
FHWA Bridge Maintenance: *Decks*

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X. DECK MAINTENANCE PROCEDURES

Bridge decks not only carry the traffic but also act as a shield to protect the rest of the structure. The deck is vulnerable to the effects of mechanical wear and weather. Consequently, decks may require more maintenance and repair than other bridge components.

Concrete bridge decks resist wear and weather well, provide good traction and ride quality, and in many designs provide a part of the structural strength of the bridge. Careful design, proper selection of materials, and good construction practices are essential for a durable bridge deck. Among the design features that improve durability are optimum cover of the reinforcement (not too small, not too large), good drainage, smaller skews, and thicker slabs. Material and construction practices that contribute to durability include achievement of the specified cover, use of air-entrained concrete, use of concrete with the lowest possible water-cement ratio, good consolidation, and procedures that prevent excessive shrinkage.

One of the main villains in concrete deck deterioration in "snow" states is deicing salts. They penetrate the surface, reach the reinforcing steel, and cause rebars to rust and concrete decks to spall. In order to prevent this, the chlorides must be kept from the rebars. Sealing the surface, overlaying the surface with a dense material, and crack sealing does this. If a significant amount of chlorides have already reached the rebars, cathodic protection may stop corrosion.

Repair of deteriorated decks requires choosing the most cost-effective treatment within the constraints of budget, work force, traffic control, and weather. The most difficult task is to determine how much concrete should be removed. For this, a condition survey is required. This procedure may range from a visual inspection to a detailed survey requiring many hours of inspection, testing, and analysis. The report of a visual examination by a skilled inspector should include locations and descriptions of all spalls, scale, and cracks on both top and bottom surfaces of the deck. The detailed survey discussed in Chapter VI may incorporate several of the available physical tests and survey methods. Usually, concrete deterioration will propagate and increase after the survey and before the repair. That increase in the amount of deterioration needs to be estimated. Estimating errors can be minimized by a thorough condition survey as close as possible to the time the work is done.

A. CONCRETE DECKS

PREVENTIVE MAINTENANCE

The main preventive maintenance objective for concrete bridge decks is to control salt and moisture penetration to prevent and/or retard corrosion of the reinforcement. Several activities may be required to accomplish this objective:

- (1) Keep the deck clean and provide good surface drainage by keeping the drains open.
- (2) Monitor the condition by testing for chloride penetration, delamination and active corrosion.
- (3) Seal or overlay the surface to prevent and/or reduce salt and moisture penetration.

- (4) Seal cracks to prevent and/or reduce corrosion of reinforcement.

CONCRETE DECK SEALING

Sealing is accomplished by providing a deck with a barrier to prevent chloride penetration of the deck. All of the sealer materials require penetration as the surface film is quickly worn away by traffic abrasion. There are many types of sealers including silanes, siloxanes, silicone, and polymers such as epoxies and methylmethacrylates. A description of these materials is found in Section VII-A. Proper application generally requires dry decks with warm conditions. The surface must be clean prior to the application.

Following are the steps needed to apply a sealer to a bridge deck:

- (1) Clean the deck by sweeping, washing and/or air-blasting. Some sealers with high film thickness may rest on the surface. In that case blasting to provide surface preparation may include sand-blasting or shot blasting to provide bond with the concrete.
- (2) Make sure conditions are in accordance with the state or manufacturer's specifications for application of sealer. The following things should be checked:
 - Measure temperature of air and deck,
 - Temperature range of materials as recommended,
 - Wind velocity not to cause drift,
 - No falling temperatures,
 - Clean deck with no moisture or oil on it, and
 - Any other condition that would prevent a satisfactory job.
- (3) Mark off or measure areas to be covered in order to ensure the correct rate of application.
- (4) Prepare sealer as required, remembering some materials will set by chemical reaction so correct proportioning and thorough mixing are vital.
- (5) Apply sealer as recommended by either:
 - Spray using pump tanks or mechanical spray equipment,
 - Notched or un-notched squeegees,
 - Rollers, or
 - Distributors.
- (6) For sealers that rest on the surface, follow-up immediately with anti-skid material (usually sand) if required. It is important to get this material in place while it is able to imbed itself in the sealer. For sealers that penetrate the surface sand is not required. However, these sealers usually have a tendency to make the deck slick prior to penetration. Sand should be available, if traffic will be using the deck, in case complete deck penetration does not occur requiring "blotting" to reduce excess material.

(7) Anticipate cure times in the method of operation, both for lane closures and proper curing and/or deck absorption.

(8) Take appropriate measures to ensure worker safety and prevent damage to the environment.

CONCRETE DECK PATCHING

The need for deck patching is almost always caused by corrosion of the reinforcement. Deck patching is a temporary repair unless all the chloride contaminated concrete is removed before the deck is patched. When only the spalled and delaminated concrete is removed, the corrosion process continues and additional spalled areas will soon appear. Research has shown that sealing and overlaying chloride contaminated concrete cannot stop, but it can retard, the continued corrosion and deterioration of concrete.

For permanent patching, a deck survey is performed to identify the areas of concrete removal. The deck survey consists of the tests for delamination, bar cover, chloride content and corrosion potential of reinforcing steel as described in Chapter VI. The results of the deck survey are used to plot areas of spalls, delaminations, active corrosion potentials, and chloride contamination. Based on the information obtained from the survey, deteriorated areas and areas with unacceptable corrosion potentials and/or chloride content are identified for removal.

Regardless of whether the repair is permanent or temporary, potholes cannot be tolerated when they adversely affect the rideability and safety of the deck. See Exhibit X.1. Rough decks also increase the vehicular impact on the bridge, which accelerates the damage and may contribute to structural damage. Therefore, when the reinforcement in a concrete deck is not adequately protected from salt-water penetration, deck patching soon will be necessary.



Exhibit X. 1 Deteriorated Deck

Following is a procedure for concrete patching:

- (1) Assess areas for patching using a drag chain. Delaminated areas will have a hollow sound.
- (2) Outline the area to be patched with lumber crayons or spray paint. Allow extra edge areas for undetected delamination, usually in straight lines to facilitate the use of a concrete saw. To ensure coverage of the delaminated area the line is usually about 150 mm (6 in.) beyond the detected delamination. Corners should be square (no feathered edges).
- (3) Usually a concrete saw is used to saw vertically for about 20 mm (0.75 in.) around the perimeter of the hole in order to provide a shoulder for the patch to bear against. See Exhibit X.2. Care must be taken not to cut any reinforcing steel in the deck. It is important not to saw past the corner of the patch since this area can become subject to spalling and can present further problems. Better results can be expected if the number of individual patches are minimized. If the patches are within 600 mm (2 feet) of each other, they should be combined.



Exhibit X. 2 Saw Cutting

- (4) Using hand tools and pneumatic hammers weighing 15 kg (30 lbs.) or less (e.g. 7kg (15 lbs.) at reinforcing steel) and at an angle of 45 to 60 degrees to the deck, remove the concrete within the designated area. Periodically sound to ensure that the area and depth are correct and free of deteriorated concrete. Fracture lines over a reinforcing bar indicate an area that will soon spall and should be removed.
- (5) The area to be patched (the hole) should be cleaned thoroughly using sandblasting or water blasting to remove any loose concrete, rust, oil, or other contaminants that would prevent a proper bond. Loose fragments still in place may be detected by moistening the surface and looking for their outline as the surface dries.

(6) Reinforcing steel is likely to be deteriorated as a result of corrosion. If it has lost over 20 percent of its original cross section, new steel should be added by lapping, welding or mechanically connecting with the deteriorated bar.

(7) Patching is normally categorized into three categories based on depth:

- Type A is above the top layer of reinforcing steel.
- Type B is from the deck surface to at least 25 mm (1 ") below the top mat of rebars.
- Type C is full deck depth.

These depths can only be established with certainty during concrete removal. If Type C is suspected, preparations should be made for traffic protection, and access to the underside of the deck will be needed.

(8) Type A patching may require special aggregate size in that the diameter of the rock can not be larger than the depth of the hole. Rebars will not be involved. The danger here is that the patch may be too thin for concrete, or it may be too thick for epoxy mortar. Epoxy patches in particular, and polymer material patches in general, should be placed and consolidated in layers of limited thickness as recommended by the manufacturer. The maximum layer thickness may be 19 mm to 25 mm (0.75 to 1.00 in.) thick. In bridge deck repair, application of more than one layer may not be practical because of concern over restoring traffic quickly.

(9) Type B patching will involve rebars and it is important that space be left under the rebars to allow fresh concrete to flow beneath them so no voids are left underneath. Type B patching will probably be too thick for epoxy mortar, unless it is applied in layers.

(10) Type C patching will involve formwork to support the bottom of the hole. This can be simply plywood wired to the rebars, or it may be formwork supported with joists. If any Type C patch is expected to exceed a 1.3 m x 1.3 m (4 ft. x 4 ft.) area, then an engineer should be consulted. This is because the bridge strength may be affected by extensive large-area patching, an errant vehicle may penetrate the open hole, the deck may be at the end of its useful life, and/or extensive Type C patching may not be economical.

(11) The surface of the existing concrete adjacent to the patch should be damp but free of standing water when fresh concrete is placed in the hole. A straight board can be used to level the patch. With a small patch, a hand float can be used to smooth the surface. Patches should not deviate more than 3 mm (0.125 in.) in height from the surrounding concrete.

(12) If the restoration of traffic before rush hours, either night or day, is a requirement, the use of quick set, hydraulic patch materials is suggested. Non-shrink materials should be used. Several pre-proportioned quick-set hydraulic materials are available in sacks. These materials are described in Chapter VII. They are mixed with water at the site using a small portable mixer. Minimum compressive strength is generally 13.8 MPA (2,000 psi) in 2 hours. In order to achieve fast curing, proportioning and mixing instructions must be followed to the letter

for the material that is used. Failure to do so could result in delayed opening to traffic and a possible weak and porous patch.

- (13) If the concrete is mixed from scratch, the mix should be designed by a materials engineer and furnished to maintenance forces with a strength curve versus time. The deeper the patch, the higher the strength requirements for restoration of traffic. Each organization has its own requirements: as a guide, Type A would need 6.9 MPA (1000 psi), Type B needs 16.5 MPA (2,400 psi), and Type C needs 25.5 MPA (3, 700 psi) before opening to traffic. It should be emphasized that before a large area is patched the advice of an engineer should be obtained as excessive concrete removal could lower the bridge capacity.
- (14) Wet curing of the patch is preferable, except for polymer patches. This can be done with dampened burlap kept on the patch surface until ready to open to traffic. If the material does not give off a lot of heat, a membrane cure is satisfactory. With quickset hydraulic material, in two hours the concrete set can be adequate for traffic use.

EPOXY DECK PATCHING

A brief explanation of epoxy patching procedures is given; however, epoxy is not a widely used patching material. The maximum depth of epoxy patching may be 19 to 25 mm (0.75 to 1 .00 inch) because of its high shrinkage factor and heat generated. The hole should be reasonably square. Epoxy patching, if done correctly, does not require a sawed hole.

It is essential that the bottom and sides of the hole be free of any moisture, dust or dirt, which will prevent good bonding. A good way to ensure this is to air-blast the hole. The epoxy used is a two-component product and it should be mixed with a low speed drill, 400 to 600 rpm, until the blend is uniform in color. This will usually take about 3 minutes of mixing. The entire surface of the hole including the steel (Type B patching) should be painted with this blended material just before filling the hole. Puddles should not be left in the bottom of the hole nor any areas left dry. If there are puddles the excess material will bleed out onto the surface resulting in a weakened portion of the patch.

Experience indicates that approximately 1 part epoxy to 4 to 7 parts of well graded, dry sand is the best mix. The sand should always be added to the epoxy when mixing. The epoxy should never be added to the sand.

An electric mixer can be used for mixing small quantities. For larger quantities, a standard mortar mixer can be used. The mixed material must be placed in the hole as soon as possible. The material should be worked to eliminate any voids and to get compaction. The patch should be struck off with a hand float or a straight edge. See Exhibit X.3. Speed is essential since the material sets up quickly, especially in warm weather. In temperatures below 18°C (65°F), the strength gain may be very slow and cause a problem.

ASPHALT CONCRETE PATCHING

Asphalt (bituminous) concrete is a porous pavement material that is not capable of waterproofing the bridge deck concrete. Moisture (with salt) penetrates the asphalt and is trapped on the top of the deck. Also, the saturated asphalt concrete will act similar to a sponge and will prevent the concrete surface from drying causing extensive freeze/thaw deterioration.



Exhibit X. 3 Finishing Deck

The use of asphalt concrete patch will cause or accelerate the deck deterioration unless a waterproof membrane is placed between the patch material and the deck. The only time that the use of asphalt concrete is permissible on a deck without waterproofing is as a temporary patch on a deck where the deterioration is so advanced that replacement is the most cost-effective permanent solution to the problem.

In some states, road crews may patch bridge decks using asphalt material to improve the riding surface without consideration of the consequences. If a temporary asphalt patch is applied to a concrete deck that is repairable, the patch should be replaced with concrete as soon as possible.

EMERGENCY FULL-DEPTH PATCHING

There are several emergency methods to patch a deck when the hole is full-depth. Caution must be used in evaluating these situations as a structural weakness in the bridge may be overlooked in trying to satisfy traffic demands. Ordinary plywood with joists may be suspended by wire from the reinforcing steel and a small full- depth hole filled with quick set hydraulic mix. See Exhibit X.4. There are several proprietary materials that are available. Some way should be worked out

to have material on hand that will quickly provide the desired strength, at low temperatures if necessary.

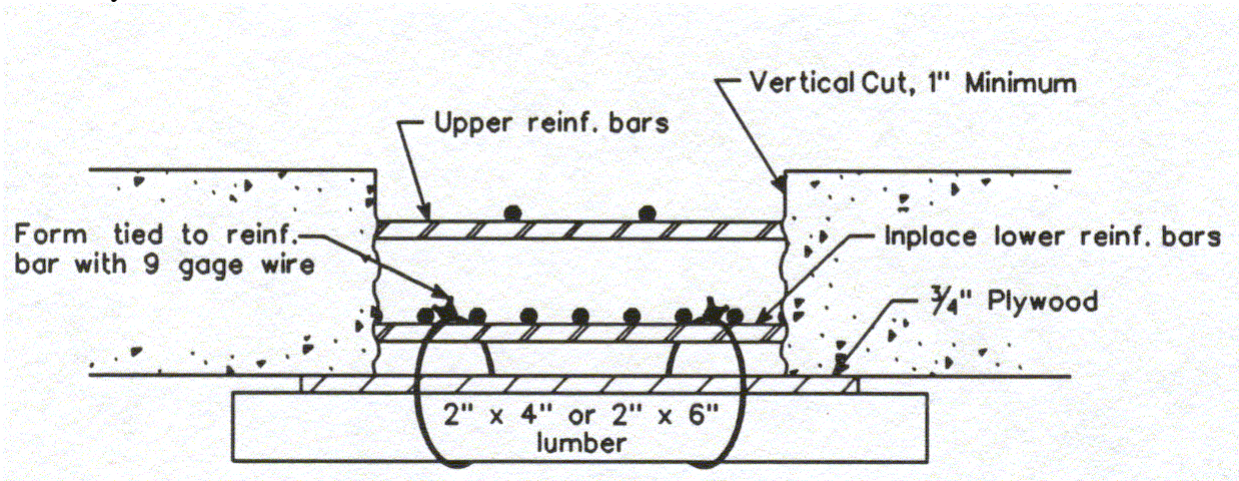


Exhibit X. 4 Formwork Support for Full Depth Removal

Steel plates are an option. The plates must be bolted at the corners to keep them from moving. Plates cannot be bought the hardware store so, as with proprietary materials, they must be on hand because the hole is going to occur at the most inopportune times. Plates should be considered temporary because they are heavy, slick and bumpy.

All these methods are temporary but since that the hole is now generally "out of sight and out of mind", proper repairs may be further delayed while additional deterioration is taking place. If the deck can be saved, the permanent repairs should be planned. Until a permanent repair is made the deterioration will continue to advance until an expensive rehabilitation or replacement is the only alternative.

CRACK SEALING

Crack sealing is an important part of deck maintenance. Concrete cracks that reach the reinforcing steel and have widths larger than 0.18 mm (0.007 in.), or the thickness of two sheets of paper, will allow moisture and chlorides to reach the reinforcing steel and corrode it. According to recent findings, cracks can even lead to corrosion of epoxy-coated rebar, since exposure may cause degradation of the coating.

Causes of bridge deck cracks

Before attempting to seal the cracks, determine the type and cause of the cracks. This may affect the type of repair. The most common causes of concrete deck cracks are listed below:

- Transverse cracks are caused by thermal and/or drying shrinkage of the concrete. Material defects such as use of aggregate that cause shrinkage, improper quantities such as too much water in the concrete mix, or improper curing of the concrete deck during construction can induce shrinkage cracks.

- Flexure of the deck or lack of cover on the reinforcement may also cause transverse cracks.
- Longitudinal cracks are common in over the keyways of adjacent concrete box beams and voided slabs. The cracks may be caused by differential deflection of the beams, or by reflection of an improperly grouted key.
- Longitudinal cracks, also, occur over the longitudinal beams of other bridge types, when the beam spacing is large and deck bends over the beam.
- Map cracks result from excessive shrinkage in fresh concrete, or they may result due to factors such as aggregate-cement reaction and freeze-thaw action.
- Diagonal cracks may result at acute corners of skewed slabs.
- Thermal expansion caused by a high temperature combined with debris filled expansion joints can cause cracks or spalls near expansion joints.

Sealing cracks

Small cracks can be sealed by some of the liquid deck sealers on the market. These products should be considered for use over the entire deck when cracks are numerous. These sealers are described in Session VII-A.

Injecting cracks

It is good practice to inject larger cracks with a material such as epoxy or polyurethane. Following is a procedure for crack injection:

- (1) Clean out the crack. Methods to clean cracks include (1) Vacuuming, (2) air blasting, and (3) water blasting.
- (2) Seal the crack surface. To do this, brush an epoxy along the surface of the crack and allow it to harden. If the crack has widely spalled edges, or if injection pressures are too high for a surface seal, saw cut the crack first and then, seal the surface by cutting a v-groove and filling it with mortar.
- (3) Drill port holes along the crack.
- (4) Inject the sealant through these “entry ports”.

Since some deck cracks are likely full-depth they must also be closed from below, before they are pressure injected from top. Brushing an epoxy along the crack from below is adequate for this since the injection pressure at the bottom of the deck will usually be low. Note that stay-in-place forms are an adequate seal.

If the crack is open and shows evidence of movement, if it has been sealed before and has failed again, or if there is evidence of recent re-cracking such as dust or surface re-grout failure, it is a working crack and it should be sealed with a flexible or elastomeric crack sealer. See Exhibit X.5. The sealer material should be designed for the anticipated movement. Usually this involves cutting a slot with sufficient width over the crack to hold the sealer, placing a bond breaker, and sealing the slot. The sealer may be a hot or cold poured flexible material.

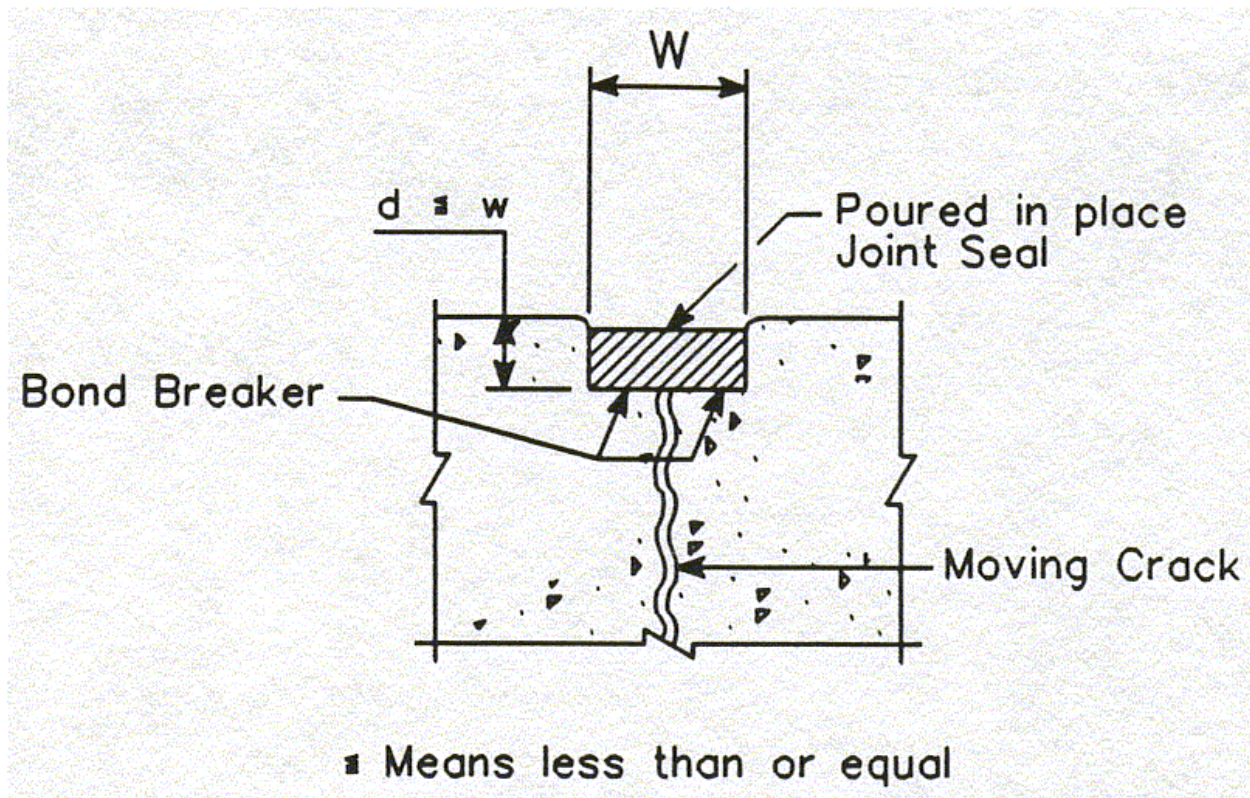


Exhibit X. 5 Flexible Seal for a Working Crack

Important things to remember in crack sealing are:

- The cause of the cracking should be addressed as part of the solution.
- Before sealing, the crack surface must be clean and dry.
- The depth must be less than or equal to the width of the seal.

OVERLAYS

Overlays may be applied as preventative maintenance or as part of deck repairs. When an overlay is applied as part of a repair to an existing deck, it is very important to make sure that salt contaminated concrete is removed, or the deterioration will continue. When rigid overlays are applied, it is common practice to remove approximately 13 mm (1/2 inch) from the top of the deck and leave a roughened surface. The roughened surface will provide bond and integrity between the overlay and the deck.

An engineer should consider the effects of the weight of the overlay. This additional dead load reduces the structure's capacity to carry live load. The reduced capacity may be unacceptable unless a comparable amount of the old concrete is removed. Depending on the thickness of the new overlay, it may be necessary to remove more of the existing concrete, say 40 mm (1-1/2 inches), to minimize the superimposed dead load. The depth of steel should be checked to ensure it would not be damaged or exposed when the concrete is removed. See Exhibit X.6.

Overlays are also applied as part of deck repair when deck concrete is contaminated, corrosion of the reinforcement is in progress, and concrete is deteriorating. To prevent the corrosion from continuing, not only is the damaged concrete removed, but also the salt-contaminated concrete must be removed from around the reinforcement before the overlay is placed. However, recent research findings show that when contaminated concrete is left in place, application of an overlay can retard the corrosion process to some extent by preventing the access of oxygen and moisture, two elements promoting corrosion. Therefore, it is not unusual to leave the salt-contaminated concrete in place before the application of an overlay. This type of treatment does not eliminate the corrosion problem, but it can add to the remaining service life of the deck.



Exhibit X. 6 Surface Removed for Overlay

The concrete removal areas are patched with regular deck concrete leaving a roughened surface and the appropriate space on top to apply the overlay. It is also possible to fill the concrete removal areas with the overlay concrete at the same time the deck is overlaid. This is called "monolithic" repair. If monolithic repair is performed, it is important that concrete is vibrated internally in the removal areas.

Most overlay systems are designed to be less permeable to moisture and salts than normal deck concrete. The most popular deck overlays used today are as follows:

Cementitious Overlays

Cementitious overlays include concrete, latex-modified concrete, silica fume concrete and fiber-reinforced concrete. They are normally approximately 38 to 50 mm (1 1/2 to 2 inches) thick. The mix has small aggregates, maximum 13 mm (1/2 inch), and a low water/cement ratio to achieve a dense and impermeable mix. Cementitious overlays are transported to the site, placed on the deck, screeded and finished like a conventional bridge deck placement. Before they are placed, the existing deck is roughened and a cement grout is applied as a bonding agent. The same type of screeding and finishing equipment is used in placing a concrete overlay as in placing the deck.

Since the thickness of cementitious overlays is relatively low, curing is very important. The following special precautions should be exercised:

- The existing deck should be pre-wetted so that it will not draw moisture from the mix. The surface should preferably be drying at the time of concrete placement.
- It is best not to place the overlay in very hot or windy conditions, since those conditions can cause cracks due to rapid evaporation of bleed water from the concrete surface.
- The finishing should be performed expeditiously, and the curing should begin as soon as possible after the finishing is complete. Delayed curing can cause cracks and/or increased permeability.

Cementitious overlays are modified in various ways to reduce the permeability and, thereby, improve the resistance to corrosion damage from salt. The method used to achieve the lower permeability is as follows:

Concrete -Concrete overlays (may be called low-slump concrete or the "Iowa method") have low water/cement ratios to achieve a dense mix. Workability may be a problem because of the low water/cement ratio. Addition of a superplasticizer may be needed.

Latex Modified Concrete -A latex additive is included in the mix to improve the workability of the low water-cement ratio concrete. The latex additive also makes the concrete self-healing, with improved bonding, and it is less permeable.

Silica Fume Concrete -Silica fume is a more recent additive used to achieve a low permeability concrete. It produces a stiff and sticky mix that may be more difficult to finish. Usually, a superplasticizer admixture is used to improve the workability.

Fiber Reinforced Concrete -Either steel or polypropylene fibers are added to the mix to improve the tensile strength of the concrete. The fibers are intended to improve the resistance of the overlay to certain types of cracking. The fibers present special problems in finishing and texturing the surface. While the reduction of cracks should improve the

resistance to corrosion, the fiber-reinforced overlay is not less permeable unless other changes are made in the mix.

Asphalt Concrete with Waterproof Membrane

Asphalt (bituminous) concrete overlays have probably been used longer than any other type. It was originally used without a waterproofing membrane to improve the riding surface rather than protect the deck. As mentioned previously, bituminous concrete is porous and absorbs moisture. Chlorides and moisture penetrate this overlay and are trapped against the deck, accelerating the deck deterioration. In the past, road crews have indiscriminately placed asphalt on bridge decks, adding weight to the bridge and reducing its capacity to carry loads.

Asphalt concrete is used with a waterproof membrane to prevent intrusion of moisture and salt into the deck. The role of the asphalt concrete is to protect the membrane from traffic. Two types of membranes are used. Those are (1) applied-in-place and (2) preformed. Applied-in-place membranes are usually squeegeed on the surface. Preformed membranes are delivered from the manufacturer in rolls and are directly applied on the deck after it is primed. Sometimes, liquid sealant or an epoxy resin system is used on the deck instead of a membrane. Much care must be exercised in placing the bituminous pavement over the waterproofing material not to damage the waterproofing qualities.

Bituminous concrete/waterproofing membrane system was the popular system before latex-modified concrete was available. Bituminous concrete is usually less durable than a rigid concrete overlay. When exposed to heavy traffic, the overlay will deteriorate rapidly. This will require removal and replacement of the overlay itself, regardless of the deck condition. Some states still consider the system be economical and effective.

Thin Polymer Overlays

Essentially the thin polymer overlay consists of a polymer applied to the deck surface with sand, or another similar fine granular material, broadcast on top to improve skid resistance of the polymer. No other wearing surface is used. Up to three layers may be applied in this fashion to provide the required thickness. Thin polymer overlays have been used for quite some time with varying success.

Problems include brittleness of the polymer over time, porosity of the overlay caused by penetration of the sand into the polymer material, loss of the sand in the overlay due to traffic wear, and debonding of the overlay, in sheets, under heavy traffic. Debonding is the result of pounding of the traffic and/or fluctuation of the temperature. Polymer concrete tends to expand and contract much more than the deck concrete when the ambient temperature fluctuates. This incompatibility causes debonding at the interface with the deck. However, sometimes the presence of a very strong bond between the polymer and deck causes the concrete to delaminate just below the thin overlay. Improvements have been made in polymers to minimize such problems by making polymers more flexible.

CONCRETE DECK REPLACEMENT

Most bridge maintenance crews do not attempt concrete deck replacement because the manpower, material, and equipment requirements are more than they can spare for the period of time required to replace a deck. The crew may have the skills required to do the work, but they are usually needed for many smaller tasks rather than one major task.

Some maintenance organizations have crews that specialize in concrete deck replacement. When replacement is contemplated it is a good idea to look at possible improvements to the structure as part of the work. Perhaps, with only slight modifications, the capacity of the bridge can be increased. This may involve the addition of shear connectors or the addition of one beam line. There may also be a need to improve or replace the rail to bring it up to current standards, or it may be possible to increase the roadway width when the deck is replaced. Deck replacement is usually considered a major event that may trigger certain capacity and safety consideration.

Bridge maintenance crews in some states also cast deck panels in their shop during winter for use in future deck replacements. Precast panels for a composite deck are shown in Exhibit X.7. This can be an efficient way of replacing a concrete deck when construction time and disruption to traffic is critical. This method of casting permits better control of the mixing, finishing, and curing than is normally possible when the deck is cast in place. The panels can be placed with minimum heavy equipment such as a boom attached to the back of a truck. See Exhibit X.8.

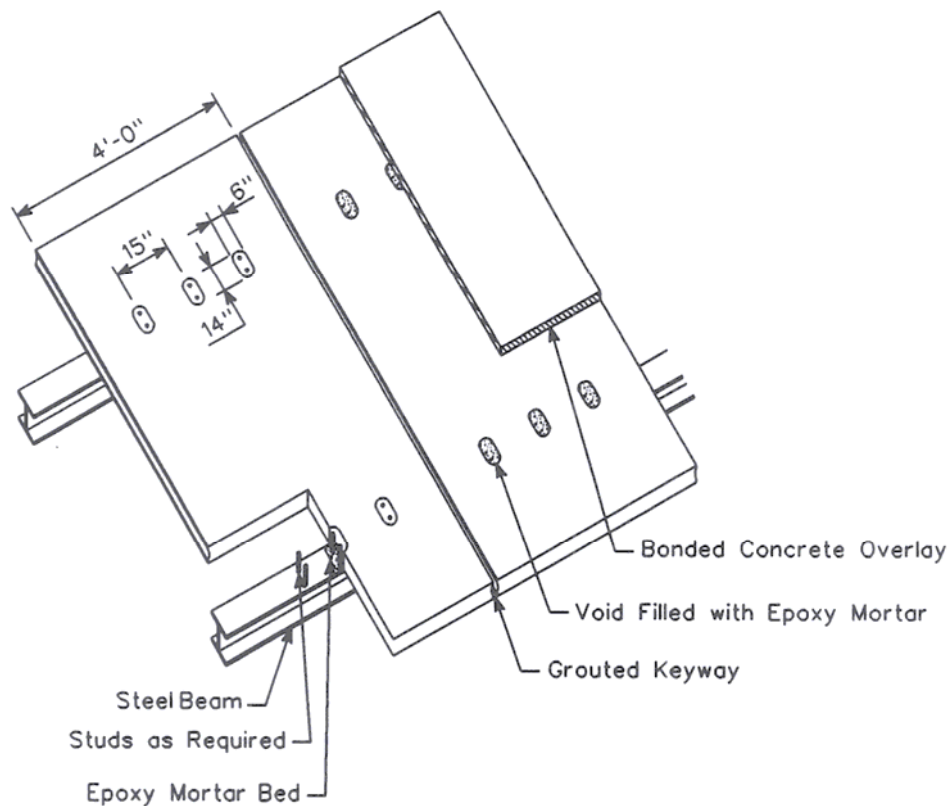


Exhibit X. 7 Precast Concrete Deck Panels

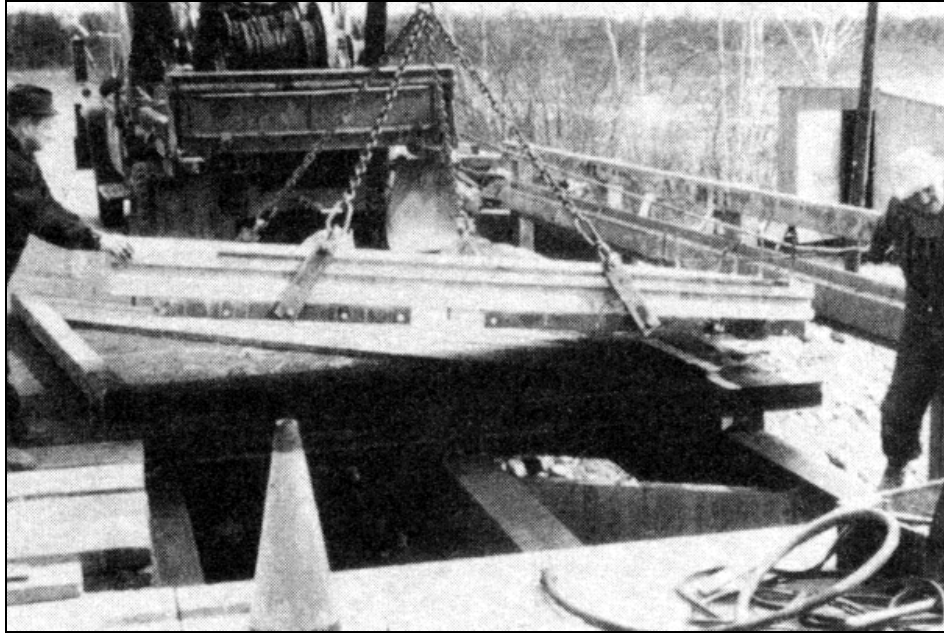


Exhibit X. 8 Panel Placement

Removal of the existing deck is a major task, requiring care not to damage the beams. There are many ways to do this including saw-cutting, using pavement breakers, tractor mounted breakers, or huge pincher crushers.

B. TIMBER DECK

PREVENTIVE MAINTENANCE AND REPAIR

MOISTURE CONTROL

Moisture control is the simplest, most economical method of reducing or preventing decay in timber bridges. When exposure to wetting is reduced, members can dry to moisture contents below that which will support most fungal and insect growth (approximately 25 percent). Moisture control was the only method used for protecting many covered bridges constructed of untreated timber, some of which have provided service lives of 100 years or more. Although modern timber bridges are protected with preservatives, decay can still occur in areas where the preservative layer is shallow or broken. This damage is the major cause of deterioration in timber bridges.

Moisture control involves a common sense approach of identifying areas with visibly high moisture contents, locating the source of water, and taking corrective action to eliminate the source. For example, drainage patterns on approach roadways can be rerouted to channel water away from the bridge rather than onto the deck. Cleaning dirt and debris from the deck surface, drains, and other horizontal components also reduces moisture and improves air circulation.

One of the most effective approaches to moisture control is restricting or preventing water passage through the deck. Decks that are impervious to moisture penetration will protect critical

structural members and substantially reduce the potential for decay. Glulam or stress-laminated decks afford the best protection because they can be placed to form a watertight surface. Leaks between glulam panels or at butt joints in stress-laminated decks can be resealed using bituminous roofing cement.

The wearing surface also plays an important role in moisture protection. Wearing surfaces constructed of lumber planks or steel plates provide little protection and often trap moisture under the planks or plates. Lumber planks are a particular problem because they inhibit drainage on watertight decks and often cause water ponding on the deck surface. When ponding occurs, the only practical option for its removal is to install tubes through the deck to drain water down and away from the deck, rather than onto the deck underside and supporting members. See Exhibit X.9.

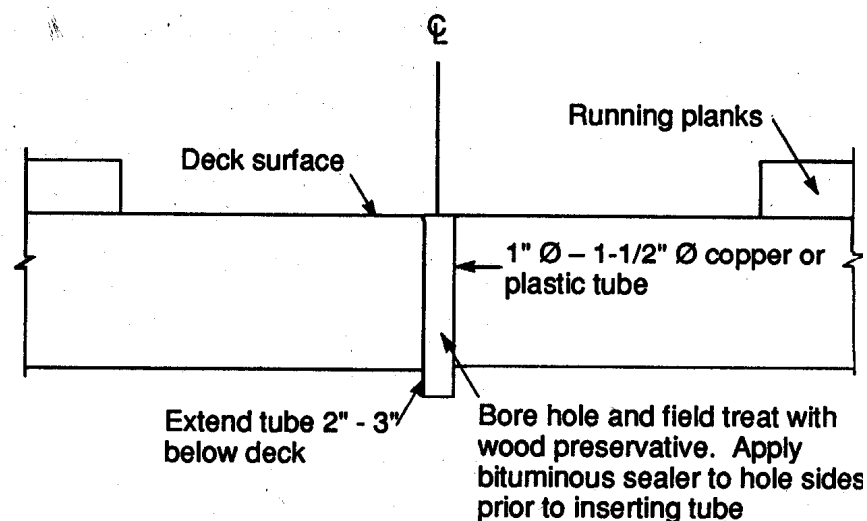


Exhibit X. 9 Drain tube to remove water trapped between planks.

In glulam, stress-laminated, and some nail-laminated decks, the addition of an asphalt wearing surface provides a moisture barrier that protects not only supporting members but also the deck. Further moisture damage may occur when the asphalt is placed without a waterproof membrane. All glulam and stress-laminated decks are normally suitable for asphalt surfaces; however, use of asphalt surfaces on nail-laminated decks may be limited by the condition of the deck. Nail-laminated decks commonly loosen after 5 to 10 years of service under heavy loads. Paving these decks is futile because the separation and movement of laminations will cause the surface to crack. The best approach to waterproofing a loose nail-laminated deck is to stress it to restore deck integrity. This will be discussed later in this Chapter.

SEALANTS

Sealants are applied to prevent infection of exposed wood, whereas fumigants are used to treat internal decay. In-place treating can provide a safe, effective, and economical method for extending the service life of timber bridges. Most of the techniques and treatments were

developed for use on railroads or utility poles, for which they have been used effectively for many years. A large number of timber bridges have been treated in-place, extending service life by as much as 20 years or more.

Surface treatments are applied to existing bridge members to protect newly exposed, untreated wood from decay or to supplement the initial treatment some years after installation. This type of treatment is most effective when applied before decay begins and is commonly used for treating checks, splits, delaminations, mechanical damage, or areas that were field-fabricated during construction. The ease of application and effectiveness of surface treatments as toxic barriers make them useful in preventive maintenance. However, the shallow penetration limits their effectiveness against established internal decay.

Conventional liquid wood preservatives are applied by brushing, squirting, or spray-flooding the wood surface. Creosote used to be the most commonly used preservative, but penta and copper naphthenate are used more commonly today. The wood surface should be thoroughly saturated with preservative so that all crevices are treated; however, care must be exercised to prevent excessive amounts from spilling or running off the surface and contaminating water or soil.

The effectiveness of surface treatments depends on the thoroughness of application, wood species, size, and moisture content at the time of treatment. Wet wood absorbs less preservative than does dry wood. This factor is significant in timber bridges because many areas requiring treatment are subject to wetting. Tests indicate that improved treatment of wet wood was obtained by using preservatives at double the normal 3- to 5-percent concentration. Although field tests show that surface treatments in aboveground locations can prevent decay infections for up to 20 years or more, it is recommended that treatments used for bridge applications be systematically reapplied at intervals of 3 to 5 years to ensure adequate protection from decay.

FUMIGANTS

Fumigants are specialized preservative chemicals that are placed in prebored holes to arrest internal decay. Over a period of time, the fumigants volatilize into toxic gases that move through the wood, eliminating decay fungi and insects. Fumigants can diffuse in the direction of the wood grain for 8 feet or more from the point of application in vertical members, such as poles. In horizontal members, the distance of movement is approximately 2 to 4 feet from the point of application. The three chemicals most commonly used as liquid fumigants are Vapam (33-percent sodium N-methyldithiocarbamate), Vorlex (20-percent methylisothiocyanate, 80-percent chlorinated C3 hydrocarbons), and chloropicrin (trichloronitromethane). Solid fumigants are available in capsules of methylisothiocyanate (MIT), which is the active ingredient of Vapam and Vorlex. Solid fumigants provide increased safety, reduce the risk of environmental contamination, and permit fumigant use in previously restricted applications.

To be most effective, fumigants must be applied to sound wood. When applied in very porous wood or close to surfaces, some of the fumigant is lost by diffusion to the atmosphere. Before applying fumigants, the condition of the member should be carefully assessed to identify the optimal boring pattern that avoids fasteners, seasoning checks, badly decayed entire structure, it is advisable to contract the project to specialists in the field. There are companies that have provided in-place-treating services for many years with excellent safety records and results.

When selecting a contractor, previous experience and performance histories should be carefully evaluated to ensure that the contractor is qualified to perform the required treating.

STRESS LAMINATING EXISTING NAIL-LAM DECKS

Stress laminating is probably the most effective method for the repair of existing nail-laminated decks. Such decks frequently delaminate from repeated loading, causing breakup of asphalt wearing surfaces, water penetration through the deck, and a loss in live load distribution capability. For these cases, the dead load capacity and condition of the deck is generally maintained, but its serviceability and ability to distribute live loads between individual laminations is greatly reduced. In this situation, the laminations no longer act together to distribute loads, and local failures occur. This condition also increases the rate of deterioration, eventually leading to failures that require complete deck replacement.

Using this approach, the laminations are stressed with a series of high-strength steel rods applied transverse to the length of the laminations. The stress squeezes the laminations together and greatly increases the load distribution characteristics of the deck. Additionally, the stress seals the deck as the laminations are pressed together, providing a watertight surface.

Stress laminating for existing decks differs in configuration from new construction in that stressing rods are positioned on the outside of the laminations, rather than in holes through the laminations. See Exhibit X.10. This allows the stressing operation to take place without removing the deck and without costly fabrication operations, while traffic is still using the bridge. It is usually necessary to add laminations to the deck before stressing because the rod force squeezes laminations together, reducing the deck width 10 inches or more, depending on the original width. Stress laminating provides a good long-term solution for repairing existing nail-laminated decks to increase load capacity and substantially extend the service life of the structure.

In an existing deck, the steel rods pass through anchor plates at the outside edges of the bridge deck, as shown in Exhibit X.10. The anchor plates apply force against a continuous steel channel bulkhead, which bears directly on the timber laminations. This bulkhead runs the full length of the bridge deck. This bulkhead helps to distribute the high prestressing force preventing local crushing of the wood.

The top rods are covered with asphalt so the traffic can drive across the bridge. The entire existing wearing surface may be removed to facilitate this or grooves may be cut into the wearing surface to minimize to allow asphalt replacement and allow traffic maintenance. Cutting grooves is an inferior method, however, since traffic will badly deteriorate the wearing surface and the final product is aesthetically unpleasing. Asphalt cutting also takes considerable time. A two-way plank wearing surface may be used as an alternative. The two-way planking system includes a bottom layer running parallel to the rods allowing a space for the rods to be installed and an upper layer running perpendicular to the planks.

Originally, pairs of rods were stressed individually. As one pair of rods was stressed, the preceding pair lost their stress. Up to 12 passes of stressing were required to reach and acceptable level of stressing in all rods. An improved method is to use a multiple system of 530

kn (60 ton) jacks, which can stress pairs of rods one at a time. These jacks could also be hollow cylinder design so they can also be used for single bar construction as in new decks. Distortion of the deck at the original toe nailing of the laminations should be taken into consideration.

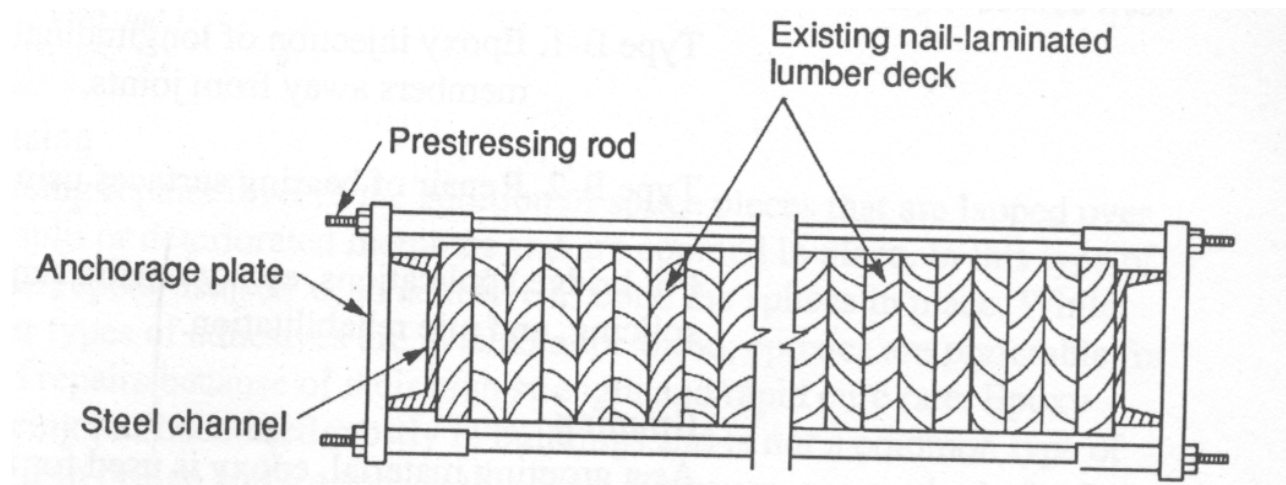


Exhibit X. 10 Stress Lamination of existing Nail-Laminated Deck

TIMBER DECK REPLACEMENT

PLANK DECKS

Maintenance crews can easily replace a timber plank deck and this may be the most cost-effective alternative when the deck has deteriorated to the stage that repeated plank replacements would be necessary. Following is a procedure for replacing plank decks:

- (1) Remove and store deck-mounted curbs, parapets, wheel guards and railing.
- (2) Remove existing deteriorated planks that can be repaired or replaced in the same day.
- (3) Clean and paint top flanges of stringers in accordance with Session VI.E.
- (4) Planks should be laid with the heart side down because it is more resistant to decay. ¼-inch spacing should be provided between planks for drainage, expansion, and air circulation. Structural grade hardwood planks, 6 to 10 inches wide, are preferred as decking material because wider planks have a tendency to curl. Planks of the same thickness should be placed adjacent to each other with a full, even bearing on the stringers. Wedges should not be used to level flooring because they are easily dislodged and leave the flooring in a loose and uneven condition.
- (5) Planks are attached to supporting beams with galvanized spikes that are 6 to 9 mm (1/4 to 3/8 in.) in diameter and approximately twice as long as the deck is thick. Two spikes are placed in each plank at each beam. Resistance to withdrawal is improved if spikes are driven at a slight angle rather than perpendicular to the beam.
- (6) Apply wood preservative to the ends of any plank that is field cut.

(7) Apply a wearing surface. (Optional)

(8) Replace deck-mounted appurtenances. If this requires drilling into the planks, then treat the holes with fumigants before installing the hardware.

NAIL-LAMINATED DECKS

Nail laminated decks were common between 1920 and 1960. Nail lamination can be done with little training in the yard or on site adjacent to the bridge. If replacement in kind is preferred, it's best to replicate the member sizes and lamination pattern of the existing deck. But, it may be preferable to install a plank deck due to the relative ease of construction. Consult an engineer before choosing this option.

C. STEEL GRID DECKS

The primary advantage of steel grid decks is that they can be designed to meet live load requirements with considerably less weight than concrete. Steel grid decks are common on moveable lift spans where the weight of the deck is a major consideration. Steel decks are often used to increase the live load capacity of bridges when used to replace concrete decks.

PREVENTIVE MAINTENANCE AND REPAIR

The primary maintenance and repair problems with steel decks are deterioration from exposure to the weather, weld failure, and skid resistance. Repairs for corrosion and welds are the same for steel decking as with any other structural steel member. The most common maintenance and repair activities follow:

CLEANING

The open grid does not protect the portions of the bridge under the deck from exposure to de-icing salts. Decks should be cleaned regularly. As shown in Exhibit X.11.

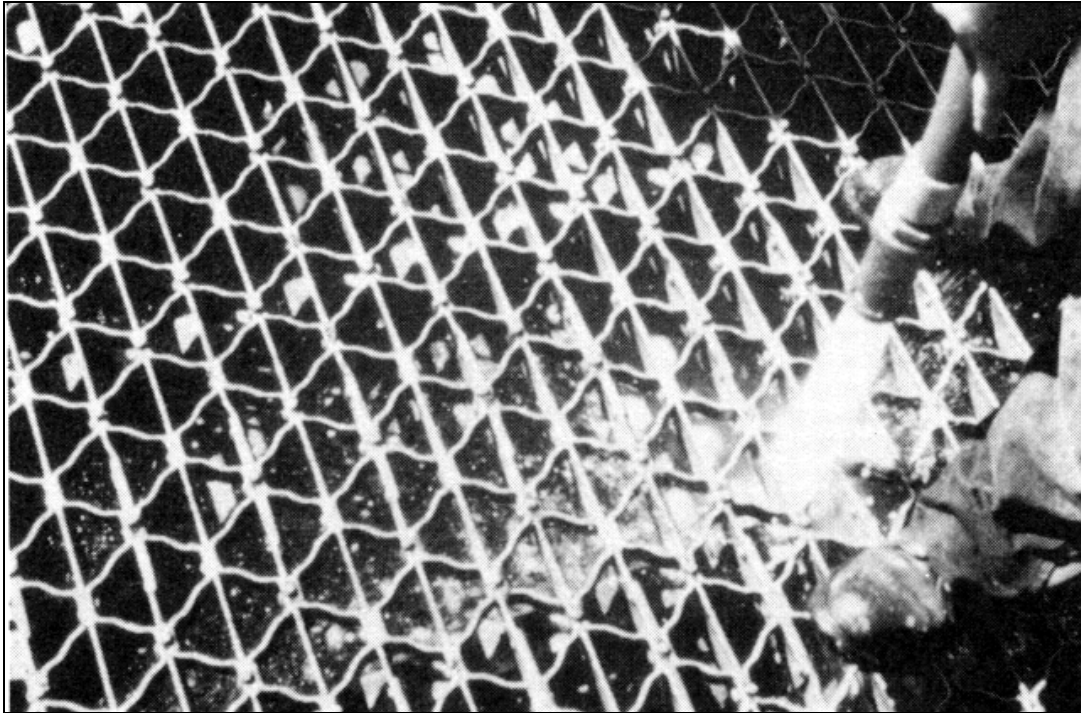


Exhibit X. 11 Steel Grid Deck Cleaning

REPAIRING BROKEN WELDS

The welds or rivets that join the grids and hold them down may break, they should be repaired or replaced since this presents a potential hazard. It may be necessary to reinforce or replace damaged grid plates. When several plates have been damaged or dislodged it is best to cut out and replace that portion of the deck.

IMPROVING SKID RESISTANCE

Some agencies apply studs to the deck surface to improve traction. The studs are 8 mm (5/16 inches) in diameter and 10 mm (3/8 inches) high and welded on intersections of the cross members to provide a grip surface to overcome slipperiness. Florida DOT is using a scrabbler device to roughen the surface of the steel grid deck. See Exhibit X.12.



Exhibit X. 12 Scabbier Roughened Grid Deck

CONCRETE FILL

Another method of repair commonly used is to fill or partially fill the steel grid with concrete or lightweight concrete. An engineer should evaluate the effects of the superimposed dead load. The concrete filled grid acts as a reinforced concrete deck. The steel grid provides the steel reinforcement and the concrete fill provides stiffness to help carry the load. This repair technique has several advantages: increased deck strength, reduction in the effect of weathering by limiting the water penetration, support of the welded grid joints, and increased skid resistance. A wearing surface can be added to the deck to provide additional skid and weather resistance.

EXODERMIC DECK

This deck consists of a thin upper layer (3-inch minimum) of precast reinforced concrete deck panels joined to the steel grid. The panels are added to an existing steel deck using shear connectors welded to the steel stringers. See Exhibit X.13. Recently, the design of exodermic deck panels has been revised to facilitate fabrication in that tertiary bars and vertical studs have been removed. The installation procedure follows:

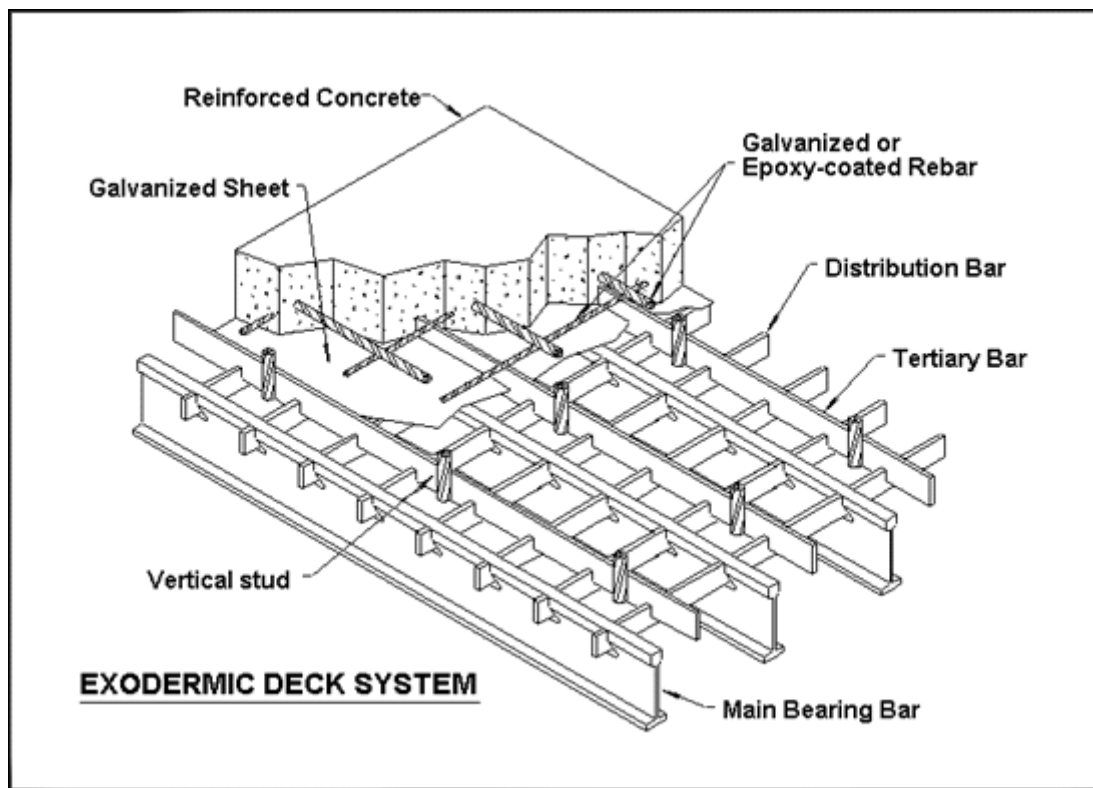


Exhibit X. 13 Exodermic Deck System

The concrete portion of the exodermic deck panels are precast. The precasting operation provides blockouts in the panels in those areas which will be above stringers. These openings allow heated studs to be welded through the grid to the stringers in the field. Rapid setting concrete is used to fill the shear stud blockouts as joints and keyways between panels.

D. DECK JOINT MAINTENANCE

Damage related to bridge deck expansion joints in the United States totals millions of dollars each year. This includes damage both to the joint and to the portion of the bridge beneath the opening that is exposed to debris and contaminants. Methods to preserve and extend the service life of bridges include the proper installation and maintenance of deck expansion joints.

One should look at different types of joints currently in service and compare to bridge ages to get a feel for the evolution of deck joints. The earlier designs provided little or no protection from passage of deck drainage and debris. More recently, flexible materials have been used to seal the opening. None of the designs have been totally successful in eliminating the problems, which is why new devices and materials continue to be marketed. The goal is to have a joint that is watertight, capable of accommodating movement, as durable as the adjacent deck, and as maintenance free as possible. Until such a marvel is available, preventive maintenance is necessary to keep joints functioning and avoid costly structural damage.

JOINT TYPES

There are several types of joints and each has a different function.

CLOSURE JOINTS

Also known as cold joints or construction joints, these are used during concrete placement to separate different sections of the pour. They are used in the decks of continuous spans where deck sections must be placed in areas of positive bending before they are placed over the intermediate supports. They may be used when concrete placement must be interrupted for a substantial period of time. They may be difficult to detect visually, except in those states where they are required to be saw-cut and sealed. In the past, it was assumed that these joints would rarely leak, but this has not been the case. Inspectors typically find seepage and efflorescence on the undersides of closure joints. An example is shown in Exhibit X.14

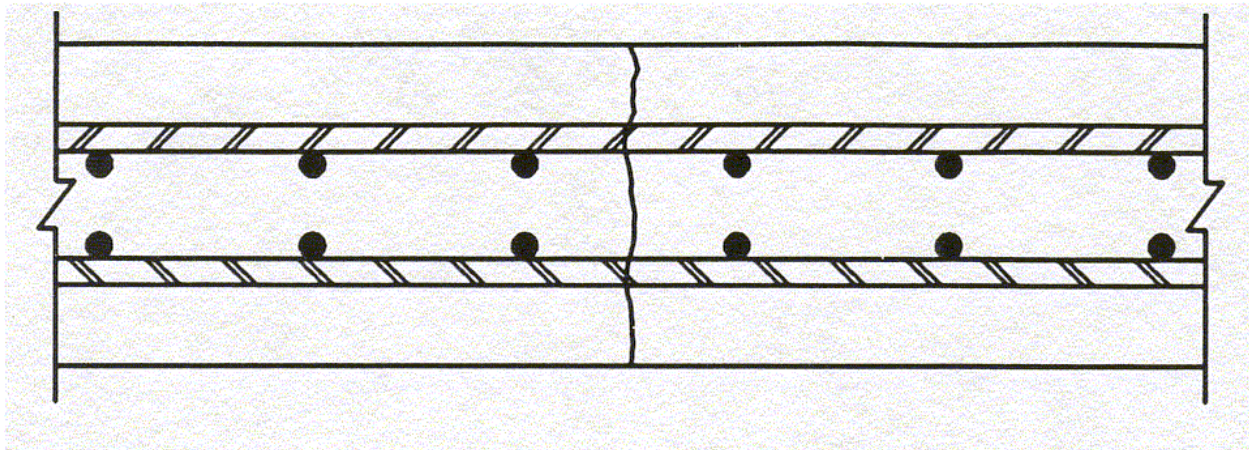


Exhibit X. 14 Closure (Construction) Joint

CONTRACTION JOINTS

These joints are used to control shrinkage so that it occurs only at these joints which are detailed with a waterstop. These joints are typically found in wingwalls and retaining walls where leakage is undesirable.

NON-EXPANSION JOINTS

Also called fixed joints. These joints are used to allow rotation of a beam end when no expansion is permitted. They are typically found at the abutment or pier supporting a fixed bearing. These joints are typically smaller than expansion joints.

EXPANSION JOINTS

Where both rotation and expansion are anticipated, expansion joints are used. The expansion joints on suspension spans can accommodate movements of up to several meters (feet).

JOINT FUNCTIONS

The function of a bridge deck expansion joint is to accommodate movement of the superstructure. This movement emanates from live loads, environmental characteristics, and the physical properties of the materials that make up the bridge. Longitudinal and transverse movements occur as the result of temperature change, creep, and shrinkage. Rotational movements occur as the result of live load deflection and substructure settlement. Transverse movement can be particularly troublesome on skewed bridges.

Providing a space between rigid sections of the superstructure equal to or greater than the anticipated movement usually accommodates the movement. As a result, discontinuity that lowers the riding quality of the roadway is created in the surface of the deck. The opening can also become a conduit through which foreign materials are deposited on the supporting elements beneath the deck.

A variety of devices have been incorporated in the design of bridge deck expansion joints. Variance in the materials and the details of designs intended for the same function are common with the result that some of these devices have been effective while others have performed poorly. The following discussion reviews the various types of joints; the related problems in maintenance, and the impact that poorly maintained joints can have on other parts of the structure.

JOINT CLASSIFICATION

Joints can be subdivided into two classifications: open and closed. Closed joints are designed to be waterproof, while open joints are not.

OPEN JOINTS

Common types of open joints are butt joints (either with or without face reinforcing), plate joints, and finger joints. These joint types were used almost exclusively in older structures. The butt joint is normally used for movement less than 25 mm (1 inch), the plate joint for movement between 25 and 75 mm (1 and 3 inches), and the toothed or cantilever joint for movements in excess of 75 mm (3 inches).

Drainage systems have been installed to carry the runoff away from the joint to alleviate the impact of water reaching components of the structure beneath the deck. Usually, this consists of a drainage trough placed beneath the joint.

The drainage trough has had problems, because of inadequate slope it can fill with debris, which then spills over onto the seat below. Cleaning the trough normally ranges from difficult to impossible. Today there is more and more use of the flexible trough, designed to be removed, making clean out easier. In many situations it would probably have been as effective to eliminate the trough and regularly clean the bearings and seats.

The open joint has lost favor with most bridge engineers because this design permits contaminants to pass through the opening and the drainage trough has not received the maintenance attention it needs when improper cross slope of the trough is a problem.

Butt Joint

Butt joints are commonly used where only rotation with minor thermal movement must be accommodated since this joint provides no transition for traffic between adjacent edges of the deck. Armoring is usually provided, although installations have been made without it. A typical detail is shown in Exhibit X.15

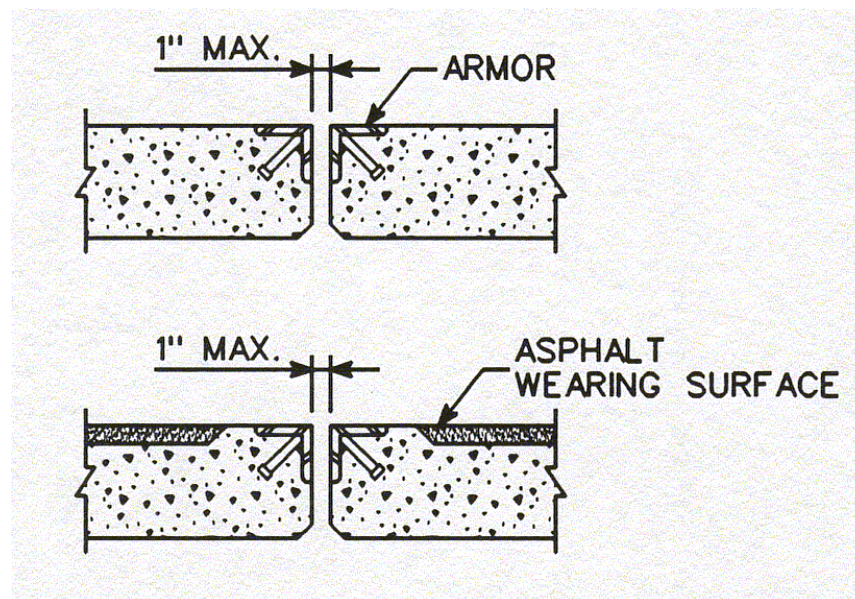


Exhibit X. 15 Open Butt Joint

It is difficult to protect the metal facing from corrosion. The joint will often fill with noncompressible materials and thus become inoperable. When used with asphalt overlays, the armoring should extend to the surface elevation of the overlay. A joint transition dam is required to achieve this; otherwise, raveling of the wearing surface can occur at the joint. Normal maintenance includes periodically clearing the opening of roadway debris, painting, and repairing the roadway surface adjacent to the armor plate or dam.

A concrete slab edge can be damaged during construction or by traffic when unarmored joints are used. Once damaged, deterioration will continue and eventually require recasting of the slab edge.

Plate Joint (Plate Dam)

Plate joints are used for movements between 25 mm and 75 mm (1 and 3 inches) and were the predominant type of bridge expansion joint used with steel-framed structures prior to the development of neoprene joints. The joint is normally designed to be self-supporting without reliance on the concrete deck for support. This is accomplished by supporting the joint on the

end diaphragm and/or the ends of the stringers. A typical detail is shown in Exhibit X.16. A similar detail has been used on concrete structures.

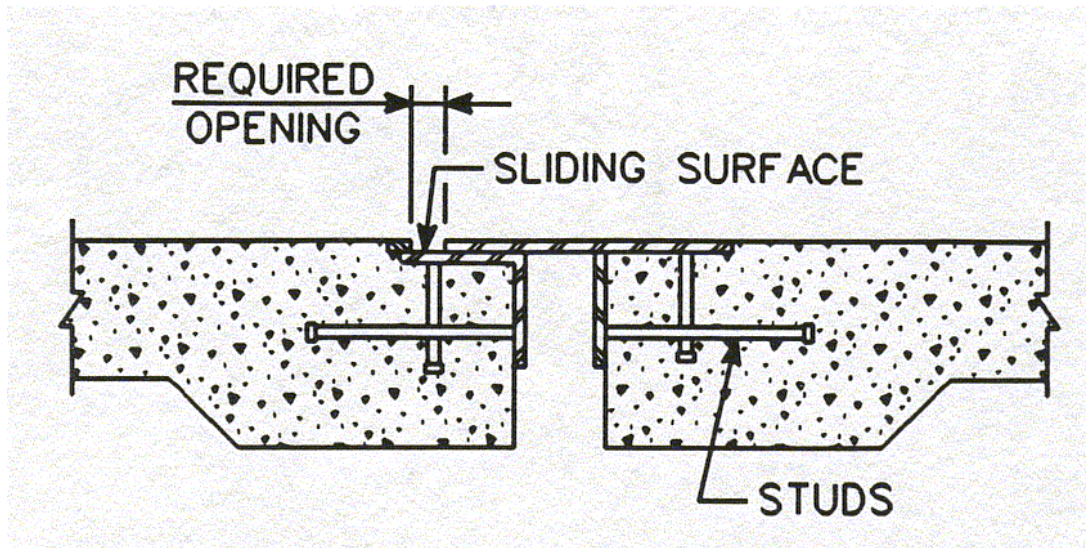


Exhibit X. 16 Plate Joint

Plate joints are difficult to maintain. It is common for plates to become loose, indicated by a loud noise as traffic crosses, and occasionally to become completely detached, which results in a safety hazard. There are several reasons for this depending on the particular design, although much of the problem can be attributed to the inadequate consolidation of the concrete under and around the plates. The anchors also corrode and are subject to fatigue from the continuous pounding of traffic. Sometimes the roadway surface around the plates deteriorates, and this deterioration increases the impact from traffic on the joint and dislodges the plates. Failure of any portion of the joint requires immediate repair.

Extensive buildup of debris in the joint will often prevent the joint from operating as intended so it is necessary to periodically clean the joint. Exposed metal must be painted and kept free of corrosion.

Finger Joint

Accommodation for movements greater than 75 mm (3 inches) is provided by a finger or cantilever joint. Finger joints operate well when properly maintained. Maintenance requirements are similar to those required for plate joints. Today, drainage troughs are almost always placed under finger joints. See Exhibit X.17

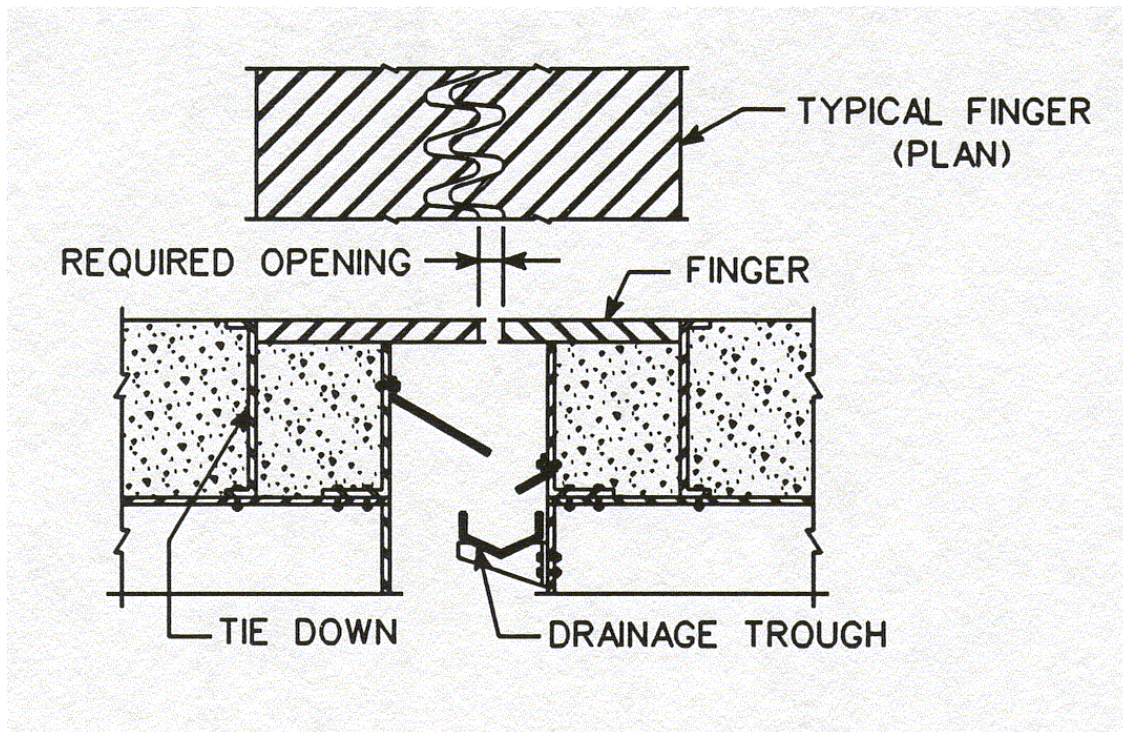


Exhibit X. 17 Finger Joint

CLOSED JOINTS

Closed joints are designed to be waterproof and include the filled butt joints, compression seals, membrane joints, and cushion joints.

Filled Butt Joint (Hot-poured sealant)

A filled joint is similar to the butt joint already described and is used to accommodate the same degree of movement. A premolded joint material is usually attached to one face of the joint or supported from below by an offset in the vertical face of the slab. A sealing compound is poured from the roadway surface to seal the opening. Exhibit X.18 shows details of a typical filled joint.

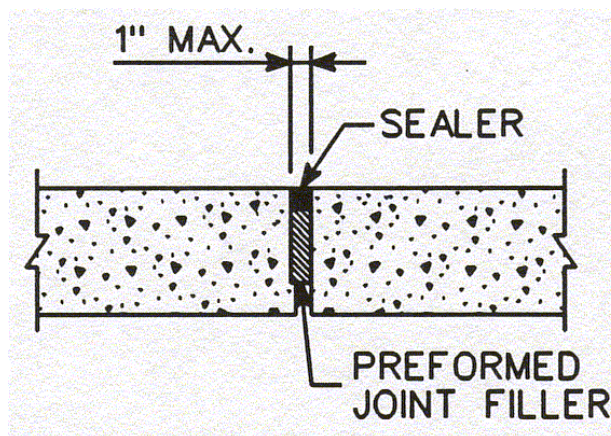


Exhibit X. 18 Filled Joint

Maintenance requirements include periodic cleaning, replacement of the surface seal, replacement of the filler when necessary and repairs to the roadway surface adjacent to the joint.

Experience has shown that hot poured tar seals work best when movement is less than that 13 mm (0.5 inch) and, even then, the adhesive and cohesive properties are very limited. The best products, when placed with strict quality controls, will remain watertight a maximum of two years. Power cleaning of the concrete surface prior to placing the seal improves the adhesion. If this type of seal is not kept watertight, the filler below will deteriorate and make resealing difficult. Noncompressibles that work their way into the seal can cause the joint to jam.

Compression Seal

Compression seals are used for movement up to 65 mm (2.5 inches). Considering the limited time compression seals have been in use, they have the best record for remaining watertight if constructed properly. See Exhibit X.19. Tests by the Florida Department of Transportation have shown that premolded compression joint seals in place for 15 years have superior performance to previously used types.

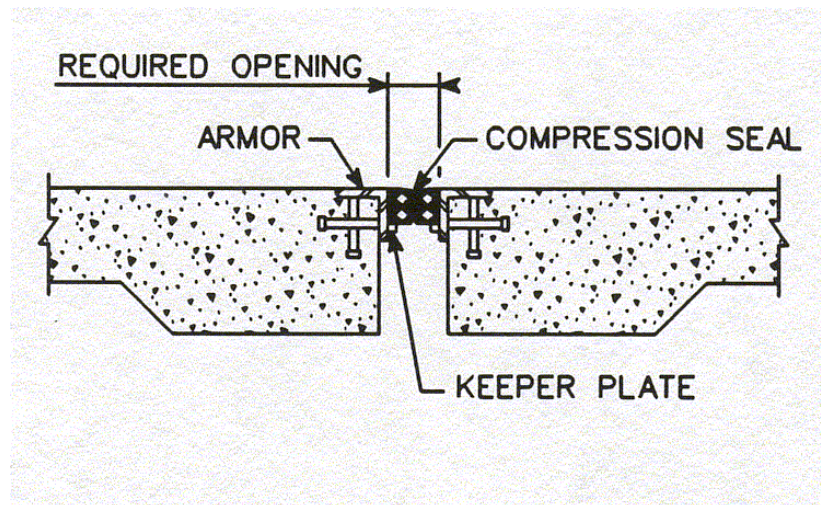


Exhibit X. 19 Compression Seal

It is critical that the opening be dimensioned properly for the seal because it is squeezed into the opening so that it expands and is compressed with the joint movement. It will separate from the deck in cold weather if the opening is too large. If the opening is too small, the compressive force in hot weather will damage the seal. If the opening is too small or the seal is placed too close to the surface, it will be damaged by traffic in hot weather as it bulges due to compression and by snowplows in cold weather. A particular problem with these seals is the cutting necessary to make bends around curbs and parapets.

Keeping the deck and approaches clean decreases the problems associated with damage from debris, particularly noncompressibles. It is more likely not to be watertight as weathering and fatigue weaken the material because the success of this type of seal depends on the ability to return to its original shape after many cycles of being compressed.

Compression seals can be used for large movements when multiple units are used. Careful attention must be paid to design details to ensure proper performance.

Maintenance requirements for compression seals are minimal. Periodic cleaning and roadway repair are all that is normally required. When evidence of leakage is discovered, immediate steps should be taken to correct the situation by repair or replacement of the seal. Many states opt to replace compression seals with cold-poured elastomeric sealants.

Membrane (Strip) Seal

A membrane seal consists of a flexible sheet of neoprene rigidly attached to two metal facings of the joint. The material is bent in the shape of a "U" and flexes with the movement of the bridge. This joint can accommodate movements of 100 mm (4 inches). A typical detail is shown in Exhibit X.20. When properly installed, these joints are very watertight. Problem areas are at gutter lines and areas where breaks in the cross section occur. Breakdown of the membrane usually occurs as the result of noncompressible material being lodged in the joint when the opening is expanded. As the joint closes these materials become wedged in the membrane and can cause a rupture with loss of watertightness of the joint. Breakdown can also occur as the result of traffic movement over debris-filled joints.

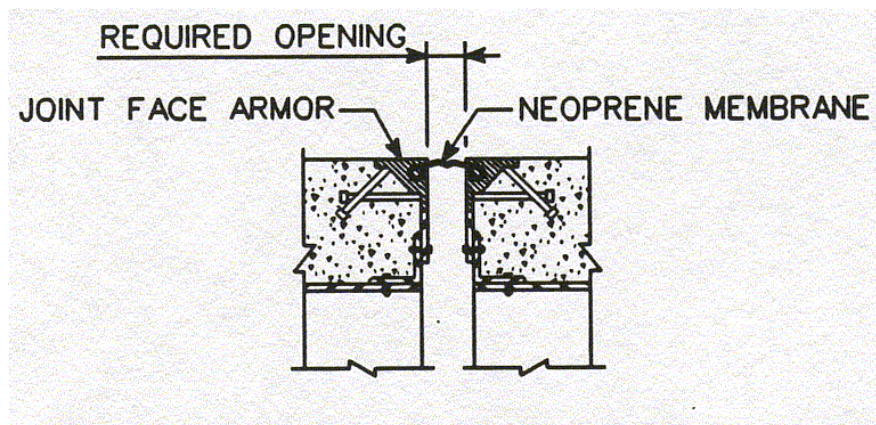


Exhibit X. 20 Strip Seal

Maintenance requirements include periodically removing debris and sealing or replacing defective membranes. As with the compression seals, these units can be used in multiple units to accommodate much larger movement.

Cushion Seal Joints

The cushion seal joint is made up of a reinforced neoprene pad that is rigidly attached to each side of the joint. See Exhibit X.22. The inherent characteristics of the material permit it to expand as the joint opens and to shrink as the joint closes. Internal reinforcement permits the neoprene pad to span the joint and makes it more durable. Cushion seal joints are normally used to accommodate movement up to 100 mm (4 inches).

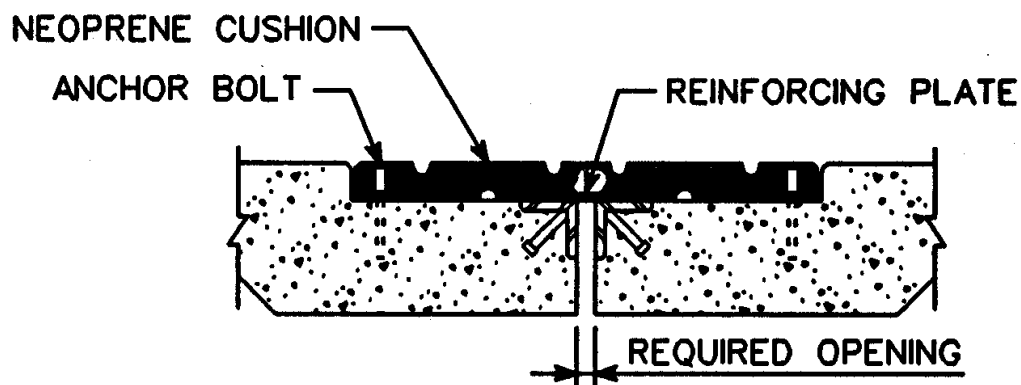


Exhibit X. 21 Cushion Seal Joint

Cushion joints have been in use for more than 30 years and in some instances have performed in a satisfactory manner. One of the more difficult problems in maintaining these joints involves the anchorage system. High-tension stress in the neoprene pad is developed as the bridge contracts. This creates high stress in the anchoring system which, if not properly designed, will fail.

Details at the curb line are also particularly troublesome. Improper design or installation can create a continual maintenance problem. Another problem is that the units are normally provided in nominal increments of length and thus require field splicing. Splicing is difficult to do to ensure long-lasting maintenance-free service, especially when subjected to heavy traffic.

Caps that seal the anchors are usually installed with an adhesive. Adhesive is also used at the interface between the cushion and the concrete to maintain watertightness. The adhesives routinely break down and result in the loss of caps and leakage of the joint.

Severe maintenance problems have developed when the units have been used in areas where snow plowing is required. Plows can tear the joint from the support or otherwise damage the cushion, which then requires extensive repair or replacement. Maintenance requirements include periodic cleaning, inspection of the anchoring devices, replacement when required, and repair of the seal. Improvements have been made in the design of the cushion seals and in the anchors; however, problems continue to be reported with damage to the seals and anchors under heavy truck traffic and damage from snow plows.

Modular Dam Joints

Modular dam deck joints are fabricated to accommodate larger movements over 100 mm (4 inches). They are special designs consisting of a series of strip or compression seals separated by beams and supported by a series of bars. Exhibit X.21 shows a modular joint with four cells. These joints may be damaged by traffic impact and snow plows. They are designed so that components can be removed and replaced.

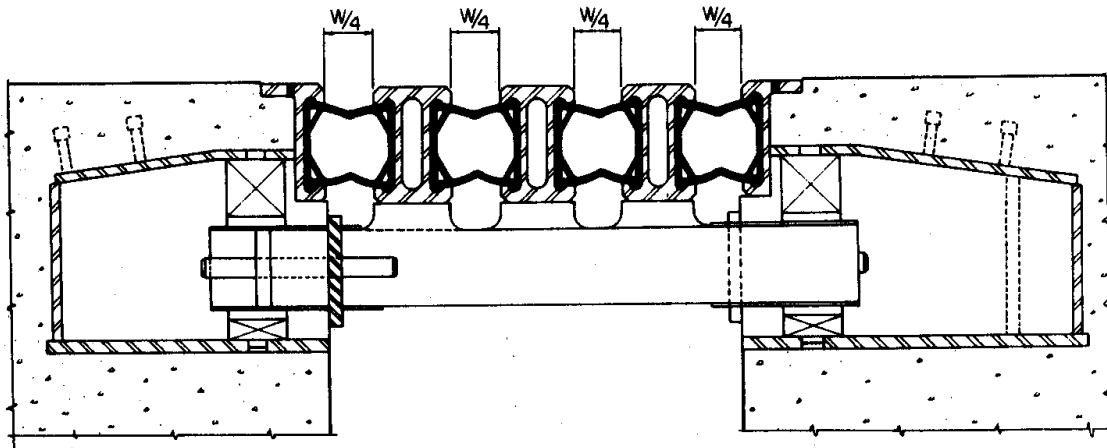


Exhibit X. 22 Modular Joint

Pourable Elastomeric/Silicone Seal

Pourable elastomeric seals have become popular over the last ten years. They may be used as a complete joint system, including header dams and a seal; or they may be sealant only applied to retrofit an existing open butt joint or replace a compression seal. The complete system consists of an elastomeric concrete joint header, which is emmed in the deck end, and a separate seal that is usually silicone based. A backer rod is placed in the gap between deck units to support the silicone seal until it cures. When the seal is used as a retrofit, the existing joint armor and/or deck ends must be cleaned and primed with an approved bonding agent.

These sealants have excellent expansion and contraction capabilities. The silicone component can be expected to accommodate movement up to three times the size of its installed width. However, these seals have very little shear, tearing or puncture resistance. They must be kept clean of glass and rocks that may be forced through the seal by traffic. The advantage to the silicone sealant is that small leaks can be easily repaired. A section can be cut out and new sealant poured in its place. Subsequent pours have excellent adhesion to existing seals.

PREVENTIVE MAINTENANCE

Preventive maintenance of bridge deck expansion joints is vital to maintaining the serviceability and prolonging the life of a bridge. Preventive maintenance is most effective if it begins when a bridge is new and continues throughout the service life. The objective of preventive maintenance for deck joints is keeping the seal securely in place and waterproof. This starts when the joint seal is installed. Too often, seals are installed improperly and were never watertight. Construction inspectors and maintenance workers must understand the importance of, and the proper installation procedures to achieve waterproof joints.

Joints are designed to provide for rotation, translation, and transverse movements of the

superstructure under live loading and thermal expansion. The system should also prevent water leakage onto the components below the bridge deck. Routine maintenance for various joint types is discussed below:

FINGER JOINTS

- *Clogged joint and drain trough.* Frequently flush and clean the joint and drainage system to remove debris accumulation in the system. This will also help prevent corrosion and concrete deterioration.
- *Loose joints.* Remove loose or faulty bolts or rivets, reposition the expansion device, and rebolt. It may be necessary to countersink the bolts or rivets to avoid future problems.
- *Broken finger joints.* Weld replacement fingers onto the joint.
- *Fingers closed.* Trim the expansion fingers or remove the system, reposition, and reinstall.

ARMORED JOINTS

If the joints are clogged, clean out the joint, repair any broken angles, and apply a liquid or preformed compression joint sealant for waterproofing and to prevent debris intrusion.

SLIDING PLATE

- *Clogged expansion gap.* Remove any dirt, debris, or asphalt from the gap to ensure that sliding plate interacts properly with its angle seat.
- *Joint closed.* Trim the steel plate.

PREFORMED STRIP SEAL

- *Faulty section.* Remove and replace.
- *Filled gland.* Remove dirt or debris.
- *Loose or broken bolts.* Remove broken bolts and replace with “J” bolts.

COMPRESSION SEAL

Leakage is the most common failure associated with this joint sealant and requires replacement of the deficient seal over its entire length. If cold poured elastomeric sealants are approved for use, they make a desirable replacement for compression seals.

COMMON MISTAKES

Casting the Joint Opening Improperly

The opening must be the proper width at the designated temperature and the sides must be vertical, straight and parallel.

Placing the Seal Too High

The seal should be properly recessed, so that when the deck is expanded in the hottest weather, the seal is not compressed above the grade of the deck. Normally, this would mean recessing the seal 6 to 10 mm (1/4 to 3/8 in.) However, on the wider compression seals this may not be enough; therefore, manufacturer's specifications should be followed.

Damaging the Edge of the Joint During Construction

Seals are not effective if the edges of the joint are damaged. The edges of concrete decks are sometimes damaged during construction. During the finishing operation, the edge should be smoother and rounded with 6 mm (1/4 in.) radius. Joints should be protected while the concrete is green. Under no circumstances should steel-wheeled equipment be permitted to cross an unprotected deck.

Poor Bond to the Concrete

The most important part of achieving a good bond is proper cleaning of the joint prior to placing the seal. This is most important on existing decks that have an accumulation of dirt and oil products on the surface. The most effective method of cleaning the surface is by sand blasting.

Most seals rely on an adhesive to help achieve a bond to the concrete. This adhesive should be properly applied and not permitted to dry before the seal is in place. The poured sealers have adhesive properties within the material.

Hot- Poured Seal at Bottom of Joint

Poured seal should be bonded on the sides, but not the bottom of the opening. If the seal is bonded on the bottom, there is insufficient distance for it to stretch and it will crack. A bond-breaker should be placed on the bottom where the seal rests on concrete or if a filler material is used. Poured seal should be thin enough to stretch or the resistance of the material will break the bond and pull it apart from the sides. Ideally the width is greater on the sides where bond is needed and less near the center so that it can stretch. Exhibit X.23, which was provided by MinnDOT, illustrates correct and incorrect hot-pour sealer installation.

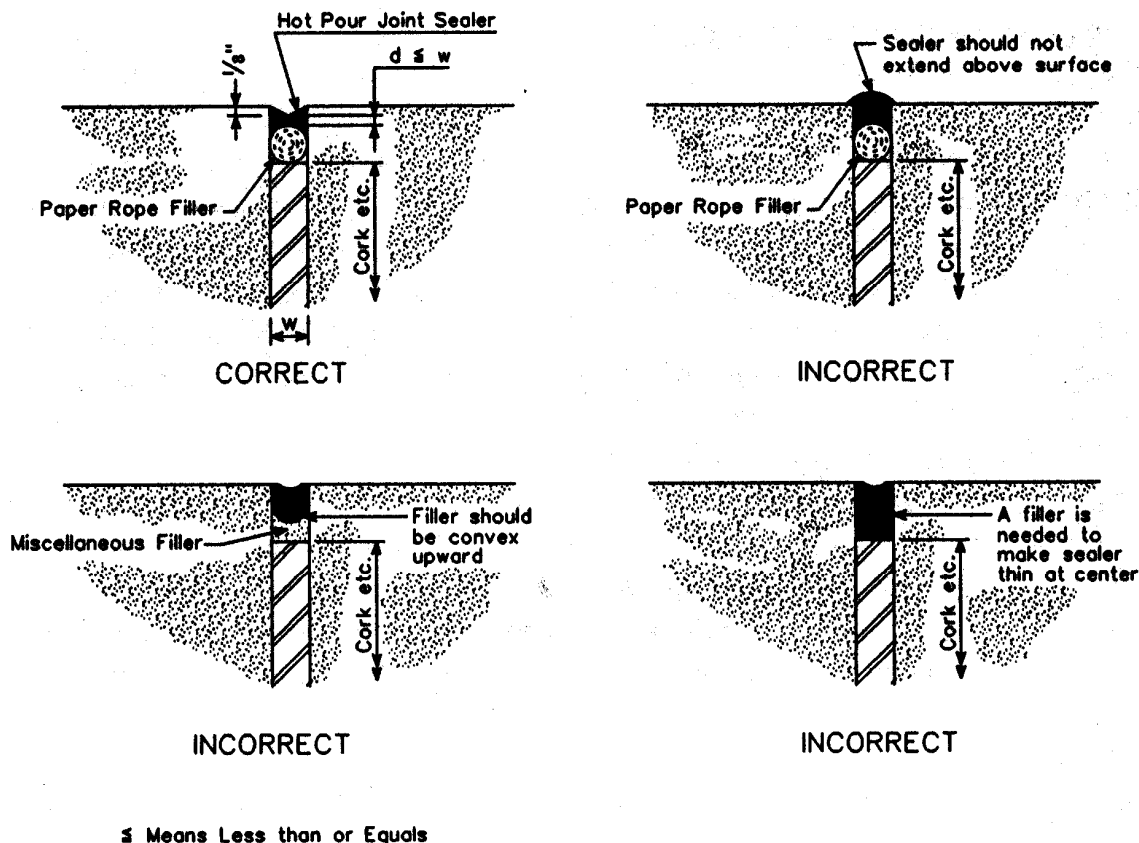


Exhibit X. 23 Hot Poured Sealer Installation

SPECIFIC JOINT PROBLEMS

A number of joint problems occur routinely including edge and surface damage as well as structural breakdown. Descriptions of these problems and some suggested repair techniques are discussed in the following sections.

EDGE DAMAGE

Excessive edge pressure on the concrete at any time either during or after construction, as caused by crossing the deck with steel-wheeled rollers or steel-tracked equipment without adequate protection, may cause edge damage. Irregularities in the grade of the deck between the two spans will also contribute to edge failure.

The width of the damaged area around the joint and other maintenance or repair work needed on the bridge will influence the method used to correct this damage. If the damaged area is narrow and the remaining concrete in the deck is sound, the joint may be widened by sawcutting and adding a compression seal. A more durable solution, particularly if the joint must be recast, is to add an armored device to reinforce the edge of the concrete. Attempts have been made to repair a

damaged edge with cement or epoxy mortar but this type of repair is not durable, particularly if the feathered edges are not eliminated by saw cutting.

RAVELING OF THE WEARING SURFACE OVER A JOINT

It has been common practice to pave or seal coat over a concrete deck with a bituminous wearing surface, thereby completely covering and obscuring the deck joints. This temporarily hides joint problems while improving the riding surface, but the deck movement causes cracking and raveling of the surface at the joints as shown in Exhibit X.24. The wearing surface prohibits inspection and maintenance of the joint seal. If wearing surfaces or overlays are required on a bridge, the joints should be redesigned to accommodate the change. The joint opening may be continued to the elevation of the new surface by adding joint transition dams. When the dams are constructed prior to the placement of the new overlay or wearing surface, it often results in a rough-riding transition. Placing the new surface, ignoring the joint, and then removing the material over the joint may avoid this. The top of the dam should be installed to match the grade of the new surface.



Exhibit X. 24 Raveling of Wearing Surface

LOOSE JOINT PLATE

It is common for steel plates to become dislodged from the anchoring system. Repairs often include redesigning the opening to include a waterproof seal because these joints are not

watertight. This can be done by adding a lip to hold the seal in place, injecting epoxy to fill voids, or removing and replacing a portion of the deck around the joint.

LOOSE PREMOLDED FILLER

Premolded joint fillers frequently deteriorate or become loose and fallout of the joint. Repairs in instances such as this should include removal of all joint material followed by thorough cleaning of the opening. A compression seal should then be installed. This may require removal of a portion of the deck and recasting to accommodate the joint armor and anchorage.

ANCHORAGE FAILURE ON CUSHION JOINTS

One of the major problems with the use of elastomeric cushion seals is the failure of the anchoring device and the subsequent loss of the seal. The voided areas may have been filled with bituminous material as a stop-gap repair. Ultimately, a new elastomeric cushion must be installed or the entire joint must be replaced.

IMPACT OF POOR JOINT MAINTENANCE

It is mandatory to design, install, and maintain waterproof joints in order to preserve other portions of the structure. The following are some of the problems that can develop when deck joints are not adequate or maintained properly.

DAMAGED END DIAPHRAGMS

Normally the first members to show discoloration due to rust are the end diaphragms on bridges with painted steel superstructures. Moisture and salts that pass through the joints cause the rust. In some areas, this rust has become evident in bridges less than two years old. Serious section loss will occur in the steel if this corrosion is permitted to continue. The corrosion on the top flange of the diaphragms expands the metal, which also causes the deck to rise. This not only results in an irregular riding surface, but in time causes transverse cracking in the deck near the joint.

Reinforced-concrete diaphragms are slower to show problems than steel diaphragms. The moisture penetrates the concrete and corrodes the rebars. This causes spalling of the concrete and section loss of the reinforced steel.

The practice of designing a drip edge on the bottom of the deck between the joint and the diaphragm has been used to try to eliminate this problem.

DAMAGED BEAM ENDS

Beam-ends are affected in a manner similar to end diaphragms. Paint systems normally break down more rapidly in this area, and corrosion damage is worse than elsewhere on the beams. On bridges where the joints are not kept watertight, the time period between necessary repainting and repairs of the superstructure elements is greatly reduced.

DAMAGED BEARINGS

When joint leakage occurs, the bridge bearings are exposed to moisture and debris that in turn cause deterioration and corrosion. Often the bearings that were designed to accommodate the superstructure movement will become frozen due to the corrosion. This places greater stresses on other members of the structure than that for which they were designed.

Serious distress problems in members such as beams, seats, or substructure supports result. Often a concrete beam will develop a diagonal crack that begins on the bottom of the beam at the end of the bearing and extends back and upward from the bearing. The force may also cause the seat to crack, as shown in Exhibit X.25. When bearings become frozen, movement is transferred to other bearings, which causes joints to jam or open excessively.



Exhibit X. 25 Crack in Seat

Movement transferred by frozen bearings may also cause adjacent bearings to tilt or slide beyond their design limits. The pressure created by the frozen bearings has been known to cause substructure columns to crack or tilt. On skewed bridges, frozen bearings can cause the superstructure to be forced out of alignment, as shown in Exhibit X.26.



Exhibit X.26 Joint Filled with Debris

DAMAGED SEATS AND CAP

Moisture, deicing salts, and debris that spill through the joints tend to accumulate and pile up on the seats and the top of the cap. The debris holds moisture, which keeps the area constantly damp. The result is that the moisture and salt deteriorate the concrete at an accelerated rate and penetrate to the reinforcing steel. The bearing areas are in turn damaged by the disintegration of the concrete. On many concrete caps a crack approximately 75 mm (3 inches) from the top extending horizontally along the face of the cap will develop. This is caused when the top mat of reinforcement expands due to corrosion and lifts the concrete.

DAMAGED SUBSTRUCTURE

Leaking joints are commonly evidenced by discoloration of the sides of the substructure. Eventual concrete deterioration and spalling ensues. On structures with end diaphragms that extend down to the top of the cap, the water drains down the end of each cap, thereby causing significant concrete deterioration.

EMBANKMENT EROSION DRAINAGE

Water leaking through joints at abutments can cause erosion of the soil embankment. If no provisions are made to check this erosion, it can undermine the footing and expose the piles.

UPGRADING JOINTS

COMPRESSION SEALS

Upgrading filled joints with compression seals is a common practice. Installation is made in either a sawed or a formed concrete joint opening. See Exhibit X.27. The success of the seal is greatly influenced by the condition of the opening that is provided. It must be properly sized and the sides must be vertical, parallel, straight and clean.

Temperature considerations are vital in determining the proper dimensions between the joint faces when forming or sawing the joint opening. The expansion movement of the deck will be restricted if the joint is too narrow. If it is too wide, a greater than required opening will occur in extreme cold resulting in the possible separation of the joint material from the joint face. An engineer should determine the width of the saw cut at the mean temperature for a geographical region.

Installation consists of compressing and inserting the joint material into the joint opening. Insertion is facilitated by the use of a lubricant adhesive, which will provide a filler between the joint face and the joint material and produce a bond of sufficient strength to maintain a waterproof seal between the deck and joint material.

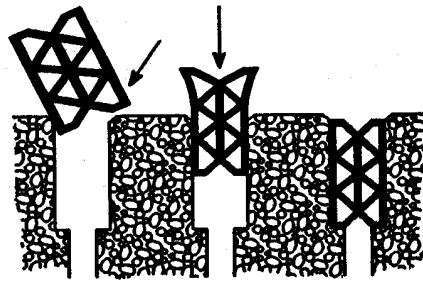
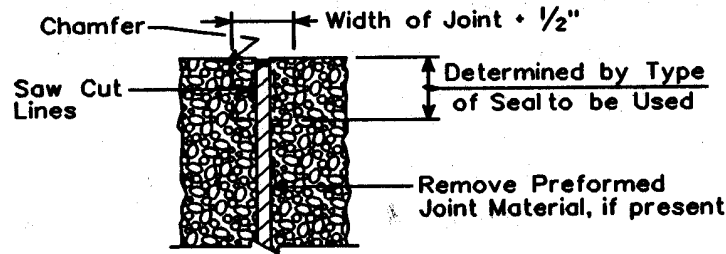


Exhibit X.27 Upgrading Joint to Accommodate Compression Seal

The compression joint material should be inserted into the joint, while the adhesive is still slippery, so that the top web of the compression seal is at least 6 mm (1/4 inch), preferably 10 mm (3/8 inch), below the deck surface. The concrete edges should be beveled 6 mm (1/4 inch) or 10 mm (3/8 inch) to reduce breaking at the corners of the deck joint.

Other types of joints generally require the cutting off of sufficient pavement so that the new joint system can be anchored to the reinforcing steel. The concrete is then formed and poured to complete the deck and the new joint. These installations are generally accomplished during a major deck rehabilitation project. If an overlay is placed on a bridge deck, this is a good time to upgrade the joint with a compression seal. See Exhibit X.28.

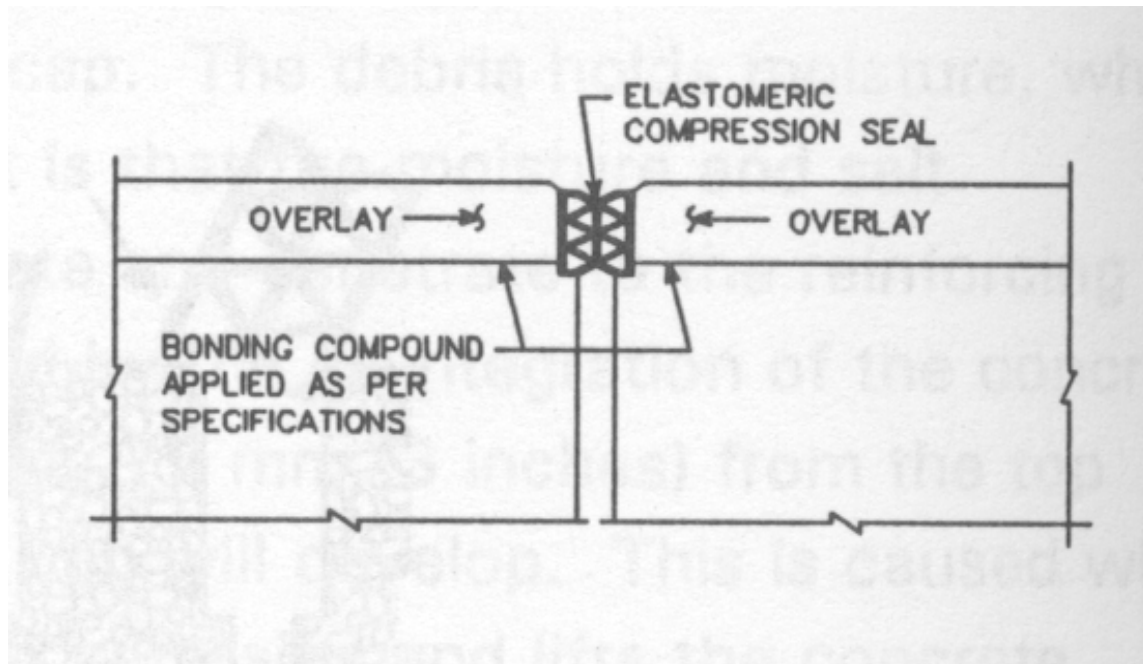


Exhibit X. 28 Installation of compression seal with overlay

Poured elastomeric/silicone sealant

Resealing joints with a pourable silicone sealant has become popular over the last ten years. A backer rod is placed in the gap between deck units to support the silicone seal until it cures. When the seal is used as a retrofit, the existing joint armor and/or deck ends must be cleaned and primed with an approved bonding agent. One manufacturer's suggested applications is shown in Exhibit X.29.

JOINT ELIMINATION

Elimination of joints in bridge decks, especially where de-icing salts are used, provides excellent protection for superstructure and substructure elements. Prior to joint elimination, however, a structural engineer shall be consulted to evaluate the feasibility of the joint elimination. Certain joints may be eliminated without alteration of the bearings. Typically, these are rotational joints. After joint elimination, flexural cracks are expected at the pier; however, the problems associated with these cracks are much less than the problems resulting from leaking joints. An overlay may be added on the above the entire deck slab after eliminating the joints.

Applications*

Bridges

The X.J.S. System is ideally suited for bridge repair and maintenance work. The system is an excellent choice for repairs on armor joints, "T" joints, elastomeric expansion devices, asphalt overlays, and strip seals. (See Figures 1 through 5.)

On bridges with either asphalt or concrete overlay joints that have closed beyond functional limits, the X.J.S. System enables the overlay joint to be resized to the proper dimensions. (See Figure 5.)

The ultra-low-modulus of DOW CORNING 902 RCS Joint Sealant also allows the system to accommodate the high degree of movement associated with expansion joints on bridges.

Highways, Parking Decks, and Airports

Because of its rapid-cure ability, the X.J.S. System is ideally suited for highways, parking decks, airports with runways that can only be closed for a limited time, and other structures where closure time is an important factor.

Figure 1 — Armor Joint Repair

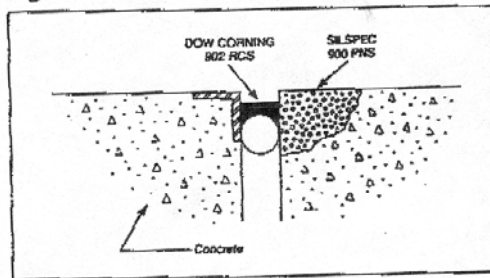


Figure 2 — New Construction "T" Joint Repair or Elastomeric Joint Repair

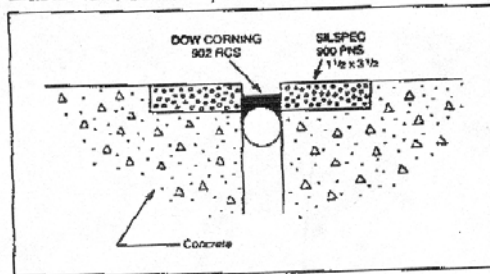


Figure 3 — Asphalt Overlays

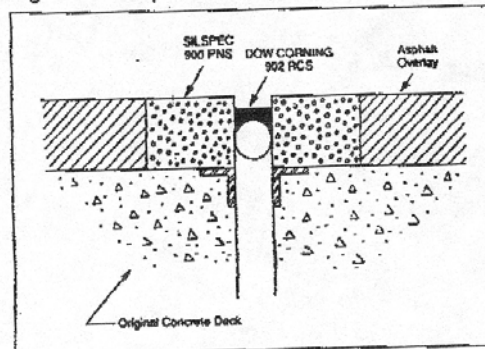


Figure 4 — Strip-Seal Repair

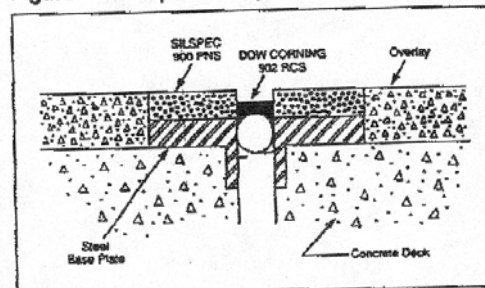


Figure 5 — Resized Joint (asphalt overlay or concrete overlay)

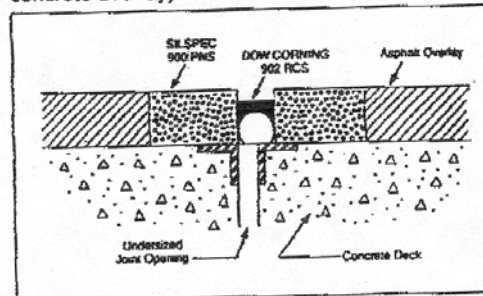


Exhibit X.29 Typical manufacturer's recommendations for a silicone joint system

Exhibits X.30 and X.31 show examples of partial-depth and full-depth bridge deck joint elimination, respectively. An advantage of partial depth joint elimination is that less concrete is removed from the joint. The disadvantage is that it is more prone to cracking. Using mechanically spliced bars instead of lap splices as shown in Exhibit X.30 also helps to reduce the amount of concrete removal.

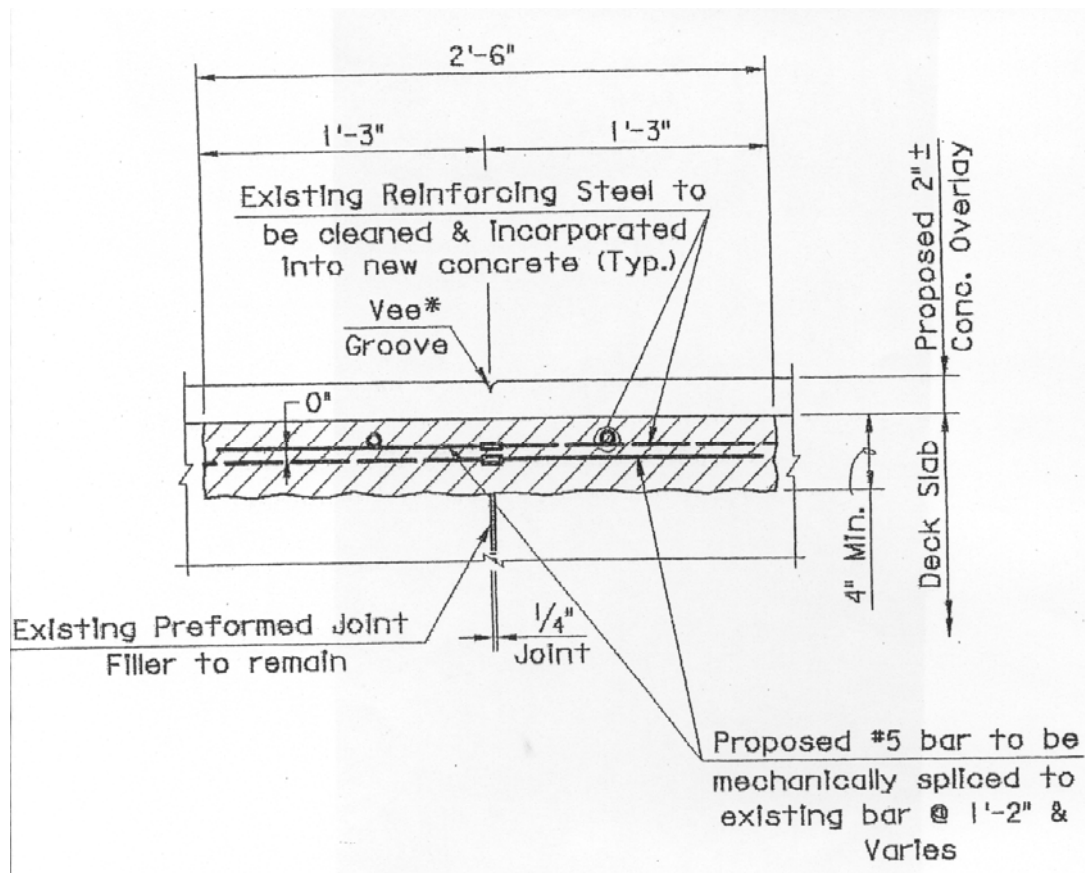


Exhibit X.30 Partial Depth Deck Joint Elimination

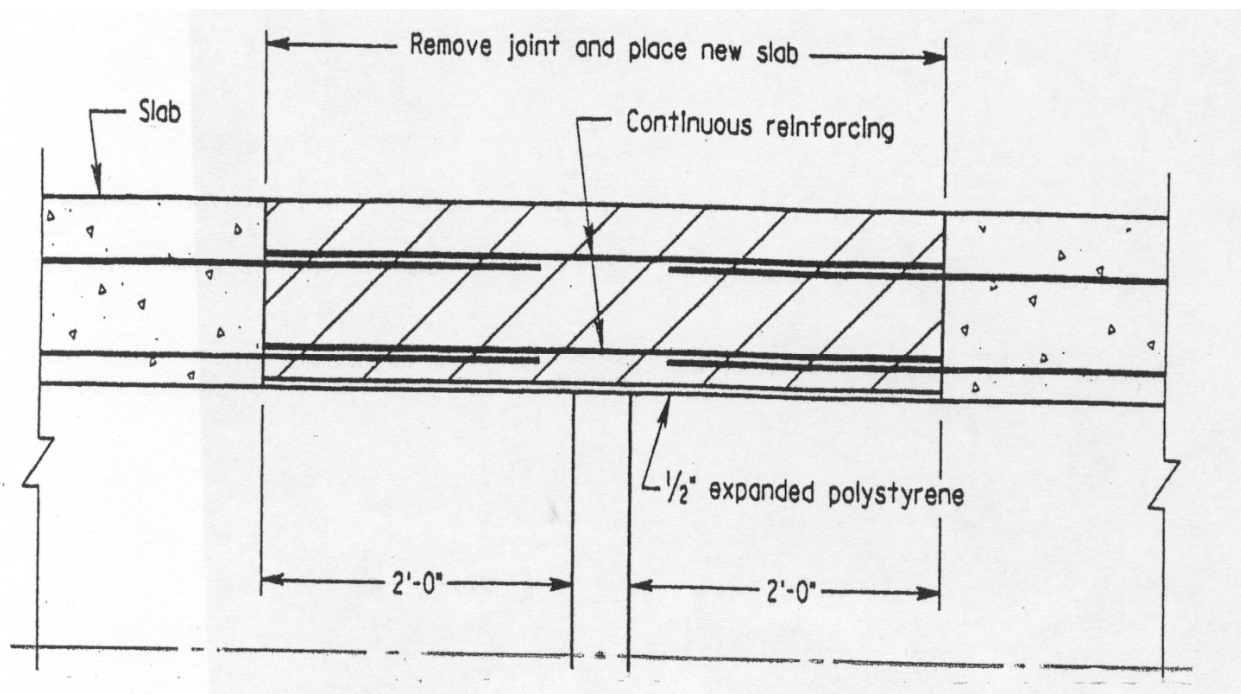


Exhibit X.31 Full Depth Deck Joint Elimination

E. RAILING

The term rail, in this section, includes parapet or other barriers that run parallel with the traffic on either side of the bridge. In its policy statement in the early 1970's, AASHTO described the purpose of a bridge railing as " A bridge rail is a longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure." To meet current standards the rail also should safely redirect the errant vehicle back into the roadway and it should not present a safety hazard when struck.

The following points are basic to good bridge rail systems:

- Exposed bridge rail ends or parapet walls should be avoided. A roadside barrier on a bridge approach should provide a smooth transition to the bridge barrier. After an emphasis was placed on smooth transitions by FHWA, the proportion of single-vehicle accidents at the end of bridge rails of parapets decreased. For example California and Texas went from 52 to 13 percent and 57 to 25 percent respectively.
- When a barrier or bridge railing installation is substandard, the barrier should either be modified to conform to an adequate system or replaced by a current system. Typical modifications would be to replace with a Jersey-type barrier, as shown in Exhibit X.32, if the structure can carry the additional dead load. Another alternative is to mount a metal guardrail across the structure as shown in Exhibit X.33.
- Collision-damaged railings should be repaired as soon as possible. Repair should include upgrading an old bridge railing that has been subjected to substantial damage to the current operational standard.
- If the railing has been severely damaged by either collision or weathering, complete replacement may be more cost effective. Since most rails are from a standard design, it should be relatively easy to obtain plan details that might be needed for replacement.



Exhibit X.32 Jersey Barrier

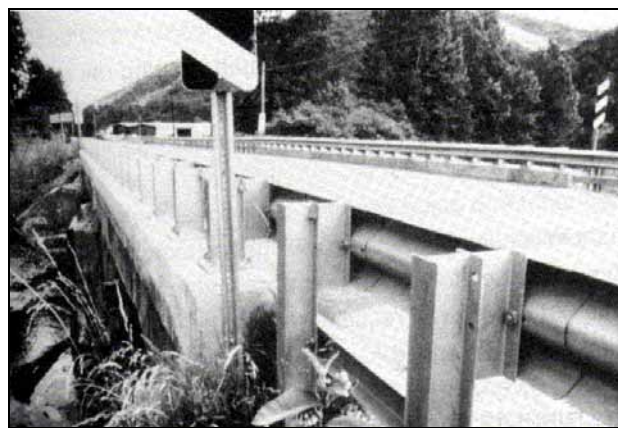


Exhibit X.33 Metal Guard Rail

CONCRETE RAILING

The need to repair or replace a concrete railing can be caused by:

- collision damage,
- deterioration such as cracks and spalls especially at metal railing connections
- corrosion of exposed electrical conduits at expansion joints, and
- obsolete original design.

CONCRETE RAIL MAINTENANCE

Concrete rail is as susceptible to cracks and spalls from salt damage as the deck. It is important to protect the surface and seal cracks. The same methods of crack sealing can be used on the rail as on the deck. Since the rail does not receive the same traffic wear as the deck there are more options for protective coatings. DOT's are using coatings, such as white epoxy that reflects light, that not only waterproof the rail, but also enhance its visibility. These coatings should be applied before the rail becomes salt contaminated.

CONCRETE RAIL REPAIR

For small areas of damage a patch may be adequate. If one or more sections of rail are broken, the procedure for concrete rail repair includes the following steps:

- (1) Assuming that the rail will be replaced "in kind," which is a decision that should be made by the bridge engineer, the plans should be obtained for use in constructing the new sections.
- (2) Remove concrete in sections of rail to be replaced using jackhammer and saw.
- (3) Straighten or position existing steel as needed for the replacement section.
- (4) Splice and replace reinforcing steel as needed.
- (5) Form new sections to conform to rail dimensions on plans.
- (6) Place concrete using one of the methods presented in Session VII.
- (7) Cure concrete for at least 72 hours.
- (8) Finish surface with a rubbing stone to match existing rail and clean up the job site.

ELECTRICAL CONDUITS

Electrical conduits imbedded in concrete railings are exposed at the expansion joints. Slip joints in the conduit should be protected to prevent corrosion that may impair the function of the joint. Frequent inspection and maintenance of the protective coating is recommended.

STEEL PIPE RAILING

The need to repair or replace these railings may result from:

- Collision damage,
- Loose anchor bolts and connections,
- Corrosion, and
- Inadequate original design or details.

STEEL RAIL MAINTENANCE

Most steel rail is galvanized and maintenance is minimal. Areas of concern are where the steel is in contact with concrete or other metals. To prevent corrosion these areas should have an insulating material to protect the steel. If painting is required, a zinc-rich coating is recommended.

STEEL RAIL REPAIR

Metal rail is fabricated in standard sections and most bridges are designed with one of the standard sections. It is a good idea to have an inventory of the common sections used in a state, with necessary hardware, for replacement needs. Repair and replacement of steel pipe and tubular railings should be made as follows:

- (1) Collision-damaged steel railings generally have to be replaced. Occasionally this type of railing can be straightened and repaired. When delays in receiving new or replacement parts are encountered, a temporary railing repair should be made to protect the public and the department.
- (2) Loose anchor bolts and connections should be tightened. If corrosion is present, painting or galvanizing procedures should be followed.
- (3) Rust stains around the perimeter of steel rail posts or anchor bolts imbedded in concrete indicate corrosion. Corroded areas should be thoroughly cleaned and painted. Railing components that have a section loss should be repaired or replaced.
- (4) Hot-dip galvanizing is recommended for new, replacement, or existing railings. Zinc-rich paint may also be used. Painted railing will require frequent repainting when located in industrial or marine environments. Care should be taken to touch up the protective coating after tightening the nuts on anchor bolts and other rail connections.
- (5) Damaged anchor bolts should be repaired or replaced as required. Where anchor bolts must be extended, chip away the concrete around the bolt to allow welding below the finished surface of the concrete. Old bolts should be cut and ground at an angle to provide for a stronger weld. Replace damaged concrete or concrete that has been removed as repairs are made. Large areas justify concrete replacement after the railing has been repaired .

ALUMINUM RAILING

Repair or replacement of aluminum railing may be caused by:

- Collision damage,
- Anchor bolt and connection damage inadequacies,
- Oxidation, and
- Inadequate original designs or details.

ALUMINUM RAIL MAINTENANCE

Oxidation protection is required at contact surfaces between aluminum railing components and dissimilar materials to which the railing is attached. Steel to aluminum contact surfaces should be caulked with a non-conductive material. The contact surface of each aluminum railing post attached to concrete should be separated from the concrete with a non-reactive bedding material such as 14 kg (30 pounds) non-perforated, asphalt-saturated felt, galvanized or painted steel plate, or an elastomeric caulking compound.

ALUMINUM RAIL REPAIR

The repair procedures vary in detail but general guidelines include the following:

- (1) Aluminum railing damaged by collision should be repaired or replaced promptly to restore the railing to its original design strength. New railing sections are generally preferred because of the lack of personnel experienced in straightening or welding aluminum. Consideration should be given to replacement with "New Jersey" type concrete railing.
- (2) Anchor bolts and connections should be inspected and repaired in the same manner as steel railing.

F. CLEANING DECK DRAINS AND INSTALLATION OF PIPE DRAINS

Correctly operating and well-maintained deck drain systems prevent traffic hazards and deterioration of the deck or other structural members. Unfortunately, bridge engineers usually regard bridge drainage as an inescapable nuisance rather than a necessary part of a preventive maintenance program.

CHARACTER OF DEBRIS

Those concerned with debris control may benefit from a tour conducted by a maintenance employee during which the kind and volume of debris with which the drainage system has to contend is evident. An example given in NCHRP Report No 67, is as follows:

In Chicago, because 12 drains located in the traffic lanes were dangerous to service, the outlet pipes were opened just below the deck, and water and debris

were allowed to fall directly onto the ground. In just two years, 127 metric tons (140 tons) of debris from those 12 drains piled on the ground.

The character of debris was diverse and included wood, rags, cigarette butts and packages, beer and soft drink cans, leaves, cups, plates, soda straws, gum wrappers, tissues, newspapers, cardboard boxes, wire, nails, nuts and bolts, straw, seed and grain (which sprouted in the inlet box), bottles, broken glass, broken parts of vehicles, dead animals (and some live ones that have taken up residence in the debris in the inlet box), and, of course, dirt and sand which comprised the major part of the debris. In the fall, leaves and dead branches are the main difficulty. They pile on top of the grate and prevent water from entering the box. Regular street cleaning becomes a necessity if the drainage system is to be kept in operation.

TYPICAL PROBLEMS

The following are typical problems caused by faulty deck drains:

- Ponding of water on the bridge deck becomes a traffic hazard .
- Since bridge decks freeze first in cold weather the presence of ponding water is an obvious risk.
- A plugged downspout containing water can readily burst in freezing weather The result of water falling in the wrong place can prove harmful.
- Poor deck drainage increases the presence of deicing chemicals during winter snow storms. These in turn increase the rate of spalling.

Although those problems probably will not result in the collapse of the bridge, they may be the source of destruction of the bridge deck when left unchecked. At today's prices, the cost of deck replacement usually exceeds the total construction cost of the original bridge.

MAINTENANCE CLEANING

Specific components of drainage systems require regular cleaning procedures. These include:

- Scuppers,
- Scuppers with downspouts,
- Troughs catching leakage under expansion dams, and
- Weepholes.

CLEANING METHODS

The necessary cleaning can be accomplished by several methods. These include:

- Shovel,
- Plumber snake,
- High pressure jet, and
- Reverse flushing with compressed air (CAL TRAN System) *

*The reverse flushing with compressed air utilizes a rubber-like plug that is inserted in the lower end of the drain pipe to make it airtight for pressures up to 480 kPa (70 psi). After the debris in the pipe has been saturated with water from above, a 25 mm (1-inch) diameter pipe through the plug provides a means of introducing the high pressure air, which usually will loosen any obstruction in the drain pipe. This method is being used successfully to open "abandoned" drains and to restore them to usefulness. A word of caution--whenever pressure is applied successfully the reverse action has an explosive effect that could startle a passing motorist. The parking of a truck over the deck drain to muffle the explosive effect is recommended.

Any of the cleaning methods should be coordinated with a proper traffic control system to protect the working area for the bridge maintenance crew. Decks are usually narrower than the roadway at each approach of the bridge. This smaller work area presents an increased danger to both the crew and motorists. A typical procedure for cleaning drains would include the following:

- (1) Remove debris from grating and lift grating from scupper,
- (2) Remove debris and sediment from scupper box and pipe.
- (3) Flush pipe and downspouting with water. The pressure of the water should be controlled to avoid damage to joints and anchors.
- (4) If debris has accumulated in downspouting, remove cleanout plugs as necessary and dislodge with water, snakes, or "roto-rooter" type devices.
- (5) Replace grating and cleanout plugs.

DRAIN INSTALLATION

Frequently it is necessary to install bridge drains, particularly drainpipes, after the bridge construction has been completed. This is usually the result of environmental changes, such as the new housing near the bridge, which makes a new drain outlet location necessary. The following things should be considered when planning to install a bridge drain.

- Drain boxes or inlet areas should be as large as possible.
- Drain covers should be designed for easy removal, yet strong enough to support traffic. Special openings may be required in locations where bicycles are ridden. Lightweight covers require hold-down clips.

- A wire clean-out basket is preferred for catching debris rather than a catch basin type inlet box. The minimum downspout piping diameter should be 150 mm (6 inches) unless a large amount of debris is anticipated. In these cases, the minimum should be 200 mm (8 in.) diameter .
- The downspout should have a minimum slope of 2 percent, preferably 8 percent, and a minimum radius of 500 mm (18 inches).
- Clean out plugs and elbows should be easily accessible. When connecting the pipe downspout to the bridge it should be at a location that will not harm the strength of the structure. Frequent communication between the bridge designer and maintenance personnel is highly desirable.
- Drain outlets should be placed so that they do not cause harmful erosion. When connection to a sewer system is required, it should be remembered that volatile liquids of an explosive nature can enter the system from a spill.
- Certain precautions should be considered, such as a ponding area before the entrance to an enclosed sewer system.

The simplest type drain and easiest to install is a straight PCV pipe through the deck shown in Exhibit X.33. Disadvantages of these drains are that considerable maintenance is required due to the small opening, and if the pipe is not long enough and placed properly, the spillout can cause damage to the structure. The procedure for installing a PVC drain is as follows:

- (1) Drill holes through deck and remove sufficient concrete to set grate of epoxy coated No.6 reinforcing bar .
- (2) Set drain pipe and grate bar with epoxy or rapid set concrete patching material.
- (3) Plug any old existing drain holes with epoxy or rapid-set concrete patching material.
- (4) Place riprap or splash block as required under drains.

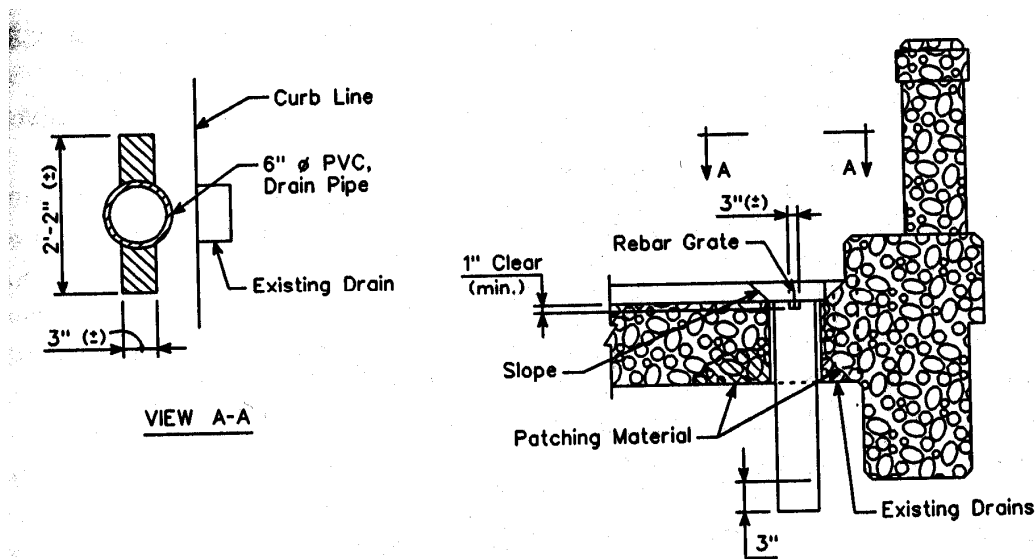


Exhibit X.34 PVC Deck Drain Installation

DRAIN EXTENSIONS

Many structures that were constructed in the 1950's and 1960's were built with short deck drains at the gutter line that barely go through the deck. Most of these drains are located close to the fascia beams (either on the inside or outside of these beams). Exposure to drainage, especially wind blown water, causes a fast rate of beam deterioration at these locations.

MinnDOT has installed drain extensions to these short drains to carry water below the lowest members of the support system. In Exhibit X.35 a box beam 150 mm x 200 mm (6 in. x 8 in.) is cut and welded in place. The weld is ground smooth and the extension is painted. Metal straps and bolts may be used to hold the extension in place instead of the weld. When the existing drain does not protrude below the deck, extensions are held in place with brackets bolted to the bottom of the deck and other brackets bolted to the web of the beam. However no bracket should be attached to a beam without approval of the bridge engineer.

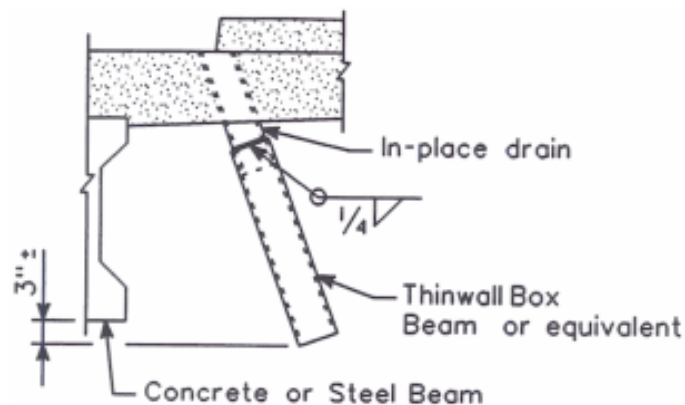


Exhibit X.35 Drain Extension