CONCRETE BRIDGE CONSTRUCTION
5-393.350

5-393.351 PREPARATIONS FOR CONCRETE PLACEMENT

Well in advance of each concrete placement, the inspector should review the operations and be assured that nothing has been overlooked that may influence the success of the proposed pour. In general, this review should be made with the Contractor. The Contractor is the responsible party and should give the orders for any corrections or preparations necessary. The review should include items contained in the following list, some of which may have been made before the initial placement.

1. The time of day that the placement is to be started should be determined and the completion time estimated.

2. Approved concrete materials in quantities adequate to complete the placement must be available. The aggregates must be approved, cement must be the proper brand and either approved or sampled according to the Concrete Manual. A small quantity of the air entraining agent, retarder or other admixture used should be available at the bridge site when Type 3 (air-entrained) concrete is mixed away from the site.

3. Time-settlement delays after embankment construction at abutments or piers may be required by the Special Provisions. A check should be made to ensure that any such requirements are fulfilled prior to footing placements. In addition, the soil must be compacted as required in Specification 2451.3 B, C and D for all spread footings placed on soil; this includes footings on natural soil as well as footings on embankments.

4. Pumps, with sumps outside the formed area, should be provided when necessary to keep footing areas dewatered. The water level must be kept below the bottom of the proposed pour for succeeding casts. All concrete, except concrete seals, should be placed "in the dry" except as permitted by Plan or Special Provision.

5. Concrete mixing equipment should be checked as required in 5-694.400 of the Concrete Manual.

6. The concrete delivery or production rate should be coordinated with the rate of placement permitted by the form plans or coordinated with a rate of placement that will permit proper finishing with available personnel and equipment. The Special Provisions may require a minimum rate of placement for placements of large seals, decks or piers. In this case, equipment and personnel must be available and the forms must be designed so that the minimum rate of placement can be maintained.

7. The rate of delivery should be fairly uniform. Ready-mix trucks should be scheduled to leave the plant at spaced intervals, not in groups. A check should be made on the cubic yards required up to the cut-off point when a delay is required in concrete placement. An example might be the top of pier columns when the pier cap is to be placed monolithically with the columns. The extent of the delay period will depend on the setting time of the concrete and the rate of pour. The minimum delay period of one hour, required by Specifications should be scheduled for hot weather and a slow to medium (up to 1.5 m per hour) rate of pour. A maximum delay period of 1 1/2 hours should be used for higher rates of pour and/or lower temperatures. The purpose of this delay is to permit maximum water release and consolidation of the concrete in the columns or walls prior to placement of concrete in the cap.

8. The use of concrete additives such as retarders for deck placements and Type III cement for cold weather placements should be discussed with the Concrete Engineer. All admixtures including air entraining must be approved.

9. Placing equipment should be reviewed to ensure that proper methods of placing are used. The possibility of a break-down in placement equipment should be discussed, as well as the availability of replacement equipment. If concrete is being placed for a critical falsework design (slab span, box girder, rigid frame or concrete arch) by means of a pump, the contractor may be required by the engineer to have a standby pump at the site.

10. Approved finishing tools and equipment must be provided. Strike-offs must have the proper crown or straightness. Longitudinal floats and straightedges must be true. The necessity for small tools such as darbies, hand floats, trowels, edgers and brooms, together with bridges to work from, must not be overlooked. Lack of an edger or specified radius for curbs and sidewalks can be very troublesome, and edgers are almost impossible to improvise on short notice. Edgers should be long enough and wide enough to permit slight variations in pressure without causing dips and gouges.

11. The number of concrete finishers necessary should be discussed, since this directly affects the rate of finishing.

12. When finishing must be done in poorly windowed housing, or it is anticipated that finishing may be required at night, adequate artificial lighting should be provided.

13. Procedures to follow in case of rainfall before the concrete has set up should be discussed with the Contractor. Deck slabs should be given careful consideration due to the large area that may be exposed and the extensive damage that may result from running water. Plastic sheeting or other protective covering should be on hand at the bridge site.

14. Curing materials (burlap, plastic curing blankets, etc.) should be at the site in sufficient quantity to cover the placement. It is very difficult to adequately seal concrete with curing blankets when dowels or other reinforcement bars project from the surface. It may be necessary to arrange to cure such areas with wet burlap.

15. When temperatures below 4EC (40EF) are anticipated or can be expected before completion of curing, cold weather protection materials should be at the jobsite prior to placement. Requirements for cold weather protection are given in Specification 2401.3C2. Arrangements should be made to preheat the forms, reinforcement bars and abutting concrete surfaces when they have been subjected to freezing temperatures. Required curing and the need for form insulation or housing and heating should be discussed. Unformed upper surfaces must be protected during finishing operations until the concrete is set up enough to bear the upper insulating material. Heat applied directly to fresh concrete must be provided by vented heaters. Combustion products from unvented heaters cause a weak layer of calcium carbonate on the surface of the concrete that interferes with cement hydration. The result is a soft, chalky surface that dusts off under traffic.

16. The need for taking control test cylinders should be considered and discussed with the Contractor. These cylinders would be in addition to cylinders required for acceptance of materials. Control cylinders are normally used when cold weather curing is anticipated. See Specification 2401.3G for further details.

17. A water supply for wetting forms and providing a fog spray should be discussed with the Contractor. The need for fog spray nozzles at the jobsite should be pointed out at that discussion.

Specification 2461.4A states that concrete production shall not be started until the Engineer has approved all preparations for concrete placement. The following items should be carefully checked during the pre-placement inspection.

1. The forms should be checked for conformance with the Plan dimensions, elevations and alignment. Surveying instruments are often necessary for checking the alignment or elevations of forms. Form lines should always be checked visually, but a blind dependence should not be placed on them. Chamfer or cove strips should be checked for location, size, warping and adequate nailing every 150 mm to 200 mm (6-8 inches). Forms and falsework plans should also be checked to see that the construction conforms to the approved Plans. It is assumed that the size, spacing and materials used have been checked for compliance with the approved form plans, and that any changes necessary have been made during construction. See Section 5-393.250 of this manual for inspection of reinforcement bars, mesh, etc.

2. Panel forms for substructure units should be treated with an approved form release agent before erection. Forms for deck slabs should be treated in advance of placing reinforcement bars. The removable portion of form bolts should be coated before placing to facilitate removal. A resin-coated form-grade plywood is available, which is said to be non-staining.

3. The face of the forms that will be in contact with concrete should be clean and all debris removed from within the forms. This may require that openings be cut through the form near the bottom, the debris removed, and the opening closed. On deck slabs, flushing the forms with water to move the debris to several central locations for removal is an excellent method of cleaning within the forms. The inspector should pay particular attention to see that paper, chips, sawdust, etc., are removed from "hard to get" locations. Industrial type vacuum cleaners or compressed air blowers are useful at such locations. A magnet tied to the end of a rod can be used for picking up metal objects such as nails and wires.

4. Deck slab forms usually take some time to construct. Wood forms that were constructed tightly may shrink, especially during hot weather, and develop openings through which mortar may leak. Thoroughly flushing the forms a day in advance of pouring will usually tighten up the forms. (Note: Flushing with water for cleaning or tightening the forms is, in addition to the Specification requirement for flushing immediately in advance of concrete placement). A close inspection should be made for holes or cracks through which mortar may leak. On steel beam spans with stools (haunches), the wedges holding the sheathing tightly against the underside of the beam flange should be checked and snugged up. Holes in vertical forms may be plugged with a piece of cork cut flush with the face of the form in contact with concrete. Holes or cracks in the forms for the underside of deck slabs may be covered with tin nailed in place. Covering holes with tin on vertical forms, where the concrete will be exposed to view, is not advisable as the slight depression will show up and a concrete patch will not adhere in such a shallow depression. Adjacent sheets of plyform sheathing or other form lining on vertical forms must be close fitting with smooth joints. If the joints are not close fitting, the crack should be filled with a non-staining putty or other suitable material to reduce the amount of ordinary surface finish work.

5. All reinforcement, inserts, anchorages and sleeves which are to be cast in should be checked for proper positioning, projection and minimum concrete cover.

6. Expansion devices should be carefully adjusted as discussed under Section 5-393.370 of this manual.

7. When temporary wood spreaders are used within vertical forms, a wire tied around the spreader and extending to

the top of the form may prevent them from being inadvertently cast into the concrete.

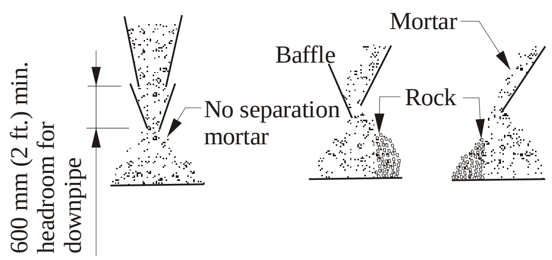
8. Slipforming equipment should be given a "dry run" to ensure clearance and minimum concrete cover over reinforcement.

5-393.352 CONCRETE PLACEMENT EQUIPMENT

Chutes

Chutes are constructed of metal in a semicircular shape or of wood in a rectangular shape. They should be mortar tight. Aluminum chutes should never be permitted since the coarse aggregate will wear off particles of aluminum and cause gassing in the concrete mix.

The amount of segregation in concrete discharged from a chute will increase as the length and slope of the chute increases. No definite rule can be laid down as to the length and slope of a straight chute that may be used without segregation. The slope is usually 1 vertical to 2 or 2 1/2 horizontal. The important thing for the inspector to remember is that, if segregation is apparent in chutes, baffles must be installed or shorter chutes that reverse the direction of the flow of concrete must be used. These corrections will slow down the coarse aggregate and permit the mortar to "catch up."



CORRECT
The above arrangement prevents segregation, no matter how long the chute. Whether concrete is being discharged into hoppers, buckets, trucks, or forms.

INCORRECT
Improper or lack of control at end of any concrete chute, no matter how short. Usually a baffle merely changes the direction of segregation.

Control Of Concrete Segregation At The End Of Chutes

At the end of a chute the coarse aggregate will discharge ahead of the mortar and segregation will result. The segregation is aggravated where the concrete hits the side of a form or mat of reinforcement bars. For this reason, if segregation is evident, the direction of discharge of concrete into the forms must change to vertical by means of a baffle or a hopper with a short length of downspout. The most satisfactory method of ensuring a vertical drop is by passing the concrete through a short section of pipe. Baffle plates are not always satisfactory as sometimes they merely change the direction of separation. This may apply to sloping discharges from mixers and truck mixers, as well as longer chutes. It does not apply when concrete is discharged into another chute or onto a conveyor belt. See the following sketch from an American Concrete Institute publication.

Chutes normally carried with ready mix trucks to discharge concrete are classified as short chutes. There is some segregation associated with their use and the segregation increases as the chute angle increases. When the concrete is chuted directly into forms, baffles or hoppers may be necessary to change the direction of the flow to prevent segregation. When ready-mix trucks are used to discharge concrete into deck slab or sidewalk forms, the chute should be moved in as large an arc as possible when discharging to minimize segregation. See Concrete Manual 5-694.622.

Downspouts

Downspouts are sometimes referred to as "drop chutes" when made of metal or as "elephant trunks" when made of rubber.

Nominal diameters vary from 200 mm to 400 mm (8 to 16 inches). Commonly used downspouts are made of sheet metal and are constructed in sections. Each section usually makes a downspout 1.3 m (4 feet) long. The sections are made in the shape of a truncated cone and are placed with the smaller end down. Hooks and chains are provided to hold the sections together. Each lower section overlaps the upper section and is suspended from it. A steel hopper completes the upper end of the downspout. This hopper is usually constructed with a short section of downspout into which the concrete is discharged.

With the hopper resting on a suitable framework on top of the form, the downspout is constructed initially to a length such that the lower end will be 1.3 m (4 feet) or less from the bottom of the concrete. As the concrete level approaches the end of the downspout, a 1.3 m (4 feet) section is removed and this procedure is repeated until the concrete level is 1.3 m (4 feet) or less from the finished surface, at which time the spout and hopper may be removed.

When large areas of concrete such as walls are being poured through downspouts, better results will be obtained if a number of downspouts are provided. The concrete can then be maintained approximately level by depositing a small amount of concrete in each spout successively rather than using one downspout and moving it from one location to another to maintain level lifts of 300 mm (1 foot) or less.

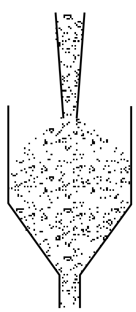
A downspout in each column of a pier in which the cap is cast monolithic with the columns is preferred. Equal lifts of concrete can then be placed alternately in each column with several advantages: the overall rate of pour is faster (the rate must not exceed the rate for which the forms were designed); the degree of set is practically the same for each column when the concrete level reaches the tops of the columns at the start of the delay period; and the forms may be maintained in better alignment.

In some cases, due to the location of the reinforcement bars or the limited space between forms, downspouts cannot be used. In these cases, it may be necessary to cut a series of openings in the back side of the form to place the concrete. The openings are closed when the concrete level approaches the bottom of the opening and the procedure is repeated to the next higher level.

Concrete Buckets

Concrete buckets are used as a crane attachment to transport concrete from one location or level to another. The size commonly used on bridge work vary from 0.5 cubic meters capacity up to 1.5 cubic meters (0.65 to 2.0 cubic yards). They are constructed with manually operated discharge gates. The rate of discharge may be varied by manually varying the gate opening which discharges the concrete.

Concrete buckets are usually designed to be self-cleaning but the inspector should check the bucket occasionally to see that it is clean and that there is no progressive build-up of mortar in the bucket. It is necessary to rest the bucket on a sheet of plywood or other material when it is being filled to prevent contamination with dirt. Concrete buckets should be filled as shown in the sketch below taken from an American Concrete Institute publication.



CORRECT
Dropping of concrete directly over gate opening.

INCORRECT
Dropping of concrete on sloping sides of bucket.

Filling Concrete Bucket

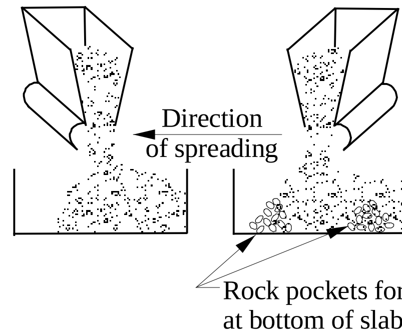
A temporary expedient which can be used if segregation has not been eliminated in filling buckets is shown in the following sketch, taken from an American Concrete Institute publication. Correction in filling the bucket should be made as soon as possible to eliminate the segregation.

Most concrete buckets are designed to handle concrete of the consistency normally used on bridge work. If concrete of specified slump cannot be properly discharged from the bucket used, the bucket, rather than the slump, should be changed.

The discharge gate should not be suddenly opened to full width, but should gradually be opened and the discharge controlled to prevent excessive impact on the forms. Discharging a 2 cubic meter (2.6 cy) bucket suddenly would drop approximately 5 metric tons (5.5 tons) of concrete into the forms. In addition, the bucket should be as close to the forms as possible to reduce the impact from dropping the concrete.

Pump Placement

The modern mobile pump with hydraulic placing boom is economical to use in placing both large and small quantities of concrete. These units are used to convey concrete directly from a truck unloading point to the concrete placement area.



CORRECT
Turn bucket so that separated rock falls on concrete where it may be readily worked into mass.

INCORRECT
Dumping so that free rock falls out on forms or subgrade.

Temporary Expedient

Typically, pumps are initially flushed with a thin water/cement paste mixture to coat the lines. This slurry must be wasted and the lines charged with the project mix before beginning. Observe and be sure initial pump charge is thoroughly removed from the pipelines. Other points to watch for include:

1. Always pump at a constant rate and keep pipelines full of concrete. High air loss can occur when concrete is allowed to free-fall inside pump lines.

2. Avoid, if at all possible, having steep angles in the pump pipelines. Steep angles and slow placement rates are probably the worst conditions for minimizing air loss and segregation.

When using pumps, concrete should not be pumped through aluminum pipe. Aluminum can be eroded by the moving concrete in sufficient quantity to cause a reaction between it and the lime in the cement which leads to the generation of hydrogen. This has the same effect as excessive air entrainment and the strength of the concrete may be drastically reduced. Problems arise in the adverse reaction of concrete with aluminum, not from the placement of concrete with pumps. All samples should be taken at the discharge end. Concrete for test cylinders should also be collected at the discharge end.

For additional information on pumping see "Pumpcrete", 5-694.624 in the Concrete Manual.

Concrete Buggies
There are two types of buggies used for placing concrete. They are commonly referred to as hand buggies and power buggies.

1. Hand buggies are two wheeled with rubber tires and have capacities of approximately 0.2 cubic meters (0.25 cy). They are pushed and dumped manually.

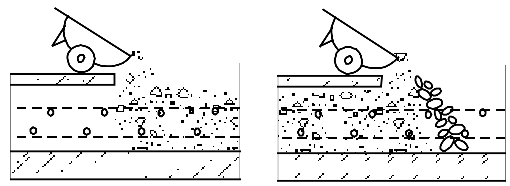
2. Power buggies are usually three or four wheeled, with rubber tires, and capacities vary from 0.3 cubic meters to 0.7 cubic meters (0.4 to 1.0 cy). They are self propelled and the rate of discharge may be controlled.

Concrete buggies require runways when they cannot operate on previously placed concrete. When used for concrete placement on piers, abutments or walls, the runway should rest on falsework that is independent of the concrete forms or falsework. Runways and the supporting falsework should be checked for structural adequacy using loadings provided by the manufacture of the power buggy. When they are used to place concrete on deck slabs, the runway is supported on cross-frames whose legs rest on the forms. The legs of the cross-frame must be long enough to allow the cross joist of the frame to clear the deck rebars. The runways are constructed in sections and the sections must be removed as the pour progresses.

When runways are necessary with buggies, the placement must start at the far end of the section and progress toward the end where the buggies are loaded. In some sectional pours, the buggies must cross deck slabs poured the day before or several days previously. This is not objectionable provided the curing materials are protected from abrasion and some provision is made to distribute the load and reduce impact. With hand buggies, boards laid on the curing material over the area to be used as a runway is usually sufficient. Sections of prefabricated runway or heavy planks should be placed on the curing material when power buggies are used to distribute the load and reduce impact. The runway should be free of abrupt vertical offsets and obstructions. Due to the mass of a loaded power buggy, its lack of springing action and the speed traveled, a noticeable shock wave will be transmitted to the concrete when a buggy crosses a board in its path. It may also be advisable to require reduced speeds to avoid cracking on previously cast concrete.

Power buggies have been successfully used on long deck slab pours where a bridge finishing machine was required. A runway is centered on the roadway slab and is connected to a short ramp leading up to a transverse unloading platform. This platform is equipped with flanged wheels which rest on the rails on which the finishing machine operates. The unloading platform permits the buggies to unload transversely without additional runways and with very little shoveling. Sections of the main runway are taken up and the loading platform rolled back as the pour progresses. The head of the concrete is thus maintained approximately parallel to the finishing machine screed.

When placing concrete from buggies, the concrete should be dumped into the face of concrete in place, rather than away from the concrete in place: see the sketch below, taken from an American Concrete Institute publication. This should prevent separation of rock and mortar.



CORRECT
To dump concrete into face of concrete in place.

INCORRECT
To dump concrete away from concrete in place.

Placing Slab Concrete from Buggies

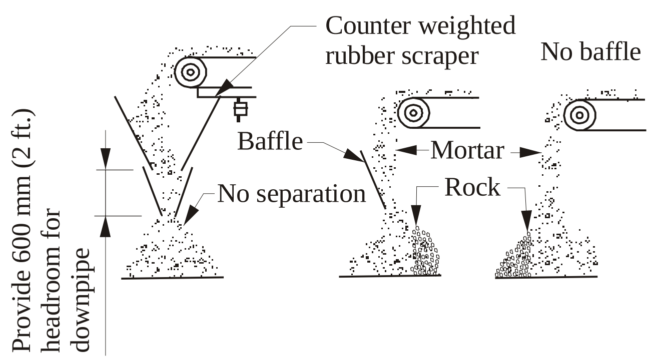
Gantry Cranes
Gantry cranes have been adapted to transport form materials, reinforcement bars, and concrete for the deck slabs of longer span bridges. They are self-propelled, very heavy, and run on the same rails used for the bridge deck finishing machine. A concrete bucket is suspended from the power operated crane which moves transversely on the supporting framework. One end of the gantry frame-work overhangs the deck. In operations, the bucket is moved to the overhang, lowered to the ground or barge to be filled, and is then raised. The crane may be moved along the rails as the bucket is raised or the bucket may be raised, centered on the gantry, and the gantry is then moved. Large, undesirable stresses and differential deflections may be set up in the bridge structure due to the mass of the gantry, impact of the moving load and the movement due to the overhanging load. Each bridge is a special case and no blanket approval or limitation on the use of a gantry crane is practical. If the use of this machine is anticipated, an investigation of resulting stresses and deflections should be made.

Tremis
A tremie consists of a watertight metal tube not less than 250 mm (10 inch) in diameter and of sufficient strength to perform the work. The lower end of the tremie is equipped with a suitable valve or device which can be tightly closed while the tremie is being charged and lowered into position and which can be fully opened in the lowered position. A typical tremie tube may be constructed of 300 mm (12 inch) O.D. steel shell pile section with a welded hopper which is either conical or rectangular with a sloping bottom. The control cables for the valve may extend from the valve through the tremie tube up to the top of the hopper. If sectional tremie tubes are used, water tight gaskets must be used where sections are bolted together.

The tube should be long enough so that the hopper will be well above the water surface when the bottom of the tube is at the bottom of the excavation.

Concrete Conveyor Belts

Conveyor belts have been used to transport concrete. Segregation will usually result at the discharge end of the belt unless a suitable hopper with vertical downspout is used. A belt that is too flat will spill mortar over the sides. Belt scrapers are mandatory. See the sketch on the following page, taken from an American Concrete Institute publication.



CORRECT
The above arrangement prevents segregation of concrete whether it is being discharged into hoppers, buckets, trucks, or forms.

INCORRECT
Improper or lack of control at end of any belt. Usually a baffle or shallow hopper merely changes the direction of segregation.

Control of Segregation of Concrete At The End Of Conveyor Belts

5-393.353 CONCRETE PLACEMENT

Concrete placement in bridges is governed by Specification 2401. Methods for controlling segregation for the various types of placement equipment are discussed under the previous section 5-393.352. The basic requirements of Specification 2401 regarding prevention of segregation of mortar and coarse aggregate are as follows:

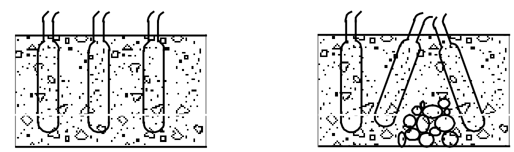
1. The height of freefall of the concrete from the end of a chute, downspout, hopper or bucket, to its final position in the forms shall not exceed 1.3 meters (4 ft).

2. Concrete shall be deposited as near its final position as possible and vibrators shall not be used to move the concrete horizontally within the forms.

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

The Specifications require that all concrete used on bridges, except cofferdam seals or cast-in-place concrete piles, must be vibrated by the use of internal vibrators. The requirements for vibration and spading are covered completely in Specification 2401.3D with supplemental information in 5-694.600 of the Concrete Manual.

Over-vibration tends to segregate the concrete. Incomplete vibration, where part of the concrete is not vibrated, may show honeycomb and insufficient consolidation when lower slump concrete is used. The vibrator should penetrate the previous lift of concrete. Systematic vibration of each new lift is shown in the sketch below, taken from an American Concrete Institute publication.



CORRECT
Vertical penetration of vibrator a few inches into previous lift (which should not yet be rigid) at systematic regular intervals found to give adequate consolidation.

INCORRECT
Haphazard random penetration of the vibrator at all angles and spacings without sufficient depth to assure monolithic combination of the two layers.

Systematic Vibration Of Each New Lift

When a vibrator is allowed to contact the forms, sand streaks may occur. When the vibrator is allowed to contact reinforcing bars, the vibrations are transmitted to the bars and, if they extend into "green" concrete, bond between the bars and concrete may be destroyed.

Vibration of concrete does not take the place of spading concrete along the forms but does reduce the amount required. Spading should always be done along bulkheads in deck slab pours, along the edge of the roadway slab, curb, coping and railing forms.

The reaction of the forms and falsework under the concrete load should also be watched. The end result of a good form plan, but careless construction practice, can be poor. The Contractor should be required to provide "form-watchers" on piers, abutments and other large wall pours. The "form-watchers" should climb the forms as the pour progresses, checking form bolts and observing the behavior of the forms under load. When excessive bulging is noticed, or if a form bolt should snap, pouring should cease until corrective measures can be taken. Sometimes due to carelessness the holes drilled through the sheathing for form bolts do not line up between opposing forms. When the form bolts are placed, they are sometimes bent to pass through the misaligned holes. The bent folds may straighten as the load is applied which tends to place a greater load on adjacent bolts, perhaps causing a serious overstress on these bolts even though the design is entirely adequate.

The plumbness of substructure units must be maintained. A description of methods for holding the forms plumb, inspecting plumbness and a discussion of tolerances are as follows:

1. The plumbness of the pier forms may be maintained by the use of: (a) guy cables and turnbuckles attached to the walers or strongbacks on the pier forms at the one end and a substantial anchorage at the other end, or (b) by pushbraces (shores) with wedges for adjustment, or (c) by cross cables with turnbuckles fastened at one end to the falsework caps and at the other end to hairpin bars cast in the footing. On piers adjacent to railway tracks, bracing may have to be confined to one side of the pier and a combination of cables and pushbraces may be required.

2. In many cases on land, such as the piers of a grade separation bridge, offset lines may be run and the plumbness of a unit checked with a transit. When the plumbness of a pier is checked with a transit, an offset line from the pier centerline is usually used. The offset distance must be sufficient to clear the walers, strongbacks and form bolts. Usually one meter (3 feet) from the face of concrete is adequate. Horizontal wood strips (lookouts) are nailed to the studs at several locations and, measuring from the outside of the sheathing, a nail is set vertically in the lookout at the offset distance. On piers with columns, at least two points should be set at each column, one about 1/4 the height of the column above its footing and one near the top of the column. More points should be required on high columns. A lookout point should be placed near the top of the pier cap forms over each column.

3. With the transit on the offset line, each lookout point is observed before the pour and the forms adjusted to be truly vertical. The inspector should verify that the transit offset line and the nails set in the lookouts are the same offset distance from the pier centerline. Intermittent observations are also taken on the points as the placement progresses. A weaving action may occur in which the forms will list slightly in one direction, then in the other, as the placement progresses. Plumb-bobs suspended from outriggers may also be used to check on plumbness during the placement.

4. With all of the concrete in place, the top of the forms should be within the plumb tolerances specified in Section 5-393.203. Generally, all the lookouts in a horizontal line should show approximately the same deviation or wavy concrete lines may result.

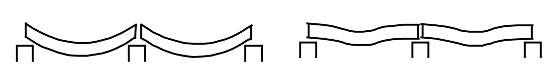
The elevation of the top of pier caps or other units supported on falsework should be determined in the following manner. Grade nails or vee strips to which the concrete surface is finished may be preset with the estimated deflection included, but this estimated elevation should not be considered as final grade. See 5-393.203 for estimating the false work deflection. When the concrete level approaches 150 mm to 300 mm (6 to 12 inches) of the top of the pier cap, one of two things should be done: (a) recheck grade nails, reset to true elevation when necessary, then place chamfer strips or (b) when chamfer strips are preset with temporary nailing, check and realign to true grade and fasten securely. It is important for true bearing areas that this check and resetting of the top grades be made after most of the concrete is placed.

Vertical forms for bridge substructures, retaining walls, etc., are usually designed to resist a certain maximum concrete pressure. The pressure used in the form design is based on the rate of pour and concrete temperature anticipated. See 5-393.200 of this manual.

The inspector should check concrete temperatures as the concrete is placed in the form. The rate of placement should be reduced when lower than anticipated concrete temperatures will cause an excessive increase in pressure. Actual placement rates should also be checked and should not be permitted to exceed the design rate.

The Plans usually show a permissible construction joint between pier caps and columns. If the Contractor elects to pour the cap monolithic with the pier columns, a time delay of 30 minutes to 90 minutes should elapse between placing column concrete and cap concrete (see Specification 2401.3C1). Before starting the cap portion of the placement, the tops of the columns should be cleaned of laitance and any loose or porous concrete. Concrete shrinks and settles very rapidly in its early stages of setting up. The purpose of the delay is to allow most of this consolidation to occur in the column before the cap concrete is placed. No delay, or an insufficient delay period, may cause visible cracks or low strength concrete at the top of the column. These cracks will not generally extend around the column but will extend from the top of the column on diagonal lines up into the pier cap at about the angle of repose of green concrete. The cap concrete over the column settles with the column and the adjacent cap concrete supported on falsework cannot settle. Excessive, slow crushing of the falsework combined with a slow rate of pour in the cap could cause the same type of crack.

Single diaphragms on prestressed girders which encase the ends of girders in adjacent spans are required to be poured monolithic with the slab. The diaphragm is poured monolithic with the slab in an attempt to have the diaphragm concrete plastic while the girder ends rotate due to slab dead load deflection. This method of construction reduces compression stresses in the ends of the girders. See the following sketch:



Rotation into diaphragm	High compression stress
CORRECT Unrestrained condition (diaphragm plastic)	INCORRECT Restrained condition (diaphragm set)

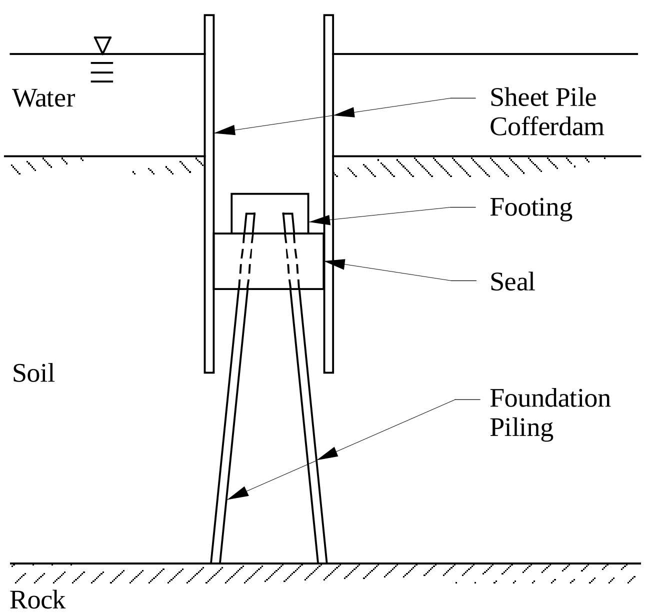
Compression Stresses Due to Restraint

5-393.354 CONCRETE PLACEMENT IN COFFERDAMS

Requirements for cofferdams are given in Specification 2451.3A3. In most cases, the Engineer will want to review the Contractor's plans for the cofferdam to ensure adequate roomfor the concrete seal (if required), pile driving and footing concrete. Safety for Mn/DOT inspectors must also be considered and the construction of cofferdams of inadequate depth or without sufficient bracing should not be permitted. It is the Contractor's responsibility to provide a safe and adequate cofferdam; however, it is in everyone's best interest to bring obvious deficiencies to the Contractor's attention prior to beginning construction. Special requirements for cofferdams may be given in the Plan and/or Special Provisions.

Concrete seals are specified in the Plan when it is anticipated that a cofferdam cannot be safely dewatered to the bottom of the footing elevation. If the conditions of the bottom are such that no appreciable penetration can be effected into the bottom and, if friction between the outside submerged soil and the sheet piling cannot be depended upon, then a concrete seal sufficiently heavy to prevent uplift from hydrostatic pressure is required. The following sketch shows one situation where a seal is required.

The Plans will show which units require concrete seals and also the seal dimensions. Usually seals are 0.5 meter (1-2 feet) larger on all sides than the footing dimensions of the pier to provide for construction room. The seal thickness depends on the depth of water above the bottom of the seal because a concrete seal is designed to resist hydrostatic uplift with its mass. The friction on the sheet piling and foundation piling also resist uplift due to hydrostatic pressure. This friction is generally ignored in design and creates an additional safety factor. The inside dimensions of the cofferdam usually conform to the horizontal dimensions of the seal.



Cofferdam With Seal

When conditions are encountered that make it impractical to dewater a cofferdam prior to placement of concrete, a foundation seal may be provided by the Contractor. Concrete seals are used to provide some or all of the following: to resist buoyancy, to minimize infiltration of water through permeable soil, to act as a lower support for the sheet piles, to tie the driven piles together to resist uplift and to provide subsequent support for the construction of the pier footing. The size and thickness of the concrete seal should be sufficient to permit subsequent dewatering without the risk of failure due to "blow out" from water pressure. Specification 2451.3A3b provides for placement of a concrete seal when no seal is indicated in the Plans, if the Contractor so desires. In this event, the cost of the seal would be covered by the Contractor. The Contractor would then be required to submit the proposal to the Engineer for approval. The Engineer should then contact the Bridge Construction and Maintenance Section for concurrence and the change could be covered by a Change Order.

With the cofferdam in place and before driving foundation piles (if they are required), excavation should be completed to the bottom of the seal. Soundings are taken to determine excavation progress by measuring the depth from the water surface to the bottom of seal. The elevation of the water surface is determined and the theoretical distance from the water surface to the established bottom of seal is computed. A benchmark is made on the cofferdam sheets near the water surface at a known elevation for checking excavation and seal elevations. The final elevation of the bottom as determined by soundings should not vary more than about 150 mm (6 inches) between the different soundings and the average elevation of the bottom should not be higher than the established bottom of the seal elevation.

A prod or measuring pole for sounding may be constructed using a 20 mm (3/4 inch) pipe with a 150 mm (6 inch) diameter board or plate fastened to one end. A mark is made on the pole at a distance above the plate equal to the distance from top of water elevation to plan bottom of seal elevation. Marks are also made above and below the original mark at 0.05 m (2 inch) intervals. The pole is lowered vertically into the water until the plate touches bottom and the depth is noted. On fairly deep seals the pole may become too heavy and awkward to lift up and transfer from one cofferdam bay to another. Flat steel plates with a ring welded to the center of the plate and suspended on a light link chain have been used in lieu of the pole for sounding. Areas near and under cofferdam struts, that may be high due to difficulty getting an excavating bucket under them, should always be checked.

When foundation piling is required in the footing, a precaution is necessary because the soil in the cofferdam may swell or be displaced upward during pile driving. Generally, contractors will excavate below the bottom of seal elevation anticipating such swell and will backfill to grade after the piles are driven. Allowance for swell of foundation material may vary from nothing to 600 mm (2 feet) or more, depending on the soil type and pile spacing. The depth must be determined by the Contractor because it is their responsibility to provide the proper foundation grade. Steel H-type bearing piles will cause muchless ground swell than will timber or steel shell piles because of their relatively small cross sectional area.

Immediately after the piles are driven, the Contractor should check the bottom elevation of the excavation so that corrections can be made. If the bottom of the excavation is below the established bottom of seal elevation, the Contractor may elect to backfill with suitable sand-gravel material rather than fill with concrete. If the Contractor elects to fill the void with concrete, it will be at their expense. After corrections are made, the Contractor should again sound and record the elevation of the bottom of the excavation.

Seal concrete must be placed as near its final position as possible by means of a tremie or by pumping. The water in the cofferdam should be relatively still and undisturbed at the point of deposit. The concrete should, unless otherwise specified, be placed to full depth in one continuous operation, completing the work to grade progressively from one end of the cofferdam to the other. The tremie pipe or pump line should be kept in the puddle at all times, being withdrawn only at the completion of each day or as may be required by the cofferdam bracing. The level of the concrete in the tremie tube should be kept approximately at the level of the water outside of the tube. After withdrawing, the tremie should be recharged with concrete above water and lowered to the new position where the discharge end can be set into the concrete puddle.

In operation, the tremie suspended from a crane line with the valve closed and out of the water is fully filled or charged with concrete. It is then lowered to the bottom near one end of the cofferdam and raised a small amount to allow the valve to be opened. As the concrete is discharged, the concrete level in the tremie will lower. As the concrete level in the tremie approaches water level, the valve should be closed so that the concrete level in the tremie is never below water level. The tremie is then recharged and the operation repeated. It may be necessary to raise and lower the tremie slightly to assist in discharging the concrete, but the bottom of the tremie should not be raised out of the concrete. Usually a valve opening of 150 mm (6 inches) or less together with the raising and lowering of the tremie is sufficient for discharge. The tremie is then moved laterally with its lower end still in the concrete. If cofferdam struts are present, lateral movement of the tremie is restricted. In this case the tremie should be completely discharged, recharged above water and placed on the other side of the strut (or other obstruction). It is then discharged in previously placed concrete whenever possible.

The operation is based on exposing as little concrete surface as possible to the eroding action of the water. Some loss of cement is anticipated; therefore, a rich mix (1X62) is used. A higher than normal slump (120 mm-150 mm) (5-6 inches) is used to facilitate lateral flow of the concrete. Loss of cement from the mix is also minimized if the water in the cofferdam is still and the equipment is moved slowly in the water or concrete.

Frequent soundings must be taken to obtain a reasonably level top surface on the seal. The same equipment used to check the excavation elevation can also be used for this purpose. The water level may rise in a tight cofferdam as the concrete displaces the water. The benchmark originally set on the cofferdam sheets for checking the excavation elevation may be used to check the elevation of the seal. Additional information on concrete seals is contained in 5-694.835 of the Concrete Manual.

The inspector should record water temperatures during the placement and several times daily thereafter until the cofferdam is dewatered. The water temperature desired is the temperature at the surface of the seal. Based on these temperatures, the length of the curing period should be determined (see Specification 2451.3A3c). Dewatering should not be done within a sealed cofferdam until the seal has been placed and cured since the foundation soils may be seriously disturbed.

After the cofferdam is dewatered, the pile cut-off is made and the top of the seal within the footing thoroughly cleaned of laitance and loose material. If the top of the seal projects above plan grade far enough to displace the reinforcement mat upwards, it must be cut down. It should also be cut down around pile heads so that the piles will project into the footing as planned. Any leaks that show up in the seal should be plugged so that the footing can be poured “in the dry.”

It is sometimes necessary to leave the struts of a cofferdam in place and cast the concrete around the struts. This condition frequently occurs adjacent to railroad tracks or in water, where the removal of the struts in advance of pouring may cause collapse.

When cofferdams struts are to be left in place, they must be of steel and generally should be cast into the concrete. Specification 2451 permits boxing out braces or struts only upon written approval of the Engineer. If the Contractor requests boxing out around struts or braces, the Bridge Office should be contacted for a recommendation.

When the concrete has gained sufficient strength, the cofferdam sheets may be braced against it or may be held in position by back filling. The struts can then be cut off.

If the struts are below final ground elevation or below low water elevation, they may be burned off close to the concrete surface. If above these elevations, a recess 75 mm (3 inches) deep should be formed out around the strut. The strut is burned off about 25 mm (1 inch) from the face of the recess and the recess then filled with a cement mortar or an epoxy mortar, to provide 50 mm (2 inches) cover over the end of the strut.

5-393.355 REMOVAL OF FORMS

The Specifications permit forms to remain in place as a curing media but they must not be permitted to become dry. If the Contractor elects to use this method of cure, the forms must remain in place until the curing requirements are met or the curing must be continued by other methods.

The Specifications also specify a minimum length of time that the forms and falsework supporting the underside of bridge members of various types must remain in place. The length of time required is based on concrete strength gain as computed under Specification 2401.3G or by control cylinders if cured under adverse weather conditions.

The soffit railing form for the cast-in-place concrete railing and the concrete base used with ornamental metal railing may be removed when 45% of concrete compressive strength is attained. Surface finishing requirements may provide for form removal as soon as concrete has set sufficiently to retain its molded shape.

The forms for the battered front face of curbs or sidewalks may be removed as soon as the concrete has set sufficiently to retain the molded shape but in no case later than 48 hours after casting. See Specification 2401.3F2d.

Formwork (including formbolts) should be removed in a manner that will not damage the concrete surface. Particular care must be taken if forms are to be removed while the concrete is still green (first or second day of cure). In this case, metal tools such as crow bars or pry bars should not be permitted to bear directly on the concrete surface.

Some parts of the structure may require rustication grooves or vertical panels in exposed surfaces. The corner, formed by the strip or panel and the concrete surface, is sharp edged without chamfer and may be easily chipped or spalled if the rustication strip or panel is removed with the wall form. Forms for the rustication grooves or panels should be fastened to the wall form with double headed nails, screws or bolts. These may be removed before the wall form is removed, leaving the rustication form in place. Be certain that rustication forms fit tightly against the wall forms to prevent entry of mortar into the joint. This creates fins and thin shells which result in spalled corners. Recesses in curbs at floor drains should be similarly treated.

Steel column forms for circular columns should not be removed by partially opening and lifting the form vertically. This method of removal leaves objectionable marks on the columns which are very difficult to remove. The form should be completely opened and each half removed separately.

5-393.356 SURFACE FINISHES

Specification 2401 gives complete requirements for ordinary surface finish and the mortar mix for repairs. When an area must be repaired (due to any reason listed in Specification 2401), it is recommended that the minimum depth of the patch be 6 mm (1/4 in.). Feather-edged patches should be avoided. On exposed areas that must be patched after the concrete has set, neat lines should be cut around the perimeter of the area with a concrete saw.

In suitable weather, filling of form bolt holes and repair of defective areas should be done immediately after the forms are stripped. When forms are used as a cold weather cure, the work may have to be delayed until the following spring. In this case, due to the advanced set of the concrete, the mortar in patched areas should be bonded to the concrete with an approved bonding agent. In addition, an epoxy mortar patch may be necessary when the patch would be difficult to cure. Bonding agents should also be used to repair concrete damaged during later construction operations. Information on approved bonding agents and epoxy mortar may be obtained from the Concrete Engineer. For units constructed inside of cofferdams, the filling of form bolt holes and any repair work necessary must obviously be done in advance of filling with water. This may necessitate work during cold weather. When repair areas will be under water, an asphalt mastic is recommended for minor repairs when the temperatures are below 0EC (32EF).

Mortar used for patching should be mixed about an hour in advance of placing and remixed immediately before application, to reduce shrinkage. Patches that show shrinkage cracks around their perimeter after the mortar has set should be considered defective and the mortar replaced.

Normally either epoxy mortar or cement mortar may be used for repairs. A list of approved epoxy materials can be obtained from the Concrete Engineer. Epoxy mortar should consist of 5 to 6 parts sand mixed with 1 part of epoxy by volume to obtain desired workability. After cleaning, the area to be repaired is primed with a coat of the same epoxy mixture which is used in making the epoxy mortar. Epoxy mortar patches do not need to be cured as required for cement mortar and will not shrink.

In addition to mortar repairs, fins at sheathing joints, marks left by finishing tools, patches (after curing for at least 24 hours) and any other projections should be removed from exposed surfaces by rubbing with a dry stone. The amount of work required on exposed surfaces will depend to a large extent on the quality and workmanship of the forms.

At construction joints that are to receive joint waterproofing, all sharp projections or mortar shells that may cut or interfere with proper placement of the waterproofing fabric should be removed.

5-393.357 ARCHITECTURAL AND SPECIAL SURFACE FINISHES

The surfaces to receive special surface finish should first receive the ordinary surface finish as defined in Specification 2401.3F2a. This ordinary finish should be the same quality as required on formed surfaces which do not require further finishing.

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 finish.

Prior to starting the special surface finish, the surface should be thoroughly wet down. Wetting should be continued so that the surface finishing will not be performed on a dry surface.

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.

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 $0.4m^2$ per L (16 square feet per gallon) of material.

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.

Finishing operations should be as continuous as possible. Interruptions in the operations result in variations of shade and texture giving a poor appearance.

Specification 2401 requires that surface finish be applied only under approved weather conditions, unless protection for the work is provided. The following guide lines may be used for application:

1. The air temperature at time of application should be 4EC (40EF) or warmer.

2. Application should not be made on a frosted surface regardless of the air temperature. The surface temperature of the concrete should be checked if low temperatures prevail especially on shaded surfaces. A surface temperature of 2EC (36EF) or higher should be required at time of application.

3. Freezing nighttime temperatures are not considered objectionable. However, in order to allow some curing time prior to freezing, no application should be performed after 3:00 PM on days when an overnight freeze is anticipated.

4. For information regarding cold weather application of special surface finish materials contact the Concrete Engineer.

5. Roller application is not permitted, however, rollers may be used to produce a uniform texture after the special surface finish is applied using a sprayer.

For complete requirements for curb, sidewalk and median finish, see Specification 2401.3F2d. The top edge of the roadway curb, sidewalk or median must be edged or rounded to the radius specified in the Plans. The specified radius and specified curb batter usually require a special edging tool. The inspector should verify that a proper edging tool is available for curbs before any curb or sidewalk pour is started. In addition to a lip formed to the proper radius and batter, the curb edger should be fairly long 200 mm - 300 mm (8"-12") and the lip should not be so thick that a significant offset between the face of the curb form and the radius will occur.

Curb edges are sometimes rounded to the required radius by using a wood cove for a form. The cove must be dressed to proper radius and batter, and the edges must be feathered out. When coves are used, the curb form will usually extend above the finished surface and the cove is set to proper elevation from grade nails set in the side of the curb form after it is placed in position. Due to the feather edge, care must be taken not to damage the cove previous to or during concrete operations. The cove should be well covered with a form coating material.

The practice of providing a radius by the use of a chamfer strip and rubbing down the concrete edges with a rubbing stone should not be permitted. This usually results in an irregular radius because of encountering coarse aggregates.

At edged joints the top of the form or bulkhead should always be set to the finished grade and the concrete struck off to the top of the form. After the initial strike-off, the edger should be placed at the top of the form and run along the joint to push the coarse aggregate back from the rounded edge. Successive strike-offs are then made, disregarding the rounded edge.

When the water sheen starts to leave the surface, the edger can then be floated on the concrete surface without digging and at this time the joint should be edged. Joints that are edged when the concrete is too plastic will be wavy. After edging, trails left by the tool should be removed and the final broom or brush finish applied.

A painted surface finish is currently used for Type “F” median barrier and inside face and top of Type “F” railing. Surfaces to be painted are sandblasted, given an ordinary surface finish (except slipformed surfaces for which sandblasting and ordinary surface finish are not required) and then painted with an approved latex or acrylic based paint.

A sack rubbed finish may be required where uniform appearance of painted surfaces is necessary. The Special Provisions will contain this requirement if it is desired on a project.

5-393.358 PLACING BRIDGE ROADWAY SLABS

Two basic requirements for a good riding surface on any roadway are a true grade line without deviations from grade and a smooth uniform surface without local bumps or depressions. The task of achieving a true grade line on bridge roadways is complicated by deflections: the deflection of falsework for cast-in-place concrete bridges and the deflection of the spanning members under the mass of the roadway slab. In addition, a long time continued deflection of concrete members, known as creep, occurs. Allowances for deflection and creep must be accurately predicted and constructed into the roadway surface to prevent undesirable deviations from a true grade line. On cast-in-place slab span and box girder bridges, a true grade line cannot be continuously maintained since the deflection is continually increasing as time passes.

There are many complications in achieving a deck of uniform smoothness. There are space limitations on a bridge roadway for handling, placing and finishing concrete, and there is the lack of completely mechanized operations and a reliance placed on hand finishing methods.

The best gauge the traveling public has for evaluating the riding quality of a bridge is to compare it to the riding quality of the roadway adjacent to the bridge. There is nothing about a bridge that is noticed by the traveling public so much as the riding quality of the deck. A structure which is satisfactory in all other respects will not be fully appreciated if the riding surface is rough or bumpy. Most concrete and asphaltic concrete pavements will have a smooth riding surface. The inspector must, therefore, pay close attention to setting grades and to the concrete placing and finishing operations to have the riding quality of the bridge equal to the riding quality of the adjacent roadway.

Bridge structural slabs are usually placed in one continuous placement. Contractors occasionally request permission to place a transverse construction joint even though a construction joint is not indicated in the Plans or Special Provisions. The usual reason for requesting the joint is that the Contractor cannot adequately place and finish the indicated area with their workforce in one continuous operation. The Engineer should consult the Bridge Construction and Maintenance Section when such requests are made. Joints in bridge curbs or sidewalks will usually be required over the construction joints in the slab to prevent cracking. Slab construction joints directly under a rail post anchorage assembly or within a concrete railpost are undesirable and should be avoided. See Section 5-393.366 of this manual for additional information regarding locating construction joints.

Concrete overlays, typically consisting of low slump concrete, are used on bridges meeting any of the following criteria:

1. All bridges carrying interstate traffic
2. All interstate highway bridges at an interchange with access to interstate
3. All bridges carrying trunk highway traffic within major metropolitan areas and municipalities with populations of 5000 or greater
4. All bridges on trunk highways with 20 year projected ADT greater than 2000

Detailed requirements for materials, placement, finishing, and curing of concrete overlays are currently found in Specification 2404.

Several additives or admixtures are commonly used to facilitate placing, finishing and curing. The latest list of approved products in Section 5-694.100 of the Concrete Manual should be checked prior to admixture use. If the proposed product is not listed, the Concrete Unit should be contacted for a recommendation. Commonly used additives or admixtures are as follows:

1. Water Reducing Agent - A water reducing agent added to the concrete will act to increase the slump without increasing the water content. The higher slump facilitates placement of concrete in heavily reinforced portions of a structure.

2. Retarders - Retarders are admixtures used to delay the setting time of the concrete. The Engineer may require a retarder on continuous slab placement. The retarder ensures that the concrete will remain plastic while dead load deflection is occurring, as early set of the concrete could result in slab cracks from the dead load deflection. (See Specification 2401.3.) Such retarders must be used with discretion on fast drying days because early drying of the concrete

surface may still occur unless a fog spray is used or other protective measures are taken.

3. Accelerators - Accelerators are an admixture that can be used to accelerate the set and the rate of heat development. When cold weather protection of the concrete is required, accelerators may be advantageous for curing (See Specification 2461.3E). Calcium chloride is not permitted for units containing prestressed steel or bridge superstructure concrete.

The delivery and placing rate should be governed entirely by the amount of slab that the Contractor's force and equipment will be able to finish properly, not by how fast the concrete can be mixed, delivered and placed. Slow or erratic concrete delivery and placement that requires frequent stops in the finishing operations will increase the frequency of bumps. Specification 2401 also requires that the rate of concrete placement for continuous pours of two or more spans shall be adequate to ensure that 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 a span length ahead of that support.

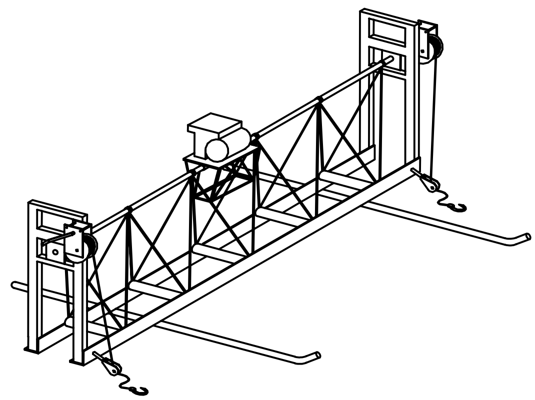
Some long span structures include a specific deck placement sequence in the plans or special provisions. Be sure to review all of your contract documents to make sure proper deck placement procedures are followed.

Some shoveling or redistribution of concrete is usually necessary with the concrete placement methods used for a bridge slab. The best results will be obtained if the concrete can be deposited in its final position with a minimum of shoveling. Differential subsidence will be minimized if:

1. Vibrators are not used to move concrete from one location to another.
2. Concrete is not deposited in large piles and hand shoveled into surrounding areas.
3. Low areas are filled with concrete not mortar.
4. Walking in the concrete is kept to a minimum and is not permitted after the initial pass of the screed.
5. Compaction is accomplished with mechanical vibrators applied internally and by spading. See Specification 2401, 5-694.600 of the Concrete Manual and 5-393.353 of this manual for information on compaction.

There are essentially two machines used for finishing monolithic concrete bridge decks. They are the Bidwell and Gonmaco series. The machines mount on a paving carriage, and utilize augers to strike off and rollers to finish. The adjustable dual augers strike off any excess concrete just above grade. The motor propels steel drums that smoothes out and finishes the concrete on successive passes. The two free-wheeling finned rollers can be leveled horizontally and adjusted vertically. Vibration is provided sometimes to prevent the concrete from sticking to the rollers. The vibration prevents any unwanted segregation. The crown of the deck is controlled by input from the operator.

Structural slabs, the base slab upon which a dense concrete overlay is cast, can be placed with a conventional paving machine as mentioned in the previous paragraph, or with an "air screed" or "template". An air screed or template is a much smaller and simpler piece of equipment that does not require screed rails for support. Instead, it is generally mounted on a 1" high pipe or ski and rides on the top mat of deck reinforcing bars. Concrete shall be spread and leveled in front of template so as not to cause "float" or overriding.



Templates or air screeds supported on slab reinforcement bars will not be permitted unless all of the following requirements are met:

1. The template shall be a product fabricated for the intended purpose by a manufacturer with at least 10 years experience. If template length exceeds 7315 mm (24 feet), the Contractor shall demonstrate to the Engineer that satisfactory adjustment can be made for crown breaks. Attached vibrators shall be evenly distributed across template length and vibration shall shut-off automatically when forward motion stops.
2. Supports for templates shall be spaced to provide no appreciable sag in the template.
3. Portions of template supports in contact with reinforcement shall consist of round tubes or rods with a smooth, low friction surface. Skis shall have a minimum length of 1520 mm (5 feet) and shall have a gradual "turn-up" nose sufficient to prevent entrapment in reinforcement.

Transverse reinforcement bars shall be supported within 150 mm (6 inches) of the location where template support skis will ride. Top reinforcement shall be securely tied and rigidly supported. Prior to beginning placement of concrete, the Contractor shall demonstrate that equipment and methods to be used will not damage or displace reinforcement bars. Any visible deflections of reinforcement will require additional bar supports and/or additional supports for template.

A manual or powered winch shall provide forward advancement of the template. Winch cables shall not be anchored to reinforcement bars. Attachments to beams (shear studs, stirrups or lifting cables) may be utilized.

Please note that templates or air screeds are only allowed for use on structural slabs. Such equipment is NOT permitted for use in finishing bridge deck slabs (monolithic slabs without an overlay) or low slump overlays.

Adjustment of slab forms and screed rails for deflection of the girders or beams, under the mass of the deck slab, determines to a great extent the smoothness of the final surface. Elevations for setting the forms and rails, including the proper deflection correction, can be obtained from the computer program entitled “Bridge Construction Elevations.” These elevations should be carefully spot checked because with certain conditions, erroneous results have been obtained. Plotting the elevations using an exagerated vertical scale provides a good check.

The screed rail should be adjusted to the proper elevation for the entire length of the bridge before starting concrete placement. If this is not possible, as in the case of a long structure with more than one series of continuous spans, the rail should then be set far enough ahead of the placement so that deflections will not be induced in the girders where the rail is being set. This generally means setting the rail for the entire length of the continuous spans between expansion devices.

The inspector should be aware of deflection conditions on skewed bridges in the area of piers that may cause variations from a true surface. Problems can occur even if the rails are set with the proper deflection taken into account. In the example shown, the concrete placement is proceeding from Span 1 to Span 3. See Figures, A, B and C 5-393.358 for an example of a simple span prestressed girder bridge. Figure A 5-393.358 shows a cross-section of the example and gives data and deflection formulas used in the problem. Figure B 5-393.358 shows a partial plan view indicating the sections A-A, B-B and C-C which are to be studied as the pour progresses from Span 1 through Span 2. Figure C 5-393.358 shows anticipated cross sectional profiles during strike-off and at completion of the deck placement compared to the desired plan profile. The solid line indicates the desired cross sectional profile. The alternate long and short dashed line indicates the cross sectional profile as it is struck off. The uniform short-dashed line indicates the final cross sectional profile after all deflections have taken place. The “rail elevation correction” is the amount the screed rail is raised to compensate for deflection and is included in computer output from the “Bridge Construction Elevations” program. The deflection shown with the placement at a certain section is the deflection when the placement is made to exactly that section. These deflections are altered to an undetermined extent by the diaphragms which tend to make the girders function together.

One solution for this deflection problem is a long back-pass of the finishing machine over the pier area after the adjacent spans have been loaded. This can be done only if the concrete can be maintained plastic for the back-pass operation.

Figure B 5-393.358 also illustrates a condition that may arise at a skewed joint between simple spans when a construction joint is placed directly over a pier. From the deflection diagram for the roadway slab as shown on the plans, the anticipated final deflections are plotted at point W, X, Y and Z. No deflection will occur at points W and Z since these points are over the girder bearings. In this example, the final deflection at X or Y is 0.1660 feet. The rail elevations may be shown on the computer output directly or derived from elevations given in the computer output for fascia girders. The anticipated dead load deflection or “rail correction,” as it is called in the previous example, is included in the computer output. Assume that Span 2 is to be placed first. With rails set according to computer elevations, point W would be set to plan grade. Point X would not be set 0.1660 feet above plan grade since Span 1 would not have deflected until after it was placed. Slab elevations along line W-Z would not conform to plan elevations unless modification was made in the runout rail elevation in Span 1. The necessary modification would be to drop the rail elevation at point X to the final grade of 0.1660 feet below the computer grade. After Span 2 is completed, Span 1 should then be poured preferably ending at joint W-Z. The runout rail at point Y should be set at plan grade, not the computer grade, because Span 2 is loaded.

Figure D 5-393.358 illustrates a condition that may occur at a square joint between adjacent spans. The condition may arise because the screed of a power operated strike-off is suspended a constant distance below the rails on which the machine rides. Span 1 or 2 is to be poured without any slab in place on the adjacent span and the pour is to start at B. A high joint may result if the machine is started with the screed at the joint and the machine approximately centered over the joint. As shown, the joint B must be lower than any constant distance below the rails at the wheels. The rails on the span that are not being poured should be lowered temporarily adjacent to B so that the screed will strike-off the concrete to the correct elevation at the joint.

Attempts have been made to strike off skewed bridges by skewing the frame and screed of the paving machine to the skew of the bridge. Such attempts have not always been successful. They should never be done when the deck slab is on a vertical curve as a warped surface may result. Skewing the paving machine may, however, be a good solution to deflection problems on a sharply skewed structure if the bridge is not on a vertical curve.

Use of an air screed to place a structural slab on a skewed bridge is somewhat less complicated. In this situation the concrete is generally placed in a line parallel with the substructure units and one or more air screeds are operated perpendicular to the centerline. In this situation care must be taken to ensure that the leading edge of concrete is not allowed to become excessively dry.

Flared bridges with strike-off rails set on non-parallel girders present a problem. This is illustrated in Figure G 5-393.358. This problem occurs if the supporting wheels move out parallel to the bed of the machine as the machine operates in the flared area. One solution is to keep the slope of the machine or the transverse grade between the rails constant as the machine moves in the flared area. The computer elevations will have to be adjusted on the flared girder to maintain a constant grade between the rails. If the machine is moving from the narrow portion into the widened portion, the computer elevations would be adjusted as follows. The elevation of the rail as given by the computer should have an amount added to it equal to the product of the flare (distance “a” Figure G 5-393.358) times the crown (0.02 ft./ft.). From this, an amount equal to the product of the transverse slope of the machine times the flare width “a” is subtracted to obtain the correct rail elevation. If the machine moved from the wide portion to the narrow portion, the rail would have to be adjusted in a similar manner to maintain the slope of the machine constant and equal to the slope at the widest portion of the slab.

Screeding equipment should be checked for trueness in cross sectional crown with a straightedge and corrected, if necessary, previous to each day’s pour. On larger bridges, a master straightedge should be requisitioned and kept at the bridge site for checking the equipment.

After the screed rails have been set to correct elevation, the top reinforcement must be checked by the Contractor, in the presence of an inspector, for vertical position by operating the paving machine on the rails as required by Specification 2472.C2. The Specifications require that a filler strip, 6 mm (1/4 inch) less in thickness than the minimum concrete cover requirement, be attached to the bottom of the strike-off during this check as a means of detecting reinforcement bars which encroach on the required clearance. This requirement should be diligently enforced regardless of the type of machine that is used. If the cylinder type machine is used, some ingenuity may be required to use the required filler strip. One method is to attach the wood strip to the cylinder and hold the cylinder motionless with the wood strip on the bottom as it passes back and forth over the reinforcing. Other methods of attaching filler strips to cylinder machines may be used provided they will give a thorough check on the reinforcing placement. In addition, spot check measurements of the total slab thickness should be made during this dry run.

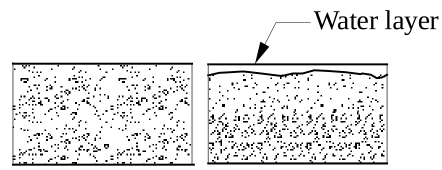
Successful operation of the strike-off machine depends on the following items:

1. On bridge slabs, the amount of concrete to be placed in the forms ahead of the strike-off is gauged by the foreman and puddlers. The first pass of the screed should be considered a leveling or checking operation to assure a proper depth of concrete for the succeeding finishing passes. The screed should be stopped during the initial pass as necessary to shovel concrete into low areas. Shoveling concrete to depressions should not be left to be done on succeeding finishing passes. Excessively large rolls of concrete in front of the screed should be shoveled out or redistributed. When a large roll is carried in front of the screed, the roll should be shoveled out and revibrated before the screed is brought up to the new head. It will not be possible to define the end of previously vibrated concrete once the screed has passed over. See Figures E and F 5-393.358 for examples of correct and incorrect strike-off.

2. The finishing passes of the screed should be made at a slow, uniform rate without stops and should cover as long a section as practicable. A continuous roll of concrete should always be carried ahead of the screed, and the size of the roll will usually decrease on successive passes.

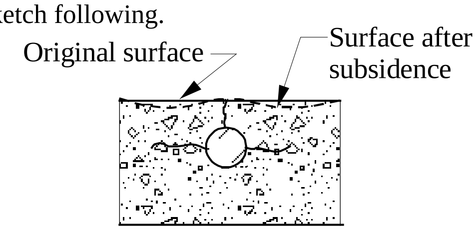
The function of the longtudinal floating operation are as follows:

1. Compaction
   After the concrete is struck off, the aggregate particles settle in the fluid concrete leaving the water on the top as shown in the sketches below.



Section Before Settlement **Section After Settlement**

This phenomenon of a water layer developing at the upper concrete surface during subsidence or settlement is commonly known as bleeding. Bleeding is not normally a problem with a well designed air-entrained concrete mix and good slump control. As this surface water disappears, the concrete settles slightly into its final surface contour. The settlement may be more or less in different areas depending on how evenly the mortar is distributed. Areas with the most coarse aggregate will settle the least. This differential settlement is aggravated by reinforcement bars near the concrete surface of roadway slabs, as shown in the sketch following.



Influence of Top Bar on Subsidence

Cracks may develop directly above the reinforcement bars and a horizontal cleavage plane may develop at these reinforcement bars. Longitudinal floating at the proper time will recompact the top aggregate and the concrete mass adjacent to the bars. This will help prevent the cracking and formation of the cleavage plane. The longitudinal floating should be delayed as long as practicable but must be completed while the surface mortar is still plastic if optimum results are to be attained. Due to its length and its overlapping operation over the entire roadway surface, the float detects and removes ripples and other irregularities left by the screed.

A typical manually operated longitudinal (Iowa) float may be a heavy plank equipped with plow handles at its ends for manipulation. The plank should be at least 3000 mm (10 feet) long and at least 180 mm (7 inches) wide. It should be braced or reinforced to resist warping so that the surface in contact with the concrete remains a plane surface. Suitable work bridges must be provided from which to operate the float. These work bridges should be readily movable and constructed to be reasonably free from wobble or excessive deflection when used by the float operators.

The float should always be operated with its length parallel to the centerline of roadway regardless of the direction of the screeding operation (transverse or longitudinal). In operation, the manually-operated longitudinal float rests on the concrete surface at one curb line with its length parallel to the curb line. It is then sawed back and forth a short distance and at the same time moved transversely across the roadway slab toward the other curb line, similar to a screeding operation. The concrete should support the mass of the longitudinal float. The float should not be tilted on edge during this operation. The operation is then repeated by returning the float over the same area to the starting position. The float is then moved one-half its length toward the head of the concrete and the operation repeated. Successive overlapping passes are made until the entire length of the placement has been covered but always staying as far behind the strike-off as the set of the concrete will permit.

The effectiveness of the longitudinal floating operation is largely dependent on timing. The operation should commence after most of the differential settlement has occurred in the concrete surface but before the initial set has hardened the concrete to such a degree that the float will not be effective. Although the motion of the longitudinal float is a screeding motion, screeds rest on rigid rails or guides whereas the manually operated longitudinal float is supported on the concrete surface. If the floating operation is performed too soon the float will dig, be unmanageable, and the surface smoothness may be impaired rather than improved.

Specification 2401 requires longitudinal floating after most of the plastic shrinkage has taken place. A visual gauge indicating the progress of plastic shrinkage is the water sheen on the surface. When the water sheen begins to leave the surface, the proper degree of set has occurred, and the longitudinal floating should begin. On hot drying days, the water sheen may appear and disappear in a short interval of time and should be watched very closely.

When the operation is performed too soon, the bleed water may be worked back into the surface mortar, resulting in a very weak surface which will likely start scaling at an early age.

When it is repeatedly necessary to cut large bumps with the longitudinal float, there is obviously something wrong in the screeding portion of the work. Modifications should be made in the screeding operation to alleviate the problem. Additional rail supports may be necessary if the problem is created by deflection between supports.

5-393.359 FINISHING BRIDGE ROADWAY SLABS

Small finishing tools should be used only where necessary. The indiscriminiate use of hand floats, long handled floats, or darbies should not be permitted. Such tools may be used to remove trails or ridges left by the longitudinal float, to correct areas where a checking straightedge has detected irregularities and to finish areas adjacent to the curbs or screed rails if such areas cannot be finished with the longitudinal float. Repeated reworking of a surface which has already been properly finished will result in a thick mortar layer at the surface of the concrete. It may also result in the sealing of bleed water under the concrete surface which is undesirable.

A 3 m (10 ft) long wooden straightedge should be used for checking the slab surface. This straightedge should be used for checking purposes only and not used as a scraping straightedge for finishing. The final check on the surface should be made immediately behind the longitudinal floating and also immediately behind the hand finishing at the gutter lines so that out-of-tolerance areas may be promptly corrected. The straightedge should be set on the slab longitudinally and the full width of the slab (usually from curb to curb) should be spot checked at various locations. In addition, the straightedge may be transversely placed near the curbs, where hand finishing is involved, to assure that the proper crown section has been obtained. The straightedge should be picked up each time it is moved so as not to mar the concrete unnecessarily. If the finishing has been conducted properly and in accordance with the Specifications, only occasional minor irregularities will be detected during this spot checking.

EXAMPLE

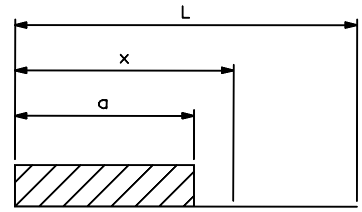
125' - 125' - 125' PRESTRESSED BEAM SPAN BRIDGE
45° SKEW
w SLAB = 0.75' x 10' x 150 LB./FT. = 1,125 LB./FT. OF GIRDER
$E_c = 4.8 \times 10^6$ PSI
$I_c = 547{,}920$ IN^4

DEFLECTION FORMULAS

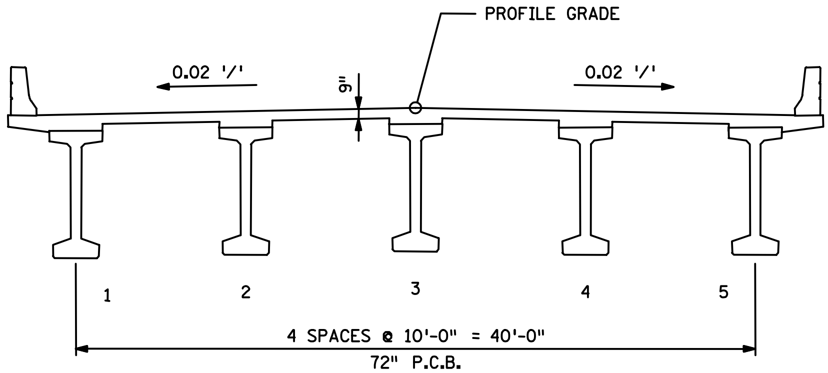
PARTIALLY LOADED GIRDER WHEN x=a $\quad \Delta x = \dfrac{wx^2 \, (L - x)}{24 \, EIL} \, (4xL - 3x^2)$

FULLY LOADED GIRDER $\quad \Delta x = \dfrac{wx}{24 \, EI} \, (L^3 - 2Lx^2 + x^3)$

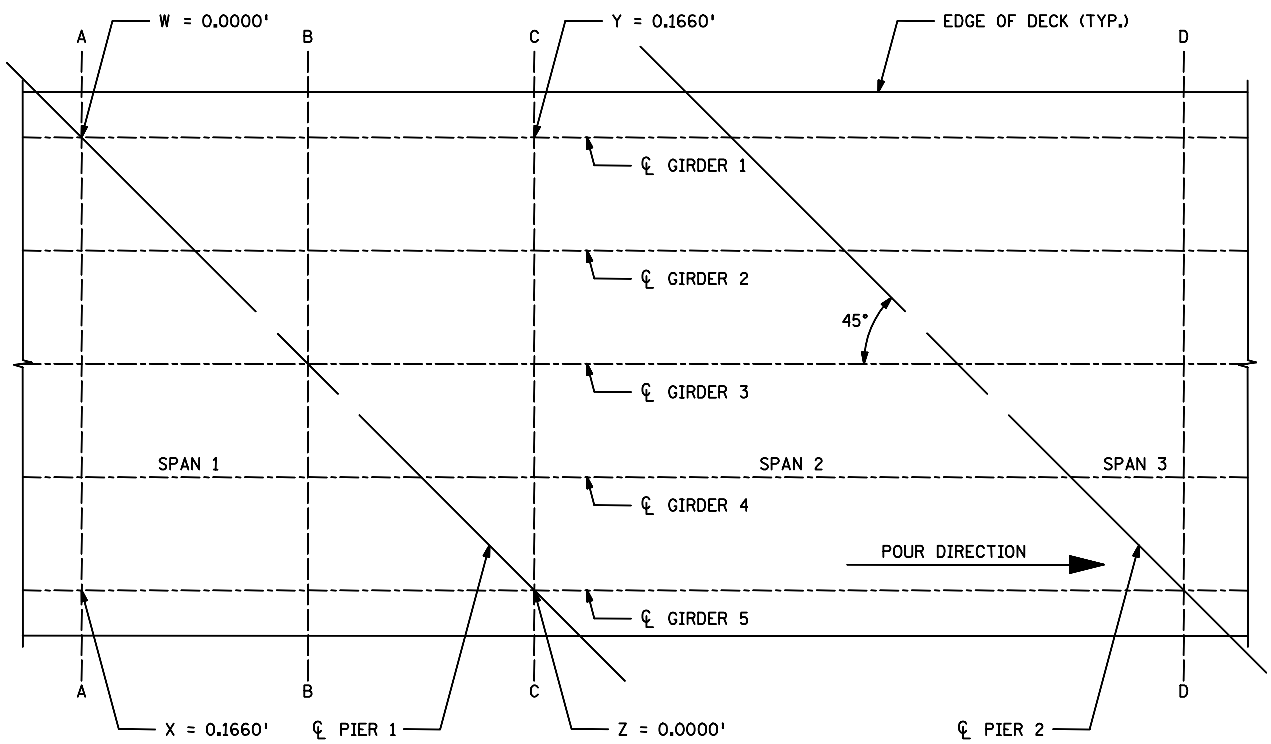
WHERE L = 125'
x = DISTANCE OUT FROM PIER ALONG THE GIRDER.



PARTIALLY LOADED GIRDER
WHEN $x \geq a$



CROSS SECTION OF EXAMPLE
FIGURE A 5-393.358



PLAN VIEW OF EXAMPLE
FIGURE B 5-393.358

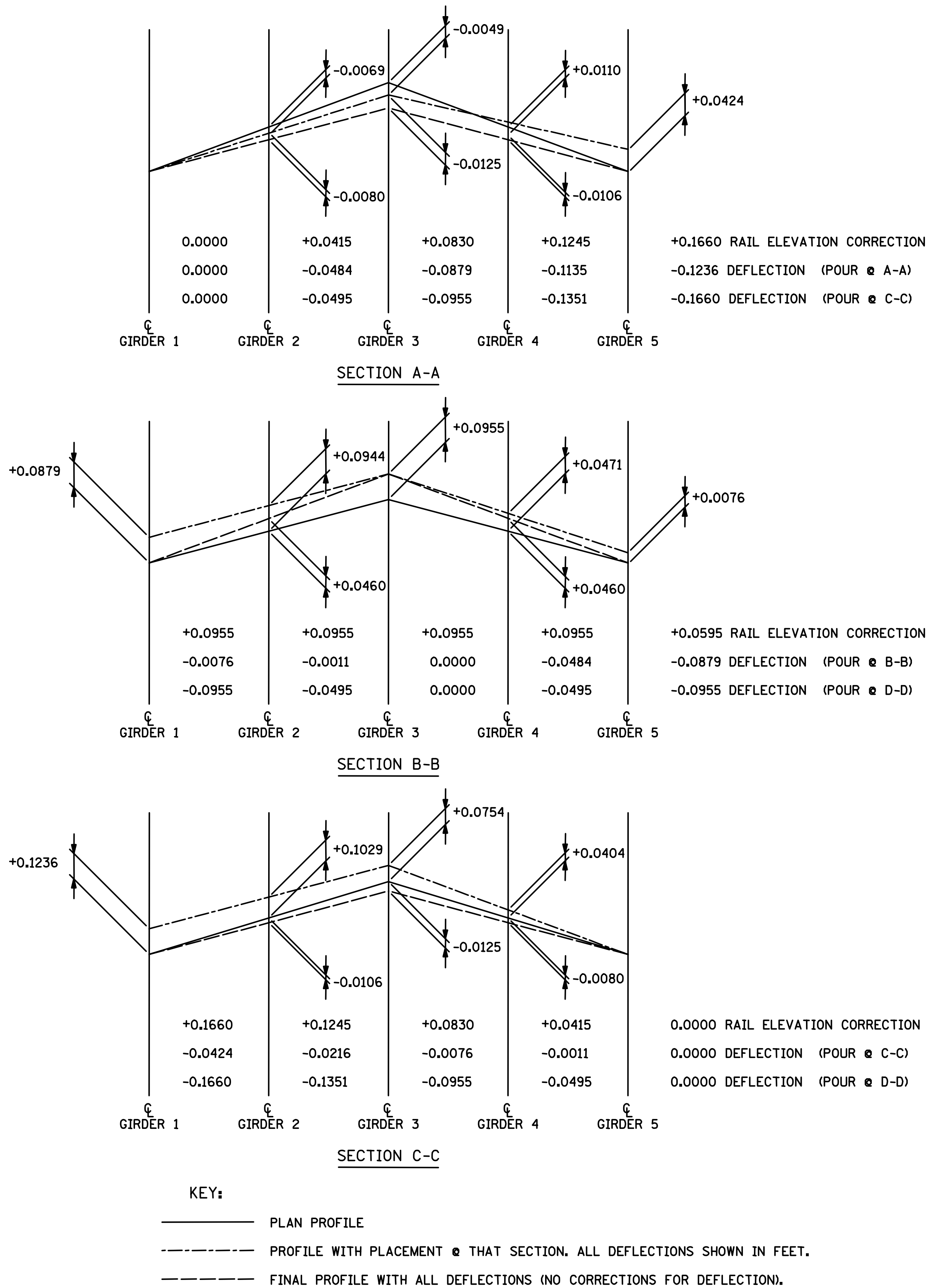
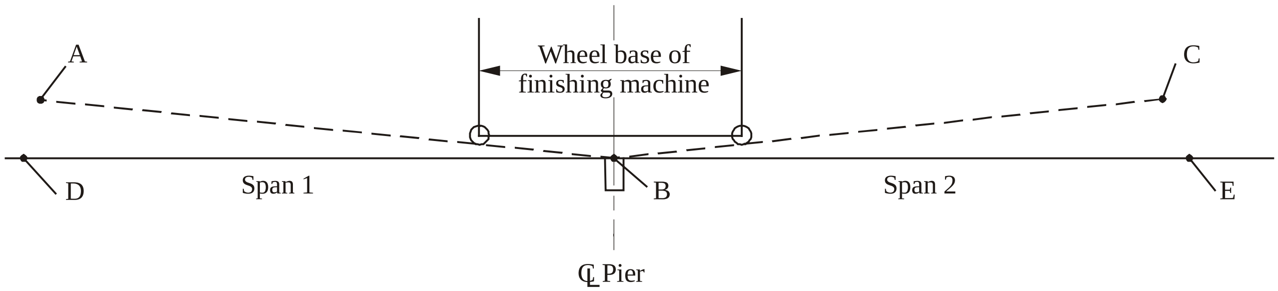
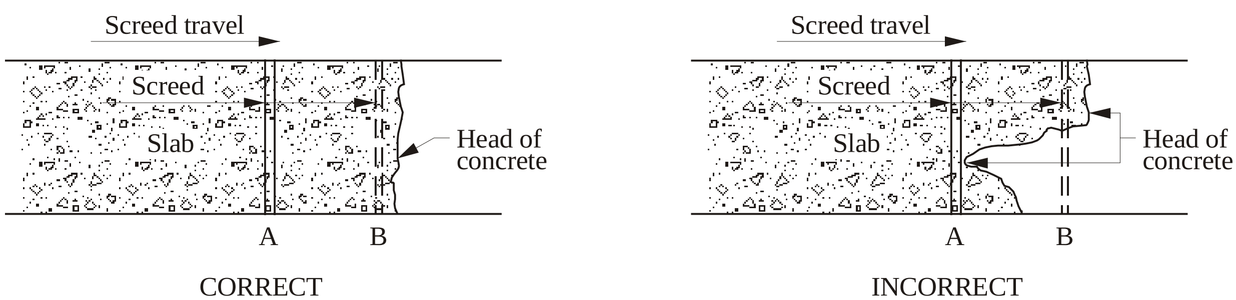


FIGURE C 5-393.358 CROSS SECTION PROFILES OF EXAMPLE



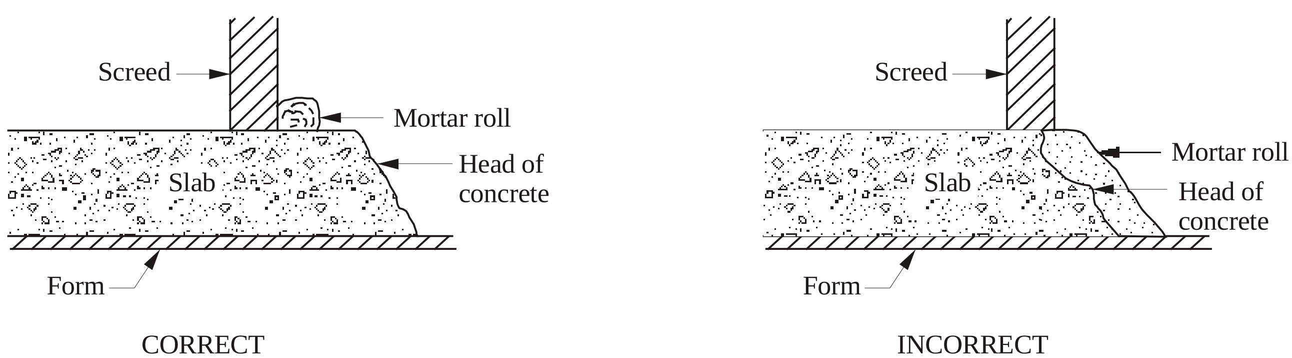
Dotted Line A-B-C = Position of rails on which finishing machine travels before concrete slab is placed.
Solid Line D-B-E = Desired position of rails with concrete slab in place on spans 1 & 2.

Fig. D RAIL POSITIONING FOR PLACEMENT STARTING AT A PIER



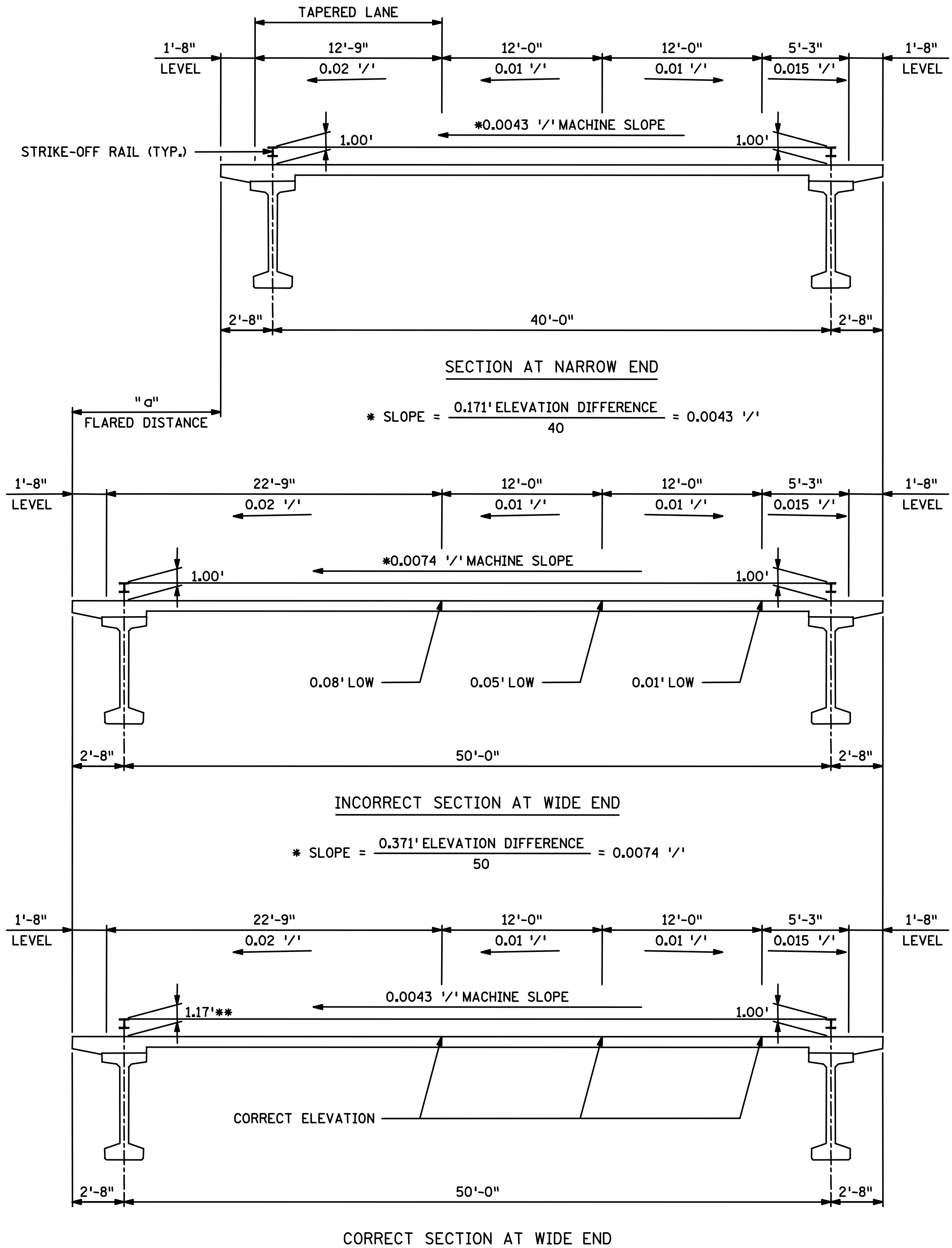
(Make head of concrete parallel to screed before operating screed from A to B.)

Fig. E PLAN VIEW OF CORRECT AND INCORRECT PLACEMENT



(Stop screed short of head of concrete, and do not permit mortar roll to be spilled over head of concrete. Leave small rolls, mix large rolls with fresh concrete as it is deposited.)

Fig. F CORRECT AND INCORRECT MORTAR ROLL



** RAIL HEIGHT = 1.00 + 0.02a - 0.0043a
= 1.00 + 0.02 '/' x 10' - 0.0043 '/' x 10' = 1.1570

ALL DIMENSIONS GIVEN IN FEET UNLESS STATED OTHERWISE.

FIGURE G 5-393.358 FLARED BRIDGE STRIKE-OFF RAIL ADJUSTMENT
(MACHINE MOVING FROM NARROW TO WIDE SECTION)

The final finish placed on the roadway surface is an artificial grass-type carpet drag followed by transverse tining. The artificial grass-type carpet drag behind the finishing machine shall be a minimum of 900 mm (13 feet) in length for bridge deck concrete (Grade 3Y36) and 1200 mm (4 feet) in length for low slump overlays (Grade 3U17A). The transverse tining may be made with a manual tining device operated from a suitable work bridge. The tining shall be made in one full pass on the surface except for a 300 mm (1 ft) wide section on the gutters. The tining device used for this opeation shall be equipped with 100 mm to 150 mm (4 in. to 6 in.) steel tines, 2 mm to 3 mm (1/16 in. to 1/8 in.) thick, arranged so as to obtain randomized grooves approximately 3 mm to 8 mm (1/8 in. to 5/16 in.) deep with a variable spacing between tines of 16 mm to 26 mm (5/8 in. to 1 in.). Depth of tining must be checked at the time the work is performed as correction is difficult after the concrete has cured. If tining depth is inadequate, grooves may be cut to provide an acceptable surface texture.

Specifications require that the final surface be free of porous spots and irregularities, and it shall not vary more than: 3 mm (1/8 in.) from a 3 m (10 ft) straightedge laid longitudinally on the surface of bridge deck slabs and latex wearing courses, 10 mm (3/8 in.) on the surface of structural slabs, and 5 mm (3/16 in.) on the surface of low slump concrete wearing courses. Transverse cross section shall be substantially in accordance with Plan dimensions. This check should preferably be made with the rolling straightedge which marks the "out of tolerance" areas on the slab. In lieu of this, the slab may be checked with the 3 m (10 ft) straightedge, although this is much more time consuming and not as thorough. See Figure A 5-393.359 for minimum surface checking which should be made performed the gutterlines and at two locations within each traffic lane.

Areas along the gutterlines, which are low as indicated by straightedging, should be rechecked with a level to see if water pockets (or bird baths) will result. If possible, the deck should be observed after flushing with water or after a rainfall to determine the presence and extent of such birdbaths.

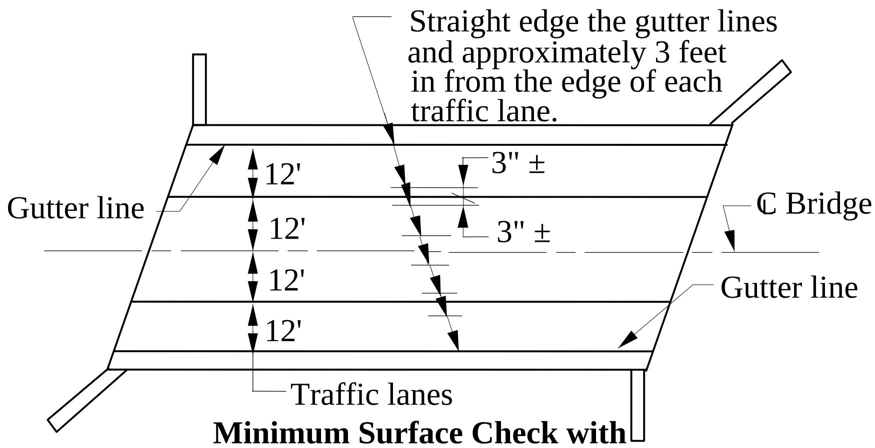
After completion of the above investigation, a decision can be made as to the need for surface correction (if any) and the type of surface correction. Surface correction should be limited to those situations in which significant improvement in rideability, skid resistance, deck drainage, cover over rebars, etc., can be obtained. In general, corrections will consist of grinding or concrete removal and replacement for high areas and concrete removal and replacement for low areas.

The Specifications require that areas corrected by surface grinding be coated with an approved surface sealer. If transverse tining is removed by the grinding, grooves should be cut to restore the texture and a sealer should be applied. When depth of grinding is shallow, so that transverse texturing is not entirely removed, treating oil will be considered as an acceptable sealer. Contact the Bridge Construction Unit for a list of approved sealers.

When it is determined that the correction will consist of building up low areas, the Bridge Office should be contacted for a recommendation for surface preparation and type of concrete mix. A price reduction might also be in the best interests of the State.

5-393.360 CONCRETE CURING

Curing of concrete refers to the maintenance of favorable conditions in the concrete for a period of time after initial set. This allows a reasonably fast strength gain in the concrete at early ages and the strength attained at later ages will approach the ultimate strength of the mix design. The conditions required during the curing period (which is assumed to start when the concrete takes a set), should not be confused with required conditions during placement. The inspector's vigilance is an important factor in obtaining such favorable conditions.



Minimum Surface Check with Rolling Straight Edge

Fig A 5-393.359

Favorable conditions that must be maintained during the curing period are:

1. Sufficient water for hydration of the cement must be present. Sufficient water will be available if evaporation of the mixing water is prevented or minimized. Curing of unformed surfaces should start as soon as the curing material can be placed without marring the surface. On formed surfaces that are stripped for surface finishing before the end of the curing period, the surface finishing should be done without delay and the curing resumed immediately.

2. The concrete must be protected from the effects of low temperatures, high temperatures and extremely rapid temperature changes. Permanent damage will result if the concrete is frozen in the early stages of cure. The temperature should be maintained at the required temperature or higher during the curing period because of the loss in durability and slow strength gain at lower temperatures. At the end of the curing period, when protection from low temperatures has been provided, the concrete temperature must be lowered gradually to avoid contraction stresses and possible cracks. Large differential temperatures between the surface and the interior of a concrete unit must be minimized for the same reason. See Specification 2401.3G for limitations on the rate of temperature decrease.

3. During the early part of the curing period when the concrete has little strength, it must also be protected from excessive vibrations, heavy shocks or application of loads.

The period of time during which favorable conditions for a gain in strength and durability is maintained is referred to as the "curing period." The curing period must start at the time the concrete takes a set and ideally be continuous throughout the specified duration. Certain finishing operations and unpredictable temperature variations may break the continuity of the curing period, but these interruptions should be limited to a few hours.

In general, the curing method shall provide temperatures above the specified minimum and shall prevent loss of the original moisture from the concrete. The method to be used is optional for the Contractor except for restrictions which are placed on the use of membrane curing compound. Curing compounds cannot be applied until the free water has disappeared from the surface of the deck.

Methods which are considered to be satisfactory are as follows:

1. Burlap Curing Blanket
   Plastic sheeting over a layer of wet burlap or a wet burlap curing blanket is a method of cure in which the loss of mixing water is minimized due to the tight nature of the cover. The plastic sheeting or plastic blankets must overlap at the seams to maintain a reasonably air tight seal. On substructure units they should be held in this position by wire or rope fasteners. They should be held in position on roadway and sidewalk slabs by holding down the blankets with sand or lumber at the joints and edges. When used as a method of cure for roadway slabs or sidewalks, the plastic sheeting should preferably be white. This color will reflect heat and reduce surface cracking due to high temperatures. Black plastic blankets may be desirable for cold weather protection when additional heat is beneficial.

   Burlap is desirable since it has the ability to act as a wick to distribute moisture uniformly over the surface. Burlap must be placed in close contact with the concrete and water must be added as necessary to assure that the concrete surface is moist at all times.

   When plastic sheeting or plastic blankets are used over areas where reinforcement dowels have been placed, it is very difficult to obtain an air tight seal in contact with the concrete surface. One method of cure at such locations is to place wet burlap in the dowel bar area, drape plastic over the tops of the dowels, and weigh down the plastic adjacent to the dowel areas. Another method is to puncture the plastic sheeting and place it directly over the burlap with the dowels projecting through the plastic sheeting. The important thing is that the burlap should not be permitted to dry out during the curing period.
2. Water Spray
   The amount of water applied in the water spray method should be limited to the amount that will keep the concrete wet without running sheets or streams. The location of the sprays should be such that there are no skips or holidays on the concrete surface. This may be accomplished with soaker hoses or sprinklers. Mineral and/or organic compounds in the water may stain the concrete and require corrective action.

3. Membrane Curing Compound
   Membrane Curing Compound (Specification 3754) is a liquid membrane forming compound suitable for approved sprayer application to retard the loss of water in concrete during the early strength gaining period. The common types in use for pavement, sidewalk, curb and gutter, and low slump concrete wearing courses is a resin based, white pigment membrane curing compound. The approved sprayer shall have a recirculating by-pass system which provides for continuous agitation of the reservoir material, separate hose and nozzle filters and a multiple or adjustable nozzle system that will provide for variable spray patterns. The membrane curing compound shall be sprayed on the concrete after finishing operations have been completed and as soon as surfacing conditions permit. Low slump concrete wearing courses require spraying within 30 minutes. The sprayed areas shall present a white, uniform surface, and any imperfections

shall be resprayed. The rate of application shall be approximately 4 m^2/L (150 ft^2/gal.).

Approved linseed oil curing compounds or emulsions (Specification 2401.3G) shall be applied on bridge decks except those which are to receive latex or low slump wearing course. Presently the only materials approved are linseed oil curing emulsions. The approved emulsions are water based and must be protected from freezing. The linseed oil curing emulsion is to be applied by power sprayers only. This curing method is temporary and conventional curing (wet curing, blankets, etc.) shall be applied as soon as possible.

Specification 2401.3G permits membrane curing compounds for such items as slope paving, footings and other sections that are to be covered with backfill materials. For those applications, conventional wet curing methods are not required after the membrane curing has been applied. Membrane curing compounds will act as a parting agent. Therefore, it cannot be used where subsequent bonded concrete will be placed or for surfaces that are to be waterproofed, treated with concrete treating oil, or are to receive a special surface finish.

All materials sprayed on the surface of the concrete for water retention are to be applied at the approximate rate of 4 m^2/L (150 ft^2/gal.). This is easily determined by placing a known quantity in the sprayer, applying uniformly, and measuring the area covered after the known quantity has been used. Additional coverage shall be required if it is not placed at the required rate or if skips or holidays are present.

Plastic shrinkage of concrete during setting may cause surface cracks to appear about the time the concrete is ready to be finished. Such cracking may develop at any time when circumstances produce an evaporation rate greater than the bleeding rate. The major difficulty occurs in the summer on deck placements, particularly if the humidity is low and evaporation is accelerated by the wind.

The following conditions tend to produce high evaporation rates:

1. Large surface areas such as deck slabs

2. Concrete of low bleeding tendency (This is not meant to suggest that bleeding, which is undesirable for other reasons, should be encouraged to prevent plastic cracking.)

3. Low humidity

4. High concrete surface temperature

5. Wind

Methods of alleviating rapid evaporation include cooling the mixing water, avoiding excessive mixing, prompt placement, erecting wind breaks, the use of fog sprays to maintain high humidity directly over the concrete or applying a spray-on monomolecular film. See Specification 2401 for requirements on the use of fog spray.

The use of a fog spray should be initiated at the first indication of surface dryness. Any delay after surface dryness is noted will almost certainly result in crack development. To help determine when a fog spray may be necessary, the American Concrete Institute has developed a nomograph to determine the approximate rate of evaporation based on current weather conditions, see Figure A 5-393.360. The following weather conditions and temperatures must be observed to use the graph to determine the amount of evaporation:

1. Air Temperature

2. Relative humidity

3. Surface temperature of the concrete

4. Wind velocity

Concrete bleeding rates generally lie in the range of about 0.5-1.5 kg per square meter per hour (0.1-0.3 lb/ft^2 hr). When the evaporation rate exceeds the lower of these figures, there is a potential for plastic cracking. Conditions which produce evaporation rates of 1.0-1.5 kg per square meter per hour (0.2-0.3 lb/ft^2 hr) make the use of precautionary measures such as the fog spray almost mandatory.

In lieu of the fog spray, the Contractor may be permitted to apply an approved membrane curing compound to reduce evaporation. The use of this material should be encouraged.

Specification 2401.3G requires curing to continue until a specified "Anticipated Compressive Strength" has been attained. This strength is computed from Table 2401-1 which gives the incremental percentage of strength gain in 24 hours for various concrete surface temperatures. As surface temperatures vary within a 24 hour curing period, the average temperature is computed from measurements taken on the concrete surface at different times of the day. The average temperatures for each 24 hour curing period is computed separately. Once the average temperature has been determined, the incremental strength gain for the first 24 hours is selected from Table 2401-1. The average temperature for the second 24 hour period is used to select the percent of strength gain for the second period and this percent is added to the strength gain for the first period to determine the total percent of strength gain after 48 hours. This process is repeated using the average temperature for the third 24 hour period and the 48 hour strength gain, the average temperature for the fourth 24 hour period and the 72 hour strength gain, etc., until the strength gain has reached the minimum required by Specification. No strength gain is credited during periods of temperatures below 4EC (40EF) and, if temperatures fall below 4EC (40E F) for a significant time period, this time period is not included as curing time. Temperatures below 4EC (40EF) and above 25EC (77EF) are not averaged in with the other data. Temperatures above 25EC (77EF) are reduced to 25EC (77EF) for the average temperature computation. Temperatures below 4EC (40EF) are discarded and the curing period is extended to include sufficient time to provide 24 hours of above 4EC (40EF) temperatures. Control cylinders may be necessary to determine strength gain if concrete is subjected to significant periods of below 4EC (40EF) temperatures prior to obtaining minimum required strength.

5-393.361 COLD WEATHER PROTECTION

Some cold weather protection requirements are as follows:

1. Specification 2401 requires that concrete be protected by methods that will prevent premature drying and will provide favorable temperatures immediately adjacent to the concrete surfaces.

2. Temperature limitations for the concrete and concrete materials are governed by the provisions of Specification 2461.

3. Concrete should not be placed on frozen ground or against concrete or steel with temperatures below freezing. When air temperatures are well below freezing, preheating the forms and adjacent surfaces will generally be required for a period of several hours, usually overnight, before making a placement.

4. The intent of the Specifications is to ensure that the poured concrete is protected and cured in accordance with the requirements which will assure adequate strength and durability.

5. When the concrete has been subjected to freezing or excessive drying prior to the completion of the required curing, the section involved should not be accepted until it has been subjected to testing that the Concrete Engineer may recommend.

The method of protection is completely at the discretion of the Contractor, provided that the temperature and moisture requirements are met. Regardless of which type of protection is used, complete records should be kept of the atmospheric temperatures and temperatures adjacent to the concrete surfaces.

The two common methods of providing cold weather protection are to insulate sufficiently to prevent the loss of heat produced by hydration or to house and provide a heat source outside of the concrete. Keep in mind that moist conditions must be maintained.

During late fall and early spring, when sudden and unpredicted temperature drops occur, emergency protection materials should be readily available. Even though this is primarily the responsibility of the Contractor, it should also be a concern to the inspector. Comparatively inexpensive preparations can save considerable expense when colder conditions do occur. It is important that all materials and equipment required for this purpose be readily available either by storage at the job site or within easy driving distance of the site. Discuss these matters thoroughly with the Contractor.

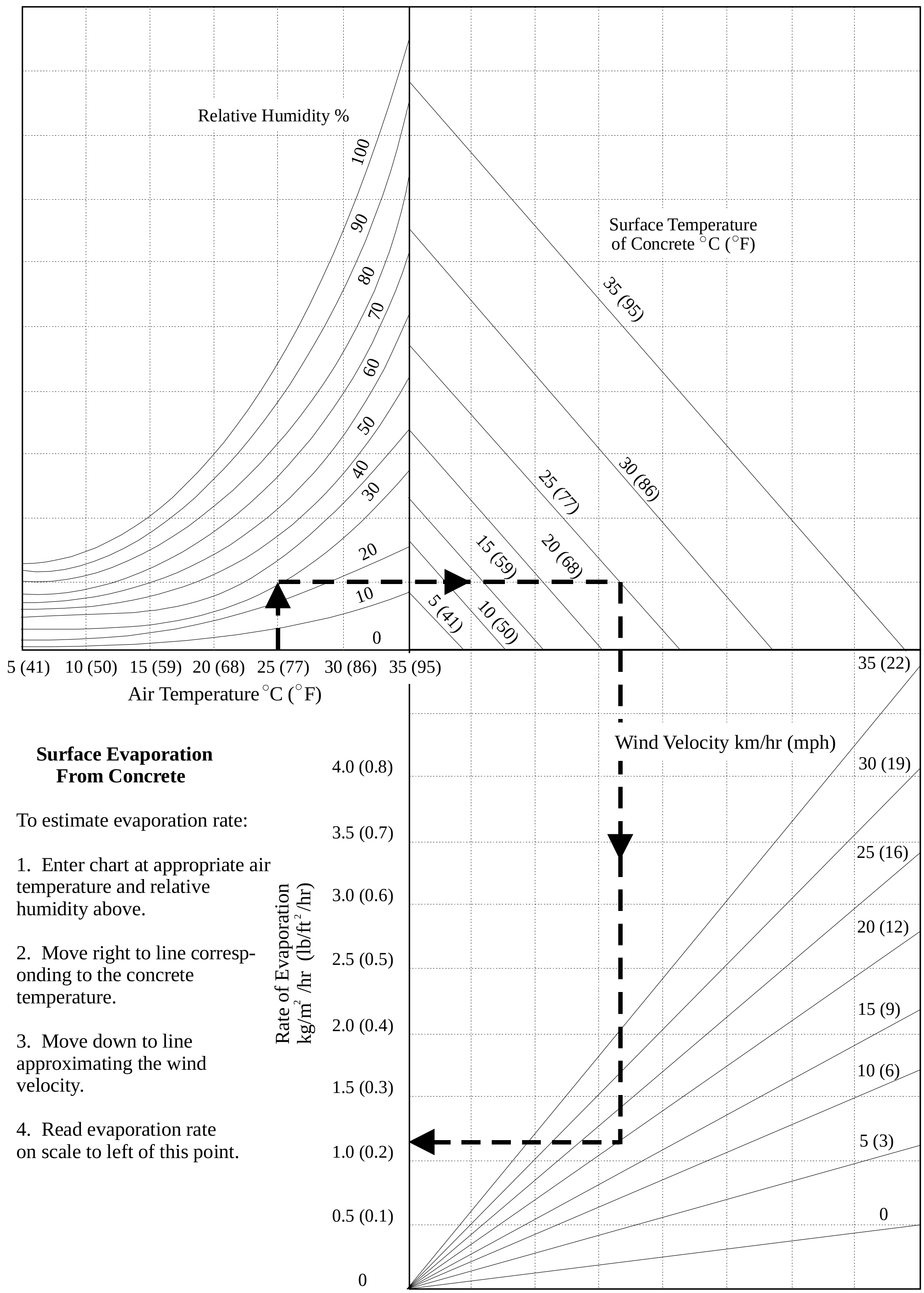
Plastic covered insulating blankets approximately 50 mm (2 inches) thick are reasonably effective in maintaining temperatures in slabs during short overnight temperature drops to freezing. Another insulator for this situation might be a bottom plastic sheet or blanket in contact with the concrete, a layer of straw approximately 100 mm (4 inches) thick and a top plastic sheet or blanket. The plywood forms provide some insulation for the bottom of the slab. The effectiveness of this method is dependent on placing the insulation immediately after the concrete has set, in order to retain as much of the heat of hydration as possible. This method cannot be expected to maintain the required temperatures adjacent to the concrete if the outside temperature remains near or below freezing for extended periods of time.

As soon as it becomes apparent that the heat of hydration will have dissipated prior to completion of the curing period, heating should be started immediately. The heat should be applied from the bottom if possible. Tarpaulins or similar material can be draped down the sides and heat applied by salamanders or blower type heaters. In the case of bridges over waterways or roadways open to traffic, the heat may have to be applied from the top and perhaps circulated by the use of fans. Keep in mind moisture requirements if circulation is needed.

The temperature within the housing should be maintained at or above the required level for the length of the curing period. Several thermometers should be placed within the housing near the concrete surfaces at locations most vulnerable to prevailing winds and farthest from the heating units. The number of thermometers required will be governed to some extent by the size of the unit to be protected but at least three thermometers should be used for units of normal size.

Small commercially available temperature monitoring devices that can be embedded into slabs, abutments, and other concrete items are very effective at determining the concrete temperature during the curing period. Contact the Bridge Construction Unit for more information.

Housing should be well constructed. The frame work must be strong enough to support not only the mass of the waterproof fabric placed on it but also to resist windloads and snowloads. When the fabric cover is a type which will not admit light from the outside, windows should be provided of sufficient size and number so that workers and inspectors may perform their work.



Surface Evaporation From Concrete

To estimate evaporation rate:

1. Enter chart at appropriate air temperature and relative humidity above.

2. Move right to line corresponding to the concrete temperature.

3. Move down to line approximating the wind velocity.

4. Read evaporation rate on scale to left of this point.

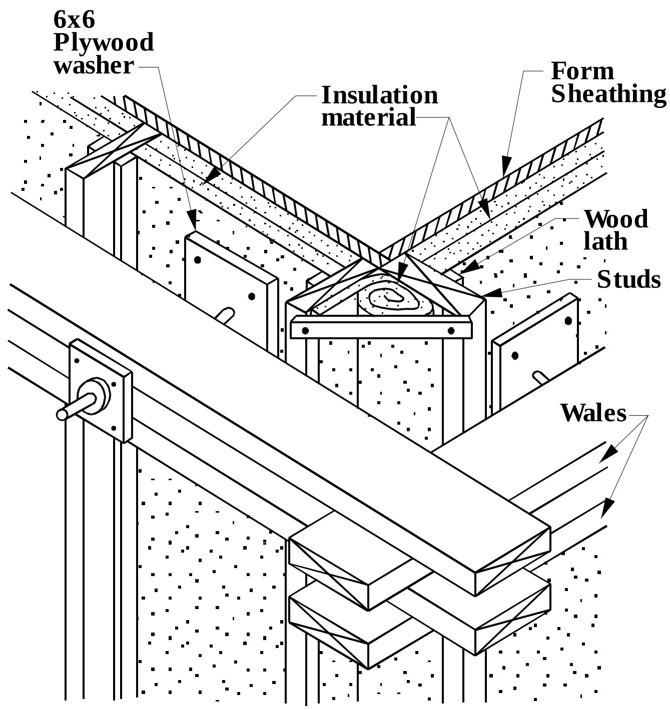
Enclosures should be constructed in such a manner that will allow free circulation of the warmed air. Salamanders and oil or gas fired heaters with blowers are commonly used as a heat source. These heaters should be moved periodically to prevent local drying and overheating of local areas. Open fires and salamanders should be avoided because they do not provide circulation obtainable with blower type heaters. They should also be avoided because exposure to the high carbon dioxide content of open fires during the first 24 hours of cure may seriously weaken the concrete at the surface. If salamanders are used, they should be blocked up to avoid damage to the slab on which they are resting and vented to the outside to prevent carbonation damage.

Dry heat for protection of concrete in cold weather tends to produce rapid drying because warm air will hold much more moisture than cold air. To illustrate, air at 25EC (77EF) can hold about four times as much moisture as it can at 0EC (32EF). Consequently, if air at 0EC, even though saturated, is warmed to 25EC (77EF), it will quickly draw moisture from the concrete. It is important that moisture conditions be carefully observed and additional moisture provided, as necessary, when dry heat is used.

Since concrete is susceptible to severe spalling and cracking when subjected to the heat of an open fire, it is unwise to store combustible materials in an area where heating operations arein progress. It is also advisable to maintain fire extinguishing equipment at the bridge site.

Several types of insulation material are suitable for or are especially produced for formwork. Among these are: a sprayed-on type used largely for steel forms; foamed polystyrene and polyurethane board that can be cut to fit between studs of vertical forms; and various kinds of wood and mineral bat or blanket insulation. These materials must be kept dry to maintain insulation values. Prefabricated form panels are now available with insulation sandwiched between two plywood faces or permanently attached to the outer face. Electric construction grade heating blankets have also been used to maintain the desired concrete temperature during cold weather.

The several kinds of wood and mineral “wool” insulating bats for formwork come in 25 mm (1 in.) and 50 mm (2 in.) thicknesses, with widths designed to fit between studs spaced at 305 mm, 406 mm or 610 mm (12, 16 or 24 in.). The insulation itself is about 25 mm (1 in.) less than these widths, and the outer casing material has reinforced flanges for nailing the bats to the studs. The outer covering or encasement may be made of polyethylene plastic, asphalt-impregnated paper or a plastic-paper laminate. The insulation may be stapled or attached with batten strips to sides of the form framing. Maximum heat loss will occur at the corners; therefore, these areas should be examined closely to see that they are well insulated. See the sketch, taken from an American Concrete Institute publication, for a recommended method of attaching insulation at corners.



Typical Method of Attaching Insulation

If cold weather conditions make it necessary, upper horizontal surfaces, such as bridge seats, should be temporarily housed and heated until the concrete has been properly struck off and finished. When the concrete at these surfaces has set to a degree that it will not be damaged, it may be covered with insulating materials and tarpaulins or plastic sheets and the housing and heating removed.

Walls with 600 mm (24 in.) minimum dimensions and columns with 760 mm (30 in.) minimum dimensions can usually be protected to -20EC (0EF) with insulation having a thermal resistance “R” of 1.23 (R11) or more. The resistance “R” is determined with the following formula.

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

Where:
R = thermal resistance per mm (inch) of thickness
T = thickness of insulation in mm (inch)
K = thermal conductivity in kW per square meter per CE (Btu per hour, per square foot, per FE)

The following table can be used as a guide for determining approximate “K” values. “K” values vary with temperature and, therefore, only approximate values can be used unless the manufacturer provides exact “K” values. The approximate thermal resistance “R” provided by 25 mm (1 inch) thickness of insulation is shown in the following table.

MATERIAL	APPRX "K" PER mm THICK-NESS	APPRX "K" PER 1 INCH THICK-NESS	"R" PER mm THICK-NESS	"R" PER 1 INCH THICK-NESS
Plywood	4.5	0.80	0.22	1.25
Concrete	30-50	6.00-9.00	0.03-0.02	0.17-0.11
Cotton Fiber *	1.50	0.26	0.67	3.85
Rock Wool *	1.00	0.27	1.00	3.70
Glass Wool *	1.50	0.27	0.67	3.70
Expanded Wood Fiber	1.40	0.25	0.71	4.00
Polystyrene (High Density)	1.30	0.23	0.77	4.35
Polystyrene (Low Density)	1.50	0.26	0.67	3.85

* Blanket or Bat Insulation

Calendar cut-off dates have been established to ensure proper curing of low slump and latex concrete wearing courses. These mixes need approximately 30 days of favorable hardening and drying in addition to the wet curing period prior to the onset of freezing weather. After the cut-off dates, housing and heating with adequate ventilation and air circulation are necessary. Upon completion of the wet cure, the cold weather housing and heating system must allow air circulation so that the concrete wearing surface dries out. This curing procedure is somewhat different from the usual recommended practice which would call for keeping the surface wet.

The need to limit rapid temperature changes is a factor that must be considered when planning removal of insulated forms in cold weather. Specification 2401 requires that the temperature inside the forms be reduced at a rate not to exceed 10EC (20EF) per 12 hour period. This is most critical with moderately massive sections and, for massive units, a slower rate of temperature reduction may be necessary.

5-393.362 VIBRATION PROTECTION

Specification 2401 requires that newly placed concrete be protected from vibrations. Damaging vibrations may be caused by pile driving, blasting, heavy road machinery and railroad operations.

Empirical methods such as observing water ripples in a small container, observing the movement of a level bubble and standing on piling in the unit in question when operations causing the vibrations are in progress, have been used as a guide in determining objectionable vibrations. Bubble movements of several divisions back and forth indicate excessive vibrations with a dumpy level (or transit with telescope level) set up firmly on the foundation material of the proposed pour. Sometimes vibrations are carried by lower ground strata from piles being driven in one unit to piles in place in an adjacent unit. The inspector can detect such vibrations by standing on a pile in the unit to be poured. The human body can detect a vibration velocity of 0.5 mm/sec. But damage does not usually result until vibration velocity reaches 50 mm/sec. This should be kept in mind when making subjective determinations of excessive vibrations.

A guide which may be used to approximate the damping distance from a pile hammer to "green" concrete is given in Figure A 5-393.362. The distance can be computed from the following formula:

$$D = \frac{\sqrt{E}}{F}$$

Where:

D = minimum distance from pile hammer to the "green" concrete in meters (ft).

E = the energy of the pile hammer in N·m (ft-lb) as taken from Figure A 5-393.164.

F = a value obtained from Figure A 5-393.362 for the corresponding concrete strength gain and soil type.

The percent of the ultimate concrete strength can be obtained from strength temperature curing curves. An example using this guide is as follows:

The concrete has obtained 16% of its ultimate strength.
Energy of pile hammer - 20340 N·m

Soil is wet sand
From Figure A 5-393.362 F = 10.8

$$D = \frac{\sqrt{20340}}{10.8} = \frac{142.6}{10.8} = 13.2 \text{ m, say } 13 \text{ m}$$

If the empirical methods and engineering judgment indicate excessive vibration, the placement should be delayed until the operation causing the vibration is completed. If this is not feasible, the vibration producing operation should be stopped for the required 72 hours.

Usually, with footings in place, succeeding pours will not be affected by pile driving in adjacent units. However, excessive vibration can be checked.

The cooperation of the Railroad Company can sometimes be obtained by requesting a "slow order" when vibrations from their traffic are considered to be detrimental.

Where requested by the Contractor and approved by the Engineer, the Contractor shall provide seismographs or other similar monitoring equipment to assure that maximum particle velocities will not be exceeded at the site of concrete placement operations. Monitoring equipment shall be securely attached next to, or on, the freshly placed concrete at a location of maximum exposure to the source of vibrations. The actual measuring point should either be buried in the soil adjacent to the structure, or grouted or mechanically fastened (bolted) to the structure or form.

The following maximum peak particle velocities are considered safe for newly placed concrete ("maximum" refers to the maximum of three mutually perpendicular transducer components).

Concrete Age (hrs)	Allowable Maximum Peak Particle Velocity (mm/sec)
0-3	NA
3-12	25
12-24	38
24-48	63
48- * CP	100

*Completion of required curing period.

The above vibration limits are intended for the protection of newly poured concrete only. These limits do not relieve the Contractor from complying with any other vibration limits that may be in force on the project, nor do they relieve the Contractor from responsibility for damage to any existing structures (on or off the right-of-way) that may be affected by the vibration producing activity. While the above vibration levels are considered safe for newly placed concrete, they are higher than what is normally allowed for older buildings and structures.

If damage occurs, such as cracking of the concrete or deterioration of support rock below footings, at less than the maximum particle velocities allowed above, the Contractor shall suspend the activity causing detrimental vibrations until necessary protection for the concrete has been installed.

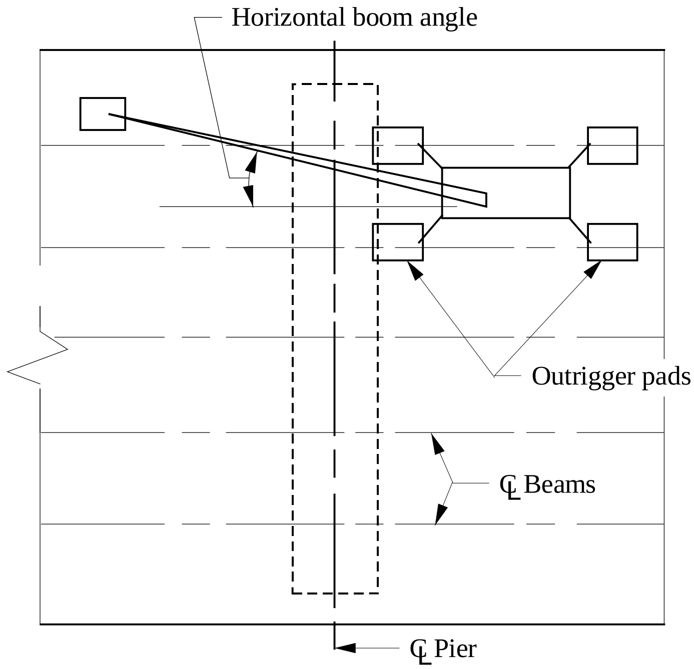
Seismographic equipment is not required when operations that may be detrimental to concrete during the curing period are not conducted so near the concrete to cause noticeable shocks or vibrations. As a general rule, vibration levels will not be of concern until they reach a level where they are clearly perceptible by a person standing adjacent to the structure in question.

Specification 2401 prohibits the operation of heavy equipment which causes detrimental shock waves during placement and curing of concrete. The inspector should be careful to prohibit the use of any equipment on the deck during the specified time interval that may cause disturbing vibrations in areas where the concrete has not attained the minimum required strength.

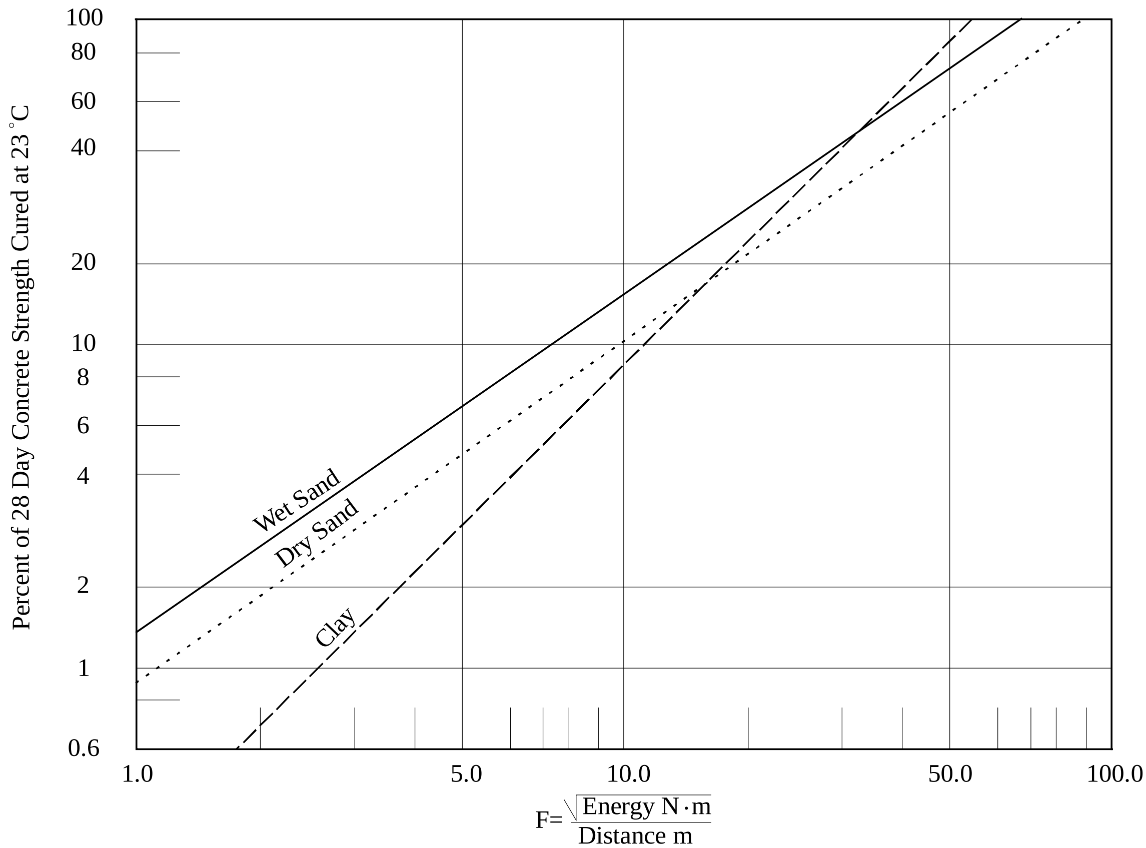
Attention is directed to Specification 1513 for limitations and requirements on construction equipment crossing or operating on new or old bridges. Permission to use ready-mix trucks to discharge concrete directly into curb or railing forms on steel beam or prestressed girder spans should not be granted until the following requirement is met. Strength gain computations or control cylinders cast with the last pour must show strengths of not less than 65 percent of anticipated 28 day compressive strength (70 percent during adverse weather). On simple spans, the strength requirement should be applied to the span on which the truck operates and to the span on either side. This same criteria should be applied to truck loads of reinforcement bars, form lumber, etc.

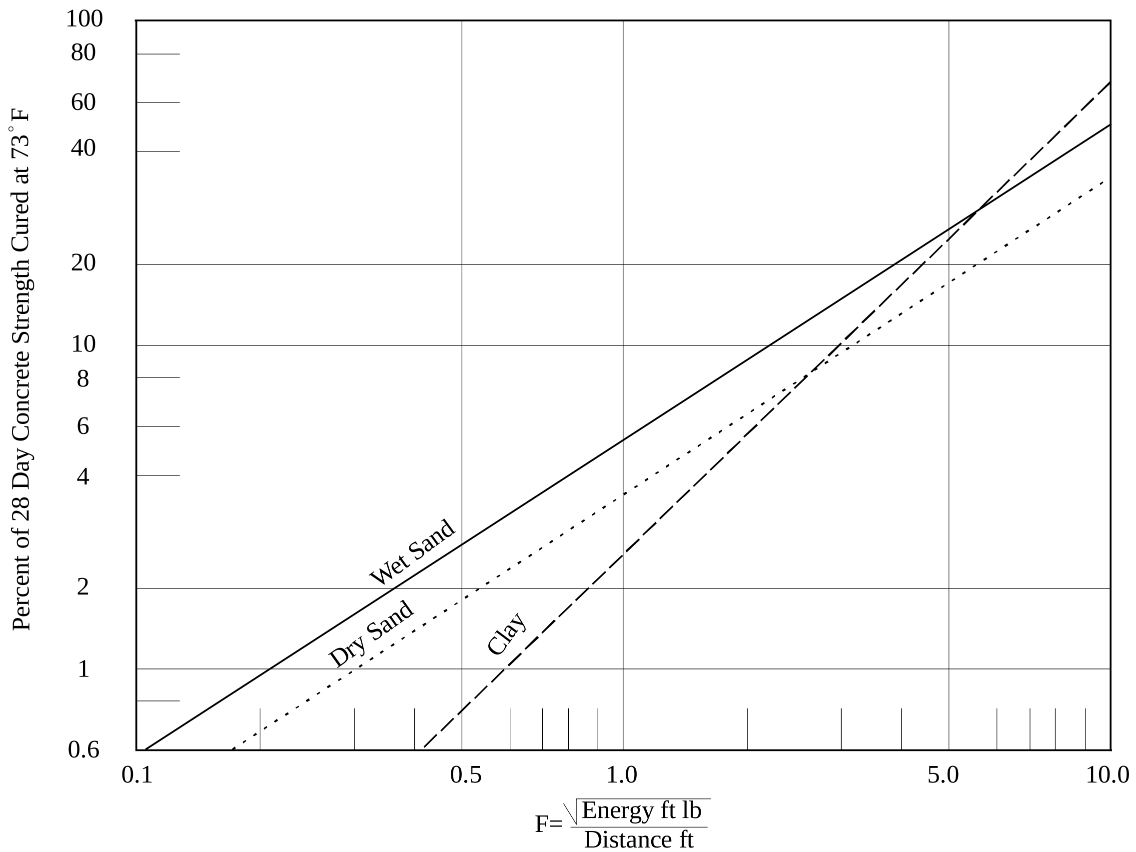
The turning of ready-mix trucks on bridge decks should be avoided. If the truck must return to the same end of the bridge for successive loads, the truck is usually driven to the point of discharge, unloaded and then backed off the bridge or vice versa. Speeds should be slow and the sudden application of brakes avoided. Mixers should be restricted to agitating speeds.

In general, the use of a crane on a bridge deck should be discouraged because of the many indeterminate factors in the stress analysis and the rigid enforcement required during the operation. Under certain conditions the use of a crane on the bridge deck may be the only feasible method of construction. The Bridge Construction and Maintenance Section should then be contacted and an analysis of the Contractor's proposed scheme will be made by the Bridge Design Section. If permission is granted to operate a crane on the deck of an in place bridge, the crane should be positioned to minimize stresses in the slab and beams. See the following sketch titled, "Plan View Showing a Possible Crane Location."



Plan View Showing a Possible Crane Location


Percent of 28 Day Concrete Strength Cured at 23 °C
100
80
60
40
20
10
8
6
4
2
1
0.6
1.0
5.0
10.0
50.0
100.0
Wet Sand
Dry Sand
Clay
F= √Energy N·m / Distance m


Percent of 28 Day Concrete Strength Cured at 73° F
100
80
60
40
20
10
8
6
4
2
1
0.6
0.1
0.5
1.0
5.0
10.0
Wet Sand
Dry Sand
Clay
F= √Energy ft lb / Distance ft

The following guidelines should be observed:

1. The crane should be located near a pier and never at midspan.

2. Outrigger pads should be centered over beams, as nearly as possible.

3. Plywood or timber should be placed under all outriggers to distribute the load.

4. The vertical boom angle should be kept as small as possible (boom as vertical as possible) to prevent high load concentrations on any outrigger pad.

5. The horizontal boom angle should also be kept as small as possible to prevent high load concentrations on any outrigger pad.

5-393.363 BRIDGE DECK LOW SLUMP AND LATEX WEARING COURSES

Specification 2404 concrete wearing courses are placed on new construction and repaired bridge decks to provide an impervious layer for the wearing surface. In general, the requirements of this chapter apply to wearing courses; however, materials are job site mixed which requires additional inspection procedures. All the materials required for normal size bridges should be stockpiled at one location on the project and inspected for specification compliance prior to any concrete work. Large bridges will require stockpiles located near the section where placement operations are planned to reduce the distance between mixing and placement operations. A minimum of two gradations shall be run on the coarse and fine aggregate to determine specification compliance. Both latex and low slump concrete mix types specify the same aggregates: CA70 Class A, B, C, and D coarse aggregate (Specification 3137) and fine aggregate (Specification 3126).

Materials are to be mixed using continuous mixers at the project site. Continuous mixers shall be calibrated prior to overlay operations following the procedures in the Concrete Manual 5-694.400. An approved stationary batch type mixer may be used for latex materials but is not acceptable for low slump concrete.

Careful study of each project by inspectors is necessary well in advance of placement operations to ensure compliance with requirements. Specific requirements apply to both mixes (except where noted) are as follows:

1. Latex wearing courses are normally placed at a minimum thickness of 40 mm (1 1/2 in.) and 50 mm (2 in.) for a low slump concrete wearing course. After the rails for the finishing machine have been set to provide a smooth ride and the required minimum thickness, a fill strip shall be secured to the bottom of the finishing machine screed and the deck area shall be run to ensure the minimum thickness requirement is met. Rail heights shall be corrected if necessary and re-run for verification.

   In some instances the finishing machine rails have been adjusted to obtain a smooth profile to the extent that the thickness of the overlay placed was excessive. This is a concern:

   a. To the Contractor because of the extra volume of concrete required

   b. To the designers because of additional dead load to the structure (Any increase in the dead load to the superstructure decreases the live load capacity of the bridge.)

2. The Latex mix calls for a slump of 140 mm ± 25 mm (5 1/2 in. ± 1 in.) and an air content between 3 1/2% and 6 1/2%. The low slump concrete mix calls for a slump of 20 mm ± 5 mm (3/4 in. ± 1/4 in.). Low slump concrete shall be produced with an air range of 6-7% with the normal tolerances of 6 1/2% ±1 1/2%. Since job site mixes are delivered before the materials have reacted with the mix water (or latex modifier), five minutes must elapse before running the slump test in order to obtain the true slump. See Specification 2404 for more details.

3. An approved power operated finishing machine, capable of forward and reverse motion under positive control is required. Provisions shall be made for raising the screeds during reverse operation. The length of the screed shall be sufficient to extend at least 150 mm (6 in.) beyond the edge of the course being placed and overlap the edge of previously placed course at least 150 mm (6 in.). A bulkhead subject to approval of the Engineer may be placed to limit waste of materials, only for latex. The finishing machine shall be so designed that the elapsed time between deposit of the concrete and final finishing does not exceed 15 minutes. Concrete placing and finishing shall proceed at a linear rate of not less than 12 m per hour (40 ft/hr) and placement width shall not be greater than 7.3 m (24 ft) unless specifically authorized in the special provisions.

   In addition to the requirements above, the finishing machine for low slump concrete must meet the following; The finishing machine must have at least one oscillating screed and be designed to consolidate low slump concrete to 98 percent of rodded density by vibration. The front screed must have effective vibration equal to that provided by one vibrator for every 1.5 m (5 ft) of screed. The bottom face of the front screed shall be at least 125 mm (5 in.) wide with a turned up or rounded leading edge. Each screed shall be provided with positive control of the vertical position, tilt and shape of the crown and must produce a pressure of at least 3.2 kg/m^2 (75 lb/ft^2) of screed area bottom face. The finishing machine shall have an adjustable power operated paddle or auger for strike off.

4 Immediately prior to overlay placement, the deck surface shall be cleaned and then sandblasted. After sandblasting, all spent sand, dust and debris shall be removed from the surface by air blast. The air supply system must have a suitable oil trap between the storage tank and the air hose nozzle. Any oil drippings from equipment, concrete buggies, etc., during overlay placement shall be removed from the surface by re-sandblasting or bush hammering.

5. For latex concrete, the surface shall be dampened with water after sandblasting; however, standing water or puddles shall not be permitted. Properly mixed latex composition shall be brushed into the dampened surface and spent aggregate removed for disposal. All vertical and horizontal surfaces shall be uniformly coated and the overlay shall be placed and finished while the bonding grout is still wet.

   For low slump concrete, the surface shall be clean and dry. The bonding grout shall consist of equal masses of sand and cement and sufficient water to form a creamy slurry. The grout shall be thoroughly scrubbed into all surfaces on which the overlay will be placed or abutted. A very important function of the inspection is to keep the grouting operation close to the placement of the overlay concrete. The grout must not be permitted to dry out before the concrete is placed.

6. Overlays are restricted to placement between April 15th and September 15th (October 1st south of the 46th parallel) and are subject to temperature restrictions in the summer. It may be possible to place an overlay during the winter by heating and housing the deck according to Specification 2404.3A.

   Latex overlays shall not be placed when the air temperature is lower than 7EC (45EF) nor can latex or low slump overlays be placed when the daytime temperature is expected to reach 28EC (80EF) or higher. When the temperature is predicted by the National Weather Service to reach or exceed 28EC (80EF), the placement shall be rescheduled or started between the hours of 7:00 PM and 5:00 AM. Placements started during this period when the air temperature is rising and reaches 28EC (80EF) shall be terminated. The Contractor shall advise the Engineer when night pours are being scheduled and shall provide suitable night illumination. Illumination provisions shall include the necessity for inspection of both surface preparation and concrete pours.

7. After placement and consolidation, low slump overlay wearing courses are finished as prescribed in Specification 2404.3.

8. Low slump concrete surfaces shall receive membrane curing compound as specified in Specification 2404.3C3. The surface shall be covered with conventional curing materials (wet burlap or curing blankets) as required by Specification 2401.3G. No impact equipment shall be operated in the adjacent lane during the first 72 hours. The cure shall be continued for a minimum period of 96 hours. After the 96 hour curing period has terminated, traffic may be permitted. If daily mean temperatures have been below 15EC (60EF) during this 96 hour period, additional curing time will be needed at the discretion of the Engineer.

   Bonded wearing courses require special curing procedures. Membrane curing compounds are not permitted for latex overlays. They shall be covered with a single layer of wet burlap as soon as the surface can support it without deformation. The wet burlap shall be covered with a layer of polyethylene film for a period of not less than 48 hours. The curing material shall remain in place at the discretion of the Engineer if the ambient temperature falls below 13EC (55EF) during the curing period. After removal of the curing material, the latex overlay shall be dried for a period of 72 hours before traffic shall be permitted.

9. Bridges with roadway widths in excess of 24 feet will require multiple passes of the overlay paving machine. However, specification 2404 states that no impact equipment shall be operated in the adjacent lane during the first 72 hours after concrete overlay placement. Since the overlay paving machine uses significant vibration to help consolidate the low slump concrete mixture, it is considered to be "impact equipment". Hence, placement of overlay concrete adjacent to previously placed overlay is prohibited until the previously placed overlay is at least 72 hours old.

5-393.364 DIAPHRAGMS

Steel diaphragms, if allowed, are shown on the Plans for prestressed beam structures. Shop drawings are required for steel diaphragms showing details of beam layouts, location of the diaphragms and location of mounting holes. High strength bolts for steel diaphragms shall be tightened by Turn-of-Nut method or the use of Direct Tension Indicators. See Section 5-393.414 for more information.

5-393.365 ANCHOR BOLTS

Special care should be given to the finishing of bridge seats, pier caps, etc., so that full and uniform bearing with the masonry plates will be obtained and the bearing areas are at the correct elevation. Also, the location of anchor bolts must be accurately laid out before the concrete is cast. If the anchor bolts are to be cast into the pour, they must be rigidly held at the correct position, alignment and depth of embedment. If the anchor bolts are to be drilled into the hardened concrete and anchored with melted lead or a grout, the position of the bolts should be checked by the use of a template and the reinforcing steel adjusted as necessary to avoid interference with the bolt locations.

Specification 2402.3H requires that holes for anchor bolts shall be drilled except where otherwise specified in the contract.

Before the substructure concrete is placed, the location of drill holes for anchor bolts should be checked because corrections are difficult to make after completion of the substructure. The placement of substructure reinforcement bars should be checked carefully so that the proper clearances between the anchor bolt holes and reinforcement bars are provided.

Also, the Plans and Shop Drawings for bearing devices should be checked to ensure that dimensions are the same and that minimum distance to edge of bridge seat can be obtained.

Placing anchor bolts using a Portland Cement grout should be done only when the air temperature is favorable. After drilling, anchor bolts should be inserted into the dry holes to check proper fit and projection and then removed. The holes for the bolt should then be filled about 2/3 full of grout and the bolt should be immediately inserted and forced down until the top of the bolt is at the correct height above the bridge seat. The anchor bolt holes should be filled with grout flush with the bridge seat. All excess grout which may have been forced out of the hole, including that which may be in the expansion slots or on any metal surface, should be removed.

The grout mix should consist of one part standard Portland Cement and one part clean fine grained sand and should be mixed with enough water so as to flow freely but not so wet to cause undue shrinkage.

When it is necessary to place anchor bolts during freezing weather, a commercial product approved by the Engineer should be used in place of grout. The anchor bolt holes should be dry and the anchor bolts and concrete adjacent to the holes should be preheated. The anchor bolts should be warm when the grout material is poured to defer the cooling process until the material reaches the bottom of the void. The anchor bolts should be in correct position. The top of the anchor bolt should be at the correct height above the bridge seat and the grout material should completely fill the void between the bolt and the edge of the hole.

When anchor bolts are to be set prior to placing concrete for the substructure units, they should be held and supported securely inplace. The correct position, including the projection above the bridge seat, should be carefully checked before and after concrete placement.

During freezing weather, anchor bolt holes that have been drilled but not filled should be provided with adequate protection. If water is allowed to freeze in anchor bolt holes, it could cause critical damage to the substructure unit. An elastic type closed cell foam-like material, such as neoprene, vinyl or butyl rubber rod stock or similar materials, may be used to fill the open holes or void space around an anchor bolt which has not been permanently set and grouted inplace. The material should be installed so that it will remain securely in place until the anchor bolts are permanently set.

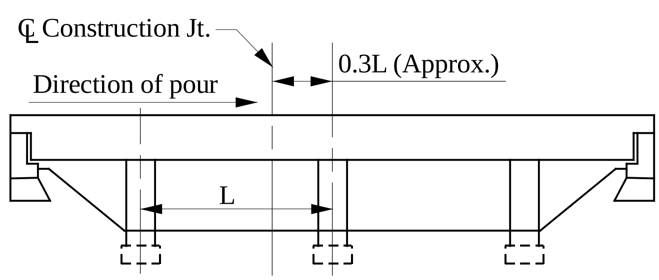
Anchor bolt nuts are seldom used but, where required, should be checked for proper adjustment. Most questions regarding the placement of anchor bolt nuts can be answered by carefully checking the Bridge Plan details. After the anchor bolt nut is adjusted, it should be secured by center punching to upset the threads at the outer face of the nut.

5-393.366 CONSTRUCTION JOINTS IN CONCRETE

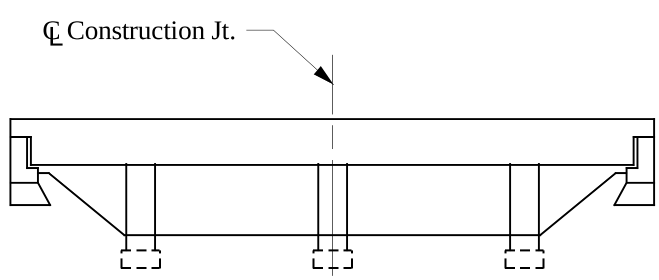
Construction joints, as distinguished from other concrete joints, are not intended primarily to permit movement between sections of the structure. They are necessary either because of a change in concrete mixes at that location, or other construction requirements. Construction joints, therefore, generally have reinforcing bars extending through the joint.

Permissible construction joints are permitted as a convenience to the contractor when large pours, or difficult forming, would otherwise be necessary. Their use is optional with the contractor. The Plans will label these joints as “permissible construction joint,” except for permissible construction joints in roadway slabs which are described in the Special Provisions. Permissible construction joints in deck slabs resting on prestressed girders or steel beams may be constructed at the locations shown in the following sketches, unless indicated otherwise in the plans.

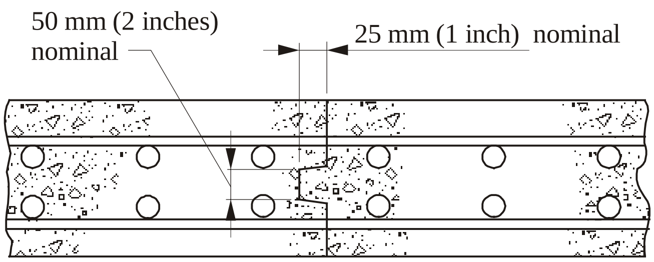
Keyways are mandatory in all slab construction joints and should be similar to the sketch labeled “Typical Slab Keyway.”



Steel Beams or Prestressed Girders with Single Diaphragm at Pier

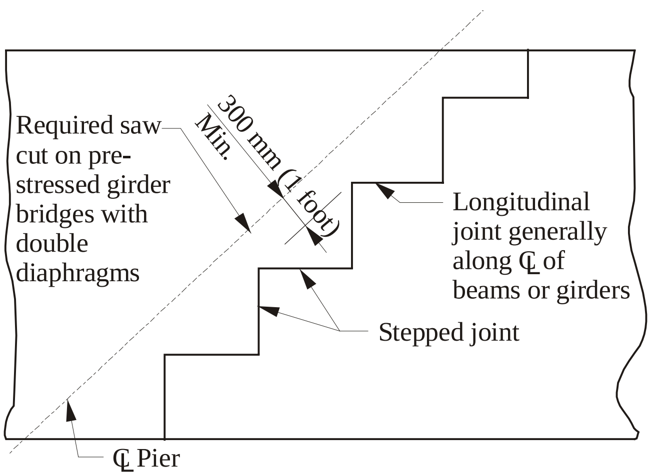


Prestressed Girders with Double Diaphragms at Piers



Typical Slab Keyway

The slab construction joint should be placed parallel to the transverse slab reinforcement for skews of 20° or less. On bridges skewed 20° or more, the joint should be placed parallel to the skew or stepped as shown in the sketch labeled "Plan View of Stepped Joint." If a stepped joint is used, the longitudinal portion would be preferably located directly over the centerline of the beams or girders. The stepped joint should never be closer than 300 mm (1 foot) to the required saw cut which is made over the centerline of the pier. See the drawing labeled "Plan View of Stepped Joint" on the next page.



Plan View of Stepped Joint

Emergency construction joints may be necessary due to equipment breakdown, delay in concrete delivery, or for other reasons. Every effort should be made to repair or replace equipment in case of a breakdown in order to avoid using the emergency joint. A "cold joint" can sometimes be avoided by covering the concrete surface with wet burlap, or by applying thin coats of job-mixed mortar (2 parts sand to 1 part cement). The following is given only as a general guide for emergency construction joints. Each joint must be treated individually as the necessity arises.

1. Joints in walls and columns should be placed level (if possible, otherwise stepped) and provisions made for a neat straight line on all exposed surfaces. Joints shouldbe placed normal to the side forms, except that slab construction joints should be placed parallel to transverse reinforcement for skews of 20° or less and stepped or skewed for skews greater than 20°. Keyways, and sometimes dowels, are necessary in emergency construction joints to resist shearing forces.

2. The Bridge Construction and Maintenance Section should be contacted for advice, if possible, as soon as the need for an emergency construction joint is known. Have a copy of the Plans available and take measurements to indicate the location of the joint before making the call.

The Plans will label a mandatory construction joint as a "construction joint." The joints are placed, to control cracks due to shrinkage, to separate concrete of different mixes, or to permit deflection in part of a superstructure before placing additional concrete. Because the elimination of such joints would adversely affect the structure, their construction is mandatory and they must be placed at the location shown in the Plans and in accordance with Plan details. Longitudinal joints are undesirable because of the unequal deflections and resulting stresses. If a longitudinal joint is necessary, the Bridge Construction and Maintenance Section should be contacted for a recommendations.

Keyways are required at all vertical and horizontal construction joints to transmit shear forces. Most keyways are 1/3 the depth or width of the structure member. This provides the maximum shear section when forces are applied to either side of the member. See the Typical Keyway with Saw Cut Location sketch.

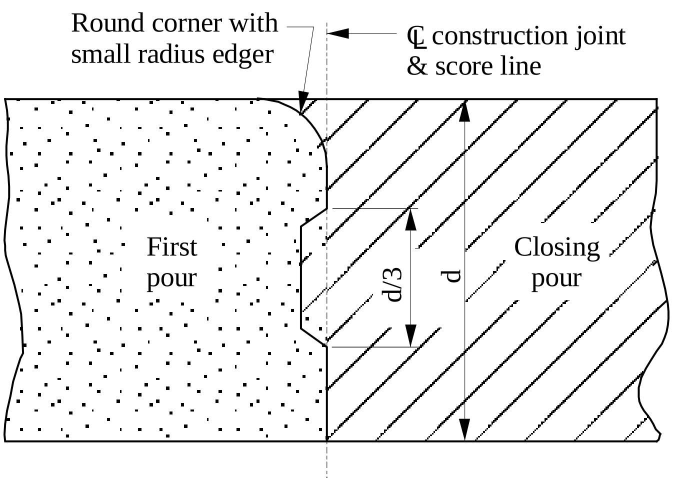
An exception to this rule is the keyways in certain horizontal construction joints which are designed to resist horizontal shearing forces (the tendency for the adjacent concrete sections to slip over each other under load). A hollow concrete box girder bridge in which the top slab and web wall are constructed in separate pours is an example. In this type of bridge, the transverse keyways are placed at a variable spacing depending on the magnitude of the shearing force.

The sides of all keyway forms should be beveled, but not more than one to twelve. This permits removal without spalling the concrete, except as previously discussed for horizontal shear. The dimensions of keyways shown on the Plans may be assumed to be nominal when such dimensions fit a standard lumber size. For example, a 2" x 6" keyway may be formed from a S4S piece of lumber with actual dimensions of 1 1/2 in. x 5 1/2 in.

The concrete surface at horizontal construction joints should be consolidated, and should be free of laitance, loose or porous concrete, dirt, sawdust, and all other foreign material. When the surface is free of these defects, and is approximately to grade, the inspector may not require any further finish. Specification 2401.3 describes in detail the finish required in the construction joint between the slab and curbs, sidewalks or medians.

Saw cuts as described in Specification 2401.3 are required at every slab construction joint. The purpose of the saw cut is to permit sealing of a potentially leaky construction joint in the slab. To effectively saw on the centerline of this construction joint, the joint must be clearly located when the closing concrete pour is made. This may be done by scoring a line with a trowel along the joint in the plastic concrete. See the sketch below.

Chamfered corners (13 mm (1/2 inch) sides) are required on all construction joints that are exposed to view and which are not required to be edged. See Specification 2401.3.



Typical Keyway with Saw Cut Location

5-393.367 JOINTS DESIGNED FOR MOVEMENT

Deflection, contraction and expansion joints are all designed to permit movement between sections of the structure without spalling or crushing of adjacent surfaces. These joints function as follows: (a) deflection joints provide relief for bending or flexing movements, (b) contraction joints provide relief during shortening or contraction movements, and (c) expansion joints provide for movement during shortening (contraction) and lengthening (expansion) movements. These joints differ from construction joints in that either an open joint or a flexible joint filler material separates the adjacent concrete surfaces and reinforcing does not generally extend through the joint. It is important that mortar or concrete does not bridge over these joints. When such a condition exists, any slight differential movement of the concrete sections on either side of the joint may cause spalling.

Joints in sidewalks shall have the first of the two abutting surfaces painted in accordance with Plan Notes. It is necessary to form the joint by placing a bulkhead at the joint location in advance of the first pour. No reinforcement shall project through this joint.

Curb joints may be constructed as described above for sidewalks, or the joint may be formed by a removable metal sheet. In this case the concrete sections on each side of the joint may be placed in the same placement and painting or bulkheading is not necessary. The plate must be well coated with a form release agent and held firmly in position by vee strips and/or saw cuts in the side forms. Concrete should be deposited equally on each side of the plate to prevent distortion. Care must be exercised as the plate is withdrawn to prevent spalling or cracking in the adjacent concrete.

Cork joints are shown in present details for all cast-in-place railing types with continuous concrete rail bases and concrete traffic barriers. The concrete railing or traffic barrier may be placed in alternate sections between cork joints or it may be poured continuously. In either case, copper nails must be used to retain the cork in the joint. Generally, contractors elect to place a railing or traffic barrier in a continuous pour to save the expense of placing and stripping bulkheads. Better concrete lines are also maintained when the railing or barrier is placed in a continuous placement. Cork has very little resistance to sideways deflection and careful attention must be given to maintain the cork in a vertical plane during the pour. The cork is held in position at each face by chamfer strips, and at the top by wood strips. To prevent bows in the cork, a sheet metal plate or a piece of 3mm (1/8 in.) tempered pressed wood is placed along one side of the cork before any concrete is placed. The concrete is then placed in equal layers on each side of the plate and cork. Vibration or spading proceeds simultaneously with the removal of the plate, as the concrete level rises in the section.

Slipforming of Type F railing requires saw cutting the top portion of the joints and sealing with an approved sealant. The Special Provisions should be consulted for detailed requirements when slipforming is used.

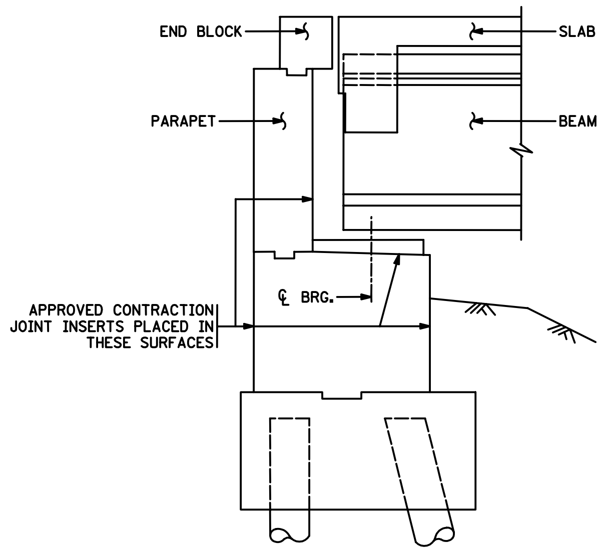
Slabs are generally continuous between expansion devices. Past experience has shown that, on prestressed girder bridges, a transverse crack occurs in the slab over the piers. Saw cuts in the slab over the pier (as described in Specification 2401) have been required in an attempt to control the location of this crack. When this works as intended, the crack coincides with the saw cut and the crack may be effectively sealed with concrete joint sealer. This joint deviates from conventional contraction or deflection joints in that reinforcing extends through the joint.

Emphasis is placed on the Plan Notes which require that saw cuts be made over the centerline of piers as soon as the cutting can be done without raveling the concrete. During hot weather it may be possible to make the saw cut on the same day as the placement. This is the ideal situation, but in most cases it will not be possible to saw until the following morning before shrinkage causes cracking to occur.

Prior to placing the deck treating oil or sealer, the area adjacent to the saw cut should be carefully inspected to determine the actual location of the crack. When this slab crack falls outside of the saw cut, corrective work is required as follows; (a) cracks within 13 mm (1/2 inch) of the saw cut should be chipped back to the saw cut and filled with concrete joint sealer and (b) cracks more than 13 mm (1/2 inch) from the saw cut should be sealed with an epoxy penetrant sealer.

5-393.368 JOINTS AT ABUTMENTS

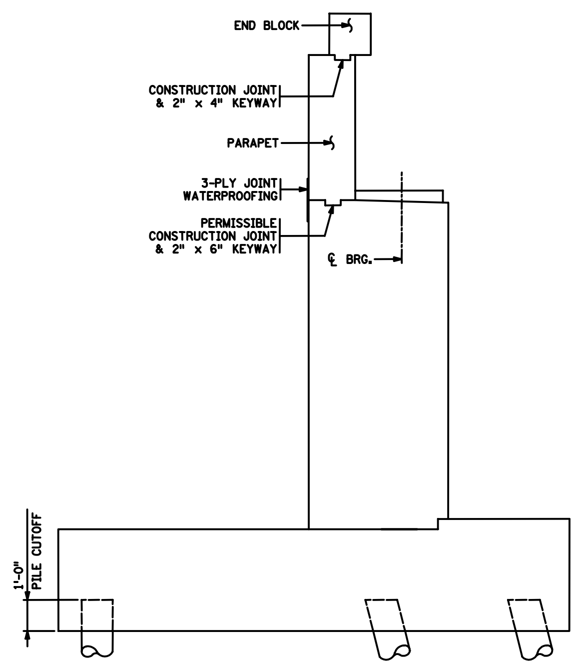
Abutments function as both earth retaining structures and as vertical load carrying components. Abutment types used in Minnesota can generally be classified into 2 different types; parapet and integral. Parapet type abutments allow the superstructure to expand and contract independent of the substructure by using strip seal or modular expansion devices between the concrete deck and the abutment end block (see sketch below). Integral abutments rigidly attach the superstructure to the substructure and the temperature movement of the bridge is accommodated through flexure of the piling and movement at the roadway end of the approach panel (see sketch below).



LOW PARAPET TYPE ABUTMENT

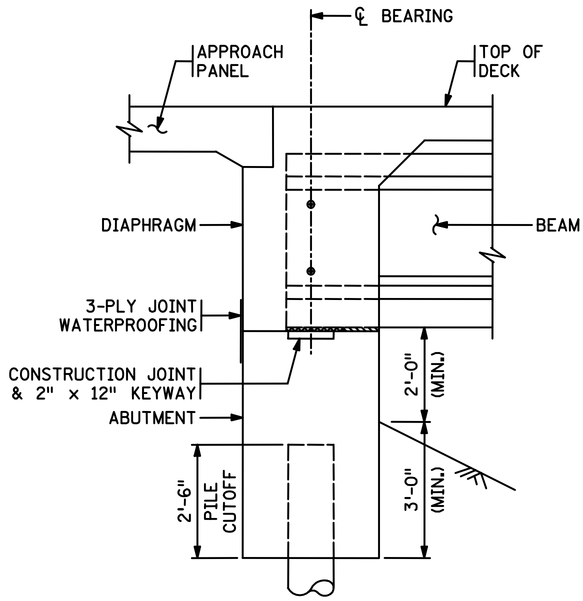
Parapet type abutments can be further subdivided into low parapet type and high parapet type. Low parapet type abutments commonly have a fairly thick but narrow footing with the front and back row of piling battered away from each other. Low parapet type abutments usually have contraction inserts to provide a plane of weakness in the bridge seats and parapet walls. These are detailed in the Plan and require metal inserts on horizontal surfaces (bridge seat) and vertical surfaces (see sketch below).

High parapet type abutments are taller, have a thinner but wider footing, may have more than 2 rows of piling, and generally the back row of piling is not battered (see sketch below). To help control shrinkage and reduce cracking in high parapet type abutments, construction joints are detailed at a maximum horizontal spacing of about 9.75 m (32 feet). The reinforcement generally runs continuous through the joint. In this case, the construction joint also serves as a contraction joint. Free standing cast-in-place concrete retaining walls also have vertical construction joints, but the reinforcement does not pass through the joint. Instead, dowels with a cork filler or shear blocks are used to keep the adjacent wall segments in alignment.



HIGH PARAPET TYPE ABUTMENT

Integral type abutments consist of a wall supported by a single line piles. The superstructure beams or slab bear on the wall. And end diaphragm is cast with the slab which encases the beams and is rigidly attached the lower portion of the abutment making the superstructure integral with the abutment. This abutment type is only used on bridges less than 300 feet long with skews less than or equal to 20 degrees.



INTEGRAL TYPE ABUTMENT

5-393.369 JOINT FILLER MATERIAL

The Plans will usually carry a summary in tabular form showing the location, size, and type of joint filler material required for the structure. The inspector should check this summary against the Plan details to determine if any discrepancies exist. This check also acquaints the inspector with the Plans, and helps to avoid omissions or misplacement of joint materials.

Cork is used as a joint filler in vertical joints. The cork should be secured with 65 mm (2 1/2 inch) long 11 gauge copper nails at about 500 mm (20 inch) centers. All cork joints which will be exposed to view and which cannot be trimmed with an edger should be edged with 13 mm (1/2 inch) triangular moulder. “V” strips should not be used on surfaces that are to be waterproofed, such as the backface of some abutments and retaining walls. Cork should be trimmed to the bottom of vees as required by Plan Notes. A cut, part way through the joint material along the inner edge of the “V” strip, made before installing the material, is helpful in trimming. The cut may also be made all the way through the cork and the strip held in place with closely spaced nails until time for its removal. It can then be easily removed by pulling it away from the parent section, exposing a neatly cut surface. The top of a vertical cork joint should be trimmed to the bottom of the vee and sealed with concrete joint sealer, if the back of the joint is waterproofed.

Bituminous felt is sometimes used as a joint filler in horizontal joints. All joints which will be exposed to view and which cannot be trimmed with an edger should be edged with the 13 mm (1/2 inch) triangular moulder. Bituminous felt should be trimmed to the bottom of vees. The bituminous felt is placed with the second pour. A float finish is necessary on the first pour on areas to be occupied by bituminous felt when differential movement occurs between the concrete surfaces. The finish on the first pour should be carefully inspected for depressions or bumps that may interfere with free movement of the upper concrete member.

Polystyrene is used as a joint filler and a material to form voids. Polystyrene is produced in various grades having different bearing capacities. The Special Provisions will list the desired grade (or type) and the required bearing capacity. The inspector may request verification from the Contractor, that the polystyrene meets the requirements for the type specified.

Concrete joint sealer per Specification 3720 or Specification 3723 (sealer per Specification 3720 is preferred) is used in curb, sidewalk and roadway slab joints to waterproof the joint. Specification 3723 permits substitution of any approved silicone rubber or urethane sealer on projects requiring less than 19 liters (5 gal.) of joint sealer. The bonding capacity of concrete joint sealer to concrete is very good provided the application is on a dry, clean surface. Joint sealing must be completed before application of deck treating oil or sealers. Since the oil tends to dissolve the joint sealer and will break the bond to concrete, the concrete joint sealer must be protected during the application of treating oil (masking tape is usually used) as required by Specification 2401.3K.

5-393.370 EXPANSION DEVICES

Four types of expansion devices are currently used depending on the amount of movement anticipated. These are as follows:

1. Waterproof joint - single gland (strip seals)
2. Waterproof joint - modular
3. Steel plate devices
4. Steel “finger” devices

An expansion device ideally performs the following functions:

1. permits the superstructure to expand or contract without structural damage.
2. provides a smooth riding surface
3. prevents water from reaching the substructure

Expansion devices can only function properly if they are accurately set for alignment, elevation, gradient and proper expansion opening, in advance of placing concrete.

The expansion gap shown on the Plans is the distance required between adjacent parts of an expansion device when the steel or concrete spans are at design temperature. If the temperature at which the gap is to be measured is not shown on the Plans, a temperature of 7EC (45E) should be assumed for the design temperature.

Expansion gaps for strip seal joints are shown in the Plan or listed in the Special Provisions. The expansion gap for steel plate, "finger" or modular type devices will be shown in the plans.

Strip seal expansion devices are the most common type of expansion joint used in Minnesota bridges. The standard strip seal device is a Type 4.0, which has a movement capacity of 100 mm (4 inches). Bridges on a horizontal curve or with a skew over 30 degrees must accommodate "racking" or transverse movements as well. For these situations a Type 5.0 seal with 125 mm (5 inches) of capacity is generally used.

For bridges with skews less than 30 degrees and expansion distances less than 45 m (150 feet) (bridge length greater than 90 m (300 feet)) the expansion device shall be set at 50 mm (2 inches) for all temperatures. Most bridges fall into this category of skew and length and hence simplifies setting joint openings for most bridges.

For bridges not meeting the criteria of the previous paragraph, the expansion gap should be increased for temperatures below 7EC (45EF) and decreased for temperatures above 7EC (45EF) as indicated by the algebraic sign in Table A and B 5-393.370. The temperatures, lengths and corresponding corrections are used to compute the correct opening. These computations should be based on the air temperature at the time the device is set.

Example

Conditions as follows:

80 ft - 100 ft - 100 ft - 80 ft Continuous steel beam spans
Fixed center pier
180 ft of expansion length
85EF temperature at time device is set.
"Strip seal" expansion device (Type 3)
Exact correction = 0.0000065(180 ft)(45-85)

$$\left(\frac{12\text{ in.}}{\text{ft.}}\right) = -9/16\text{ in.}$$

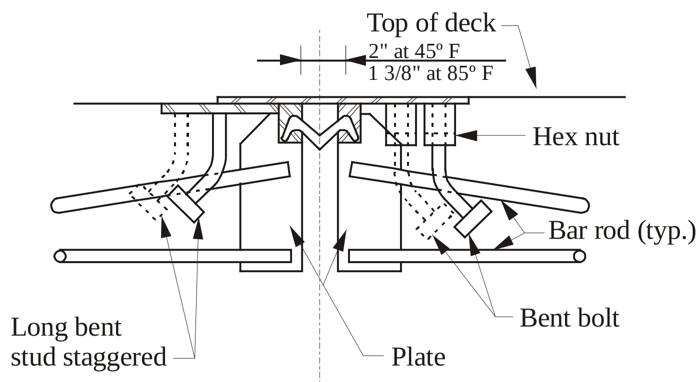
Correction from Table B 5-393.370 = -9/16 in.

Set concrete bulkheads to provide an opening of 1.5 inches minus 9/16 = 15/16 inches.

Note that a 5/16 inches opening may not be sufficient to allow installation of the neoprene seal. In that case, set the opening at the minimum width which allows seal installation and check the opening at -30EF to make sure it will not exceed the design capacity at the joint.

Specifications for "strip seals" allow suppliers to furnish a joint with greater capacity than the type specified. Most suppliers furnish the 100 mm (4 inch) movement joint in all cases. This allows presetting the device when a smaller capacity joint is specified. No adjustment should be necessary when a Type 4 joint is substituted for a Type 2 or Type 3 joint; however, the inspector should measure the preset opening and check to make sure the opening at (-30EF) will not exceed the design capacity of the joint. (In the preceding example, if a Type 4 joint were preset at 50 mm (2 in.), no adjustment would be necessary unless the temperature exceeded (110EF) at the time of installation since the total movement from (-30EF) to (110EF) is only 50 mm. (2 in.).

For the same conditions as in the previous example, the designer has selected a steel plate type joint. A 75 mm (3 inch) expansion gap is shown in the Plans. The corrected expansion gap is 75 mm (3 inch) minus 15 mm (1/2 inch) which equals 60 mm (2 1/2 inches). The concrete bulkheads are then set to provide the 60 mm (2 1/2 inches) opening as shown in the sketch titled Temperature Adjustment.



Temperature Adjustment

On long spans, particularly with deep beams, the gap to which the device must be set may be affected by the deflection and corresponding rotation of the beam end under the dead load of the roadway slab.

The following procedure is recommended for elevation adjustment:

1. Compute a finished grade elevation along the outer edges of the device at each support and at the breaks in crown. Take elevations on the supports and furnish the Contractor the heights from the support to the finished surface. Another method is to have the device set in position and take elevations on the device at each support and furnish the Contractor the required adjustment at each support. Repeat elevation shots on the device at supports after all adjustments are made and readjust if necessary.

2. The longitudinal profile gradient of the roadway expansion device is very important. If the slope of the device is not the same as the slope of the adjacent concrete, a noticeable bump will be created. A straightedge should be laid on the expansion device parallel to the centerline of roadway to check for slope or

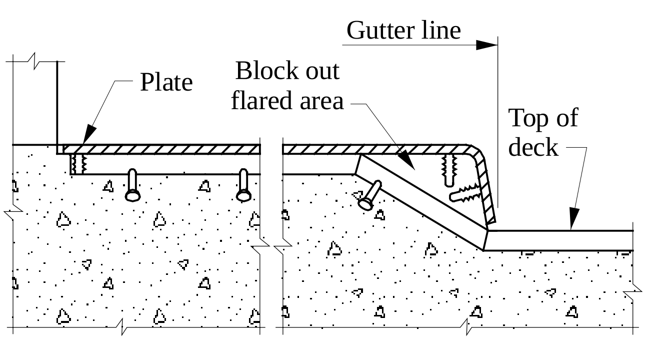
gradient when the device is being adjusted for elevation. The strike-off machine should be set to plan crown and passed over the expansion device during the pre-pour inspection to check for any deviations from plan at the device. This can serve as an effective check on the earlier adjustments.

3. The deflection of the adjacent spans under the dead load force of the roadway slab must also be considered. As the spans deflect, the ends of the beams will rotate, therefore the two parts of an expansion device should show a plane surface or slightly concave surface before the slab is poured. The surface should never indicate a convex surface. Also on overlapping plates, the bottom edge of top plate should be in contact with the lower plate after dead load rotation occurs. Since predetermination of beam rotation is quite difficult, the Plans may require slab construction joints about 1500 mm (5 ft) from each side of an expansion device where steel plate, “finger,” or modular type devices are specified. This permits the Contractor to straightedge across the device to adjacent inplace concrete. The final adjustment of the device is then made after dead load rotation has occurred.

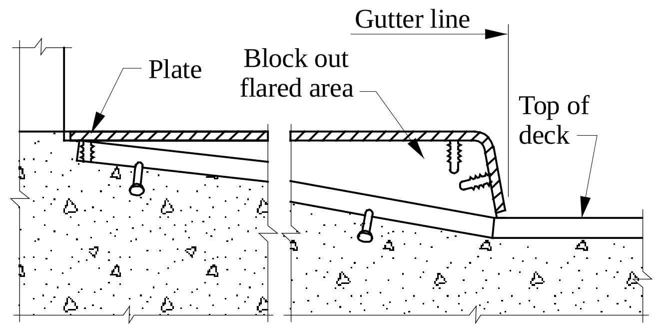
5-393.371 SIDEWALK AND CURB PLATES

Sidewalk expansion plates sometimes slide in a recess or notch in the concrete of the adjacent span. A notch approximately 6 mm (1/4 in.) wide should be provided at the ends of the plates to prevent spalling due to any differential movement of the spans, as shown in the following sketches. This is particularly important at plates in end spans over abutments, where the expansion of the span sideways may differ from the expansion of the abutment concrete.

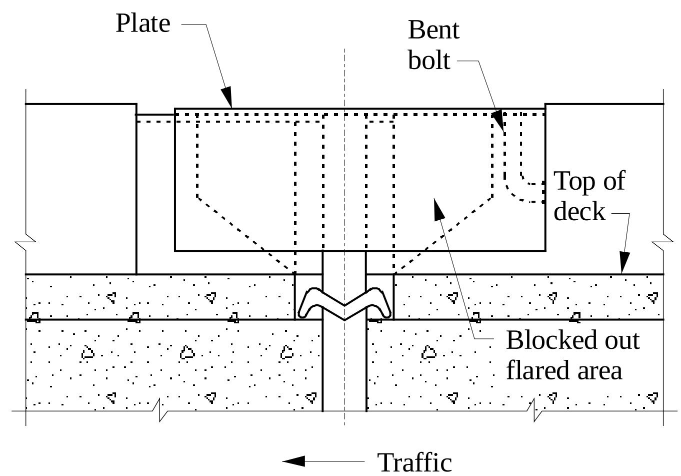
On curved and sharply skewed bridges the Plans will normally require polystyrene behind the vertical curb plate. The polystyrene will normally have a minimum thickness of 12 mm (1/2 inch). The purpose of this is to form a large enough opening to prevent cracking due to the racking movements which result from expansion and contraction of the structure.



Section Thru Sidewalk
Option 1



Section Thru Sidewalk
Option 2



Inside Curb Plate Elevation

Modular expansion joints with multiple neoprene glands are being utilized on long structures where the “strip seal” joints do not provide for sufficient movement and where a waterproof joint is desired. Modular joint openings should be set in accordance with shop drawings, with adjustments made for temperature as shown in tables contained in the drawings. Careful installation in accordance with manufacturer’s instructions is essential for this type of joint.

Openings in strip seal joints must provide sufficient room for installation of the gland, which is inserted after placement of the concrete around the joint anchorages. Glands are to be installed in accordance with manufacturer’s instructions using a lubricant adhesive recommended by the manufacturer. Skewed bridges may require the installation of snow plow fingers which are welded to the top surface of the grip after the gland is installed. Careful welding is required to protect the gland from damage due to excessive heat because the weld area is limited. A sand layer is often placed on the gland as a protective measure during welding. There is a tendency to install the strip seal joint lower than detailed in the Plan to be on the safe side. This practice should be avoided as it results in a rough riding joint, and reduces the effectiveness of the snow plow fingers which should be flush with the roadway surface.

TEMP ° C.	MOVEMENT OF CONCRETE SUPERSTRUCTURES (EXPANSION COEFFICIENT OF 1.08×10^{-5})*							
	20 m	30 m	40 m	50 m	60 m	70 m	80 m	90 m
35	-6	-9	-12	-15	-18	-21	-24	-27
30	-5	-7	-10	-12	-15	-17	-20	-22
25	-4	-6	-8	-10	-12	-14	-16	-17
20	-3	-4	-6	-7	-8	-10	-11	-13
15	-2	-3	-3	-4	-5	-6	-7	-8
10	-1	-1	-1	-2	-2	-2	-3	-3
7	Desired Width of Joint Openings at 7 ° C							
0	2	2	3	4	5	5	6	7
-5	3	4	5	6	8	9	10	12
-10	4	6	7	9	11	13	15	17
-15	5	7	10	12	14	17	19	21
-20	6	9	12	15	17	20	23	26
-25	7	10	14	17	21	24	28	30
-30	8	12	16	20	24	28	32	36
-35	9	14	18	23	27	32	36	41

Joint width decreases by ↑ / ↓ Joint width increases by

TEMP ° F.	MOVEMENT OF CONCRETE SUPERSTRUCTURES (EXPANSION COEFFICIENT OF 6.0×10^{-6})						
	60'	100'	140'	180'	220'	260'	300'
95	-3/16"	-3/8"	-1/2"	-5/8"	-13/16"	-15/16"	-1-1/16"
85	-3/16"	-5/16"	-7/16"	-1/2"	-5/8"	-3/4"	-7/8"
75	-1/8"	-3/16"	-5/16"	-3/8"	-1/2"	-9/16"	-5/8"
65	-1/16"	-1/8"	-3/16"	-1/4"	-5/16"	-3/8"	-7/16"
55	-1/16"	-1/16"	-1/8"	-1/8"	-3/16"	-3/16"	-3/16"
45	Desired Width of Joint Openings at 45 ° F						
35	1/16"	1/16"	1/8"	1/8"	3/16"	3/16"	3/16"
25	1/16"	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"
15	1/8"	3/16"	5/16"	3/8"	1/2"	9/16"	5/8"
5	3/16"	5/16"	7/16"	1/2"	5/8"	3/4"	7/8"
-5	3/16"	3/8"	1/2"	5/8"	13/16"	1-5/16"	1-1/16"
-15	1/4"	7/16"	5/8"	3/4"	15/16"	1-1/8"	1-5/16"
-25	5/16"	1/2"	11/16"	15/16"	1-1/8"	1-5/16"	1-1/2"

Joint width decreases by ↑ / ↓ Joint width increases by

1. This table contains bridge movements for various lengths between expansion joints due to temperature changes. Joint openings established during construction must be corrected (decreased on temperatures above 7 ° C (45 ° F) and increased on temperatures less than 7 ° C (45 ° F)) accordingly.

2. Formula for computing values not shown on table: Opening width (at right angles to the joint) = Width desired @ 7 ° C (45 ° F) + [Movement length in mm (in.) x Coefficient of expansion x [7 ° C (45 ° F) - Temperature]]

3. * Joint openings have dimensions of mm unless otherwise noted.

Joint width decreases by ▲ / Joint width increases by ▼

TEMP °C.	MOVEMENT OF STEEL SUPERSTRUCTURES (EXPANSION COEFFICIENT OF 1.17×10^{-5})*							
	20 m	30 m	40 m	50 m	60 m	70 m	80 m	90 m
35	-7	-10	-13	-16	-20	-23	-26	-29
30	-5	-8	-11	-13	-16	-19	-22	-24
25	-4	-6	-8	-11	-13	-15	-17	-19
20	-3	-5	-6	-8	-9	-11	-12	-14
15	-2	-3	-4	-5	-6	-7	-7	-8
10	-1	-1	-1	-2	-2	-2	-3	-3
7	Desired Width of Joint Openings at 7 °C							
0	2	2	3	4	5	6	7	7
-5	3	4	6	7	8	10	11	13
-10	4	6	8	10	12	14	16	18
-15	5	8	10	13	15	18	21	23
-20	6	9	13	16	19	22	25	28
-25	7	11	15	19	22	26	30	34
-30	9	13	17	22	26	30	35	39
-35	10	15	20	25	29	34	39	44

Joint width decreases by ▲ / Joint width increases by ▼

TEMP °F.	MOVEMENT OF STEEL SUPERSTRUCTURES (EXPANSION COEFFICIENT OF 6.5×10^{-6})						
	60'	100'	140'	180'	220'	260'	300'
95	-1/4"	-3/8"	-9/16"	-11/16"	-7/8"	-1"	-1-3/16"
85	-3/16"	-5/16"	-7/16"	-9/16"	-11/16"	-13/16"	-15/16"
75	-1/8"	-1/4"	-5/16"	-7/16"	-1/2"	-5/8"	-11/16"
65	-1/16"	-1/8"	-3/16"	-1/4"	-5/16"	-3/8"	-7/16"
55	-1/16"	-1/16"	-1/8"	-1/8"	-3/16"	-3/16"	-1/4"
45	Desired Width of Joint Openings at 45 °F						
35	1/16"	1/16"	1/8"	1/8"	3/16"	3/16"	1/4"
25	1/16"	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"
15	1/8"	1/4"	5/16"	7/16"	1/2"	5/8"	11/16"
5	3/16"	5/16"	7/16"	9/16"	11/16"	13/16"	15/16"
-5	1/4"	3/8"	9/16"	11/16"	7/8"	1"	1-3/16"
-15	1/4"	7/16"	5/8"	13/16"	1"	1-3/16"	1-3/8"
-25	5/16"	9/16"	3/4"	1"	1-3/16"	1-7/16"	1-5/8"

1. This table contains bridge movements for various lengths between expansion joints due to temperature changes. Joint openings established during construction must be corrected (decreased on temperatures above 7 °C (45 °F) and increased on temperatures less than 7 °C (45 °F)) accordingly.

2. Formula for computing values not shown on table: Opening width (at right angles to the joint) = Width desired @ 7 °C (45 °F) + [Movement length in mm (in.) x Coefficient of expansion x [7 °C (45 °F) - Temperature]]

3. * Joint openings have dimensions of mm unless otherwise noted.

5-393.372 BEARING ASSEMBLIES

Bearings are generally placed between the bridge superstructure and substructure and provide two main functions; support the gravity loads (dead load and live loads) and to accommodate the changes in length of the bridge resulting from temperature variations and rotations caused by bending.

The concrete in the area of the bearing surface directly under the bottom plate of the bearing must be finished to a true horizontal plane. Careful finishing of this area will result in a true surface which will eliminate much corrective work. The surface shall be power ground so the surface variance is less than 2 mm (1/16 in.). Prior to setting the bearings, the bearing area should be checked for full bearing and level surface by laying a carpenter's or mason's level in several positions on the area.

Irregular surfaces should be bush hammered or ground down to provide a level and uniform surface. Shallow depressions may be filled with an epoxy mortar, and roughened areas where concrete is removed should also be smoothed with an epoxy mortar. See the Steel Construction Section 5-393.400 of this manual for a description of bearing surfaces for steel bridges.

Elevations should be taken as soon as the bearing surfaces are finished. For continuous steel beam bridges, the Bridge Construction and Maintenance Section should be contacted for a recommendation when any bridge seats deviate from plan elevation by more than 6 mm (1/4 in.). For prestressed girder bridges, the Bridge Construction and Maintenance Section should be contacted for a recommendation when there is a deviation from plan bearing elevation greater than 13 mm (1/2 in.). For cast-in-place concrete bridges the elevation of the bridge seat should not deviate from plan by more than 6 mm (1/4 in.).

Elastomeric bearings are made of synthetic rubber called Neoprene. This type of bearing allows the superstructure to translate and rotate, but also resists loads in the longitudinal, transverse and vertical directions. As loads are applied, movement is accommodated by distorting the pad. Elastomeric bearings are generally more economical, easier to maintain and to install than conventional metallic bearings. Elastomeric bearings may consist of unreinforced pieces of neoprene (generally no more than 1/2" thick) often used for integral abutment bridge bearings. Generally elastomeric bearings thicker than 1/2" are reinforced with 1/8" thick steel plates sandwiched between layers of elastomer.

Fixed bearing assemblies for prestressed girders and steel beams are fastened to the bridge seats with anchor bolts which are drilled in after beam or girder erection. For additional information on placing anchor bolts, see 5-393.365 of this manual.

Anchor bolts are sometimes cast in bridge seats of pedestrian bridges where they are required to resist uplift forces produced by wind. Hold down bolt assemblies may also be cast in abutments on steel beam spans when hold downs are used in lieu of counter weights. Care must be exercised in setting these bolts to ensure proper location and projection. A template should be used to hold these bolt assemblies rigidly in position.