Oregon Department of Transportation

SECTION 1.9
Decks & Slabs

Revisions for the current edition are highlighted yellow. Deleted text is not marked.

Past editions of the Bridge Design Manual are available through our website.

1.9.1 Design Considerations

1.9.2 Deck Systems

1.9.3 Existing Decks

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1.9 DECKS AND SLABS

1.9.1 Design Considerations

Consider the site-specific conditions when designing both new and existing decks. These can include but are not limited to:

- Rutting.
- Mobility.
- Truck traffic volumes.
- Weather conditions.
- Future and adjacent projects.
- Chloride contamination levels, etc.

Actions to treat a deck could range from district maintenance tasks to MBM funded tasks associated with large STIP projects.

C1.9.1

ODOT spends most of our maintenance dollars on bridge decks and we should take measures to protect them. Research is continually being performed on ways to construct, maintain and replace bridge decks. As a result this section is dynamic.

In an effort to get to longer service life of decks, a silane treatment is applied to all decks and structural overlays 12 months after casting. Refer to the *Bridge Maintenance Design Manual* for information on silane and epoxy treatments.

1.9.2 Deck Systems

1.9.2.1 Deck Slabs

Ensure project specific deck design conforms to the following minimum requirements:

- *AASHTO LRFD Bridge Design Specifications* Section 4.6.2.1.
- Concrete Class per *BDM Table 1.5.1-1*.
- Provide wearing surface specified in *BDM 1.3.2.1*.

For bare concrete decks, discount ½ inch deck thickness when calculating composite properties for girder/slab systems, but include as a non-composite dead load.

HPC decks must be cast-in-place, unless full-depth precast panels are used with either longitudinal post-tensioning or ultra-high performance concrete closures.

C1.9.2.1

For additional information on concrete type for CIP bridge decks see *BDM 1.5.1*. For additional deck requirements on precast prestressed elements, see *BDM 1.5.6.1*.

For a typical 8 inch deck, consider 7 ½ inches structural and ½ inch a sacrificial wearing surface and included as non-composite dead load.

See *BDM 1.9.3.1* for structural capacity of deck overlays and *BDM 1.3.2.1* for wearing surface thickness and loading.

Do not use FRP deck panels in traffic lanes of bridges. FRP deck panels are allowed on pedestrian structures.

When the opening between parallel bridges is 10 feet wide or less, provide protection between the opening between structures. Protection can be achieved with protective fencing or pedestrian rail. Protection must be a minimum 54 inches in height.

Do not use ACP on state-owned structures with bare concrete decks. ACP is allowed on new decks on local agency projects. When an ACP is used see *BDM 1.9.3.1.6* for requirements.

Installations of thermal ice-melting equipment on bridge decks or problematic sections of highway require a design deviation. Contact the Bridge Preservation and Design Engineer for further information.

It is not recommended to install thermal equipment unless there is a natural source of warm water at the bridge, as exists in the city of Klamath Falls. All other installations in Oregon have been turned off due to overly expensive power bills or early failure of key components.

Limit the use of stay-in-place forms for decks as required in *BDM 1.5.6.2.1* and *1.5.7.12*.

1.9.2.1.1 Skewed Decks

For skewed decks, orient transverse bars according to *LRFD 9.7.1.3*.

LRFD 9.7.1.3 provides no guidance when skew angle exceeds 25 degrees.

C1.9.2.1.1

Per *LRFD 9.7.1.3*, the primary reinforcement may be orientated along the skew for skew angles that do not exceed 25 degrees, where the skew angle is measured from a line that is perpendicular to the centerline of the bridge to the centerline of the support.

The acute corners of a skewed (greater than 25 degrees) concrete deck slab are often difficult to adequately reinforce. As the angle of skew increases, large portions of the deck can be unreinforced and therefore subject to spalling and chipping, as shown in *Figure 1.9.2.1.1-1*. Because the orthogonal bars are too short to develop, it is typically necessary

to detail diagonal bars that extend into the deck over the girders, to carry the deck overhang loads. Similarly, acute corners in concrete barriers are also difficult to reinforce, and require special consideration.

When skews exceed 25 degrees, use breakback detailing where the ends of the skewed deck are turned so that the end is normal to the longitudinal edge of the deck, as shown in *Figure 1.9.2.1.1-2*.

This breakback detailing shown in *Figure 1.9.2.1.1-2* effectively eliminates the acute and obtuse corners of the concrete deck and barriers.

Use a minimum breakback width of 3 feet and increase width with increased skew angle.

Figure 1.9.2.1.1-1 Inadequate Reinforcement Provided in Acute Corner of Concrete Deck Slab

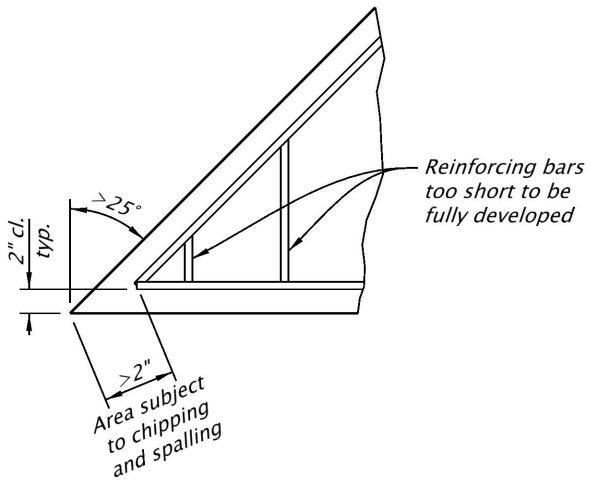
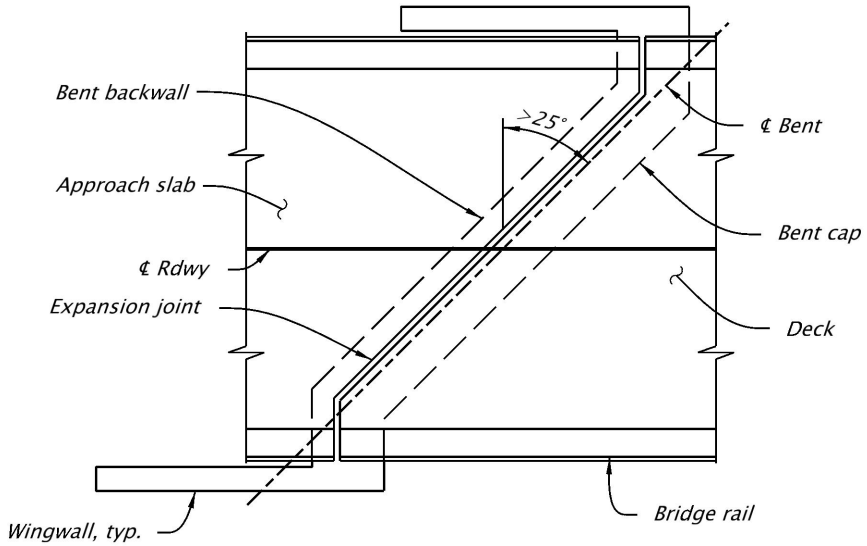


Figure 1.9.2.1.1-2 Breakback Detailing to Eliminate Skew Effects Associated with Detailing Acute Corners at Ends of Skewed Deck Slab



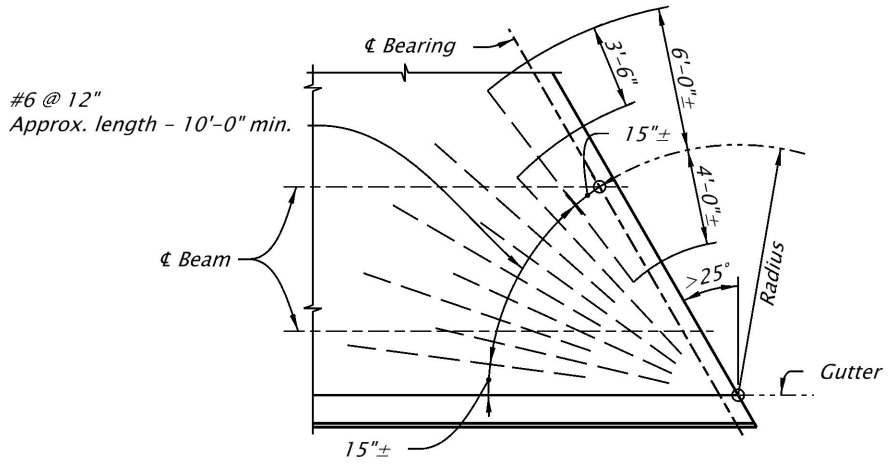
On skewed bridges with concrete end diaphragms and when a breakback detail is not used, place additional reinforcement in a radial manner to eliminate diagonal cracks which form in the acute corners of concrete deck. See *Figure 1.9.2.1.1-3* for the reinforcement pattern.

A portion of the bars must extend back into the corner sufficiently to terminate above the junction of exterior beam and end diaphragm. Place a note on the plans that states:

Place the corner reinforcement beneath the longitudinal and transverse reinforcement in the top of the slab.

The objective of the reinforcement fan is to offset buildup of shrinkage across the long diagonal dimension of the slab which would pull a shrinkage crack across the weak corner of the slab.

Figure 1.9.2.1.1-3 Corner Reinforcing Detailing



In skewed box girders, orient bottom slab transverse bars the same as the deck transverse bars. Note the intended bar placement on the bridge contract plans.

See *BDM 1.5.7.8* for additional bottom slab requirements.

See *BDM 1.9.4.1* for detailing requirements due to screed machines on skewed decks.

1.9.2.1.2 Reinforcing

DESIGN

Do not use the empirical design method for deck reinforcing steel.

Use the *Concrete Deck Reinforcement (LRFD Design)* and *DET3170* for design and detailing decks on steel girders and CIP concrete box girders.

Use *Concrete Deck Reinforcement (LRFD Design)* and *DET3171* for design and detailing decks on precast prestressed concrete girders.

Develop a project specific bridge deck reinforcement design only when the design criteria of *DET3170 or DET3171* does not apply. Ensure project specific deck design

C1.9.2.1.2

Excessive deck cracking, apparently due to under reinforcement, precludes the use of the empirical method.

conforms to the following minimum requirements:

- *BDM 1.9.2.1* Reinforcement: grade 60 or grade 80.
- Reinforcement no larger than #6 bar (except in distinct areas).
- Reinforcement spacing ≥ 5 inches and ≤ 8 inches (applies to top mat only).
- Limit top of concrete compressive service stress due to positive moment in the deck (between girders) to $0.4f'c$.

Local agency projects only need to meet minimum *LRFD AASHTO 4.6.2.1* design criteria, not the additional requirements of this section stated above.

Submit a design deviation request for any concrete bridge deck reinforcement design not meeting any one of the minimum requirements listed above or in *DET3170* or *DET3171*.

Include the following with the design deviation request:

- Design loading assumptions (dead, live, and future wearing surface).
- Documentation of which minimum requirements were met and which were not met.
- Orientation of the top mat (longitudinal on top or transverse on top).
- Deck thickness.
- Maximum service stress in the top of the deck due to positive moment in the deck (between girders).
- Maximum service stress in the bottom of the deck due to negative moment in the deck (over a girder).

LRFD 5.6.7 (*Control of Cracking by Distribution of Reinforcement*) is applicable for negative moment steel for bridges made continuous for live load but is not applicable to bridge deck slab reinforcement.

The 8 inch maximum bar spacing is adequate to control cracking in bridge decks.

PLACEMENT

Orient the top mat of deck steel with the transverse bars on top when the direction of primary loading is transverse. For typical deck steel placed in two mats, place bottom mat bars such that each bottom mat bar is directly below and in line with a top mat bar. At deck expansion joints and at deck construction joints, it is not necessary for all bottom bars to be directly below a top bar.

Reinforcing shall conform to *BDM 1.5.5*.

When necessary, you may use larger than a #6 bar for deck reinforcement in distinct sections such as joints, post tensioned anchorage areas and to resist negative moment for continuous-span girders. When the top mat has longitudinal bars on top, place any longitudinal reinforcement larger than a #6 bar in the bottom mat.

TYPE

When high strength reinforcement (higher than grade 60) is used in a bridge deck, use it for both longitudinal and transverse bars. See *BDM 1.5.5.15.4* for application of high strength reinforcement.

Verify the quantity of deck steel to determine if grade 80 rebar is appropriate. When the quantity of deck reinforcement using grade 80 rebar is less than 30 tons, verify rebar availability with the steel mill.

Use of grade 80 rebar is expected to reduce construction cost and potentially reduce rebar congestion.

When the quantity of deck reinforcement using grade 80 rebar is less than 30 tons, consider providing primarily details with grade 80, showing grade 60 rebar as an alternate.

See *BDM 1.5.5.15.1* for additional information on grade 80 reinforcing.

Grade 100 rebar can be considered as well, however the rebar does not provide substantial benefit due to the compressive concrete stress and the 8-inch maximum bar spacing limits.

See *BDM 1.5.5.15.2 and BDM 1.5.5.15.3* for additional information on grade 100 reinforcing.

See *BDM 1.5.5.17* for additional information on FRP reinforcing.

Design GFRP-reinforced concrete according to the latest edition of the *AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings*.

See *BDM 1.5.5.16* for additional information on GFRP reinforcing.

Using GFRP for deck and slab temperature reinforcement is a good example of the complimentary use of this non-ductile material.

It is generally advised that GFRP reinforcement be used in a straight bar configuration. Consider accommodating necessary bar bends (such as bridge rail stirrups embedded in the deck) with stainless steel reinforcement. Do not use GFRP reinforcement in locations where ductility is a desirable material property (negative moment reinforcement, etc.).

To meet bridge performance and service life expectations, you are encouraged to use and design alternative materials for concrete reinforcement applications. When proposing to use alternative reinforcements in environments not already required by *Table 1.9.2.1.3*, obtain concurrence from the BDM technical resource before the draft DAP milestone via the DCSA.

There are a variety of reinforced concrete applications that may benefit from the use of alternative reinforcing materials. Common benefits include corrosion resistance, high strength, ductility, increased service life and reduced concrete cover for reduced dead load. These benefits are usually compromised by factors that may include material availability, cost, unique material testing and non-ductile material properties.

When multiple metals are specified for reinforcing bars in the same elements, provide electrical isolation between the different rebar metals to avoid galvanic corrosion.

Consider interaction between dissimilar metals and the increased complexity of design and construction when deciding if it is appropriate to use alternative reinforcements. Consider bar support and wire tie materials. Obtain technical input from the Bridge Corrosion Engineer.

1.9.2.1.3 Reinforcement Protection

For protection of existing deck reinforcement see *BDM 1.9.3.2*.

The protection system for deck and approach slab reinforcement is shown in *Table 1.9.2.1.3-1*. Environments are defined in *BDM 1.2.4*.

See *Table 1.5.5-2* for required reinforcement cover for decks.

C1.9.2.1.3

The level of effort required to prevent reinforcing steel corrosion depends mainly on the potential for exposure to a corrosive environment.

Table 1.9.2.1.3-1 Deck and Approach System Reinforcement Protective Practices

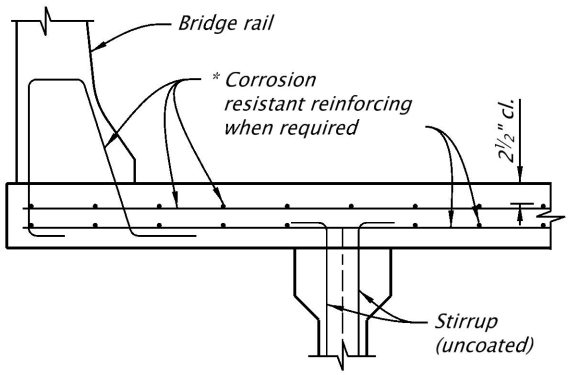
Environment (Defined in BDM 1.2.4)	**Marine Areas**	**Coastal Areas**	**Snow and Ice Areas**	**Mild Areas**
Wearing Surface Type	HPC	HPC	HPC or PPC overlay	HPC or PPC overlay
Reinforcement Type	Deck - stainless steel or GFRP top and bottom mats. Precast Deck Panels - black steel (no epoxy coating) or uncoated prestressing strands (to allow for future cathodic protection if needed). Paved Approach System - black steel (no epoxy coating)	Deck – stainless steel, GFRP or ChromX9100 top and bottom mats. Approach System – black (uncoated) top and bottom mats.	Deck and Approach System - epoxy coated or ChromX4100 top and bottom mats.	Deck and Approach System - black (uncoated) top and bottom mats.

Use the same type of reinforcement as used in the deck or approach slab for reinforcing steel extending out of the deck or approach slab into bridge rails, curbs or sidewalks. This applies to both CIP and precast deck elements. Use black (uncoated) steel for all other bridge rail, curb or sidewalk reinforcement. Stirrups having a portion extending above the top surface of precast concrete members do not need to be corrosion resistant. The portion of the stirrups is covered by the deck concrete.

Examples are shown in *Figures 1.9.2.1.3-1* and *1.9.2.1.3-2*.

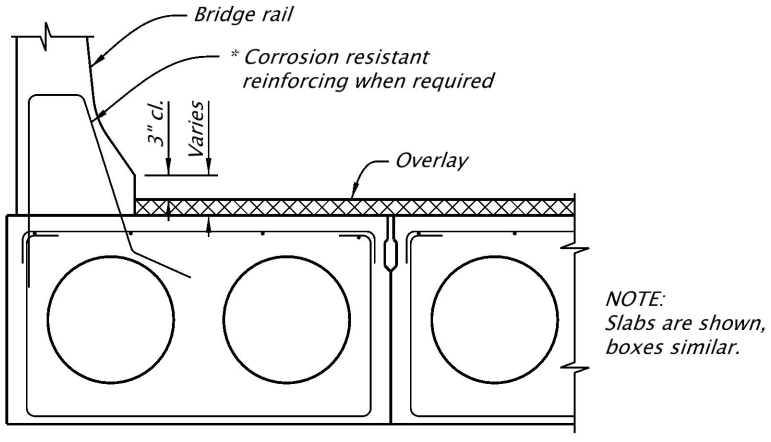
See the standard drawings for other corrosion resistant bars in the precast slabs and box beams.

Figure 1.9.2.1.3-1 Reinforcement Protection for Reinforced Concrete Decks



** See Table 1.9.2.1.3–1 for locations where corrosion resistant reinforcing is required.*

Figure 1.9.2.1.3-2 Reinforcement Protection for side-by-side Precast Slabs and Boxes



** See Table 1.9.2.1.3–1 for locations where Corrosion resistant reinforcing is required.*

MARINE AREAS

Review additional protection measures including concrete sealers, cathodic protection or others with the Bridge Corrosion Engineer on a project-by-project basis.

C MARINE AREAS

There is no evidence of approach slabs failing due to corrosion, hence the use of black steel per *Table 1.9.2.1.3-1*. Consider site specific considerations, such as higher AADT locations, that would make approach slab replacement more difficult. Consider using more corrosion resistant reinforcing at those locations.

The two inch cover required in marine areas, per *Table 1.5.5-2*, is because of the corrosion resistant reinforcing used. Chloride content has to be significantly higher to corrode a stainless, thus the concrete cover can be reduced. GFRP bars do not corrode, and thus concrete cover can be reduced.

1.9.2.1.4 Inlaid Durable Striping on Bridge Decks

Concrete deck surface removal of up to ¼ inch is acceptable for placing longitudinal inlaid striping on new concrete bridge decks, except on decks with an MPCO. Use only sprayed striping on decks with an MPCO.

Placement of such striping will likely reduce wear at stripe locations. In nearly all cases, the majority of wear for concrete bridge decks occurs within the travel lane. Therefore, it is unlikely ¼ inch maximum removal will significantly impact bridge load capacity.

For existing concrete bridge decks, allow deck surface removal of up to ¼ inch for placing inlaid striping only in the longitudinal direction and only in locations where there is no significant rutting or other deck wear.

Do not allow inlaid striping on concrete decks where the striping would be placed in the transverse direction.

Concrete removal for such striping would reduce the load capacity of the bridge.

Allow concrete removal using a diamond grinder according to *SP 00503*.

SP 00503 also permits removal by micro-milling and by hydrodemolition. However, only allow diamond grinding for striping applications. *SP 00850* also requires diamond grinding equipment for

installation of inlaid/grooved pavement markings.

Do not allow rumble strips on concrete bridge decks.

Allow raised pavement markers on concrete bridge decks only when installed without removal of any deck concrete (i.e. no grooving). Do not allow recessed pavement markers on concrete bridge decks.

Allow grooving up to 5/8 inch depth for striping (longitudinal or transverse) or rumble strips on existing asphalt concrete pavement.

Do not install thermally applied pavement markings (i.e. thermal plastic) on an MPCO or PPC overlay.

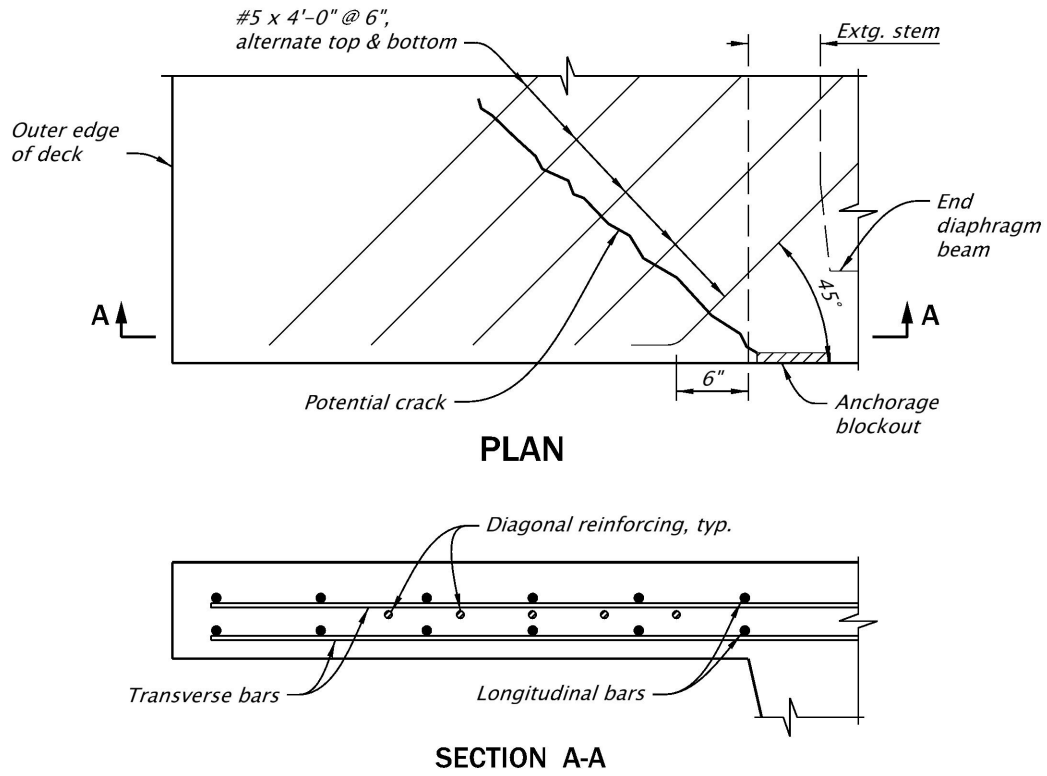
1.9.2.2 Deck Overhangs

1.9.2.2.1 Reinforcement of Deck Overhangs

To prevent cracking at the end of post-tensioned spans, extend the end diaphragm beam to the edge of the deck or provide additional diagonal deck reinforcement similar to shown in *Figure 1.9.2.2.1-1.*

C1.9.2.2.1

Figure 1.9.2.2.1-1 Deck Overhang Reinforcement Detail



1.9.2.2.2 Deck Overhang Capacity

Do not consider bridge railings to be structurally continuous for the purposes of distributing the deck loads per *LRFD 3.6.1.3.4* as this limits options for bridge rail retrofits in the future.

Place deck overhang reinforcement according to *DET3170* and *DET3171*.

C1.9.2.2.2

See *BDM 1.13.5* and *1.13.6.2* for rail and collision loading requirements.

There is crash test report data available upon request to facilitate overhang reinforcing design for *BR208*. Contact the BDM Rail Specialist.

TL5 barrier requires a custom overhang design and is not listed on *DET3170* and *DET3171*. Consider using a diaphragm in the end section instead of additional overhang reinforcement as a more efficient solution when using TL5 barrier.

It is only necessary to strengthen a bridge deck overhang as a result of a rail retrofit or rail replacement when any resulting damage would be within a traffic lane. To determine this, identify the critical sections in the deck. When a critical section is within a traffic lane, evaluate the capacity to demand ratio and design strengthening when less than 60 percent.

1.9.2.2.3 Post-Tensioned Deck Overhangs

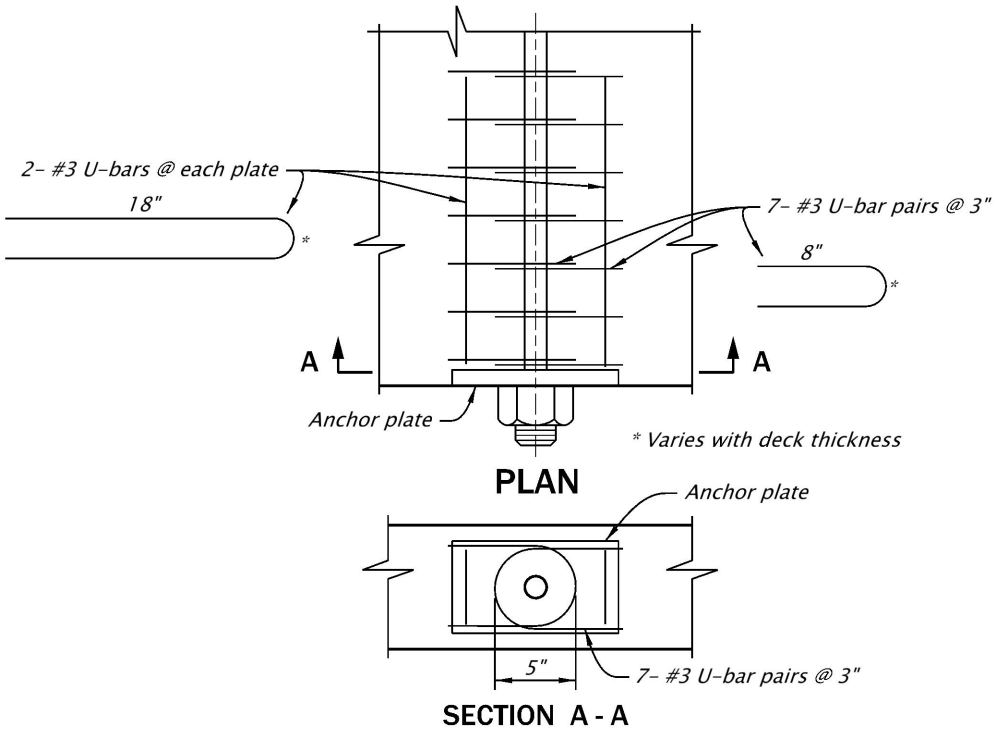
Place post-tensioning ducts and deck reinforcement normal to the centerline of the structure, as shown in *Figure 1.9.2.2.3-1*.

See *BDM 1.13.4* for guidance on when to use wall segment vs end segment in regard to joint placement.

The intent of this policy is to avoid unnecessary deck strengthening for situations that will not cause loss of life or irreparable damage to the bridge. Capacities below 60 percent indicate the possibility of concrete deck cracking. Cracks under live traffic are harder to repair. All other cracks that may occur after a collision can be repaired as part of rail repair.

C1.9.2.2.3

Figure 1.9.2.2.3-1 Transverse Prestress Anchorage



1.9.2.3 Precast Concrete Deck Panels

When determined to be the preferred option, use full depth precast deck panels with high-strength abrasion-resistant concrete for bridge decks. Partial depth precast deck panels are not permitted, except on local agency projects.

Apply a PPC overlay to precast deck panels.

To make deck panels fit on a bridge span, provide either CIP end segments or precast exterior deck panels (end pieces).

Deck panels can accommodate skew, superelevation, slight horizontal curve, and vertical roadway profile. For a mild vertical roadway profile, a flat layout of deck panels constructed on bridge girders is adequate and makes the construction of joint

C1.9.2.3

Bridge deck replacement can be accelerated by using precast deck panels.

Standard details are available for precast concrete deck panels to be used with precast concrete girders and steel girders. The current standard details for precast deck panels limit the maximum deck panel length to 50 feet and the effective width to 10 feet. These dimensions are limited by shipping weight and maximum shipping width (assuming panels are placed flat).

CIP end segments can accommodate construction tolerances, variations, and are a better option for most cases.

For a precast end option, a different panel width may be required. When deck panels are post-tensioned, end pieces may need to be thickened to accommodate post-tensioning anchorages.

Prestressed reinforcement is typically used on the long side of deck panels that span between the bridge girders. This is the main reinforcement that provides flexural strength for resisting applied loads during shipment, erection, superimposed dead load, and vehicular live load. Panel thickness may be increased to accommodate final surface grinding and reinforcement detailing.

connections easier. When the vertical roadway profile is significant, chorded deck

panels are recommended to fit the profile with CIP reinforced concrete joints connecting the deck panels. Reinforcement and anchor bolts for bridge railing can be cast into the deck panels.

1.9.2.3.1 Deck Panel Connections

Two types of transverse joint connections along the length of the bridge are:

- CIP reinforced concrete.
- Longitudinal post-tensioning.

CAST-IN-PLACE CONNECTIONS

For CIP joint connections use ultra-high performance concrete (UHPC).

Specify splice length according to FHWA Research, Development, and Technology published *FHWA-HRT-19-011*.

Show exposed aggregate finish at the connection surface on plans.

POST-TENSIONING CONNECTIONS

Use grouted keyway or match cast joints for post-tensioning deck panel connections.

Identify and detail a point of no movement and the direction of the movement due to post-tensioning on the plans. Account for compressive stresses from post-tensioning in positive bending zones in the composite section.

C1.9.2.3.1

Each connection type has its own advantages and disadvantages. A survey of connection details used by various states was published in 2006 as *NCHRP 12-65*.

C CAST-IN-PLACE CONNECTIONS

UHPC has superior bond properties, durability, compressive strength, and tensile strength.

This document provides substantial information regarding design and construction of UHPC. The excellent bond behavior provided by UHPC creates a significantly shorter non-contact splice length for rebar extending out from deck panels than required in conventional concrete.

To ensure good bonding against precast deck panels, pre-wet the interface and an exposed aggregate finish.

C POST-TENSIONING CONNECTIONS

To ensure that camber or deflection of deck panels does not occur after post-tension, place P/T ducts at the CG of the deck panel section.

When there are geometric constraints that prevent locating P/T ducts at the CG of the section, consider the movement after post-tensioning in the design or provide hold-down devices to maintain the deck panel position.

POST-TENSIONED GROUTED KEYWAY CONNECTIONS

Post-tensioned grouted keyway joints include deck panels constructed with shear key edges, erected on girders having a 1 ¾ inch wide space, filled with keyway grout, and then post-tensioned together.

Post-tensioning ducts are spliced in pockets with an air and water-tight seal. Fill all splicing pockets and keyways with grout. Gain specified strength before the post-tensioning operation to ensure continuous flow of the compressive force.

The grouted keyways joints are similar to the joints between precast prestressed slab and box girders.

POST-TENSIONED MATCH CAST CONNECTIONS

Deck panels are match cast at the precaster site. Each deck panel is identified, delivered to the site, and erected in sequence as an erection plan.

Specify duct couplers used in precast segmental construction. With a proper installation, this type of duct couplers provides a continuous, air, and watertight seal. Detail match cast deck panels to fit all possible duct couplers.

In the U.S. a number of P/T suppliers can provide segmental-type duct couplers. Historically only a few suppliers have furnished post-tensioning for bridge construction projects in Oregon. Duct coupler dimensions vary from different suppliers.

Specify epoxy be applied at match cast deck panel interfaces before post-tensioning.

As each match cast deck panel is added, temporary post-tensioning is used to secure the new panel to previously installed panels until the epoxy begins to set. The epoxy serves as a lubricant during placement of the match cast deck panels, prevents water intrusion, and provides some tensile strength across the joint. This construction technique reduces the number of pockets in the finished deck panels.

1.9.2.3.2 Leveling Bolts

Specify location of leveling bolts for erection. Ensure leveling bolts are located on all supporting girders for proper load distribution. Place steel plates on top of precast concrete girders under the leveling bolts to accommodate deck panel erection. Remove leveling bolts or cut down the top 1 ½ inch minimum below the finish surface and leave in place. Fill leveling bolt holes with non-shrink grout.

C1.9.2.3.2

Leveling bolts are used to place deck panels to the appropriate elevation before duct splice openings and joints are filled with concrete or grout.

1.9.2.4 Bridge Approach Systems

A bridge approach system provides a smooth transition between a highway pavement and a bridge. The key components of a bridge approach systems are the following:

Approach slabs and their wearing surfaces. See *BDM 1.9.2.4.1*.

- Abutments and their foundations. See *BDM 1.11.2*.
- Connections between the deck, abutment, and approach slab. See *BDM 1.14*.
- Expansion joints. See *BDM 1.14.2*.
- Approach slab supports (such as ledges and sleeper slabs). See *BDM 1.9.2.4.1 and 1.9.2.4.2*.
- Backfill materials and reinforcement.
- Subsurface and surface drainage systems.

C1.9.2.4

Refer to *NCHRP Synthesis 566* for additional information on bridge approach systems.

Moment slabs are not considered part of the bridge approach system. Refer to the *GDM* for guidance.

1.9.2.4.1 Approach Slabs & Supports

Provide reinforced concrete bridge approach slabs for bridges.

C1.9.2.4.1

Approach slabs were formerly known as bridge end panels in Oregon.

Approach slabs on new bridges may be excluded under unique conditions. Include a geotechnical and structural evaluation as supporting documents to the design deviation.

Refer to *BDM 1.9.2.1.3* for approach slabs corrosion protective practices, such as reinforcement type. Refer to *BDM 1.5.5* for reinforcement clear cover requirements.

LOCAL AGENCY PROJECTS

Reinforced concrete bridge approach slabs do not need to be provided for new local agency design category bridges that meet all the following requirements:

- No evidence of ongoing settlement.
- ADT less than 1000.
- ADTT less than 20%.

Show the general outline of approach slabs on the bridge plans. Reference the slab details shown on *Bridge Standard Drawings* or detail plans.

Detail ledges, corbels or other methods of approach slab supports on all bridges (even when approach slabs are not called for when the bridge is built). A design loading for approach slab ledges detailed in *BR165* may be used as follows:

- DC = 1.60 klf.
- DW = 0.35 klf.
- LL = 6.50 klf per lane distributed over 10 feet (includes impact and multiple presence factor).

When the site geometry is non-standard, determine the design loading for approach slab ledges using site specific geometry.

Evaluate existing ledges, corbels and other methods of approach slab supports for required capacities when replacing or adding approach slabs to existing bridges.

C LOCAL AGENCY PROJECT

Traffic restrictions may require staging of the approach slab installation or the use of Type III cement (high-early strength concrete) to accelerate construction times.

For bridges with sidewalks and no approach slabs, provide a method of supporting approaching sidewalks at the bridge ends (present or future).

Bridges constructed after 1960 generally have paving ledges at the bridge ends, even though approach slabs were not installed at the time of construction. When adding approach slabs to bridges built prior to 1960,

assume addition of approach slab support will be needed.

For integral and semi-integral end bents where the approach slab movement is used to accommodate thermal expansion:

- Design and provide additional confinement and dowel reinforcement at bearing seat connection.
- Use a sleeper slab per *BDM 1.9.2.4.2* and replace the standard 180-degree hook bars with horizontal connection bars.

In most cases, extend the bridge rail to the end of the approach slab.

Avoid supporting barriers on wingwalls (rail cast with wingwall) because water leaks into the subgrade along the wall. Rather, place barriers on approach slabs or moment slabs.

In cases where the bridge rail is not extended to the end of the approach slab, the required width of the approach slab depends on the approach rail type as follows:

- When the approach rail is a flex-beam rail, provide an approach slab width of inside face to inside face of the flex-beam rails at the end of the bridge.
- Where the approach rail is concrete, support the barrier on the approach slab and provide a slab width equal to the out-to-out dimension of the barriers at the end of the bridge.

Use a nominal approach slab length of 20 feet, unless otherwise required due to site-specific settlement concerns.

The measured length of approach slabs is 20 feet 4 inches to simplify rebar fabrication while accommodating two inch cover. Prior to 2019 the typical approach slab length was 30 feet.

In 2019 *DET3160* was published. It specifies the use of granular structural backfill behind the abutment, and thus the approach slab length was reduced.

Where the approach roadway is flexible pavement use asphalt concrete pavement (ACP) on the approach slab.

With flexible pavement, if the approach slab settles, compensating overlays can be easily feathered onto the existing ACP. See *BDM 1.9.3.1.6* for additional information on using ACP.

Where the approach roadway is rigid pavement, do not use ACP on the approach slab. See *BDM 1.9.2.4.2* for sleeper slab requirements. Work with the pavement designer to modify *DET1604* to the site.

The intent of adding a sleeper slab and joint for rigid pavement is to reduce roadway impact on the bridge.

Evaluate the roadway end of the approach slab for movement. Consider if a larger bridge joint is appropriate to address any anticipated large movement.

When widening a bridge with existing approach slabs, use the same approach slab length for the new portion as the existing. Connect the new approach slab segment to the existing with dowels.

Do not add approach slabs to existing bridges unless there is ongoing settlement or the project impacts the full width of the approach embankment.

On-going settlement is noted in maintenance records or when inspection element 999 (roadway impact) is in condition state three or higher. A site visit is likely necessary to determine whether or not adding approach slabs to the structure is the best choice to minimize pavement cracks and settlement at the bridge ends. The largest costs associated with adding approach slabs is often traffic control. When traffic control is already in place, it is beneficial to add approach slabs.

PRECAST APPROACH SLABS

C PRECAST APPROACH SLABS

Oregon has limited experience with precast approach slabs.

Consider issues regarding subgrade compaction and the contractors' ability to construct the surface of the subgrade to a smooth level condition prior to placement.

Consider the ability of precast slabs to accommodate differential settlement (especially if subgrade is not level)

Consider the design of the connection detail to pile cap/abutment wall and any joint construction.

APPROACH SLABS AT SKEWED

See *BDM 1.9.2.1.1* for reinforcing details in acute corners of approach slabs.

Detail the roadway end of the bridge approach slab normal to the roadway centerline or use a terminal transition panel per *DET 1604*.

When using a stepped approach slab, provide a minimum 20-foot nominal approach slab length at any point. When stepped, provide the minimum number of steps and locate the longitudinal construction joint(s) on lane lines.

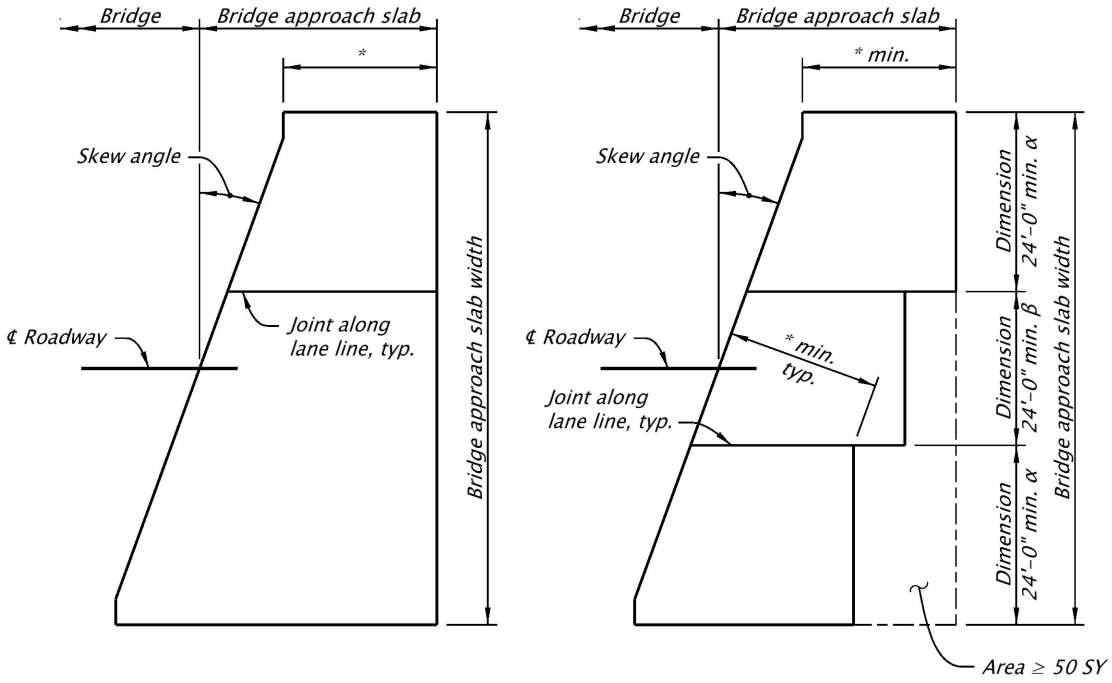
C SKEWED APPROACH SLABS

Skews greater than 25 degrees may require modification of the expansion joint. Skews greater than 45 degrees require a unique design for the approach slab reinforcement.

A normal joint alignment is to reduce the historic issues where roadway pavement is shoving bridges. This requirement applies to bridges with all pavement types even though ACP is more easily modified to match the bridge and to repair the surface where there are issues.

Consider stepping the roadway end of bridge approach slabs to reduce size when the approach slab area can be reduced by 50 square yards. See *Figure 1.9.2.4.1-1* for clarification.

Figure 1.9.2.4.1-1 Stepped Approach Slab



SKEWED APPROACH - TYPICAL **SKEWED APPROACH - STEPPED**

α – Dimension may be one lane width plus the shoulder width if the shoulder ≥ 8'–0"

β – Dimension may be two lane widths

** – Minimum Approach Slab Length per 1.9.2.4.1*

1.9.2.4.2 Sleeper Slabs

Provide a sleeper slab at the roadway end of the approach slab when any of the following conditions are met:

- Adjacent roadway pavement is rigid.
- Abutment is integral or semi-integral, and the approach slab slides ½ inch or more.
- Adjacent roadway pavement is flexible and there is no AC on the approach slab.
- When recommended by the Geotechnical Engineer.

Show the general outline of sleeper slabs on the bridge plans with reference to the slab details shown on *Bridge Standard Drawings*.

Regardless of the approach slab width, use a sleeper slab length that matches the roadway width between inside faces of the bridge rails.

C1.9.2.4.2

Sleeper slabs help maintain good ride quality by mitigating rotation of the approach slab and by supporting the roadway end of the approach slab, as well as the joint between the approach slab and the roadway approach.

The approach slab movement is to accommodate for thermal expansion and contraction of the superstructure. Considerations for creep and shrinkage movement depends upon design assumptions.

When an expansion joint is needed at the roadway end of the approach slab and the adjacent roadway pavement is flexible, the stem of the sleeper slab provides the rigid surface needed for the joint.

In combination with proper backfill installation behind the abutment, sleeper slabs provide secondary support for the roadway end of the approach slab to further reduce the risk of slab rotation and provide smooth transition between the roadway pavement and the approach slab.

See *DET 3161*.

This is to accommodate for the first post space of the guardrail.

1.9.3 Existing Decks

Evaluate the structure for the possibility of:

- Bridge rail and bridge rail transition retrofit or replacement.
- Deck joint repair or replacement.
- The addition of reinforced concrete approach slabs.
- The addition of protective fencing (see *BDM 1.13.12*).
- The need for protection from runoff or deck drainage.
- Seismic retrofit and bearing repair.

For load restricted bridges, confirm that the weight of the construction equipment will not overstress the bridge. Restrictions may be required on the spacing of a paving train or the size of the milling equipment.

1.9.3.1 Deck Overlays

There are three overlay categories available for use on bridge decks:

- Structural Concrete Overlays – HESC, HPC, SFC, MC, *BDM 1.9.3.1.4*.
- Non-Structural Concrete Overlays – Including Multi-Layer Polymer Concrete Overlay (MPCO) and Premixed Polymer Concrete (PPC), *BDM 1.9.3.1.5*.
- Asphalt Concrete Pavement (ACP), *BDM 1.9.3.1.6*.

C1.9.3.1

The purpose of an overlay on a bridge deck can be to:

- Restore the structural integrity of the deck.
- Improve the load capacity.
- Improve or restore rideability.
- Improve skid resistance.
- Improve deck drainage.
- Modifying roadway profile or cross-slope.
- Seal deck cracking.
- Increase reinforcement cover and provide sacrificial wearing surface.

See *BDM 1.15* for more information on maintenance and preservation activities.

Provide a line on the DCSA for all deck treatment selections. Technical concurrence from Structural Materials Engineer is required.

See the *Bridge Maintenance Design Manual* or consult with the Structural Materials Engineer for additional overlay and membrane options not listed in the *BDM*.

1.9.3.1.1 Field Investigation

C1.9.3.1.1

At project kickoff, review the latest Bridge Inspection Report, noting the ratings for the deck, superstructure, bridge rails, deck joints and deck drains.

A site visit may be needed to gather additional information.

Thorough investigation means a delamination survey of the entire deck, chloride profiles taken from areas of highest exposure to drainage and requires concrete cores. Chloride content at the surface is not adequate as levels can vary greatly.

These results are used to determine the remaining concrete deck integrity before determining the appropriate deck treatment or if deck replacement is warranted (see *BDM 1.9.3.4*)

When performing a structural concrete inlay, a reinforcement depth survey is required to determine accurate depth of reinforcement.

A reinforcement depth survey may be good practice for other overlay types as well depending on the chloride depth and deck preparation methods. Contact the Structural Materials Engineer.

A typical reinforcement depth survey may involve a GRP scan correlated with physical measurements.

Use a rebar detector to locate existing deck reinforcement. Avoid coring through existing rebar. Repair core locations with a rapid setting repair mortar from *Section 02015.20* of the *QPL*.

Obtain guidance from the Bridge Corrosion Engineer to verify the coring and testing requirements stated below are appropriate for the structure. Coordinate pavement cores on bridge decks and bridge approach slabs with the Pavement designer at project initiation.

Coordinate pavement cores with Pavement Section and roadway coring request to avoid separate efforts.

Generally the bridge deck program performs concrete cores and pavement section can perform ACP cores.

For chloride testing take minimum 4 inch diameter cores with minimum 4.5 inches long. Take a minimum of four cores at a frequency of a pair of two cores for every 10,000 square feet of bridge deck, not to exceed 12 cores total. For each pair include one core within a wheel track/rut and one core between wheel track/ruts. Avoid locations with existing patches. Take photos of the cores and core holes to assist designer. Log photos and core holes on a pdf of the existing plan sheet. Provide information in Chloride Report or PW as appropriate.

Sampling a single lane of a multilane structure is often sufficient. In rare cases, additional cores may be required for compressive strength testing, other chemicals of interest or to perform petrographic analysis. Cores may not be needed when there is information from previous cores on the same structure, an adjacent structure, or an applicable structure within the same corridor. Contact the Bridge Corrosion Engineer for this information.

Test all cores for chloride analysis according to *ASTM C1152* or *AASHTO T260.* Discard the top ¼ inches and slice cores in ½ inch increments to a depth of 2.75 inches below the surface of the concrete or the bond line between overlay and substrate materials.

Typically, an additional 2 inches below the deepest test is necessary to cut and pulverize the core for testing. For thin decks or thick overlays where 2.5 inch depth testing is not practical, test as many sample depths as possible without taking a full depth core.

For structures with ACP, take core samples to determine ACP thickness. Obtain one core at each approach slab and a minimum of two bridge deck cores. Take one core at the bridge centerline and one core near the curb line when possible. Consider additional cores at joints and mid span to determine existing ACP depths that vary due to camber. Identify any membranes present during coring operations and collect hazmat samples.

It is common for ACP to be used to modify or build the bridge crown so consider taking cores at different locations in the deck profile.

One bridge deck core may be sufficient for bridges less than 20 feet in length. Methods other than deck cores are acceptable to determine ACP thickness only (e.g. drilling, GPR).

1.9.3.1.2 Overlays Warrants

Use the overlay criteria matrix in *Table 1.9.3.1.2-1* to determine whether an overlay is warranted.

Bridge decks that do not meet the matrix criteria are not recommended for an overlay. Consider an alternative action (e.g. maintenance activity, deck replacement, no action).

C1.9.3.1.2

See *BDM 1.9.3.1.1* for investigation requirements and definition of thorough investigation.

See *BDM 1.9.3.2* for corrosion considerations.

See *BDM 1.9.3.4* for deck replacement warrants.

Table 1.9.3.1.2-1 Deck Treatment Warrants Matrix

Deck Preservation Action Guidance			MPCO	PPC Overlay	Structural Concrete Overlay (HPC, HESC)	Structural Concrete Inlay (HPC, HESC)	Install New ACP Overlay With Membrane	Remove ACP & Reinstall ACP with Membrane
Primary Factors	**Warrants**	Inspection Report Item 58 "Deck Condition"	≥ 4	4-6	4-6	-	≥ 4	≥ 4
		Elements 12, 13, 15, 16, 38, or 39 defect 1080 "spall/delam/patch" in CS2 or worse	1% ≤ deck area ≤ 5%	1% ≤ deck area ≤ 5%	1% ≤ deck area ≤ 5%	*requires thorough investigation per *BDM 1.9.3.1.1*	-	1% ≤ deck area ≤ 5%
		Area identified by delamination survey for class 2 prep (must be less than 2 years old)	deck area ≤ 10% - YES	deck area ≤ 10% - YES	deck area ≤ 15% - YES	*requires thorough investigation per *BDM 1.9.3.1.1*	-	-
		Chloride threshold (* chloride data required) (ǂ chloride data suggested)	< 0.04 % by mass of sample at shallowest rebar *	< 0.04 % by mass of sample at shallowest rebar *	< 0.04 % by mass of sample at shallowest rebar *	Remove concrete contaminated beyond 0.04% by mass of sample.*	< 0.04 % by mass of sample at shallowest rebar ǂ	< 0.04 % by mass of sample at shallowest rebar ǂ
		Roadway classification	<6000 ADT where design speed is less than 45 m.p.h.	Any	Any	Any	Acceptable in Region 4	Any

Table 1.9.3.1.2-2 Deck Treatment Installation Criteria Matrix

			MPCO	PPC Overlay	Structural Concrete Overlay (HPC, HESC)	Structural Concrete Inlay (HPC, HESC)	Install New ACP Overlay with Membrane	Remove ACP & Reinstall ACP with Membrane
Primary Factors	**Can be installed on:**	CIP deck	Requires a design deviation	YES	HPC - YES HESC - YES	HPC - YES HESC - YES	Requires design deviation	YES
		CIP box/tub/slab	Requires a design deviation	YES	HPC - YES HESC - YES	HPC - YES HESC - YES *Removal depth limited by structure	Requires design deviation	YES
		Precast slabs & boxes without a cast in place deck	NO	NO	HPC - YES HESC - YES	NO	Requires design deviation	YES
		Deck bulb-T girders without a cast in place deck	NO	YES with UHPC connections	HPC - YES HESC - YES	NO	Requires design deviation	YES
		Precast deck panels	Requires a design deviation	YES	HPC - YES HESC - YES	HPC - YES HESC - YES *Removal depth may be limited by structure	Requires design deviation	YES

Table 1.9.3.1.2-3 Deck Treatment Material Characteristics Matrix

			MPCO	PPC Overlay	Structural Concrete Overlay (HPC, HESC)	Structural Concrete Inlay (HPC, HESC)	Install New ACP Overlay with Membrane	Remove ACP & Reinstall ACP with Membrane
Secondary Factors	**Material Characteristics**	Minimum thickness (inch)	3/8	¾	≥ 2 minimum	≥ 2 minimum	≥ 2 Varies by membrane type	≥ 2 Varies by membrane type
		Cure time	2-6 hours temperature dependent	2-4 hours temperature dependent	HPC- 7 days HESC- 3 hours	HPC - 7 days HESC - 3 hours	2-6 hours (polymer membrane)	2-6 hours (polymer membrane)
		Minimum closure width	Can be done in single lane phases, placing longitudinal joints on the lane lines.	14 feet for slipform 6 feet for roller screed	16 feet for Deck Finishing Machine 6 feet for roller screed	16 feet for Deck Finishing Machine 6 feet for roller screed	16 feet *can be reduced with extra labor	16 feet *can be reduced with extra labor
		Atmospheric restrictions (degrees F when applicable) Amb. – Ambient temperature Surf. – Surface temperature	visibly dry for ≥ 72 hours 50 ≤ temp ≤ 90 deck temp ≥ dew point+5 No rain	Visibly dry for ≥ 5 days 50 ≤ temp ≤ 90 deck temp ≥ dew point+5 No rain forecasted for 12 hours	40 ≤ Surf. rising ≤ 45 40 ≤ temp ≤ 80	40 ≤ Surf. rising ≤ 45 40 ≤ temp ≤ 80	Varies by membrane type as specified in the specification.	Varies by membrane type as specified in the specification.

			forecasted for placement and cure time	from the start of placement.				
		Provides structural strength	NO	NO	YES	YES	NO	NO
	Cost	2020-2021 $/unit H: High L:Low W: Weighted Average — Materials	SqYd H $33.50 L $15.26 W $19.69	CuYd H $4,015.71 L $2,173.52 W $2,911.16	CuYd H $871. 40 L $342.50 W $534.87		CuYd H $695.00 L $258.00 W $390.89 (Converted from Tons to CuYd by assuming 0.5 Cy/Ton)	
		2020-2021 $/unit H: High L:Low W: Weighted Average — Installation	SqYd H $152.75 L $13.90 W $20.29	SqYd H $155.00 L $26.88 W $42.86	SqYd H $154. 97 L $97.00 W $152.69			
Information Only	Common unit weight		Negligible	Refer to *BDM 1.3.2*				
	Surface preparation		According to *00504*					
	Specification number		*00556*	*00557*	*00559*	*00559 & 00540*	*00590 – 00592* *00744 & 00745*	*00590- 00592* *00744 & 00745*

Table 1.9.3.1.2-4 Deck Preparation Matrix

		Micromill	Shot blast	Hydrodemolition	Rotomill
Removal Method Characteristics	Description	Rotating tool that grinds away small thickness of concrete	Steel shot used to impact surface removing concrete	High pressure water jet used to remove unsound concrete	Grinder or cold planer used to remove variable thickness asphalt
	Preparation rate	16,000 sy/day	3,500 sf/hr	Refer to *BDM 1.9.3.3*	72,000 sf/day
	Set up time per shift (minutes) (plus traffic control)	30	30	90	30
	Best used for:	Inlays where removal ≤ 1 inch	Overlays where minimal removal is expected	Inlays where removal > 1 inch Shallow rebar	Asphalt removal
	Can also be used for:	Inlays where removal >1 inch, membrane removal	Secondary process to remove micro fractures	Selective concrete repairs	N/A
	Requires	Shot blast to remove micro fractures	N/A	Water handling	N/A
	Pros and Cons	Efficient removal method		Hydrodemolition is not required for HPC and HESC overlays.	

1.9.3.1.3 Overlay Selection

After determining whether a bridge deck overlay is warranted, use the overlay criteria matrix in *Table 1.9.3.1.2-1* to select an overlay type based on design criteria.

Consider the structure type and secondary factors listed in *Tables 1.9.3.1.2-2, 1.9.3.1.2-3* and *1.9.3.1.2-4.*

During the overlay selection process, review the structure's **As Constructed** plans, paying special attention to the following items:

- Existing bridge rail – Review the existing bridge rail for functional adequacy and replace if unacceptable (see *BDM 1.13*). Verify the dimension from the top of the rail to the overlay finish grade meets the minimum rail height.
- Effect of additional dead load

- Deck joints – When necessary, clean and repair deck joints as part of the overlay project. Review the Bridge Inspection Report or field notes for information to determine if any deck joint work is needed.
  Adjust joints when placing a new overlay exceeding 3/8 inch thickness. Revise joint types when thickness deviates by more than one inch.

C1.9.3.1.3

Check for the presence of an existing overlay or wearing surface. When one is present, note what material type it is. Also, check for the presence of an existing waterproof membrane. Some bridges may have asbestos containing membranes, which require additional testing and care during removal. This information is used in estimating unit costs for deck preparation.

Typically the dead load from a 2 inch concrete overlay has little effect on the capacity or operation of the structure. Exceptions to this are load posted bridges or movable bridges, where a structural concrete overlay's dead load may have a significant impact. A thinner or non-structural concrete overlay may be required.

A site visit may be necessary to determine the best type of joint repair or replacement. See Standard Joint Drawings for typical deck joint reconstruction details. See *Standard Specifications* and *SP 00585* for expansion joints.

- Deck drains – Note existing deck drains on the overlay plan view. Adjust deck drain grates to match the new deck surface when necessary. Deck drains do not require adjustment for MPCOs. Verify if deck drain grates need to be upgraded for bicycle safety.

For a non-structural concrete overlay, the existing deck drain taper may be adequate. See *BDM 1.9.5* for additional information about bridge drainage.

- Approach slabs – Confirm the need for approach slabs per *BDM 1.9.2.4.1* and by reviewing the current Bridge Inspection Report and the maintenance file records.

See *BDM 1.9.2.4* and *SP 00545* for additional information about bridge approach slab design.

- Protective fencing - When a structure crosses over a roadway and does not have existing protective screening, consult with the Bridge Standards and Program Engineer during scoping to determine whether screening is appropriate to include with the overlay project.

This is required since the 1993 law *ORS 366.462*.

There is a statewide priority list for protective fencing. See *BDM 1.13.12*.

1.9.3.1.4 Structural Concrete Overlays

C1.9.3.1.4

The term **structural** is used to describe an overlay that is rigid enough and thick enough to increase the stiffness of the deck and decrease live load deflections. Structural concrete inlays are considered **structural** because they restore the stiffness of the deck but they typically do not increase deck strength. Overlay and inlay can be used interchangeable in this section.

A deck overlay is when a deck treatment is applied on top of the existing deck material. A deck inlay is when parent deck material is removed and replaced with deck treatment material.

See *BDM 1.3.2.1* for wearing surface thickness and loading. Include the structural concrete overlay in the stiffness and capacity calculation.

Structural overlays typically have a compressive strength and elastic modulus similar to conventional concrete, but it may vary depending on the specific product used.

Do not include the top ½ inch of overlay in the structural deck thickness, since it is considered a sacrificial wearing surface per *BDM 1.9.2.1*.

Structural concrete overlays require elastomeric concrete nosings or armored corners at the bridge ends and joints.

This is because of the high incidence of debonding at expansion joints or at bridge ends. See *SP 00584* for specifications developed for concrete nosing.

It may be possible to place a non-structural concrete overlay and not do any work to the joints.

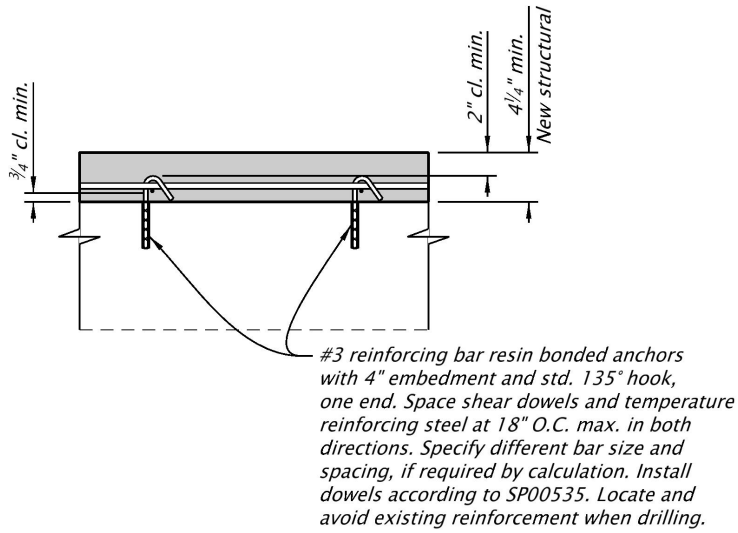
STRUCTURAL CONCRETE OVERLAY DEPTH

Adjust nominal overlay depths according to the following guidelines:

- For depths of 2 to 3 inches use a full depth structural concrete overlay with no added reinforcing.
- For depths between 3 to 4 inches contact the BDM Technical Resource for options to decrease shrinkage.
- For depths 4 inches and greater, provide shear dowels from existing concrete to improve bond. Specify 2 inch clear cover over shear dowels.
- For depths greater than 5 inches, include both shear dowels and temperature reinforcing steel. Dowels are designed for shear loading only. See *Figure 1.9.3.1.4-1.*

The required minimum thickness of a structural overlay on a bridge deck is 2 inches per *00559*. Thickness of 1 ½ inches is allowed in certain circumstances (e.g. not able to apply an inlay, cannot increase grade due to bridge rail, vertical clearance, etc.). A 1 ½ inch thick overlay comes with added risk of delamination and shorter service life. Load is better distributed with increased thickness, decreasing delamination and cracking risk. Do not base overlay thickness solely or primarily on cost or volume of materials.

Figure 1.9.3.1.4-1 Shear Dowel Details



STRUCTURAL CONCRETE OVERLAY TYPES

High performance concrete (HPC) overlays are the preferred material over SFC, often referred to as microsilica concrete (MC).

HPC is a similar mix to SFC, but uses larger aggregate, among other changes, to reduce cracking.

Hydrodemolition is generally the preferred method of surface preparation. It is not always the appropriate surface preparation method to use.

Hydrodemolition is preferred because it creates a better bond. The consistency of hydrodemolition decreases with increased depth. When removing more than one inch, mill first (to with ½ inch of reinforcement) then hydrodemo. Verify the rebar is located low enough to allow this type of removal. When doing hydrodemolition of existing overlays, consider the risk of punch through if the overlay does not debond. Consider the cost of containment needed. It is often not economical to use hydrodemolition for overlays. See MPCO and PCC for additional information. See *BDM 1.9.3.3* for additional information.

SFC is a specialized concrete mix with a silica fume modifier. Batching is normally done at a batch plant. SFC placement is

accomplished with more conventional construction methods.

The other option for structural concrete overlays is high-early strength concrete (HESC).

HESC overlays utilize calcium sulfoaluminate cement which can reach return-to-traffic strength in as little as 3 hours. HESC overlays utilize the same ¾ inch maximum aggregate size as HPC overlays and have the same recommended 2 inch overlay thickness. Durability performance (shrinkage, permeability, and freeze-thaw) meets or exceeds that of HPC overlays therefore they have the same anticipated service life.

Review *SP 00559* and *SP 00558* for HPC and HESC requirements and restrictions.

Latex modified concrete (LMC) overlays are no longer used.

LMC is a concrete mix with a latex emulsion modifier. The latex emulsion has a milky color and texture. LMC overlay technology was a common type of structural concrete overlay used since 1958, but has not been used in Oregon since the early 2000s.

1.9.3.1.5 Non-Structural Concrete Overlays

Use non-structural concrete overlays in situations where structural integrity is not an issue and does not add to the deck stiffness.

C1.9.3.1.5

Polymer is a very general term used to classify a wide variety of compounds that chemically combine in a reaction (polymerization).

Polymer binder resins are formulated in hundreds of different combinations, depending upon the properties desired. The most common categories of polymer binder resins in use as bridge deck overlays or patching material include epoxy and polyester.

Polymer concrete is a composite material in which coarse aggregate is bound together with the polymer binder resin.

Polymer concrete can be placed as an overlay in generally two different ways – as a MPCO (also known as broom and seed) or as PPC, which is screed finished to grade.

The most common polymer used for MPCOs is epoxy.

The most common polymer used for PPC overlays is polyester.

Construction advantages of non-structural concrete overlays include:

- Non-structural concrete overlay flexibility reduces the potential for cracking due to thermal or design load movement.
- Non-structural concrete overlays are very light as compared to structural concrete overlays. This reduction in dead load can be significant on load posted bridges or movable bridges.
- Non-structural concrete overlay construction time is much less compared to structural concrete overlay applications. The short construction time provides a great advantage in time critical urban areas.
- Non-structural concrete overlay bond strength is typically double that of a structural concrete overlay.

Construction disadvantages of non-structural concrete overlays include:

- Atmospheric conditions: The prepared deck surface must be dry prior to placement. This provision could influence construction schedules. For off-season applications, *SP 00556* and *SP 00557* provide guidance for inclement weather plans, which can involve heating the bridge deck to force it to dry. This will impact traffic control

requirements and costs. Avoid scheduling non-structural concrete overlays in wet weather.

MULTI-LAYER POLYMER CONCRETE OVERLAYS

Do not place MPCOs on new bridge decks.

Place MPCOs on existing structures where an existing MPCO can be topped without being removed.

There are several risks with using MPCOs:

- ¼ inch loss of parent concrete to refresh MPCO per specifications.
- MPCOs wear out fast with 'high' ADT and studded tire use. MPCO's have been used on the interstate in some locations with reduced lifespan.
- MPCOs trap moisture in the bridge deck, not allowing the concrete to 'breath'. This can drive a corrosion cell when chlorides are high.
- Covers the concrete deck and makes inspection difficult. A delamination survey does not reveal what layer was delaminated (the MPCO or in the concrete).
- MPCO aggregates polish in the wheel lines, potentially reducing skid resistance and increasing road glare, as compared to other overlay types.

Consult with the Bridge Maintenance Engineer and Structural Materials Engineer for additional guidance.

MPCOs cannot be considered a structural concrete overlay.

Place MPCOs to a nominal 3/8 inch thickness. Do not use MPCOs for grade corrections.

MPCO's are a composite material formed by combining polymer binder resin and coarse aggregates. MPCOs have a significantly lower modulus compared to PCC.

MPCO's are constructed using any of the commonly available polymer resins. Each resin has its own advantages and disadvantages. Use each in accordance with manufacturer's recommendations.

The finished MPCO surface is not tined or screeded.

Refer to the *Qualified Products List* for MPCO products that have been approved for use. MPCOs and MPCO aggregates are listed separately on the *QPL*. The MPCO binder manufacture is required to select the appropriate MPCO aggregate from the *QPL*. *SP 00556* covers the use of MPCOs.

MPCO applications don't require specialized equipment and are well suited for maintenance crews and smaller contractors. There have, however, been advances in application methods which have increased application efficiency vs. traditional manual application methods.

A typical MPCO is constructed by first removing all dirt, debris and laitance on the deck surface. This is best accomplished with the use of a shot-blast system. Since the deck surface must be clean and dry prior to the application of the MPCO, the industry recommends the use of the shot-blasting method. Shot-blasting leaves the surface dry and vacuumed.

A layer of polymer is next applied to the prepared deck using a squeegee, broom, spray bar or other methods at a rate specified by the manufacturer. The aggregate is then broadcast, at a specified rate, over the surface. The excess aggregate is swept off the surface. Apply lifts according to manufacturer's directions to achieve a nominal 3/8 inch thickness. Place additional MPCO material in ruts to provide a finished MPCO surface that is free of ruts, depressions, and irregularities.

PREMIXED POLYMER CONCRETE OVERLAYS

PPC has a significantly lower modulus compared to PCC and therefore cannot be considered a **structural** concrete overlay.

PPC is a composite material formed by combining polymer binder resin and coarse aggregates in a mobile mixer, then applied to the deck and finished to grade. See *BDM 1.9.4.1* for screed information.

PPC may be used as a preservation measure on decks in good condition (outside the range shown in *Table 1.9.3.1.2-1*) at the request of maintenance.

Preliminary numbers indicate a slight advantage over MPCO's in skid resistance.

PPC overlays are typically placed to a nominal ¾ inch thickness.

PPC is more appropriate for minor grade improvements than MPCO's, due to the grade controls of the screed finish machine. Due to the increased material thickness, PPC overlays are more expensive than MPCO's.

See *Table 1.9.3.1.2-1* for estimated application rates. See *BDM 1.3.2* for unit weight of PPC.

PPC is rapid setting and is best placed with a paving machine whenever practical. There are circumstances where a machine cannot be used, such as along the gutter lines which will require manual finishing.

PPC is constructed by first removing all dirt, debris and laitance on the deck surface using a shot-blast system. Since the deck surface must be clean and dry prior to the application of the PPC mixture, the industry recommends the use of the shot-blasting method over the others. Shot-blasting leaves the surface dry and vacuumed.

A layer of primer is next applied to the prepared deck surface using a squeegee or brooms. Next the polymer resin binder is mixed with the other components into a premixed condition. The premixed material is then placed onto the primed surface and finished to grade with specialized equipment designed for PPC applications.

Silica sand is broadcast in areas of high resin content to maintain skid resistance.

The final product looks similar to PCC but with longitudinal tining.

Do not include PPC in projects that do not have a viable construction window based on the weather requirements in *SP 00557*.

Placement of PCC is dry weather work, in line with the paving season. Do not bid a job with anticipated placement in wet weather.

PPC is currently not listed on the *QPL* and needs to be specified accordingly. *SP 00557* covers the use of PPC.

1.9.3.1.6 Asphalt Concrete Overlays

C1.9.3.1.6

ACP is not permitted on new decks or existing bare concrete decks per *BDM 1.9.2.1*, except on local agency projects.

ACP does not add to the deck stiffness and is not considered to be a **structural** concrete overlay.

On bridges with existing ACP and where roadway ACP depths allow, consider replacing the ACP with another overlay type.

When ACP is the only feasible option for overlay, install a waterproofing membrane per *BDM 1.9.3.1.6.1*.

Do not use emulsified asphalt concrete (EAC), cold mix, on bridge decks or slabs. Specify ACP materials per *00744* and *00745* for use on bridge decks and slabs.

Use of commercial grade ACP and vibratory rollers are not permitted on bridge decks or slabs.

Use the same ACP on the bridge except for layer thickness and vibratory compaction as discussed below:

- 2 inch lift or thicker: ½ inch ACP.

The pavement designer assigns an appropriate pavement type, design level, layer thickness, and aggregate size for ACP on the highway and bridge approaches. Consider impacts to the approach roadway when adjusting ACP thickness on bridge decks. Reducing pavement thickness can cause rebuilding of roadway approaches.

- 1 inch lift but thinner than 2 inch lift: 3/8 inch ACP.

3/8 inch ACP is only cost effective when used in substantial quantity and when multiple changes in paving operations are not required by the change in the mix.

- Lift thinner than 1 inch: not allowed.

When a Class **F** mix (free draining) is used, give special attention to drainage details at joints and deck drains to prevent trapping water adjacent to these areas.

Matching the wearing course (top lift) thickness used beyond the bridge ends may improve asphalt durability on bridge decks, if the project is staged such that the wearing course on the pavement and bridge can be paved in the same operation.

Discuss pavement mix design recommendations with the Pavement designer to address lateral shoving on bridges with superelevations of five percent or greater.

Less than four inches of ACP has demonstrated lateral shoving on structures with superelevations of five percent or greater. The issue is exacerbated on high speed roadways (over 40 mph) and where chains and studded tires are used. Consider higher quality asphalt or a different overlay material in these situations.

Provide details on plans to pave out cambers in the bridge deck. Provide ACP quantities to the roadway designer, including additional ACP to pave out cambers.

ACP thickness can vary by several inches due to camber.

See *BDM 1.9.2.1.4* for striping information on ACP.

See *BDM 1.9.3.1.1* for field investigation requirements.

See *BDM 1.14.2.2* for control joints and asphalt paving on bridge joints.

1.9.3.1.6.1 WATERPROOFING MEMBRANES

When placing ACP on existing decks, a waterproofing membrane is required.

C1.9.3.1.6.1

Prior to 1992, FHWA requirements for state owned bridges stated that if deicing salts may be used in the future, some type of deck protection shall be used.

Waterproofing membranes are used as part of an overall deck protection concept to increase service life.

See *BDM 1.12.1* for culvert sealing and waterproofing requirements.

Waterproofing membranes often fail due to movement in adjacent slabs, sometimes making their installation ineffective or not worthwhile. Consider if it will serve the purposes of the bullets listed below.

Do not use spray membranes on bridge decks.

Polymer waterproofing membranes are specified in *SP 00590* and are selected from the *ODOT Qualified Products List*. They are primarily applied to bare concrete decks.

When performing ACP removal, maintain 1 inch minimum ACP over an existing polymer membrane with approval of pavement designer. Otherwise remove ACP to bare deck.

Rolled membranes are specified by *SP 00592* and accepted according to *SP 00592.10*. There is not currently a rolled membrane section in the *QPL*. Place rolled membranes between layers of ACP according to *SP 00592*.
Spray membranes are specified by *SP 00591* and accepted according to *SP 00591.10*.

Waterproofing membrane types change over time based on industry research. Consult with the Structural Materials Engineer to select the correct membrane type for each structure.

Membranes serve the following purposes:

- Protect reinforcing steel in concrete members from corrosion by preventing moisture from roadway runoff (which potentially contains chlorides and other contaminates) from penetrating the concrete surface.
- Protect galvanized tie rods in precast prestressed concrete members placed side-by-side from roadway runoff.
- Protect timber bridge decks from moisture damage.
- Prevent untreated roadway runoff from passing through bridge elements to a roadway, waterway, bikeway or pedestrian way underneath the bridge.

To allow for multiple lifts, the standard minimum ACP thickness used with rolled membranes is four inches.

EXISTING STATE BRIDGES

All areas of Oregon potentially use deicing chemicals. Actual use of deicing chemicals in the project area can be verified by contacting the Region District Maintenance Manager.

C EXISTING STATE BRIDGES

Perform chloride testing on the existing bridge deck when warranted per *BDM 1.9.3.1.2* to verify existing chloride thresholds are acceptable.

Do not skip bridges during roadway paving operations. Remove all ACP and existing membranes during paving projects, except when the existing membrane is a spray or polymer membrane that is performing well. When possible, protect these types of membranes in place during paving operations.

LOCAL AGENCY PROJECTS

When detailing ACP without a waterproofing membrane, the local agency provides justification in their submitted design deviation. Include a copy in the calculation book.

1.9.3.1.7 Construction Considerations

QUANTITY ESTIMATES

All overlays require the use of *SP 00504*. Bridge decks with existing ACP also require *SP 00503*.

Use any necessary removal bid items, depending on the existing bridge deck surface. All existing overlay removal is measured by square yard. When the ACP is too thick to be removed in one pass (i.e. greater than 2 inches), increase the unit cost for the additional passes required.

Mobilization is a significant cost to bridge paving projects.

C1.9.3.1.7

Bonded waterproofing membranes, such as polymer membranes, have an additional bid item in *SP 00504* for removal. Fabric membrane removal is incidental to *SP 00503*.

Once the existing overlay or membrane is removed, the deck is prepared per *SP 00504*.

When there is a known quantity, use a separate bid item. The quantity should be estimated after consulting with Maintenance and the bridge inspector. A site visit may be required. Additional Class 3 Deck Preparation beyond the known quantity can then be paid for as extra work.

A deck survey is required to confirm the estimated quantity of both Class 2 and Class 3 Deck Preparation. Visual inspection and

Class 1 Preparation takes place in areas where no additional concrete removal is necessary to reach sound concrete. This level of preparation is not measured and payment for it is included in the construction of the new overlay.

Class 2 Preparation is any removal of unsound concrete that does not extend the full depth of the deck. It is measure by the square yard. The repair method and pay item for Class 2 preparation varies depending on the new overlay type.

Class 3 Preparation is any removal that extends through the entire deck. Class 3 Deck Preparation is usually required due to severe deep delaminations, a severely cracked deck in all directions, a badly spalled bottom deck or poor aggregates. In most cases, the quantity of Class 3 Deck Preparation is very small. If so, no bid item is necessary. The work will normally be performed on an extra work basis.

sounding (e.g. chain drag) are the primary methods for determining quantities. Advanced non-destructive evaluation (NDE) methods, such as infrared scanning, impact echo, or ground penetrating radar (GPR) have been used in limited, high-risk, environments. Consult with Structure Services prior to using advanced methods.

A typical structural overlay for a bridge deck consists of the following structure bid items in addition to any removal items:

- Class 2 preparation for SC Overlay installations (per sy)- *SP 00504.*
- Furnish Concrete Overlay (per cy) – *SP 00559.*
- Construct SC Resurfacing (per sy) – *SP 00559.*
- Saw Cut Texturing (per sy) – *SP 00559.*

Class 1 Deck Preparation, which is not paid or measured separately from the overlay placement, includes roughening the surface to a surface texture depth profile of 1/8 in.

Furnish Concrete Overlay – Calculate this quantity from the Class 1 deck preparation area and a depth of ½ inch greater than the specified minimum depth. This increase accounts for field quantity overruns due to minor grade corrections and irregular Class 1 deck preparation. When Class 2 deck preparation has been identified, add that quantity into the **Furnish Concrete Overlay** total. Work with the roadway designer to confirm that the 3D model, when available, and roadway finish grade profile match the estimated overlay quantities.

Construct Structural Concrete Overlay Resurfacing – This quantity is typically measured for gutter to gutter and end joint to end joint.

A typical non-structural concrete overlay for a bridge deck consists of the following structure bid items in addition to any removal bid items:

- Class 2 Preparation (per sy) – *SP 00504.*
- Furnish MPCO Material (per sy) – *SP 00556.*

Or

- Furnish PPC Material (per cy) – *SP 00557.*
- Construct PC Concrete Overlay (per sy) – *SP 00556* or *SP 00557.*

Deck Preparation - Deck preparation for non-structural concrete overlays is constructed per *SP 00504*. Class 1 Preparation for non-structural concrete overlays requires roughening the existing deck to a 1/16 inch surface texture profile depth. Class 2 Preparation for non-structural concrete overlays includes repairing the deck with a PCC repair material at least five days prior to placing the overlay.

Furnish non-structural concrete overlay – Calculate this quantity from deck area (gutter to gutter and end joint to end joint) and a depth of 1/8 inch greater than the specified nominal depth.

Construct non-structural concrete overlay – Calculate this quantity from the deck area (gutter to gutter and end joint to end joint).

A typical ACP for an existing bridge deck consists of the following bid items:

- Bridge Deck Cold Plane Pavement Removal (per sy) – *SP 00503.*
- Class 2 Preparation (per sy when needed) – *SP 00504.*
- Membrane waterproofing (per sy).

- Asphalt concrete mixture (per ton).

The membrane waterproofing bid item includes full compensation for applying the membrane waterproofing system and the asphalt tack coat.

The asphalt concrete bid item is typically the responsibility of the roadway designer.

Communicate with the roadway designer to make sure all the bid items are covered.

In addition to these bid items, the following items may also be required:

- Deck joints (each or linear feet).
- Deck drain construction (each).
- Bridge rail retrofit or replacement (linear feet).
- Reinforced concrete approach slabs (per sy).

1.9.3.2 Corrosion Considerations

Discuss the proposed deck treatment project with the Bridge Corrosion Engineer when any of the following conditions are met. Otherwise follow reinforcement protection design provided in *BDM 1.9.2.1.3*.

- The structure is in a marine area, per *BDM 1.2.4.1*.
- Deck rebar corrosion is visible.
- There is reason to suspect the structure may be occasionally salted during winter months.

C1.9.3.2

When the maximum acceptable chloride level in the deck has been exceeded, deterioration of the deck rebar will continue regardless of the presence of a new overlay.

See *BDM 1.9.3.4* for deck replacements.

1.9.3.3 Partial Depth Deck Removal

Use partial depth deck removal only in conjunction with a structural overlay or inlay (see *BDM 1.9.3.1.4*).

C1.9.3.3

See *SP 00505* for concrete deck hydrodemolition. Refer to *ICRI Guideline No. 310.3R Guide for the Preparation of Concrete*

Surfaces for Repair Using Hydrodemolition Methods for additional information.

The primary function is to remove chloride contaminated concrete and unsound concrete using hydrodemolition equipment. Hydrodemolition processes also remove microfractures caused by impact based deck removal equipment and prepares the deck for a structural inlay or overlay.

1.9.3.3.1 Hydrodemolition Methods

C1.9.3.3.1

Use one of the two types of hydrodemolition as specified in *SP 00505*:

- Selective Hydrodemolition
- Deep Cut Hydrodemolition

Selective Hydrodemolition - Selectively removes all unsound concrete and achieves a roughened profile of approximately ½ inch in areas of sound concrete. When using high early strength concrete overlay for a "fast-track" hydrodemolition project, only selective hydrodemolition can be used.

When operating at pressures ranging from 14,000-20,000 psi, robotic hydrodemolition units selectively remove unsound concrete from the parent deck. It is often more economical to remove unsound concrete with hydrodemolition than it is with chipping hammers.

Selective hydrodemolition limits the amount of removal and debris generated which allows for increased production rates. Deep cut hydrodemolition produces too much debris and cannot be used in conjunction with high early strength concrete overlays for "fast-track" hydrodemolition projects.

Deep Cut Hydrodemolition – Removes the parent deck material to a specified depth, typically beyond the top mat of reinforcement. This is specified to remove chloride contaminated concrete. The plans and specification should clarify depth, whether it is measured from existing top of deck, or to a depth below the top mat of reinforcement. To facilitate consolidation of concrete, removal to ¾ inch below the top mat should be specified.

Chloride contaminated concrete that exceeds the corrosion threshold of *Table 1.9.3.1.2-1*, should be removed. Reinforcement depth plays a critical role in the final removal depth. In traditionally reinforced decks, removing ¾ inch beyond the top mat will help unsure consolidation and bond of the new overlay material.

This process requires longer duration closure windows than scarification due to

the amount of wastewater, debris, and slurry produced.

Consider consequences of undermining the top mat of reinforcement in negative moment areas.

The results of the field investigation (see *BDM 1.9.3.1.1*) will help determine which type of hydrodemolition to specify.

In most situations, selective hydrodemolition is sufficient and comes with significant cost and schedule advantages compared to deep cut hydrodemolition.

1.9.3.3.2 MicroMilling

Micromilling prior to hydrodemolition should be specified on all projects; exceptions are listed in the commentary. The micromilling depth should be specified to minimize the amount of hydrodemolition, while maintaining a minimum of ½ inch clearance from reinforcement to prevent damage to the reinforcement and the milling equipment during milling operations.

When there are existing bridge deck treatments (PPC, MPCO, structural overlay, etc.), the payment for removal of these deck treatments is included in the payment of the micromilling bid item. Account for the thickness of the PPC or structural overlay in the depth of removal. Asphalt Concrete Pavement overlays are removed according to *Section 00503*.

C1.9.3.3.2

Micromilling is important prior to hydrodemolition as it:

- Removes deck surface treatments.
- Results in a more uniform removal depth, helping ensure minimum overlay thickness is achieved.
- Decreases required hydrodemolition pressure by opening pores of the concrete, which helps prevent full depth blow-throughs.
- Reduces amount of slurry and wastewater produced.
- Often more economical than hydrodemolition alone.

1.9.3.3.3 Estimating

For deep cut hydrodemolition, the following removal rates can be used as part of schedule estimates:

- 3,000psi concrete – 50 cuft/hr
- 5,000psi concrete – 30 cuft/hr
- 7,000psi concrete – 20 cuft/hr

Selective hydrodemolition production rates can be estimated to be approximately 1,000 sqft/hour.

Account for ¼ inch overlay material thickness when specifying selective hydrodemolition. The specified depth of deep cut hydrodemolition can be used as the average overlay thickness.

C1.9.3.3.3

Removal rates with hydrodemolition equipment is affected by the depth of removal and the compressive strength of the concrete. These removal rates are approximate, and do not account for the percentage on unsound concrete, which is removed at a faster rate. These values are also per robotic unit, and most systems have the capability to run multiple robotic units in parallel.

These rates do not include cleanup, which can add a significant amount of time depending on removal depth.

Account for delaminated areas when estimating overlay volume quantities.

1.9.3.3.4 Containment

Do not use *00253, Temporary Access and Containment*, for hydrodemolition containment. Containment for hydrodemolition is only necessary when both of the following circumstances apply:

- Deep cut hydrodemolition with
    - > 1 inch removal, or
    - dense map cracking of the soffit, or
    - existing full depth repairs, **and**
- Live traffic, or sensitive environmental areas beneath the hydrodemolition operations.

C1.9.3.3.4

Hydrodemolition containment is rarely required. The purpose of the additional bid item and language in *Section 00505* is to reduce the risk of harm to the traveling public or for environmental reasons in the event of a blow-through.

Provide protection for traffic adjacent to the hydrodemoliton removal process as follows, in order of preference:

1. Remove traffic from work zone via detour, holding of traffic with flaggers, or similar.
2. Maintain traffic as far from work as feasible and shield traffic from debris with positive protection.

Concrete removal via hydrodemolition results in difficult to contain high pressure water and concrete debris being flown from the work area. It is also possible to unintentionally remove the entire deck thickness in an isolated area, or blow-through, resulting in uncontained water and debris falling below the structure. Therefore, protection from these hazards for the traveling public is required.

Positive containment for protection of traffic typically consists of items like temporary traffic barriers, plywood shielding installed adjacent to the work activity, and under deck work containment systems for blow-through protection.

1.9.3.3.5 Existing Structure Considerations

Do not specify hydrodemolition on prestressed members without cast-in-place concrete decks.

When hydrodemolition is required on cast-in-place post tensioned structures, evaluate the capacity of the structure, using LRFR techniques, assuming the specified concrete removal plus 1 inch. Mitigate when the resultant critical rating factor is <1.0.

Hydrodemolition can damage GFRP reinforcing. Do not perform hydrodemolition on structures that contain GFRP in the top mat of deck reinforcing.

Detail hydrodemolition stopping 1-foot from bridge joints that are to remain in place.

Evaluate overhangs for stability assuming the specified concrete removal plus 1 inch.

C1.9.3.3.5

Unintentional removal of concrete around critical reinforcing, of prestressed elements, and where the concrete is critical to the stability of the structure can result in damage or failure of the structure or element.

Concrete removal by hydrodemolition is not easily controlled in regards to removal limits and material types removed. Be aware of the structure type and functionality when detailing the hydrodemolition removal.

Critical reinforcement includes negative moment reinforcement located in the deck, prestressing tendons near the top of the element, and similar reinforcing where their continued effectiveness is critical to the stability of the structure.

Employ shoring when required to maintain stability of the overhang.

1.9.3.3.6 Special Repair Zones

Identify Special Repair Zones in the contract documents. Add clarity to identify what is contributing to the area being designated a Special Repair Zone. Detail allowable concrete removal limits and removal methods within the Special Repair Zones.

When concrete removal is required in Special Repair Zones, ensure stability of the structure during construction.

C1.9.3.3.6

Special Repair Zones are areas that contain critical reinforcement or concrete whose removal could lead to damage or failure of the element or structure.

Ensure stability of the structure during construction by using techniques such as:

- Staged concrete removal.
- Staged concrete replacement.
- Strengthening prior to concrete removal
- Temporary shoring structure or element.

1.9.3.4 Deck Replacements

BDM 1.9.3.4 applies to composite concrete deck replacements.

Consider a deck replacement when any of the following warrants are met:

- The deck condition is rated as a four or less in Item 58 of the Bridge Inspection Report.
- Delaminated and patched areas are greater than 15 percent of the deck area.
- 10 percent or more of the bridge deck area will require full depth repairs during hydrodemolition.

- Cracking represented in Condition State 3 is greater than 50 percent of the deck area.
- The chloride content exceeds 0.040 percent by mass of sample at the depth of shallowest rebar. See *BDM 1.9.3.2*.
- Additional investigation confirms that the deck deterioration has become too severe to repair and exceeds values in *Table 1.9.3.1.2-1*.

When superstructure strengthening is required, include a superstructure or bridge replacement option in the alternatives analysis, as well as a deck replacement.

Perform a pre-design load rating per *BDM 2.10.8.1* to verify existing structure meets strength requirements of *BDM 1.3.3.4* when there is not a current load rating.

C1.9.3.4

See *BDM 1.9.3.1.2* and *Table 1.9.3.1.2-1* for deck treatment warrants.

For estimating purposes, the combination of soffit map cracking and heavy efflorescence is a strong indication of locations that may blow through during hydrodemolition and will require full depth repairs.

When extensive strengthening or seismic retrofit is necessary, consider whether a bridge replacement is more feasible. Coordination with bridge program is needed to determine the appropriate course of action.

Life cycle costs analysis is an effective tool for evaluating project scope. Incorporate the design considerations from *BDM 1.9.1.*

Deck replacements fall under the Bridge Modernization design category. In the spirit of practical design, perform a holistic review of the structure from a service life perspective when a bridge deck replacement is being scoped. Opportunities often exist to minimize future maintenance costs and efficiently extend the service life of other bridge elements including, but not limited to:

- Bearing upgrades.
- Omitting joints.
- Adding approach slabs.
- Incorporating seismic retrofit components (e.g., installing diaphragms or shear lugs).
- Repairing existing paint systems.
- Washing structures.

Coordination with other disciplines is necessary to set adequate project limits and consider impacts to roadway drainage.

Design a deck replacement according to *BDM 1.9.2.* Ensure superstructure elements meet the strength requirements of *BDM 1.3.3.4*.

Consider that the bridge deck elevation will likely rise to accommodate various features of a new deck (i.e., additional deck thickness, build-up for constructability, etc.) and new geometry will increase dead load.

Install approach slabs per *BDM 1.9.2.4.1*.

During project initiation, obtain cores from concrete girders for compressive strength tests. Use this information (f'c and calculated modulus) to inform estimated deflection and profile grade calculations.

Consider remaining service life of bridge when selecting reinforcement materials. This may not align with the requirements of *BDM 1.9.2.1.3.* See *BDM 1.9.3.2* for additional guidance.

Design for all stages of construction loading.

Verify the system is stiff enough and will remain stable without a deck in place. See *BDM 1.3.4* for construction loading. See *NCHRP Report 536* for information on bridge demolition.

Check interface shear between the girder and deck for composite action. Add interface shear reinforcement or welded studs as needed.

Deck removal work is likely to damage existing stirrups/studs. Provide details to address damaged stirrups/studs.

PLANS AND SPECIFICATIONS

C PLANS AND SPECIFICATIONS

Incorporate into *SP 00501* a requirement for contractors to submit a girder repair plan when there is damage.

Incorporate into *SP 00501* a girder damage repair plan for unknown conditions.

Consider during design whether details are required for repair of known girder damage and corrosion.

Require a stamped removal plan in *SP 00501*.

Require a survey of the top of existing girder elevations after removal of the bridge deck. Review survey information prior to final placement of formwork to verify final screed elevations.

Coordinate with Roadway to include a profile gradeline or provide top of deck elevations at discrete points (i.e., typically tenth points along the bridge) in the bridge plans.

Falsework will need to be attached to existing girders in a manner that does not damage reinforcement, prestressing strands or steel elements. The contract should specify that attachment details are subject to Engineer approval.

1.9.4 Construction Considerations

Cure bridge decks according to *BDM 1.5.4.*

1.9.4.1 Deck Screeding

C1.9.4.1

Consider deck constructability issues when specifying deck screeding requirements for both new decks and when installing an overlay.

When the deck width or skewed dimension causes the length of the screed equipment to be excessive (more than 100 feet), the deck may need to be placed in stages with or without a closure pour.

At a minimum, provide a 3-line profile for structural and PPC overlay projects on existing decks.	It is challenging to fit a design surface to the existing surveyed surface. The existing surface is going to vary and equipment will need to accommodate variations. Advanced grade control is typically needed. Consider the minimum constructible thickness of the chosen overlay material and the appropriate construction tolerances. The nominal thickness of the overlay may need to be increased to accommodate these tolerances. Unless other information is available, the minimum overlay thickness is typically two times the aggregate thickness.
On skewed decks, a sharp vertical curve on the structure may cause problems with screeding on the skew. When a structure has different skews at adjacent bents, base the skew of the screed equipment on the average of the bent skews.	It may be necessary to perform some unique sequencing, such as preloading the deck with plastic concrete far enough ahead of the screed machine to preload the beams to get unison deflections and allow the screed to run normal to the beams. There are circumstances where a machine cannot be used, such as along the gutter lines which will require manual finishing.
Where staging is shown on the plans, place a longitudinal joint along a longitudinal beam line and not in a wheel line. Consider this in the beam layout.	
Consider whether the finishing machine can follow the actual slope of the roadway in one placement. Place longitudinal joints along a longitudinal beam and consider this in the beam layout.	Deck screeds can accommodate a crown section in one placement, full width, when the superelevation remains constant. When the superelevation rates vary, the deck will normally need to be placed in separate placements.
When a structure is curved with radial bents, the screed equipment and deck placement remains normal to the roadway centerline. In this case, the screed equipment must be equipped with variable speed capacity at both ends.	Perform sufficient geometric calculations to determine the best method or direction of deck screeding. When necessary, place the required sequencing and direction of screeding, skewed or normal, on the detail plans.

1.9.4.1.1 Beams not Supported by Falsework

When the structure has a skew, add a note to the plans specifying that the screed equipment shall run parallel to the bents, on a skew.

1.9.4.1.2 Falsework Supported Beams

Ideally it would be best to place and screed skewed decks on the skew, but practically it is not required.

C 1.9.4.1.1

The main concern of this type of placement is that the beams deflect equally in unison, so deck thickness and clearances end up as shown on the plans. To deflect equally the beams need to be loaded equally.

C1.9.4.1.2

There is less concern regarding how the concrete is placed for falsework supported beams. There will still be a small amount of falsework crush due to the added dead load of the deck.

1.9.4.2 Deck Closure Pours

The use of polypropylene fibers are required in all portions of the deck, including the deck closures. On local agency projects polypropylene fibers are recommended but not required.

C1.9.4.2

Where deck closures are placed under traffic, minor cracking within the closure can be expected. This cracking is typically minor and does not result in significant long-term maintenance. The amount of cracking expected will be a function of the traffic induced vibrations at the site. See *BDM 1.9.4.4* for a discussion on vibration levels.

See *BDM 1.9.4.3* for discussion of closure pour options.

See *BDM 1.5.6.2.5* for discussion of precast beam bridges.

See *BDM 1.5.7.11* for discussion of CIP superstructures.

See *BDM 1.6.2.18* for discussion of steel structure widening.

See *BDM 1.11.2.5* for discussion of integral abutments.

1.9.4.3 Deck Pour Sequence

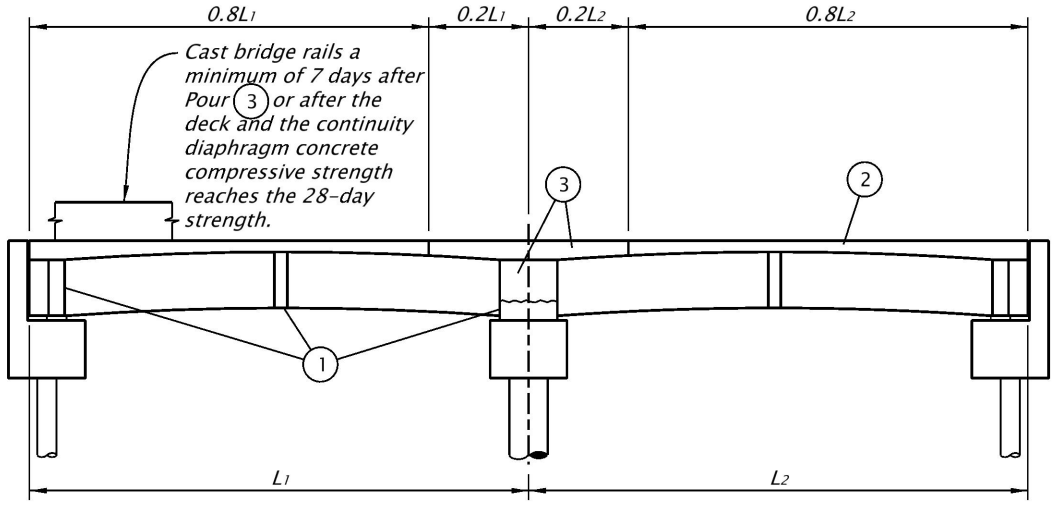
1.9.4.3.1 Prestressed Concrete Girder Bridges

Place decks on precast prestressed beams no less than 30 days after prestress transfer. For bridges designed simple for dead loads made continuous for live loads, pour the bottom portion of the continuity diaphragm 30 days minimum after prestress transfer. Cast bridge deck seven days minimum after the diaphragm concrete pour. Cast top portion of the continuity diaphragm and the remaining bridge deck a minimum of seven days after the previous bridge deck cast. The pour sequence of two spans designed simple for dead loads made continuous for live loads is shown in *Figure 1.9.4.3.1-1*.

C1.9.4.3.1

The 30 day wait is to allow a majority of the prestress camber to occur, thus enabling more accurate determination of beam build-up for the deck screeding and to minimize restrain moments due to girder creep and shrinkage.

Figure 1.9.4.3.1-1 Deck Pour Sequence – Prestressed Concrete Spans



DECK POUR SEQUENCE - PRESTRESSED CONCRETE GIRDER SPANS

POUR SEQUENCE

1. *Cast end diaphragms, intermediate diaphragms, and bottom portion of continuity diaphragm 30 days minimum after prestress transfer.*
2. *Cast bridge deck a minimum of 7 days after Pour (1).*
3. *Cast top portion of continuity diaphragm and the remaining bridge deck a minimum of 7 days after Pour (2).*

1.9.4.3.2 Steel Girder Bridges

Develop deck pour sequences for continuous steel spans according to the span and deflection characteristics of the particular bridge.

Provide minimum negative flexure slab reinforcement per *LRFD 6.10.1.7* as needed. Set retarding admixture may be required to reduce excessive induced stresses in adjacent spans placed sequentially.

Any changes to the pour sequence during construction must be analyzed by the contractor's engineer to determine any effects on stresses and camber. Complete this review early in the process, because it may affect the beam fabrication.

The following steps are a general rule for pour sequence of continuous steel bridges:

1. Pour (1) consists of all positive moment areas along the bridge which will not cause upward deflection on other span/s. No waiting period is required between these spans.
2. Pour (2) consists of multiple separate placements of all positive moment areas of spans that cause upward deflection on other spans. The wait period between these span placements is a minimum of three days after the last pour (1) ended and reaches 70 percent of final strength. When multiple spans are placed sequentially in the same pour, set retarding admixture may be required to reduce excessive induced stresses in adjacent spans.

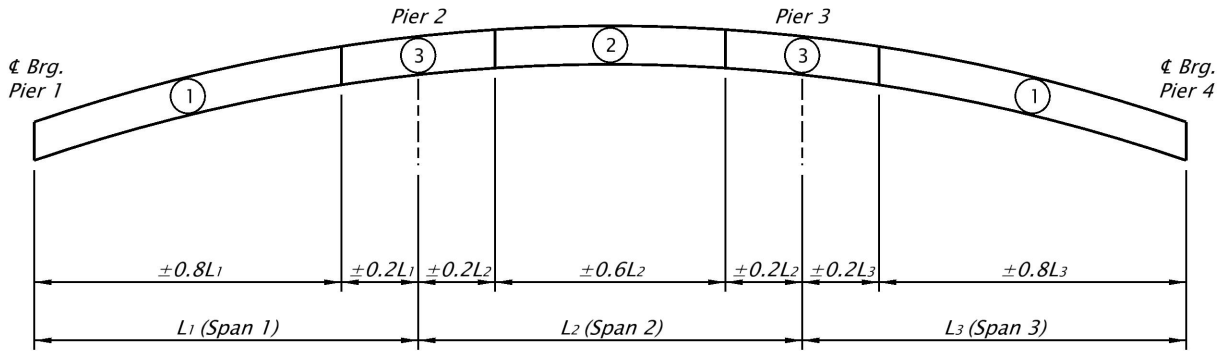
C1.9.4.3.2

The general principal is to first place the sections that are outside of the negative moment zones. Subsequent placements may produce negative flexure in the previously placed sections (See *LRFD C6.10.3.4.1* for commentary).

3. Pour (3) consists of all negative moment areas. The pour can be placed a minimum three days after the last pour (2) ended.

The pour sequence of three span continuous balanced bridges is shown in *Figure 1.9.4.3.2-1*.

Figure 1.9.4.3.2-1 Deck Pour Sequence – Steel Spans



DECK POUR SEQUENCE - STEEL SPANS

POUR SEQUENCE

1. *Make Pours (1). May be made simultaneously or separately as desired by the contractor.*
2. *After a minimum of 3 days after the completion of Pour (1) and concrete has reached 70% full strength. Make Pour (2).*
3. *After a minimum of 3 days after completion of Pour (2), make Pours (3). Pours (3) may be made simultaneously or separately.*

The deck pour sequence for bridges designed continuous for live load consists of two pours. Pour (1) for all positive moment areas except for closure pours. Pour (2) consists of all closure pours at interior and end bents a minimum of three days after pour (1).

1.9.4.4 Vibrations

Although damage to concrete due to vibrations is rare, avoid unnecessary vibrations where reasonable measures can be taken. For staged construction, providing deck closure segments is preferred to minimize both vibrations and the effects of adding additional deck dead load, creep and shrinkage to the first stage.

Providing either a joint or closure segment between substructure (cap) stages will also reduce potential for traffic vibrations to be transmitted through those elements. See BDM *1.11.2.5* for more discussion.

Where there is a concern that vibrations may be excessive, consider the following practices as mitigation:

- Low-slump concrete – Although concrete damage due to vibrations is rare, use of low-slump concrete (greater than 4 inches) will minimize the risk. ODOT's HPC deck concrete mix is generally a low-slump mix that meets this requirement. Therefore, generally no change to the standard HPC deck concrete mix is necessary.
- Reinforcing details – Do not use hooked bars in closure segments. Ensure lap splices are in contact and well-tied as much as possible. Where lap splices cannot be in contact, use two rows of longitudinal bars tied to both lap splice segments to create a rebar mat that cannot be easily moved.

C1.9.4.4

Vibrations from adjacent traffic and construction activity are not likely to cause cracking in freshly placed deck concrete. One ODOT project recorded vibrations up to 0.6 in/sec during a second stage deck placement with only minor deck cracking near the closure area. Typical deck closure placements may have even higher vibrations.

Minor cracking can be expected in deck closures placed under traffic. However, this cracking rarely results in long-term maintenance concerns. See the **Deck Closure Pours** discussion in *BDM 1.9.4.2* for closure pour options.

See *BDM 1.11.2.5* for joint options at integral abutments.

Table 1.9.4.4-1 is a very rough guide to vibration levels.

- Retarder admixture – Varying amounts of set retarder admixture can be used such that the entire deck will set up at about the same time. The Structure Quality Engineer from the ODOT Construction Section can assist in determining when this admixture is needed and how to apply it.
- Reduce vehicle speed – Where vibration is due to adjacent traffic, reducing vehicle speed will generally reduce the amount of vibrations. However, vehicle speeds will generally need to be reduced down to around 15 mph before a significant reduction in vibrations can be obtained. Therefore, only consider this measure in extreme circumstances. Where possible, moving traffic laterally from an adjacent deck placement will likely be more effective than reducing vehicle speed.

Table 1.9.4.4-1 Vibration Levels

Measured Vibration (inch/second)	**Vibration Perception Level**
0.08	vibrations perceptible
0.1	continuous vibrations may begin to annoy people
0.2	short-term vibrations may begin to annoy people
0.4 to 0.6	typical max. short-term vibration, concrete bridge < 100 foot span
0.6 to 1.0	typical max. short-term vibration, concrete bridge > 100 foot span

1.9.4.5 TP&DT / Stage Construction

Discuss traffic control issues early in the project with both region project development team and the Traffic Control designer.

When stage construction is proposed, arrange the stage construction widths so that the overlay can be constructed in widths between 6 feet and 30 feet which are comfortable widths for structural concrete overlay finishing machines and placement of non-structural concrete overlays or ACP. Avoid placing longitudinal construction joints in the wheel paths.

C1.9.4.5

Temporary protection and direction of traffic (TP&DT) requirements are important design considerations and could control project cost, project scheduling and, as a result, the type of overlay. Urban projects or narrow roadway width structures may require very short overlay cure times that could limit the use of a SC overlay.

1.9.5 Bridge Drainage

Provide an appropriate drainage system on or adjacent to bridges that have curbs or concrete parapet rails.

Review the roadway plans drainage details. Provide the hydraulics designer the bridge length, deck grades, cross-slope, typical section, and deck surface so the deck drain layout can be determined.

C1.9.5

Normally, drainage retrofitting needs to be addressed only when the project involves a major rehabilitation of the bridge. Generally, retrofitting existing bridges from a direct discharge to a piped system is not necessary. Bridge widening normally can use the same type of drainage system as the existing bridge. Contact the Hydraulics Unit for additional guidance about when drains are required. Contact the Environmental Unit to ensure drains meet environmental regulations.

When drains are required, the Hydraulics Unit does the designs and determines the size and spacing. See the *Hydraulics Design Manual Chapter 12 (Storage Facilities, Chapter 13 Storm Drainage* and *Chapter 14 Water Quality* for additional information.

1.9.5.1 Design Considerations

Incorporate features into the bridge deck drainage system to facilitate and minimize maintenance activities. Coordinate with the Environmental and Hydraulics to determine the appropriate bridge drainage system.

Capture drainage upslope of the bridge in inlets before coming onto the bridge. When grades allow, carry drainage off the bridge to inlets. Drainage not carried to inlets at the ends of the bridge is removed from the bridge deck using drains.

C 1.9.5.1

The primary objective of the bridge deck drainage system is to remove runoff from the bridge deck before it collects in the gutter, shoulder or lane thus exceeding the allowable design spread of water. Early coordination is beneficial to the project delivery process.

The benefits of a properly designed and maintained deck drainage system include the following:

- Efficient removal of water from the bridge deck which decreases the risk of hydroplaning and enhances public safety.
- Long-term maintenance and service life of the bridge is improved.
- Preservation of the structural integrity of the bridge.
- Enhanced aesthetics by elimination of superstructure and substructure staining.
- Minimized or eliminated erosion on bridge end slopes.
- Reduced pollutant discharges into streams and wetlands, and compliance with permits and laws that regulate these discharges.

Special environmental considerations may be required on some projects (see Environmental *BDM 2.14.8*). Hydraulic requirements take precedence over water quality requirements (see Storm Water *BDM 2.14.9*).

Drains are not allowed to discharge directly into:

- Designated water quality limited streams.
- Streams with severe non-point source pollution problems.
- Streams with populations of listed, proposed or candidate threatened and endangered (T&E) species of fish or other aquatic life.

In these conditions, provide a piping system that carries the drainage to a storm water control facility (see the Hydraulics Design Manual for additional information). Roadway surface and sidewalk runoff needs to be actively contained and treated because they are considered pollutant sources. When there is a hard barrier separating the sidewalk from the roadway surface, collecting drainage is more complex. In these situations, coordinate with the hydraulic designer to find a solution to treat or mitigate storm water to the maximum extent possible. Coordinate with the hydraulic designer to include sidewalk runoff in drainage calculations. When new sidewalks are added to an existing bridge where storm water previously sheet flowed off the side, contain and treat the runoff from the roadway surface for the new condition.

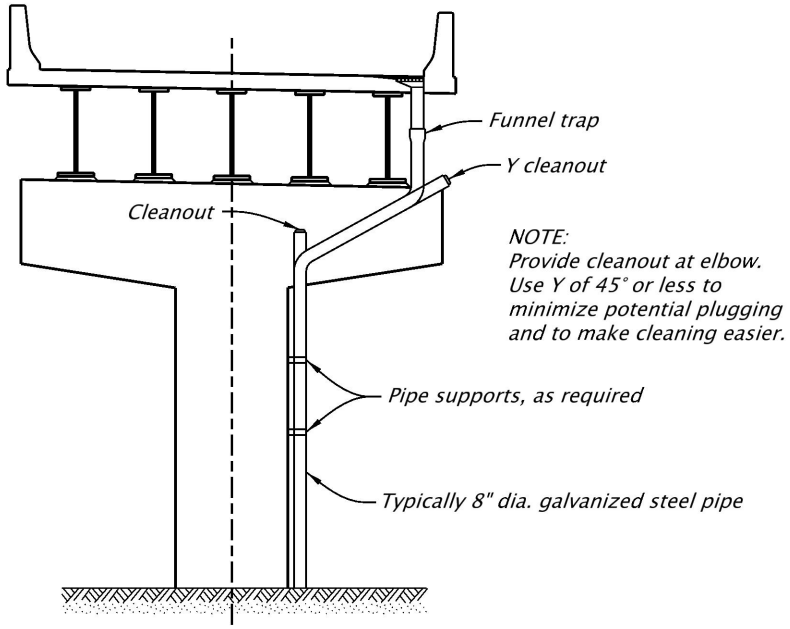
When the above conditions are not present, direct discharge to the ground below may be allowed. Drainage directly discharged to the ground below is not to cause erosion or be a hazard to the public. To prevent exposure of the superstructure to the drainage, carry it by drainpipes to 3 inches below the bottom of the superstructure.

1.9.5.2 Detailing

Indicate drain locations on the General Plan and Girder Layout sheets, and appropriate detail sheets. Show drainpipes and details on abutment, interior bent, deck and girder detail sheets. On viaducts or structures with extensive piping, provide a separate sheet showing entire drainage layout.

Provide minimum 8 inch diameter galvanized steel drainpipe.

Figure 1.9.5.2-1 Drainpipe Detail



Seismic design requirements for concrete containment within columns precludes placement of drainpipes within columns.

For 90 degree pipe connections, use 2-45 degree connections or a 4 foot minimum radius sweeping 90 degree connection. Add clean-out ports or junction boxes at every 90

C 1.9.5.2

See *DET 3120* for general deck drainage details. *Figures 1.9.5.2-1, 1.9.5.2-2 and 1.9.5.2-3* are examples of different applications. The detailing would need to be adapted to the specific girder type used.

degree connection. Clean-outs should be at a 45 degree angle to the main line.

Deck drains and drainpipes become easily clogged and are a continual maintenance problem. High pressure hoses used for cleaning cannot make 90 degree turns.

Verify that the gutter profiles do not result in **birdbaths** or unsightly dips in the rail.

When there is a question, plot the gutter grade.

Place drains upslope from expansion joints to capture drainage before it reaches the joints.

When long pipe runs are utilized for longer crossings (greater than 100 feet) and bridges with multiple spans, match pipe grade with roadway grade and see the following references for additional guidance:

- *Bridge Crossing with Ductile Iron Pipe, DIPRA*.
- *Guidelines for Bridge Water Pipe Installations*, Raj B, Mark P & Web C.

Provide sufficiently sturdy and properly located pipeline support to accommodate the weight of the pipe, its contents and other applicable loadings such as joint movement, seismic activity, traffic vibrations, insulation, etc.

Include expansion/contraction couplings on plans when required (longer than 100 feet lengths). Locate expansion/contraction couplings in the pipeline adjacent to bridge expansion joints.

The number and location of expansion/contraction couplings, if required, are determined by the length and design of the bridge in consideration of the maximum anticipated temperature differential.

Figure 1.9.5.2-2 Example Bridge Drainage Plan and Elevation

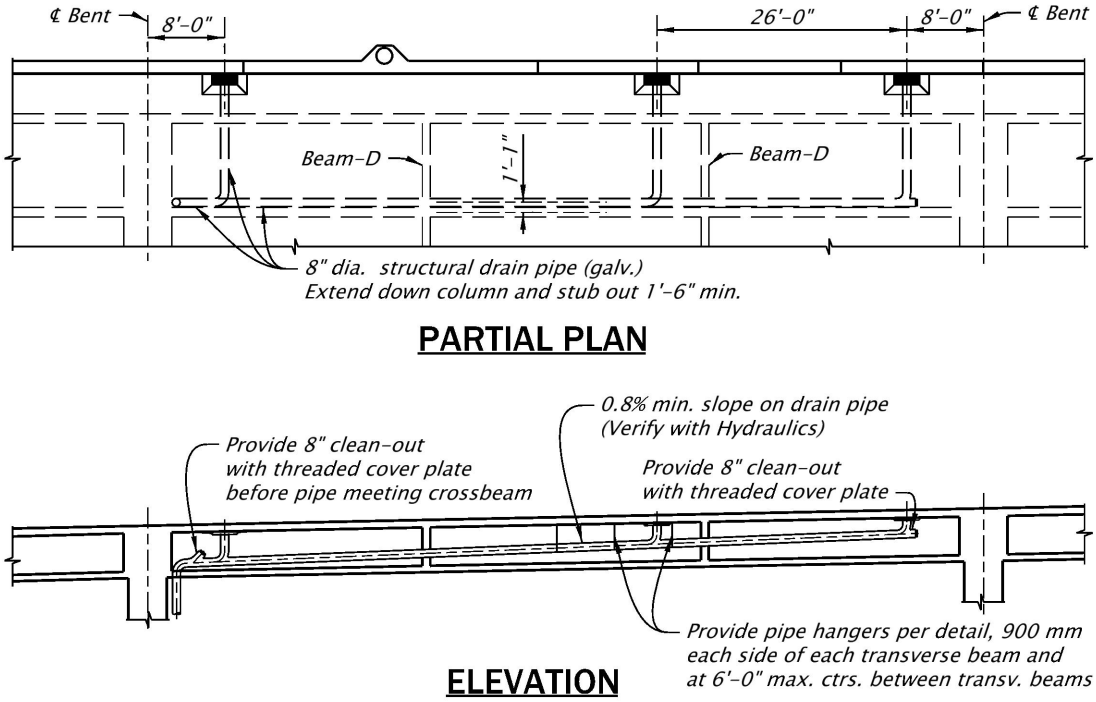
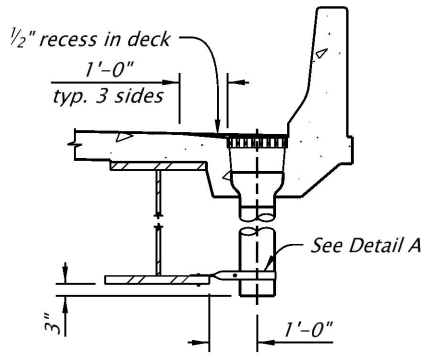
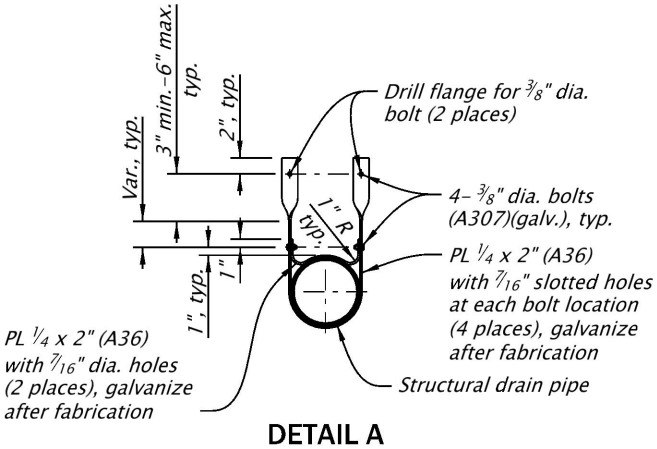


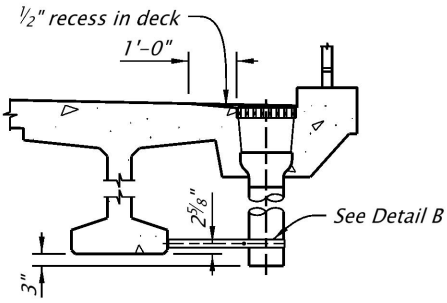
Figure 1.9.5.2-3 Example Bridge Deck Drain Details



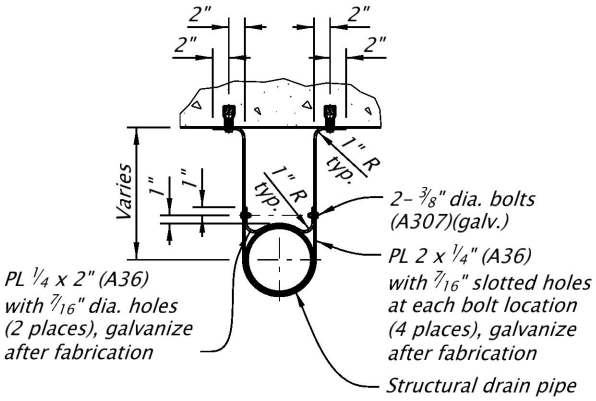
DECK DRAIN DETAIL



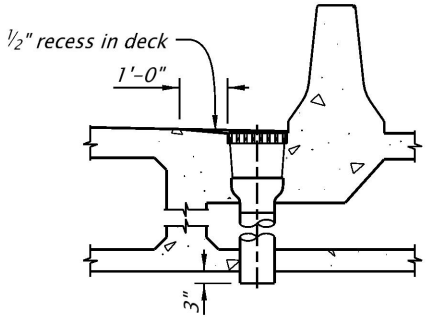
DETAIL A



DECK DRAIN DETAIL



DETAIL B



DECK DRAIN DETAIL