Section 2403. Structural Concrete

2403.01 DESCRIPTION.

Portland Cement Concrete used for constructing bridges and other structures. For PCC Pavement, refer to Section 2301.

2403.02 MATERIALS.

A. General.

1. Meet the requirements for the respective items in Division 41.

2. Unless otherwise specified, use Class 2 durability coarse aggregate, or better, as defined in Section 4115.

3. Unless otherwise specified, use the following:
- **a.** Class BR or Class C concrete for bridge barrier rails.
- **b.** Class X concrete for seal courses.
- **c.** Class C concrete for all other structural concrete, including concrete for bridge curbs, bridge medians, and bridge sidewalks. Refer to Article 2412.02 for concrete used for one course bridge floors and the first course of two course bridge floors.

B. Proportions.

1. General.
- **a.** Materials for structural concrete may be mixed in proportions for any of the mixes allowed for the class of concrete specified in the contract documents and the current Materials I.M. 529, provided the gradation of each aggregate conforms to the gradation required for that proportion.
- **b.** The contract documents will indicate where each class shall be used and the approximate quantities of each class.
- **c.** Class D or Class M mixtures may be substituted for Class C proportions, except in bridge floors.

2. Water and Consistency.
- **a.** Place with a slump between 1 and 3 inches (25 and 75 mm) as a target range, allowing a maximum of 4 inches (100 mm) as a tolerance.
- **b.** If the characteristics of the materials used are such that the total quantity of water used (including free water in aggregate) to secure the required consistency reduces, by more than 2%, the batch volume computed on the basis of absolute volumes of the batch quantities used, the proportions may be adjusted accordingly.
- **c.** If the characteristics of the materials used are so that the required consistency is not secured within the specified maximum water content, increase the proportions of cement to aggregate as necessary to secure the required consistency within the specified maximum water content. Additional cement will be considered as incidental, and no additional payment will be allowed. Free moisture

in the aggregate plus the total mixing water shall not exceed that shown in Table 2403.03-1.

Table 2403.03-1: Mixing Water and Free Moisture

Class of Concrete	Pounds (kg) of Water per Pound (kg) of Cementitious Material
C Separated Aggregate	0.488
X Separated Aggregate	0.444
C with Class V Aggregate	0.444
X with Class V Aggregate	0.422
D57	0.437

3. Entrained Air Content.
Use an approved air entraining agent complying with Section 4103 to accomplish air entrainment. Air content will be tested according to Materials I.M. 318. The intended air entrainment is 6%. To allow for loss during placement, use a target value of 6.5%, with a maximum variation of -1.0% and +1.5%, for the air content of fresh, unvibrated structural concrete.

4. Other Admixtures.

a. Other approved admixtures may be used with the Engineer's approval.

b. Approved retarding admixture complying with Section 4103 may be required by the contract documents or by the Engineer. Add the retarding admixture in amounts recommended by the manufacturer for conditions which prevail on the project and as approved by the Engineer. When used, introduce it into the mixer after all other ingredients are in the mixer. The Engineer may approve other procedures.

c. Ensure retarding admixtures are compatible with the air entraining agent used. Previous experience, satisfactory to the Engineer, will be required to indicate the approximate adjustments necessary by the addition of the admixture and compatibility with other materials to be used. Agitate the retarding admixture prior to and during its use.

d. Calcium chloride will not be allowed where reinforcing steel is used.

5. Use of Fly Ash and GGBFS.
The Contractor may use fly ash or GGBFS as a substitute for a portion of the Portland cement in structural concrete. Use fly ash and GGBFS meeting the requirements of Section 4108. The maximum allowable substitution rates are 20% for fly ash and 35% for GGBFS with a maximum total mineral admixture substitution rate of 50%.

C. Proportions for Lightweight Structural Concrete.
When lightweight concrete is specified, the aggregate quality, proportions, mixture characteristics, and controls will be included in the contract documents.

D. Proportioning and Mixing of Concrete.
Apply the respective paragraphs of Article 2301.02, C, to storage and handling of cement, fly ash, aggregates, measurement of materials, and ready mixed concrete, except for the truck dumping area required in Article 2301.02, C, 1, c.

1. Mixing of Materials.
Thoroughly mix materials in an approved mixer at the site of placement or by an approved ready mix plant. The Engineer may withhold approval for using ready mixed concrete from any plant with a previous record of unsatisfactory performance.

2. Concrete Mixed on the Site.
a. When using approved mixers at the site of placement, mix materials according to the specific requirements for the equipment used. Use a mixing capacity so that finishing operations can proceed at a steady pace with final finishing completed before concrete starts its initial set.
b. Ensure concrete discharged from the mixer is uniform in composition and consistency. Thoroughly discharge each batch of concrete from the mixer before the next batch is introduced. Thoroughly clean and flush the mixer upon cessation of mixing for any considerable length of time.

3. Heating Aggregates.
When aggregates are heated, heat and handle them to avoid damage by overheating and to ensure uniform moisture content of aggregate entering the mixer. Aggregates may be heated by steam pipes or coils through aggregate piles. Do not heat aggregates by direct, dry heat unless they are mechanically agitated during the heating process.

2403.03 CONSTRUCTION.

A. Equipment General.
Use equipment meeting the requirements of Section 2001 and the following:

1. Weighing and Proportioning Equipment.
Apply Article 2001.20.

2. Mixing Equipment.
Apply Article 2001.21.

3. Bins.
Apply Article 2001.06.

B. Placing and Finishing Equipment.
Use equipment complying with the following requirements:

1. Above Water or Dry Placement Equipment.
a. Tremies.
When required, use a tremie to deposit concrete in the dry. Use a tremie that:

- Is no more than 12 inches (300 mm) in diameter,
- Has no aluminum parts in contact with the concrete, and
- Is of sufficient length to extend to the bottom of the placement area.

b. Chutes.

Use chutes for depositing concrete that are constructed of metal or have a metal lining, and:

- Have no aluminum in contact with the concrete,
- Are of sufficient length for the delivery point to be as close as possible to the point of deposit, and
- Provide a slope to allow the concrete to flow slowly without segregation.

2. Underwater Placement Equipment.

a. Place concrete under water using a tremie, pump, or other equipment which meets the Engineer's approval.

b. Use a tremie that:

- Is constructed to be water tight and readily discharge concrete,
- Is no more than 12 inches (300 mm) in diameter,
- Has no aluminum parts in contact with concrete,
- Has the discharge end constructed to prevent water intrusion and permit free flow of concrete during placement operations, and
- Is of sufficient weight (mass) and length to rest on the bottom of the placement area prior to start of concrete placement.

c. Support the tremie so that it can be raised or lowered to increase or reduce the discharge of concrete.

3. Consolidation.

a. Use vibrating units to vibrate all concrete for box and arch culverts, bridge substructures, bridge decks, and bridge deck overlays. Operate all vibrators at speeds no less than 3500 vibrations per minute.

b. Furnish adequate vibration equipment to avoid delays due to breakdown.

c. Use a sufficient number of vibrating units to properly consolidate the concrete placed.

d. Use vibrator heads covered with rubber or other resilient material approved for consolidation when consolidating concrete reinforced with epoxy coated bars.

4. Heating and Protection Equipment.

Meet the following requirements whenever heating is done:

a. Equip the attendant with no less than one non-freezing fire extinguisher of adequate capacity.

b. To prevent movement or overturning, adequately support, anchor, and guy any heating equipment involving combustion in or near the space to be heated.

c. Use of a salamander or other type of open flame heating unit is prohibited.

d. Use heating equipment constructed with a shield so that metal in direct contact with the open flame is not exposed.

5. Forms.

a. Use forms that are:

- Metal, surfaced lumber, plywood, masonite, hard pressed composition board, or other approved material backed by suitable studding, walers, and so on, and
- Are free from knotholes, cracks, splits, warps, or other defects which would prevent it from producing the strength, accuracy, and appearance necessary in the finished concrete surface.

b. Construct forms with mortar tight joints. Use material sufficient in strength to hold concrete without bulging between supports.

c. Design forms for strength as specified in Article 2403.03, O. Use metal, plywood, fiberglass, or hard pressed water resistant composition board no less than 3/16 inch (5 mm) thick to line wood forms for all exposed surfaces, except:

- wingwalls parallel to the culvert barrel,
- headwalls, and
- such portions as may be completely covered by a single board.

d. Use forms in good condition. Make joints in the lining mortar tight. Smoothly cut and break joints with the form lumber. Small irregular areas may be formed with lumber against concrete to be rubbed, provided there is no joint in lumber used on any flat surface of concrete except at angles, ribs, bevels, molding, and so on where there is a juncture between two surfaces. Place blocks, ribs, bevels, moldings, and so on for ornamental effect on lined surfaces inside the lining.

e. Design and construct forms so that they may be removed without damage to the concrete. Remove blocks and bracing with the forms. In no case leave any portion of wood forms in the concrete.

f. Construct forms so that the finished concrete is of the form and dimensions shown in the contract documents, and true to line and grade. Fillet forms 3/4 inch (20 mm) at all sharp corners (90 degrees or sharper). Give a draft in the case of all projections, such as girders, copings, and so on, sufficient to insure their easy removal. Ties and bracing shall be sufficient to support the expected load.

g. When forms appear to be insufficiently braced or unsatisfactorily constructed either prior to or during placement of concrete, the Engineer will order the work stopped until defects have been corrected.

h. Coat forms with an approved form release agent prior to the placement of concrete. Thoroughly wet forms with water immediately prior to concrete placement. Thoroughly clean reused forms and ensure they are free of bulges, splits, warps, or bends.

i. Use stay-in-place forms only when specified in the contract documents.

C. Placing Concrete.

1. Place concrete mixed at the site of the work immediately after mixing. Place ready mixed concrete as soon as practical after delivery, but in all cases within the specified time limit for the equipment used for delivery.

2. Place concrete in a manner which will avoid segregation or separation of the ingredients. In placing concrete, observe all the following precautions:

- **a.** In handling concrete from the mixer to the place of deposit, take care to avoid segregation.
- **b.** When concrete is deposited through a chute, slope the chute to allow concrete to flow slowly without segregation. Place the delivery point of the chute as close as possible to the point of deposit. Keep chutes and spouts clean. Thoroughly flush them with water before and after each run. Discharge the water outside the forms. Do not pump concrete through aluminum conduit or tubing.
- **c.** A tremie is not required when filling steel pipe piles or encasing steel H-piles. Use a tremie whenever the distance through which other concrete must be dropped vertically exceeds 6 feet (2 m). Do not exceed a drop of 3 foot (1 m) for bridge floors and culvert slabs. A tremie is not required for concrete placement of elements which have a maximum dimension no greater than 12 inches (300 mm) provided that Paragraph d below is adhered to and concrete is placed in lifts.
- **d.** Do not deposit concrete in large quantities at a single point, causing it to flow along inside the forms.
- **e.** In depositing concrete, take care to fill the form entirely without bulging the form or disturbing its alignment.
- **f.** Manipulate and vibrate concrete in a manner to bring a thick layer of mortar into contact with forms and reinforcement and to prevent formation of pockets of coarse aggregate.
- **g.** Do not place concrete in flowing water within the area of a footing. Control such flowing water in pipes or trenches outside the forms. In extreme cases, a seal course may be ordered to overcome this difficulty.
- **h.** Protect concrete placed when the air temperature is at or below 40°F (4°C) as provided in Article 2403.03, I.

3. Maintain an adequate supply of water suitable for washing testing equipment at a convenient location, as directed by the Engineer, near the site of concrete placing operations.

4. When concrete is being placed during cold weather, provide an approved, conveniently located shelter (enclosed on at least three sides and covered), suitable for use in performing on the site tests of the concrete being placed. Place the shelter to provide maximum protection from the weather.

D. Vibration of Concrete.

1. Manipulate vibrators through all available space in the mass of concrete, with particular attention to corners and faces of concrete against forms and joints. Use caution to prevent the vibrator from penetrating any portion of previously set concrete.

2. Vibrate each batch of concrete as it is placed in the form to settle and thoroughly consolidate the concrete into close contact with the forms, reinforcement, and previously placed concrete. Discontinue vibration before segregation or localized areas of grout form. Ensure placement and consolidating operations result in concrete that, upon removal of forms, is smooth and dense and free from all honeycomb or pockets of segregated aggregate.

3. Design forms to withstand effects of vibration without appreciable distortion from the desired shape or position.

E. Protection and Curing of Concrete.

1. Protect concrete which has been placed from external stress between the time it ceases to be plastic and the time it may be stressed, as provided in Article 2403.03, N.

2. Ensure runways for transporting materials over concrete floors less than 7 calendar days old are supported directly over structural members, piers, or abutments so the floor concrete is subjected to compressive stress only.

3. Ensure runways built over portions of formed, but unpoured floors are supported on floor forms or beams.

4. Unless concrete is protected as specified in Article 2403.03, I, protect exposed surfaces, including surfaces from which forms have been removed less than 60 hours after the concrete has been placed, in the following manner for at least 4 calendar days after concrete is placed:

- **a.** Coat the surface immediately after required finishing operations are completed with white pigmented curing compound, meeting requirements of Article 4105.05, applied at a rate of no more than 135 square feet per gallon (3.3 m^2/L).
- **b.** As alternatives, the surfaces may be covered with paper or plastic film, meeting requirements of Section 4106, or the surface may be covered with burlap, straw, or sand kept continuously wet.

5. Do not use white pigmented curing compound on surfaces against which concrete is to be placed or which will receive a sealer. When the Contractor elects to use white pigmented curing compound on any part of an integral unit, the Engineer may require use of the curing compound on adjacent areas of the integral unit so that each pier, abutment, or other surface visible after construction presents a uniform and pleasing appearance.

6. Cure concrete floors as provided in Article 2412.03, E.

7. Cure barrier railing as provided in Article 2414.03, A.

F. Placing and Protection in Cold Weather.

1. Do not place concrete, without notifying the Engineer, when the air temperature is 40°F (4°C) or less.

2. Do not use frozen materials in the concrete.

3. Do not place concrete against frozen forms, earth, or rock or against other concrete having a temperature below 40°F (4°C).

4. In addition to protecting the concrete against chilling or freezing, heat the water or aggregates, or both, so that when placed the concrete will have a temperature appropriate for the mass and dimensions of the portion of the structure being placed, but from 45°F (7°C) or to 80°F (27°C).

5. Before concrete is placed at ambient air temperatures below 40°F (4°C) or when these temperatures might occur during the protection period, provide heating or protecting facilities, or both, meeting requirements of Article 2403.03, B, 4, adequate to protect the work as follows:

- **a.** Maintain the concrete temperature at no less than 50°F (10°C) for the first 48 hours after placing. Then gradually reduce the concrete temperature at a rate not exceeding 25°F (15°C) in 24 hours. When heating and housing is used, locate temperature monitors in the concrete at the furthest and closest point from the heat source. Do not allow the maximum temperature of the monitor point closest to the heat source to exceed 150°F (65°C).
- **b**. In lieu of protection involving housing and heating, the Contractor may protect concrete by the use of forms insulated with a commercial insulating material adequate to maintain the concrete temperature at no less than 50°F (10°C) for the first 48 hours after placing. Leave these insulated forms undisturbed for the next 48 hours, after which they may be removed. When forms are insulated, protect exposed horizontal surfaces with a similar layer of the insulating material or an adequate layer of hay or straw, properly secured.
- **c.** Make suitable provision, including cast-in-wells for thermometers, to provide a means for determining the temperature of the concrete.
- **d.** Whenever heating is done, firmly secure combustible material to prevent contact with any source of heat, and take adequate precautions to prevent fires.
- **e.** If all the concrete is at least 1 foot (0.3 m) below ground water level, it may be placed at a temperature no less than 40°F (4°C) and flooded to a minimum depth of 1 foot (0.3 m) in lieu of other methods of protection and curing. Ensure that concrete cured in this manner is not subjected to freezing temperatures within 10 calendar days after it is placed. In lieu of flooding, culvert footings

may be protected from freezing by an adequate layer of straw or hay for at least 5 calendar days.

G. Placing Large Volumes of Concrete.
Whenever the volume is too great to be placed in one continuous operation, subdivide the work as shown in the contract documents or as directed by the Engineer.

H. Bonding Construction Joints.

1. When concrete placement in any section of a structure must be interrupted, locate the construction joint as specified in Article 2403.03, O. Leave the surface of the concrete in horizontal joints rough (except in the area near the form) to increase the bond with concrete that is to be placed later. Finish the top surface of the concrete adjacent to the forms to a horizontal 3/4 inch (20 mm) bevel strip.

2. Embed keyways no less than 1 1/2 inches by 3 inches (35 mm by 75 mm) into the surface of the concrete. Form tapered sections, which would otherwise result in a feather edge, by an insert so that the succeeding layer of concrete will end in a section no less than 6 inches (150 mm) thick. In addition to the key notches in concrete that is not reinforced, set steel dowels no smaller than 3/4 inch (20 mm) around the edge of the section at intervals no greater than 2 feet (0.6 m). Set the dowels to project at least 1 foot (0.3 m) on each side of the joint.

I. Bonding New and Old Work.

1. When new concrete is placed in contact with existing concrete, first thoroughly clean the existing concrete surface of laitance, loose particles of concrete, dirt, or other foreign materials by sandblasting followed by an air blast. Next, place forms against the existing concrete, using care to avoid contamination of the cleaned surface. Finally, place fresh concrete against the clean, dry surface and thoroughly consolidate it to ensure a tight joint and a good bond.

2. Bonding agent may be required as specified in the contract documents.

J. Displacing Water with Concrete.
Do not place concrete into or under flowing water. Concrete may be placed in still water only under the following conditions and under the Engineer's supervision.

1. The Contractor may place the concrete starting at a point most removed from the sumps and progressing toward the sumps, shoving and displacing water as the placement progresses if:
- Water courses and sumps are provided outside the area over which concrete is placed, and
- It is demonstrated that the water elevation can be controlled to an elevation at or near the elevation of the bottom of the concrete to

be placed to the extent that no appreciable or objectionable flow crosses said area.

2. Maintain the water elevation within the forms at the start of placing at substantially the same elevation through the pour by bailing or pumping. Direct pumping from inside the forms will not be permitted in excess of the pumping necessary to remove the quantity of water displaced by concrete.

3. The Contractor may slowly displace entrapped water with concrete during placement if:

- There are required excavations or trenches within the area, the bottoms of which are below the general elevation of the area, and
- It is impossible or impractical to provide gravity drainage to the sumps.

4. The Contractor may be required to bail or otherwise dewater the trench immediately prior to or during the placement. A prerequisite to placing concrete in excavations or trenches is that the depth of water shall not appreciably exceed 30% of the depth of concrete being placed.

5. Place seal courses in the following manner if other methods for placement are not provided in the contract documents:

a. When possible, place seal courses in one continuous operation. Place concrete to approximately the required depth. Progress from one end over the entire area in such a manner that the volume of concrete will be gradually expanded without dropping the concrete through water. Minimize agitation. Ensure the surface of the seal course is approximately level. Place sumps or depressions for pumping out the water outside the area of the footing.

b. Place concrete using equipment described in Article 2403.03, B, 2. In operating a tremie, keep the tremie filled at all times. Raise the discharge end only an amount sufficient to permit the concrete to be discharged.

c. When pile encasements are placed by use of a tremie and the bottom of the encasement is below the controlled water level, provide drain holes no less than 1 inch (25 mm) in diameter in the encasement form at intervals of 1 foot, 2 feet, and 3 feet (0.3 m, 0.6 m, and 0.9 m) above the controlled water elevation. Place the concrete in this area at a rate so no free water is entrapped inside the form above the top drain hole.

K. Laitance.

Remove laitance from the surface of seal courses before the footing is placed. Use care in placing other concrete to prevent formation of laitance on the surface of the concrete. Entirely remove laitance by means of shovels, stiff wire brooms, or by other suitable methods before the succeeding layer of concrete is placed.

L. Design and Construction of Forms and Falsework.

1. General.

a. Have a Professional Engineer licensed in the State of Iowa design and certify falsework plans.

b. Materials for forms and falsework may be either new or used. It is the Contractor's responsibility to ensure that materials are suitable for the use intended. Material which the Engineer determines to be damaged, defective, or otherwise unsuitable will be rejected.

c. Design values for lumber and timber vary considerably depending on size and or use, species, and grade. For each type of structural member, list on the falsework plans specifications for the following if known: size or use category, species group, and minimum grade.

2. Construction of Forms.

a. Use materials, and construct forms that will be in direct contact with concrete, as specified in Article 2403.03, B.

b. For wall or column forms, use studs, wales, and ties designed to withstand the maximum fluid pressure discussed below.

c. Use prefabricated form systems certified for the expected pressures.

d. Guy, shore, and/or brace forms for walls and columns to withstand wind loads and to prevent alignment shift resulting from construction live load.

3. Construction of Falsework.

a. Build falsework used to support construction of reinforced concrete superstructures, reinforced beams, and substructure cantilevers, on sufficiently strong foundations to carry the loads safely and without significant deflection. Drive ample falsework piling to support falsework which cannot be founded on rock, shale, thick deposits of compact gravels, coarse sand, or the firm clays in natural beds. On the soils materials listed above, mudsills or other spread footings may be used. Determine their sizes considering the applied loads and the bearing value of the soil.

b. Determine bearing values of all piles used to support falsework as provided in Section 2501. Bearing values are to be at least equal to the applied loads.

c. To ensure stability for pile bents 10 feet (3 m) or less in height that are not sway braced, show pile type, size, and minimum embedment length on plans. Transversely sway brace pile bents exceeding 10 feet (3 m) in height to resist lateral loads. Longitudinally brace pile bents exceeding 10 feet (3 m) in height to resist construction live loads, unless the bents are secured to longitudinal members which are secured against longitudinal movement. Bracing and connections are to be shown on falsework plans. The Engineer will review adequacy of bracing and connections.

d. Secure pile caps to each pile. Ensure blocks, wedges, and jacks for height adjustment are secure and stable. The Engineer will review them before concrete placement. Hold transverse joists against

individual collapse. Use a positive spreader system over each support of a longitudinal stringer.

e. Secure continuous members against uplift from unbalanced concrete placement. Place concrete in a manner which will minimize unequal loads on hanger legs.

4. Design Loads.

Design formwork and falsework for the following loads:

a. Vertical load of concrete with a density of 150 pounds per cubic foot (2400 kg/m^3).

b. Horizontal load of fresh concrete as a liquid with a density of 150 pounds per cubic foot (2400 kg/m^3) for the depth of plastic concrete, except when lesser pressures are permitted by AASHTO Guide Design Specifications for Temporary Works.

c. Vertical dead load of forms and falsework.

d. Vertical dead load of rail and walkway applied at edge of deck form equal to 75 pounds per linear foot (1.1 kN/m)

~~**d**~~**e.** Construction live load equal to 50 pounds per square foot (2.4 kPa) of horizontal projection.

f . Live load equal to 6 kips (26.69 kN) of finishing machine located along the edge of the deck form to maximize the design condition.

~~**e**~~**g.** Wind loads ~~on walls and columns according to the requirements of the ACI~~ equal to 50 pounds per square foot (24 kPa) for elevations to 30 feet (10 m) above the ground, increased for elevations above 30 feet (10 m).

h. Other applicable loads such as horizontal loads due to equipment or construction sequence, additional live load, impact, stream flow, and snow loads specified in AASHTO Guide Design Specification for Bridge Temporary Works.

5. Design Stresses.

a. Design formwork and falsework using load groups specified in AASHTO Guide Design Specifications for Bridge Temporary Works and material working stresses ~~and a normal duration of load, as for a permanent structure~~. For structural steel and reinforced concrete use the allowable stress percentages given with load groups. For lumber and timber use appropriate load and duration factors instead of percentages. Calculate lumber strength on the basis of dressed size ~~and, except for sheathing, a dry condition~~.
Publications of the APA – The Engineered Wood Association, ACI, and the ~~National Forest Products Association~~ American Forest & Paper Association, American Wood Council will be considered standard references for design and analysis of plywood, lumber, and timber formwork and falsework.

b. Do not exceed 50 times the dimension of the least side for the unsupported length of wood~~en~~ columns and compression members. ~~Analyze the member as a column.~~

c. Unless the Contractor certifies a higher stress grade or value as allowed by AASHTO Guide Design Specification for Temporary Works, adequacy of falsework material will be ~~checked~~ reviewed on the basis of the following values:

1) Structural steel stresses ~~per AASHTO~~ for ~~30,000~~ 36,000 psi (~~207~~ 248 MPa) yield strength and ~~22,500~~ 22,000 psi (~~155~~ 151 MPa) maximum working stress.

2) Plywood sheathing stresses per ~~American Plywood Association~~ APA – The Engineered Wood Association for ~~concrete form grade~~ Plyform, Class I, wet use, ~~permanent loading~~ 7 day duration of load, span-perpendicular-to-face grain. Orientation of plywood panels must be shown on drawings if advantage is taken of greater strength with span-parallel-to-face grain.

3) ~~Stresses~~ Design values for lumber in good condition and 4 inches (100 mm) or less in thickness, in psi (MPa) as follows:

f_b, bending	= ~~1000~~ 875 (~~6.90~~ 6.03)
f_t, tension	= ~~625~~ 450 (~~4.30~~ 3.10)
f_v, shear	= ~~120~~ 135 (~~0.83~~ 0.93)
f_c, perpendicular to grain	= ~~345~~ 425 (~~2.40~~ 2.93)
f_c, parallel to grain	= ~~1050~~ 1150 (~~7.20~~ 7.93)
E, modulus	= ~~1,500,000~~ 1,400,000 (~~10,300~~ 9650)

These design values are to be modified for seven-day duration of load (except for fc, perpendicular to grain and E, modulus) and other applicable adjustment factors when determining allowable stresses.

4) ~~Stresses~~ Design values for lumber in good condition and 5 inches (125 mm) thick and thicker in psi (~~MPs~~ MPa) as follows:

f_b, bending	= ~~1200~~ 850 (~~8.30~~ 5.86)
f_t, tension	= ~~1000~~ 450 (~~6.90~~ 3.10)
f_v, shear	= ~~120~~ 125 (~~0.83~~ 0.86)
f_c, perpendicular to grain	= ~~390~~ 425 (~~2.70~~ 2.93)
f_c, parallel to grain	= ~~1000~~ 625 (~~6.90~~ 4.31)
E, modulus	= ~~1,600,000~~ 1,300,000 (~~11,000~~ 8960)

These design values are to be modified for seven-day duration of load (except for fc, perpendicular to grain and E, modulus) and other applicable adjustment factors when determining allowable stresses.

5) Safe bearing value of coarse sand, gravel, very firm clay, and other similar confined soils in thick beds at 1500 pounds per square foot (72 kPa) unless recommended otherwise by a Professional Engineer licensed in the State of Iowa. Safe bearing value of compacted berms at 2000 pounds per square foot (96 kPa).

6. Deflection.

a. Ensure falsework for slab and girder bridges provides for slight settlements, deformations of members, crushing, and closing of joints. Sag in excess of 1 inch (25 mm) or 1/800 of the span length, whichever is greater, in the soffit of a girder or slab may be cause for rejection.

b. Limit deflection of sheathing and joists to 1/360 of the span length. Calculate deflection of falsework stringers. Adjust screed guides to compensate.

7. Falsework Plans.

a. Submit plans for falsework and centering on all concrete slab and cast-in-place concrete girder bridges according to Article 1105.03. Submittal of forming details for bridge decks on concrete beam and steel beam bridges is not required unless specified in the contract documents.

b. The Engineer may require calculations or evidence of adequacy. The Engineer may require revised plans later because of unforeseen site conditions, unusual construction procedures, or deviation from original falsework plans.

M. Removal of Forms and Falsework.

Remove forms and falsework, unless otherwise indicated in the contract documents. Normally, they may normally be removed according to the following provisions. However, in cool or unfavorable weather, the Engineer may require forms to remain in place for longer periods.

1. Forms Which May be Removed in Less than 5 Calendar Days.

a. Forms for ornamental work, railings, parapets, curbs, and any other vertical surfaces may be removed whenever the concrete will not be damaged by doing so, but no less than 12 hours after the concrete is placed.

b. Do not remove forms for concrete open railing less than 24 hours after concrete placement.

c. Forms for roofs of culverts may be removed when the concrete has attained an age of 3 calendar days and a flexural strength of:

- 350 psi (2.4 MPa) for spans of 4 feet (1.2 m) or less,
- 400 psi (2.8 MPa) for spans 4 to 6 feet (1.2 m to 1.8 m), and
- 450 psi (3.1 MPa) for spans exceeding 6 feet (1.8 m).

d. When Maturity Method (according to Materials I.M. 383) for strength determination is used, the above stated flexural strengths will be required. The days of age will depend on the Maturity Curve for the concrete mix used.

2. Forms Which Shall Remain in Place 5 Calendar Days or Longer.

a. Except when form removal is permitted in less than 5 calendar days, forms may be removed as soon after 5 calendar days as the concrete has attained the strength required in Article 2403.03, N, 2. When Maturity Method (according to Materials I.M. 383) for strength determination is used, the flexural strength of 550 psi (3.8 MPa) will be required. The days of age will depend on the Maturity Curve for the concrete mix used.

b. When strength is not determined, forms for box culverts 4 feet (1.2 m) or less in width may be removed after the concrete has attained an age of 7 calendar days. Forms for other concrete may be removed after the concrete has attained an age of 14 calendar days.

c. Remove forms and supporting falsework for continuous concrete slabs, concrete girders, and rigid frame structures in the following manner:

Ensure there is at least one span for which the concrete has attained the age (or age and strength) specified above between the span from which forms are about to be removed and any span for which the concrete has not attained the age (or age and strength) specified above.

3. Falsework and Falsework Piling.

Remove falsework and falsework piling in the berm slope fill, extended to the streambed, to at least 1 foot (0.3 m) below the finished berm line or berm line extended. For falsework and falsework piling in the channel area:

a. For structures spanning natural streams or overflow channels of natural streams, removal to at least 1 foot (0.3 m) below streambed elevation will be required.

b. For structures spanning drainage channels constructed under the drainage laws of Iowa, removal to at least 4 feet (1.2 m) below streambed elevation will be required unless complete removal is specified.

N. Subjecting Concrete to Exterior Loads.

Concrete may not be subjected to loads other than the load caused by the weight (mass) of the concrete itself except as follows:

1. Loads Producing Simple Compressive Stress Only.

Concrete may be subjected to simple compressive stress as soon as it sets sufficiently to prevent the surface being marred or the edges being chipped from the effect of such loads.

2. Loads Producing Flexural Stresses.

a. Unless otherwise indicated in the contract documents, concrete may be subjected to loads due to placing backfill material or to legal traffic when the concrete has reached the minimum age stipulated in Table 2403.03-2 and developed a flexural strength of at least 550 psi (3.8 MPa).

Table 2403.03-2: Minimum Age for Concrete

Portland cement (Type I and Type II with or without Class C fly ash)	7 calendar days
With Class F fly ash substitution	8 calendar days
Class M mix (with or without Class C or Class F fly ash)	3 calendar days
If strength is not determined (regardless of type of cement or class of fly ash)	14 calendar days

b. Determine flexural strength by testing (according to Materials I.M. 316) specimens of concrete used in the part of the structure in question, cured under conditions similar to those of the concrete in the structure.

c. Footings for piers supported by piling may be subjected to loads of subsequent pier stem concrete placement no less than 18 hours after footing placement is complete, with no minimum strength requirements.

d. Unless otherwise specified in the contract documents, the Contractor may request, the time for subjecting to loads to be determined through the use of the Maturity Method as described in Materials I.M. 383. When the Maturity Method is used, the time for loading will be based on strength requirements only, as specified above. Furnish labor, equipment, and materials necessary for the development of the maturity-strength relationship as described in Materials I.M. 383.

e. Determining sufficient strength has been achieved for loading a part of a structure remains the Engineer's responsibility when the Maturity Method is used. The Contractor's maturity testing may be used as the basis for this determination. Provide sufficient documentation of maturity testing before loading a part of a structure or opening to traffic.

f. Apply the following when the Maturity Method is used:

1) Should circumstances arise beyond the Contractor's or Engineer's control and strength cannot be determined by the Maturity Method, the minimum age, minimum flexural strength, and fly ash restrictions apply. Cure flexural strength specimens under conditions similar to those of the concrete in the structure.

2) Any changes of a material source or proportion in the concrete mixture require a new maturity curve.

O. Joints.

Unless otherwise provided in the contract documents, construct joints in the following manner:

1. Construction Joints.

a. Place construction joints between successive layers of concrete as provided in Article 2403.03, K.

b. The location of required or optional construction joints in the structure will be shown in the contract documents. If the volume of concrete is too great to be placed without use of additional construction joints, locate and construct these joints in a manner not impairing the strength and appearance of the structure.

c. Locate construction joints in planes perpendicular to principal lines of stress and at points the Engineer designates.

2. Expansion Joints.
Construct expansion joints as shown in the contract documents.

P. Surface Finish.
Finish and seal concrete surfaces exposed, or will likely be exposed, after the structure is completed as follows:

1. Finish concrete floors and concrete sidewalks as provided in Sections 2412, 2413, and 2511.

2. Provide a Class 1, finish to horizontal surfaces not cast against a form and not subject to wear (for example, bridge seats, tops of backwalls, piers, abutments, wingwalls, retaining walls, spandrel walls, struts between pedestal piers, and horizontal surfaces of curbs and sidewalks of the bridge). For all other surfaces required to be finished, provide a Class 2, finish to low water line or 1 foot (0.3 m) below the finished ground line. Provide a Class 3, finish to those areas designated in the contract documents.

a. Class 1, Floated Surface Finish.
Overfill forms with concrete. Strike off concrete to the required elevation with a template and thoroughly work the surface with a wood float until the surface is uniformly smooth, dense, and true.

b. Class 2, Strip Down Surface Finish.
Immediately after removal of the forms, complete the following:

1) Remove rods and other devices used as form ties to the extent contemplated in their design.

2) Remove paper or fiber tubes used to facilitate removal of rod ties.

3) Except as designated below, cut off wires used as form ties flush with the surface of the concrete and drive them 1/4 inch (5 mm) below the surface.

4) Remove all fins and irregular projections from the concrete surfaces required to be finished.

5) On surfaces, thoroughly clean the cavities produced by form ties and all other holes, honeycomb spots, and broken corners and edges. After being saturated with water, carefully fill, point, and true with a mortar of cement and fine aggregate of the same kind as that which was used in the concrete being finished. Shallow voids, other than honeycomb, which appear on the formed surface after proper consolidation will not be considered as holes and need not be filled unless they appear in an abnormal concentration.

6) Clean the entire surface required to be finished of stains from form oil or other substances.

7) Ensure the resulting surfaces are true and uniform.
8) Clip off flush with the surface wire ties or reinforcing steel chairs protruding through culvert barrels or the bottom of bridge floors.
9) Leave construction and expansion joints in the completed work carefully tooled and free from mortar and concrete.
10) Leave expansion joint filler exposed for its full length and thickness and with clean true edges.

c. **Class 3, Special Surface Finish.**
This operation shall obtain a surface reasonably smooth and uniform in texture and appearance.
1) Apply a bonding agent mixed with standard or commercially packaged mortar. More than one application may be necessary. Products approved for this use are identified in Materials I.M. 491.10. Use the same materials and methods for all surfaces to be given a Class 3 finish.
2) The Class 3 finish requirements do not relieve the Contractor of the responsibility for performing the Class 2 finish as specified prior to commencing Class 3 finish operations.
3) Do not commence application of the Class 3 finish until:
- All other work which may mar the surface finish has been completed, or
- Finishing operations can be carried on continuously from beginning to completion on any one bridge or structure.

3. **Concrete Sealer.**
a. Use sealer material meeting the requirements of Article 4139.01, B, when designated in the contract documents.
b. The contract documents may designate a sealer for the bridge seat surface or tops of piers or both. This surface includes bridge seat steps and edge fillets. The contract documents or the Engineer may also designate other concrete surfaces to be sealed.
c. All surfaces to be sealed shall be sound, clean, and dry. For existing surfaces, the Engineer may require removal of unsound material by hand methods or sandblasting, or both. As a minimum, all designated surfaces, both existing and new, shall receive a light sandblast (brush blast), followed by air cleaning. Clean sufficiently to remove road film and contamination from existing concrete and form oil from new concrete.
d. Perform application procedures according to the manufacturer's recommendations. Unless otherwise required in the contract documents, apply sealer material at the coverage rates in Materials I.M. 491.12.

2403.04 METHOD OF MEASUREMENT.
Measurement will be as follows:

A. Structural Concrete:

1. Quantity shown in the contract documents.

2. The Engineer will compute in cubic yards (cubic meters) the total volume of the respective classes of structural concrete placed using dimensions shown in the contract documents, along with the changes that have been made according to a written order from the Engineer. From this volume, 0.8 cubic foot (0.075 m^3) will be deducted for each linear foot (meter) of concrete, steel shell, or wood piling projecting into the footings or caps. Deductions from the volume of concrete will not be made for the volume of concrete displaced by the steel reinforcement, floor drains, expansion joints, shear lugs, beam flanges, H-piles, or metal strips for sealing joints.

3. Additional concrete required to bring floors, curbs, and handrails to the required elevation will not be measured for payment if such addition is made necessary by inaccuracies in the shape or placement of steel or concrete beams or by distortion of falsework.

B. Reinforcing Steel and Structural Steel: according to Sections 2404 and 2408, respectively.

C. The surface area on which concrete sealer is applied to structural concrete: not measured separately for payment.

D. Subdrains, porous backfill material, and granular backfill material required and furnished for structural concrete placement at bridge abutments: not measured separately for payment.

2403.05 BASIS OF PAYMENT.

Payment will be as follows:

A. Net volume of Structural Concrete as specified above:

1. Contract unit price per cubic yard (cubic meter).

2. For concrete placed within the contract period between November 15 and April 1, additional payment will be made for heating or protecting or both; however, no payment will be made when winter work is specified in the contract documents.

3. Payment for heating will be made when materials which are proportioned and mixed at the site are heated to meet requirements of Article 2403.03, F, or when heating is charged by the supplier of ready mixed concrete. For concrete proportioned and mixed at the site, the additional payment for heating will be $5.00 per cubic yard ($6.60 per cubic meter). For ready mixed concrete, the additional payment for heating will be the customary amount charged for heating, and separately identified on the invoice, with a maximum of $5.00 per cubic yard ($6.60 per cubic meter). Heating, protection, or both, required outside the above dates, will be paid for when approved by the Engineer.

4. Payment for protection will be made when heated housing or insulated forms are used to meet requirements of Article 2403.03, I. The

additional payment for protection will be $7.00 per cubic yard ($9.25 per cubic meter). If a footing is protected by flooding with water, no payment will be made. If footings are protected with coverings of burlap, hay, straw, plastic, insulation, and/or other materials sufficient to meet the temperatures and time specified in Article 2403.03, I, payment for protection will be made.

B. Reinforcing Steel and Structural Steel: according to Sections 2404 and 2408, respectively.

C. Concrete sealer application to structural concrete: included in the contract unit price for structural concrete.

D. Subdrains, porous backfill material, and granular backfill material required and furnished for structural concrete placement at bridge abutments: included in the contract unit price for the structural concrete.

E. When an admixture is required to be added by the contract documents or the Engineer for the purpose of retarding the set, the cost of the retarding admixture is incidental to the contract unit price per cubic yard (cubic meter) of structural concrete

F. Payment is full compensation for:

- Furnishing all materials, including materials for filling and sealing joints, but not including structural steel or steel reinforcement.
- Furnishing, constructing, and removing all forms, ties, and falsework.
- Incidental work necessary for completion of the work in conformance with the contract documents.

G. Heating frozen soil or protecting soil from freezing, or both, prior to concrete placement is incidental regardless of winter work being specified on the contract documents.