11.70 BARRIER RAILS

11.71 CONCRETE F-SHAPE, OPEN, & RETROFIT RAIL

Before cast-in-place barrier rail is constructed on the existing bridge curb section, *Specification* 2403.03, I requires that old concrete which is to be in contact with the new concrete be cleaned of all laitance (loose particles of concrete, dirt, or other foreign materials) by sandblasting followed by an air blast.

Structurally, the existing curb surface need not be roughened, but must be clean. To assure a clean surface and to obtain maximum bond at the interface, sandblasting the old curb surface shall be required. Other methods of cleaning may be approved by the project engineer.

Surface preparation, such as sandblasting, should be completed prior to setting the epoxy coated dowels.

When retrofit is part of a deck overlay, the contractor may request permission to place the finish machine on the retrofit rail. Construction's policy will be:

- A minimum cure time of at least 48 hours prior to placing the weight of a finish machine on the rail, **AND**
- Finish machine rail support feet must be spaced less than 550 mm (22 inches) apart.

If these conditions are unacceptable to the contractor, a minimum cure time of 72 hours will be required. After 72 hours there are no special conditions for placing a finishing machine on the barrier rail.

Rail Concrete Placement and Bridge Deck Falsework

Bridge deck falsework is typically constructed to include a walkway for workers along the outside edge of the concrete deck placement. This walkway serves as a working platform during placement of reinforcing steel and bridge deck concrete. Many times, contractors have requested that these walkways be allowed to remain in place during concrete bridge rail placement to facilitate worker access to the outside of the barrier rail.

Placement of barrier rail concrete imposes additional deadload and results in deflection of the bridge deck. This deadload deflection must be carried by the bridge deck (not temporary falsework) and needs to occur while the concrete is still plastic. To facilitate worker access while ensuring that the anticipated deadload deflection is allowed to occur, the following requirements have been established.

- On beam bridges, the concrete in the bridge deck must have achieved a strength of 3.8 MPa (550 psi) and a minimum age of 7 days prior to placement of concrete for bridge barrier rails. Since concrete barrier rail deadload on beam bridges is distributed to the beams during placement, temporary falsework that is supported by the beams will not require removal prior to concrete barrier rail placement.
- On concrete slab bridges, the concrete in the bridge deck must achieve a strength of 3.8 MPa (550 psi) and a minimum age of 7 days prior to placement of concrete for bridge barrier rails. Since temporary falsework for concrete slab bridges does not allow deadload deflection movement to occur, all temporary falsework must be removed prior to concrete barrier rail placement. An exception to this is for staged concrete slab bridges which require the temporary falsework to remain in place until all of the bridge deck slab has been placed. For this case the barrier rail will have to be placed prior to removal of the temporary falsework.

11.72 SLIP FORM BARRIER RAIL

Slip form rails have at times displayed transverse cracks, longitudinal cracks (in top and face of rail), reinforcing steel shadows, and nonuniformity of top elevations and alignment. In 1997, a study of slip formed barrier construction was initiated in cooperation with industry contractors, material suppliers, and equipment manufacturers. The focus of this effort is to better understand current construction problems and identify areas for improvement in the quality of slip form barrier rails.

Consideration of the following construction problems and solutions will help to eliminate problems:

Longitudinal Cracks

A tendency to develop longitudinal cracks on an inside face about 75 mm (3 inches) down from the top is thought to be the result of rail tending to slump to the outside. The remedy:

- Lower the slump
- Increase consolidation through additional vibration
- Adjust the machine's outside form to batter inward approximately 25 mm (1 inch) from bottom to top

Reinforcement

Reinforcement must be accurately placed and rigidly fastened. If cages are not rigid and braced diagonally in both transverse and longitudinal directions, problems can occur. The remedy:

- Recommended Procedure
  Epoxy coated smooth bar, about 6 mm (1/4 inch) in diameter can be placed diagonally from the top of a leading cage to the bottom of the second trailing cage. (Description is referenced to direction of paver's travel.)

Reinforcement Bar Cover

Reinforcement bar cover has contributed to shadow effect. This occurs when reinforcing cage is not rigid or has only a minimum of cover and too much vibration was used. The remedy:

- Increase bar cover to 65 mm (2-1/2 inches) from minimum of 50 mm (2 inches)
- Maintain uniformity of bar cover
- Build in rigidity to the reinforcing bar cage by placing diagonal braces as described above
- Reduce slump and do not over vibrate the concrete
- Require a "dry run" to check alignment and uniform spacing between the edge of the mule and rebar cage

Misalignment and Nonuniform Top Elevation

Misalignment and nonuniform top elevation are reflections of poor workmanship and lack of adequate machine control. Our specifications allow 19 mm (3/4 inch) deviation in both the elevation and alignment. (This tolerance is under review.) Other midwest states have 6 mm (1/4 inch) as their allowable deviation. Contractors can do a better job, but additional labor and closer scrutiny of equipment are required. While a tolerance closer than what specifications require cannot be mandated, contractors are capable of providing a better end product.

The remedy:

- Good rail alignment begins with the placement of reinforcing steel for the bridge deck. The horizontal and vertical alignment of the lower reinforcing steel for the

barrier rail during deck steel placement can significantly impact the final rail alignment quality. In preparation for installing the rail reinforcing in the deck, request that the contractor provide guide controls for accurate horizontal and vertical placement. Once this reinforcing has been placed, it should be secured to prevent movement during placement of concrete for the bridge deck. If barrier reinforcing is disturbed during deck placement, adjustments should be made while the deck concrete is still plastic to re-establish the correct position of this reinforcing steel.

- Installation of the upper reinforcing steel for the barrier rail should receive the same attention as discussed above. Along with controlling accurate horizontal and vertical alignment, plumbness of the barrier rail reinforcing cage becomes critical. Again, guide controls are recommended both at the bottom and top of the barrier rail reinforcing cage installation. Once the installation of the barrier rail reinforcing has been completed, it should be secured, until time of concrete placement, to prevent disturbance.

- In preparation for concrete placement, recheck alignment and plumbness of the barrier rail reinforcing cage. Pay close attention to the guide controls to be used with the slip form machine - either wire, string, or edge of deck. A “dry run” of the slip form machine over a portion of the proposed placement is recommended to ensure that required clearances can be met. Check dimensions, alignment, and plumbness of the slip form mule.

- Pay close attention to alignment and elevation variance of the overhang and previously placed bridge deck. Deviations in either of these will have an impact on the quality of the barrier rail alignment and plumbness.

- Uniform delivery and discharge of concrete into the slip form machine, along with consistency of concrete slump and air content, are also factors in alignment.

Shadowing

Shadowing occurs as a result of several factors: reinforcing steel alignment and plumbness, accurate alignment and plumbness control of the slip form machine, concrete slump, and concrete cover over the reinforcing steel. Shadowing appears as depressions in the concrete barrier face immediately behind each vertical reinforcing bar as the slip form machine advances.

Preliminary observations during the 1997 study of slip form barrier rail appear to indicate that insufficient concrete cover over reinforcing and concrete slump greater than 32 mm (1 1/4 inches) may be the principle contributors to shadowing. Slip form barrier rail will continue to be evaluated through trial adjustments in placement controls to improve rail quality and appearance.

Mix Design for Slip Form and Cast-in-Place

Improvements have been made in the concrete mix design used for slip form and cast-in-place concrete barrier rail. The changes include a uniform aggregate gradation to improve concrete stability at higher slump. Also included was the addition of water reducer or retarding admixture to improve workability and aid in air entrainment.

Specification 2513.03, 2 provides the requirements for this alternate mix design. This mix design was successfully tried by several contractors during the 2000 construction

season. The workable slump range increased and control of air entrainment was more easily managed. For slip form barrier rail construction the required concrete mix is Class BR. For cast-in-place concrete barrier rail construction the required concrete mix is Class C.

Curing of Slip Form Barrier Rail

Since slip form barrier rail does not have forms which can provide moisture retention during curing it is necessary to apply a curing compound to the finished surface of the concrete. Typically, clear curing compounds are sprayed on the concrete surface. To ensure uniform application and coverage, a fugitive dye shall be used with clear curing compounds. Based on field evaluations of slip form barrier rail placements, observations show that the clear curing compound must be applied soon after the surface finishing is completed. To prevent surface moisture loss from evaporation and to minimize the potential for concrete cracking, the clear curing compound should be placed within 10 – 15 feet of the slip form machine. This will ensure a minimal time of exposure of the finished concrete surface and the loss of moisture.

Expansion Joint Construction in Barrier Rail

Several problems have been observed related to installation of steel extrusion expansion joints and the construction of concrete barrier rail. *Bridge Standard Sheet 1026, Expansion Device Details - Steel Extrusion with Neoprene Gland*, provides construction details for installation of this expansion joint and placement of the concrete barrier rail.

Through reference to *Bridge Standard Sheet 1026,* the following discussion of installation problems and explanation of design intent should provide guidance for correct expansion joint construction.

- Steel extrusion for the expansion joint is installed to correct location and grade prior to placement of the bridge deck concrete. The extrusion must be rigidly supported when installed to ensure that correct location and grade are maintained. The contractor is required to submit for approval provisions for holding the expansion joint during concrete placement.

- Top grade of the steel extrusion is to be 6 mm (1/4 inch) below the finished grade for top of slab or backwall. This needs to be checked closely. If steel extrusion is not recessed below concrete surface, there is potential for the extrusion to be damaged by snow plows.

- A table of expansion joint settings is provided in the plans. The temperatures for each represented joint setting are temperatures of the concrete deck, NOT air temperatures. Temperature setting of the expansion joint opening should be based on the temperature of the concrete deck at the time of concrete placement.

- The steel extrusion, as shown in the detail on the Bridge Standard, is angled upwards at 60 degrees (two 30 degree bends) in the concrete barrier rail section. The purpose in elevating the extrusion is to prevent surface runoff of the bridge deck from escaping through the joint location in the barrier rail. In preparation for placing the barrier rail concrete, the contractor will need to form a box-out area above the steel extrusion to facilitate installation of the neoprene gland (refer to detail of allowed box-out area). It is critically important that this box-out not extend below the top of the extrusion to ensure that the joint will function to resist leakage of water

through the barrier rail. The concrete in the barrier rail must be finished flush with the top surface of the steel extrusion.

- Correct installation of the sliding cover plate for the expansion joint includes:
  1. Installing plate with the anchors and plate cap screws located on the oncoming traffic side of the expansion joint.
  2. Recessing the full plate below the finished surface of the barrier rail face, and
  3. Providing an extended recessed area in the barrier rail face to accommodate movement of the sliding plate due to expansion of the bridge deck.

- Contractors will typically use forming materials to form the expansion joint gap through the concrete barrier rail section. Immediately after placement of concrete for the barrier rail, the expansion joint should be checked for leakage of concrete into the joint and steel extrusion. Concrete should be removed from the inside of the steel extrusion to provide a clean surface for installation of the neoprene gland. Any concrete which has leaked into the joint opening in the barrier rail and would interfere with the intended expansion movement must be removed.

- Installation of the neoprene gland should be according to manufacturer's requirements. It is recommended that the contractor have a manufacturer's representative on site to assist with correct installation of the neoprene gland. Checks for correct installation should include:
  1. Are the upper and lower ear lugs, on each side of the neoprene gland, securely seated in the cavity of the steel extrusion to prevent leakage of the joint?
  2. Is the end of the neoprene gland cut correctly at each end of the steel extrusion? The ends of the gland must be cut level from the top of the steel extrusion ends as shown in the Bridge Standard detail. This ensures that the lower trough of the neoprene gland is the same height as the end of the steel extrusion to prevent leakage through the joint.

11.73 CAST-IN-PLACE (RETROFIT) BARRIER RAIL

This work is routinely combined with a deck repair project and includes an overlay. Often contractors will place the new rail prior to placing overlay. In these situations, the contractor intends to place the finish machine's rail on top of the new barrier rail.

Question: How long must the new rail cure before allowing the deck finishing machine to be placed on it?

Cast-in-place rail requires Class "C" concrete.

If requested, the project engineer may allow rail loading provided:

- 48 hours must expire prior to placing the weight of a finishing machine on the rail.
- Rail supports (legs) must be placed at a spacing of no greater than 550 mm (22 inches).
- Rail supports and rail cannot be placed until the surface has sufficiently cured to prevent scuffing and/or marring.
- Care must be taken to prevent damage to the face or back of the barrier rail.

If above conditions are not acceptable to the contractor, a 4-day cure time will be required as per specifications.

Preventing Dowel Installation Damage of Conduit

Prior to installation of dowels for retrofit barrier rail construction, the project plans and bridge structure shall be reviewed to determine whether conduit is present in the existing curb and bridge deck section. When conduit has been determined to be present, the contractor will physically locate the existing conduit.

It is extremely important that existing conduit be located prior to drilling dowels for retrofit barrier rail. Drilling into existing conduit can have the following impacts:

- Potential for serious injury from electrocution
- Damage to the conduit and electrical services which will result in replacement of the conduit and electrical wiring to restore service. Do not assume that a conduit does not exist simply because there are no electrical services present. An existing conduit may not currently be in service, but may be needed in the future. Drilling into an existing conduit breaches the integrity of a sealed duct for electrical wiring and cannot be successfully repaired. Any damaged to the conduit will require replacement.
- Destroys the structural integrity of the dowel embedment and bond. A hole drilled into a conduit will result in the dowel epoxy flowing into the conduit and leaving little or no epoxy for bonding and anchorage of the dowel. This can critically affect the retrofit barrier rail connection to the existing bridge curb and the rails resistance to vehicle impact.

When conduit is located and determined to be in potential conflict with intended dowel installation, contact the Office of Construction. The actual conduit location can be reviewed with the Office of Bridges & Structures and adjustments in the dowel locations identified to eliminate the conflict with conduit.

11.74 CAST-IN-PLACE OPEN BARRIER RAIL FORM REMOVAL

County bridge standards provide for cast-in-place reinforced concrete open barrier rail. This open barrier rail design consists of a concrete barrier beam mounted to concrete posts spaced at approximately 7’- 8’.

In the past, contractors have frequently requested approval to remove form work as soon as the concrete in the barrier beams would have sufficient strength to support itself. The horizontal barrier beam is considered a flexural member and as such the specifications require that the concrete have a minimum flexural strength of 550 psi prior to removal of supporting formwork.

Due to the increased number of requests, the Office of Bridges & Structures evaluated the concrete flexural strength needed for the barrier beam of open barrier rail to support itself. The required flexural strength for the barrier beam to support itself is minimal and is considered to be easily achieved by standard Class BR or Class C concrete mixes in 24 hours. This is based on past strength history for these mixes under weather conditions that do not require cold weather protection. The current specifications permit form removal of open concrete barrier rail after a minimum of 24 hours when cold weather protection is not required. Specification curing requirements must still be satisfied if forms are removed.

When conditions require cold weather protection, removal of forms will be controlled by the curing and protection requirements.