

CHAPTER 412

Bridge Preservation

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The design memorandum applicable revision date is noted in brackets next to each section heading below.

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BRIDGE PRESERVATION

There are approximately 19,000 bridges on public roads and streets in Indiana. Over 5,500 of these are on the State highway system. These bridges are designed and constructed to provide an adequate margin of safety and service life for the traveling public through the application of stringent design criteria and construction specifications. Nevertheless, all structural elements deteriorate over time, sometimes prematurely, and they will eventually present a hazard to the bridge users if not remedied. The Department's efforts to maintain its bridge inventory in a state of good repair requires a balanced approach between bridge preservation and bridge replacement. This chapter focuses on bridge preservation.

412-1.0 INTRODUCTION TO BRIDGE PRESERVATION [REV. MAR. 2021]

Bridge preservation as defined by FHWA is actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridge, keep bridges in good condition and extend their life. Bridge preservation encompasses two work types: Preventive Maintenance and Rehabilitation.

Preventive maintenance treatments preserve the system, slow future deterioration, and maintain the functional condition. Preventive maintenance may be condition-driven or on a fixed cycle (scheduled) but does not include treatments that substantially increase structural capacity. Eligibility criteria contained in the *Bridge and Culvert Preventative Maintenance Agreement* (BCPMA) for bridge preventive maintenance treatments have been incorporated into this chapter. For a Local Public Agency (LPA) to participate in preventive maintenance activities, the LPA must have an INDOT-approved Bridge Asset Management Plan.

Rehabilitation treatments include major work required to restore the structural integrity of a bridge as well as work necessary to correct major safety defects. Functional improvements such as adding a travel lane or increasing the vertical clearance are considered rehabilitation by the Department, but are not necessarily preservation.

The following sections describe project development procedures, design criteria, and type of treatments for Preventive Maintenance and Rehabilitation projects.

412-1.01 Bridge Preservation Program [Rev. Mar. 2021]

Each district identifies bridge preservation projects through the Bridge Asset Management process. The process includes developing a preliminary scope of work and budget based on the need for preventive maintenance or rehabilitation treatments.

The need and extent of a bridge preservation project should consider the following:

1. Condition of structural elements;
2. load carrying capacity;
3. adequacy of seismic resistance;
4. adequacy of traffic carrying capacity;
5. need to address safety hazards;
6. need to address geometric deficiencies; and
7. economics of rehabilitation versus replacement.

Bridge Inspection reports created for the INDOT Bridge Inspection Program are a valuable resource when scoping a Bridge Preservation project. All routine, fracture-critical, and underwater reports can be found in the Bridge Inspection Application System (BIAS). For access to BIAS, contact the system administrator at INbridgeshelp@indot.in.gov.

412-1.02 Bridge Preservation Project Types and Treatments [Rev. Mar. 2021]

The scope of work will determine whether a project is classified as either Preventive Maintenance or Rehabilitation. The scope of work should consider the following:

1. Age of the existing bridge deck;
2. Number of previous bridge deck overlays;
3. Quantity of estimated deck patching;
4. Remaining service life of the structure;
5. Cycle and cost of future repairs; and
6. Level One design criteria.

See Section 412-2.0 for design criteria and submittal process.

412-1.02(01) Preventive Maintenance Project [Rev. Mar. 2021]

A Preventive Maintenance project aims to prevent, delay or mitigate deterioration. Treatments may be condition driven or on a fixed cycle (scheduled) but do not include structural or operational improvements of an existing bridge beyond its originally designed strength or capacity. For a Local Public Agency (LPA) to participate in preventive maintenance activities, the LPA must have an INDOT-approved Bridge Asset Management Plan.

Condition-Driven Preventive Maintenance

The following treatments are considered condition-driven preventive maintenance:

1. Bridge-Length Culvert Lining;
2. Bridge Deck Patching, partial or full depth;
3. Approach Slab Repair and Replacement;
4. Joint Repair, Replacement, and Elimination;
5. Mudwall Patching;
6. Bridge Deck Overlays - Polymeric (thin) or Concrete (rigid);
7. Spot Coating and Bridge Painting;
8. Substructure Patching or Sealing;
9. Superstructure Crack Mitigation;
10. Erosion Mitigation;
11. Debris Removal and Channel Cleaning;
12. Slopewall Repair and Replacement;
13. Bearing Repair and Replacement;
14. Scour Mitigation;
15. Bridge Deck Creak Sealing;
16. Brush Cutting¹ and Herbicide Application¹;
17. Railing Repairs¹;
18. Relief Joint Repairs¹; and
19. Upgrading End Treatments, Guardrail, Railing, Attenuators^{1 2}.

¹Items may only be included in a project which incorporates other preservation treatments.

²When found to be cost effective.

Eligibility criteria for condition-driven preventive maintenance treatments is shown in Figure [412-1A](#). Exceptions to the eligibility criteria may be considered when the bridge conditions or the proposed treatment do not meet the criteria but the recommended treatment is justified and proven to be effective. Exceptions require the approval of both the Bridge Asset Manager and the Bridges Division Director.

Scheduled Preventive Maintenance

Scheduled preventive maintenance treatments are more appropriately completed on a fixed cycle to maintain a structure at its current level and prevent or reduce deterioration. These treatments are typically accomplished by district maintenance forces. The Bridge Rehabilitation Department should be contacted prior to including a scheduled preventive maintenance treatment in a contract.

The following is a list of treatments considered as scheduled preventive maintenance:

1. Cleaning and Flushing Bridge Decks;
2. Substructure and Superstructure Washing;
3. Cleaning Deck Drains;
4. Cleaning and Lubricating Bearings;
5. Cleaning Joints; and
6. Bridge Deck Sealing.

Eligibility criteria for scheduled preventive maintenance treatments is shown in Figure [412-1B](#).

412-1.02(02) Rehabilitation [Rev. Mar. 2021]

Rehabilitation consists of treatments in which portions of the existing bridge remain and may include treatments which substantially increase structural capacity. In addition to the following, treatments which do not meet the eligibility criteria for preventive maintenance are considered rehabilitation.

1. Bridge deck replacement;
2. Bridge deck patching, exceeding maximum 10% deck area - partial or full depth;
3. Superstructure replacement;
4. Superstructure repair to restore structural capacity;
5. Coping reconstruction;
6. Bridge widening;
7. Increasing vertical clearance.

For questions regarding activities not listed above, the Bridges Division, Office of Bridge Design should be contacted.

412-1.02(03) Historic Bridge Rehabilitation

Historic bridge rehabilitation is a special project type which includes a Select or Non-Select historic bridge. Rehabilitation of a historic bridge must be undertaken in accordance with the programmatic agreement to manage and preserve Indiana's Historic Bridges. See Section 412-5.0 for additional information on historic bridge rehabilitation.

412-2.0 PROJECT DEVELOPMENT [REV. MAR. 2021]

A Bridge Preservation project should be developed as either a Preventive Maintenance or a Rehabilitation project. The following activities may not be applicable to all Bridge Preservation projects but should be evaluated for each project. The design criteria and submittal process are distinct for each project type and discussed separately.

Scour Analysis

Each Bridge Rehabilitation project crossing a waterway requires a scour analysis. For an INDOT-maintained bridge, a Preventive Maintenance project does not require a scour analysis, except for Latex Modified Concrete (LMC) or other rigid overlay. For an LPA-maintained bridge, a scour analysis is required for each Preventive Maintenance project. When a scour analysis is required, the designer should contact the Office of Hydraulics manager to determine if a scour analysis has been completed previously or should be completed as part of the current project. The determination should be documented in the Bridge Preventive Maintenance Meeting Minutes or Bridge Rehabilitation Report.

For INDOT-maintained bridges, scour countermeasures deemed necessary by analysis or a scour-critical bridge inspection rating will be included in the scope of work for each Rehabilitation project. For Preventive Maintenance projects, the necessary scour countermeasures will be installed as part systematic scour projects. For LPA-maintained bridges, scour countermeasures deemed necessary by analysis or a scour-critical bridge inspection rating must be included in the scope of work for both Rehabilitation and Preventive Maintenance projects. A decision matrix is illustrated in [Figure 412-2C](#), Scour Analysis and Countermeasures.

When a scour analysis is completed as part of the project, it must be signed, sealed, and dated by a professional engineer licensed in Indiana and submitted for review at least 30 days prior to the Preliminary Plans Submission. A template for documenting scour calculations is available from the Department's [Editable Documents webpage](#), under Hydraulics.

Load Rating

For a Preventive Maintenance project, the need for the existing load rating should be determined at the field inspection. Utilizing an LMC or other rigid overlay requires a load rating, but a polymeric or other flexible overlay does not. Other treatments that add significant deadload, e.g. replacing an aluminum railing with a concrete railing or otherwise changing the structural behavior of the bridge also require a load rating. For a Rehabilitation project a load rating is required regardless of the preservation treatment proposed.

The load rating request should be submitted via email to Coordinator 8 and the Bridge Load Rating Engineer copied. Relevant plans sheets that are too large to email should be uploaded to ERMS. The Load Rating Request Form and Load Rating Summary are available from the Department's [Editable Documents webpage](#), under Bridges.

Asbestos Report

An Asbestos Report is required for all Bridge Preservation projects. The designer should contact the project manager early in the development of the project to determine if the report is on file or needs to be completed. It is the responsibility of the District Bridge Inspection Engineer to complete the Asbestos Report for each of the INDOT-maintained bridges within their district. For LPA projects the designer is responsible for coordinating the obtaining of the report with the LPA.

Environmental, Utilities & Railroads, and Right of Way

Each Bridge Preservation project is subject to NEPA and permitting requirements, utility and railroad coordination, and right-of-way acquisition requirements.

412-2.01 Preventive Maintenance Project [Rev. Mar. 2021]

The goal of a Preventive Maintenance project is to maintain the existing infrastructure in good condition. Preventive maintenance projects are discouraged on structures with load ratings less than 1. Preventive maintenance treatments proposed on a structure with a load rating less than 1 require the approval of the Bridges Division Director.

412-2.01(01) Design Criteria [Rev. Mar. 2021]

A Level One Design Criteria checklist is not required for permanent conditions of a Preventive Maintenance project. As such, a design exception is not required for the retention of an existing feature which does not satisfy INDOT criteria. However, a new design feature which does not satisfy INDOT criteria created by the project, or existing ones made worse, require a design exception, because such action in effect changes the structure as built. See Section 40-8.02 for design exceptions.

A Level One Design Criteria checklist is required for maintenance of traffic, except for detours.

Bridge Railing and Americans with Disabilities Act (ADA) requirements for a Preventive Maintenance project are discussed in Sections 412-3.01(03) and 412-3.01(04).

412-2.01(02) Submittal Process [Rev. Mar. 2021]

See Chapter 14 for specific documents to be submitted for review.

412-2.02 Rehabilitation Project [Rev. Mar. 2021]

A Rehabilitation project encompasses preservation treatments which do not meet eligibility criteria for preventive maintenance in Section 412-1.02(01). Rehabilitation treatments also include bridge deck or superstructure replacement, widening for added travel lanes or increased clear roadway and other rehabilitation altering the out to out coping width.

412-2.02(01) Design Criteria

A Level One Design Criteria checklist is required. Typically the 3R criteria are appropriate for bridge rehabilitation; however, the use of 3R versus 4R criteria depends on the scope of work. For example, a structure to be widened as part of an added travel lanes 4R project should utilize the 4R design criteria. See Chapters 53, 54, and 55 for 4R, 3R Freeway, and 3R Non-Freeway criteria, respectively.

Existing features made worse require a design exception, regardless of the proposed feature meeting the criteria. Reductions in vertical clearance are of particular importance. See Section 40-8.02 for design exceptions.

Exceptions to Level Two design criteria should be documented in accordance with Section 40-8.02

412-2.02(02) Submittal Process [Rev. Mar. 2021]

See Chapter 14 for specific documents to be submitted for review.

412-2.03 Historic Bridge Rehabilitation Project [Rev. Feb. 2018]

The *Programmatic Agreement among the Federal Highway Administration, the Indiana Department of Transportation, the Indiana State Historic Preservation Officer, and the Advisory Council on Historic Preservation Regarding the Management and Preservation of Indiana's Historic Bridges* (Historic Bridges PA) governs the project development process for historic bridges in Indiana. The PA was executed on August 22, 2006, and is available on the Indiana Historic Bridges Inventory website at <http://www.in.gov/indot/2530.htm>.

Historic bridge project development process documents are available on the Historic Bridge Inventory Summary & Results webpage at <http://www.in.gov/indot/2531.htm>.

Where a project involves a historic bridge, the bridge owner must prepare a Historic Bridge Alternatives Analysis for review and concurrence by the Department, after which it will be submitted to consulting parties for review and approval as part of the Section 106 consultation process.

See Section 412-5.0 for additional information on historic bridges and alternatives analysis.

412-2.03(01) Design Criteria [Rev. Feb. 2018]

See Section 412-5.0 for design criteria associated with evaluating alternatives.

412-2.03(02) Submittal Process [Rev. Feb. 2018, Mar. 2021]

A Historic Bridge Rehabilitation project should follow the submittal process for a standard Rehabilitation project, except that a Historic Bridge Alternatives Analysis will serve as the Bridge Rehabilitation Report.

412-3.0 PROJECT CONSIDERATIONS

This section discusses project considerations and issues that relate specifically to bridge preservation projects. Designs should also follow guidance in other sections of Part 4 as economically feasible and applicable to bridge preservation projects.

412-3.01 General Preservation Considerations

412-3.01(01) AASHTO Bridge Design Specifications

INDOT practice is to design new structures using the current edition of the AASHTO *LRFD Bridge Design Specifications*. Rehabilitation often involves structures designed under a previous set of design specifications. The matrix in Figure [412-3A](#) describes which design methodology is to be used based on work type.

412-3.01(02) Minimizing Bridge Joints

Whenever possible, bridge deck joints should be eliminated. Consideration to leave an expansion joint in place should include the joint type and expansion length, structure type, and remaining life of the bridge. End bent construction may be either semi-integral or fully integral to achieve this goal. Semi-integral design should be used where existing battered piling is to be reused. Battered piling may be removed by excavation and removal to a depth of one foot below the bottom of the new end bent. INDOT practice is to build fully integral end bents where possible.

The use of a link slab may be considered for both end bent and interior joint elimination. Standard details have not been created for link slabs. Project-specific details should be developed in coordination with the Bridge Rehabilitation Department.

412-3.01(03) Bridge Railing [Rev. Mar. 2021]

1. Preventive Maintenance Project. Existing bridge railing may remain in place as part of a preventive maintenance project if the railing is in good condition and is functioning as originally intended with the following exception. All existing aluminum bridge railing on the NHS should be replaced when the treatments include a rigid overlay. The current standards apply to new bridge railing. The intent to leave substandard railing in place should be clearly stated in the Initial Field Check Minutes and agreed upon by the Bridge Rehabilitation reviewer.
2. Rehabilitation Project. The current standards apply to bridge railing (retained or new) as part of a Bridge Rehabilitation project. A design exception is required for bridge railing which do not meet the current standards or required test level.

412-3.01(04) *Americans with Disabilities Act (ADA)* [Rev. Mar. 2021]

1. Preventive Maintenance Project. Flexible and rigid overlays are considered alterations in accordance with the Department of Justice/Department of Transportation Joint Technical Assistance on the Title II of the ADA. When an overlay is included in a Preventive Maintenance project, ADA-compliant curb ramps must be included in the scope of work. A Determination of Technical Infeasibility is required for curb ramps which cannot be constructed compliantly due to an existing constraint. See Section 40-8.04.
2. Rehabilitation Project. For a Rehabilitation project, ADA requirements are evaluated with other Level One criteria.

412-3.01(05) Roadside Safety [Rev. Mar. 2021]

1. Preventive Maintenance Project. Roadside safety features should be upgraded to current standards when proved to be cost effective at part of a preventive maintenance project.
2. Rehabilitation Project. All existing roadside safety items including but not limited to guardrail, transitions and end treatments will be upgraded to current operational standards.

412-3.01(06) Field Survey

When a rehabilitation project involves bridge deck replacement, superstructure replacement, or widening of the substructure, a field survey may be warranted. A typical survey will involve a structure profile and a check of features such as cap and bridge seat elevations.

The purpose of the survey is to verify elevations so that datum corrections can be made in the plans and do not have to be determined in the field during construction. The Bridge Rehabilitation Department will approve the extent of survey before field work begins.

Existing vertical and horizontal railroad clearances should be measured and included in the bridge inspection report if the project involves a railroad.

412-3.01(07) Bearings

Due to low cost, low maintenance and superior seismic performance, INDOT prefers the use of elastomeric bearings when possible. The decision to replace other bearing types will be made on a project by project basis. The replacement of steel bearings with elastomeric bearings should only be considered when deck or bent cap removal is included in the rehabilitation.

Replacement of steel bearings which are in good condition may not be warranted even during a deck removal. Existing bearings may be left in place when bent cap modifications would add substantial cost to the project, unless replacement or retrofit is required for seismic considerations.

Bearing types should not be mixed on the same pier or bent due to differences in movement.

412-3.01(08) Anchor Systems for Reinforcement

Preference is to lap new reinforcement to existing reinforcement. However, it may not always be possible or cost effective to expose sufficient existing reinforcement to lap with new reinforcement. An anchor system may be used to develop the strength of new reinforcement by attaching it to existing concrete. This type of connection develops the strength of the reinforcing within the new construction but does nothing to develop continuity with reinforcing that remains in the existing concrete. Thus, no attempt to transfer moment across the interface of old and new concrete should be attempted. When moment transfer is desired, existing reinforcing should be exposed and adequately spliced. This can be achieved by lapping new reinforcing with existing reinforcing or through the use of an approved mechanical splice.

The allowable materials used to anchor reinforcement are found on the Approved Materials List of Chemical Anchor Systems. The pay item for this work is Field Drilled Holes in Concrete, which includes creating the hole and applying the grout. Grout material for field drilled holes in concrete should be either a high-strength, non-shrink, non-metallic, cementitious grout or an approved 100% solids chemical anchor system in accordance with the Standard Specifications.

The embedment requirements to obtain a given tensile pullout value will vary between products. To maintain consistency, the plans should show the minimum required pullout value with the reinforcement sized to project 6 inches into the hole. Necessary adjustments to the hole depth or diameter or reinforcement length is the responsibility of the contractor.

Where vertical holes are to be drilled into the top of a concrete bridge deck, a minimum clearance of 2 in. should be maintained between the bottoms of the holes and the bottom of the slab. Where vertical holes are to be drilled over a concrete- or steel-beam flange, the holes may be extended to the top of the flange. A reduction in capacity may occur depending on the edge distance and spacing of field drilled holes in concrete. Further information on spacing between anchors and minimum edge distances can be found on the Approved Materials List for Chemical Anchor Systems.

If an anchorage system is used, place a note on the plans identifying the connection as follows:

*Field drilled hole in concrete. Embed bar 6 inches with an approved anchor system.
Minimum pullout = _____ kips.*

The value should be obtained from Figure [412-3B](#), Design Data for Anchor Systems. The values shown are for ultimate loads. If the full strength of the reinforcement is required, the values for $125\% f_y$ should be used. For all other connections, $100\% f_y$ may be used. These values are general guidelines for the embedment of reinforcement. Threaded or smooth dowels and headed studs can obtain significantly different values. The designer should review manufacturers' literature before specifying anchor systems.

412-3.01(09) Vehicular Vibration During Construction

All structures deflect when subjected to live loading, and many bridge widening projects are constructed with traffic on the existing structure. Fresh concrete in the deck is subjected to deflections and vibrations caused by traffic. Studies such as NCHRP 86 *Effects of Traffic-Induced Vibrations on Bridge-Deck Repairs* have shown the following.

1. Good-quality reinforced concrete is not adversely affected by jarring and vibrations of low frequency and amplitude during the period of setting and early strength development.
2. Traffic-induced vibrations do not cause relative movement between fresh concrete and embedded reinforcement.
3. Condition evaluation of widened bridges has shown the performance of widened section, with and without the use of a closure pour, to be satisfactory.

Additional measures need not be taken to prevent movement and vibration during concrete pouring or curing.

412-3.02 Bridge Deck Preservation Techniques and Considerations

412-3.02(01) Hydrodemolition

INDOT practice is to use hydrodemolition on bridge rehabilitation projects requiring deck patching when cost effective. This method should be specified to remove unsound or delaminated concrete. Hydrodemolition uses high pressure water jets to remove unsound concrete material. This minimizes residual cracking around patched areas caused by manual methods such as jackhammers. Hydrodemolition may not be cost effective for small bridge decks or in isolated locations.

When hydrodemolition is utilized, partial depth patching is included in the cost of hydrodemolition and should not be included in the contract.

412-3.02(02) Circular Crown

The normal cross slope on a new bridge deck is 2%. When an existing deck is to remain in place a minimum 1.5% cross slope may be retained. Maintaining the minimum cross slope is a requirement when an existing bridge deck to remain in place was built using a circular crown or other irregular form. An overlay depth exceeding 3 inches requires the approval of the Bridges Division, Office of Bridge Design manager.

412-3.02(03) Multiple Overlays

It is acceptable to remove an existing overlay and replace it with a new one. A new overlay should not be placed over an existing bridge deck overlay. The second overlay is counterproductive and adds to the dead load of the structure.

412-3.02(04) Rigid Overlay [Rev. Mar. 2021]

Rigid overlay is a general term, used describe multiple types of concrete overlays for bridge decks.

The latex modified concrete (LMC) overlay has been successfully used by INDOT since the 1970s. This overlay can be expected to protect the bridge deck for approximately 15 years depending on traffic and site conditions. The use of a rigid overlay requires proper preparation of the bridge deck by milling and removal of unsound concrete. The minimum LMC overlay thickness is 1.5 inches.

The use of a microsilica-based overlay on a State-owned bridge requires the approval of the Bridges Division, Office of Bridge Design manager.

Typically, a bridge deck should be replaced rather than overlaid a third time. A bridge deck should also be replaced if the amount of patching exceeds 35% of the deck area. See Figure 412-1A for the preventive maintenance eligibility requirements for rigid overlays.

412-3.02(05) Asphalt Overlay

This method was used in the past with limited success. However, new research, performance and materials may indicate that asphalt overlays over sheet membranes are an effective method of deck repair. Designers should contact the Bridge Rehabilitation Department prior to use.

412-3.02(06) Flexible Overlay [Rev. Mar. 2021]

A flexible overlay, also referred to as polymeric or thin overlay, has been utilized more in recent years. A flexible overlay is not appropriate for bridge decks which have previously received a concrete overlay and better suited for bridge decks with small amounts of delamination. See [Figure 412-1A](#) for the preventive maintenance eligibility requirements for flexible overlays.

412-3.02(07) Deck Patching

Deck patching is often required for bridge deck overlay projects. Full-depth patching should be estimated during the field check as the area to be replaced. If full depth patching is required, a minimum 50 ft² should be estimated. Partial-depth patching is not included as a pay item and estimated quantities are not required for projects with hydrodemolition.

If a large contiguous area of the deck is to be replaced, details for replacement of reinforcement should be provided. Actual deck patching areas will be determined by the amount of unsound concrete removed during the hydrodemolition process or by deck chaining for projects without hydrodemolition.

412-3.02(08) Additional Bridge Deck Overlay

Additional bridge deck overlay material is required to account for unsound concrete areas and surface irregularities. For bridge deck overlay projects, include an estimate of the pay item for additional bridge deck overlay. The estimate for this quantity should be calculated as follows:

$$\text{Additional Bridge Deck Overlay (yd}^3\text{)} = (0.00617) * (\text{Estimated Unsound Concrete Area, ft}^2) + (0.00486) * (\text{Overlay Area, yd}^2)$$

The estimated unsound concrete area should be determined at the field check and is equivalent to the area of the bridge deck that requires partial-depth patching. The coefficient assumes the patching is an average of 2 in. deep.

The estimated overlay area is the total exposed bridge deck surface. The coefficient assumes an additional 10% of the bridge deck area to compensate for surface irregularities.

The coefficients are derived as follows:

$$0.00617 = (2\text{in.})\left(\frac{1\text{ft}}{12\text{in.}}\right)\left(\frac{1\text{yd}^3}{27\text{ft}^3}\right)$$
$$0.00486 = (1.75\text{ in.})\left(\frac{1\text{yd}}{36\text{in.}}\right)(.10)$$

The material required for full-depth patching is included with the pay item for Bridge Deck Patching, Full Depth. It should not be included in the pay item for Bridge Deck Overlay, Additional.

412-3.02(09) Profile Grade Adjustments

Frequently, the profile of the proposed deck surface will be higher than the existing. An asphalt wedge should be constructed to transition between the new deck surface and the existing approach pavement. A pavement design is required to determine the appropriate pavement section

An asphalt wedge consists of a continuation of the bridge deck profile which extends 30 ft beyond the end of the approach slab. Beyond the grade continuation, the grade tapers back to the existing at a rate of 1 inch in 60 ft. The minimum thickness of asphalt wedge material is 1.5 inches. This requires a saw cut and transition milling at the end of the wedge. Considerations include existing pavement type and condition, grade change dimension and approach roadway geometry.

If the adjacent roadway pavement is concrete, pavement replacement is often the best method for tying into existing profile grades. The same taper rates apply for concrete pavement as for asphalt wedges.

See the INDOT *Standard Drawings* series 722-HMAW and 306-TMPT for more details.

412-3.02(10) Overlay Dams

Overlay Dam. An overlay dam is thickened section of overlay material at the bridge end. The existing reinforcement is exposed and then encased with overlay material providing better protection from damaged caused by snowplow blades and other hazards. Hydrodemolition or chipping hammers are used to remove an additional depth of existing deck at the bridge end. Overlay dams should be placed at expansion joints. Placement of overlays dams adjacent to 1A joints is optional. See [Figure 412-3C](#) for typical overlay dam details.

412-3.03 Superstructure Preservation Techniques and Considerations [Rev. Apr. 2020]

412-3.03(01) Dead Load Deflections

Unless the widened structure is completely prefabricated, deflection of the beams or girders will occur due to superimposed dead loads, such as the deck slab, diaphragms, or railings. To prevent the undesirable effects of this deflection, the widening should initially be built above the grade of the existing structure to allow for dead-load deflection. The deflected widening should approximate the grade of the existing structure. If proper provisions are not made to accommodate the dead-load deflection, construction and maintenance problems will ensue. Where the dead-load deflection exceeds 2 in., a closure pour should be considered to complete the attachment to the existing structure. A closure pour serves two useful purposes: it defers final connection to the existing structure until after the deflection from the deck-slab weight has occurred, and it provides the width needed to make a smooth transition between differences in final grades that result from design or construction imperfections.

In terms of the effects of dead-load deflection, two groups of superstructure types can be distinguished: precast-concrete-beam or steel-beam construction. The largest percentage of deflection occurs when the deck concrete is placed. For cast-in-place construction, e.g., a reinforced-concrete slab bridge, the deflection occurs after the falsework is released.

In precast-concrete-beam construction, dead-load deflection after placement of the deck is usually insignificant. In a cast-in-place structure, the dead-load deflection continues for a lengthy time after the falsework is released. In a conventionally-reinforced concrete structure, approximately one half to three quarters of the total deflection occurs over a four-year period after the falsework is released due to shrinkage and creep. The theoretical differential deflection that occurs between a new and existing structure is difficult to account for during design. Past performance indicates, however, that theoretical overstress in the connection reinforcing has not resulted in maintenance problems. It is assumed that some of the additional load is distributed to the original structure with no difficulty, or its effects are dissipated by inelastic relaxation. When a closure pour is utilized, the width should account for the amount of dead load deflection that is expected to occur after the closure is placed. A minimum closure width of 20 in. is recommended.

INDOT is satisfied with the performance of its bridge decks that are widened without the use of closure pours. This satisfactory performance also applies to a deck replacement that is poured in two phases while maintaining traffic and without the use of closure pours. Consequently, deck widening and phased deck replacement do not require closure pours unless the designer or district representative recommends otherwise. An example of where a closure pour may be warranted is for a steel beam or girder structure where uplift could occur.

412-3.03(02) Longitudinal Joints

Past performance indicates longitudinal expansion joints in a bridge deck between a widened portion and the existing portion have been a continuous source of bridge maintenance problems. Therefore, longitudinal expansion joints should not be used to separate existing and widened bridge decks.

When widening between adjacent structures, provide a minimum 1" open joint between the copings. An example would be the addition of travel lanes to twin structures separated by concrete barriers.

Experience has shown a positive attachment of the widened and original decks provides a better riding surface, usually presents a better appearance, and reduces maintenance problems. A positive attachment of old and new decks should be made for the entire length of the structure. The preferred method for attachment is to lap reinforcement. The following recommendations should be considered when widening existing decks.

1. A structure should be widened by removing concrete for a distance sufficient to allow adequate length for lapping the original transverse deck reinforcing to that of the widening.
2. Where removal will not provide sufficient lap length, reinforcing should either be doweled to the widened section or have transverse reinforcing exposed and extended by means of a mechanical lap splice. The design should ensure the development of existing reinforcement.
3. A structure with no overhangs, such as a longitudinally reinforced concrete slab, may be attached by doweling the existing structure to the widening. Double-row patterns for the dowels are preferred over a single row. Benching into existing concrete as a means of support has proven to be unsatisfactory and should be avoided.
4. Removal of the deck past the outside beam line will result in a cantilever slab condition. The design should ensure that the deck can resist the loadings anticipated during construction.
5. A longitudinal construction joint located over a beam flange should be avoided when possible. Longitudinal construction joints should preferably be aligned with permanent lane lines. These joints tend to be more visible than the pavement markings during adverse weather conditions.

412-3.03(03) Concrete Slab Structures

The designer should assess the condition of the coping and the portion of the deck from the coping to the first construction joint. This area is often in poor condition due to the presence of water and ice melting chemicals and consideration should be given to removal of this portion.

The overall condition of the superstructure should be evaluated. Large amounts of patching are rare in this type structure, so excessive patching may indicate the need for replacement of the structure.

412-3.03(04) Reinforced Concrete Girder Structures

RC Girder structures should be evaluated for replacement. Their age and condition do not usually make them a candidate for widening. A cost study should be performed to validate the need for replacement versus widening.

Deck replacement or widening of RC Girders should be considered only where a cost comparison indicates the replacement is not cost effective. Due to tee beam action, the designer should analyze the effect of removing the deck over girders to remain in place. Temporary girder supports may be required and will likely add significant cost and time to the project.

For structures with RC Girder end spans and steel or concrete beam main spans, the concrete girders should be removed and replaced in order to eliminate the deck joint. The new or widened superstructure should be made continuous if possible.

412-3.03(05) Prestressed Concrete Girder Structures

The following should be considered when rehabilitating a bridge with prestressed concrete girders:

1. Continuity. Simple span structures should be made continuous when the bridge deck is being replaced. Factors to consider include span ratio, deck reinforcement, diaphragm reconstruction and expansion lengths.
2. Girder Repair. Deterioration at the ends of prestressed concrete girders due to joint leakage or shear cracking can be repaired by encasing the girder ends in concrete. An example is constructing an integral or semi-integral end bent at the support.

An alternate to repair using concrete encasement is to apply a fiber wrap system at the girder end. Cracks and spalls in the girder are repaired by epoxy injection or other methods, and then the fiber wrap system is applied to the girder surface. Fiber wrap may only be used for encasing deterioration and may not be utilized for adding capacity.

For prestressed girders that have damaged or exposed prestressing strands, the designer should evaluate if girder replacement is required. Prestressing strands can be repaired or replaced in lieu of deck and beam replacement. Repair methods include mechanically coupling strands or encasing strands in high strength grout or concrete.

3. Field Drill Holes. Field drilled holes can be used to retrofit existing prestressed girders, but are not desirable. Drilled holes should only be placed in the web and should be placed to avoid draped prestressing strands and mild reinforcement. Where the girder is to be encased in concrete, such as an integral end bent situation, drilling near reinforcement is acceptable. The designer should review bridge plans and shop drawings for strand and reinforcement locations.
4. Diaphragms. Replace existing pier and end diaphragms when the bridge deck is to be replaced. The designer should evaluate if interior (intermediate) diaphragms should be replaced based on existing conditions.

Steel diaphragms should be considered when widening existing prestressed girder structures.

412-3.03(06) Steel Beam and Plate Girder Structures [Rev. Apr. 2020]

The following should be considered when rehabilitating a bridge with structural steel beams and plate girders:

1. Shear Connectors. Introducing composite action between the deck and the supporting beams is a cost-effective way to increase the strength of the superstructure. Beams should be made composite whenever the deck is being removed.

Composite action considerably improves the strength of the upper flange in a positive-moment area, but its beneficial effect on the beam as a whole is only marginal. The combination of composite action in conjunction with selective cover plating of the lower flange is the most effective way of beam strengthening.

Introducing composite action near joints prevents the deck from separating from the beams, thus increasing the service life of the deck.

2. Grinding and Peening. If the penetration of surface cracks is small, the cracked material can be removed by means of selective grinding without substantial loss in structural material. Grinding should be performed parallel to the principal tensile stresses when possible. Surface striations should be removed because they may initiate future cracking.

The most common application of grinding is to the toe of the fillet weld at the end of the cover plate so that it is in accordance with the fatigue requirements. Grinding can also be used where beams have been nicked due to the sawing off of an old deck.

Peening is an inelastic reshaping of the steel at the surface locations of cracks, or of potential cracks, by use of ultrasonic methods. This procedure not only smoothes and shapes the transition between weld and parent metal, it also introduces compressive residual stresses that inhibit the cracking. Peening is most commonly used where fatigue is an issue such as at the ends of cover plates or welded diaphragm connections.

3. Drilled Holes. At the tip of a crack, tensile stress exceeds the ultimate strength of the metal causing rapid progression when the crack size attains a critical level. Drilled holes placed at the tips of the crack are commonly used to alleviate this problem. The tips of the crack should be located by means of an established crack-detection method.

Sections should be checked to ensure that the reduced-member capacity due to the crack and the drilled hole is still adequate. The mitigation of the stress concentration at the tip is more critical, however, than the loss of net section. Hole size should be optimized to eliminate stress concentrations while considering loss of cross sectional area.

4. Welded Diaphragms. Current practice is to use only bolted connections for all new or replacement diaphragms. Welded diaphragms are a fatigue concern, however, retrofitting of existing welded diaphragm connections should be undertaken only when cracks are noticed upon inspection.
5. Welded Cover Plates. Termination of certain cover plates may be a fatigue concern. Typical mitigations should include peening or bolted retrofits. However, mitigations should be performed only when cracks are noticed upon inspection.
6. Other Fracture-Critical and Fatigue-Prone Details. An E or E' fatigue category detail, and Hoan detail should be identified. The need for retrofit will be determined by analysis.

7. Beam Straightening. This technique is restricted to hot-rolled steels. Steel deriving its strength from cold drawing or rolling tend to weaken when heated. The premise of heat-straightening is that the steel, when heated to an appropriate temperature, usually to cherry color, loses some of its elasticity and deforms in a plastic (inelastic) manner. This enables the steel to rid itself of built-up stresses or permits forcing the steel into a desirable shape or straightness. The steel should not be overheated. Accordingly, this technique should be implemented only by those individuals having experience with it. The heating temporarily reduces the resistance of the structure. Measures such as vehicular restriction, temporary support, or temporary post-tensioning, may be applied as appropriate. Replacement should be considered when beams have been heat straightened more than once.

8. Top Flange Cleaning During Deck Replacement. Steel beam and plate girder bridges constructed before 1995 may have been painted with coating systems that included hazardous materials. The bridge deck covers the top flange and prevents this material from being removed during painting projects. When the scope of work includes bridge deck removal, the top of the top flange of all steel members will need to be cleaned and the waste material will need to be properly disposed.

412-3.03(07) Construction Loading

For a Rehabilitation project with a beam or girder superstructure, construction loadings should be evaluated in accordance with AASHTO LRFD Article 3.4.2, described in Chapter 403-4.0. Engineering judgment should be used when determining the need to check construction loadings for deck replacements.

412-3.03(08) Local Public Agency Adjacent Box Beam Bridges [Rev. Mar. 2021]

An LPA may place a 6 in. reinforced concrete deck over an adjacent box beam bridge that does not have a deck as preventive maintenance. The superstructure and substructure must meet the component rating criteria as shown in Figure 412-1A, Condition Driven Preventive Maintenance Eligibility Criteria.

412-3.04 Substructure Preservation Techniques and Considerations

412-3.04(01) Geotechnical Assistance

The Pavement Division, Office of Geotechnical Services should be notified early in the design process under each of the following circumstances:

1. new piling or foundations are to be constructed;
2. existing embankments are to be widened or require retaining walls;
3. new retaining walls are to be constructed; and
4. other known soils issues exist at the site.

412-3.04(02) Foundations

Foundation recommendations are the responsibility of the Pavement Division, Office of Geotechnical Services. The Office should be contacted early in the design of the project. Designers may provide suggested foundation types based on existing foundations.

Designers should consider differential settlement when designing foundations. Widened footings should be placed on piling unless original footings are founded on rock or some similarly hard stratum. This applies even when the existing structure makes use of spread footings.

For a stream crossing where the original structure is founded on spread footings and non cohesive soil, widening should not be accomplished using driven piling. Other types of piling to consider are micro piles, caissons, drilled shafts and auger cast piles.

When existing footings are on piling, pile driving records should be reviewed for guidance in estimating quantities.

412-3.04(03) Frame Bents

Frame bents may be widened by constructing additional columns and extending the cap. Connection of the new and existing cap may be made by dowelling into the existing cap unless loads are to be placed between the end of the existing cap and first new column. In this type of widening, a portion of the existing cap should be removed so that existing reinforcement can extend into the new construction and lap with new reinforcement. Existing crashwalls may be connected to new crashwalls by dowelling. The height of both existing and new crashwalls should meet current standards.

412-3.04(04) Solid Stem and Cantilever Piers

Solid wall type piers should generally be widened in kind. New construction may be connected to existing through the use of dowelling when the end of the existing wall is a flush surface. When the end of the existing wall is rounded, concrete should be removed back to the radius point. Where the existing wall contains a cantilever or hammerhead, the cantilever can either be removed or the area beneath the cantilever can be filled with concrete.

Alternatively, walls may be widened with columns and a cap beam. A solid wall should be provided to a level above the high water at a stream crossing. The Bridges Division, Office of Hydraulics should be contacted for guidance.

412-3.04(05) End Bents

Every effort should be made to eliminate joints which exist above end bents. When converting an existing expansion end bent to an integral situation, all existing battered piles should be cut off below the bottom of the new end bent and may not be reused.

If the existing end bent is in good condition, consideration should be given to converting the end bent to a semi-integral situation. This will allow reuse of existing battered piles. When new concrete is placed adjacent to existing concrete, consideration should be given to the following:

1. When only one new pile is added past the end of the existing cap, a portion of the existing cap should be removed so that existing reinforcement can extend into the new construction and lap with new reinforcement.
2. When multiple piles are being added past the end of the existing cap, connection of the new and existing cap may be made by dowelling into the existing cap unless loads are to be placed between the end of the existing cap and first new pile. A portion of the existing cap should be removed so that existing reinforcement can extend into the new construction and lap with new reinforcement.

412-3.05 Special Project Considerations and Techniques

The following topics should be considered on a project-specific basis.

412-3.05(01) Cathodic Protection

A cathodic protection system should be considered for a location where traffic-maintenance costs are very high and where additional service life between repairs would be advantageous.

The advantage of cathodic protection is that it can halt the progress of corrosion without the removal of chloride-contaminated concrete. Corrosion requires an anode – a point on the reinforcement where ions are released. Cathodic protection is the application of direct current such that the steel becomes cathodic to artificial anodes located on the deck. These anodes usually consist of sheets of thin wire mesh. A relatively small DC rectifier operating on AC line voltage and a control panel are located beneath the bridge.

A cathodic protection system need not operate 24 hours per day to be beneficial. Therefore, it can be powered by means of solar panels or in line with the highway-lighting system.

412-3.05(02) Beam Straightening

This technique is restricted to hot-rolled steels. Steels deriving their strength from cold drawing or rolling tend to weaken when heated. The premise of heat-straightening is that the steel, when heated to an appropriate temperature, loses some of its elasticity and deforms in a plastic (inelastic) manner. This enables the steel to rid itself of built-up stresses or permits forcing the steel into a desirable shape or straightness. The steel should not be overheated. Accordingly, this technique should be implemented only by those individuals having experience with it. The heating temporarily reduces the resistance of the structure. Measures such as vehicular restriction, temporary support, or temporary post-tensioning, may be applied as appropriate.

412-3.05(03) Post Tensioning

External post-tensioning can be applied to either steel or concrete structural members to reduce tensile stresses, to strengthen beams, or to make simply-supported beams continuous. There is a variety of successful methods of post-tensioning. The designer should research the most updated literature prior to use.

412-3.05(04) Deadman Anchor

The lateral force exerted by retained earth or stone, and superimposed gravitational loads thereon, tends to push forward and rotate an abutment or retaining wall. One solution for this problem is the application of a deadman.

A deadman is a heavy solid mass, usually concrete blocks that are connected to the retaining structure by long steel rods. A deadman is located in a stable earth mass well behind the structure. For wingwalls, or walls located on both sides of the roadway, they can be connected together by steel rods.

The rods should be protected against corrosion, and the effects of differential settlement should be considered.

Since this stabilization technique modifies the wall support from a cantilever to simple span pinned, the wall reinforcement should be checked for the revised moments.

412-3.05(05) Fiber Reinforced Polymer Composite Materials [Rev. Sep. 2016]

Externally bonded fiber reinforced polymer (FRP) composite materials or “fiber wrap” may be considered for bridge preservation and retrofitting. However, the Department currently does not allow the use of FRP systems to restore the structural capacity of bridge components.

Preservation may include the repair of deteriorated concrete components, such as concrete piers near leaking joints, or the repair of prestressed concrete girders due to vehicle impact. Seismic retrofitting of columns may include fiber wrap in conjunction with adding confinement reinforcement.

Considerations for the use of FRP composite materials should include the cost compared to conventional construction materials, along with the benefit of shorter construction duration and less impacts to the travelling public.

412-3.05(06) Scour Countermeasures

When signs of scour at existing foundations are apparent, measures should be taken to correct the problem. The stability of a streambed and banks is largely a function of water velocity and the size of the material constituting such bed and banks. If the size exceeds critical dimensions, scour will not likely occur.

Artificially placed protective material can consist of natural stone, specially-made concrete, or recycled (crushed) concrete. The weight of the riprap material should be considered in the design of footings and foundations. For steeper embankments, the riprap may be enclosed in galvanized, wire mesh envelopes called gabions.

For more information, see Part 2 of the *Manual*.

412-3.05(07) Seismic Evaluation and Retrofit [Rev. Mar. 2021]

For a Preventive Maintenance project, seismic evaluation is not required.

For a Rehabilitation project, seismic evaluation is not required if any of the following conditions are present:

1. The bridge is a single span;
2. the shelf length is greater than the calculated length of need; or
3. the existing bents are integral or semi-integral.

Where none of the above conditions are present, the decision to incorporate a seismic retrofit into the project scope should take into consideration the location and importance of the structure; the type and magnitude of rehabilitation; and cost. The discussion should be documented in the field check minutes.

Guidance on specific seismic retrofit measures can be obtained from the current edition of the [*Seismic Retrofitting Manual for Highway Structures, Part 1 – Bridges*](#) published by the Federal Highway Administration.

412-4.0 CONDITION SURVEYS AND TESTS

The type and appropriate extent of bridge rehabilitation should be based on information acquired from condition surveys and tests. The selection of the condition surveys and tests for a proposed project is determined by a site-specific assessment for each bridge. The structural factors to be considered are as follows:

1. age;
2. estimated remaining life (i.e., before bridge replacement is necessary);
3. size;
4. historic significance; and
5. potential investment in bridge rehabilitation.

The information normally available that may be requested if deemed pertinent is as follows:

1. original design plans and previous rehabilitation plans;
2. as-built plans;
3. shop drawings;
4. pile-driving records;
5. geotechnical report;
6. previous surveys;
7. accident records;
8. flood and scour data, if applicable;
9. traffic data;
10. roadway functional classification;
11. current load rating;
12. bridge inspection reports;
13. structural ratings (sufficiency, operating, inventory); and
14. maintenance work performed to date.

The condition surveys and tests to be selected should be those appropriate for the bridge site conditions based on an assessment of the structural factors and the available information.

The most effect method for determining the condition of a structure is visual inspection. Material tests have proven to be less effective, therefore contact the Bridges Division, Office of Bridge Design manager for further guidance and testing coordination.

412-4.01 Bridge Deck

For the purpose of this section, the bridge deck includes the structural continuum directly supporting the riding surface, deck joints and their immediate supports, curbs, barriers, reinforced-concrete bridge approaches, and utility hardware. The bridge deck and its appurtenances provide the services as follows:

1. support and transmittal of wheel loads to the primary structural components;
2. protection for the structural components beneath the deck;
3. lateral bracing for girders;
4. a smooth riding surface;
5. drainage of surface runoff; and
6. safe passageway for vehicular and bicycle or pedestrian traffic, e.g., skid-resistant surface, bridge railings, guardrail-to-bridge-railing transitions.

Deterioration in these services warrants investigation and possible remedial action. The most common cause of bridge deck deterioration is the intrusion of chloride ions from roadway deicing salts into the concrete. The chloride causes formation of corrosive cells on the steel reinforcement, and the corrosion product (rust) induces stresses in the concrete resulting in cracking, delamination and spalling. Chloride-ion (salt) penetration is a time-dependent phenomenon. There is no known way to prevent penetration, but it can be decelerated such that the service life of the deck is not less than that of the structure. Salt penetration is, however, not the only cause of bridge-deck deterioration. Other significant problems include the following.

1. Freeze-Thaw. This results from inadequate air content of the concrete. Freezing of the free water in the concrete causes random, alligator-type cracking of the concrete and then complete disintegration. There is no known remedy other than replacement.
2. Impact Loading. This results from vehicular kinetic energy released by vertical discontinuities in the riding surface, such as surface roughness, delamination, and inadequately-set or damaged deck joints. Remedial actions include surface grinding, overlaying or replacement of deck concrete, or rebuilding deck joints.
3. Abrasion. This results from contact with metallic objects, such as chains or studs attached to tires. Remedial actions include surface grinding or overlaying.

The objective of the condition surveys and tests is to quantify the extent of deterioration based on INDOT criteria to determine the appropriate remedial action.

412-4.01(01) Visual Inspection

Visual inspection and sounding are the primary methods for determining existing condition. Material tests should only be requested in special circumstances.

1. Description. A visual inspection of the bridge deck should identify the following:
 - a. the approximate extent of cracking, delamination, spalling and joint opening;
 - b. evidence of corrosion;
 - c. evidence of efflorescence, discoloration, or wetness at the bottom of bridge deck;
 - d. deformation in the riding surface or ponding of water;
 - e. operation of bridge deck joints;
 - f. functionality of bridge deck drainage system;
 - g. bridge railing and guardrail-to-bridge-railing transitions accordance with current Department standards.
 - h. deterioration and loss in a wooden deck;

- i. compatibility with geometric design criteria; and
 - j. condition of bridge railing and bridge railing transitions and compliance with current standards
2. Purpose. The purpose of visual inspection is to approximate the extent of cracking, corrosion, delamination, spalling and other deterioration identified during visual inspection and determine if a more extensive inspection is warranted.
 3. Consideration. Visual inspection should be used for each potential deck rehabilitation project.
 4. Analysis of Data. Based on the extent of bridge-deck delamination, the following will apply.
 - a. Delamination of 5% of surface area is a rule of thumb for considering remedial action; and
 - b. Delamination of 30 to 40% of surface area is a rule of thumb for considering bridge deck replacement.

Remedial work or deck replacement outside the above guidelines may be appropriate and should consider the following:

- traffic control;
- timing of repair;
- age of structure;
- AADT;
- slab depth;
- structure type; and
- hazard potential to other traffic (e.g. vehicular, cyclist, pedestrian).

412-4.01(02) Sounding

1. Description. Sounding establishes the presence of delamination, based on audible observation by chain drag, hammer, or electromechanical sounding device. It is based on the observation that delaminated concrete responds with a hollow sound when struck by a metal object. For more information refer the design should refer to ASTM D 4580.
2. Purpose. The purpose of sounding is to determine the location and extent of delamination.

3. Consideration. Sounding should be used on each deck rehabilitation project, except where proper traffic control cannot be provided during the test.
4. Analysis of Data. Quantities are approximate for bid purposes only and should be rounded off to the nearest 5%.

412-4.01(03) Half-Cell Method

1. Description. Copper-copper sulphate half-cell method for the measurement of electrical potential is used as an indicator of corrosive chemical activity in the concrete. For more information, the designer should refer to ASTM C 876.
2. Purpose. The purpose of the half-cell method is to determine the level of activity of corrosive cells in the bridge deck with non-epoxy coated steel.
3. Consideration. The method should be used if non-destructive testing is warranted.
4. Analysis of Data. A potential difference of -0.35 V or more negative indicates active corrosion. A potential difference of -0.20 V or less indicates a state of no corrosion. The range between -0.20 and -0.35 V is considered questionably active.

412-4.01(04) Coring

1. Description. Cores of 1½ in. to 3¾ in. diameter are taken by means of a water-cooled, diamond-edged rotating shell.
2. Purpose. The purpose of coring is to establish strength, composition of concrete, crack depth, position of reinforcement, delamination, and profile of chloride content and gradient.
3. Consideration. Coring should be completed when questions exist relating to the compressive strength or soundness of the concrete, or if the visual condition of the reinforcement is desired. Coring should also be completed when compression or chloride analysis tests are requested.
4. Analysis of Data. Concrete cover of less than 2 in. is considered inadequate for corrosion protection. A concrete compressive strength of less than 3000 psi is considered inadequate. Core locations can have a significant impact on the findings.

412-4.01(05) Chloride Analysis

1. Description. Chloride analysis consists of a chemical analysis of pulverized samples of bridge-deck concrete extracted from slices of 1½ in. diameter cores.
2. Purpose. The purpose of chloride analysis is to determine the chloride content profile from the deck surface to a depth of about 3 in. or greater.
3. Consideration. The results from a chloride analysis test have proven difficult to analyze. The Office of Materials Management (OMM) does not promote the use of this testing method and the validity of test results should be discussed with the OMM before use.
4. Analysis of Data. In the past a chloride content of 0.06 lb/cft of concrete at the level of top reinforcement was used as a rule of thumb for indicating a potential for corrosion to occur in the uncoated reinforcement of the deck. However, new bridge deck concrete has been known to have chloride content in this range. Therefore, the results of this test should not be used solely in determining the degree of rehabilitation. The locations of cores can also have a significant impact on the findings.

412-4.02 Superstructure

For the purpose of this section, the superstructure includes all structural components located above the bearings, except the deck. For a bridge without bearings, such as a rigid frame or fixed arch, this includes every visible structural component, except the deck. The following describes condition surveys and tests which may be performed on the superstructure elements to determine the appropriate level of rehabilitation.

412-4.02(01) Visual Inspection

Visual inspection and sounding are the primary methods for determining existing condition. Material tests should only be requested in special circumstances.

1. Description. A visual inspection of the superstructure should include an investigation of the following:
 - a. surface deterioration, cracking, and spalling of concrete;
 - b. major loss in concrete components;
 - c. evidence of efflorescence;
 - d. corrosion of reinforcement or prestressing strands;
 - e. loss in exposed reinforcement or prestressing strands;
 - f. corrosion of structural-metal components;

- g. loss in metal components due to corrosion;
 - h. cracking in metal components;
 - i. excessive deformation in metal components;
 - j. loosening and loss of rivets or bolts;
 - k. deterioration and loss in wood components;
 - l. damage due to collision by vehicles, vessels, or debris;
 - m. damage due to leakage through deck joints;
 - n. ponding of water on abutment seats;
 - o. state and functionality of bearings; and
 - p. presence of low-fatigue-life components.
3. Purpose. The purpose of visual inspection is to record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.
4. Consideration. It should be used on each bridge rehabilitation project.
5. Analysis of Data. Analysis should be performed as required.

412-4.02(02) Fracture-Critical Member

A fracture-critical member is defined as a structural metal component in tension whose failure would render the bridge dysfunctional or cause its collapse. A major portion of this determination relates to redundancy. For example, loss of a girder in a multi-girder or continuous girder structure may not be critical, while inadequate welding of a stiffener in other situations may be critical.

If the issue arises, criticality should be investigated by an experienced structural engineer.

412-4.02(03) Tests for Cracking in Metals

Such tests are used to determine the appropriate remedial action if the visual inspection revealed the existence of cracking in a steel structure. The extent and size of cracks should be established. The following are the most common test methods used in locating cracks in a steel structure, and for measuring their extent and size:

1. Dye-Penetration Test. The surface of the steel is cleaned, then painted with a red dye. The dye is wiped off. If a crack is present, the dye penetrates the crack. A white developer is painted on the cleaned steel and cracks are indicated where the red dye bleeds from the crack.

2. Magnetic-Particle Test. The surface of the steel is cleaned and sprinkled with fine iron filings while a strong magnetic field is induced in the steel. Magnetism is not resisted by the void in the cracks; therefore, the particles form a footprint thereof.
3. Acoustic Test. Although the above two methods require no special equipment, the acoustic method needs both a transmitter and a receiver. The method works on the principle that cracks reflect acoustic waves. It can only establish the presence of cracks.
4. Radiogram. This is a highly reliable but cumbersome and expensive test because it requires a medium for producing x-rays which penetrate the cracks and mark the film located at the other side.
5. Ultrasonic Test. This consists of the use of testing devices that use high-frequency sound waves to detect cracks, discontinuities, and flaws in materials. The testing depends a great deal on the expertise of the one conducting the test to interpret the results.

All tests should be conducted by, at a minimum, a Level II ANSI approved technician. For more information, see *FHWA-RD-89-167, Fatigue Cracking of Steel Bridge Structures*; *AASHTO Guide Specifications for Fatigue Evaluation of Existing Steel Bridges*; or *FHWA-NHI-90-043, Economic Design of Fracture Critical Members*.

412-4.02(04) Fatigue Analysis

1. Description. Fatigue is defined as a progression in the crack size caused by cyclical loading to a critical dimension at which cracking is no longer effectively resisted, thus, leading to fracture of the component. The progression is a function of the following:
 - a. crack size;
 - b. location of crack (i.e., structural detail);
 - c. energy absorbing characteristics of metal;
 - d. temperature; and
 - e. frequency and level of stress range (transient stresses).
2. Purpose. The purpose of fatigue analysis is to establish type and urgency of remedial action.
3. Consideration. This analysis should be performed where cracks found by visual inspection are believed to be either caused by fatigue or are progression-prone under transient loading as well as where components have an E or E' category detail. For welded cover plates, a fatigue analysis need be performed only when cracks are identified during visual inspection.

4. Analysis of Data. For the analysis, fatigue characteristics of the metal should be established by the applicable design specification. See Chapter 407 for fatigue considerations for structural steel.

412-4.03 Substructure or Foundation

The substructure transfers loads to the foundation such as rock or earth. Substructures include unframed piers, bents or abutments, footings, piles, and drilled shafts. A substructure including piles and drilled shafts is referred to as a deep foundation. They also include fenders and dolphins used in navigable waterways. The following briefly describes those condition surveys and tests which may be performed on these elements to determine the appropriate level of rehabilitation.

412-4.03(01) Visual Inspection

Visual inspection and sounding are the primary methods for determining existing condition. Material tests should only be requested in special circumstances.

1. Description. A visual inspection of the substructure components should address the following:
 - a. surface deterioration, cracking, and spalling of concrete;
 - b. major loss in concrete components;
 - c. distress in pedestals and bearing seats;
 - d. evidence of corrosion of reinforcement;
 - e. loss in exposed reinforcement;
 - f. deterioration or loss in wood components;
 - g. leakage through joints and cracks;
 - h. dysfunctional drainage facilities;
 - i. collision damage;
 - j. changes in geometry such as settlement, rotation of wingwalls, or tilt of retaining walls;
 - k. compliance with current INDOT seismic-design standards;
 - l. accumulation of debris;
 - m. erosion of protective covers;
 - n. changes in embankment and water channel;
 - o. evidence of significant scour; and
 - p. underwater inspection (as needed).

2. Purpose. The purpose of visual inspection is to record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.
3. Consideration. It should be used on each bridge rehabilitation project.
4. Analysis of Data. Analysis should be made as required.

412-4.03(02) Other Test Methods

Other test methods described in Section 412-4.02 for a bridge deck may be used to determine the level and extent of deterioration of the substructure components.

412-4.03(03) Scour Analysis

A scour analysis should be included for each bridge that crosses over water. INDOT's methodology for performing this analysis is discussed in Chapter 203-5.0. The specific performance criteria for this analysis are discussed in Chapter 203-3.02(06).

Scour analysis for a consultant-designed bridge-rehabilitation project should be completed by the consultant and submitted to the Bridges Division, Office of Hydraulics for review. Scour analysis for an INDOT-designed project is completed by the Office of Hydraulics. Scour countermeasures may be necessary based on the results of the scour analysis and require the approval from the Office of Hydraulics.

412-5.0 HISTORIC BRIDGES [REV. FEB. 2018]

A historic bridge is one which was built prior to 1966, and is in, or is eligible for inclusion in, the National Register of Historic Places. The Department has developed a listing of all publicly-owned historic bridges that are National Register-eligible or -listed.

Where a project involves a historic bridge, the bridge owner must prepare a Historic Bridge Alternatives Analysis for review and concurrence by the Environmental Services Division Office of Cultural Resources and Bridges Division Office of Bridge Design, after which it will be submitted to consulting parties for review and approval as part of the Section 106 consultation process.

412-5.01 Types of Historic Bridges

A historic bridge will be classified as either Select or Non-Select. The Department has determined each bridge's classification in accordance with the *Programmatic Agreement Among the Federal Highway Administration, the Indiana Department of Transportation, the Indiana State Historic Preservation Officer, and the Advisory Council on Historic Preservation Regarding the Management and Preservation of Indiana's Historic Bridges (PA)*. The PA, a listing of Select and Non-Select bridges (inventory summary & results), and historic bridge marketing information are available on the Indiana Historic Bridges Inventory website at <http://www.in.gov/indot/2530.htm>.

412-5.01(01) Select Bridge

A Select bridge has been identified as a historic bridge that is an excellent example of its structure type to be a suitable candidate for preservation. The intent of the PA is to preserve Select bridges in place for continued vehicular use. If rehabilitation alternatives are not in accordance with Section 412-5.02, and the owner is not granted a design exception or does not request one, the Select bridge must be bypassed or relocated for another use. See the PA for further guidance on bypassing or relocating the bridge.

412-5.01(02) Non-Select Bridge

A Non-Select bridge has been identified as a historic bridge that is not an excellent example of its structure type, nor is a suitable candidate for preservation. If the rehabilitation alternatives are not in accordance with Section 412-5.02, and the owner is not granted a design exception or does not request one, the Non-Select bridge must be marketed for re-use. In accordance with the PA, if no party steps forward to assume ownership of the bridge, the bridge may be demolished. See the PA for further guidance on marketing or demolishing the bridge.

412-5.02 Historic Bridge Alternatives Analysis [Rev. Feb. 2018]

Where a project involves a historic bridge, the bridge owner must complete a Historic Bridge Alternatives Analysis and receive concurrence from the Environmental Services Division Office of Cultural Resources and the Bridges Division Office of Bridge Design prior to proceeding to the Preliminary Plans milestone. The required contents of the analysis, including explanations and tips for discussion of alternatives, is available from the Department's Historic Bridge Inventory Summary & Results webpage at <http://www.in.gov/indot/2531.htm>, under Historic Bridge Project Development Process Documents.

The evaluation of alternatives must address the following alternatives for both Select and Non-Select Bridges. The list is a hierarchy, meaning that the analysis must prove an alternative is either not feasible or prudent prior to proceeding to the next alternative. Note that Select bridges must be preserved as part of the project.

1. No Build/Do Nothing
2. Rehabilitation for continued vehicular use (two-lane or one-lane option), meeting the Secretary of Interiors Standards for Rehabilitation.
3. Rehabilitation for continued vehicular use (two-lane or one-lane option), not meeting the Secretary of Interiors Standards for Rehabilitation
4. Rehabilitation for continued vehicular use (one-way pair option), meeting the Secretary of Interiors Standards for Rehabilitation.
5. Rehabilitation for continued vehicular use (one-way pair option), not meeting the Secretary of Interiors Standards for Rehabilitation.
6. Bypass (non-vehicular use)/Build New Structure
7. Relocation of Historic Bridge and New Bridge Construction
8. Replacement – Demolition of Historic Bridge and New Bridge Construction

412-5.03 Design Criteria [Rev. Feb. 2018]

The following design criteria should be used to evaluate if a historic bridge can be rehabilitated for continued vehicular use. The criteria should not be viewed as an absolute, that is, a design exception may be appropriate and should be considered where appropriate.

A historic bridge on low-volume road should be evaluated using the design criteria described herein. A low-volume road is defined as having a design-year ADT of less than or equal to 400 vpd. A historic bridge on roadway with a design-year ADT greater than 400 vpd should be evaluated using the 3R design criteria for the applicable functional classification. See Chapter 55 for 3R criteria. The criteria for Existing Structure to Remain in Place should be used for bridge clear roadway width and structural capacity. These criteria should be used to determine if a historic bridge can be rehabilitated for continued vehicular use.

Design Speed

The existing posted speed should be used as the design speed. If the road is not posted, an engineering speed study should be performed and the road should be posted between logical termini.

Approach Roadways Horizontal and Vertical Alignment

These should be analyzed within 300 ft of either side of the bridge in accordance with AASHTO's *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT < 400)* or the 3R design criteria, as applicable.

Structural Capacity

The structural capacity should be in accordance with Figure [412-2A](#), Historic Bridge Structural Capacity. The required capacity designations are those described in AASHTO *Standard Specifications for Highway Bridges*.

Bridge Width

The minimum bridge width should be in accordance with Figure [412-2B](#), Historic Bridge Minimum Clear Roadway Width.

Bridge Railing

Bridge railing may be left in place if there is no documented crash history or other evidence of crash history within the past 5 years such as damaged railing or concerns by local police agencies. If only slightly damaged, railing should be replaced in kind. If there is evidence of crash history within the past 5 years, the possible causes should be corrected, or new bridge railing provided as described in Section 404-4.0.

Approach Guardrail

Approach guardrail, if in place, should remain. If not in place, it may be omitted if there is no documented crash history or other evidence of crash history within the last 5 years, such as vehicles hitting the ends of the bridge railing or vehicles leaving the roadway. Crash history, such as that regarding damaged ends of bridge railings, may be an indicator of the need for approach guardrail.

In addition to those guardrails which the Department has standardized, there are others which have passed NCHRP 350 or MASH crash tests for specified test levels. If one of these devices is desired to be used for a specific project, the documentation to be provided is as follows:

1. an FHWA eligibility letter; and
2. complete details for the device as successfully crash tested.

Hydraulic Capacity

Improvements may consist of removal of sand bars or debris, channel clearing, or adding a supplemental structure. If a bridge is to remain in place and its approaches are realigned, the removal of existing roadway fill is an option toward improving the hydraulic capacity.

412-5.04 Economic and Other Criteria [Rev. Feb. 2018]

412-5.04(01) Select Bridge [Rev. Feb. 2018]

The appropriateness of rehabilitating a Select historic bridge should be determined based on the cultural significance of the bridge. The appropriateness of rehabilitating a Select bridge on a low volume road, as defined above, should further be assessed based on the cost effectiveness as follows:

1. if the initial rehabilitation cost is less than 80% of the replacement cost, rehabilitation is warranted; or
2. if the initial rehabilitation cost is equal to or greater than 80% of the replacement cost, the owner may request further consultation with FHWA to determine rehabilitation eligibility.

The above thresholds should not be viewed as absolute, i.e., if the initial rehabilitation cost is above 80% of the replacement cost, rehabilitation may still be considered a viable alternative. A rehabilitation project should result in a 20-year design life for the rehabilitated bridge.

A Select bridge may be rehabilitated and left in place, and a new bridge and new approaches may be built adjacent to it. This effectively creates one bridge and approaches for each direction of travel. For this situation, the new bridge must meet all design standards for a new bridge or obtain a design exception. Where appropriate, the new one-way bridge must be able to accommodate future widening to provide for two-way travel.

412-5.04(02) Non-Select Bridge [Rev. Feb. 2018]

The appropriateness of rehabilitating a Non-Select historic bridge should be determined based on the cultural significance of the bridge. A Non-Select bridge on a low-volume road, as defined above, should further be assessed based on the cost-effectiveness of the project and other criteria as follows.

If the initial rehabilitation cost is greater than or equal to 40% of the replacement cost, or the bridge meets two or more of the following criteria that cannot be economically corrected as part of a rehabilitation project, then replacement is warranted.

1. The bridge waterway opening is inadequate (i.e., National Bridge Inventory Item 71 is rated 2 or 3).
2. The bridge has a documented history of catching debris due to inadequate freeboard or due to piers in the stream.
3. The bridge requires special inspection procedures (i.e., the first character of National Bridge Inventory Item 92A or 92C is Y).
4. The bridge is classified as scour-critical (i.e., National Bridge Inventory Item 113 is rated 0, 1, 2, or 3).
5. The bridge has fatigue-prone welded components that are expected to reach the end of their service lives within the next 20 years. See Section 412-4.03(04) for information on conducting a fatigue analysis.
6. The bridge has a Sufficiency Rating of lower than 35.

The above cost thresholds should not be viewed as absolute. If the initial rehabilitation cost is above 40% of the replacement cost, rehabilitation may still be considered a viable alternative. A rehabilitation project should result in a 20-year design life for the rehabilitated bridge.

Treatments Type	Bridge Component (Item Code)	Component Rating	Other Criteria ²
Bridge Culvert Liners	Culverts (62)	2-5	N/A ³
Deck Patching (partial/full depth)	Wearing Surface (58.01)	>4	D/SS >4 and Max. 10% Deck Patching
Approach Slab Repair/Replacement	Approach Slab (Misc. Asset Data) or Concrete approach slab Elements	<6, or >10% Element Level in CS2 or any % in CS3	WS/D/SS>4
Expansion Joint Repair/Replacement/ Elimination	Transverse Joints (Misc. Asset Data - Joints) or Joint Elements	<6, or >10% Element Level in CS2 or any % in CS3	WS/D/SS>4
Mudwall Patching	Substructure Backwall (60)	<6, or >10% Element Level in CS2 or any % in CS3	WS/D/SS>4
Bridge Deck Overlays - Flexible	Wearing Surface (58.01)	>4	D/SS>4 and Max. 10% Deck Patching
Bridge Deck Overlays - Rigid	Wearing Surface (58.01)	>3	D/SS>4 and Max. 15% Deck Patching
Spot Coating/Bridge Painting	Condition of Paint (Misc. Asset Data – Paint Condition Steel Superstructure Corrosion Elements, and/or Steel Bearing Corrosion Elements)	<7 ⁴ or >10% Element Level in CS2 or any % in CS3	WS/D/SS>4
Substructure/Pile Patching/Sealing/Fiber Wrap	Substructure (60)	N/A	WS/D/SS>4
Superstructure Crack Mitigation Superstructure Patching / Fiber Wrap	Concrete Girders (59) or Concrete Beams (59)	N/A	WS/D/SS>4
Erosion Mitigation	Channel and Channel Protection (61)	<6	WS/D/SS>4
Debris Removal/Channel Cleaning	Channel and Channel Protection (61)	<6	WS/D/SS>4
Slopedwall Repair/Replacement	Misc. Asset Data - Slopedwall	<6	WS/D/SS>4
Bearing Repair/Replacement	Bearings (Misc. Asset Data), or Bearing Element Items	<6, or any % Element Level in CS2 or CS3	WS/D/SS>4

**CONDITION-DRIVEN PREVENTIVE MAINTENANCE
ELIGIBILITY CRITERIA**
Figure 412-1A (Page 1 of 2)

[Rev. Mar. 2021]

Treatments Type	Bridge Component (Item Code)	Component Rating	Other Criteria ²
Scour Mitigation	NBI Scour Evaluation Code (113)	2-4	Not Programmed for Bridge Replacement
Deck Crack Sealing	Wearing Surface (58.01)	>5	D/SS>5
Brush Cutting/Herbicide Application ¹	Deficiency Noted	N/A	WS/D/SS>4
Railing Repair ¹	Deficiency Noted	N/A	WS/D/SS>4
Relief/Terminal Joint Repair ¹	Deficiency Noted	N/A	WS/D/SS>4
Upgrading End Treatments, Guardrail, Railing, Attenuators ^{1, 4}	N/A	N/A	WS/D/SS>4
Adding Reinforced Concrete Deck to an Adjacent Box Beam Bridge without a Deck ⁵	Superstructure (59) and Substructure (60)	(59) >5 (60) >4	N/A

CS = Condition State

¹ Items may only be included in a project incorporating other preventive maintenance treatments

² WS = Wearing Surface (58.01); D = Deck (58); SS = Superstructure (59) and Substructure (60)

³ Treatments should raise the condition of the rating to 5 or higher

⁴ When found to be cost-effective

⁵ Treatment is applicable to LPA bridges only. The minimum allowable deck thickness is 5 in.

CONDITION-DRIVEN PREVENTIVE MAINTENANCE ELIGIBILITY CRITERIA Figure 412-1A (Page 2 of 2)

[Rev. Mar. 2021]

Treatment Type	Bridge Component (Item Code)	Component Rating	Cycle (years)
Cleaning/flushing bridge decks	Deck (58)	>4	1
Substructure/superstructure washing	Superstructure (59) & Substructure (60)	>4	1
Clean Deck Drains	Deck (58)	>4	1
Cleaning/lubricating bearings	Superstructure (59)	>4	1
Clean Joints	Misc. Asset Data - Joints	>4	1
Deck Sealing	Wearing Surface (58.01)	>5	5

SCHEDULED PREVENTIVE MAINTENANCE ELIGIBILITY CRITERIA

Figure 412-1B

[Rev. Mar. 2021]

	Detour Length < 5 mi		5 mi ≤ Detour Length < 10 mi		Detour Length ≥ 10 mi		Detour of Any Length
Design Year ADT	< 100	100 ≤ ADT ≤ 400	< 100	100 ≤ ADT ≤ 400	< 100	100 ≤ ADT ≤ 400	ADT > 400
AASHTO Live Loading	H-15	HS-15	HS-15	HS-15	HS-15	HS-20	3R Criteria for Structural Capacity, Existing Bridge to Remain in Place
Required Capacity	15 tons	27 tons	27 tons	27 tons	27 tons	36 tons	

Notes:

1. Detour length is defined as the total additional travel a through-bound vehicle would experience from closing the bridge. This is determined by the shortest route on which a vehicle with a loading of HS-20 (36 tons) is legally capable of traveling.
2. Vehicles that may use a bridge with AASHTO loading of H-15 (15 tons) or HS-15 (27 tons) include typical farm vehicle (15 tons), school bus carrying up to 84 passengers (15 tons), loaded garbage truck (27 tons), and single-unit fire engine (27 tons).
3. Vehicles that may use a bridge with AASHTO live loading of HS-20 (36 tons) include all of the H-15 and HS-15 vehicles, plus payloaded ready-mix-concrete truck (30 tons), and tractor-apparatus fire engine (36 tons).
4. A bridge on a dead-end road will be considered as having a detour length greater than 10 miles.
5. The annual traffic growth factor used in determining Design Year ADT must be justified.

HISTORIC BRIDGE STRUCTURAL CAPACITY

Figure 412-2A

Minimum Clear Roadway Width ^{2,3}			
Lanes on Bridge	Design Year ADT < 100	100 ≤ Design Year ADT ≤ 400	Design Year ADT > 400
One ¹	15 ft	16 ft	Not Applicable
Two	18 ft	20 ft	3R Criteria for Clear Roadway Width, Existing Bridge to Remain in Place.

Notes:

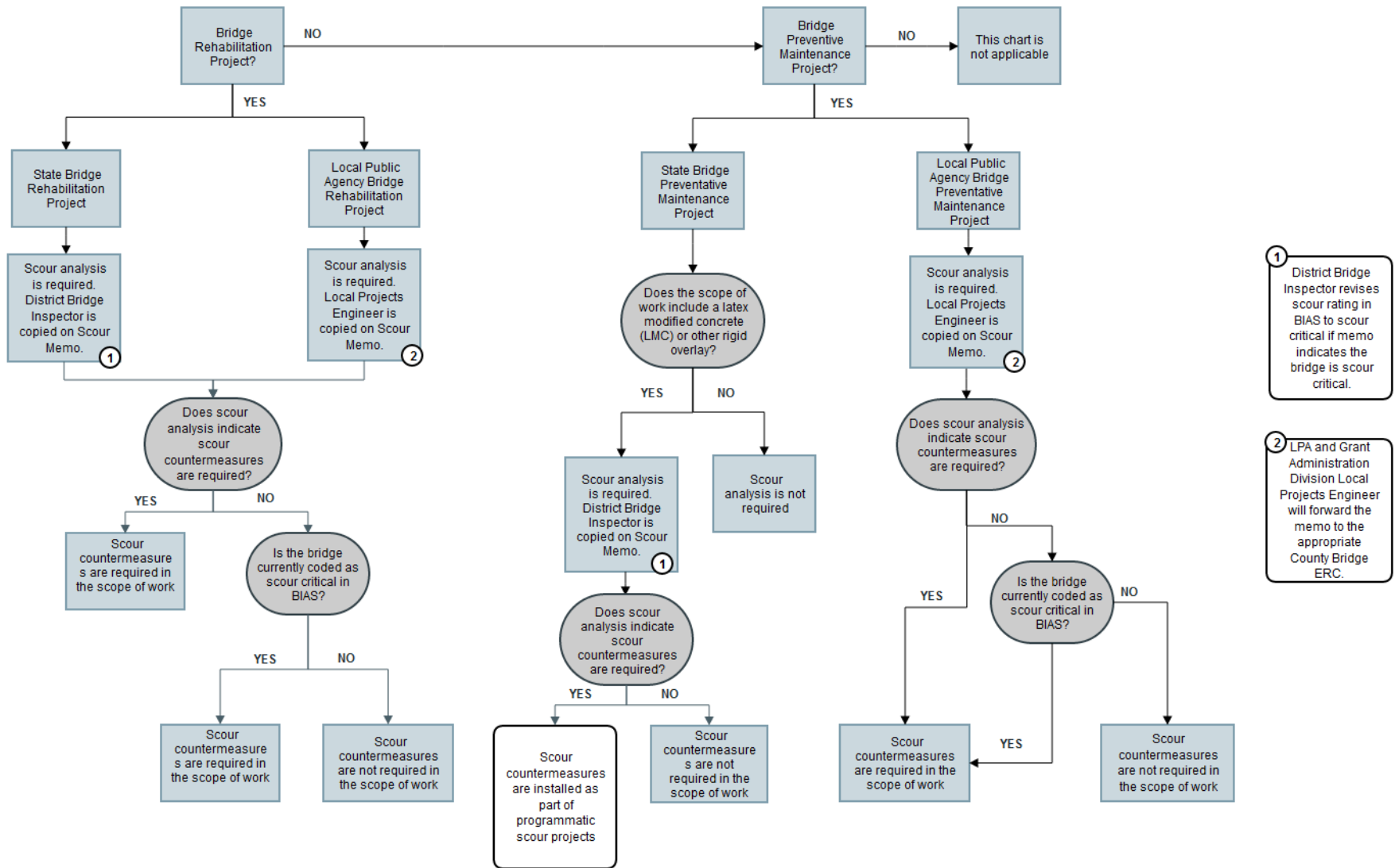
¹ The given values are applicable for rehabilitation of a Select bridge in a one-way pair or two-way configuration. The given values are applicable for rehabilitation of a Non-Select bridge in a one-way pair configuration. The owner must obtain a design exception for rehabilitation of a Non-Select bridge in a two-way configuration, or where the ADT is greater than 400 vpd.

² The minimum bridge width is defined as the most restrictive minimum distance between curbs, railings, or other obstructions on the bridge roadway.

³ The annual traffic growth factor used in determining Design Year ADT must be justified.

HISTORIC BRIDGE MINIMUM CLEAR ROADWAY WIDTH

Figure 412-2B



SCOUR ANALYSIS AND IMPLEMENTATION OF COUNTERMEASURES

FIGURE 412-2C

Work Type and Design Methodology					
Original Design Methodology	Deck Replacement	Bridge Widening, Reusing Existing Beams	Bridge Widening, Full Superstructure Replacement	Superstructure Replacement	Bridge Replacement
ASD or LFD	All Elements: LFD ^{1, 2}	All Elements: LFD ¹	Superstructure: LRFD Substructure: LFD ¹	Superstructure: LRFD Substructure: LFD ¹	Superstructure: LRFD Substructure: LRFD
LRFD	All Elements: LRFD	All Elements: LRFD	All Elements: LRFD	All Elements: LRFD	All Elements: LRFD

Notes:

¹ LFD in accordance with the AASHTO *Bridge Specifications for Highway Bridges, 17th Edition*.

² LRFD design methodology is acceptable.

BRIDGE DESIGN METHODOLOGY BY WORK TYPE

Figure 412-3A

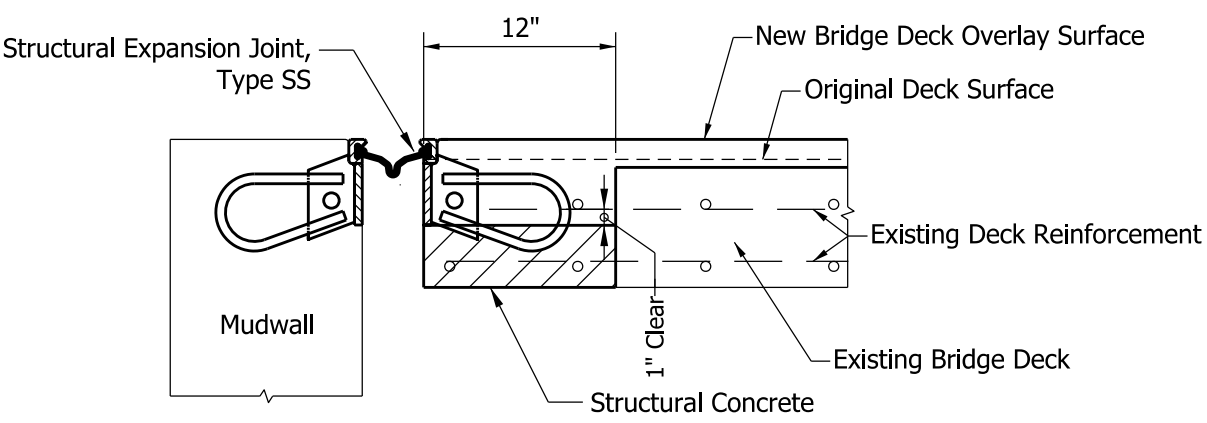
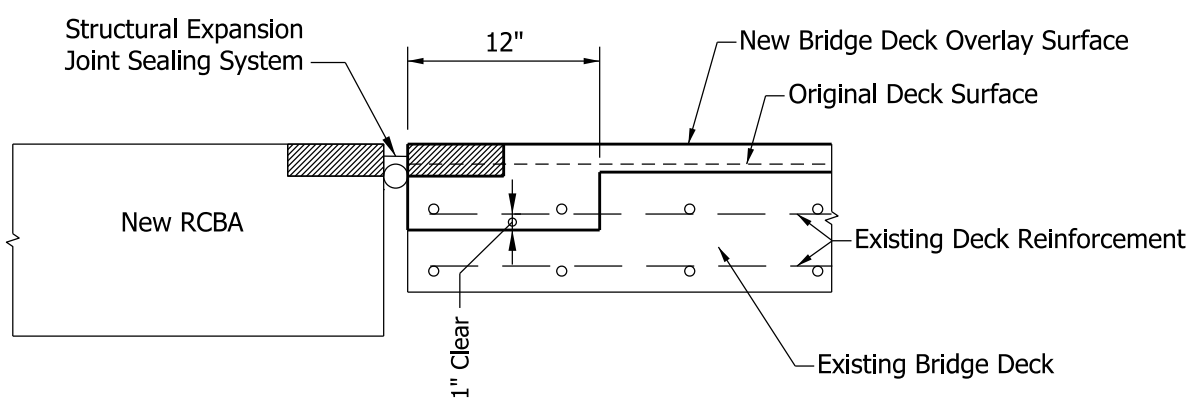
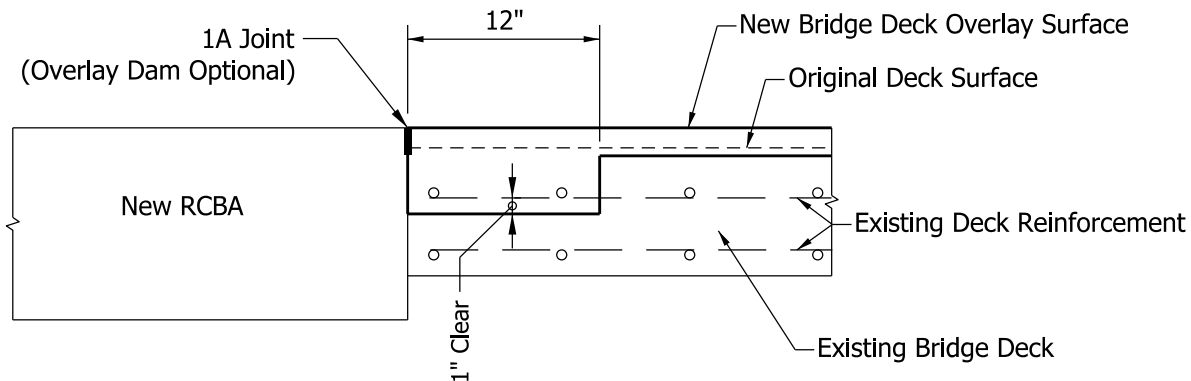
Bar Size	Hole Diameter (in.)	Embedment (in.)	Tension Ultimate Bond Strength (kip)		Shear Strength (kip)
			100% f_y	125% f_y	
#4	5/8	4½	12.0	15.0	2.6
#5	3/4	5¾	18.6	23.2	4.8
#6	1	6¾	26.4	33.0	7.4
#7	1 1/8	8	36.0	45.0	10.6
#8	1 1/4	9	47.4	59.2	14.4
#9	1 3/8	10½	60.0	75.0	18.7

Notes:

1. Values are based on the use of 60-ksi reinforcement.
2. Hole diameter and embedment depth shall be per the manufacturer's requirements. The values shown are general guidelines.
3. Anchors are considered 100% effective if the edge distance is equivalent to, or greater than, the standard embedment depth. The edge distance may be reduced to half the standard embedment depth if the strength is reduced linearly to 70%.
4. Anchors are considered 100% effective if the spacing is equivalent to, or greater than, the standard embedment depth. Spacing may be reduced to half the standard embedment depth if the strength is reduced linearly to 50%.

DESIGN DATA FOR ANCHOR SYSTEMS

Figure 412-3B



OVERLAY DAM DETAIL

Figure 412-3C