline to centerline of beam along the axis of the diaphragms.

2405.5 BASIS OF PAYMENT

Payment for prestressed concrete beams, at the Contract price per unit of measure, will be compensation in full for all costs of

manufacturing, transporting, and erecting the beams in their final position, including the placement of temporary bracing as specified in 2405.3M.

Payment for intermediate diaphragms for prestressed concrete I-beams will be made at the Contract price per unit of measure, which price will be compensation in full for all costs of constructing the intermediate diaphragms complete in place, including all structural steel or concrete and reinforcement bars required.

Payment for prestressed concrete beams and appurtenances will be made on the basis of the following schedule:

Item No.	Item	Unit
2405.501	Prestressed Concrete Beams Type ___	each
2405.502	Prestressed Concrete Beams ___	meter **(linear foot)**
2405.505	Prestressed Concrete Double Tee-Beam Type ___	each
2405.511	Diaphragms for Type ___Prestressed Beams	meter **(linear foot)**

2411
Minor Concrete Structures

2411.1 DESCRIPTION

This work shall consist of constructing concrete structures of miscellaneous types and varied designs, either with or without metal reinforcement, and including box culverts, retaining walls, culvert headwalls, open flumes, and other cast-in-place items not covered by other Specifications.

2411.2 MATERIALS

A Concrete 2461

Mix designations shall be as indicated in the Plans for the specific items of work.

B Reinforcement Bars 3301

C Steel Fabric 3303

D Preformed Joint Filler 3702

E Geotextile Filter 3733

2411.3 CONSTRUCTION REQUIREMENTS

Construction requirements shall be the same as those specified in 2401.3, except as modified by the following provisions:

A General

The structure locations shown in the Plans will be considered as being approximate only, and the exact locations shall be determined in the field by the Engineer. Each structure shall conform to the planned design, but the Engineer may change the dimensions to fit on-site

conditions. Materials shall not be ordered until the exact locations and dimensions have been established.

All details and notes shown on the Mn/DOT Standard Box Culvert Plans, pertaining to construction joints, reinforcement bar splicing and computation of quantities, shall apply except as modified by the following:

(1) Transverse construction joints, if used, shall be staggered at least 1200 mm (**4 feet**) in relation to any other joint that would result in a plane of weakness through the culvert structure.

(2) Where long culverts result in lengths of reinforcement bars that are impractical for use, but are less than 18.3 meters (**60 feet**) long, additional splices will be permitted. The extra bar material used in making these additional splices will not be included in the pay quantity.

(3) Pay quantities for concrete and reinforcement bars shall be as determined from the formulas given on the box culvert Plans, except that such formula quantities will be adjusted to account for any additional materials due to design modifications made by the Engineer or to provide a completed structure in conformance with the Plans and Special Provisions.

B Falsework and Forms

Form lining shall be used on all vertical faces that will be exposed to view in the completed work. Detailed falsework or forming plans will not have to be furnished unless specifically required by the Special Provisions.

C Concrete Curing and Protection

All concrete structures shall have curing protection in accordance with the applicable requirements of 2401.3G, until the concrete has attained a strength gain of not less than 45 percent.

D Geotextile Filter

Geotextile shall be furnished and installed as shown in the Plans. Furnishing and installing the fabric shall be incidental work with no direct compensation being made therefor.

2411.4 METHOD OF MEASUREMENT

Measurement of structural concrete will be based on Plan dimensions, with each Grade or Mix being measured separately, and with no allowance being made for excess quantity beyond the minimum dimensions specified. No deductions will be made for volumes displaced by metal reinforcement, chamfer strips, or other incidentals.

Measurement of metal reinforcement items will be in accordance with 2472.4A.

When separate items are provided in the Proposal for structure excavation or granular backfill material, quantities will be measured in

accordance with 2451, but only for those structures where the Plans show an estimated quantity.

2411.5 BASIS OF PAYMENT

Payment for structural concrete of each Grade or Mix designated at the Contract prices per unit of measure will be compensation in full for all costs of constructing the structures complete in-place as specified, except that separate payment will be made for metal reinforcement, structure excavation, and backfill materials when the Proposal contains specific unit prices therefor.

Payment for concrete structures of each Design or Type designated at the Contract prices per unit of measure will be compensation in full for all costs of constructing the structures complete in-place as specified, except that when payment is made in surface area units the concrete incorporated therein will be paid for separately under the provisions of 2461.5.

Separate payment will be provided for structure excavation and special backfill materials only when the structures are paid for by volume, and then only when the Plans show an estimated quantity for the specific structure, but not when the structures are paid for as individual units.

Payment for concrete structures will be made on the basis of the following schedule:

Item No.	Item	Unit
2411.501	Structural Concrete (Grade or Mix No.)	cubic meter **(cubic yard)**
2411.503	Concrete (Type of Structure)	square meter **(square yard)**
2411.505	Concrete Structure, Design ___	each
2411.507	Concrete (Type of Structure) ___	each
2411.511	Structure Excavation, Class ___	cubic meter **(cubic yard)**
2411.521	Granular Backfill (1)	cubic meter **(cubic yard)**
2411.523	Aggregate Backfill (1)	cubic meter **(cubic yard)**
2411.541	Reinforcement Bars	kilogram **(pound)**

NOTE: (1) Specify the basis of measure (LV or CV) after the item name. See 2451.4B.

2412
Precast Concrete Box Culverts

2412.1 DESCRIPTION

This work shall consist of the installation of precast concrete box culverts.

2412.2 MATERIALS

A Concrete 2461
B Reinforcement Bars 3301
C Steel Fabric 3303
D Joint Sealer Materials
D1 Preformed, Type A or B 3726
D2 Bituminous Mastic 3728
E Granular Materials 3149
F Geotextile, Type II 3733
G Precast Concrete Box Culverts 3238

2412.3 CONSTRUCTION REQUIREMENTS

Construction requirements shall be subject to 2411, 2451, and 3236 and the following additional requirements.

A Foundations

Foundation preparation shall be in accordance with 2451.3C, except that a minimum 150 mm (**6 inch**) thickness of granular bedding conforming to 3149.2F shall be provided. The bedding shall be shaped to a flat base using a template. Compaction adjacent to the bottom corner radii shall be accomplished with a mechanical hand compactor.

B Laying Precast Concrete Box Culvert

Precast concrete box culvert sections shall be laid with the groove end of each section up-grade, and the sections shall be tightly joined. The individual sections shall be tied together with concrete pipe ties. The joint on the bottom of the culvert shall be sealed with a preformed mastic. A strip of geotextile material extending 300 mm (**12 inches**) or more on each section shall be placed over the joints on the top and sides a manner that will prevent displacement during backfilling operations.

When so required by the Contract, the joints in the precast concrete box culvert shall be effectively sealed to provide a flexible water tight joint using an approved joint sealer material (preformed rubber, preformed plastic, or bituminous mastic).

Mastic joint sealer materials shall be applied in accordance with the recommendations of the manufacturer. All joints shall be wiped clean on the inside after sealing. Lifting holes shall be plugged with a precast concrete plug, sealed and covered with mastic or mortar.

2412.4 METHOD OF MEASUREMENT

A Culvert Excavation

When the Proposal contains separate items for culvert excavation under the payment provisions of this Specification, the excavation for concrete box culverts will be classified and measured in accordance with the applicable provisions of 2451.4A.

B Precast Concrete Box Culverts

Precast concrete box culverts will be measured by length, as determined by the summation of the nominal laying lengths of the individual sections incorporated into each structure. Measurements will be separated as to size indicated in the item name.

Transition sections between two different sizes will be measured for payment as the larger (or more costly) size, except for such special sections as may be designated for measurement as a unit. Any cast-in-place concrete work for extending an existing box culvert will be included for payment with the adjacent precast box culvert.

C End Sections and Other Appurtenant Items

End sections and other appurtenant items such as flap gates and other specially identified units designated for payment on a per each basis, will be measured separately by the number of complete units of each type and size incorporated into the box culvert structures.

Any cast-in-place concrete work, other than end sections, required in connection with the construction of precast concrete box culverts will be measured for payment under 2411.

D Granular Materials

The 150 mm (**6 inches**) granular bedding is incidental and no direct payment will be made. When the Proposal calls for any other special backfill or bedding, such material will be measured in accordance with 2451.4B.

2412.5 BASIS OF PAYMENT

Payment for precast concrete box culverts and end sections will be made on the basis of the following schedule; this payment in each instance will be compensation in full for all costs of furnishing and installing the culverts and end sections complete in place as specified and will include, but not be limited to, the necessary excavations, drop-wall, foundation preparation, granular bedding material, and backfill, unless payment for any of these items is shown in the Plans and provided for by separate Contract pay items.

Item No.	Item	Unit
2412.511	___ x ___m **(foot)** Precast Concrete Box Culvert.....	meter **(linear foot)**
2412.512	___ x ___ m **(foot)** Precast Concrete Box Culvert End Section.....	each

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2422
Crib Walls

2422.1 DESCRIPTION

This work shall consist of constructing retaining walls of the crib type, using preformed galvanized metal units or precast concrete units.

2422.2 MATERIALS

A Metal Cribbing..... 3351

B Concrete Cribbing..... 3661

C Hardware

Hardware shall be of the type and size shown in the Plans, and shall be galvanized as specified in 3392.

2422.3 CONSTRUCTION REQUIREMENTS

A Preparation of Foundation..... 2451.3

B Erection

Crib walls shall be erected in accordance with the Plans for the type being constructed. The planned length of the structure will be adjusted during construction so that only units of standard length will be required.

C Backfilling

Backfilling shall mean the placement of excavated material within the limits of the excavation, whether inside or outside the crib. If the material is suitable for that purpose, it shall be used for crib filling as hereinafter described. Backfilling outside of the crib shall progress with the crib filling, and the material shall be placed in layers not more than 200 mm (**8 inches**) thick, with each layer being thoroughly compacted before the succeeding layer is placed.

Any excavated material that is not used for backfilling shall be disposed of as directed by the Engineer. If the excavated material is not suitable for use as backfill, the backfill shall be made with the same material as provided for crib filling, and it will be paid for as such.

D Crib Filling

The material to be used for filling the interior of the crib shall be approved prior to its use, and the filling shall progress with the erection of the cribbing units.

Approved earth material shall be used to fill the interior of the cribs when the cribbing is to be used principally for the retention of an embankment where there is no wave action against the face of the wall. It shall be placed in layers not more than 200 mm (**8 inches**) thick, with each layer being thoroughly compacted before the succeeding layer is placed.

When the wall is to be subjected to wave or current action, boulders or quarry run rock shall be used to fill the interior of bar type cribs, and pit run gravel or quarry run rock shall be used for the bin type. The

minimum size of the rock for filling bar type cribs shall be larger than the vertical distance between bars, and the material shall be so placed that no damage is caused to the cribbing units and that the void content is reduced to a minimum.

2422.4 METHOD OF MEASUREMENT

A Excavation

When separate items are provided in the Proposal for structure excavation under this Specification, the excavation will be classified and measured in accordance with 2451.

B Crib Walls

Crib walls of each type will be measured separately by the overall area of the front face of the wall, based on actual completed dimensions.

C Crib Filling

Crib filling will be measured for payment only when separate items are provided therefore, and then the material used will be measured by volume, vehicular measure.

2422.5 BASIS OF PAYMENT

Payment for constructing crib walls of each type at the Contract prices per unit of measure will be compensation in full for all costs of constructing the walls complete in place, except for any crib filling provided for under separate items.

If the crib is constructed in conjunction with the construction of an adjacent embankment and if no special crib filling material is required, the crib filling will be considered as embankment construction and no separate payment will be made therefore.

If the crib is not constructed in conjunction with the construction of an adjacent embankment or if special crib filling material is required, the crib filling will be paid for as Extra Work in the absence of a Contract item therefore.

Payment for structure excavation will be made in accordance with 2451, whenever an item therefore is provided in the Proposal. Otherwise any excavation work involved shall be performed without direct ompensation.

Payment for crib wall construction will be made on the basis of the following schedule:

Item No.	Item	Unit
2422.501	Structure Excavation, Class ___	cubic meter **(cubic yard)**
2422.506	Metal Crib Walls	square meter **(square foot)**
2422.507	Concrete Crib Walls	square meter **(square foot)**
2422.511	Earth Crib Filling	cubic meter **(cubic yard)**
2422.512	Gravel Crib Filling	cubic meter **(cubic yard)**
2422.513	Rock Crib Filling	cubic meter **(cubic yard)**

2433
Structure Renovation

2433.1 DESCRIPTION

This work shall consist of renovating existing structures, by widening, rebuilding, or restoring, as indicated in the Plans and Special Provisions, including necessary removals to accomplish the improvements.

2433.2 MATERIALS

Except when otherwise specified all materials used in this work shall conform to the requirements of Division III.

2433.3 CONSTRUCTION REQUIREMENTS

A General

A1 Traffic Provisions

Traffic provisions shall be as defined in the Special Provisions. In addition to the requirements set forth in 1710 and unless otherwise specified in the Contract, the Contractor will furnish flaggers, and erect and maintain temporary curbs, rails, extra warning lights, special signs, or other protective devices, as may be required by the Engineer for the protection of all traffic and workers at no expense to the Department.

When the Contract specifies the construction of temporary sidewalks for the use of pedestrians, the sidewalks shall be constructed entirely outside of the vehicular traffic lanes. They shall be provided with suitable hand rails and shall be not less than 1200 mm (**4 feet**) wide.

A2 Explosives

Explosives shall not be used to remove any portion of a structure that is to be widened or reconstructed. The restricted use of explosives to remove any material not directly connected to the structure will be permitted only upon written authorization of the Engineer and subject to 1711.

A3 Field Measurements

The dimensions of the old structure as shown in the Plans shall be considered as being approximate. Before any shop detail drawings are made or any fabrication is performed, the Contractor shall take sufficient measurements of the old structure to ensure that the old and new work will be properly joined, and furnish these measurements to the Engineer. Field measurements shall be shown on the shop detail drawings as specified in the detailed Specification for the type of work involved.

B Removal and Disposal Requirements

The removal and disposal of materials encountered in the renovation of existing structures shall be in accordance with 2442 insofar as they are applicable, together with the following additions and modifications.

The removal of old concrete or stone masonry shall not extend beyond the limits shown in the Plans and shall be accomplished in such a manner as not to damage any portion of the remaining structure. Saw cuts to a depth of about 25 mm (**1 inch**), or more if necessary, shall be made on faces that will be exposed to view, in order to produce neat appearing joints.

Where shown in the Plans, keyways shall be cut into the concrete that remains in place, without damage to the remainder of the structure.

The removal of piling located within the new footing area shall be accomplished in a manner that will not impair the supporting power of the foundation soil or damage any part of the remaining structure.

When old piles interfere with the planned spacing of new piles the Engineer may require the Contractor to drive the old piling sufficiently to determine their bearing capacity and suitability for use in the new construction. Unless otherwise provided in the Contract, such extra pile driving will be paid for as Extra Work.

C Concrete Construction

Concrete construction shall be in accordance with 2401 together with the following additions:

Bolt anchors and other fasteners shall be placed and secured as specified.

When no surface finishing of old concrete is specified, at least 600 mm (**2 feet**) of the adjoining portion of the old concrete shall be given a surface finish in a manner that will blend the finish of the new with the old work.

Unless otherwise shown in the Plans the size and depth of the drilled holes and the installation of bolt anchorages shall conform to the recommendation of the manufacturer.

D Reinforcement Steel

Reinforcement steel shall be placed in accordance with 2472 together with the following additions:

Unless otherwise shown in the Plans or required by the Special Provisions, reinforcement bars that extend through the cut line shall not be cut nearer than 40 diameters to the cut line.

When the strength of any bar has become impaired due to careless operation of removing old concrete, an approved bolt anchor or clamp, capable of developing the strength of such bar, shall be installed at no expense to the Department and as directed by the Engineer.

E Structural Steel Construction

Structural steel shall be fabricated as provided in 2471 and erected as provided in 2402, together with the following additions:

(1) So far as practicable, holes for field connections between new and old steel shall be subpunched in the shop and reamed to proper size in the field after assembly. When the holes for these connections are made in the field, the parts shall be firmly clamped together and

the holes drilled, using the holes in the old steel as a template. The use of a flame-cutting torch for making holes will not be permitted.

(2) The tops of all steel stringers, floor beams, etc., that are to be in contact with timber or concrete shall be cleaned of rust, scale, and other foreign matter and then be given the required coats of field paint and allowed to dry for not less than 24 hours. Before new steel is permanently connected to old steel, the contact surfaces of the old steel shall be thoroughly cleaned of all foreign matter and be given a coating of the designated primer paint. Painting of the structure shall be in accordance with 2476 or 2478, whichever is applicable.

F Masonry Construction

Masonry shall be constructed in accordance with the Plans.

Connections to old stone masonry shall be made at the old mortar joints and such joints shall be stepped, as directed by the Engineer.

All mortar and all loose or fractured material shall be cleaned from old stone masonry at the juncture of old and new work before new work is joined thereto. Immediately before placing new concrete or stone masonry, the surface of the old masonry shall be thoroughly wetted.

G Timber Construction

Timber construction shall conform to 2403 and the following:

(1) New nails, spikes and hardware shall be used throughout the work.

(2) Before placing either new or old timber on any part of a structure, the contact surfaces of the timber shall be thoroughly cleaned. Contact surfaces, except new treated timber and those that constitute parts of the structure to be treated with oil paint, shall be given at least two applications of copper naphthenate or another compatible preservative material meeting the requirements of AWPA Standard M4, with a minimum time lapse of 2 hours between applications.

2433.4 METHOD OF MEASUREMENT

A Structure Removals

The item of structure removals will be measured by lump sum.

B Item Removals

Removal of specified items such as concrete, masonry, structural steel, timber, etc., will be made by the unit of measure as indicated in the pay item and in accordance with the following:

B1 Lump Sum

Lump sum measurement will include the entire item as designated in the Contract or authorized by the Engineer.

B2 Mass

When measurement of structural steel is specified by mass, the mass will be computed in accordance with 2402.4A.

B3 Length

Length will be measured longitudinally along the center of the unit and as limited by the Plans or removal limits designated by the Engineer.

B4 Area

Area will be computed on the basis of actual width and length measurements and as limited by the Plans or removal limits designated by the Engineer.

B5 Blank

B6 Volume

Volume measurements, except for timber, will be computed on the basis of actual dimensions of the unit as removed. Timber will be measured based on nominal sizes and actual length measurements.

B7 Each

When the unit of measurement is designated as each, the Department will count each complete item needed for performing the required work.

C Anchorages

Furnishing and placing anchorages of each type specified will be measured separately by the number of units complete in place.

D Placing Used Materials

Placing used materials such as structural steel, timber, etc., will be measured separately by unit of measure as prescribed for removal items.

2433.5 BASIS OF PAYMENT

Payment for structural removals will include the removal of all specified portions of the existing structure as necessary to accomplish the renovation work and will include disposal of the materials removed and such other work as may be necessary to properly prepare the structure for the new work.

Payment for structure renovation work will be made on the basis of the following schedule:

Item No.	Item	Unit
2433.501	Structure Removals	lump sum
2433.502	Remove (1)	cubic meter **(cubic yard)**
2433.503	Remove (1)	kilogram **(pound)**
2433.505	Remove (1)	square meter **(square foot)**
2433.506	Remove (1)	meter **(linear foot)**
2433.507	Remove (1)	lump sum
2433.509	Remove (1)	each
2433.510	Place Used (1)	each
2433.511	Place Used (1)	kilogram **(pound)**
2433.512	Place Used (1)	lump sum

2433.513 Place Used (1) ..... cubic meter (**Mbm***)
2433.515 Place Used (1) ..... meter (**linear foot**)
2433.516 Anchorages, Type___..... each

*** Mbm = 1,000 Board-feet measure**

(1) Specify item name such as structural steel, concrete, timber, masonry, etc.

2442
Removal of Old Bridges

2442.1 DESCRIPTION

This work shall consist of the removal and disposal of old bridges, or portions thereof, as indicated in the Contract.

2442.2 USE OF EXPLOSIVES

In addition to the requirements of 1711, the use of explosives in conjunction with the removal of old bridges shall be subject to approval of the Engineer.

2442.3 REMOVAL AND DISPOSAL REQUIREMENTS

A General

Except as otherwise provided in the Plans or Special Provisions, the Contractor will not be required to salvage any materials during bridge removal . Materials that are not to be salvaged for the Department may be removed by any means the Contractor may desire, provided adequate precautions are taken to avoid damage to members that are to be salvaged.

All materials salvaged for the Department shall be placed in stockpiles at locations convenient for loading as directed by the Engineer. When the Contract specifies that certain materials are to be hauled to a storage yard, or some other designated location, those materials shall be neatly placed on suitable skids furnished by the Contractor. All materials not required to be salvaged for the Department shall be disposed of by the Contractor in accordance with 1506 and 2104.3C.

All portions of substructures, including piling and minor obstructions, shall be completely removed when they interfere with the new structure. Old piles under new footings shall be removed to the bottom of the new footings. Old substructure units located outside the limits of the new structures shall be removed to the elevation of the stream bed or to an elevation not less than 600 mm (**2 feet**) below the final ground surface, except that, in established navigation channels, they shall be removed to an elevation not less than 600 mm (**2 feet**) below the established bottom of the channel. Substructure units and piles that are located within the roadbed shall be removed to an elevation not less than 1200 mm (**4 feet**) below subgrade. When located on a railroad grade, such substructure units and piles shall be removed

to an elevation 1200 mm (**4 feet**) below base of rail, unless otherwise directed.

Piles, portions of drift material, sheet piling and other minor construction within the limits of the Right of Way that are not a part of the old bridge but that constitute obstructions to the stream channel or that present an unsightly appearance shall be removed as incidental to the removal of the old bridge. This provision is intended to apply to minor items of work that may not be shown in the Plans but that are readily discernible upon inspecting the site of the work. Items such as ice breakers, portions of old piers, and similar units, will be designated for removal in the Contract. The removal of items that are not included in the Contract and that are not visible on inspection of the site of the work will be paid for as Extra Work, except when the removal is solely for the Contractor's convenience.

Pits or trenches resulting from the removal operations shall be filled with suitable earth material. Backfill placed above water level shall be placed in layers not more than 300 mm (**1 foot**) in thickness, and each layer shall be thoroughly compacted.

When a bridge designated for removal is located elsewhere than at the site of the new structure, the removal of the old bridge shall include the excavation and disposal of the embankments adjoining the abutments, as directed by the Engineer, to slopes conforming to the natural ground surface or to a 1 vertical to 2 horizontal slope beginning at the intersection of the front face of the abutment and the natural ground surface. In no case shall the stream channel be constricted except as provided for in the Contract, or as specifically permitted by the Engineer.

When it is necessary to remove part of an existing concrete pavement, the pavement shall be removed to an existing joint or cut on a straight line at right angles to the centerline of the road. When cutting is to be performed the top surface shall be cut for a depth of at least 25 mm (**1 inch**) with a saw, and care shall be taken to prevent damage to any portion of the pavement that is to remain in place. Precautions shall be taken during excavation operations to prevent undermining or disturbing the foundation material under pavement that will not be removed.

B Structural Steel

Structural steel that is to be salvaged shall be dismantled in sections, individual members, or parts as indicated in the Plans, or if not indicated in the Plans, then as directed by the Engineer. Unless otherwise specified in the Contract, the removal shall conform to the original erection in reverse sequence. The manner and method of removal shall be one that will preclude damage to the members. Only field driven rivets shall be cut. Pins shall be drawn by means of pilot nuts wherever possible.

The Contractor shall match-mark all members with approved paint, in accordance with a diagram furnished by the Department. All pins, pin

nuts, loose plates, ring fills, etc., shall be similarly marked to indicate their proper location. All loose parts shall be securely wired or bolted to adjacent members, or packed in boxes, properly identified.

All pins, pin-holes and machined surfaces shall be coated with an approved grease.

Rivets shall be removed with an approved pneumatic or hand tool. The use of torches will not be permitted unless specifically permitted in the Contract.

Structural steel shall be stockpiled on suitable skids and the material so arranged that dissimilar parts are in separate piles. This material shall be piled in order to preclude damage to the members.

C Timber

Timber and lumber shall be removed by methods that will minimize breakage or splitting. Nails, spikes, fastenings, and hardware shall be removed therefrom and the timber material cleaned of dirt and all other foreign matter except paint and bituminous surfacing materials.

2442.4 METHOD OF MEASUREMENT

Each bridge removed will be measured as a single lump sum with no separate measurement being made of any portions of the work. Salvage materials will be measured as a single lump sum for each bridge with no separate measurement if more than one type of material is salvaged.

2442.5 BASIS OF PAYMENT

Payment for material salvage shall be compensation in full for loading, hauling and unloading the specified materials, and all work incidental thereto in accordance with the Contract.

Payment for the removal of old bridges or material salvage will be made on the basis of the following schedule:

Item No.	Item	Unit
2442.501	Remove Old Bridge	lump sum
2442.502	Salvage and Haul Material (Bridge)	lump sum

2451
Structure Excavations and Backfills

2451.1 DESCRIPTION

This work shall consist of excavating, preparing foundations and placing backfill for bridges and miscellaneous structures. It shall also include the construction and removal of cofferdams, making soil bearing tests, and the disposal of surplus excavated materials.

For the purpose of this Specification, the various types of structures shall be considered as being either the "cast-in-place" type or the "prefabricated" type. "Cast-in-place" structures shall be construed to be such structures as bridge substructures, concrete box culverts, concrete retaining walls, structural plate arch footings, etc. "Prefabricated"

structures shall be construed to be such precast concrete or prefabricated metal structures as pipe culverts and sewers, cattle passes, subsurface drains, etc. The detailed Specification for a particular class of work will generally designate the applicable provisions of this Specification for each type of structure.

2451.2 MATERIALS

A Granular Materials 3149

Granular materials for special backfill, bedding, drain or filter purposes shall meet the requirements for the item of work as specified.

2451.3 CONSTRUCTION REQUIREMENTS

The following construction requirements are subject to any specific requirements or modifications that may be provided in the detailed Specifications for a particular class of work.

A General Requirements

All foundations shall be prepared to the designated elevations and grades, and the structure or substructure placed in open excavations in the dry, by use of temporary construction adequate to accomplish this purpose.

A1 Site Preparations

All necessary clearing and grubbing shall be performed in accordance with 2101. The entire area bounded by straight lines between the structure extremities shall be cleared and grubbed. In the case of bridge construction, the clearing and grubbing shall extend to the Right of Way between the bridge extremities. Any tree branches that overhang the structure to the detriment of its function shall be neatly removed.

When the Proposal does not contain an estimated quantity for clearing and grubbing, any clearing and grubbing required for construction of the structure shall be considered to be Extra Work and paid for accordingly.

Any necessary preliminary embankment construction shall be performed in accordance with 2105 and will be paid for as provided therein.

A2 Elevations and Dimensions

The elevations shown in the Plans for the bottom of footings for bridges shall be considered as approximate only and the Engineer may order, in writing, such changes in elevations and dimensions of footings as may be necessary to secure a satisfactory footing.

The location and orientation of all box culverts and pipe structures, as shown in the Plans, shall be considered as approximate only. The Engineer will make whatever adjustments necessary to provide the most satisfactory placement.

A3 Temporary Construction

The Contractor shall provide temporary construction necessary to properly prosecute the work without unnecessary hazard or disruption, at no expense to the Department. Proper and adequate sheeting, shoring, bulkheads, dikes, channels, drainage pipes, sluiceways, cofferdams, warning signs and fencing shall be provided as may be necessary.

When specified in the Contract, the Contractor shall obtain the Engineer's approval of detailed construction Plans and methods prior to their execution.

A3a Cofferdams

Cofferdams shall be sufficient in size and construction to allow safe and adequate construction work to be performed therein, and to permit pumping and waterways outside of the forms. Provisions shall be made that will allow for lowering the foundation elevation to 1 m (**3 feet**) below that shown in the Plans.

No cofferdam bracing shall bear against the concrete forms or the structure. Steel bracing may extend through the poured concrete, if located below the final ground elevation. Boxing out of braces or struts will not be permitted except upon written approval of the Engineer.

Cofferdams located within roadbed embankments shall, when no longer needed, be removed to an elevation at least 1.2 m (**4 feet**) below the subgrade elevation. Those located in a stream or lake and within the limits of low water shall be removed to the elevation of the stream or lakebed except that, in established navigation channels, they shall be removed to an elevation at least 0.6 m (**2 feet**) below the established bottom of the channel. Those located outside the above defined limits shall be removed to an elevation at least 0.6 m (**2 feet**) below grade.

A3b Concrete Foundation Seal

When not indicated in the Plans, the Contractor may, at no expense to the Department and with the Engineer's prior approval, install a concrete seal within a cofferdam. A written notice shall be delivered to the Engineer that indicates the planned seal thickness, sources of materials, and other pertinent facts. If the Engineer approves the use of the proposed seal, the Engineer will also furnish the Contractor with a mix design for the concrete to be used.

The seal shall be entirely below the planned foundation elevation. Excavation below the planned foundation elevation will be incidental to the seal construction. The seal placement shall be in accordance with 2401.3C insofar as it applies.

A3c Pumping

Pumping from within any foundation enclosure shall be conducted in a manner that will preserve the foundation materials intact and not draw water through or over the fresh concrete. Pumping will be permitted during concrete placement, or within 24 hours thereafter, only

if done from a suitable sump that is separated from the work by a watertight wall or other effective means of preserving the foundation.

Pumping to dewater a cofferdam sealed with concrete shall not be started until the seal has cured for a minimum period of:

(1) Three days when the temperature of the water within the cofferdam has been maintained at or above 20ºC (**70ºF**);

(2) Four days when the temperature of water has been maintained between 7ºC (**45ºF**) and 20ºC (**70ºF**); or

(3) Five days when the temperature of the water within the cofferdam has been 7ºC (**45ºF**) or below during the curing period.

A4 Restoration Work

Where the function and general features of the former surface at the excavation site will continue after the work is completed the Contractor shall satisfactorily restore the site to a like or better condition, for the intended function, as it was previous to the construction. Payment for necessary special materials in the restoration will be made only when the Contract specifically provides for payment under separate items.

A5 Cold Weather Protection

The Contractor shall protect foundation soils against hard freezing and related heaving actions after a bridge substructure footing has been cast or foundation pilings have been driven. Protection may be obtained by placing permanent or temporary backfill materials or by using other insulating materials acceptable to the Engineer.

When, at the time of freezing conditions, the only pile driven within the foundation area is test piling, the aforementioned foundation protection requirements will not apply. However, if there is evidence of frost heaving, the Engineer may require that the test pile be further driven at the time the remainder of the piles are installed.

B Excavating

B1 General

The Contractor shall excavate sufficiently to permit erection of all necessary forms, temporary construction, and proper compaction of the backfill materials, unless otherwise restricted in the Contract or allowed by the Engineer.

B2 Types

Classification of excavation type, as signified by the letters U, E, WE, or WR, shall be in accordance with the following designations:

U --- All materials within the excavation unclassified as to the materials encountered or the conditions of removal.

E --- All materials within the excavation except for those materials that are as described for Class R below.

R --- Ledge rock, and boulders, detached rock, or concrete pieces, each having a volume of 0.4 m^3 (**1/2 cubic yard**) or more.

W --- The upper limit of any excavation so designated will be the elevation of low water, assumed or actual, as specifically shown in the Plans for waterway bridges.

The volume of structures, to be removed from within the excavation limits as a separate removal item, will not be considered as part of the excavation.

B3 Cast-In-Place Structures

Accumulation of water within the excavation, to the detriment of the structure or the stability of the backfill, may be considered as grounds for rejection of the work.

Excavation in streams or lake beds shall generally be confined within caissons or cofferdams. Any disturbance of a stream or lake bed shall be satisfactorily repaired using materials approved by the Engineer.

Special attention should be directed to completing excavation operations within sealed cofferdams before other operations are started, particularly in those areas that are not readily accessible to the excavating equipment, such as under walers, struts and other framework members.

B3a Earth Excavations

When the Plans call for concrete to be placed on a natural soil foundation without piling, the bottom of the excavation shall be accurately shaped to the required dimensions and elevations. The foundations shall be compacted by vibratory methods, where and to the extent determined by the Engineer. Unsuitable foundation soils shall be replaced with acceptable material, firmly compacted. Materials from below the foundation area that are removed unnecessarily by the Contractor, shall be replaced at no expense to the Department.

Excavation shall be nearly completed in advance of pile driving operations for a unit. After the piles have been driven, the bottom of the excavation shall be accurately shaped to the required elevation. Any excavation below the established elevation of the foundation shall, as directed, be backfilled with sand, gravel, or concrete at no expense to the Department.

B3b Rock Excavation

Class R and WR materials encountered in the excavation shall not be removed, unless the excavation is classified as Class U, before necessary measurements or other data have been obtained for pay quantity determination purposes by the Engineer.

Where the foundation for a footing is in solid rock, the rock shall be carefully removed to the elevation shown in the Plans for the entire area bounded by vertical planes through the neat lines of the footing. If no elevation is shown in the Plans, the rock shall be removed to an elevation no higher than the established elevation for the bottom of the footing or to the elevation designated by the Engineer.

Rock shall be removed in a manner that will not impair the quality of the foundation.

B4 Prefabricated Structures

B4a Earth Excavations

Where no special foundation construction is required, the excavation shall be completed in a manner that will provide uniform support under the entire structure, permit the satisfactory placement of the structure to the staked grade and line, and allow for the proper installation of backfill materials.

When special foundation treatment is required, the excavation shall be made to the extent necessary to provide the proper foundation thickness and uniform structure support.

B4b Rock Excavations

When materials are encountered during Class E or Class WE excavation that will be removed under the classification of Class R or Class WR excavation, these materials shall be sufficiently exposed before removal so that any necessary data for determination of pay quantities may be obtained by the Engineer.

Any unyielding materials such as bedrock, boulders or concrete located within 300 mm (**1 foot**) from the sides or the bottom of the structure shall be removed and replaced with "selected materials" as defined in 2451.3D, to the extent that a satisfactory foundation may be constructed in accordance with 2451.3C.

C Foundation Preparations

The structure foundations shall be prepared according to the following provisions, except as modified by the applicable structure Specification and the Plans.

The Contractor shall, at no expense to the Department, provide temporary construction, pumping or other means to the extent necessary to permit structure construction in a dry excavation.

C1 Cast-In-Place Structures

All rock foundations shall be cleaned of all disintegrated and loose material or thin strata rock, after which all seams shall be cleaned out and filled with concrete, cement mortar or grout as directed. Unless otherwise provided in the Contract, the cleaning and filling of seams in rock foundations will be paid for as Extra Work.

Where the character of the natural foundation soil is unsuitable, additional excavation may be ordered below the planned footing elevation as the Engineer considers necessary to provide a satisfactory foundation. Limits of the excavation and the placement of special backfill shall be as the Engineer directs.

C2 Prefabricated Structures

Where a structure has its foundation in new embankment, the embankment shall first be constructed to an elevation 300 mm (**1 foot**) above the low point of the structure in accordance with the applicable

provisions of 2105. Natural topsoil beneath the structure site shall be removed when the height of embankment to the bottom of the structure is 1 m (**3 feet**) or less.

Unsuitable foundation materials, when encountered at or below the foundation elevation, shall be removed and suitable replacement materials shall be installed as directed. The subfoundation excavation shall have near vertical sides and a bottom width equal to the structure width plus twice the depth of excavation. Unless otherwise provided, the replacement material shall conform to "selected material" as defined in 2451.3D, and shall be installed in 150 mm (**6 inch**) layers, each compacted to uniform density.

Before the structure is installed, the foundation shall be shaped to closely fit the bottom of the structure and provide uniform support. For lines of pipe the foundation shall be prepared according to the following requirements for Class C bedding, unless otherwise indicated in the Plans or Specifications.

Class C bedding shall consist of shaping the foundation material to closely fit the lower part of the pipe to a depth of: (a) at least 15 percent of the outside diameter for circular pipes; and (b) at least 50 percent of the height at the point of maximum span above the bottom of the arch for pipe-arch structures.

Class B bedding where specifically called for in the Plans, shall consist of bedding the culvert on a minimum 150 mm (**6 inch**) thickness of granular bedding material shaped by means of a template to accurately fit the lower part of the pipe exterior to at least 60 percent of the pipe width for round pipe and at least 80 percent for pipe-arches. After excavating the trench to an elevation that is approximately 15 percent of the outside diameter or rise of the pipe above the established grade for the bottom of the pipe, the foundation for the bedding shall be prepared by carefully excavating to the required depth and shape of the bedding.

All granular materials used for Class B bedding and foundation backfill at pipe installations shall be compacted as required for embankment materials under 2105 with the exception that, within the 150 mm (**6 inch**) layer immediately below and parallel to the bottom surface of the pipe, consolidation need only be sufficient to produce uniform pipe support. Compaction and any subsequent scarification of the bedding layer shall be such that only a layer of uniform and minimal thickness will remain uncompacted to facilitate template shaping.

D Backfilling Excavations

Excavations for structure construction shall be backfilled to the required extent and at the appropriate time. Suitable backfill materials shall be uniformly distributed in layers 200 mm (**8 inches**) or less in thickness (loose measurement) and thoroughly compacted to the required density before successive layers are placed.

Compaction of the backfill shall be in accordance with 2105 when Specified Density is required by the Plans for adjacent and overlying embankment construction. In all other cases, compaction of each layer shall continue until the density of the backfill and the adjacent material at the same elevation is considered by the Engineer to be acceptably equivalent.

Where special backfill materials are not specified, the backfill material within 450 mm (**18 inches**) of the sides and 300 mm **(12 inches**) above the top of the structure shall be "selected material" and the remainder of the backfill shall be acceptable embankment material as provided under 2105; or when outside the roadbed construction, any suitable material found in the excavation.

"Selected material" shall be an acceptable mineral soil that is free of clods, stones over 75 mm (**3 inches**) in greatest dimension, sod, and roots.

Backfill material shall not be placed on a foundation that is frozen deeper than 75 mm (**3 inches**), or when the material will freeze during the placement or compaction work.

Sides of the excavation that are steeper than 1 vertical to 4 horizontal shall be stepped in every case where potential wedging action of the backfill is considered detrimental to the structure; except that the Contractor, at no expense to the Department, may enlarge an excavation and flatten the side slopes for backfill and compaction reasons when no specific maximum dimensions are required of the excavation.

To the extent that it will apply, backfilling shall progress uniformly in horizontal layers throughout the excavation area to be filled. Removal of any shoring or bracing from within the excavation shall proceed in a manner that will maintain the sides of the excavation intact and prevent voids in the backfilling.

E Surplus Materials

The Contractor shall dispose of excavated materials not needed for backfilling excavations at no expense to the Department and in accordance with 2105.3D.

2451.4 METHOD OF MEASUREMENT

The Department will determine quantities of excavation and embankment according to 1901, except as modified by these provisions. The Contractor shall provide sufficient time for the Engineer to determine quantities.

A Structure Excavation

The Engineer will not adjust (P) designated quantities except as provided for in 1901 or when certain excavation materials have been reclassified.

When the Contractor disputes an excavation quantity and the Engineer agrees to consider the dispute, the Engineer will recomputed the

excavation quantity for the entire structure. However, if the excavation has been completed prior to a change ordered by the Engineer no deduction will be made for any resulting decrease in volume, nor will any addition be made for any increase in volume when no enlargement of the excavation is required.

For bridge excavations, any additional quantities disclosed in the recomputation will be considered separate from the quantities in the bid schedule.

When rock is encountered in the excavation, the volume of excavation under each classification will be recomputed using measurements of the rock quantity obtained when the rock is exposed. An increase or decrease in the volume of rock will result in a proportional decrease or increase in the other excavation classes to provide the total excavation quantity.

No adjustments will be made in the low water elevations shown in the Plan nor for safety concerns, working clearances, or stability of soils, regardless of existing conditions.

The Department will calculate structure excavation in accordance with the following except as modified for the type of structure, or as specified elsewhere in the Contract. The volume of structure excavation will be contained within the following limits:

(1) Vertical planes that encompass the structure, located 450 mm (**1-1/2 feet**) beyond the outermost limits of the structure or its projections within the excavation.

(2) A top elevation that is either the natural ground surface or the designated elevation, in embankment or excavation, from which the structure excavation will begin.

(3) The bottom of the structure and its projections.

When an old structure is removed as a separate Contract item from within the excavation limits of the new structure, structural excavation will be reduced by a quantity equal to the space taken by the old structure.

Excavation quantities will not include material removed by the Contractor to expedite the work when that material is planned for removal by others or as a different Contract item.

A1 Cast-In-Place Structures

In ledge rock, the horizontal limits of excavations for footings will be the Plan footing limits.

Excavation for timber pile abutments and timber bents will be measured to the limits shown in the Plan. If no limits are indicated, the excavation will be incidental to the construction.

A2 Prefabricated Structures

Where foundation construction is required to a greater surface dimension than that provided above, the excavation will be measured using the greater dimension.

A2a Induced Trench

Where the induced trench method (2501.3E) of structure installation is required, the additional excavation required to accommodate the loose backfill over the structure will be measured as the volume:

(1) Within the planned grading section,

(2) Between vertical planes separated by a distance equal to the outside width of the structure, and

(3) A depth equal to the outside height of the structure.

B Granular Materials

The Engineer will measure granular materials for special backfill, bedding, or filter purposes by volume in accordance with 1901 and as specified in the Contract:

(1) Loose volume (LV), or

(2) Compacted volume (CV).

2451.5 BASIS OF PAYMENT

Except as specifically modified, the payment at the Contract unit price for the classes of structure excavation listed in the Proposal will be considered as compensation in full for all costs incurred in performing the required structure excavation and preparing the foundation for the subsequent construction.

When the Contract does not provide a unit price for Class R and Class WR excavation and the materials in this category are encountered during Class E or Class WE excavation, payment will be made separately for this work at a unit price determined as follows:

(a) Class R at 5 times the unit price of Class E.

(b) Class WR at 3 times the unit price of Class WE.

The unit bid prices for excavation for cast-in-place structures will be subject to adjustment as follows:

(a) Additional required excavation depth. The unit price will be increased 25 percent for additional excavation to 1 m (**3 feet**) below the planned excavation. When excavation is required to a depth greater than 1 m (**3 feet**) below the planned elevation, this portion of the additional excavation will be measured separately and will be paid for as Extra Work unless the unit price increased by 25 percent, or a lower price, is mutually acceptable to both the Contractor and the Engineer.

(b) Changed structure dimensions. When additional excavation is required because of changes in the dimensions, and the Contractor objects to payment therefore at the Contract prices, the additional excavation will be measured and paid for as Extra Work.

(c) Disputes of the Plan quantities. Any additional structure excavation disclosed for a bridge structure, when the quantities are recomputed at the Contractor's request, will be paid for separately at 50 percent of the Contract bid price per unit of measure.

Payment on the basis described above will be construed to include compensation in full for the work of making all removals and disposals necessary to the excavation; providing all necessary safeguards for the maintenance of drainage and proper prosecution of the work; and making whatever restoration or improvement that is required over, around, or because of the structure; all that is not otherwise paid for under separate Contract items.

Payment for granular material items at the appropriate Contract prices therefore will be compensation in full for all costs of furnishing the materials, placing and compacting the materials as specified, including the excavation required therefore in cases where Structure Excavation is not paid for as separate items.

Granular materials used for bedding, backfill, or filter purposes as required by the Plans, these Specifications, or by order of the Engineer, will be paid for as Extra Work in the absence of an appropriate pay item therefore.

Structure excavation will be paid for as a separate item only when so provided for in the detailed Specification for the type of structure involved, and then payment will generally be made under the items provided therein.

Payment for work performed under this Specification will be made in accordance with the following schedule:

Item No.	Item	Unit
2451.501	Structure Excavation, Class ___.	cubic meter **(cubic yard)**
2451.503	Granular Backfill	cubic meter **(cubic yard)**
2451.505	Aggregate Backfill	cubic meter **(cubic yard)**
2451.507	Granular Bedding	cubic meter **(cubic yard)**
2451.509	Aggregate Bedding	cubic meter **(cubic yard)**
2451.511	Coarse Filter Aggregate	cubic meter **(cubic yard)**
2451.513	Fine Filter Aggregate	cubic meter **(cubic yard)**

NOTE: For all granular material items, specify the basis of measure (LV or CV) after the item name. See 2451.4B.

2452
Piling

2452.1 DESCRIPTION

This work shall consist of the furnishing and driving of piling for the purposes indicated in the Contract.

2452.2 MATERIALS

A Timber Piling 3471

B Preservative Treatment 3491

C Steel H-Piles 3372

D Cast-in-place Concrete Piles

D1 Steel Pile Shells 3371

D2 Concrete, Mix No. 1C62 2461

E Reinforcement Bars 3301

2452.3 CONSTRUCTION REQUIREMENTS

A Delivery and Inspection of Piling

When test piles are specified in the Contract, the number of piles and lengths shown in the Plans are subject to change. The Engineer may designate that piles authorized for one unit of a structure be driven in another unit of the same structure or any unit of an adjacent structure constructed under the same Contract. When test piles are not specified in the Contract, the number and lengths of piles to be delivered will be shown in the Contract.

Prior to delivery, the Contractor shall establish the quality of the material in steel H-piles and in steel shells for cast-in-place concrete piles. The Contractor shall submit to the Engineer the Mill Test Reports and Mill Shipping Papers as specified in 3371 and 3372. In addition, the Contractor shall deliver check test coupons to the Materials Laboratory when so requested by the Engineer.

The Contractor shall have a sufficient number of coupons tested at a laboratory for metallurgical testing accredited by the American Association for Laboratory Accreditation when mill test reports are not available. The Contractor shall furnish to the Engineer three certified copies of the test reports indicating that the material is in compliance with 3371 or 3372, whichever is applicable. All required test samples shall be cut by the Contractor from the actual material to be used, as directed by the Engineer, and they shall be furnished in such numbers as the Engineer determines necessary.

Piling shall not be driven until the material has been accepted on the basis of either mill test reports or laboratory testing of samples. All piling will be given a visual inspection at the site before driving, to ascertain the quality of welding done in manufacture or splicing, and to

determine that the pile lengths contain no physical defects such as kinks or buckles that would cause the pile to fail in driving or not perform as intended.

B Handling, Transportation and Storage

Piling shall be handled, transported, and stored by methods that will not be detrimental to any portion of the piles that will remain in the completed structure.

C Equipment for Driving

C1 Requirements for Pile Hammers

In addition to conformance with the minimum ram mass and energy requirements shown in Table 2452-1, the pile hammer selected for a particular job shall be one that will yield a computed bearing at least equal to that which is defined as substantial refusal under 2452.3E1, as determined in 2452.3E2, at a penetration rate of not less than 3.8 mm (**0.15 inches**) per blow for gravity hammers and not less than 1.3 mm (**0.05 inches**) per blow for power-driven hammers.

The mass of the driving cap shall be included with the pile mass when it receives the hammer blow, but it should not be included when the ram delivers the blow directly to the pile.

When requested by the Engineer, the Contractor shall furnish the necessary statistical information concerning the pile hammer to be used. The same pile hammer, or a similar hammer, shall be used for driving the test piles as will be used for driving the piles authorized as a result of the test pile driving, except as may otherwise be indicated by driving conditions or substantial differences in pile sizes.

TABLE 2452-1
MINIMUM REQUIREMENTS
FOR
PILE HAMMERS

Pile Type	Hammer Type		
	Gravity Hammers	Power Driven Hammers	
Timber & Steel H-Pile	**Mass kg (lbs)**	**Required Ram Mass kg (lbs)**	**Energy J (ft - lbs)**
Less than 15.24 m (**50 feet**) long	1090 (**2,400**)	680 (**1,500**)	9490 (**7,000**)
15.24 m (**50 feet**) or longer	1360 (**3,000**)	815 (**1,800**)	16 950 (**12,500**)
Steel Shells for Cast-In-Place Pile	---	815 (**1,800**)	16 950 (**12,500**)

Gravity hammers shall not be used for driving cast-in-place concrete pile shells except when specifically permitted by the Special Provisions.

C2 Pile Driving Caps

When necessary to protect the pile against damage during driving, the top of the pile shall be equipped with a driving cap of a size and type that will serve the purpose. A shock block of approved type and size shall also be used on the upper side of the driving cap, when necessary. Generally, the recommendations of the pile hammer manufacturer shall be followed with respect to driving caps and shock blocks.

C3 Pile Driver Leads

Pile driver leads shall be of a type that will hold the pile and the pile hammer in proper alignment during driving operations, and shall be long enough to preclude the necessity for the use of punches or chasers. Leads for drop hammers shall be steel or steel shod. Generally, the recommendations of the pile hammer manufacturer shall be followed with respect to pile driver leads.

C4 Water Jets

When water jets are used, the number of jets and the volume and pressure of water at the jet nozzles shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to deliver at all times at least 690 kPa (**100 psi**) pressure at two 19 mm (**3/4 inch**) jet nozzles.

D Pile Driving

The Contractor shall notify the Engineer at least 24 hours before beginning any pile driving operations. The Engineer will reestablish the working points for each substructure unit after the excavation has been completed for that unit, but staking the pile locations shall be the responsibility of the Contractor.

Before any foundation piles, including test piles, are driven in any unit, the excavation shall be completed to approximately the planned footing elevation. During pile driving operations, the water level in the excavation shall be kept below the top of the pile. Under-water pile driving will not be permitted unless a concrete foundation seal is required.

For each foundation pile, pile driving operations shall be as continuous as practicable unless otherwise directed by the Engineer.

In general, timber piles shall be sharpened to a minimum square point of 127 mm (**5 inches**) at the tip unless the subsoil is unusually soft or the piles will have point bearing on hard stratum. In such cases the pile shall remain blunt.

When the Contract provides for the construction of a concrete foundation seal, the piling may be driven by means of a power-driven hammer equipped to drive when submerged. The use of punches or chasers for pile driving will not be permitted. When the top of the hammer is submerged during the driving it shall be equipped with accurate detachable measuring rods for the purpose of recording pile penetration. Special care shall be given to obtain accurate location and spacing of the piling.

The pile material and all appurtenances shall be capable of withstanding driving to substantial refusal, as defined in 2452.3E1, without failure. Failure shall mean any buckling, bending, kinking, splitting, or rupture that will impair the strength of the pile, or that will reduce the effectiveness of the energy delivered by the pile hammer, as determined by the Engineer.

In the event that the piling material and appurtenances furnished for the work cannot satisfactorily withstand driving to substantial refusal, the Contractor shall discontinue pile driving until changes or corrections can be made in the pile driving operations and equipment, or until pile material with satisfactory strength is furnished. Only when failure of the pile occurs subsequent to issuance of an order by the Engineer to continue driving after substantial refusal has been obtained will the damage be considered to be the responsibility of the Department.

D1 Jetting and Preboring

Water jetting may be used, or may be required, as an aid to driving timber or other displacement type piles, when driving to satisfactory penetration might otherwise be impractical or might be detrimental to the piles. Jetting shall not be used in embankments, or other areas where

it may cause damage to the existing soils. Before the desired penetration is reached, the jets shall be withdrawn and the piles shall be driven with the hammer to secure the final penetration.

Preboring will be required for displacement type piles that are to be driven through embankments, when the depth of the embankment, measured below the bottom of the footing, is more than 2.4 m (**8 feet**). The depth to which preboring will be required shall be approximately the depth of the embankment, except that in the case of a shallow, dense crust at the surface of the original ground, preboring shall be continued through this crust when directed by the Engineer.

The Engineer may require preboring through embankments less than 2.4 m (**8 feet**) in depth when the character and density of the material is likely to cause damage to the piles during driving. The Engineer may also require preboring for displacement type piles when the character and density of the material below the bottom of a footing is of a nature that precludes driving to a penetration of approximately 3.0 m (**10 feet**) below the bottom of the footing without causing damage to the piles. A penetration of less than 0.75 mm (**0.03 inch**) per blow for each 1356 J (**1000 foot pounds**) of rated energy will be considered, for this purpose, as an indication of probable damage, due consideration being given to the mass of the ram and to the type and size of the piles.

The diameter of the prebored holes shall be sufficiently large to admit the largest section of the pile without creating friction between the faces of the pile and the prebored hole.

Sawing or cutting the body of a pile to assist in springing it to proper location will not be permitted. If a pile vibrates excessively, or shows signs of buckling during driving, it shall be braced or guyed as directed by the Engineer.

D2 Test Piles

Test piles shall be furnished as required by the Contract, and shall be driven at the locations shown in the Plans except when otherwise permitted or directed by the Engineer.

Except when otherwise permitted by the Engineer, test piles shall be full length when placed in the leads, and driving shall be as continuous as practicable. When the Engineer determines, from information shown on the survey sheet or from previous pile driving in the area, that test piles can be driven in sections without the danger of "freeze-up" during the period required for splicing, sectional driving will be permitted.

The Contractor shall cooperate with and assist the Engineer in obtaining data for bearing for the full length of the driving. When driving in soft or plastic soils, the Engineer may require the redriving of test piles. In such cases, the driving will be stopped at a point when the top of the pile is from 0.6 to 1.5 m (**2 to 5 feet**) above cut-off and resumed after a minimum delay of 24 hours.

In the event the Engineer determines that steel test piles or steel shells for cast-in-place test piles of specified length have not developed adequate bearing capacity, the Engineer may order additional lengths spliced thereon.

D3 Pile Load Tests

D3a General

Pile load tests, when required by the Contract, shall be made at the indicated locations or as directed by the Engineer. Concrete for cast-in-place concrete piles shall have been cast at least 7 days prior to starting the load test; this requirement may be reduced to 5 days when high-early strength concrete is used. Unless piles are driven to end bearing on rock or other similar hard strata, load testing shall not start until at least 5 days have elapsed since driving.

Pile load tests shall be accomplished by means that will provide accurate information and not be detrimental to the work or hazardous to the workers or inspectors. The Contractor shall submit details of the method and equipment proposed for use for the load test to the Engineer at least 10 days in advance of the scheduled test.

Pile load tests shall be completed and sufficient time allowed for analysis before proceeding with any further pile driving upon which the results of the load test may have an influence. Piles that are to be used as reaction piles, if driven at proper locations, may later be included as foundation piles. Reaction piles shall not be driven within 2.1 m (**7 feet**) of the pile to be load tested unless authorized by the Engineer. Final determination regarding the use of permanent piles as reaction piles will be subject to approval of the Engineer, and redriving of these piles may be required if there is evidence that uplift has occurred.

When a hydraulic jack is used as a means of applying load on the pile in specified increments, it shall be equipped with a pressure gauge. The jack and the gauge shall be calibrated as a unit to the satisfaction of the Engineer. The jack shall be capable of maintaining specified loads within a tolerance of plus or minus 5 percent for loads up to 45 metric tons (**50 tons**) and 3 percent for loads in excess of 45 metric tons (**50 tons**). A certified calibration chart shall be available to the Engineer for each jack and gauge combination to be used.

Ames dials for measurement of settlement will be furnished, placed and read by the Engineer, but the Contractor shall provide and install posts and cross frames as required for proper support of these dials.

The support system for the Ames dials shall be independent of the other loading apparatus and shall have the support beams perpendicular to the reaction beam.

The Contractor shall provide a suitable temporary shelter at the location of each load test to protect the workmen, inspectors, and equipment during the time the load test is being conducted. Heat and lights shall be provided if deemed necessary by the Engineer.

D3b Pile Load Tests, Type 1

Test loads shall be applied in increments up to a total of not less than 200 percent of the minimum pile bearing required by the Plans for the unit in which the load test is required, unless failure results at a lesser load. Failure, for this purpose, shall be considered to have occurred when the total settlement of the pile being load tested is in excess of 50 mm (**2 inches**). The load increments, defined as a percent of the total load, shall be applied as shown in the following tabulation, and shall be held for the indicated time after all measurable settlement has ceased.

Reading to determine cessation of measurable settlement will be taken every 15 minutes, and measurable settlement shall be considered as having ceased when the average of two or more dials indicates a settlement of less than 250 µm (**0.01 inch**) during a 15 minute period. Readings thereafter will be taken at 1-hour intervals, until the required time has elapsed for that increment, except when the Engineer determines that readings should be taken at closer intervals.

The load test increments shall be removed in reverse order from that in which they were applied, except that the time interval to be held for each increment will be limited to one 15 minute period. The final reading will be taken 2 hours after all load has been removed.

TABLE 2452-2
PILE LOAD TEST
LOAD INCREMENTS

Percent of Total Load	Holding Time After Measurable Settlement
40	1 hour
50	2 hours
60	3 hours
70	4 hours
80	5 hours
90	6 hours
100	12 hours

D3c Pile Load Tests, Type 2

The total load to be applied for each Type 2 pile load test shall be 400 percent of the minimum pile bearing required by the Plans for the unit in which the load test is required, unless failure results at a lesser load. Failure is considered to have occurred whenever continuous pumping of the hydraulic jack is required to maintain load or when the settlement becomes disproportionate to the load being applied.

In addition to satisfying the requirements for hydraulic jacks in 2452.3D3a, the device for increasing jacking load shall be located in the immediate vicinity of the load test such that the person reading the pile deflection gauges and the person applying the jacking pressure can readily communicate necessary information. The jack shall have a minimum ram travel of 150 mm (**6 inches**).

The load shall be applied in increments of 4.5 metric tons (**5 tons**) at 2.5 minute intervals. Once failure has occurred or the required load has been reached, all load shall be quickly and smoothly removed.

D4 Foundation Piles

Piles shall be guided during driving so as to terminate with the indicated batter, or plumbness, within a tolerance of 40 mm per meter (**1/2 inch per foot**), and so that the pile will be properly positioned within the footing area. Improperly positioned piles may be rejected, or payment reduced, when the Engineer determines that their function is impaired.

When there is evidence or probability that some piles in a unit have heaved while driving subsequent piles, the Engineer may require that these piles be redriven, and the pile driving will not be considered to be complete until these piles have been redriven.

D5 Trestle Piles

Trestle piling refers to any types of piles that are driven in single rows and that are capped with timber, steel or concrete caps, requiring that the piles be driven to closer tolerances than those generally associated with pile driving.

Piles shall be guided during driving so as to terminate with the indicated batter, or plumbness, within a tolerance of 20 mm per meter (**1/4 inch per foot**), and so that the pile will be properly positioned in the bent. Improperly positioned piles may be rejected, or payment reduced, when the Engineer determines that their function is impaired. Timber trestle piles shall be so selected that all piles in a bent will be of reasonably uniform diameter.

D6 Cast-in-Place Concrete Piles

The bottom of each pile shell shall be equipped with a driving shoe that shall be made watertight by welding and that shall not extend more than 6 mm (**1/4 inch**) outside the periphery of the shell.

Each pile shall be inspected jointly by the Contractor and the inspector as soon as practicable after driving, for depth to the driving shoe and for condition of the shell. Any observable impairment or damage shall be called to the attention of the Engineer who will determine the acceptability of the pile, taking into consideration the bearing requirements and driving conditions. Suitable light shall be provided by the Contractor for the inspection.

Reinforcement bars will not be required unless indicated in the Plans.

Vibration of the concrete will be required only when reinforcement cages are used within the shells, and then only for that portion of the pile containing the reinforcement cages.

Pile driving and other operations that may be detrimental to concrete during setting shall not be conducted so near to the concrete-filled piles as to cause noticeable vibrations thereat until the concrete has been in place for at least 3 days.

Concrete for footings and caps shall not be placed until the day following concrete placement for the piles.

Concrete in the piles shall be protected against freezing temperatures for not less than 3 days after placement. Concrete in that portion of the pile that is above a location 3 m (**10 feet**) below the groundline or waterline shall have 30 percent additional cement if the concrete is placed during freezing weather.

E Penetration and Bearing

E1 General

The pile bearing requirements shown in the Plans are based on design loadings and indicate the loads that the piles may be required to support. The pile bearings computed using the dynamic formulas defined under Determination of Bearing Capacity are approximations only, and driving shall continue beyond these bearings until the required penetration is reached, or until the pile has been driven to substantial refusal or to a penetration and bearing satisfactory to the Engineer.

The following definition for "substantial refusal" is provided as a guide, and is based on normal conditions, normal pile lengths and sizes, and for pile hammers with a ram mass not less than the mass of the pile plus the driving cap. The Engineer will make such modifications as necessary to compensate for conditions less favorable than those defined above.

Except for conditions less favorable than those defined above, substantial refusal for drop hammers will be considered to have been attained when the penetration per blow produces a computed bearing that is not less than 130 percent of the design load; and for power driven hammers substantial refusal will be considered as 160 percent of the design load. Bearing computations are based on formulas and

conditions specified under Determination of Bearing Capacity. Design loads are those shown in the Plans after reduction factors have been applied.

E2 Determination of Bearing Capacity

The bearing capacity of piles will be determined by dynamic formulas, as follows:

All types of piles driven with gravity hammers.

$$P(metric) = \frac{2.5WH}{S + 13} \; x \; \frac{W + 0.1\ M}{W + M} \qquad P(english) = \frac{3WH}{S + 0.5} \; x \; \frac{W + 0.1\ M}{W + M}$$

Timber, concrete, and shell type piles driven with power-driven hammers.

$$P(metric) = \frac{289E}{S + 5} \; x \; \frac{W + 0.1\ M}{W + M} \qquad P(english) = \frac{3.5E}{S + 0.2} \; x \; \frac{W + 0.1\ M}{W + M}$$

Steel H-piling driven with power-driven hammers.

$$P(metric) = \frac{289E}{S + 5} \; x \; \frac{W + 0.2\ M}{W + M} \qquad P(english) = \frac{3.5E}{S + 0.2} \; x \; \frac{W + 0.2\ M}{W + M}$$

WHERE:

P = Safe bearing capacity in Newtons (**pounds**).

W = Mass of the striking part of the hammer in kilograms (**pounds**).

H = Height of fall in millimeters **(feet**).

S = Average penetration in millimeters (**inches**) per blow for the last 5 blows for gravity (drop) hammers and for the last 10 or 20 blows for power-driven hammers, except in cases where the pile may be damaged by this number of blows.

M = Total mass of pile plus mass of the driving cap in kilograms (pounds).

*The following definition is for Metric units, see English units below:

E = WH x 0.00981 for single acting power-driven hammers. It is equal to the joules or newton-meters (joules = newton-meter) of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.

*The following definition is for English units:

E = WH for single acting power-driven hammers. It is equal to the foot pounds of energy per blow for each full stroke of either single acting or double acting hammers as given by the manufacturer's rating for the speed at which the hammer operates.

NOTES:

When provisions are not made available for field determination of the energy output on a power-driven hammer, such as measurement of the drop for single-acting hammers, or such as pressure gauges or determination of energy on the basis of the frequency of the blows (cycles per minute) for double-acting hammers, computed bearings based on dynamic formulas shall be reduced by 25 percent. This reduction is not intended to apply when determining the required hammer size. Double-acting hammers, for the purpose of these requirements, will include all hammers for which a power source is utilized for acceleration of the down-stroke of the ram. The dynamic formulas specified herein-before are applicable only when:

(a) The gravity hammer has a free fall.

(b) The height of the fall of a gravity hammer will produce an energy blow between 37 950 and 48 800 J (**28,000 and 36,000 foot pounds**).

(c) The head of the pile is free from broomed or crushed fibre.

(d) The penetration of the pile is at a reasonably uniform rate.

(e) There is no noticeable bounce after the blow. When there is a noticeable bounce, twice its height shall be deducted from H to determine the value of H in the formula.

F Pile Cutoff

F1 Piles

Timber piles shall be cut off in the manner and at the elevation shown in the Plans, within a tolerance of plus 13 mm (**1/2 inch**) and minus 25 mm (**1 inch**). The head of the pile, after cut-off has been made, shall be sound, undamaged wood.

Steel piles shall be cut off by an approved method at the established elevation, except that when they are driven approximately to cut-off elevation without damage to the pile head, a tolerance of 25 mm (**1 inch**) above or below cut-off elevation will be permitted.

F2 Pile Bents

After the pile bent has been aligned and securely braced, the tops of timber piles shall be accurately cut off at the established elevation, so as to provide uniform bearing for the cap without the use of shims or fills.

Steel piles shall be cut off by an approved method at the established elevation when the type of construction is such as to require accurate framing of the members.

F3 Field Treatment of Tops of Timber Piles

After being cut off, the tops of all treated piles shall be treated with three coats of copper naphthenate or another compatible preservative

conforming to AWPA Standard M4, with a minimum time lapse of 2 hours between applications.

G Disposal of Pile Cut-offs

The Engineer shall have the right to require that pile cut-offs belonging to the Department be used in substructure units for which piling lengths have not been authorized for the same structure or for adjacent structures under the same Contract.

In the event that the Engineer directs the Contractor to make up a steel shell pile entirely from Department-owned cut-offs, furnishing and attaching the end plate will be considered to be equivalent to making an additional splice and the payment will be made accordingly.

All remaining steel H-pile and steel shell pile cut-offs, together with any timber cut-offs designated by the Engineer for salvage, shall be stockpiled by the Contractor on skids at a location convenient for truck loading. Cut-offs not designated for salvage shall be disposed of by the Contractor in a manner satisfactory to the Engineer.

H Extensions and Splices

Splices for steel H-piles and steel shell piles shall be made in accordance with the details shown in the Plans, except that splices for cold rolled fluted steel shells shall be made as recommended by the manufacturer, subject to approval of the Engineer.

Welding shall be governed by 2471.3F, and the welders shall have been qualified as prescribed therein.

Splices made on piles that are to be driven in pile bents, shall be made at points that will not be exposed to view, unless otherwise specifically directed or authorized by the Engineer, in which case they shall be finished to present a neat appearance.

Commercial drive-fit splices may be permitted on a performance basis, subject to approval of the Engineer. However, such splices shall not be used in pile bent-type piers or abutments, where foundation soils are soft or unstable, in foundations where uplift is anticipated, or within 3 m (**10 feet**) of the pile cut-off .

I Blank

J Painting Steel H-Piles and Steel Pile Shells

The paint and painting shall be in accordance with 2478.

Steel H-piles and steel pile shells that will extend above ground surface or water surface shall be protected by epoxy zinc-rich primer on the outside of the piles for the entire length, except for those sections below splices that will be at least 600 mm (**2 feet**) below the final ground surface or low water elevation. Primer shall be applied at least 2 days before the piles are driven, and preferably before shipment.

After driving, the piles shall be painted with intermediate and finish coats on those exposed portions that are above the level of the water, as

it exists at the time the paint is applied, or above an elevation 150 mm (**6 inches**) below the final ground surface. The color of the finish coat shall match Federal Standard 595 B No. 37200 (lusterless aluminum) where the superstructure is concrete and the topcoat color when the superstructure is painted steel. When superstructure is unpainted 3309 steel or timber, finish coat shall match 595 B No. 10075 (brown) but have a semi gloss finish.

2452.4 METHOD OF MEASUREMENT

A Test Piles

When the Proposal contains specific Contract items for test piles, measurement will be by the number of test piles furnished in accordance with the Contract and driven as directed by the Engineer. Test piles will not be eliminated from the Contract, unless all piles for the unit in which they are to be driven are eliminated, or unless mutually agreed upon by the Contractor and the Engineer. When test piles are not a separate item, measurement will be made as piling delivered and piling driven.

In the event the Engineer determines that steel H-test piles or steel shells for cast-in-place concrete test piles, furnished in accordance with the lengths specified in the Contract, do not develop sufficient bearing capacity or do not provide adequate information for ordering foundation piles, the Engineer may order that extensions be spliced onto these test piles, or that longer piles be delivered in their place. Additional quantities of piling so ordered and driven will be measured and paid for under 2452.4B, 2452.4C, 2452.5B and 2452.5C.

B Piling Delivered

Piling delivered will be measured, as indicated in the Proposal, for acceptable piling delivered at the site of the work, and furnished in accordance with the lengths and sizes specified in the Contract when test piles are not required, or the lengths authorized by the Engineer when test piles are required.

C Piling Driven

Piling driven will be measured by the length of acceptable piling below cut-off.

D Pile Load Tests

Pile load tests will be measured by the number of piles load tested in accordance with the Contract and as directed by the Engineer.

E Reinforcement Bars

Reinforcement bars used in cast-in-place concrete piles will be measured by mass, in accordance with 2472.

2452.5 BASIS OF PAYMENT

The fixed costs of all piling delivered and all piling driven are included in the compensation for the test piles when test piles are a separate item in the Contract. When test piles are not a separate item in

the Contract and when no other provisions are made for fixed costs, fixed costs are included in the compensation for mobilization.

A Test Piles

Payment for test piles of each kind and length, as a separate item at the Contract price per pile, will be compensation in full for all costs of furnishing and driving the piles in accordance with the requirements of the Contract, including the costs of furnishing and placing driving caps and concrete for cast-in-place concrete piles and painting steel H-piles and steel shell piles.

B Piling Delivered

Payment for piling delivered at the Contract price per unit of measure for each kind will be compensation in full for all costs of furnishing the piling in the required lengths at the job site, in accordance with the requirements of the Contract and as authorized by the Engineer, except as otherwise provided for hereinafter.

Steel H-piles and steel shells for cast-in-place concrete piles delivered to the job site in stock lengths, prior to authorization of final lengths based on test pile driving, shall be entirely the Contractor's responsibility. Partial payments may include the actual cost of piles so delivered, but payment at the Contract bid prices for piling delivered will be made only for piles that have been furnished by authorization of the Engineer. Final payment for piling delivered will only be for authorized lengths, and any remaining unauthorized piles delivered shall be the property of the Contractor and shall be removed from the Project by the Contractor.

Piles, or portions of piles, that become damaged during handling will not be eligible for payment. Piles that become damaged during driving, so as to cause their rejection as structural members, may be eligible for payment if the Engineer determines that the damage was not due to the Contractor's carelessness or negligence. Piles rejected due to the use of an excessively heavy hammer will not be eligible for payment.

Splicing of steel H-piles and steel shell piles will be eligible for extra compensation when the splice is actually made and:

(a) Changes were ordered by the Engineer after the piles have been cut to lengths previously authorized;

(b) Lengths longer than the length of the longest test pile shown in the Plan were authorized by the Engineer for a particular unit, and then only for any extra splices required;

(c) The Engineer ordered cut-offs, belonging to the Department, to be spliced together or onto other sections, except when this is done solely for the Contractor's convenience.

Unless otherwise provided for in the Contract, each splice eligible for payment under conditions enumerated above will be paid for at the rate of two (six) times the Contract unit bid price for piling delivered.

C Piling Driven

Payment for piling driven at the Contract price per unit of measure for each kind will be compensation in full for all costs of preparing the piles for driving, preboring, jetting, furnishing and placing the driving shoes and concrete for cast-in-place piles, cutting and trimming, and painting steel H-piles and steel shell piles.

In the event foundation conditions are found to exist at the site of a structure, or a portion thereof, that are quite different from those upon which the foundation design was based, resulting in changes in foundation design or resulting in requirements for foundation pile lengths substantially different from those upon which the unit bid prices were established, the Engineer will, upon presentation of documentary evidence by the Contractor, enter into a Supplemental Agreement to reimburse the Contractor for any additional pile driving expense incurred as a result of those changes.

Payment for driving pile cut-offs from previously driven piles in the same Contract, which are the property of the Department, will be made at the following percentages of the Contract bid prices for piling driven:

(1) Timber and Steel H-Piles 150%

(2) Cast-in-Place Concrete Piles 200%

Payment for driving pile cut-offs in accordance with the above provisions will include all costs incidental thereto, except making the required splices, the costs of which will be compensated for under the item for piling delivered.

D Pile Load Tests

Payment for pile load tests at the Contract price per pile tested will be compensation in full for all costs of the labor, material and equipment required to complete the test as specified, including the costs of furnishing and driving any reaction piles at locations that preclude their use in the structure as foundation piles.

E Pay Items

Payment for piling will be made on the basis of the following schedule:

Item No.	Item	Unit
2452.501	Untreated Timber Piling Delivered	meter (**linear foot**)
2452.502	Untreated Timber Piling Driven	meter (**linear foot**)
2452.503	Treated Timber Piling Delivered	meter (**linear foot**)
2452.504	Treated Timber Piling Driven	meter (**linear foot**)
2452.507	Cast-in-Place Concrete Piling Delivered	meter (**linear foot**)
2452.508	Cast-in-Place Concrete Piling Driven	meter (**linear foot**)
2452.510	Steel H-Piling Driven	meter (**linear foot**)
2452.511	Steel H-Piling Delivered	meter (**linear foot**)
2452.516	Untreated Timber Test Pile, ___ m (feet) long	each
2452.517	Treated Timber Test Pile, ___ m (feet) long	each
2452.519	Cast-in-Place Concrete Test Pile,___ m (feet) long	each
2452.520	Steel H-Test Pile, ___ m (feet) long	each
2452.525	Reinforcement Bars	kilogram **(pound)**
2452.526	Pile Load Test, Type ___	each

2461
Structural Concrete

2461.1 DESCRIPTION

This work shall consist of producing, furnishing, and placing Portland cement concrete for placement in structures, pavements and incidental construction as specified.

Except when otherwise specified, the concrete shall be proportioned and mixed as provided for herein, so as to meet the requirements specified for the Mix Designation indicated in the Contract.

2461.2 MATERIALS

A Portland Cement..... 3101

The Contractor:

(1) Shall only use cement from certified sources. The Mn/DOT Concrete Engineer maintains the certification procedures and a list of certified sources.

(2) Shall use Type 1 nonair-entrained concrete produced by using Type I Portland cement and Type 3 air-entrained concrete produced by using either Type IA air-entraining Portland cement or Type I Portland cement plus an approved air-entraining agent.

(3) May use a blend of the two cements (Type I and Type IA) provided they are both manufactured at the same mill and the blending ratio to be used is approved by the Engineer.

(4) Shall comply with exceptions noted elsewhere in the Contract for the class of work in which the concrete is to be used.

B Portland-Pozzolan Cement, Type IP or IP-A..... 3103

C Fine Aggregate..... 3126

D Coarse Aggregate..... 3137

The gradation of the coarse aggregate that will be required or permitted in the work shall be as specified in 2461.3B3, subject to any exceptions noted in the detailed Specifications for the item of work in which the concrete is to be used.

Class B aggregate or a mixture containing Class B aggregate will not be permitted in that portion of a bridge deck slab that is directly exposed to vehicular traffic.

Unless otherwise specified, the class of coarse aggregate, as defined in 3137.2B, shall be optional with the Contractor.

E Water..... 3906

F Concrete Admixtures..... 3113

G Fly Ash..... 3115

2461.3 MIX REQUIREMENTS

A Mix Designation and Control

Concrete mix design shall be governed by the gradation and void content of the job aggregates; the absolute volume relationships and basic mix proportions set forth herein for control of cement, water and air content; and the degree of workability necessary for placement conditions and finishing requirements.

B Classification of Concrete

Concrete will be classified by type, grade and mix designation as provided for hereinafter, and the mix requirements shall be as prescribed for and by the Mix Number given for each item of work in which the concrete is to be used.

The first digit in the Mix Number designates the type of concrete; the following letter designates the grade of concrete; and the two digits following the grade designation letter will indicate the maximum permissible slump and the coarse aggregate gradation range, respectively. A letter following the last two digits designates a specific class of coarse aggregate that will be required. Optional use of Class R aggregates will only be permitted by written authorization of the Engineer.

In case no Mix Number is given for a particular concrete unit, the concrete to be used shall meet the requirements for Type 3, Grade A, and shall have a slump and aggregate gradation that will give the desired workability properties.

Concrete produced in conformity with the requirements for an established job mix other than the Mix Number designated for use may be accepted as a substitute, with no additional compensation being made therefor, provided the design strength is maintained or exceeded, Type 1 concrete is not substituted for Type 3, and the mix is capable of being acceptably placed and finished.

B1 Type Designation

Concrete will be classified as either Type 1 or Type 3, depending on whether or not an air-void system is desired in the cement paste. Type 3 concrete shall have entrained air meeting the specified percentages. Type 1 concrete has no air entrainment requirements.

B2 Grade Designation

Concrete will be classified into strength grades established in terms of the cement void ratio relationship to compressive strength.

The grade designations, cement-void ratios, and anticipated compressive strengths of the concrete are shown in the following tabulation:

TABLE 2461-1
CONCRETE CLASSIFICATION

	Type 1 Concrete		Type 3 Concrete	
Grade of Concrete	**Cement-Void Ratio**	**Anticipated Compressive Strength Mpa (psi)**	**Cement-Void Ratio**	**Anticipated Compressive Strength Mpa (psi)**
U	0.80	43 (**6300**)	0.70	39 (**5600**)
V	0.76	41 (**6000**)	0.66	37 (**5300**)
W	0.72	39 (**5700**)	0.62	34 (**5000**)
X	0.68	37 (**5400**)	0.58	32 (**4700**)
Y	0.62	34 (**5000**)	0.54	30 (**4300**)
A	0.56	31 (**4500**)	0.50	27 (**3900**)
B	0.52	28 (**4100**)	0.46	23 (**3400**)
C	0.44	22 (**3200**)	0.40	19 (**2700**)

The cement-void ratio is defined as the ratio of the absolute volume of cement in the mix to the sum of the absolute volumes of water (less water absorbed by the aggregates) and any air that may be entrained in the concrete.

The cement-void ratios shown shall control the cement contents of all concrete mixes with the following exceptions:

(a) When the cement content is fixed by the minimum values provided for in 2461.3C.

(b) As otherwise authorized herein.

(c) For bridge deck concrete, the ratio of the mass **(weight)** of water to the mass **(weight)** of cement shall not exceed 0.44.

The compressive strength listed above for each type and grade of concrete is the minimum strength that can be expected when the concrete is produced in accordance with this Specification in the laboratory and cured for 28 days under laboratory conditions. If the test cylinders show a strength less than the strength listed, the Department reserves the right to increase the cement content to the extent deemed necessary by the Engineer. The Contractor may be permitted to increase the cement content upon approval of the Engineer.

B3 Mix Designation

The first digit following the grade designation letter in the Mix Number designates the upper limit of a 25 mm (**1 inch**) slump range.

TABLE 2461-2
SLUMP RANGE DESIGNATION

Slump Designation	**Maximum Slump mm (inches)**	**Slump Range mm (inches)**
1	25 (**1 inch**)	0-25 (**0-1 inch**)
2	50 (**2 inches**)	25-50 (**1-2 inches**)
3	75 (**3 inches**)	50-75 (**2-3 inches**)
4	100 (**4 inches**)	75-100 (**3-4 inches**)
5	125 (**5 inches**)	100-125 (**4 -5 inches**)

Except for permissible deviations, the limits so defined shall be the minimum and maximum slump limit within which the concrete mix is to be maintained. If unusual placement conditions are encountered in the work that render the specified consistency unsuitable, the mix composition shall be altered to produce the desired change in consistency while maintaining the other specified properties of the concrete mix. The addition of water only, for the purpose of temporarily facilitating the placement of concrete under such unusual conditions, will not be permitted.

B4 Coarse Aggregate (CA) Designation

The second digit following the grade designation letter in the Mix Number shall be the range number that defines the optional coarse aggregate designations contained in Table 3137-2, that may be used in the mix, and those options shall be as indicated in the following schedule:

TABLE 2461-3
COARSE AGGREGATE DESIGNATION
FOR CONCRETE

Range	Optional CA Designation
0	CA-00 Only
1	CA-15 to 50, Inclusive
2	CA-15 to 50, Inclusive
3	CA-35 to 50, Inclusive
4	CA-35 to 60, Inclusive
5	CA-45 to 60, Inclusive
6	CA-50 to 70, Inclusive
7	CA-70 Only
8	CA-80 Only

In any mix design where it is required that the coarse aggregate composition be of a specified Class as defined in 3137.2B, the Class designation will be identified by letter following the last digit of the Mix Number.

Grout will be designated by Type and Grade, followed by "GROUT". Grout shall contain no coarse aggregate. If no type or grade is indicated, the designation shall be 3A GROUT and be so indicated on all reports.

C Cement Content

In the mix design, the minimum quantity of cement per cubic meter (**yard**) of the various grades and consistencies of concrete shall be as indicated in the following schedule:

TABLE 2461-4
MINIMUM CEMENT CONTENT
Kilogram per Cubic Meter (Pounds per Cubic Yard)

	For Grades:							
Specified Slump Limit mm (in.)	**U**	**V**	**W**	**X**	**Y**	**A**	**B**	**C**
25 **(1 inch)**	475 **(800)**	435 **(730)**	--	--	--	--	--	--
50 **(2 inches)**	490 **(830)**	455 **(765)**	390 **(660)**	375 **(630)**	340 **(570)**	315 **(530)**	290 **(490)**	250 **(420)**
75 **(3 inches)**	505 **(850)**	475 **(730)**	410 **(695)**	395 **(665)**	360 **(605)**	335 **(560)**	305 **(515)**	265 **(445)**
> 75 **(3 inches)**	--	--	435 **(730)**	415 **(700)**	380 **(640)**	350 **(590)**	320 **(540)**	280 **(470)**

The maximum cement content for a cubic meter (yard) of concrete shall not exceed 505 kg (**850 pounds**) unless the concrete is designed as high early, in which case, the maximum shall be 535 kg (**900 pounds**). These maximums shall not apply to GROUT mixtures.

Unless the use of high early strength Portland cement (Types III or IIIA) is specifically permitted by the Specifications applying to the item of work in which the concrete is to be used, production of high early strength concrete shall be accomplished by increasing the normal cement content of the concrete mix by 30 percent. The addition of calcium chloride may also be required to further accelerate the gain in strength, subject to the admixture restrictions of 2461.3E.

D Cement Substitutions

At the Contractor's option, fly ash or Portland-pozzolan cement may be substituted for Portland cement, except when recycled aggregates are used. When recycled aggregates are used, fly ash or Portland-pozzolan cement shall be substituted for Portland cement. The substitution is subject to the following restrictions:

(1) Class C and Class F Fly Ash substitutions shall not exceed 15 percent, on a one for one basis, by mass **(weight)** of the designed Portland cement.

(2) When fly ash is used, the computed cement-voids ratio shall be based on a cement content equal to the originally designed cement content.

(3) Batch mass of coarse aggregates will be adjusted to compensate for volume changes due to substitution of fly ash or Portland-pozzolan cement.

(4) When fly ash or Portland-pozzolan cement substitutions are made, the air entraining admixture shall be specifically approved for such use.

GROUND GRANULATED BLAST FURNACE SLAG CEMENT

Ground granulated blast furnace slag cement (GGBFS) may be substituted for Type 1 portland cement in concrete mixes according to the following restrictions:

The GGBFS cement may be incorporated as a separate product meeting the requirements of ASTM C-989 Grade 100 or Grade 120 or blended with Type 1 portland cement to meet the requirements of ASTM C-595 and ASTM C-1157.

The substitution of GGBFS in both of the above conditions shall be limited to 25 percent except that 35 percent shall be allowed in concrete paving.

The GGBFS cement or blend shall be from a certified source and comply with the latest requirements for certified cement on file in the Concrete Unit.

Fly Ash substitutions are not allowed along with GGBFS unless specifically approved by the Concrete Engineer.

The supplier of the concrete admixtures shall provide a letter of certification to assure the Engineer that the concrete admixtures are compatible with cementitious materials used on the Project.

E Admixtures

No substances other than cement, aggregate, water and air-entraining admixture shall be used in the concrete except by permission from the Engineer or as otherwise required or permitted in the Specifications applying to the item of work in which the concrete is to be used. No reduction in the normal cement content of the concrete mix will be made when accelerators, retarders or water reducing admixtures are specified or permitted, except by written permission of the Engineer, and in no case will the cement content be reduced below the minimum specified in 2461.3C.

The use of calcium chloride in concrete will not be permitted prior to September 15. After September 15, the Engineer may permit the use of calcium chloride for the purpose of accelerating the hardening of concrete. In any event, calcium chloride will not be permitted in units containing prestressing steel nor in bridge superstructure concrete.

F Tentative Proportions

As an aid to prospective bidders in estimating concrete production costs, estimated mix proportions and quantities per cubic meter (**yard**)

will be furnished by the Department on request. It shall be understood that, in furnishing this preliminary information, the Department does not, expressly or by implication, guarantee or agree that the estimated proportions and quantities will apply exactly to the materials actually furnished for the work. The estimated mix proportions issued for bidding purposes will not include any optional or required admixtures.

The Department will render all reasonable assistance in testing preliminary samples from proposed sources for the purpose of determining the general quality and suitability of the materials after the Project is awarded. The Engineer will establish the job mix proportions as provided below, after a sufficient quantity of satisfactory material has been produced to ensure that the material is representative of that which is to be used in the work.

Laboratory testing of the material to determine the properties upon which the mix proportions are to be based will require not less than 7 days after the samples have been delivered to the Materials Laboratory, and some testing may require a considerably longer time period. To avoid delays in starting the work, production of aggregates should be started sufficiently in advance of concrete production to permit this preliminary testing to be completed.

G Job Mix Proportions

A tentative job mix will be designed for use at the start of construction and until the required water content under existing job conditions can be accurately determined. This tentative mix will be based on water and air contents estimated on the basis of previous experience with the materials from the sources to be used; or, in the case of materials from sources not previously used, on the Department's established rules of design.

As soon as practicable after the required water content can be accurately determined, the Engineer will establish the job mix in accordance with the cement-voids ratio or minimum cement factor, whichever requires the greater quantity of cement.

H Concrete Yield

The yield of concrete as placed in the work is the ratio of the volume of mixed concrete, less accountable waste, to the planned volume of the work constructed. Since a large portion of the ingredients of the concrete mixture is naturally occurring and therefore not entirely homogeneous, the Department does not assume responsibility for the yield that will be obtained in terms of units of completed work from a given volume of mixed concrete.

I Blank

J Mix Adjustments

The Department reserves the right to make adjustments in the mix composition at any time as may be found necessary to maintain the

specified consistency and cement-void ratio of the concrete, without any adjustments in compensation being made either for or against the Contractor.

After the job mix has been established, the production of concrete shall be so controlled that the following tolerances are not exceeded:

(1) The cement-voids ratio of the concrete as actually produced shall not be more than 4 percent less than the minimum value given in 2461.3B2.

(2) When the cement content of the concrete is not controlled by the minimum cement content specified, the water content as actually used shall not exceed the established value by more than 4 percent.

If, at any time, it is found impossible to maintain production of the established job mix within the above specified tolerances because of changes in materials, equipment or placement conditions, the Engineer will establish a new job mix for subsequent production. However, the Engineer may accept on an occasional basis any concrete batch in which:

(1) The total aggregate does not exceed the design mass **(weight)** by more than 5 percent,

(2) The cement content is not deficient by more than 3 percent of the design mass **(weight)**, or

(3) The cement content does not exceed the design mass **(weight)** by more than 50 percent.

2461.4 PRODUCTION REQUIREMENTS

A Production Controls

A1 Batch Material Requirements

Unless authorized by the Engineer, no change in the source, kind or gradation of batch materials shall be made after the start of concrete production for the work. If any changes are authorized, the supply at hand shall be completely exhausted before using different material.

When freshly washed aggregates are delivered to the batching plant, they shall be drained for a period of at least 12 hours prior to being used in the batching operations. When freshly washed aggregates are to be drained at the site of the batching plant, provisions shall be made for complete separation of the drained material currently being used in the batching operations from the undrained materials, and adequate means shall be provided for the disposal of water that accumulates from the drainage of materials.

The sites of all stockpiles shall be smooth, firm, and well drained, and they shall be cleared of all vegetable and extraneous matter. Where the natural foundation is unsatisfactory, the Engineer may require that the stockpiles be constructed upon suitable platforms. In congested

areas, suitable bulkheads or partitions shall be constructed as will ensure separation of aggregate of different kind, gradation or water content.

Stockpiles shall be constructed by methods that hold segregation and degradation to a minimum. If evidence of segregation or degradation exists, the Engineer may designate that pile as being unacceptable for use.

A2 Concrete Mixing Restrictions

Concrete production shall not be started on any day until the Engineer has been given adequate notice to provide the necessary inspection forces and has approved all preparations for placement of concrete, nor until it has been determined that weather conditions will permit the placement, finishing and curing of concrete in accordance with the Specification requirements and restrictions.

Concrete production shall be commenced, suspended, or otherwise regulated so as to comply with the following provisions governing the placement, finishing and protection of concrete:

(a) Concrete shall not be placed in any unit or section of work until the Engineer has inspected and approved the required foundation preparations, form and falsework erection, placement of reinforcement steel, materials, equipment condition, and any provisions for cold weather protection that might be needed.

(b) Concrete shall not be placed on a frozen foundation or against any surface the temperature of which is below freezing.

(c) Unless provisions satisfactory to the Engineer have been made in advance for cold weather protection of concrete, concrete production shall not be commenced or continued when the air temperature at the construction site in the shade and away from artificial heat is below 2°C (**36°F**), except as authorized by the Engineer when the air temperature is rising and has reached 1°C (**33°F**) .

(d) Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions, the Contractor shall expedite the application of curing media or temporarily suspend the mixing and placing operations, as the conditions require.

(e) Except as otherwise specifically authorized by the Engineer, in the case of emergency or when adequate artificial lighting is provided, concrete shall not be produced for placement earlier than 60 to 90 minutes before official sunrise nor shall concrete be produced or dispatched from the mixing plant so early or late in the day that it cannot be finished and protected in accordance with the Specification requirements. Written permission from the Engineer will be required to conduct the placement and finishing operations under artificial lighting.

The Contractor shall assume full responsibility for the acceptable production, placement, finishing, and curing of concrete under the conditions prevailing, regardless of the restrictions imposed, and any artificial lighting and rain or cold weather protection provided shall be at no expense to the Department. Any defects in the concrete or concrete surfaces resulting from weather conditions, inadequate lighting, or other causes shall be subject to 1503 and 1512.

A3 Concrete Temperature Control

Aggregates whose temperature is 0°C (**32°F**), or less, shall not be used except under direct supervision of the Engineer.

When mixed, all concrete shall have a temperature of not less than 10°C (**50°F**) nor more than 30°C (**90°F**), except that a temperature of not less than 5°C (**45°F**) will be acceptable with the use of an approved accelerator and dosage. The concrete shall be maintained within that temperature range until it is deposited in the work.

If necessary to obtain the specified temperature, either the water or the aggregate, or both, shall be heated prior to being introduced into the mixer. However, aggregates shall in no case be heated to a temperature of more than 55°C (**130°F**), and the cement shall not be heated in any case. Cement shall not be permitted to come in contact with any other batch material the temperature of which exceeds 55°C (**130°F**).

When heating of any batch materials is required, they shall be heated by means of an approved heating system operated in a manner satisfactory to the Engineer. Spot heating of the material by means of steam jets as the work progresses will not be permitted.

Mixer heaters intended for heating the batch materials within the mixer drum will not be permitted.

A4 Concrete Mixture Requirements

A4a Water Content

Water content of the concrete shall be the minimum that will produce the desired consistency. The water content shall consist of the free water carried by the aggregate plus the water added at the mixer, and may also include the water used in making extremely dilute admixture solutions.

The Engineer will make determinations of the quantity of water carried by the aggregates by periodic testing during the pour and so inform the Contractor.

The quantity of water added to the concrete mix shall not be changed without prior notification of the Engineer.

The Engineer will test the concrete for consistency as often as may be necessary during the progress of the work. The Department reserves the right to reject any concrete batch the consistency of which is found to be outside of the permissible slump range. When any test shows the slump to be in excess of the upper limit by more than 25 percent or below the upper limit by more than 50 percent, the concrete represented

by that test will be rejected unless adjustments satisfactory to the Engineer are made in the concrete prior to use.

If any mix composition is altered by the Engineer to effect a change in consistency, the permissible slump range shall be as established for the revised mix.

A4b Air Content

Except as otherwise specifically authorized, the air content of Type 3 concrete shall be maintained at 6.5 percent, plus or minus 1.5 percent, of the measured volume of the freshly mixed concrete. The quantity of air-entraining agent needed to obtain the desired air content shall be the responsibility of the Contractor. Any adjustments necessary to meet the desired air content range shall be made immediately. The air content of the concrete shall be maintained within the required limits except that an additional 0.5 percent deviation (plus or minus 2.0 percent) will be permitted for one test each day on paving and base construction or for one test per 400 m^3 (**500 cubic yards**) of concrete on other types of construction.

When air-entraining cement is used and it is found that the air content of the concrete is less than 6 percent or more than 7 percent, the use of that particular brand of cement shall be discontinued immediately, until corrective action has been taken to obtain the desired air content, either by adding a sufficient quantity of an approved air-entraining agent to each batch to bring the air content up to the desired range or by blending a sufficient quantity of Type I Portland cement with the air-entraining cement to bring the air content down to the desired range, whichever is necessary. Once satisfactory proportions have been determined, the air content shall not be allowed to fluctuate outside the desired range without corrective action begin taken to re-establish optimum control.

Type 3 concrete not conforming to the above air content requirements will not be allowed in the work. Should any nonconforming concrete be inadvertently placed in the work, that which is found to have an air content less than 4.8 percent or more than 8.2 percent, when tested in accordance with the prescribed procedure and excluding permissible exceptions, will not be accepted for payment at Contract prices, but shall be subject to the following provisions governing acceptance and payment:

(1) Concrete having an air content of more than 8.2 percent or less than 4.8 per cent but not less than 3.8 percent will be paid for at an adjusted unit price equal to 95 percent of the Contract bid price for the item involved.

(2) Concrete having an air content less than 3.8 percent but not less than 3.0 percent will be paid for at an adjusted unit price equal to 75 percent of the Contract bid price for the item involved, subject to items (5) and (6) below.

(3) Concrete having an air content less than 3.0 percent but not less than 2.5 percent may be left in place without any payment being made therefor, subject to items (5) and (6) below.

(4) Concrete having an air content less than 2.5 percent shall be removed and replaced, subject to item (5) below.

(5) Concrete having an air content less than 3.8 percent, which is placed in any part of a retaining wall, box culvert, bridge abutment, or similar unit, such that it would not normally be exposed to salt-brine freeze-thaw cycling, will be accepted for payment at an adjusted unit price equal to 90 percent of the Contract bid price for the item involved.

(6) Concrete having an air content less than 3.5 percent, which is left in place where its surface will be exposed to salt-brine freeze-thaw cycling, shall be coated with an approved epoxy penetrant sealer at the Contractor's expense.

All determinations regarding the disposition, payment, or removal of concrete not having the required air content shall be made by the Engineer. Price adjustments will apply only to the Contract item under which the concrete is furnished.

For determination of compliance with cement-voids ratio requirements as described in Table 2461-1 for mix design and 2461.3J for mix adjustments, the air content shall be assumed to be 5.5 percent.

A5 Test Methods and Specimens

Concrete sampling and testing will be performed in accordance with the procedures described in the Mn/DOT Concrete Manual.

The forms for the test specimens and the testing equipment will be furnished by the Department.

When requested, the Contractor shall transport the test specimens from the site of the work to the Department's field laboratory or office, in such manner as to protect them from damage. The Contractor shall also furnish facilities for curing the concrete specimens in a manner similar to the structure curing or as otherwise directed by the Engineer. No compensation in addition to the Contract prices will be made to the Contractor for any concrete, material, labor, equipment, or other assistance that the Contractor may be called upon to furnish in connection with handling and curing test specimens.

When the sequence of construction operations is dependent upon the rate of concrete strength developments this strength shall be determined by control cylinders. The Contractor (or producer of precast units) shall

furnish 150 by 300 mm (**6 x 12 inch**) cylinder forms (The Contractor may use 100 by 200 mm (**4 x 8 inch**) cylinder forms if the maximum aggregate size is less than or equal to 31.5 mm (**1-1/4 inch**), shall cast the control cylinders, and shall cure the cylinders in the same location and under the same conditions as the concrete structure or unit involved. A sufficient number of control cylinders shall be cast to accurately determine when the strength of the concrete for all desired control limitations has been attained. All control cylinders shall be cast in the presence of and under the direction of the Engineer and the cylinders shall be clearly marked for positive identification with the concrete unit or section of concrete represented.

The Contractor shall transport the control cylinders to the Materials Laboratory for testing in such quantity and at such times as it is agreeable with the Engineer. Upon completion of the testing procedure, the Engineer will be notified of the test results. In lieu of transporting the cylinders to the laboratory, the Contractor may perform the tests in the presence of the Engineer on a portable mechanical or hydraulic testing machine that has been checked and calibrated with a standard proving ring.

B Batching Requirements

B1 Proportioning Methods

Concrete batch materials shall be proportioned by mass **(weight)** except where volumetric proportioning is specifically authorized or required in accordance with the following provisions:

(a) Concrete for bridge deck overlays shall be proportioned by volume.

(b) Volumetric proportioning will be permitted when the concrete for any single item or group of items of work is produced at a single batching and mixing set-up and the quantity produced does not exceed 50 m^3 (**cubic yards**).

(c) Volumetric proportioning may be permitted on other items of work by written authorization of the Engineer, provided the mixer is calibrated for the specific batch materials to be used.

(d) The methods and equipment used in volumetric proportioning shall be subject to approval by the Engineer.

(e) Volume proportions will be determined on the basis of 100 kg (**pounds**) of cement and the appropriate conversions for the other materials.

(f) Unless the mixer is calibrated for the specific materials being used, only sacked cement furnished in the original mill containers shall be used, and fractional sacks will not be permitted.

(g) Unless the mixer is calibrated for the specific materials being used, the cement content shall be increased by 10 percent in the computation of volume proportions.

B2 Weighing Equipment

Scale indicators or beams shall be so graduated as to permit readings and settings to be made within the specified tolerances, but in no case will graduation units finer than 2 kg (**pounds**) be required. The use of spring scales for weighing concrete batch materials will not be permitted. The weighing equipment used shall be so constructed or shielded as to provide protection and accurate operations under adverse weather conditions.

Weighing equipment shall be subject to 1901 and such tests as the Engineer deems necessary to ensure continued accuracy and sensitivity. Material bins from which any weighing equipment is suspended shall be fully loaded for a period of not less than 2 hours prior to testing that weighing equipment.

B3 Batching of Cement

When proportioning by mass **(weight)**, the bulk cement shall be weighed independently of the aggregates, either on separate scales or in separate compartments.

The use of sacked cement will be permitted only when the operations are such that the Engineer can accurately determine the quantity of cement proportioned into each batch.

B4 Batching of Aggregates

Aggregates shall meet the specified gradation requirements and have a stable and reasonably uniform moisture content at the time of being proportioned into the batches. Aggregates will be considered to have unstable moisture content if there is evidence of gravity drainage in the weighing hoppers or on the bottom of truck boxes, and they will be considered not to be reasonably uniform in moisture content if the variations in moisture carried by any one or more of the materials causes a marked variation in the consistency of successive batches of the mixed concrete.

Aggregates used by the Contractor in constructing runways for loading or hauling equipment shall not be used in concrete batches. The use of aggregate from the bottom 0.3 m (**1 foot**) of a stockpile placed on an earth foundation shall be avoided until necessary for final cleanup, unless there is to be a change in the kind or gradation of aggregate to be stockpiled at that location. Materials from the bottom layer of stockpiles shall only be used under the direct supervision of the Engineer, and then only if the material meets all requirements for quality, gradation and cleanliness.

B5 Admixture Proportioning

When two or more different types of admixtures are to be added to the concrete mix, each type shall be added in a manner that will prevent contact between or intermixing of the different admixtures prior to their being mixed with other batch materials.

Unless otherwise authorized, admixtures shall only be added to the batch mix in liquid or solution form. Admixture solutions shall be maintained at a uniform concentration at all times. When the use of calcium chloride is permitted or required, the concentration of solution and proportions to be used shall be as designated by the Engineer, but the dosage shall not exceed the equivalent of 2 kg (**2 pounds**) of Type I (flakes) or 1.5 kg (**pounds**) of Type II (pellets) per 100 kg (**pounds**) of cement.

When concrete is mixed at the site of the work in mixers having a rated capacity of 0.5 m^3 (**16 cubic feet**) or more, air-entraining admixtures shall be measured and added to the concrete batch by a mechanical dispenser that discharges the air-entraining agent into the discharge pipe of the mixer water system. In the production of ready-mix concrete, the air-entraining admixture shall be measured in a transparent tube having a graduated scale showing the net contents.

When a mechanical dispenser is used for proportioning Class I or II admixtures, it shall either be a transparent device or an approved meter connected in such a manner that the quantity being discharged can be observed. Any dispenser used shall be checked periodically to determine its accuracy and ensure unobstructed flow.

B6 Batching of Fly Ash

Fly ash shall be proportioned by mass **(weight)** unless volume proportioning is specifically authorized by the Engineer. The bulk fly ash shall be weighed independently of the aggregates either in separate compartments or on separate scales. Fly ash may, however, be weighed cumulatively with the cement provided the cement is weighed first and there is a way of determining the cement quantity, suitable to the Engineer, on any required cement recorder printout.

C Mixing Requirements

C1 General Requirements

Before mixing operations begin, and at any other time that the Engineer considers it necessary, the water measuring equipment shall be checked for accuracy and calibrated under operating conditions.

Except as otherwise restricted by delivery or placement time, concrete may be mixed at the site of construction, at a central plant site (stationary plant), or wholly or in part in truck mixers.

The mixer shall be so operated that the batch being mixed will not become merged or intermixed with the following dry batch. If two or more dry batches become merged or intermixed while charging the mixer, or prior thereto, they shall only be used in a manner satisfactory to the Engineer.

Concrete shall be mixed until the cement and water are uniformly distributed throughout the mass and the mixture is homogeneous and uniform in color. Concrete batches that show a marked variation in

consistency or composition or evidence of improper mixing shall be rejected and disposed of in a manner satisfactory to the Engineer.

Hand mixing of concrete will not be permitted except in case of emergency, and then only by permission of and under the direct supervision of the Engineer.

Concrete shall be produced in such quantity and at such a rate as proper placement and finishing will permit. The retempering of concrete that has become partially set will not be permitted.

C2 Mixer Requirements

C2a General Condition

The pickup and throwover blades of mixers having a rated capacity of 0.4 m^3 (**14 cubic feet**) or less shall not show a wear loss of more than 13 mm (**1/2 inch**) and, in mixers of greater capacity, not more than 19 mm (**3/4 inch**) from the original manufactured depth. Blades that do not meet such requirements shall be replaced or reconditioned.

When compliance with the blade wear requirements is questionable, or when the uniformity of mixing is questionable due to excessive accumulation of hardened concrete or other reasons, slump tests will be taken at approximately the 15 and 85 percentage points during unloading. If the results of these tests show a slump variation greater than 40 mm (**1-1/2 inch**), the use of that mixing unit shall be discontinued until the cause has been corrected.

C2b Manufacturer's Rating Plate

All mixers shall carry the manufacturer's plate showing the serial number of the unit and its rated capacity.

C2c Drum Speed for Stationary Mixers

While the mixer is in operation, the drum speed shall be as specified by the manufacturer; however, if the specified speed does not provide satisfactory mixing or if no drum speed is specified, the Engineer shall have the right to designate a satisfactory drum speed.

C2d Auxiliary Equipment Requirements

Mixers having a capacity of less than 0.3 m^3 (**10 cubic feet**) may be operated under control of an approved timer for regulating the length of the mixing period. The batch water may be measured by manual methods.

Mixers having a capacity of 0.3 m^3 (**10 cubic feet**) or more shall be equipped with a timing device, a discharge locking device, and a water measuring device; all of which shall be so constructed and incorporated in the mixer design as to operate mechanically and automatically during each batching cycle.

The water measuring equipment shall be of such design and construction as to permit rapid and easy adjustment and calibration. It shall not be subject to pressures other than atmospheric pressure. An

adjustable indicator device shall be provided that shall be graduated to represent the volume of discharge in increments not greater than 1 L (**1/4 gallon**). The Contractor shall furnish personnel, equipment, and accessories as may be required to calibrate or check the accuracy of the equipment, with the Engineer providing reasonable assistance.

C2e Mixer Capacity

The maximum volume of concrete that may be mixed in one batch shall not exceed the rated capacity of the mixer.

The batch volumes permitted above are contingent upon the ability of the individual mixer to hold these quantities of materials and properly mix them without spillage, leakage, or segregation during the charging, mixing, and discharging operations. No mixer with a capacity of less than a 0.25 m^3 (**1-sack**) batch shall be used.

C2fMixing Time

The mixing time per batch is defined as the time period beginning when the cement and aggregates are all in the mixer drum and ending when the discharge begins.

The minimum mixing time for single drum mixers shall be as recommended by the manufacturer of the mixer. In the absence of such recommendation, the minimum mixing time shall be as designated by the Engineer. The minimum mixing time shall be 60 seconds except as hereinafter permitted.

In the event there is evidence of inadequate mixing when the concrete is incorporated in the work, the Engineer reserves the right to increase the mixing time as needed.

In central mix plants with capacities in excess of 3.8 m^3 (**5 cubic yards**) per batch, the mixing time may be reduced to 50 seconds after all solids are in the drum, provided uniform mixing is obtained as determined from tests. The samples and sampling, for uniformity tests, shall be provided by the Contractor under the direction of the Engineer, who will perform the testing and determine the adequacy of the mixing. Should the test results or subsequent job performance indicate non-uniformity in concrete mixing, the mixing time will be increased until the desired uniformity is obtained.

The number of revolutions at mixing speed shall not exceed 150. Any concrete mixed in excess of 150 revolutions shall be wasted.

C3 Turbine Type Mixers

Turbine type mixers shall meet the applicable requirements for conventional type mixers, except as modified herein.

The mixer drum shall be maintained in good and clean condition, and shall not deviate by more than 19 mm (**3/4 inch**) at any point from being cylindrical in shape. The discharge gate of the mixer shall be maintained in mortar tight condition when it is in the closed position.

Mixer paddles shall be replaced or reconditioned whenever they show a wear loss of more than 13 mm (**1/2 inch**) from the original factory dimensions.

The mixing water shall be added to the batch materials in the mixer in such a manner as to distribute the water to the inner or central areas of the drum. The flow of water shall start slightly before the solid batch materials are introduced into the mixer drum.

During the mixing operations, the paddles shall operate at a speed of not less than 20 nor more than 30 revolutions per minute. After all batch materials are in the drum, the concrete shall be mixed for 45 seconds or for 18 revolutions of the mixer paddles, whichever provides the longer mixing period.

C4 Horizontal Axial-Revolving Blade Type Mixers

The horizontal axial-revolving blade type mixer shall meet the applicable requirements for conventional type mixers except as modified herein.

The sequence of charging the aggregates and cement is contingent upon the method of introducing water into the mixer and therefore shall be subject to approval of the Engineer. After approval of the charging operations, the Engineer will determine the minimum mixing time for the mixer based on concrete uniformity tests conducted by the Contractor under the direction of the Engineer.

C5 Delivery Requirements

Concrete, other than that transported in agitator trucks, which cannot be properly placed in the work or cannot reach its final position in the forms within 45 minutes, shall be rejected and removed from the work.

In transporting mixed concrete, the use of open or tub type truck bodies, which are not equipped with paddles or blades for agitating, will be permitted only upon written permission from the Engineer and then only for Type 3 concrete.

D Ready-Mixed Concrete

D1 Definition

Ready-mixed concrete shall be understood to mean:

(a) Any concrete that is proportioned and mixed in a central plant and hauled to the point of placement in revolving drum agitator trucks, or

(b) Concrete that is proportioned in a central plant and fully mixed in transit-mix trucks.

D2 General Requirements

Ready-mixed concrete shall be subject to, and shall meet all the requirements set forth elsewhere in these Specifications for concrete, except as those requirements may be modified in this section.

The use of ready-mixed concrete will not be permitted until the facilities and methods by which it is to be proportioned, mixed, and transported have been approved by the Engineer.

If ready-mixed concrete is not delivered to the site of the work at the designated rate, or if the delivery time, consistency, quality, air-content, or other properties of the concrete do not conform to the specified requirements, the Contractor shall discontinue its use.

The minimum load of concrete that will be permitted to be batched and delivered to the Project shall not be less than 1 m^3 (**cubic yard**).

Slump and air-content requirements as they apply to ready-mixed concrete shall be determined at the time the concrete is incorporated into the work.

Central proportioning or mixing plants shall provide satisfactory quarters for the use of the plant inspector in making tests. Such quarters shall be provided with adequate lighting, heating and locks to prevent damage or loss of testing equipment.

D3 Notice of Inspection

In order to permit arrangements to be made for inspection of materials, the Contractor shall notify the Engineer at least 24 hours in advance of the time scheduled for delivery of ready-mixed concrete. Failure on the part of the Contractor to cooperate in this respect may result in delays in delivery for which the Department will assume no responsibility.

D4 Central Plant Requirements

The central plant shall be designed, constructed, and equipped to permit proportioning and mixing concrete of the various grades in accordance with these Specifications. The weighing and measuring equipment shall be designed and arranged to provide ready access for the purpose of checking and calibration.

The Contractor shall inspect, test, and calibrate the scales according to 1901 and the Mn/DOT Concrete Manual.

The mixing water shall be measured on approved scales or by using an approved water metering device. To be approved, the water meter shall comply with the following.

(a) It shall have a discharge indicator capable of being set to within 5 L (**1 gallon**) of a predetermined quantity.

(b) It shall have a positive automatic shutoff valve that stops the flow of water when the indicated quantity of water has been delivered.

(c) It shall operate within a maximum delivery tolerance of 1 percent of the required water setting at the time of batching.

(d) It shall bear an approved inspection seal dating the time of the previous calibration and adjustment, which shall be within 6 months prior to time of use.

Unless evidence is furnished indicating that the water meter was calibrated and adjusted within the previous 6 months by an authorized service agency (as listed in the Mn/DOT Concrete Manual), it shall be calibrated and adjusted prior to use in accordance with the weighing procedure given in that Manual. The water meter shall be checked for accuracy at least once each month as the work progresses. Any platform scale used in the calibration of water meters shall be subject to the requirements of 1901.

The mixer at the central plant shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. In the event the timing device is not available or is out of order, the specified mixing time shall be increased by one-half minute.

D5 Transportation Units

D5a General Requirements

Transportation units intended for use in the delivery of concrete that has previously been completely mixed shall be equipped with a watertight revolving drum, suitably mounted and powered and containing properly designed built-in mixing or agitating blades. They shall be capable of delivering the concrete without segregation or loss of any of the batch materials.

Transportation units intended for both mixing and agitating shall be equipped with watertight revolving drums suitably mounted and powered and fitted with properly designed mixing blades. They shall be capable of combining all the ingredients into a homogeneous mixture. They shall be so designed as to provide two drum speeds, as hereinafter specified, one for mixing and the other for agitating. The unit shall be equipped with a counting device that will record the number of revolutions of the mixer drum.

When compliance with the blade wear requirements is questionable, or when the uniformity of mixing is questionable due to excessive accumulation of hardened concrete or other reasons, slump tests will be taken at approximately the 15 and 85 percentage points during unloading. If the results show a slump variation greater than 40 mm (**1-1/2 inch**), the use of that mixing unit shall be discontinued until the cause has been corrected.

D5b Capacity of Transportation Units

The maximum capacity of the unit shall be as shown on the Truck Mixer Manufacturer's Bureau Certification Plate attached to the unit. If the unit will not satisfactorily mix the maximum volume shown, the batch volume shall be reduced to an extent that will provide proper mixing.

D5c Mixing In Transit Mix Units

The materials shall be charged into the mixing drum in such a manner that sufficient water is introduced prior to addition of any of the solid materials to prevent packing action and to ensure adequate mixing. All charging operations shall be performed without the loss of any of the materials.

When the concrete is mixed in a truck mixer loaded to its rated capacity, the number of revolutions of the drum or blades at mixing speed shall be not less than 50 nor more than 150. All revolutions over 150 shall be at agitating speed.

Unless the mixing unit is equipped with an accurate and dependable device that will indicate and control automatically the number of revolutions at mixing speed, the unit shall remain on the site of the proportioning plant during the mixing period after which the drum speed shall be promptly reduced to agitating speed and the unit shall then proceed to the point of delivery, unless the delivery time is short enough so that the maximum number of revolutions for mixing will not be exceeded in transit, or the mixing operation is performed at the site of the work when required for Type 3 concrete.

Any flushing water remaining in the drums shall be taken into account in batch computations or it shall be entirely discharged prior to batching.

D5d Agitating

After the concrete has been completely mixed, either in a central plant mixer or a transit-mix unit, it shall be continuously agitated, while in transit to the point of placement, so as to maintain the concrete in a thoroughly mixed and uniform mass until it is discharged from the unit.

D6 Delivery Requirements

Whether the mixing is done in a central plant, in transit mixers or by a combination of these two methods, ready-mixed concrete shall be deposited in the work within 90 minutes after the cement is added to the other batch materials except that, in the case of Type 3 Concrete, the time interval shall be no greater than 60 minutes when the air-entraining agent is added to the mix at the central plant.

D7 Certified Ready-Mix Plant Program

Mn/DOT has developed a program for the quality control of concrete production under a Certification program for ready-mix concrete plants. It shall be the Contractor's responsibility to make certain that all ready-mix concrete being used on this Contract shall be produced by a certified ready-mix plant.

To ensure that proper testing procedures and documentation are followed, the Ready -Mix Producer shall obtain and have on site a copy of the Minnesota Department of Transportation's Concrete Manual. The manual may be obtained via the INTERNET at the following address: http://mnroad.dot.state.mn.us/concrete.html

D7a Certification Documents

The Contractor shall obtain all of the ready-mix concrete used on this Contract (other than mainline paving) from a Certified Concrete Plant capable of meeting all of the pertinent requirements of Mn/DOT Standard Specifications 1604 and 2461 and the following.

It is the Contractor's responsibility to ensure that the ready-mix concrete producer adheres to all of the following requirements. Each individual truckload of ready-mixed concrete used by the Contractor or any sub-contractor on this Contract shall, at the time of delivery, be accompanied by a signed Certificate of Compliance from the producer. Each Certificate of Compliance shall include:

a. Name of the ready-mix concrete plant
b. Name of the Contractor
c. Date
d. State Project Number (S.P.)
e. Bridge Number (when applicable)
f. Time concrete was batched/discharged
g. Truck number
h. Quantity of concrete in this load
1. Running total quantity of this concrete mix batched on this day for this project
j. Type of concrete (Mn/DOT Mix Designation Number)
k. Cement brand and production mill
l. Fly ash brand and production power plant
m. Admixture brand and product name
n. Pit number for each aggregate source
o. Admixture quantity ml/100 kg (**fluid ounces/100 pounds**) for:
   air-entraining admixtures,
   water reducing admixtures,
   other admixtures

p. Design weights (Oven Dry) per cubic meter (**cubic yard**) for:
cement,
fly ash,
each coarse aggregate fraction 19 mm+ (**3/4 inch+**)
& 19 mm- (**3/4 inch-**)
fine aggregate (sand)

q. Design water weight

r. Target and Actual batched weights for:
cement,
fly ash,
each coarse aggregate fraction 19 mm+ (**3/4 inch+**)
& 19 mm- (**3/4 inch-**)
fine aggregate (sand),
actual water added,
any trim water added,
total water

s. The ticket shall also include the following information printed with enough room beside each item to allow the field inspector to record the appropriate test results: air content, air temperature, concrete temperature, slump, cylinder number, and location/part of structure

Items k.,l.,m.,n., and p. need only be provided on the first certificate per day per mix designation or when one of these items changes.

By signing the Certificate of Compliance the representative agrees to the terms of this policy and further agrees that the materials itemized in this shipment are certified to be in compliance with the applicable Minnesota Department of Transportation specifications and the project plans.

Projects administered by the Metro Division:

The ready-mix producer shall provide to the Agency representative, a completely computer generated Certificate of Compliance that is approved by the Mn/DOT Concrete Engineer. The Certificate of Compliance must contain all of the information required above including water measurements, and it must be signed at the time of batching by a responsible representative employed by the ready-mix production company. The Certificate of Compliance shall consist of a single sheet maximum. If the computer that generates the Certificate of Compliance malfunctions, the producer may finish any pours that are in progress provided the plant issues handwritten Certificates of Compliance on the most current version of Mn/DOT form TP 00042. New pours will not be permitted to begin without a working computerized Certificate of Compliance.

Projects administered by the Outstate Districts:

Computerized Certificates of Compliance are required when Contract quantities exceed 385 cubic meters (**500 cubic yards**) for general concrete work and 155 cubic meters (**200 cubic yards**) for bridge concrete.

For Contracts that do not exceed the limits addressed above, the Ready-mix Producer may use handwritten Certificates of Compliance. These must be the most current version of Mn/DOT form TP 00042. The form must contain all of the information required above including water measurements. The form must consist of a single sheet maximum.

D7b Contractor Testing and Sampling

The Contractor, supplying concrete from a ready-mix plant involved in the Certified Plant Program, will provide testing of the materials involved in the mixture as outlined below. All testing and plant operations will be overseen by a Quality Control Supervisor who is a Plant Level II Technician certified by Mn/DOT. The Quality Control Supervisor must be on site at all times concrete is being produced or be accessible by cellular phone and must be able to be at the plant site in a reasonable time frame when called. The Quality Control Supervisor will maintain or oversee the maintenance of a plant diary. The diary will document yards produced each day, tests performed, material problems, breakdowns, weather, etc., all to the approval of the Engineer.

Mechanical shakers are required for sieve analysis of fine and coarse aggregates. AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing discuss the equipment and calibration necessary for performing the required tests. The following is a list of the applicable tests and standards.

Sieve Analysis of Fine and Coarse Aggregates ..... AASHTO T-27

Total Moisture Content of Aggregate by Drying..... AASHTO T-255

Wire-Cloth Sieves for Testing Purposes..... AASHTO M-92

Weighing Devices Used in the Testing of Materials

..... AASHTO M-231

The sieves shall comply with the requirements of 5-693-420B of the Department's Bituminous Manual "Equipment Calibration and Verification Policies and Procedures for Laboratory Certification".

The provisions of 2461.4D3 still apply as to requirements of notification of the Engineer of intent to pour concrete. If the ready-mix producer would need to change plants for an unexpected reason, this is allowable on an infrequent basis if the Quality Control Supervisor contacts and obtains approval from the Project Engineer or Metro Inspection (for the Metro Division) before the plant change is made.

All cement and fly ash shall be supplied from Certified sources. When requested by the District Materials Engineer, the ready-mix producer will be required to obtain samples of fly ash and cement for subsequent testing by the Agency. The samples should be between 2500-3000g and placed in an Agency provided container and sealed to prevent contamination. The samples should be identified with information to include brand, mill location and date sampled, and should be retained for the Agency plant monitor. The material sampling process should be monitored by an Agency Plant Monitor whenever possible.

D7c Moisture Content

The ready-mix producer shall determine the moisture content in the fine (sand), the fine fraction of the coarse 19 mm- (**3/4 inch**-), and the coarse fraction **19 mm+ (3/4 inch+**) of the coarse aggregate at a rate of one test per 200 cubic meters (**cubic yards**) of Agency concrete production with a minimum of one test per day when more than 20 cubic meters (**cubic yards**) of Agency concrete are produced. Additional tests may be required as dictated by changes in the material. The initial moisture content must be computed within the first hour of concrete production each day. The producer shall be responsible for all costs associated with determining the moisture content, including equipment, labor and materials.

The moisture content of the aggregate shall be determined by the oven dry method as outlined in the Mn/DOT Concrete Manual. Other methods may be used with written permission of the Engineer. All moisture tests will be run by a Plant Level I Technician certified by Mn/DOT.

The ready-mix producer will provide the State with all documentation for each moisture test which will be kept in a file at the plant site. A chart tracking the moisture content of each aggregate will be openly displayed at the plant. The producer must allow Agency personnel to observe the batching process to verify weights shown on the Certificate of Compliance.

D7d Gradations

The ready-mix producer shall determine the gradation of the fine aggregate at the rate of 1 test per 200 cubic meters (**cubic yards**) of Agency concrete production in order to insure conformity to 3126. The ready-mix producer shall determine the gradation of all fractions of the coarse aggregate at the rate of 1 test per 100 cubic meters (**cubic yards**) of Agency concrete production in order to insure conformity to Mn/DOT 3137. A minimum of 1 test on all aggregates will be required when more than 20 cubic meters (**cubic yards**) of Agency concrete are produced in a day. The initial gradations will be completed within the first hour of concrete production each day. This gradation testing will serve as the quality control of the producer's material. The producer will be responsible for all costs associated with running gradations including equipment, labor and materials. To assure the ability of the producer to

immediately resample material that does not comply with gradation requirements, all testing shall be performed at the plant site. The gradations shall be run and computed as outlined in the Mn/DOT Concrete Manual. All process control samples taken by the producer will be split with one half bagged, clearly marked (Date, Test No., Time, Type of Material, Plant), and retained for a period of one week for companion sampling by the agency. All gradation testing will be performed by a Plant Level I Technician certified by Mn/DOT.

The ready-mix producer shall document the results of all gradations on the Weekly Concrete Aggregate Report (form #2449) utilizing every other column in order to leave room for agency companion results. Supporting documentation for all gradations will be kept in a file at the plant site. The ready-mix producer will chart all sieves of the coarse aggregate and the 2.36 mm (#8), 600 µm (#30), and 300 µm (#50) sieves of the fine aggregate with procedures outlined in the Concrete Plant I Certification Course. In addition, the results of the Agency companion and audit gradations should be plotted on the same chart as the ready-mix producer. These charts must be openly displayed at the plant site.

Agency Plant Monitors will, during production for this project, take audit samples for quality assurance. The audit gradations will be taken at the rate of one per day or 1 per 500 cubic meters (**cubic yards**) whichever results in the lowest sampling rate. The maximum requirement is 3 audit samples per week and the minimum requirement is 1 per week. The first audit sample shall be taken as soon as possible. (NOTE: Where problems with compliance with the Certified Ready Mix Program occur, plant inspections and testing rates shall be increased). The Agency plant monitor will split these samples and provide one-half the sample for the Ready-Mix Producer. The Ready-Mix Producer shall test the split sample as a comparison check with the Agency results. The Ready-Mix Producer shall use their comparison check results as part of their quality control test program. This sample is used in fulfilling the testing rate requirement listed in paragraph one of this section. Plant Monitors shall observe the actual water batched on a minimum of one load of concrete each time a audit gradation is collected. This observation should include watching the ready-mix truck reverse the drum after washing to remove all wash water, check to verify that an accurate moisture test is being utilized during batching, confirm that the water measuring device is providing accurate data and verify that if any additional water is being added to adjust the slump that it is being recorded. It is extremely important that the design water is verified since the durability of the concrete depends on maintaining a low water-cement ratio. Documentation for the above information should be recorded on Mn/DOT form #24143, Weekly Certified Ready Mix Plant Report, and submitted to the Concrete Office with the Weekly Concrete Report (form #2448).

If the gradation tests on split samples from process control or audit samples result in a variation between the Producer and the Agency greater than that set forth below, a new sample will be split and tested by the Producer and witnessed by the Agency Plant Monitor. This will serve as a check on the process and corrections can be made if necessary. If this problem continues, the Project Engineer and Concrete Engineer will make a total review of this plant.

Allowable variations on percent passing any sieve:

Sieve	% Allowed
50 mm - 9.5 mm (2 inch - 3/8 inch)	± 6
4.75 mm - 600 µm(#4 - #30)	± 4
(300 µm) (#50)	± 3
150 µm (#100)	± 2
75 µm (#200)	± 0.6

The ready-mix producer, after an acceptable time period, may request a reduction in testing rates if past results warrant. Such a request is subject to approval by the Concrete Engineer. This approval will be based only on extra-ordinary procedures performed by the aggregate supplier and ready-mix producer to insure consistency and quality control. Extra fractions and bins are an example of such a procedure.

D7e Concrete Plant Contact Report

Prior to the beginning of the project or once per year, an Agency Plant Monitor shall perform a thorough on site inspection of the concrete plant in order to complete a Concrete Plant Contact Report. This Contact Report contains the information necessary to assure that the plant can produce concrete meeting specification, and has a signature block for the ready-mix producer representative certifying that the plant will be maintained in that condition.

D7f Non-Compliance

If a proposed plant cannot produce concrete, perform testing, or report information as required at the time of the Concrete Plant Contact Report, concrete will not be accepted on this project from this plant. Concrete will not be accepted on the Project if: companion verification samples or audit acceptance samples fail to meet requirements; a review of the plant indicates that there may be a cause for concern as to the quality of the concrete; a plant fails to comply with any part of the certification program. If concrete inadvertently is placed in the work, it will be subject to Mn/DOT specification 1512, "Unacceptable and Unauthorized Work". Price deductions shall be determined according to the 'Schedule of Price Reductions for Failing Materials for Concrete, Bituminous and Grading & Base Construction" based on Agency audit samples.

After being allowed to start this project through the Concrete Plant Contact Report, any procedure changes that cause non-compliance with this program, the plant will be Decertified and not allowed to produce further concrete for this project. Decertification will also occur to any plant that continually produces concrete that is in noncompliance as detailed above. Complete disregard of this specification or fraudulent test reports will be grounds for immediate Decertification. Decertification could include any or all, but is not limited to, the following actions:

1) Revocation of Plant Certification.
2) Revocation of Technician Certification for individual(s) involved.
3) Loss of bidding privileges.
4) Criminal prosecution for fraud.

Decertification actions are determined by the Concrete Engineer.

D7g Measurement and Payment

All costs associated with this Certified Ready-Mix Plant Process will be considered incidental for which no direct compensation will be made.

2461.5 MEASUREMENT AND PAYMENT

Only when payment is prescribed under the provisions hereof will the quantity of concrete mixture produced and furnished be measured as a separate item. Then, the volume of fresh concrete will be measured as the computed, theoretic volume based on mass **(weight)** of the batch ingredient. The quantities so determined will be reduced for payment by all accountable waste.

In general, whenever practicable, payment for the concrete mixture used will be made on the basis of structure dimensions as provided for in the detailed Specifications for the item of work involved. In cases where concrete is furnished for incorporation in miscellaneous items for which there is no detailed Specification or Pay item, no direct compensation will be made for the concrete used.

Payment for Concrete of each mix number or grade specified, at the Contract price per unit of measure will be compensation in full for all costs of producing and furnishing the concrete and for all costs of placing, finishing, and curing the concrete as specified, except for such costs that are specifically compensated for under other Contract items.

Payment for concrete will be made on the basis of the following schedule:

Item No.	**Item**	**Unit**
2461.501	Concrete, Mix. No. ___	cubic meter **(cubic yard)**
2461.502	Concrete, Grade ___	cubic meter **(cubic yard)**