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* Indicates 11 x 17 sheet; all others are 8½ x 11.

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* Indicates 11 x 17 sheet; all others are 8½ x 11.

INTRODUCTION - CHAPTER 32

This chapter establishes the practices and guidelines of the Structure and Bridge Division for the maintenance of VDOT's highway structures. It is intended to serve as both a standard for those familiar with bridge maintenance and as an introduction to those who are new to the field. This chapter addresses a broad array of bridge maintenance topics, including:

Recommended decision processes
Types of maintenance activities
Federal funding
Technical resources

The chapter is focused primarily on bridges with concrete decks, concrete or steel superstructures and concrete substructures. Future versions of the chapter will address culverts, timber decks and other types of structures commonly found in VDOT's inventory. Jacking and other maintenance activities will also be addressed.

It is intended that future versions will expand the informational role of the chapter by adding design aids and bridge management practices as well as links to standard details, standard special provisions and contract templates. The chapter will serve as a commonly utilized reference for bridge and maintenance engineers.

Throughout the document there are requirements to obtain the approval of the District Structure and Bridge Engineer. This requirement is included because the chapter will be used by many individuals, including consultants, Central Office employees and individuals in the Districts. While it is generally understood that the District Structure and Bridge Engineer has authority over the maintenance activities in his/her District, there are certain times when the designer should be certain that the matter has been elevated to the District Structure and Bridge Engineer's level.

For bid items required for work covered within this chapter, refer to Chapter 3.

It is expected that the users of this chapter will follow the practices and guidelines stated herein.

Major changes to past practices are as follows:

1. Updated performance measures and targets for VDOT adoption of FHWA definitions of Good, Fair and Poor/SD condition categories and included best practices to slow deterioration rates in Section 32.00.
2. Completely replaced Section 32.03, Concrete Deck Repair, Rehabilitation or Replacement.
3. Revised Sections 32.01, 32.02 and 32.04 through 32.08 by updating, expanding or adding content, removing obsolete items or reorganizing.
4. Added Sections 32.09, Bridge Deck Joint Elimination, and 32.10, Preventive Maintenance.
5. Added Section 32.11, Guidelines for the Restorative Maintenance and Structural Rehabilitation of Existing Culverts.

NOTE:
Due to various restrictions on placing files in this manual onto the Internet, portions of the drawings shown do not necessarily reflect the correct line weights, line types, fonts, arrowheads, etc. Wherever discrepancies occur, the written text shall take precedence over any of the drawn views.

Performance Measures and Targets – General:

Performance measurement is an essential tool for guiding asset owners toward making the best use of limited funds in a transparent and accountable manner. Years of performance data are required in order to develop a sound performance measurement program and adopt a set of metrics that are meaningful, actionable, and practical to measure.

Virginia's bridge inventory is large and complex, so in order to more readily guide maintenance efforts, the inventory has been divided into three condition categories: Good, Fair, and Poor/SD. While Virginia has been using these condition categories and performance measures for many years, the FHWA has only recently required states to track bridge conditions, establish performance targets, and report results. Virginia's federal (external) goals will be based on reasonable projections of actual conditions assuming that current funding will remain constant. However, Virginia also uses internal goals to promote peak performance among its staff, consultants and contractors.

Virginia's historical definitions of Good, Fair, and Poor/SD condition categories were as follows:

VDOT's Historical Condition Category and Definition*		
Poor/SD	**Fair**	**Good**
Min GCR ≤ 4	Min GCR = 5	Min GCR ≥ 6

The FHWA established the following definitions of Good, Fair, and Poor/SD condition categories (23 CFR Part 490 § 490.409). VDOT has adopted the FHWA definitions of Good, Fair and Poor/SD categories to align with current convention.

Agency	**Condition Category and Definition***		
	Poor/SD	**Fair**	**Good**
FHWA	Min GCR ≤ 4	4 < Min GCR <7	Min GCR ≥ 7

* "Min GCR" refers to the minimum General Condition Rating (GCR) for a structure. At each bridge safety inspection, GCRs are assigned and recorded for the major bridge components: Deck, Superstructure, Substructure and Culvert.

Poor/SD structures have a minimum GCR of 4 or less. As of January 1, 2018, FHWA's definition of Structurally Deficient (SD) structures is in complete alignment with the definition of Poor structures so now all Poor structures are SD and all SD structures are Poor. This represents a departure from previous definitions, where certain Fair or Good structures were SD. See link below for the new federal definition of SD bridges:

https://www.federalregister.gov/documents/2015/01/05/2014-30085/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway

VDOT further subdivides the Fair structures into "Cusp" (min. GCR =5) and "Satisfactory" (min. GCR = 6) subcategories. This subdivision provides information supportive of good bridge management practices.

Virginia's Internal Performance Measures:

1. Performance Measures for SD/Poor Structures

Virginia's new overall goals for SD structures are indicated in the table below:

Virginia's Targets for Percentage of Structures not Structurally Deficient (by Count)			
Bridge Population	**Target**	**Applies To**	**Target Date**
NBI Structures	95.5%	Statewide	12/31/2018
All Bridges and Large Culverts			
NBI Structures	94.0%	Each District	
All Bridges and Large Culverts			

The formally established targets above are based on informal statewide sub-targets for each highway system for percentage not structurally deficient:

- Interstates 99%
- Primaries 96%
- Secondaries 94%

Virginia's long-term goal is for more than 99% of its bridges to be not structurally deficient and to have no structurally deficient bridges on the interstate highway system.

2. Performance Measure for Cusp Structures (Fair structures with min. GCR = 5)

Each district has a target of reducing the percentage of Cusp Structures by 0.5% by June 30, 2019. The targets apply to both NBI structures and all bridges and large culverts. Improvement percentage will be measured using a baseline date of October 1, 2017.

3. Preventive Maintenance Performance Measure

In order to slow deterioration, each district has a target of increasing the percentage of bridge deck expansion joints in Condition States 1 and 2 by 0.5% by December 31, 2018. Improvement percentage will be measured using a baseline date of October 1, 2017.

4. Performance Measure for Fracture Critical Bridges

Virginia has a goal of reducing the percentage of fracture critical bridges by 15% from the baseline of 139 on December 31, 2013.

FHWA Performance Measures:

The 2012 federal "Moving Ahead for Progress in the 21st Century Act" (MAP-21) established requirements for states to establish performance targets for the deck area of SD/Poor structures and Good structures. These targets apply only to NBI bridges on the National Highway System (NHS). Virginia established these targets on May 18, 2018.

Performance against the targets will be reported in October, 2020 (interim report) and October, 2022 (final report). Baseline data (start date) will be January 1, 2018. The reports for 2020 and 2022 will each be based on data as of January 1 of those years. Unless new federal legislation is passed that changes the requirements, these four-year reporting and target establishment cycles will continue every four years.

1. Performance Measure for SD/Poor Structures (Min GCR ≤ 4)

- No more than 10% of the deck area of SD NBI bridges on the NHS
- Each state must establish a goal for the percentage of Poor bridge deck area and report their progress against the goal every two years. This goal applies only to NBI bridges on the NHS**.** See the table below for Virginia's targets.

2. Performance Measure for Good Structures (FHWA Definition: Min GCR ≥ 7)

- Each state must establish a goal for the percentage of Good bridge deck area and report their progress against the goal every two years. This goal applies only to NBI bridges on the NHS. See the table below for Virginia's targets.

Virginia's Performance Targets for Map-21*		
	10/2020	10/2022
Percentage of bridges in Poor/SD condition	3.5	3.0
Percentage of bridges in Good condition	33.5	33.0

* Targets are expressed as a percentage of deck areas.

Notes on FHWA Performance Targets:

- The classification is based on National Bridge Inventory (NBI) condition ratings for item 58 – Deck, 59 – Superstructure, 60 – Substructure and 62 – Culvert.
- The condition is determined by the lowest rating of deck, superstructure, substructure or culvert. If the lowest rating is greater than or equal to 7, the bridge is classified as Good. If it is less than or equal to 4, the classification is Poor. Bridges rated below 7 but above 4 will be classified as Fair (there is no related performance measure).
- Deck area is computed using NBI item 49 – Structure Length and 52 – Deck Width or 32 – Approach Roadway Width (for some culverts).
- Targets must be established for all bridges carrying the NHS, which includes on- and off-ramps connected to the NHS within a State, and bridges carrying the NHS that cross a State border, regardless of ownership.

Link to FHWA Fact Sheet for Bridge Performance Measures –
https://www.fhwa.dot.gov/tpm/pubs/PM2BridgeFactSheet.pdf

FHWA Computation Procedure for the Bridge Condition Measures –
https://www.fhwa.dot.gov/tpm/guidance/hif18023.pdf

Best Practices To Slow Deterioration Rates:

The previously discussed performance measures and targets were established to measure progress against goals that are deemed attainable within current funding and system constraints (traffic, procurement rules, etc.) As such, the previous discussion addressed practical goals. However, there is value in defining an ideal set of goals that would, if achieved, serve to create a steady state in the average system conditions over time. True system preservation should extend the service life of structures, which requires a balanced approach that places emphasis on structures in good, fair and poor condition.

The following informal performance goals are presented not as actual targets that will be measured and tracked, but rather serve as a template or "best practices" guide for ideal long-term system management and investment.

- Maintain 90% of expansion joints in Condition State 1.

  The joint condition state performance measure emphasizes the importance of keeping moisture and salts from reaching bridge components located below the deck. Leaking bridge joints are the primary cause of bridge substructure and superstructure deterioration. Furthermore, many of the bridges that require premature replacement are allowed to deteriorate to poor condition primarily as a direct result of leaking expansion joints. Condition State 1 is defined by the FHWA's *Specification for the National Bridge Inventory Bridge Elements (https://www.fhwa.dot.gov/bridge/nbi/131216_a1.pdf) and AASHTO's Manual for Bridge Element Inspection.* Joints in Condition State 1 are sound, functional, secure, do not leak and display minimal deterioration.

- Eliminate 2% of the expansion joints in each District in each fiscal year.

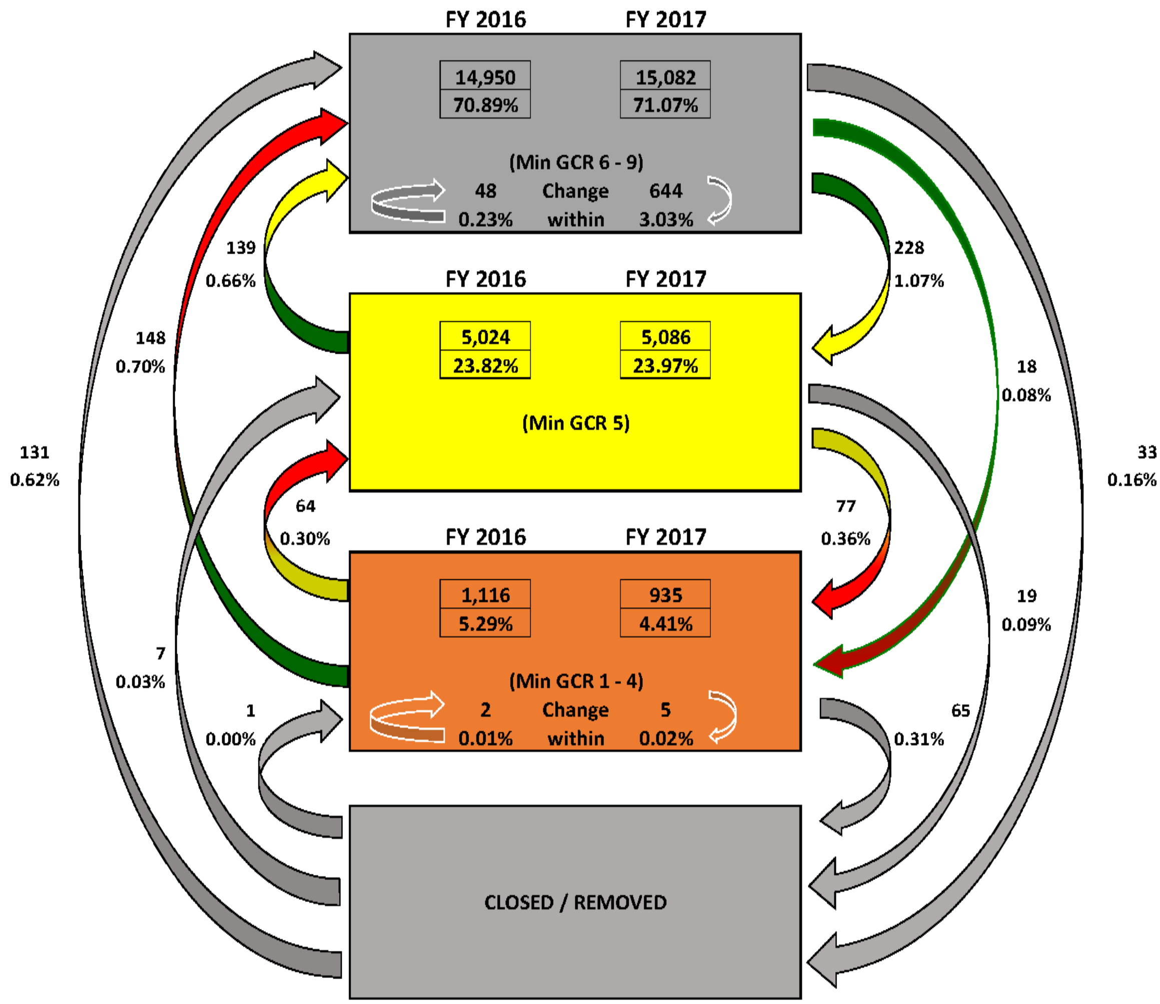
  Expansion joint elimination may be accomplished by making structures continuous for live load or by installing link slabs over piers or deck extensions at abutments.

- Perform maintenance activities on at least 6% of the Fair structures (minimum General Condition Rating 5 or 6) in each District in each fiscal year.

- Perform maintenance activities on at least 2% of the Satisfactory or Good structures (minimum General Condition Rating 6) in each District in each fiscal year.

These recommended targets were determined using an analysis of the annual transition of VDOT's structures from one condition category to another. The transition study was performed to determine the number of structures whose minimum GCR either improves or deteriorates in any particular year. Recognizing that the bridge maintenance program requires a balanced approach, where the maintenance needs of structures in each of the three condition categories are regularly addressed, the analysis sought to establish thresholds that would achieve the goal of maintaining the average GCR of the existing inventory over time. There is no unique solution for these goals (various combinations of thresholds for Good, Fair and Poor could achieve the desired result of maintaining the average GCR).

The initial study focused on the transition between 2009 and 2010, and results of the study were used to establish a baseline and develop achievable goals for each condition category. The study is replicated annually. The following chart depicts the Annual Transitions of Good/Fair/Poor or SD from end of FY2016 to end of FY2017.



Note: Percentages based on total structures in the inventory from FY16 to FY17 inclusive of those closed and/or removed over that time period.

Based on the study, it was determined that system sustainability could be achieved with the goals in Chapter 32. Furthermore, these goals were deemed to be reasonably attainable with existing staff. However, the funding required to meet these goals remains significantly higher than that provided.

COMMON BRIDGE-RELATED DEFINITIONS:

National Bridge Inventory (NBI) Structure: Any bridge or culvert having a track or passageway for carrying traffic or other moving loads and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches or extreme ends of openings for multiple boxes. It may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening. See Recording and Coding Guide for the Structure and Inventory of the Nation's Bridges, Report FHWA-PD-96-001(Recording Guide). While NBI structures include both bridges and large culverts, any structure that meets the requirements for an NBI structure is referred to the FHWA guidance as an NBI "bridge".

Non-NBI Structure: A structure that meets the requirements of current IIM-S&B-27, Bridge Safety Inspections. A structure is referred to as a "Non-NBI structure" if it is a bridge with a clear span opening (as defined above) of less than 20' or a culvert with an opening of greater than 36 square feet but not meeting the definition of an "NBI structure" given above.

General Condition Rating (GCR): Every structure begins to deteriorate from the completion of construction. Condition ratings have been established to measure deterioration levels of bridges in a consistent and uniform manner to allow comparison of the condition of bridges on a national level. According to the NBI policy, condition ratings are used to describe the condition of the existing, in-place bridge or culvert. Evaluation is for the materials-related, physical condition of the deck, superstructure and substructure components of a bridge and condition evaluation of culverts. GCR is a numerical system that ranges from 0 (worst condition) to 9 (excellent condition). Condition ratings are one-digit numbers given by the field inspector to the various components of a bridge or culvert. For guidelines about assignment and meaning of general condition ratings, refer to the AASHTO Manual for Bridge Evaluation (MBE). The ratings are based on objective criteria rather than opinion and are assigned values in accordance with the Recording Guide which may be found at: https://www.fhwa.dot.gov/bridge/mtguide.pdf.

Sufficiency Rating (SR): (Legacy term; discontinued) A formula-based value formerly used by FHWA to allocate funds and to serve as a prioritization rating tool for the bridges in the United States.

Structurally Deficient (SD): A Structurally Deficient Structure is one that has a general condition rating of 4 or less for one or more of the following components:

- Item 58 - Deck
- Item 59 - Superstructures
- Item 60 - Substructures
- Item 62 - Culvert

603 (Construction) Program: Virginia's 603 (construction) program is directed toward more extensive projects that cannot be readily addressed with the maintenance program. The Code of Virginia requires that 45% of the statewide construction program be dedicated to the State of Good Repair (SGR). SGR funds must be used for structurally deficient bridges (SD) and deficient pavements. SGR funds may be used for rehabilitation or replacement but the work must remove the structurally deficient status. The program is available to fund both VDOT and locality-owned NBI structures. Additional information may be found at the link below:

http://www.virginiadot.org/business/state_of_good_repair_sgr.asp

604 (Maintenance) Program: Virginia's 604 (maintenance) program is used for all bridge maintenance and operational needs. Each district receives an annual bridge maintenance budget that is used to fund inspection, load rating, operations (where appropriate), certain design activities, preventive and restorative maintenance (preservation)and rehabilitation. Certain small bridge replacement projects may also be funded with the 604 program. See current IIM-S&B-87, Limitations on the use of Maintenance Funding for Structure Replacement Projects at:

http://www.virginiadot.org/business/resources/bridge/Manuals/IIM/SBIIM87.2.pdf

Element Level Condition Data: Element-level data provide more detailed bridge condition information for bridge components. This data differs significantly from the General Condition Ratings (GCRs). Whereas GCRs are provided for four major structure components (deck, superstructure, substructure, culvert), element level data are gathered on many more structure elements (decks, railing, joints, bearings, girders/beams, abutments, piers, etc.). In addition to a higher level of detail, element level data are summarized using an entirely separate grading system. As mentioned above, under the NBI inspection program, bridge components are coded with GCRs of 0 (worst) through 9 (best). These ratings represent an **average** rating, which provides an overall indication of the general condition of the **entire** component being rated. The grading scale for element data works in the opposite direction, with 1 being the best and 4 being the worst. With element level data, bridge elements are rated in quantitative units and the element condition is distributed into various condition states. An element is a significant part of a bridge (such as abutments, girders, piles, caps, etc.) that can be further subdivided by material type (such as prestressed concrete, reinforced concrete, timber, steel, etc.). Each bridge will not have **all** the possible elements, and more likely will have under a dozen. Each element has a set of defined condition states. The standard number of condition states is four. The standard condition states are good (1), fair (2), poor (3) and severe (4) general descriptions. Additional guides to the collection and recording of element condition states may be found at:

FHWA Introduction to Element Level Bridge Inspection
https://www.in.gov/dot/div/contracts/standards/bridge/memos/ParticipantWorkbook2-day20140515.pdf

VDOT Supplement to the AASHTO Manual for Bridge Element Inspection
http://www.virginiadot.org/business/resources/bridge/VDOT_Suppl_to_the_AASHTO_Manual_for_Bridge_Element_Insp_2016.pdf

AASHTO Manual for Bridge Element Inspection – This manual may be purchased from the AASHTO Bookstore - https://bookstore.transportation.org/browse_bookstore.aspx

Repair: The remediation of damage or deterioration that affects the structural integrity of a bridge or culvert element.

Routine maintenance: Maintenance work that is planned and performed on a routine basis to maintain and preserve the condition of the highway system or to respond to specific conditions and events that restore the highway system to an adequate level of service. This includes spot deck patching and crack sealing. The state is responsible for routine maintenance, so it must be funded with state funds.

Ordinary maintenance: Work that preserves roadway assets, corrects minor defects or problems, and extends the life of the asset.

Preventive maintenance: Preventive maintenance may be condition based or planned (scheduled). Defined by AASHTO and accepted by the FHWA, it is the planned systematic implementation of cost effective treatments to an existing roadway system and its appurtenances that preserve the system, retards future deterioration and maintains or improves the functional condition of the system without increasing structural capacity. Preventive maintenance work does not have a requirement to bring the structure up to current railing or geometric standards. See current Eligibility of Preventive Maintenance in Federal-Aid Projects letter concerning preventive maintenance and system preservation activities in Section 32.07.

Examples of Preventive Maintenance – Bridge Cleaning, Deck Sealing, Sealing Joints, Thin Deck Overlays, Removing Large Debris in Channels, Spot and Zone Painting and Reconstructing/ Closing Joints.

Restorative Maintenance: The term “restorative maintenance” as used in this document applies to maintenance activities that are performed as a reaction to deterioration of bridge elements. This work is performed on an as-needed basis rather than on a regular schedule. Restorative maintenance is generally reactive rather than proactive. Restorative maintenance is different from planned preventive maintenance, which is generally performed in order to slow the rate of deterioration of a structure or one of its elements.

Examples of Restorative Maintenance – Painting (Over Coating and Complete Removal and Re-Coating), Hydro Demolition and Rigid Deck Overlays, Reconstructing/Closing Joints, Superstructure Repairs, Substructure Repairs, Fatigue Retroffiting, Scour Repairs, Cathodic Protection, and Electrochemical Chloride Extraction.

Bridge Preservation: Preventative Maintenance and Restorative Maintenance which are the components of the VDOT Structure/Bridge Preservation Program.

Rehabilitation: Rehabilitation involves major work required to restore the structural integrity of a bridge as well as work necessary to correct major safety defects (Source: 23 CFR 650.403(c). Rehabilitation projects can include component replacement (deck and or superstructure), repair or some combination thereof. Rehabilitation must be conducted in conjunction with preservation practices that mitigate and slow the causes of the damage being repaired.

Examples of Rehabilitation – Superstructure Replacements, Deck Replacements, and Culvert Rehabilitation. Rehabilitation can include significant repairs that to not involve replacement of a bridge component. Examples include but are not limited to hydromilling with concrete overlay, structural beam end repair or strengthening or other significant improvements to bridge components.

Replacement: NBI bridges that are structurally deficient (poor) are eligible for replacement or rehabilitation with the State of Good Repair program. Replacement and rehabilitation of non-NBI SD bridges must be performed with funds other than SGR.

Repair or Rehabilitation Candidate: VDOT uses the NBI General Condition Rating (GCR) as an index to identify bridges and culverts that may need some type of preservation or rehabilitation. Preservation or rehabilitation work is generally performed on structures with a GCR of less than 7. VDOT also uses element condition data to determine preservation or rehabilitation needs. Typically, condition states 1 and 2 would indicate no action or preventive maintenance activities, while condition states of 3 and 4 indicate the need for restorative or rehabilitation activities.

Condition Categories:

(1) Good: When the lowest rating of the 3 NBI items for a bridge (Items 58-Deck, 59-Superstructure, 60-Substructure) is 7, 8, or 9, the bridge will be classified as Good. When the rating of NBI item for a culvert (Item 62-Culverts) is 7, 8, or 9, the culvert will be classified as Good.

(2) Fair: When the lowest rating of the 3 NBI items for a bridge is 5 or 6, the bridge will be classified as Fair. When the rating of NBI item for a culvert is 5 or 6, the culvert will be classified as Fair.

(3) Poor: When the lowest rating of the 3 NBI items for a bridge is 4, 3, 2, 1, or 0, the bridge will be classified as Poor. When the rating of NBI item for a culvert is 4, 3, 2, 1, or 0, the culvert will be classified as Poor.

All bridges and culverts require some level of maintenance; however, a GCR of less than 7 is used to identify those structures that require more than routine or preventive maintenance.

The VDOT Bridge Program includes the following:

- Preventive Maintenance (604 program)
- Restorative Maintenance (604 program)
- Rehabilitation (603 or 604 program)
- Replacement (603 or 604 program)

Viewed from a high level:

- Preventive maintenance candidates are structures in Good Condition
- Restorative maintenance candidates are structures in Fair Condition
- Rehabilitation and replacement candidates are structures in Poor Condition

In general, rehabilitation and replacement candidates are structures having one or more components with a GCR of 4 or less, restorative maintenance candidates are structures having one or more components with a GCR equal to 5 or 6, and preventive maintenance candidates are structures having one or more components with a GCR of 6 or greater.

Preventive maintenance, restorative maintenance, and rehabilitation activities are typically funded by maintenance (VDOT Program 604) funds.

The federally recognized maintenance activities are listed in the table in Section 12.07, along with their associated VDOT Bridge Maintenance activity codes and activity code descriptions.

Note - Due to the changes implemented by both MAP-21 and FAST act the VDOT/FHWA Virginia Division Agreement for Federal Aid Maintenance Projects is not needed however it is still highly encouraged for contract and programmatic consistency.

Bridge Preservation: AASHTO defines bridge preservation as follows: Bridge Preservation is "actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life." Source: AASHTO Board of Directors, Policy Resolution PR-3-11, October 17, 2011.

A link to the FHWA Bridge Preservation web page is provided below:

https://www.fhwa.dot.gov/bridge/preservation/

The following commentary is also included in the bridge preservation definition:

Effective bridge preservation actions are intended to address bridges while they are still in good or fair condition and before the onset of serious deterioration.

An effective bridge preservation program: 1) employs long-term network strategies and practices that are aimed to preserve the condition of bridges and extends their useful life; 2) has sustained and adequate funding sources; 3) has adequate tools and processes to ensure that the appropriate treatments are applied at the appropriate time

An effective bridge preservation program includes, but is not limited to, the following components:

1. Qualifying parameters for bridge types and related conditions, i.e. bridge elements or components that are in fair to good condition such as concrete decks, coated steel elements, substructure elements in a marine environment, etc.
2. Appropriate treatments such as cleaning, installation of deck overlays, coating of steel elements, installation of cathodic protection and prevention systems, etc.
3. Regular needs assessment to identify, prioritize, and estimate the cost of planned work.

The FHWA has published a *Bridge Preservation Guide* that can be viewed at the following link:

http://www.fhwa.dot.gov/bridge/preservation/guide/guide.pdf

A preservation approach to maintaining a structure inventory will include performing preventive, , and restorative work actions that address structures while they are still in good or fair condition and before the onset of serious deterioration.

A balanced structure maintenance program will provide for preservation, rehabilitation, and replacement actions, and may be the most efficient and effective way to maintain and improve health of the structure inventory.

The following breakdown is recommended for the allocation of structure maintenance funds:

- Preventive Maintenance (including painting) – 25% (Program 604)
- Restorative Maintenance (in conjunction with preservation) – 50% (Program 604)
- Rehabilitation/Small Structure Replacement – 25% (Program 604)

The exact breakdown of maintenance allocations will vary and will depend on the particular condition and needs of the structures in each district. The breakdown for a district may be determined by calculating the unconstrained needs using the Bridge Management System, assigning work actions to a program (preventive maintenance, painting, restorative maintenance, rehabilitation/small structure replacement) and calculating the sum for each program.

Small structure replacements funded under Program 604 must be accomplished in accordance with the requirements of the current IIM-S&B-87, Limitations on the Use of Maintenance Funding for Structure Replacement Projects.

Planned preventive maintenance should be performed on a schedule to be developed for each structure. See Section 32.10 for chart establishing a basis for scheduling planned preventive maintenance activities.

Notes on deck crack sealing: There are two distinct schools of thought on the application of gravity sealants to seal active deck cracks. Recent research has shown that this activity has, at best a very limited functional duration and is not a cost-effective maintenance technique for active cracks. However, some districts have had good experience with the practice and have both practical and anecdotal evidence to support this position. This document does not recommend the use of gravity sealants on active cracks but recognizes that a valuable short-term maintenance activity for dormant cracks.

REPAIR/PRESERVATION, REHABILITATION OR REPLACEMENT: DECISION PROCESS

INTRODUCTION

This section provides guidance for high level scoping of bridge projects that have been selected for condition-based interventions. This section does not address specific, detailed actions required for bridge components or elements, but rather provides direction on whether a bridge should be preserved, rehabilitated or replaced.

See Section 32.01 for descriptions of preservation and rehabilitation. Sections 32.02 through 32.05 apply to bridges with concrete decks (with or without overlays).

REQUIREMENTS FOR DESIGNERS:

1. If either repair/preservation or rehabilitation is selected as the preferred alternative, the work must include actions to extend the service life.

2. Replacement is the preferred option only if the cost of rehabilitation or repair/preservation exceeds 65% of replacement or unless there are strong mitigating factors indicating replacement is required. Cost estimates should include all highway and project costs necessary to develop the complete cost estimate, including the cost for Maintenance and Protection of Traffic.

   The following mitigating factors may be used to justify a replacement if the rehabilitation or repair/preserve cost is less than 65% of replacement:

   - Scour susceptibility
   - Hydraulic inadequacy
   - Fracture critical superstructure elements
   - Alkali-silica or alkali-carbonate reactive aggregate
   - Accident history or potential
   - Inadequate horizontal or vertical clearances
   - Unsafe site distance or roadway alignment (vertical or horizontal)
   - Requirements to accommodate bicycle and/or pedestrian access
   - Overloads/effects on permit vehicles
   - Ship collisions or U.S. Coast Guard issues
   - Extraordinary environmental constraints
   - Life Cycle Cost Analysis indicates that replacement is the most cost-effective alternative over a 75 year life

   Similarly, mitigating factors may justify repair/preservation or rehabilitation, even when the cost of doing so exceeds 65% of replacement.

3. Documentation of all factors contributing to the final decision (calculations, tests condition data, etc.) must be kept in the project file in the District Bridge Office.

4. Follow guidelines established in the Decision Chart in this section.

5. Requirements established in this section do not apply to historical structures. For purposes of this document, a historical structure is one that is either listed in the *Management Plan for Historic Bridges in Virginia*, published by VTRC, or a contributing element to a designated historical district. Intervention decisions for historical structures involve parameters that do not affect conventional, newer bridges. Wherever possible, historical structures should be preserved.

   Many historical structures were designed to sustain loads significantly lower than those associated with modern trucks, so these bridges are highly susceptible to damage or collapse from vehicles that exceed weight, height or width limits. Given their sensitivity to modern trucks, the first preference for historical structures should be to remove truck traffic, and, if possible, all vehicle traffic. This action will provide the highest probability that the bridge will be preserved into the future. The following options should be considered for historic bridges:

   - Close the structure if a convenient bypass structure already exists
   - Build a bypass structure
   - Close the historical bridge to all but pedestrian and bike traffic if the structure can sustain these loads
   - Consider preserving all or a portion of the structure in a public space such as a park or highway rest area. Where appropriate, structures may be disassembled and partially or fully re-assembled at a different site.
   - If closure to truck traffic is not a viable option, then consider positive means to limit the risk that the bridge will be subjected to overheight or overweight trucks. These might include height detection and weigh-in-motion devices placed along the approach roadways.

   The VTRC *Management Plan* is available at the link below:
   http://www.virginiadot.org/vtrc/main/online_reports/pdf/14-r9.pdf

RECOMMENDATIONS:

Life Cycle Cost Analysis:

Cost estimates for projects less than or equal to $2M may be based on the estimated cost of initial construction. A life cycle cost analysis is recommended for projects costing more than $2M or when comparing alternatives of differing life expectancies and/or differing degrees of proficiency. For example, the elimination of joints in multiple simple span bridges by the use of joint closures or deck extensions have a longer life expectancy (the remaining life of the deck) and are more proficient in preventing moisture penetration than joint replacement, but have a higher initial cost. See Life Cycle Cost Analysis Guidelines, Section 32.06.

Approach Slabs:

Assess top of approach slabs in the same manner as the deck. See Section 32.03. Consult with District Structure and Bridge Engineer to determine if scope of work will be to repair/preserve and/or proceed with further evaluation, replace or eliminate.

- Estimate cost for preventative maintenance or repair/preserve/rehabilitation of structurally adequate approach slabs

- Estimate cost for replacement or elimination of approach slabs that extend over the backwalls and are in contact with the joint, are structurally inadequate, are shifting away from the abutments or are experiencing other forms of failure.

Unusual Conditions:

The decision-making process, as outlined herein and illustrated in the Decision Chart, is based on normal or most probable condition relationships between the deck, superstructure and substructure. However, unusual conditions may exist that require evaluation by the bridge design engineer on a case by case basis as an overall condition assessment of the bridge is developed. Consideration needs to be given to deviating from this process as conditions warrant. The following cases are examples of structures with unlikely, yet possible, combinations of conditions that do not fit the norm:

- Deck and superstructure are both in good condition; however, substructure is in poor condition or susceptible to scour. In this case, replacement of one or more substructure elements could dictate partial/full rehabilitation or replacement of the bridge.
- Deck and substructure are in good condition; however, superstructure is in poor condition and the rehabilitation of the supporting members dictates replacement of the superstructure.
- Structure is well within the cost range of justifying preservation or rehabilitation; however, issues such as scour susceptibility, hydraulic inadequacy, accident history/potential, or redundancy (e.g. fracture critical) make replacement the preferred alternative.

For situations such as these, the order of investigation as recommended by this process may be adjusted, resulting in savings of time and reduction in evaluation costs.

COMMENTARY:

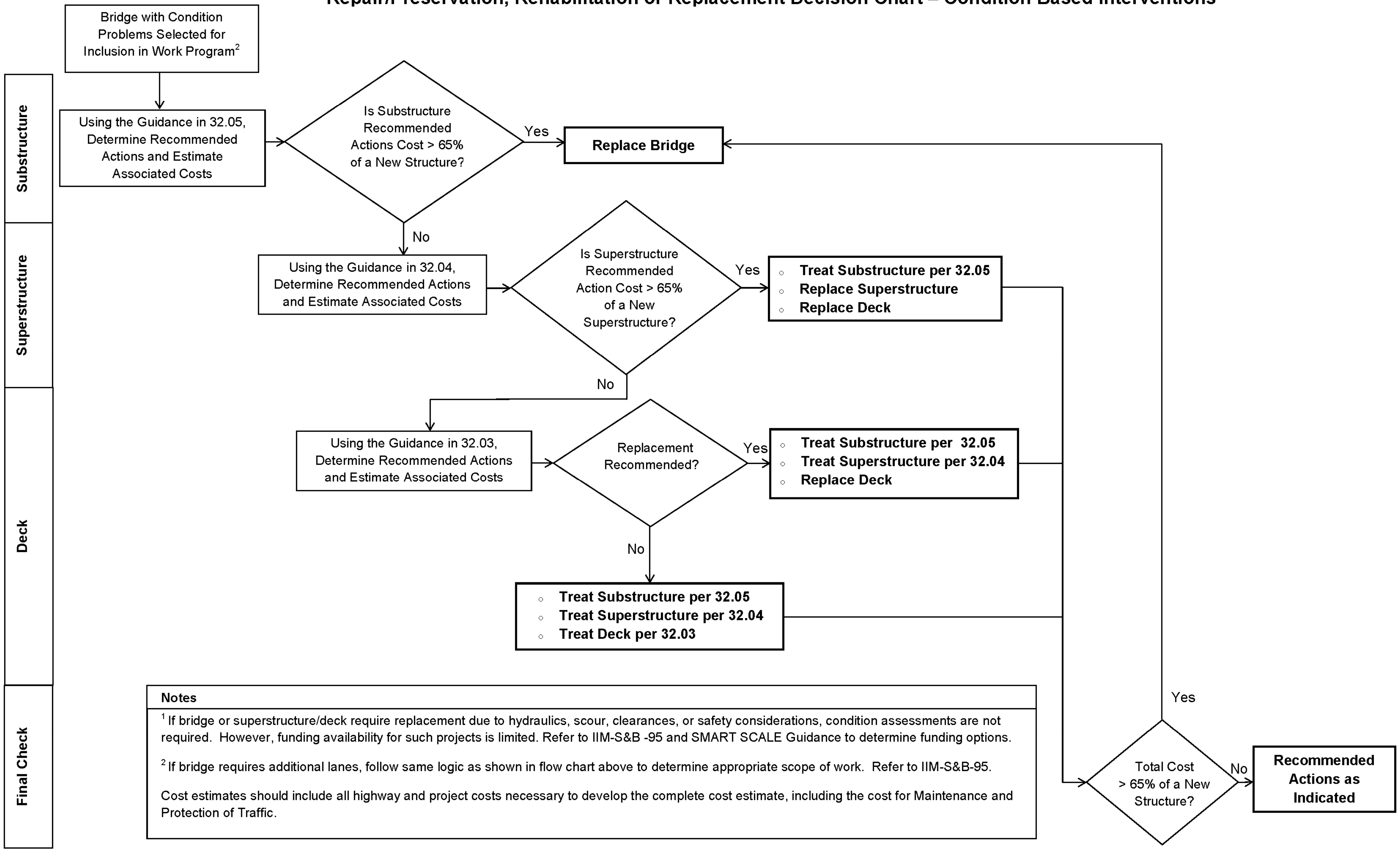
Virginia's bridge inventory has reached a critical age. Approximately 50% of our highway structures have exceeded their anticipated service lives, and that percentage is expected to exceed 65% in 10 years. Over the next 50 years, the funding required to replace bridges as they exceed their service lives is about 5 times as much as the funding levels that are currently available ($11B presumed available vs. $54B needed over 50 years). This means that there will not be enough money to replace all the aging and deteriorated bridges over the next several decades.

However, an opportunity exists to preserve, rehabilitate, and repair/preserve bridges now, wherever possible, in lieu of replacement. An aggressive program of preservation can extend bridge service lives and postpone the need to replace bridges. However, there is not adequate funding available today to both preserve all the structures that require it and replace bridges. In general, bridge rehabilitation/preservation costs about 15% of bridge replacement. This means that about 6 bridges can be rehabilitated and preserved for the price of one bridge replacement.

Accordingly, wherever possible, the most cost-effective options should be pursued for all bridge projects. Historically, full bridge replacement has been chosen more frequently than necessary, leading to a "worst first" approach. When viewed from the perspective of the health of the entire inventory, replacement should be the last resort, with rehabilitation and preservation as the default actions.

This approach is also being emphasized at a national level. The FHWA Bridge Preservation Guide recognizes that, due to limited funds and increased competition for funds among highway assets, bridge owners are challenged to cost effectively preserve and maintain their bridges to support overall highway mobility.

Repair/Preservation, Rehabilitation or Replacement Decision Chart – Condition Based Interventions[1]



Notes

[1] If bridge or superstructure/deck require replacement due to hydraulics, scour, clearances, or safety considerations, condition assessments are not required. However, funding availability for such projects is limited. Refer to IIM-S&B -95 and SMART SCALE Guidance to determine funding options.

[2] If bridge requires additional lanes, follow same logic as shown in flow chart above to determine appropriate scope of work. Refer to IIM-S&B-95.

Cost estimates should include all highway and project costs necessary to develop the complete cost estimate, including the cost for Maintenance and Protection of Traffic.

INTRODUCTION

This section establishes guidelines for the evaluation, preservation, rehabilitation and replacement of existing concrete bridge decks. For the design of new bridge decks, see Chapter 10.

The decision processes and requirements this section addresses consider bridge decks only. Decisions involving additional bridge components have more parameters and therefore greater complexity. Multi-component decision processes are addressed elsewhere in this chapter.

REQUIREMENTS FOR BRIDGE DECK EVAL., REPAIR AND RESTORATION:

1. The testing and evaluation requirements of this section have been established to require only the level of testing/evaluation necessary to make an informed decision. In many cases, the appropriate intervention may be inferred with a visual examination and a minimum amount of additional information. In such cases, the money spent to evaluate the deck may be better used for the actual maintenance intervention. The logic of the Deck Decision Matrix on File No. 32.03-3 was developed to allow districts the flexibility to perform more aggressive interventions in lieu of additional tests and evaluations. However, the table also provides additional guidance if a more refined analysis is preferred.

   Unless waived by the District Structure and Bridge Engineer, decks must be evaluated and tested in accordance with the Evaluation Requirements and Recommendations for Concrete Decks table on File No. 32.03-6. Designer may elect to perform additional testing if warranted by conditions.

2. The determination of which bridge decks will receive maintenance and repair is a budget-constrained selection process that is the responsibility of the District Structure and Bridge Engineer. For those decks selected for intervention, maintenance shall be performed in accordance with the Deck Decision Matrix on File No. 32.03-3 unless waived by the District Structure and Bridge Engineer in writing.

3. The Deck Decision Matrix on File No. 32.03-3 applies to concrete decks with or without overlays of any kind and whether widening is contemplated or not. However, if widening is either part of the scope or is planned for future work, consideration should be given by the designer to the selection of a more aggressive treatment option. This is a judgment that should be made on a case-by-case basis and predicated on the best long term value for the Department.

4. This section provides guidance for condition-based intervention decisions. Condition-driven decisions fall into the category of maintenance rather than new construction, and for such actions there is no requirement to increase functionality by widening existing bridge decks. Nor is there a requirement to replace bridge barriers or rails unless they exhibit damage requiring replacement. The District Structure and Bridge Engineer may elect to widen a structure or replace bridge barriers in conjunction with a deck maintenance/replacement action if there is a compelling need to do so and the additional cost is justifiable based on traffic or safety considerations.

5. Deck joints shall be eliminated, replaced or repaired in accordance with the Requirements for Deck Joint Treatments provided on File No. 32.03-8.

HIERARCHY OF DECK TREATMENT OPTIONS:

Hierarchy of Deck Treatment Options (Least Protective to Most Protective)	
Rank	**Deck Treatment**
1	Patching - Type B and Type C
2	Crack Sealing with Mesh, Polymer Fill, V Groove or Epoxy Injection
3	Epoxy Overlay
4	Asphalt Overlay with Approved Membrane[1]
5	Rotomill[2] and Rigid Overlay[5]
6	Shallow Hydromill[3] and Rigid Overlay[5]
7	Deep Hydromill[4] and Rigid Overlay[5]
8	Replace Deck

1. Asphalt overlays may be placed only over approved membranes. Asphalt overlays may be installed over Type I, II or III membrane systems on secondary bridges but must be placed on Type I or II membrane systems on interstate or primary system bridges. Approved membrane types are defined in Section 429 of the *VDOT Road and Bridge Specifications*.

2. Type A Milling (rotomilling): Consists of milling the surface of the bridge deck and approaches to the depth specified, usually 1½ inch nominally.

3. Shallow Hydromilling: Referred to as “Type A Hydro-demolition” in the *VDOT Road and Bridge Specifications*, consists of removing concrete to a depth of ½ inch below the milled surface in areas of sound concrete, and removing concrete to a depth of 1 inch below the bottom of the top mat of reinforcing steel in areas of deteriorated concrete. Usually performed after 1 ½” to 1 ¾” of Type A milling (rotomilling).

4. Deep Hydromilling: Referred to as “Type B Hydro-demolition” in the *VDOT Road and Bridge Specifications*, consists of removing concrete to a depth of 1 inch below the bottom of the top mat of reinforcing steel over the portion of the deck surface receiving this treatment.

5. Rigid Overlay: A hydraulic cement concrete overlay placed on a milled concrete bridge deck. Depth varies from 1¼” over Type A Milling to 4” for a Deep Overlay. Designer must specify overlay type, nominal thickness, material, and substrate preparation (milling type). See the *VDOT Road and Bridge Specifications*.

FACTORS AFFECTING BRIDGE DECK INTERVENTION DECISIONS:

The determination of the most appropriate intervention for existing bridge decks is primarily based on the following factors:

- Depth and concentration of chloride penetration into the deck surface
- Area of delamination, spalls and patches (compromised area)
- Extent of corrosion in existing steel
- Extent and widths of cracks
- Condition of the bottom of the deck
- Presence of reactive aggregates susceptible to alkali-silica reaction (ASR)
- Strength of concrete
- Permeability of concrete

DECK DECISION MATRIX:

Deck Decision Matrix: Concrete Decks[1, 9, 10]					
Worse of These		Condition Category	Year Built	Evaluation Results	Minimum Required Action
Deck GCR	% CA[2]				
7 – 9	≤ 5	Good	Prior to 2003	Recommended, but Not Required	Patch, Epoxy Overlay, Fill Cracks[3], Clean Drains and Sweep/Wash Annually
			2003 or later	Recommended, but Not Required	Patch, Fill Cracks[3], Clean Drains and Sweep/Wash Annually
6	≤ 10	Satis-factory[4]	Any	CA < 5% & CF < 1”	Patch and Epoxy Overlay
				CA ≤ 10% & CF ≤ 1.5”	Patch and Rigid Overlay on Rotomilled Substrate
				No Evaluation or CF[5] >1.5”	Rigid Overlay on Shallow Hydromilled Substrate
5	≤ 15	Fair[4]	Any	CF[5] ≤ Average Cover Depth of Top Bar Mat[6]	Rigid Overlay over Shallow Hydromilled Substrate
				4” > CF[5] ≥ Avg. Cover Depth of Top Bar Mat[6]	Rigid Overlay over Deep Hydromilled Substrate
≤4	≤ 20	Poor[4]	Any	CF[5] ≤ Average Cover Depth of Top Bar Mat[6]	Rigid Overlay over Shallow Hydromilled Substrate
				4” > CF[5] ≥ Avg. Cover Depth of Top Bar Mat[6]	Rigid Overlay over Deep Hydromilled Substrate
Any	Any	Any	Any	CF[5] > 4”	Replace Deck[7,8]
Any	Any	Any	Any	Spalls - deck bottom >3%	Replace Deck[7]
Any	Any	Any	Any	Reactive Aggregates Present & CI > 0.02 in/yd	Replace Deck[7]
Any	Any	Any	Any	f_c' ≤2,400 psi (average)	Replace Deck[7]
Any	Any	Any	Any	Cost to Rehab or Repair > 65% of Replace Cost	Replace Deck[7]

Notes on the Deck Decision Matrix:

1. If any deck exhibits signs of alkali-silica reaction based on a qualitative visual assessment, then petrographic analysis is required. If petrographic analysis establishes the presence of highly reactive aggregate, then measure the Cracking Index (CI) to analyze the severity of damage. If CI < 0.02 in/yd, provide a rigid overlay on a hydromilled surface. Establish depth of hydromilling to eliminate chloride front. CI is defined in FHWA’s *Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures.* A link is provided in Reference 1 on File No. 32.03-13.

2. Compromised Area (CA) of Deck is expressed as a percentage of the total deck area (width is based on the out-to-out dimension of the bridge) and is determined by either of the methods below. If nondestructive testing is used, CA will be the greater of the two.

   - The total area of deck in condition state 2 or greater, as defined in terms of the AASHTO element definitions. Determined by visual examination.

   OR

   - The deck area measured as delaminated, spalled or patched (determined using and acceptable methodology) plus additional areas of deck in condition state 1 with half-cell potential readings more negative than -0.35mV.

DECK DECISION MATRIX (Cont'd):

3. Cracks wider than 0.20 mm allow the inflow of water and must be sealed or overlaid. An asphalt overlay with approved membrane is required for Good decks with active cracks. Active cracks are those with widths that vary with temperature and/or live load. The District Structure and Bridge Engineer shall determine whether active cracks are significant enough to require an overlay. Good decks with non-active cracks wider than 0.20 mm require an epoxy overlay if built prior to 2003 and gravity filled polymer sealing (Crack Repair Type C) or epoxy injection (Crack Repair Type B) if built in or after 2003. Overlays or crack seals are recommended for decks with an average of more than 0.2 linear feet of crack per square foot measured over the entire deck (e.g., 20 linear feet for 100 sf of deck).

4. A deck evaluation is required for decks in Fair or Poor condition unless more than 3% of deck bottom exhibits spalls and recommended for decks in Satisfactory condition.

5. Chloride Front (CF): The depth, measured from the top of the existing deck, at which the average chloride ion concentration in concrete exceeds the chloride threshold (defined below). The CF is determined by graphing the chloride profile (concentration of chloride ions versus depth) using the average readings from chloride ion tests taken from the bridge deck.

   Chloride Threshold: Concentration of chloride ions required at the depth of the reinforcing steel to initiate corrosion. Value: 2.0 pounds per cubic yard.

6. Average Cover Depth of Top Bar Mat: Measured from the top of the deck to the top of the top bar layer in the top mat. For structures with existing concrete overlays the top of the overlay is considered to be the top of the deck.

7. If a deck replacement is indicated as the most appropriate action but funds are not currently available, the replacement may be delayed for a period of 3 to 5 years by patching the worst portions of the deck and placing a 2" to 2 ½" intermediate mix asphalt overlay over a low-cost membrane. This is only a stop-gap measure to provide time until funds can be provided. The bridge must be load rated for additional dead load.

8. For concrete decks that are integral parts of concrete T-beam superstructures, a deep hydromill and rigid overlay is required as long as beams are suitable for preservation. Where beams require replacement, replacement of the entire superstructure is required.

9. Evaluation of Existing Rigid Overlays: If an existing rigid overlay exhibits more than 5% spalling, the bond strength of the overlay should be evaluated and areas with low bond strength (≤100 psi) should be replaced by patching. If the area to be replaced exceeds 20% and is not confined to one lane, the entire overlay should be replaced. Evaluate the deck and base final intervention decision on the requirements of this section.

10. Decks with corrosion resistant reinforcement (CRR): Minimal corrosion-induced damage is anticipated for decks with CRR over the next decade. Decks with CRR that exhibit distress or damage should be evaluated individually to determine cause(s) of deterioration.

PLANNING LEVEL PRODUCTION RATES AND COST FACTORS:

The Deck Decision Matrix provides required actions for bridge decks based on the measured or observed physical characteristics of the deck. Constraints such as access to lanes to perform the work are not considered in the matrix. There are, however, practical restrictions on the availability of lane closures that can strongly influence the type of work selected and its cost. Rigid overlays placed on hydromilled surfaces are strongly encouraged where appropriate for the deck conditions, but hydromilling is an additional process that requires additional lane closure time. To provide designers with realistic estimates of the time and cost of hydromilling for rigid overlays, the table below was developed in conjunction with industry for situations where lane closure availability is highly restricted.

Planning Level Production Rates and Cost Factors: Shallow Hydromilling and Overlay with Very High Early Strength Latex Mod. Concrete - Interstate Highway Conditions[1,2,3]

Available Closure Duration (hours)	1 Lane Closed During Operations		2 Lanes Closed During Operations	
	Average Possible[4] Production per Closure (Square Feet)	Cost Factor[5]	Average Possible[4] Production per Closure (Square Feet)	Cost Factor[5,6]
12	1,200	2.25	1,800	1.60
14	1,600	1.90	2,100	1.40
16	2,000	1.60	2,400	1.25
18	2,400	1.35	2,900	1.10
20	2,800	1.26	3,300	1.01
24	3,600	1.26	4,400	1.01
36	6,000	1.26	7,400	1.01
48	8,400	1.25	10,000	1.00
60	12,000	1.25	14,000	1.00
>60	5,000 per calendar day	1.25	7,000 per calendar day	1.00

Notes on Planning Level Production Rates Chart:

1. Assumes Type A milling and joint elimination/repairs are performed during separate, prior closures (work performed during closure consists of hydromilling and placement of overlay behind barrels).
2. For production rates less than 120 linear feet per closure, overlays should be cast ¼" higher than the final planned deck elevation, and the overlay should be diamond ground after the overlay has been cast over the entire deck.
3. Assumes that the contract contains incentive/disincentive clause(s) for accelerated construction.
4. The term "possible" applies to cases where other constraints are not present. Production may be limited by bridge length, span length and other geometric constraints particular to the project rather than the potential production rate of the operation.
5. Cost factors are a rough indication of relative premiums per square foot necessary if work windows are shortened or otherwise constrained. 1.0 is selected as the baseline. For example: a cost factor of 1.35 indicates that users should expect to pay about a 35% premium over ideal conditions for the constraints indicated.
6. An additional cost factor of 0.50 should be added for weekend work.

DECK EVALUATION REQUIREMENTS:

Evaluation Requirements and Recommendations for Concrete Decks				
Condition Category	**Test Type**	**Minimum Frequency or Number**	**Locations**	**Recommended or Required**
Good	Visual and Delamination Survey[1,3]	Entire Deck	Entire Deck	Recommended
	Half Cell Potential[2,3]	5' x 5' Grid	Entire Deck	Recommended
Satisfactory	Visual and Delamination Survey[1,3]	Entire Deck	Entire Deck	Recommended
	Half Cell Potential[2,3]	5' x 5' Grid	Entire Deck	Recommended
	Chloride ion profile[5]	10 total or 4 per span for multi-span	Emphasize Shoulders	Recommended
	Depth of Cover[4]	Entire Deck (GPR) or 1 Reading per 25 SF for Pachometer	Take Readings on a Grid	Recommended
Fair	Visual and Delamination Survey[1,3]	Entire Deck	Entire Deck	Recommended
	Half Cell Potential[2,3]	5' x 5' Grid	Entire Deck	Recommended
	Chloride ion profile[5]	10 total or 4 per span for multi-span	Emphasize Shoulders	Required
	Depth of Cover[4]	Entire Deck (GPR) or 1 Reading per 25 SF for Pachometer	Take Readings on a Grid	Required
	Visual assessment of deck bottom[6]	Entire Deck	Entire Deck	Required
Poor	Chloride ion profile[5]	10 total or 4 per span for multi-span	Emphasize Shoulders	Required
	Depth of Cover[4]	Entire Deck (GPR) or 1 Reading/25 SF for Pachometer	Take Readings on a Grid	Required
	Visual assessment of deck bottom[6]	Entire Deck	Entire Deck	Required
Any	Petrographic Analysis[7]	4 Tests	Designer Decision	Required if ASR Suspected
	Compressive Strength[8]	4 Tests	Designer Decision	Required Only if Soft Concrete or Live Load-Induced Distress are Evident

DECK EVALUATION REQUIREMENTS (Cont'd):

Notes on Evaluation Requirements and Recommendations for Concrete Decks:

1. Delamination: Delamination may be determined using one of four methods.

    a. Sounding per ASTM D4580/ASTMD4580M (this method is not effective on decks with asphalt or concrete overlays)

    b. Infrared Themography (IRT) performed in accordance with ASTM D4788

    c. Ground Penetrating Radar (GPR) performed in accordance with ASTM D 6087 - 08, or ASTM D6087-08(2015)e1 Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar

    Note - Multichannel GPR has been found useful for identifying substandard concrete condition, such as the presence of excess moisture, honeycombing, etc. However, if the primary goal is to locate delamination in concrete, IRT is the recommended NDT method for use at highway speed. Often a combination of both GPR and IRT has been useful in giving a better picture of the concrete. GPR provides indirect indication of poor concrete quality (analogous to a half-cell), while IRT provides the direct location of current delaminations/debondments, if conducted at an appropriate time of the day.

    d. Impact Echo – ASTM C1388, Test Method for Measurement P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method, which is implemented in deck evaluation by conducting point testing on a grid of a selected spacing.

    Designer may use a combination of these methods to determine delaminated area. Delamination evaluation of decks with asphalt overlays is not required, as the only options for determining delaminated areas are GPR and Impact Echo, which currently provide variable degrees of accuracy for decks with asphalt overlays. If decks with asphalt overlays are believed to be in fair to poor condition, the asphalt overlay should be removed as necessary to perform necessary evaluations. See link below to VDOT's most recent contract for non-destructive evaluation of concrete bridge decks:

    https://insidevdot.cov.virginia.gov/div/SB/BMGT/Shared%20Documents/Forms/AllItems.aspx?RootFolder=%2Fdiv%2FSB%2FBMGT%2FShared%20Documents%2FSHRP2%20R06A%20Contract%2FSecond%20Contract&InitialTabId=Ribbon%2EDocument&VisibilityContext=WSSTabPersistence

2. Half Cell Potential: Perform tests in accordance with ASTM C876-09. Note that half-cell potential tests have limited utility on decks with epoxy reinforcement. Half-cell readings will have the greatest validity in those locations where the epoxy coatings have experienced significant deterioration. See report from Utah Department of Transportation (link provided in Reference Section) for further information.

3. Delamination and half-cell potential tests are most valuable (and preferable to chloride sampling for chloride ion profile) when determining quantities and locations of patches for decks (where anticipated work is limited to patching, and rigid overlays are not being considered due to budget constraints or because condition category of deck is Good).

4. Depth of Cover: Conduct per 404.04(a) of the *VDOT Road and Bridge Specifications* with pachometer readings on a 5' grid or GPR in accordance with ASTM D6087–08.

DECK EVALUATION REQUIREMENTS (Cont'd):

5. Chloride Ion Profile: Perform tests in accordance with AASHTO T 260-97 (2005), Procedure A. Provide chloride ion concentrations at depths of ½", 1 ½", 2 ½" and 4". Provide results in tabular format and attach to the Bridge Deck Evaluation Summary Form. Chloride ion profile tests provide the most critical information for overlay candidates, as the results will govern the required depth of milling (removal of contaminated concrete). Because hydromilling operations will remove soft/delaminated locations, determining delaminated or corroded bar locations is not critical where overlays will be placed on hydromilled decks.

6. Use depth of chloride front to determine best action for decks with stay-in-place forms.

7. Perform petrographic analysis in accordance with ASTM C 856 only when ASR is suspected after visual examination. See Supplemental Information section for references that provide guidance on identifying ASR-damaged concrete.

8. Compressive strength: Cores to be taken and tested in accordance with ASTM C42/C42M.

DECK JOINT REQUIREMENTS:

Elimination of existing joints using joint closures is expected in all cases where feasible. The designer shall investigate the feasibility of eliminating all deck expansion joints. Guidance on evaluating bridges for joint elimination is provided elsewhere in this chapter.

Requirements for Deck Joint Treatments when Deck Work is Performed See Section 32.08 for Normal Maintenance Requirements for Joints	
Deck Treatment	**Minimum Deck Joint Treatment**[1]
Type B Patching	Adhesive-Based Seal or Pourable Seal[2]
Polymer Fill or Epoxy Injection	Adhesive-Based Seal or Pourable Seal[2]
Epoxy Overlay	Adhesive-Based Seal or Pourable Seal[2]
Asphalt Overlay with Approved Membrane	Asphalt Plug Joint
Rotomill and Rigid Overlay	Elastomeric Expansion Dam
Shallow Hydromill and Rigid Overlay	Joint Elimination
Deep Hydromill and Rigid Overlay	Joint Elimination
Replace Deck	Joint Elimination[3]

Notes on Requirements for Deck Joint Treatments when Deck Work is Performed:

1. When joint elimination is not practical, joint treatments indicated in the table may be selected. Justification for any remaining joints must be provided via email to the Assistant State Structure and Bridge Engineer for Maintenance and posted in IPM. Elastomeric expansion dams are strongly preferred to other available joint types.

2. Adhesive-based seals may be used irrespective of highway system. Silicone seals may be used only on Secondary system bridges. Check movement rating.

3. For replacement decks, joints shall be eliminated at abutments. Joints over piers shall be eliminated unless the substructure is inadequate to sustain superstructure loads. Where joint elimination is not possible due to substructure limitations, new joints must be replaced with elastomeric expansion dams.

BRIDGE DECK EVALUATION SUMMARY FORM:

Bridge Deck Evaluation Summary Form[1, 5]				
Recommended Action per Deck Decision Matrix: ***State Recommended Action Here***				
Condition Category	**Test Type**	**Results to Report**		**Number of Tests Performed**
Indicate whether deck is Good, Satisfactory, Fair or Poor	Delamination/Spalls/ Patches[2]	*CA (%)*		#
	Half Cell Potential	*Average potential*[3]		#
	Chloride Ion Profile[4]	½" depth	*Avg. Chloride (#/CY)*	#
		Depth of Bar	*Avg. Chloride (#/CY)*	
		1 ½" depth	*Avg. Chloride (#/CY)*	
		4" depth	*Avg. Chloride (#/CY)*	
	Depth of Cover	*Average depth to center of top mat*		#
	Visual assessment of Deck Bottom	*% Delaminated, spalled or patched (approximate per visual examination)*		*N/A*
	Petrographic Analysis	*Carbonation*		#
		ASR Susceptibility		#
	Compr. Strength	*Average Compressive Strength (psi)*		#

Notes on Bridge Deck Evaluation Summary Form:

1. Fields to be filled in by evaluator are shown in italics. Submit actual test results in tabular format as an attachment to the Summary Form. Indicate "N/A" for tests/evaluations not performed.

2. Mark delaminated areas with paint during delamination survey. Borders of delaminated areas must be rectilinear.

3. Provide map or index of half-cell potential readings so that designers may correlate locations with readings.

4. Provide a graph of average chloride content vs. depth of cover in addition to actual results.

5. See File No. 32.03-4 for note on the Deck Decision Matrix regarding the Evaluation of Existing Rigid Overlays.

COMMENTARY:

1. **Deck Decision Matrix Philosophy:** VDOT's bridge inventory has reached an age where a large number of decks are in need of preservation, , rehabilitation or replacement. Chloride contamination levels in many of these decks have reached depths and concentrations that require action. In order to meet the very high cost of addressing these needs within the constraints of existing budgets, VDOT must emphasize repair in conjunction with preservation techniques over replacement. The deck matrix was developed to allow designers to make rational, cost-effective decisions without requiring any more testing or evaluation than necessary.

   The matrix allows and encourages the placement of overlays rather than the much more expensive option of replacement. With the advancement of hydromilling technology, decks need only be replaced when deterioration has reached an advanced stage. Even for very problematic decks, deep hydromilling allows the removal of the top 3 ½" to 4" of deteriorated concrete and replacement with a low-permeability, structural overlay.

   One of the primary goals of the matrix is to promote actions that eliminate the worst of the chloride contamination through milling followed by the placement of an overlay over the milled surface. Decks with Condition Categories below Good are generally candidates for actions more aggressive than maintenance patching, and in these cases the determination of the preferred action is driven primarily by the depth and concentration of chloride ions.

   For decks with minimal contamination, less expensive options such as crack repair or waterproofing are often preferred. All overlays and deck treatments have the effect of preserving the deck by shedding moisture.

2. **High Performance Concrete:** In 2003 VDOT started requiring the use of High Performance Concrete (HPC) for all concrete bridge components. HPC includes pozzolans, which reduce permeability. Most concrete bridge decks built prior to 2003 are more permeable, which allows the slow intrusion of salt-laden water, leading to corrosion of reinforcement and eventual delaminations. Current specifications for rigid overlays also use low permeability concrete.

3. **Value of Hydromilling:** Hydromilling is always preferable to rotomilling because it improves bond between the deck and overlay. It is strongly preferred to install a rigid overlay over a hydromilled surface. In addition to providing an improved bond, hydromilling removes much of the most contaminated portion of the deck. Recent field evaluations suggest that when rigid overlays eventually fail the cause is more frequently related to bond failure than to corrosion-induced spalling. An additional value of hydromilling is that contractors may forego the additional step of performing Type B patching prior to overlay installation. This is because delaminations are naturally removed as part of the hydromilling process. If evaluated based solely on first cost, shallow hydromilling and overlay placement is less expensive than the process of patching, followed by rotomilling and overlay when the Compromised Area of the deck exceeds 8% -10%, depending on traffic and production rates.

4. **Expansion Joints:** Elimination, improvement or repair of existing expansion joints is a vital component of any bridge deck repair project. The topic of maintaining existing expansion is addressed in another section of this chapter. However, the Requirements for Deck Joint Treatments Table is included in this section to address specific actions required in association with deck interventions. Compression seals are no longer approved for use on VDOT bridges.

COMMENTARY (Cont'd):

5. **Decks Exhibiting Distress (Cracks) Due to ASR:** The presence of reactive aggregates (susceptible to ASR) is not an automatic requirement for deck replacement, but it is a cause for serious concern requiring evaluation. The appearance of crack patterns consistent with ASR is strong evidence that the deck has sustained ASR-related damage. The Engineer should consider the depth of the damage caused by reactive aggregates. Reactive aggregates require sustained exposure to moisture to react, so it is possible in some cases to remove the damaged concrete and replace with a low-permeability concrete. This course of action would both remove compromised concrete and protect the remaining concrete, but the expected life span would be limited, as eventually moisture will reach the reactive concrete. Decisions regarding decks with reactive aggregate are the responsibility of the District Structure and Bridge Engineer and should be based on the depth of damage and the required life of the bridge deck. Replacement is required if ASR-related cracking is visible on the bottom of the deck.

6. **T-beam/slab spans:** When deck replacement is indicated due to condition for concrete T-beam spans or concrete slab spans, a deck replacement may not be practical, and a complete superstructure replacement or deep hydromill with overlay may be required due to the difficulty of removing only the deck.

7. **Bridges to be Widened:** If an existing deck to be widened has a rigid overlay that is more than 15 years old, strong preference should be given to replacing the existing overlay immediately after the new widened portion of the deck is built. A significant portion of the perimeter of the existing concrete overlay will be disturbed as part of the deck widening, which may result in delamination of the existing overlay in these areas, even if the overlay is in good condition.

8. **Existing Asphalt Overlays:** Determine the type and bond of the existing membrane system through the use of cores. Repair any breaches to the membrane and overlay caused by coring or chloride testing. If an existing asphalt overlay has an impermeable waterproofing membrane, its integrity may be inferred by a visual inspection of the bottom of the deck (check for evidence of moisture or efflorescence). If the membrane is functioning properly and the CF front has not reached the top mat, a simple replacement of the asphalt is acceptable. If the asphalt overlay requires replacement and the existing membrane is sound and depth allows, mill 1 ½" of the existing overlay and replace with new asphalt.

9. **New Asphalt Overlays:** Must be placed over an approved membrane. Asphalt thickness should be at least 3 ½" to allow for maintenance milling and repair of the overlay without damaging the membrane. Designer must indicate overlay depth on plans. The bridge must be load rated for additional dead load.

10. **Diffusion rates:** There may be instances in which it is desirable to calculate the diffusion rate of the concrete to predict the number of years before chlorides will reach a particular location in the deck. VTRC 08-CR4 provides guidance on calculating diffusion rates. This is not usually necessary, but it can be helpful in cases where desired deck life is limited, or for situations where the best course of action is not immediately apparent.

COMMENTARY (Cont'd):

11. **Cathodic Protection Systems:** Impressed Current Cathodic Protection (ICCP) systems may be used to sustain decks for decades. Usually incorporating a titanium anode mesh within a rigid overlay, ICCP deck systems are not cost-effective in most cases. Such a system might be considered for rare cases where site conditions do not allow replacement but chloride contamination is (or is expected to become) high enough to cause significant deck deterioration.

12. **Electrochemical Chloride Extraction (ECE):** ECE is a process that passivates reinforcing steel and removes chlorides from concrete. This procedure is generally too expensive for bridge decks but may be considered in special cases.

13. **Arc-Applied Zinc (Sacrificial Galvanic Anode):** This treatment involves placing a spray-arc applied zinc anode on the bottom of the bridge deck. The anode is connected to the reinforcing mat and is consumed over time. The process requires a humid environment to function properly. Prior to applying zinc, surfaces must be cleaned and prepared in order to promote bond. A humectant coat should be applied over the zinc coating with some openings intentionally left in the coating. As with ECE and ICCP systems, arc-applied zinc systems are not usually economical in Virginia but may have merit in special cases such as when concrete removal and repair is particularly expensive. Use requires approval of the Assistant State Structure and Bridge Engineer for Maintenance.

SUPPLEMENTAL INFORMATION:

Papers, Studies and Other Reference Documents:

1. Concrete with ASR damage tends to exhibit one or more visually recognizable particular physical characteristics. Understanding these characteristics allows evaluators to make a visual assessment about the likelihood of an ASR problem and whether a structure is a candidate for additional testing and evaluation. The link below provides guidance on making such determinations:

   https://www.fhwa.dot.gov/pavement/concrete/pubs/hif09004/asr00.cfm

2. VTRC 08-CR4, *Bridge Deck Service Life and Cost*, Gregory Williamson, Richard E. Weyers, Michael C. Brown, and Michael M. Sprinkel, 2007

   http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-cr4.pdf

3. *VDOT Supplement to the AASHTO Manual for Bridge Element Inspection*

   http://www.virginiadot.org/business/resources/bridge/VDOT_Suppl_to_the_AASHTO_Manual_for_Bridge_Element_Insp_2016.pdf

4. *VDOT Inventory Coding Guide*:

   http://www.virginiadot.org/business/resources/Coding_Manual.pdf

5. SHRP2 Report *S2-RO6A-RR-1 Nondestructive Testing to Identify Concrete Bridge Deck Deterioration*, 2013

   https://www.nap.edu/download/22771

6. Federal Highway Administration Research and Technology
   Nondestructive Evaluation (NDE) Web Manual

   https://fhwaapps.fhwa.dot.gov/ndep/

7. NCHRP Report, *Guidelines for Selection of Bridge Deck Overlays, Sealers and Treatments, Krauss, Lawler, et.al, 2009*

   https://www.tsp2.org/library-tsp2/uploads/698/FINAL_NCHRP_Guidelines_20-07_Task234_WJE__Comments_5-19-09.pdf

8. Crack Repair. See Section 412.03 (b) 5. of the 2016 Specifications.
   A link to the "VDOT Guide Manual for Causes and Repair of Cracks in Bridge Decks":

   http://www.virginiadot.org/business/resources/const/GuideManCrackRepair.pdf

9. Utah DOT report titled *"Sensitivity Of Half Cell Potential Measurements To Properties Of Concrete Bridge Decks"*

   http://www.udot.utah.gov/main/uconowner.gf?n=7904305897105603

10. *RILEM report titled "Half-cell potential measurements - Potential mapping on reinforced concrete structures"*

    http://dipcia.unica.it/superf/Corrosione/TC154EMCpotential%20copy.pdf

SUPPLEMENTAL INFORMATION (Cont'd):

Sample Plans and Contracts

1. I-64 over Dunlap Creek – Staunton District; Joint Elimination & Rigid Overlays over Shallow Hydromill
2. I-64 over Shockoe Creek – Richmond District; Rigid Overlays over Shallow Hydromill
3. I-64 over Shockoe Bottom – Richmond District; Rigid Overlays over Shallow Hydromill
4. Mill Patch and Overlay sample job
5. I-85 Deep Overlay Sample Job
6. Lynchburg Deep Overlay Sample Job

SUPERSTRUCTURE PRESERVATION OR REHABILITATION - OVERVIEW:

Examples of Superstructure Preservation – Bridge Cleaning, Spot and Zone Painting, Complete Painting (Over Coating and Complete Removal and Re-Coating), Superstructure Repairs, and Fatigue Retrofitting.

Examples of Superstructure Rehabilitation – Superstructure Replacements and Deck Replacements.

The superstructure shall be tentatively assessed to the extent possible with available information, including As-Built plans, repair plans, inspection reports, work done reports, previous superstructure evaluations and visual inspection to determine repair/preventative maintenance needs.

Consult with the District Structure and Bridge Engineer to decide if scope of work will be preservation or rehabilitation prior to proceeding with any superstructure evaluation.

STEEL SUPERSTRUCTURES:

For steel superstructures with a significant portion of the superstructure in Condition State 4, estimate the cost of preserving the existing superstructure (with or without widening) versus the cost of total replacement of the superstructure (with or without widening).

The cost analysis of preserving the existing steel superstructure should include, but not be limited to, the following (as applicable):

- Preserving or replacing the deck as determined in Section 32.03
- Effects associated with the elimination of deck joints (see Section 32.09)
- Recoating of the structural steel if needed
- Repairing areas with section loss and retrofitting all fracture critical and/or fatigue prone details
- Strengthening, if necessary, to provide non-posted service for an estimated 40-year design life
- Replacing severely corroded or non-functional bearings
- Adding redundancy
- Temporary support of the superstructure due to rehabilitating or replacing the substructure (e.g. blocking and jacking to perform seat repair or towers to support the superstructure)
- Seismic retrofit if needed
- Replacing or eliminating approach slabs that extend over backwalls. In these cases, the joint material bears directly against bridge deck and end of approach slab. If settlement occurs, the joint opens up.

If the cost of preservation (with or without widening) is less than 65% of the cost of a superstructure replacement, then preserve the existing superstructure unless bridge replacement controls (see relative issues on File No. 32.02-2).

If preservation is indicated as the preferred alternative, the designer must evaluate the structure for the feasibility of eliminating all deck joints, including joints at backwalls. If feasible, deck joints shall be removed in conjunction with the superstructure rehabilitation work. If joint elimination is determined to be not feasible, justification for any remaining joints shall be provided via email to the Assistant State Structure and Bridge Engineer for Maintenance and posted in IPM.

If the cost of preservation (with or without widening) exceeds 65% of the cost of a superstructure replacement, then superstructure is eligible for replacement unless bridge rehabilitation controls (see relative issues on File No. 32.02-2). If replacement is indicated as the preferred alternative, the replacement superstructure must eliminate deck joints.

If the superstructure is not replaced, then perform necessary preservation actions.

Consult with the District Structure and Bridge Engineer.

STEEL SUPERSTRUCTURES (cont'd):

An evaluation of a steel superstructure should begin with a review of the condition states, as reported in the most recent inspection reports. In general, the following activities will be associated with each condition state as indicated below:

Steel (National Bridge Elements 107, 102, 113, 120, 141, 152, 161, or 162)

Condition State	Defects*	Suggested Action
1	No Defects	None
2	Freckled rust. Corrosion of the steel has initiated. Crack that has self-arrested or has been arrested with effective arrest holes, doubling plates, or similar. Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended. Distortion not requiring mitigation or mitigated distortion. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Spot Coat None None None Repair Impact Damage
3	Section loss is evident or pack rust is present but does not warrant structural review. Identified crack that is not arrested but does not warrant structural review. Missing bolts, rivets, or fasteners; broken welds; or pack rust with distortion but does not warrant structural review. Distortion that requites mitigation that has not been addressed but does not warrant structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Spot Coat Arrest crack Replace missing fasteners/repair welds Repair distortion Repair Impact Damage
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Replace element

*See AASHTO Manual for Bridge Element Inspection

Steel Protective Coating (Bridge Management Element 515)

Condition State	Defects*	Suggested Action
1	No defects and the coating is fully effective	None
2	The surface is dulling.	Spot Coat
	Peeling, bubbling, cracking in the finish coats only.	Spot Coat
	Granular texture.	None
	Coating is substantially effective.	None
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Spot Coat damaged areas
3	Loss of pigment.	Recoat
	Peeling, bubbling, cracking in the finish and primer coats.	Recoat
	Small flakes, less than ½" in diameter.	Recoat
	Coating has limited effectiveness.	Recoat
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Recoat
4	Exposure of bare metal.	Recoat
	Dark black color. Large flakes, ½" diameter or greater, or laminar sheets or nodules.	Recoat
	Coating has failed, no protection of the underlying metal.	Recoat
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Recoat

*See AASHTO Manual for Bridge Element Inspection

Beam/Girder End – Steel (Virginia Agency Developed Element 811)

Condition State	Defects**	Suggested Action
1	No Defects	None
2	Freckled rust. Corrosion of the steel has initiated. Crack that has self-arrested or has been arrested with effective arrest holes, doubling plates, or similar. Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended. Distortion not requiring mitigation or mitigated distortion. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Spot/Zone Coat None None None Repair Impact Damage
3	Section loss is evident or pack rust is present but does not warrant structural review. Identified crack that is not arrested but does not warrant structural review. Missing bolts, rivets, or fasteners; broken welds or pack rust with distortion but does not warrant structural review. Distortion that requires mitigation that has not been addressed but does not warrant structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Spot/Zone Coat Arrest crack Replace missing fasteners/repair welds Repair distortion Repair Impact Damage
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Cut out and replace beam end or use strengthening plates or angles bolted to the existing beam end

** See VDOT Supplement to the AASHTO Manual for Bridge Element Inspection

Beam/Girder End Protective Coating – Steel (Virginia Agency Developed Element 886)

Condition State	Defects**	Suggested Action
1	No defects and the coating is fully effective	None
2	The surface is dulling.	Zone Coat
	Peeling, bubbling, cracking in the finish coats only.	Zone Coat
	Granular texture.	None
	Coating is substantially effective.	None
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Zone Coat
3	Loss of pigment.	Zone Coat
	Peeling, bubbling, cracking in the finish and primer coats.	Zone Coat
	Small flakes, less than ½” in diameter.	Zone Coat
	Coating has limited effectiveness.	Zone Coat
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Zone Coat
4	Exposure of bare metal.	Zone Coat
	Dark black color. Large flakes, ½” diameter or greater, or laminar sheets or nodules.	Zone Coat
	Coating has failed, no protection of the underlying metal.	Zone Coat
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Zone Coat

** See VDOT Supplement to the AASHTO Manual for Bridge Element Inspection

CONCRETE SUPERSTRUCTURES:

For concrete superstructures with a significant portion of the superstructure in Condition State 4, estimate the cost of preserving the existing superstructure (with or without widening) versus the cost of total replacement of the superstructure (with or without widening).

The cost analysis of preserving the existing concrete superstructure should consider the following as applicable:

- Preserving or replacing the deck as determined in Section 32.03
- Effects associated with the elimination of deck joints (see Section 32.09)
- Repairing prestressed or reinforced concrete beams and concrete slab spans
- Impact strengthening of prestressed or reinforced concrete beams using carbon fiber reinforcement on bridges spans with a history or high potential of vehicular impacts
- Mitigating effects of alkali-silica or alkali-carbonate reactive aggregate
- Replacing severely corroded or non-functional bearings
- Adding redundancy
- Temporary support of the superstructure due to rehabilitating or replacing the substructure (e.g. blocking and jacking to perform seat repair or towers to support the superstructure)
- Seismic retrofit if needed
- Replacing or eliminating approach slabs that extend over backwalls. In these cases, the joint material bears directly against bridge deck and end of approach slab. If settlement occurs, the joint opens up.

If the cost of preservation (with or without widening) plus the cost of performing a concrete superstructure evaluation is less than 65% of the cost of a superstructure replacement, then a concrete superstructure evaluation may be performed unless bridge replacement controls (see relative issues on File No. 32.02-2). Consult with the District Structure and Bridge Engineer.

If preservation is indicated as the preferred alternative, the designer must evaluate the structure for the feasibility of eliminating all deck joints, including joints at backwalls. If feasible, deck joints shall be removed in conjunction with the superstructure rehabilitation work. If joint elimination is determined to be not feasible, justification for any remaining joints shall be provided via email to the Assistant State Structure and Bridge Engineer for Maintenance and posted in IPM.

If the cost of preservation (with or without widening) plus the cost of performing the concrete evaluation exceeds 65% of the cost of a new superstructure, then superstructure is eligible for replacement unless bridge preservation controls (see relative issues on File No. 32.02-2). If replacement is indicated as the preferred alternative, the replacement superstructure must eliminate deck joints.

If the superstructure is not replaced, then perform necessary preservation actions.

Consult with the District Structure and Bridge Engineer.

CONCRETE SUPERSTRUCTURES (cont'd):

An evaluation of a concrete superstructure should begin with a review the Condition States, as reported in the most recent inspection reports. In general, the following activities will be associated with each condition state as indicated below:

Prestressed Concrete - (National Bridge Elements 109, 104, 115, 143, or 154)

Condition State	Defects*	Suggested Action
1	No Defects. Insignificant cracks or moderate-width cracks that have been sealed.	None
2	Delaminated. Spall I in. or less deep or 6 in. or less in diameter. Patched area that is sound.	None
	Exposed rebar present without measurable section loss.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin).
	Exposed prestressing present without section loss.	Coat exposed prestressing with epoxy (Waterproofing – Epoxy Resin).
	Unsealed moderate-width cracks or unsealed moderate pattern (map) cracking.	Seal cracks (Waterproofing – Epoxy Resin).
	Efflorescence/Rust Staining - Surface white without build-up or leaching without rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin).
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Repair impact damage (Concrete Superstructure Surface Repair).
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	Perform concrete superstructure surface repair.
	Exposed rebar present with measurable section structural loss but does not warrant structural review.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin).
	Exposed prestressing present with section loss but does not warrant structural review.	Coat exposed prestressing with epoxy (Waterproofing – Epoxy Resin).
	Wide cracks or heavy pattern (map) cracking.	Repair cracks using epoxy injection (Crack Repair Type B).
	Efflorescence/Rust Staining - Heavy build-up with rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin).

	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Repair impact damage (Concrete superstructure surface repair).
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Replace element.

*See AASHTO Manual for Bridge Element Inspection

Reinforced Concrete - (National Bridge Elements 110, 105, 116, 144, or 155)

Condition State	Defects*	Suggested Action
1	No Defects. Insignificant cracks or moderate-width cracks that have been sealed.	None
2	Delaminated. Spall I in. or less deep or 6 in. or less in diameter. Patched area that is sound. Exposed rebar present without measurable section loss. Efflorescence/Rust Staining - Surface white without build-up or leaching without rust staining. Unsealed moderate-width cracks or unsealed moderate pattern (map) cracking. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	None Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin). Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin). Seal cracks (Waterproofing – Epoxy Resin). Repair impact damage (Concrete superstructure surface repair).
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review. Exposed rebar present with measurable section loss but does not warrant structural review. Efflorescence/Rust Staining - Heavy build-up with rust staining. Wide cracks or heavy pattern (map) cracking. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Perform concrete superstructure surface repair. Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin). Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin). Repair cracks using epoxy injection (Crack Repair Type B). Repair impact damage (Concrete superstructure surface repair).
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Replace element.

*See AASHTO Manual for Bridge Element Inspection

Beam/Girder End – Concrete (Virginia Agency Developed Element 811)

Condition State	Defects**	Suggested Action
1	No Defects. Cracking < 0.004 in. for PSC (< 0.012 in. for RC) or spacing greater than 3.0 ft.	None
2	Delaminated. Spall 1" or less deep or 6" or less in diameter and/or a patched area that is sound	None
	Exposed rebar present without measurable section loss.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin).
	Exposed prestressing present without section loss.	Coat exposed prestressing with epoxy (Waterproofing – Epoxy Resin).
	Cracking Prestressed Concrete - Width 0.004 - 0.009 in. or spacing 1.0 - 3.0 ft.	Seal cracks (Waterproofing – Epoxy Resin).
	Efflorescence/Rust Staining – Surface white without build-up or leaching without rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin)
	Cracking Reinforced Concrete - Width 0.012 - 0.05 in. or spacing of 1.0 - 3.0 ft.	Seal cracks (Waterproofing – Epoxy Resin).
	Distortion not requiring mitigation or mitigated distortion.	None
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate defect entry.	Repair impact damage (Concrete superstructure surface repair).
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	Perform concrete superstructure surface repair
	Exposed rebar present with measurable section loss but does not warrant structural review.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin).
	Exposed prestressing present with section loss but does not warrant structural review.	Coat exposed prestressing with epoxy (Waterproofing – Epoxy Resin).
	Cracking Prestressed Concrete - Width greater than 0.009 in. or spacing less than 1 ft.	Repair cracks using epoxy injection (Crack Repair Type B).
	Efflorescence/Rust Staining - Heavy build-up with rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin).

	Cracking Reinforced Concrete - Width greater than 0.05 in. or spacing of less than 1 ft. Distortion requiring mitigation that has not been addressed but does not warrant structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate defect entry.	Repair cracks using epoxy injection (Crack Repair Type B). Repair distortion damage (Concrete superstructure surface repair). Repair impact damage (Concrete superstructure surface repair).
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Replace element.

** See VDOT Supplement to the AASHTO Manual for Bridge Element Inspection

Beam/Girder End Protective Coating – Concrete (Virginia Agency Developed Element 887)

Condition State	Defects**	Suggested Action
1	No defects and the coating is fully effective	None
2	Underlying concrete not exposed, coating showing wear from UV exposure. Coating is substantially effective. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	None None Repair impact damage (Concrete superstructure surface repair.
3	Underlying concrete not exposed; thickness of coating is reduced. Coating has limited effectiveness. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	None None Repair impact damage (Concrete superstructure surface repair.
4	Underlying concrete exposed. Protective coating is no longer effective. The protective system has failed or is no longer effective. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Remove any remaining coating and apply new coating (Waterproofing – Epoxy Resin or Concrete Surface Penetrant Sealer). Remove any remaining coating and apply new coating (Waterproofing – Epoxy Resin or Concrete Surface Penetrant Sealer). Repair impact damage (Concrete superstructure surface repair.

** See VDOT Supplement to the AASHTO Manual for Bridge Element Inspection

CONCRETE SUPERSTRUCTURE EVALUATION:

Evaluate the concrete superstructure to determine the condition. Perform only those evaluations required to make an informed decision. The hierarchy of investigative needs is outlined below:

1. Perform detailed visual examination, including documentation and measurement of crack size and location as well as crack orientation. Make a judgment regarding the cause of any cracking. If cracks appear to be stress-induced (such as crack oriented at 45 degrees away from a support or cracks associated with a bridge strike) perform analysis of affected superstructure elements. Cracks caused by exposure to moisture and salts should be evaluated separately from stress-induced cracks.

2. Include spall location and size in visual examination.

3. Check prestressed elements for distress, excessive deflections or loss of prestress.

4. Sound and mark concrete surfaces to determine extent of delaminations.

5. Determine depth of cover of mild and prestressing steel.

6. Determine chloride content and/or carbonation depth in concrete. If indicated by visual evidence, analyze for alkali-silica reactivity in the paste and aggregate.

7. If the strength of the concrete is suspect, such as may be the case with older, cast-in-place concrete tee beams, determine compressive strength of cores after careful determination of reinforcement locations.

Perform an engineering assessment with respect to the degree of the problem. This assessment shall include, but not be limited to, the following:

- Age of structure
- Physical evidence from the investigation described above
- Problems encountered when performing previous repairs
- The practicality of remediation techniques, such as the use of waterproofing to limit the moisture content of the concrete

Consult with the District Structure and Bridge Engineer for recommendation.

If compressive strength tests are performed and they reveal strengths less than the 28-day design strength of the concrete (or the assumed strength based on the vintage), then assess need to determine structural adequacy. Assemble the following information:

- Concrete 28-day design strength
- Concrete compressive strength
- Present and future ADT
- Present and future ADTT

Consult with the District Structure and Bridge Engineer for recommendation to:

- Replace the superstructure or
- Proceed with structural analysis to determine if non-posted service for an estimated 40-year design life can be obtained.

CONCRETE SUPERSTRUCTURE EVALUATION (cont'd):

Re-evaluate cost of preserving the bridge (with or without widening) based on the concrete superstructure evaluation.

If the cost of preservation (with or without widening) is less than 65% of the cost of a superstructure replacement, then preserve the existing superstructure unless bridge replacement controls (see relative issues on File No. 32.02-2). The notes regarding joint removal on File No. 32.04-7 shall apply.

If the cost of preservation (with or without widening) exceeds 65% of the cost of a new superstructure, then superstructure replacement is the preferred alternative unless bridge rehabilitation controls (see relative issues on File No. 32.02-2). The notes regarding joint removal on File No. 32.04-7 shall apply.

If the superstructure is not replaced, then perform necessary preservation actions.

Consult with the District Structure and Bridge Engineer.

REPAIR OF PRESTRESSED CONCRETE BEAMS WITH DAMAGED TENDONS:

Prestressed concrete beams with significant tendon damage (more than one tendon severed) should be evaluated and repaired in accordance with the following guidelines:

1. There are three acceptable methods for repairing damaged prestressed concrete beams with severe tendon damage:

    a. Fiber reinforced polymers (FRPs)

    b. Fabric reinforced cementitious matrix (FRCMs)

    c. Splice chucks for severed tendons

    Splice chucks alone are recommended if the number of strands severed is no more than 15% of the total number of strands and there is adequate space to splice the strands without congestion.

    All three repair methods require restoration of the original shape of the damaged beams with an acceptable cementitious repair material.

    Combination repairs using more than one method may be employed. For example, splice chucks may be used in conjunction with FRP or FRCM to repair severely damaged beams.

2. Evaluate original and repaired strength in accordance with:

    - ACI440.2R (2008) for the added strength if fiber reinforced polymers (FRPs) are used for the repairs

    - ACI549.4R (2013) along with the AASHTO LRFD method for flexural strength for the added strength if fabric reinforced cementitious matrix (FRCMs) are used for the repairs. These methods provide conservative estimates of repaired strength.

    - For tendon repairs using splice chucks, engineers may assume the repaired tendons will develop 100% of the strength of the tendon. However, engineers may elect to reduce the assumed strength if conditions warrant.

Note that cementitious patch materials will very likely crack under the combination of shrinkage and service loadings. The FRP or FRCM over the repair concrete not only provides added strength but also protects the patch materials and prestressing steel from deterioration related to this cracking and ensuing ingress of water and salts and corrosion of strand.

Reference: VTRC Report 18-R8, Evaluation of Repair Techniques for Impact-Damaged Prestressed Beams.

CONCRETE SUBSTRUCTURE PRESERVATION OR REHABILITATION OVERVIEW:

Substructure units should be examined for preservation or rehabilitation on an individual basis. Furthermore, substructure foundations and neatwork should be investigated independently. Foundations shall be evaluated for safety and a judgment must be made regarding the safety of the structure and whether emergency repairs are required. Substructures that exhibit instability shall be investigated by an engineer to determine the cause of the problem. Structures exhibiting slow deterioration or movement shall similarly be evaluated by an engineer for determination of cause. Cost/benefit of repair or remediation vs. structure replacement must be conducted. Substructure instability or failure caused by scour shall be investigated for hydraulic and hydrological vulnerability.

Examples of Concrete Substructure Preservation – Removing debris in the stream, Concrete Substructure Surface Repair, Stream bed scour counter measures and repair, footing undermining repair, pile repair, application of carbon fiber reinforced wrap systems, coating pier caps and columns/stems

Example of Concrete Substructure Rehabilitation – Temporary support and replacement of all or a portion of individual substructure unit(s)

FOUNDATIONS:

The initial investigation of foundations should include the following, as applicable:

- For foundations determined to be primarily on rock:
  - confirm integrity of foundations with respect to any differential settlement and/or undermining and/or footing deterioration.
  - estimate cost of any necessary repairs such as toe walls (walls formed alongside the footing that are cast monolithically with concrete placed beneath the footing to repair undermining) and include in rehabilitation estimate.
- For foundations determined to be on firm material:
  - estimate cost of replacing any substructure unit where previous or calculated scour is at or below the top of the footing and include in rehabilitation estimate.
  - estimate cost of placing scour countermeasures at each appropriate substructure unit where previous or calculated scour is above the top of the footing and include in rehabilitation estimate.
- For foundations on piles:
  - estimate cost of replacing any substructure unit where previous scour resulted in shifting or differential settlement of the footing and include in rehabilitation estimate.
  - estimate cost of placing scour countermeasures at each appropriate substructure unit where the previous scour has exposed the piling with no detrimental consequences and include in rehabilitation estimate.
- Estimate the cost to perform a scour analysis of the existing bridge or superstructure replacement alternative and the cost of pile stability evaluations for each applicable substructure unit that will remain in place at this point. Include cost in rehabilitation estimate.

SUBSTRUCTURE NEATWORK:

The initial investigation of substructure neatwork shall include, but not be limited to, the following, as applicable:

- Determine substructure neatwork preservation and rehabilitation needs based on information available and estimate cost.
- Estimate the cost of substructure neatwork evaluation.

Consult with the District Structure and Bridge Engineer to determine if scope of work will be to repair or proceed with further evaluation.

Estimate cost of temporary support of the superstructure due to rehabilitating the substructure (e.g. blocking and jacking to perform seat repair or towers to support the superstructure). Include in superstructure rehabilitation, Section 32.04.

If superstructure preservation / rehabilitation cost plus the cost of substructure foundation rehabilitation plus the cost of scour analysis (if applicable) plus the cost of pile stability analyses (if applicable) plus the cost of substructure neatwork preservation/rehabilitation plus the cost of performing substructure neatwork evaluation exceeds 65% of the cost of a new bridge, then bridge replacement is the recommended action.

Otherwise, perform scour analysis (if applicable), substructure stability analyses (if applicable) and then re-evaluate substructure preservation/rehabilitation costs based on the analysis results.

If total of superstructure rehabilitation costs plus the cost of substructure foundation rehabilitation plus the cost of substructure neatwork preservation plus the cost of performing the substructure neatwork evaluation exceeds 65% of the cost of a new bridge, replacement is the recommended action.

Otherwise, substructure neatwork evaluation may be performed unless bridge replacement controls.

Consult with the District Structure and Bridge Engineer.

SUBSTRUCTURE NEATWORK EVALUATION:

For substructure units under continuous superstructures, perform visual and sounding surveys to determine amount and location of cracks, spalls and delaminations to determine repair quantities. Estimate cost and include in preservation estimate.

For substructure units under joints, obtain the necessary data and samples as follows:

- Perform visual and sounding surveys to determine amount and location of cracks, spalls and delaminations to compute repair quantities. Mark all spalling and delaminated areas.

- Obtain the reinforcing steel cover, half-cell potentials, core samples and chloride samples from the representative areas for each substructure unit. For abutments, obtain information from backwall, seat and breastwall. For piers, obtain information from cap, stem, exterior and interior column.

The hierarchy of investigative needs is outlined below:

1. Perform detailed visual examination, including documentation and measurement of crack locations and size as well as crack orientation. Make a judgment regarding the cause of any cracking. If cracks appear to be stress-induced (such as crack oriented at 45 degrees away from a support or cracks associated with a bridge strike) perform analysis of affected substructure elements. Cracks and spalls caused by exposure to moisture and salts should be evaluated separately from stress-induced cracks.
2. Include spall location and size in visual examination
3. Sound and mark concrete surfaces to determine extent of delaminations.
4. Determine depth of cover of reinforcing steel.
5. Determine half-cell potentials
6. Determine chloride content and/or carbonation depth in concrete. If indicated by visual evidence, analyze for alkali-silica reactivity in the paste and aggregate.
7. If the strength of the concrete is suspect, determine compressive strength of cores after careful determination of reinforcement locations.
8. If an unreinforced concrete substructure element is acting in flexure, determine if flexural cracking (if visible) requires remediation.

Evaluation of substructures should include a review of the Condition States, as reported in the most recent inspection reports. In general, activities will be associated with each condition state as indicated in the following sheets.

Reinforced Concrete Condition States - National Bridge Elements 205, 210, 215, 220, 227

Condition State	Defects*	Suggested Action
1	No Defects	None
2	Delaminated. Spall 1 inch or less deep or 6 in. or less in diameter. Patched area that is sound.	None
	Exposed Rebar present without measurable section loss.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin)
	Efflorescence/Rust Staining - Surface white without build-up or leaching without rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin)
	Unsealed moderate width cracks or unsealed moderate pattern (map) cracking.	Seal cracks (Waterproofing – Epoxy Resin)
	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Seal areas of abrasion or wear (Waterproofing – Epoxy Resin)
	Settlement exists within tolerable limits or arrested with no observed structural distress.	None
	Scour exists within tolerable limits or has been arrested with effective countermeasures.	None
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Repair impact damage (Concrete Substructure Surface Repair)
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is showing distress or unsound. Does not warrant structural review.	Perform Concrete Substructure Surface Repair
	Exposed Rebar present with measurable section loss but does not warrant structural review.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin)
	Efflorescence/Rust Staining – Heavy build-up with rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin)
	Wide cracks or heavy pattern (map) cracking.	Repair cracks using epoxy injection (Crack Repair Type B)
	Coarse aggregate is loose or has popped out on the concrete matrix due to abrasion or wear.	Perform Concrete Substructure Surface Repair
	Settlement exceeds tolerable limits but does not warrant structural review.	Determine whether settlement is uniform or differential and monitor

	Scour exceeds tolerable limits but is less than the critical limits determined by scour evaluation and does not warrant structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Monitor scour Repair impact damage (Concrete Substructure Surface Repair)
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Rehabilitate Substructure Unit

National Bridge Element 234

Condition State	Defects*	Suggested Action
1	No Defects	None
2	Delaminated. Spall 1 inch or less deep or 6 in. or less in diameter. Patched area that is sound. Exposed Rebar present without measurable section loss. Efflorescence/Rust Staining - Surface white without build-up or leaching without rust staining. Unsealed moderate width cracks or unsealed moderate pattern (map) cracking. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	None Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin) Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin) Seal cracks (Waterproofing – Epoxy Resin) Repair impact damage (Concrete Substructure Surface Repair)
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is showing distress or unsound. Does not warrant structural review. Exposed Rebar present with measurable section loss but does not warrant structural review. Efflorescence/Rust Staining – Heavy build-up with rust staining. Wide cracks or heavy pattern (map) cracking. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Perform Concrete Substructure Surface Repair Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin) Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin) Repair cracks using epoxy injection (Crack Repair Type B) Repair impact damage (Concrete Substructure Surface Repair)
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Rehabilitate Substructure Unit

*See AASHTO Manual for Bridge Element Inspection

Reinforced Concrete Wingwall (Virginia Agency Developed Element 824)

Condition State	Defects**	Suggested Action
1	No Defects	None
2	Delaminated. Spall 1 inch or less deep or 6 in. or less in diameter. Patched area that is sound.	None
	Exposed Rebar present without measurable section loss.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin)
	Efflorescence/Rust Staining - Surface white without build-up or leaching without rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin)
	Unsealed moderate width cracks or unsealed moderate pattern (map) cracking.	Seal cracks (Waterproofing – Epoxy Resin)
	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Seal areas of abrasion or wear (Waterproofing – Epoxy Resin)
	Settlement exists within tolerable limits or arrested with no observed structural distress.	None
	Scour exists within tolerable limits or has been arrested with effective countermeasures.	None
	The element has impact damage. The specific damage caused by the impact has been captured in Condition State 2 under the appropriate material defect entry.	Repair impact damage (Concrete Substructure Surface Repair)
3	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is showing distress or unsound. Does not warrant structural review.	Perform Concrete Substructure Surface Repair
	Exposed Rebar present with measurable section loss but does not warrant structural review.	Coat exposed rebar with epoxy (Waterproofing – Epoxy Resin)
	Efflorescence/Rust Staining – Heavy build-up with rust staining.	Seal areas of efflorescence/ Rust Staining (Waterproofing – Epoxy Resin)
	Wide cracks or heavy pattern (map) cracking.	Repair cracks using epoxy injection (Crack Repair Type B)
	Coarse aggregate is loose or has popped out on the concrete matrix due to abrasion or wear.	Perform Concrete Substructure Surface Repair
	Settlement exceeds tolerable limits but does not warrant structural review.	Determine whether settlement is uniform or differential and monitor

	Scour exceeds tolerable limits but is less than the critical limits determined by scour evaluation and does not warrant structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 3 under the appropriate material defect entry.	Monitor scour Repair impact damage (Concrete Substructure Surface Repair)
4	The condition warrants a structural review. The element has impact damage. The specific damage caused by the impact has been captured in Condition State 4 under the appropriate material defect entry.	Rehabilitate Substructure Unit

** See VDOT Supplement to the AASHTO Manual for Bridge Element Inspection

SUBSTRUCTURE NEATWORK EVALUATION (cont'd):

When performing the substructure neatwork evaluation, evaluate potentially higher cost items first. If at any point the total preservation/rehabilitation cost exceeds 65% of the cost of a new bridge, replacement is the recommended action.

If the chloride content exceeds 4 lbs. per c.y. and/or extensive corrosion is evident in any of the representative areas, then close the deck joint, consider electro chemical chloride extraction, thermally sprayed galvanic anode (aluminum zincindium) or other approved galvanic cathodic protection system for the affected areas of the substructure unit and repair. Where it is determined that the joint cannot be closed, repair the joint, consider the protection systems, repair and waterproof the substructure neatwork. Include cost in preservation estimate.

Recommend performance of one petrographic analysis per substructure unit. If petrographic analysis reveals that the concrete contains alkali-silica or alkali-carbonate reactive aggregate, then perform an engineering assessment with respect to the degree of the problem to determine if substructure units should be replaced. This assessment shall include, but not be limited to, the following:

- Age of the structure
- Physical evidence such as the degree of map cracking
- Problems encountered when attempting previous repairs
- Use of waterproofing to limit the moisture content of the concrete

Consult with the District Structure and Bridge Engineer for recommendation and re-estimate rehabilitation and/or substructure unit(s) replacement costs.

Perform compressive strength tests. If tests reveal strengths less than the 28-day design strength of the substructure concrete, then assess need to determine structural adequacy. Assemble the following information:

- Concrete 28-day design strength
- Concrete compressive strength
- Present and future ADT
- Present and future ADTT

Consult with the District Structure and Bridge Engineer for recommendation to:

- replace the substructure unit(s) or
- proceed with structural analysis to determine if non-posted service for an estimated 40-year design life can be obtained. Re-estimate rehabilitation and/or replacement costs.

Consider application of epoxy or other waterproofing coatings to protect newly repaired substructure neatwork.

Consider the use of fiber reinforced polymer wrap systems for repairing and/or strengthening of pier columns.

In no instance shall substructure surface repairs be performed under non-functional (leaking) joints. Non-functional joints shall be eliminated or repaired in conjunction with substructure repairs.

LIFE CYCLE COST ANALYSIS GUIDELINES:

A life cycle cost analysis should be used when comparing alternatives with different life expectancies. A life cycle cost analysis is strongly recommended for projects costing more than $2M. Life cycle cost comparison shall be made for a projected 75-year evaluation horizon. The FHWA provides a life cycle cost primer, fact sheet and Technical Bulletin. Information is available at:

http://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm

In an effort to maintain consistency within the life-cycle cost analysis, the following criteria shall be used when applicable:

Element	Presumed Maintenance during Usable Life	Presumed Life
Thin-bonded overlays*		15 years
Rigid Overlays over rotomill*	2% at 10 years and 2% patching every 2 years thereafter until age of overlay reaches 30 years	25 years
Rigid Overlays over Type A Hydromill*	2% at 20 years and 1% patching every 2 years thereafter until age of overlay reaches 40 years	35 years
Rigid Overlays over Type B Hydromill*	Type B patching will be 1% at 40 years and 1% patching every 2 years until overlayed. Overlay deck at 50 years. Estimate 2% patching at time of overlay.	60 years
New Decks	Type B patching will be 1% at 40 years and 1% patching every 2 years until overlayed. Overlay deck at 50 years. Estimate 2% patching at time of overlay.	75 years
Overlayed portions of existing decks that remain (built before 2003)	Use 50% higher unit costs for Type B patching. 2% Type B patching every 2 years.	50 years
Painted Steel Superstructure	Estimate zone overpaint at 20 years. Estimate repaint at 40 years.	40 Years
Weathering Steel Superstructure	Away from joints & fascia girders – no action. Fascia girders and under –joints – same as painted steel.	150 years (away from joints). 40 years where painted
Substructures Away from Joints	Assume 1-2% per 50 years	100 years
Substructures Under Joints	Assume 1-2 % per 15 years	50 years

*Include costs for Type B Patching prior to initial installation of overlays

LIFE CYCLE COST ANALYSIS GUIDELINES (continued):

Substructure of a bridge over land/highway or non-tidal waterways:

1. If the substructure unit is under an existing and future joint, a preventive measure of one of the following cathodic protection methods should be considered:

    a. If deterioration and contamination is minor, then consider patches with embedded galvanic anodes (30 year life) plus an additional 1% patching per year.

    b. If deterioration and contamination is moderate, then consider using one of the following:

        i. Thermally sprayed galvanic anode (aluminum-zinc-indium) – Estimate initial cost and cost of redoing every 10 years plus cost of 2% patching each time

        ii. Thermally sprayed zinc plus humectant – Estimate initial cost and cost of redoing every 10 years plus the cost of 2% patching each time.

    c. If deterioration and contamination are extensive, then consider impressed current cathodic protection systems. Include anticipated annual service monitoring costs. Estimate cost to replace rectifiers every 30 years.

2. If the substructure unit is under an existing joint but will not be under a future joint (*i.e.,* under deck closures, deck extensions, continuous superstructures, etc.), then estimate 2% patching plus the cost of a preventive measure (one time treatment) of one of the following:

    a. Electrochemical chloride extraction

    b. Thermally sprayed zinc plus humectant - Estimate initial cost and cost of redoing every 10 years

    c. Thermally sprayed galvanic anode (aluminum-zinc-indium).

Substructure of a bridge over tidal waterways or under unsuitable joints:

Compare the following cathodic protection systems and select the most cost-effective alternate:

- galvanic jackets
- bulk zinc anodes
- coating of vulnerable areas
- Impressed current cathodic protection system.

		LIFE CYCLE COST TABLE						
		INITIAL CONSTRUCTION COST *	LIFE CYCLE COSTS (PRESENT WORTH) MAINTENANCE	USER	INITIAL COSTS + MAINT. COSTS (PW)	INITIAL COSTS + USER COSTS (PW)	TOTAL PRESENT WORTH (Initial Cost + Life Cycle Costs)	
ALT.	DESCRIPTION	A	B	C	A + B	A + C	A + B + C	RANK
1								
2								
3								
4								

*** Initial construction costs include structural items, Right of Way and utility costs.**

Consideration of user costs is left to the discretion of the District Structure and Bridge Engineer.

Contact VTRC for current discount and inflation rates and guidance on user costs.

MAINTENANCE AND REPAIR
LIFE CYCLE COST ANALYSIS
TABLE

PART 2
DATE: 08Aug2018
SHEET 3 of 3
FILE NO. 32.06-3

FEDERAL FUNDING BACKGROUND

MAP-21, the Moving Ahead for Progress in the 21st Century Act (P.L. 112-141), was signed into law by President Obama on July 6, 2012. MAP-21 creates a streamlined and performance-based surface transportation program and builds on many of the highway, transit, bike, and pedestrian programs and policies established in 1991. A key feature of MAP-21 is the establishment of a performance and outcome based program. The objective of this performance and outcome based program is for States to invest resources in projects that collectively will make progress toward the achievement of the national goals.

MAP-21 established national performance goals for the Federal-aid highway program in seven areas:

Goal area	National goal
Safety	To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
Infrastructure condition	To maintain the highway infrastructure asset system in a state of good repair
Congestion reduction	To achieve a significant reduction in congestion on the National Highway System
System reliability	To improve the efficiency of the surface transportation system
Freight movement and economic vitality	To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
Environmental sustainability	To enhance the performance of the transportation system while protecting and enhancing the natural environment
Reduced project delivery delays	To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices

On December 4, 2015, President Obama signed the Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94) into law. The FAST Act provided contract authority to fund six formula programs (including certain set-asides within the programs described below):

- National Highway Performance Program (NHPP);
- Surface Transportation Block Grant Program (STBG);
- Highway Safety Improvement Program (HSIP);
- Congestion Mitigation and Air Quality Improvement Program (CMAQ);
- Metropolitan Planning; and
- The new National Highway Freight Program (NHFP).

The Moving Ahead for Progress in the 21st Century Act (MAP-21), enacted in 2012, included provisions to make the Federal surface transportation more streamlined, performance-based, and multimodal, and to address challenges facing the U.S. transportation system, including improving safety, maintaining infrastructure condition, reducing traffic congestion, improving efficiency of the system and freight movement, protecting the environment, and reducing delays in project delivery. The FAST Act builds on the changes made by MAP-21.

The FAST Act provides funding for the National Highway Performance Program (NHPP), which will support the condition and performance of the National Highway System (NHS), enable the construction of new facilities on the NHS, and ensure that investments of Federal-aid funds in highway construction are directed to support progress toward achieving performance targets established in a State's asset management plan for the NHS.

The FAST Act converts the long-standing Surface Transportation Program into the Surface Transportation Block Grant Program (STBG) acknowledging that this program has the most flexible eligibilities among all Federal-aid highway programs and aligning the program's name with how FHWA has historically administered it. The FAST Act provides funding for the STBG, which States and localities may use for projects to preserve or improve conditions and performance on any Federal-aid highway, bridge projects on any public road, facilities for nonmotorized transportation, transit capital projects, and public bus terminals and facilities.

The FAST Act also continues to require FHWA to set aside a portion of a State's STBG funds (equal to 15 percent of the State's FY 2009 Highway Bridge Program apportionment) for bridges not on Federal-aid highways (off-system bridges), unless the Secretary determines that the State's needs are insufficient to justify this amount.

Bundling of Bridge Projects

The FAST Act encourages States to save costs and time by bundling multiple bridge projects using NHPP funds as one project under one project agreement and it places requirements on how that bundling is to be conducted. [23 U.S.C 144(j)]

After passage of the FAST Act, Title 23 of the United States Code (USC) includes the following:

23 USC §119. National highway performance program

(d) Eligible Projects – Funds apportioned to a State to carry out the national highway performance program may be obligated only for a project on an eligible facility that is

(2) for 1 or more of the following purposes:

(B) Construction, replacement (including replacement with fill material), rehabilitation, preservation, and protection (including scour countermeasures, seismic retrofits, impact protection measures, security countermeasures, and protection against extreme events) of bridges on the National Highway System.

23 USC §133. Surface transportation block grant program

(b) Eligible Projects.-Funds apportioned to a State under section 104(b)(2) for the surface transportation block grant program may be obligated for the following:

(9) Protection (including painting, scour countermeasures, seismic retrofits, impact protection measures, security countermeasures, and protection against extreme events) for bridges (including approaches to bridges and other elevated structures) and tunnels on public roads, and inspection and evaluation of bridges and tunnels and other highway assets.

On February 26, 2016 FHWA issued a memorandum that provided Guidance on Highway Preservation and Maintenance. A link to this memorandum follows:

https://www.fhwa.dot.gov/preservation/memos/160225.cfm

Federal-aid funds may not be used to perform routine maintenance. Routine maintenance encompasses work that is performed in reaction to an event, season, or over all deterioration of the transportation asset. This work requires regular reoccurring attention.

The maximum share of project costs that may be funded with Federal-aid highway funds (the "Federal share") varies based upon the Federal aid program from which the project receives funding. In some cases this share is also adjusted based on related statutory provisions. The FAST Act made relatively few changes to Federal share. 23 U.S.C. 120 provides that except as otherwise provided, the Federal share payable shall be:

- 90% for a project on the Interstate System (including a project to add high occupancy vehicle lanes or auxiliary lanes but excluding a project to add other lanes);
- and 80% for any other project.

Project Development

All contract projects that are federally eligible must be developed as federally eligible unless an exception is granted as follows:

- **Estimate of less $1 million** – Asset Management Division Administrator can grant the exception.
- **Estimate greater than or equal to $1 million** – Asset Management Division Administrator will request approval from the Chief Engineer for exception.

If an exception is granted, the project should be marked in the Project Pool as "Federally Eligible with Exception" with the date that the exception was approved.

See Asset Management Division IIM AMD-1 – a link to this IIM follows:
https://insidevdot.cov.virginia.gov/div/opd/Documents/AMD_IIM.pdf

The Federal Programs Management Division has developed a presentation. A link follows:
https://insidevdot.cov.virginia.gov/div/FPMD/UDLAG/Shared%20Documents/FPMD%202018%20Workshop/Federal%20Funds%20Management%20Presentation%20--%20FINAL.pdf

STEWARDSHIP AND OVERSIGHT AGREEMENT ON PROJECT ASSUMPTION AND PROGRAM OVERSIGHT BY AND BETWEEN FEDERAL HIGHWAY ADMINISTRATION, VIRGINIA DIVISION AND THE VIRGINIA DEPARTMENT OF TRANSPORTATION

The most recent Stewardship and Oversight Agreement On Project Assumption And Program Oversight By And Between Federal Highway Administration, Virginia Division And The Virginia Department Of Transportation is dated June 2, 2015. A link to this document follows:

https://www.fhwa.dot.gov/federalaid/stewardship/agreements/va.pdf

VDOT/FHWA VIRGINIA DIVISION AGREEMENT FOR FEDERAL AID MAINTENANCE PROJECTS

The most recent VDOT/FHWA Virginia Division Agreement for Federal Aid Maintenance Projects is dated March 13, 2015. A link to this document follows: https://insidevdot.cov.virginia.gov/div/opd/L7TF1/Shared%20Documents/2015%20PM-3R%20Agreement.pdf

Note: Due to the changes implemented by both MAP-21 and FAST Act, prior agreement with the FHWA Virginia Division for Federal Aid Maintenance Projects is not needed. However, it is still highly encouraged for contract and programmatic consistency.

The federally recognized maintenance activities as shown in the VDOT/FHWA Virginia Division Agreement for Federal Aid Maintenance Projects are listed in the following table, along with their associated VDOT Bridge Maintenance activity codes and activity code descriptions.

	Activity Description in FHWA/VDOT letter Agreement for Planned Preventive Maintenance and System Preservation	VDOT Bridge Maintenance Activity Code	VDOT Bridge Maintenance Activity Code Description
1	Seal or replace leaking joints, reconstruction of joint areas during joint replacement or elimination of deck joints	61704	Joint Rehabilitation
2	Thin bonded overlays	61703	Thin Overlay
3	Rigid overlays	61705	Rigid Overlay
4	Asphalt overlays with waterproof membranes	62708	Asphalt Overlay
5	Spot and zone painting/coating of structural steel to include bearings for prestressed concrete members	62729	Spot Paint
6	Painting/coating of structural steel	62728	Paint
7	Cathodic Protection (CP) Systems for Bridge Decks, Substructure Elements, Superstructure Elements other than bridge decks	None	None
8	Electrochemical Chloride Extraction (ECE) Treatment for bridge decks and substructure elements	None	None
9	Scour countermeasures installation	62746	Repair Undermining
10	Removing large debris from channels	60740	Ordinary Maintenance
11	Retrofit of fracture critical members	62726	Steel Super-structure Repair
12	Retrofit of fatigue prone details	62726	Steel Super-structure Repair
13	Concrete deck repairs in conjunction with installation of deck overlays, CP systems, or ECE treatment	61701, 61703, 62705, 62708	Patching, overlays
14	Galvanic anodes in conjunction with approved concrete deck repairs, concrete substructure surface repairs and joint elimination	61701	Deck Patching
15	Substructure concrete repairs in conjunction with installation of CP system in the bridge element, ECE treatment of the element, or galvanic anodes in the element. (Includes substructure units with cathodic protection jackets.) Includes preventive maintenance of piles using jackets in conjunction with cathodic protection.	62745	Substructure Surface Repair
16	Application of concrete sealants, coatings, and membranes for surface protection of the concrete	60700	Ordinary Maintenance

Activity Description in FHWA/VDOT letter Agreement for Planned Preventive Maintenance and System Preservation		VDOT Bridge Maintenance Activity Code	VDOT Bridge Maintenance Activity Code Description
17	Bridge cleaning and/or washing service – decks, joints, drains, superstructure and bearing devices, substructure horizontal elements	60700	Ordinary Maintenance
18	Concrete mat along the flow line of steel pipe culverts	62755	Surface Repair
19	Culvert Liners, including steel or polymer pipe inserts, spray on liners such as shotcrete, epoxy or polyuria - based systems	72749	Major Rehabilitation
20	Cleaning and lubricating bearing devices, including removal and disposal of debris and lubricating moveable bearings	62727	Bearing Repair
21	Movable bridge preservation including rebalance movable span(s), maintenance of gear reducer, maintenance of hydraulic pumps and motors and maintenance of hydraulic systems	62211	Movable – Mech. Repairs
22	Cleaning of drainage facilities (on individual bridges)	60700	Ordinary Maintenance
23	Corrosion protection activities (on individual bridges)	60740	Ordinary Maintenance

VDOT and FHWA Virginia Division have agreed to establish programmatic authorizations for pavement resurfacing work (construction phase of a pavement project) and bridge preliminary engineering activities as outlined in the Federal-Aid Preventative Maintenance Agreement between FHWA Virginia Division and VDOT. This approach will streamline project delivery and enable VDOT to continue progress to meet or exceed performance targets as required at the state and federal levels. This effort also reduces significantly the number of individual federal agreements that would need to be established, monitored, and managed by VDOT and FHWA. With the programmatic agreement already in place, VDOT can more efficiently begin preliminary engineering work on bridges and construction activities on pavements identified as needing some preventative maintenance treatment when those needs are identified.

A link to the Programmatic Authorizations for Preventative Maintenance Activities - Pavements and Bridge PE document follows:
https://insidevdot.cov.virginia.gov/div/FPMD/Lists/Announcements/Attachments/3/Programmatic%20Authorizations_District%20Guidance%20-%20042017.pdf

Ordinary Maintenance is defined by VDOT as follows:

Work that preserves roadway assets, corrects minor defects or problems, and extends the life of the asset.

Planned Preventive Maintenance (PM) is defined by VDOT as follows:

Any planned activity performed in advance of a need for repair or in advance of accumulated deterioration so as to avoid or minimize such occurrences and reduce or arrest the rate of future deterioration. The activities may correct minor defects as a secondary benefit. PM is usually planned cyclical, and generally is designed to extend the useful life of the asset, without, necessarily, extending structural capacity of the assets.

BRIDGE DECK EXPANSION JOINTS:

This section establishes guidelines for the evaluation, preventive maintenance, restorative maintenance and replacement of existing bridge deck expansion joints (referred to in this section as “expansion joints”) on bridges with concrete decks when additional significant deck work is not part of the scope. For additional information related to expansion joints for bridge decks, see Chapter 14. For bridge deck joint elimination guidelines and requirements on bridges undergoing deck repair, rehabilitation or replacement, see Section 32.09.

Significance of Expansion Joint Maintenance and Elimination: The overwhelming majority of bridge deterioration in Virginia is caused by corrosion in steel reinforcement and steel girders/ stringers. The corrosion is primarily attributable to exposure to chloride-laden water that attacks bridge elements due to leaking expansion joints. It follows that the integrity of expansion joints is a vital element of bridge preservation.

Definitions: Definitions of commonly used terms associated with expansion joints are provided below. See Chapter 14 for detailed descriptions and details.

<u>Expansion joint:</u> An opening in a bridge deck that allows differential movement between the bridge decks or between the deck and other bridge elements. Expansion joints accommodate bridge translation and rotational movements caused by thermal and vehicular (live) loads.

<u>Header:</u> Material adjacent to and in contact with the expansion joint, located at the ends of the deck, at abutment backwalls, and over piers

<u>Seal:</u> Type of system and material used in expansion joint

<u>Joint Elimination:</u> Elimination of an existing expansion joint through one of the three techniques below.

- Link Slab
- Deck Extension
- Continuity for Live Load

<u>Adhesive Based Joint Sealers:</u> Seals that rely primarily on adhesives to retain their connection to the headers. There are three classes of adhesive based seals.

- Class I: A preformed, extruded polychloroprene (neoprene) material having serrated sidewalls, which is air pressurized and bonded in place with a structural epoxy adhesive
- Class II: An inverted ‘V’ shaped, preformed, extruded silicone rubber or EPDM (ethylene propylene diene monomer) rubber seal material bonded in place with a structural adhesive
- Class III: A preformed, pre-compressed, self-expanding joint system with silicone pre-coated surfaces, bonded in place with a structural epoxy adhesive

<u>Elastomeric Expansion Dam (Strip Seal):</u> A manufactured seal comprised of two parts: parallel steel “rails” anchored in the header material with headed studs; and “glands”, usually neoprene or silicone, that fit into retaining slots fabricated in the rails.

<u>Tooth Expansion Joint (Finger Joint):</u> Comprised of pairs of independent elements with parallel teeth, anchored in the headers. Assemblies include a neoprene gland supported by the steel elements at each header.

Asphalt Plug Joint: A wide and shallow material patch that spans over the gap between headers. Material is comprised of blended polymer modified asphaltic binder and aggregate to allow adequate flexibility to function as an expansion joint.

Flexible Concrete Plug Joint: A wide and shallow material patch that spans over the gap between headers. Material is comprised of a semi-rigid polymer and aggregate placed over a steel plate to allow adequate flexibility to function as an expansion joint.

Silicone Joint Seals: A two-part silicone seal that is mechanically mixed on the site and poured into the opening between headers over a “backer rod” that serves as a temporary dam to hold the silicone in place until curing is complete.

Modular Joint (*Discontinued*): A mechanical device installed in expansion joint openings comprised of a series of smaller devices referred to as cells. Cells are typically comprised of steel rails and a flexible gland that spans between the rails.

Compression Seal (*Discontinued*): An extruded polychloroprene (neoprene) material compressed in order to allow placement in opening between headers.

Expansion Length (L): As used in this section, the term “expansion length” refers to the distance between the bearing at the expansion joint under consideration and the nearest translationally fixed bearing. Expansion length equals the span length for all simple span bridges and for those continuous spans with translationally fixed bearings at the adjacent (continuous) pier. In the uncommon case where a pier includes two translationally free bearings for the two adjacent spans supported by the pier, required movement ranges, gaps, and expansion joint sizes are additive.

Movement Range (MR): Total movement due to thermal expansion and contraction, and live load.

Hierarchy of Expansion Joint Types: The table below provides a preferential list of expansion joint types, based on past performance and durability. Minimum requirements for expansion joint treatment are provided later in this section. Use the most effective expansion joint type within practical constraints such as budgets and lane closures for the bridge under consideration while meeting the minimum requirements.

Hierarchy of Expansion Joint Types (Most Effective to Least Effective)	
Rank	**Expansion Joint Type and Specification Reference**
1	Joint Elimination – Specification Section 412*
2	Tooth Expansion Joint (Finger Joint) – Specification Section 423
3	Elastomeric Expansion Dam (Strip Seal) – Specification Section 421
4	Adhesive Based Joint Sealer– Specification Section 420
5	Flexible Concrete Plug Joint**– Special Provision Specification
6	Asphalt Plug Joint– Specification Section 424
7	Silicone Joint Seal (Pourable Seal)– Specification Section 427
8	Modular Joint – disallowed except for partial joint replacement
9	Compression Seal – disallowed except for partial joint replacement

*Specification Section 412 is referenced here to address concrete repair techniques and requirements that pertain to joint elimination, particularly regarding concrete removal and placement.

**The flexible concrete plug joint is under evaluation. Current ranking in the hierarchy is based on a conservative estimate of performance. As more performance data becomes available, its rank in the list will be reviewed and adjusted as appropriate.

REQUIREMENTS

1. **General:** Procedure for repairing or replacing expansion joints on existing bridges:

- Repair or replace seals for entire length unless remaining (undamaged) length exhibits excellent integrity. Do not perform partial replacement unless the seal type has an established performance history in bonding to itself when field-applied techniques are used
- Repair all portions of headers that exhibit signs of cracks, spalls, scaling, delamination or other damage (condition state 2 or worse)
- Select a permissible joint type in accordance with Requirement 2 below. Use the most durable action practical within constraints on budget and lane closures
- Determine the Movement Range (MR) for the expansion joint being considered in accordance with Requirement 3 below
- Select required size of seal for the movement range, seal type, effective expansion length and highway system
- Measure existing gap and record temperature at time of measurement. Check that the size and type of seal are appropriate for the available gap and the existing bridge geometry and system. See Chapter 14 for tables indicating acceptable gaps for each seal type and size. If gap is too small, use a different expansion joint type or modify or reconstruct header. If gap is too large, use a larger seal size or a different seal type
- Maintain integrity of seals along their full length (both on the deck and through the barrier)
- Shop drawings are required for all joints other than pourable seals. Suppliers are required to fabricate bends, cuts and fuse in the shop to the maximum extent practical

2. **Permissible Joint Types:** Replacement joint types must meet the requirements in the table below. The recommended action applies to the entire length of expansion joint.

Permissible Bridge Deck Expansion Joint Types			
Movement Range (MR)	**Highway System**	**Minimum Recommended Action (EED = Elastomeric Expansion Dam)**	**Minimum Required Action**
MR ≤ 1½”	Interstate	Joint Elimination or EED	Adhesive Based Joint Sealers
	Primary	Joint Elimination or EED	Adhesive Based Joint Sealers
	Secondary	Elastomeric Expansion Dam	Silicone Joint Seal
MR > 1½”	Interstate	Joint Elimination or EED	Elastomeric Expansion Dam
	Primary	Joint Elimination or EED	Elastomeric Expansion Dam
	Secondary	Elastomeric Expansion Dam	Elastomeric Expansion Dam

- Asphalt plug joints may be used for decks with existing asphalt overlays on any highway system as long as the provided MR exceeds required MR, although EED’s are preferred in all cases
- Use of flexible concrete plug joint is limited to secondary bridges with ADT < 2,000 until additional data become available.
- Match existing seal type for partial expansion joint replacements (instances when entire length of expansion joint seal is not being replaced) unless the existing joint is a compression seal.
- Replacement of glands is the most appropriate course of action for existing elastomeric expansion dams where the integrity of existing rails is sound. Glands must be replaced for the entire length of the expansion joint unless the material can be field-fused.
- Adhesive based joint sealers and expansion joint types with lower ranking (as shown in Hierarchy Table) are not permitted for MR in excess of 1½”.
- For bridges with MR in excess of 1½” , the minimum required action may be waived with a design approval by the District Structure and Bridge Engineer.

3. Movement Range (MR)

In addition to the requirements for effective expansion length and highway system established in the previous table, seal types must be selected to meet the movement requirements of the expansion joint. The MR is based on the requirements for thermal movement (expansion and contraction) and live load rotation for each particular bridge. Dead load rotation and shrinkage need not be considered in developing required movement ranges for existing bridges, since they will have already occurred at the time of joint installation. For existing bridges, MR may be calculated in accordance with the requirements of the AASHTO LRFD Bridge Design Specifications and VDOT Modifications or may be selected from the table below, which provides conservative requirements for MR for bridges with steel and concrete girders. For the bridge configurations noted below, custom calculations of MR are required.

Minimum Movement Ranges for Existing Bridges by Expansion Length			
Expansion Length (L)		**Min. MR at Expansion Bearing**	**Min. MR at Translationally Fixed Bearing**
Steel Bridge	Concrete Bridge		
L ≤ 40'	L ≤ 60'	½”	½”
40' < L ≤ 60'	60' < L ≤ 80'	¾”	½”
60' < L ≤ 80'	80' < L ≤ 110'	1”	½”
80' < L ≤ 100'	110' < L ≤ 140'	1 ¼”	½”
100' < L ≤ 130'	140' < L ≤ 180'	1 ½”	¾”
130' < L ≤ 150'	180' < L ≤ 210'	2”	1”
150' < L ≤ 170'	210' < L ≤ 260'	2 ¼”	1”
170' < L	260' < L	Calculations Required	Calculations Required

- Values apply to bridges with centerline radii over 800’ and bridges with skews between 0° and 15°
- Add 3/8” to required MR at expansion and fixed bearings for skews between 15° and 45°.
- Custom calculations required for bridges with radii less than or equal to 800’ or with skew angles greater than or equal to 45°.
- Custom calculations required for superstructures other than parallel girder structures, such as curved girders, trusses, arches, and post-tensioned boxes
- For longitudinal expansion joints, measure the existing gap and replace with a suitable seal.

4. Minimum Opening at Time of Seal Installation

The existing expansion joint opening may or may not be appropriate for the seal type being installed. Measure existing gap and record temperature at time of measurement. See tables in Chapter 14 to determine whether the existing opening is adequate for the selected seal size and type and the MR. In cases where the Chapter 14 tables do not provide adequate, specific information, consult the manufacturer’s requirements.

If gap is too small, use a different expansion joint type or modify or reconstruct the header.

5. Headers

Repair header material with Low Shrinkage Class A4 concrete or a material approved for deck patching. For seals that rely on bond between the header and expansion joint material (adhesive seals, silicone seals, flexible concrete plug joints and asphalt plug joints), use only header materials that are compatible with the joint manufacturer’s requirements. Verify acceptability of header material with manufacturer prior to selecting header materials. Headers must be prepared and installed in accordance with the requirements for concrete repairs described in Section 412 of the 2016 VDOT Road and Bridge Specifications.

RECOMMENDATIONS

1. There are two general approaches to maintaining system-wide expansion joint integrity: condition-based actions and planned preventive maintenance actions. Section 32.10 provides a recommended schedule for maintaining existing expansion joints. This schedule serves as a guide for an ideal systematic maintenance approach to expansion joints and will, if followed, lead to a bridge system with sound expansion joints.
2. The focus of expansion joint maintenance should be on both headers and seals. A significant proportion of expansion joint failures are due to deterioration of header material caused by reinforcement corrosion as well as impacts from plows and trucks. Expansion joint treatments with smooth profiles, such as joint elimination and plug joints, tend to mitigate header deterioration and should be considered for locations where header performance is poor.
3. Consideration should be given to addressing all expansion joints on a particular bridge at the same time. This will lead to an approximately simultaneous rate of deterioration so that a bridge can eventually come under a schedule for expansion joint maintenance. It also reduces costs for more mobilization and traffic control.

GUIDELINES FOR BRIDGE DECK JOINT ELIMINATION:

The overwhelming majority of bridge deterioration in Virginia is caused by corrosion in steel reinforcement and steel girders/stringers. The corrosion is primarily attributable to exposure to chloride-laden water that attacks bridge elements due to leaking expansion joints. It follows that the integrity of expansion joints is a vital element of bridge preservation.

The designer shall investigate the feasibility of eliminating all or some deck expansion joints for all rehabilitation projects or projects requiring significant restoration. See Section 32.03 for requirements for joint elimination on projects involving significant deck work.

The tables below provide a preferential order based on durability for complete elimination of bridge deck expansion joints on concrete bridge decks.

Piers Hierarchy of Options for Eliminating Bridge Deck Expansion Joints (Most Durable to Least Durable)	
Rank	**Deck Treatment[1]**
1	Structurally Continuous (Deck and Superstructure)
2	Continuous for Live Load
3	Flexible Link Slab
4	Rigid (Partial Depth) Link Slab[2]

[1]Virginia Pier Caps could in principle be built on an existing structure, but they are generally incorporated only in new bridges and thus are not included in this chapter. They are a highly desirable intervention. See Chapter 15 for information on Virginia Pier Caps.

[2]Rigid Link Slabs have been used in other states and are encouraged by the FHWA, but Virginia does not have adequate performance data for this connection detail. This intervention is not currently sanctioned by VDOT except on an experimental basis. It is included in this list for reference.

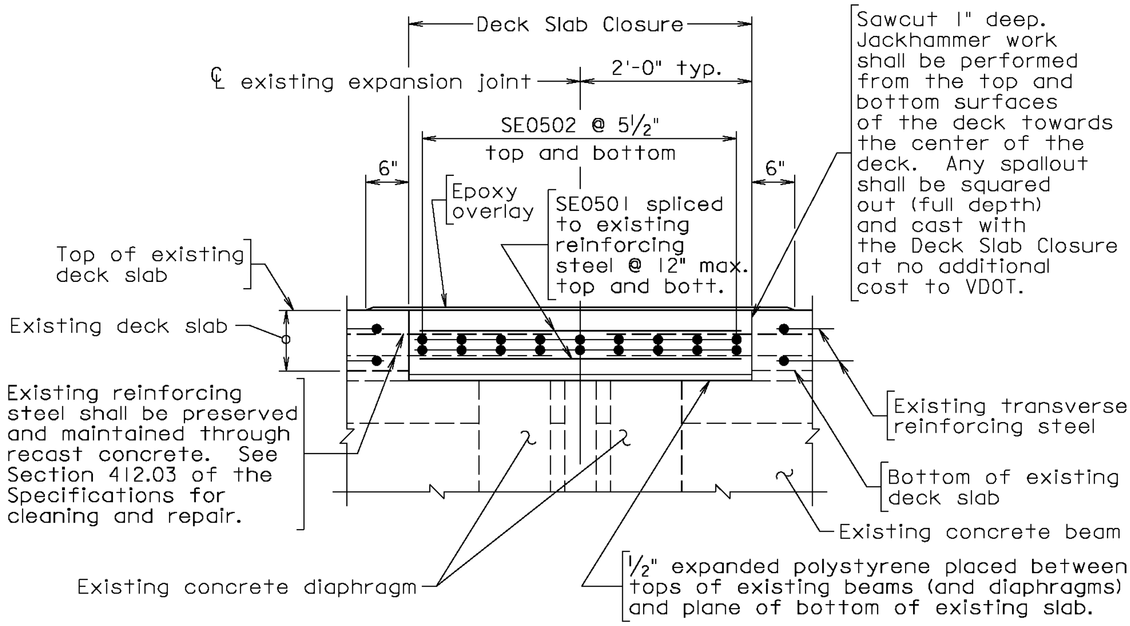
Abutments Hierarchy of Options for Eliminating Bridge Deck Expansion Joints (Most Durable to Least Durable)	
Rank	**Deck Treatment**
1	Semi-Integral Abutment[1]
2	Deck Extension
3	Virginia Abutment, Virginia Micro-Abutment or Virginia Alternate Micro-Abutment[2]

[1]Semi-Integral Abutments may be built on an existing structure, especially for superstructure replacements, and even deck replacements. Details for new bridges may be adapted for existing bridges and are not included in this chapter. See Chapter 17 for information on Semi-Integral Abutments.

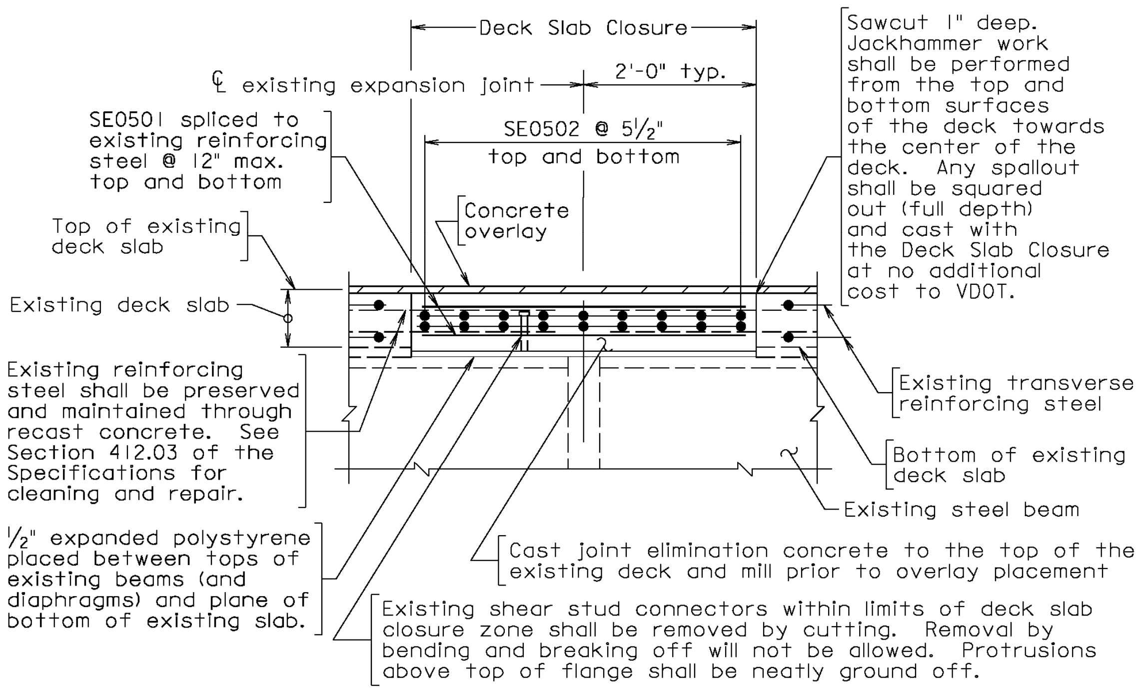
[2]Full-size Virginia Abutments have been built modifying existing abutments, but they are generally incorporated only in new bridges and thus are not included in this chapter. They are a highly desirable intervention. See Chapter 17 for information on Virginia Abutments.

Whenever practical, joint eliminations should be conducted in conjunction with placement of overlays. Overlays should be placed after the joint elimination is complete. This provides an additional level of protection over the cold joint between the existing deck and the link slab or deck extension. Also, for projects involving hydromilling, placement of the joint elimination prior to hydromilling simplifies the process of containing the waste water produced during hydromilling.

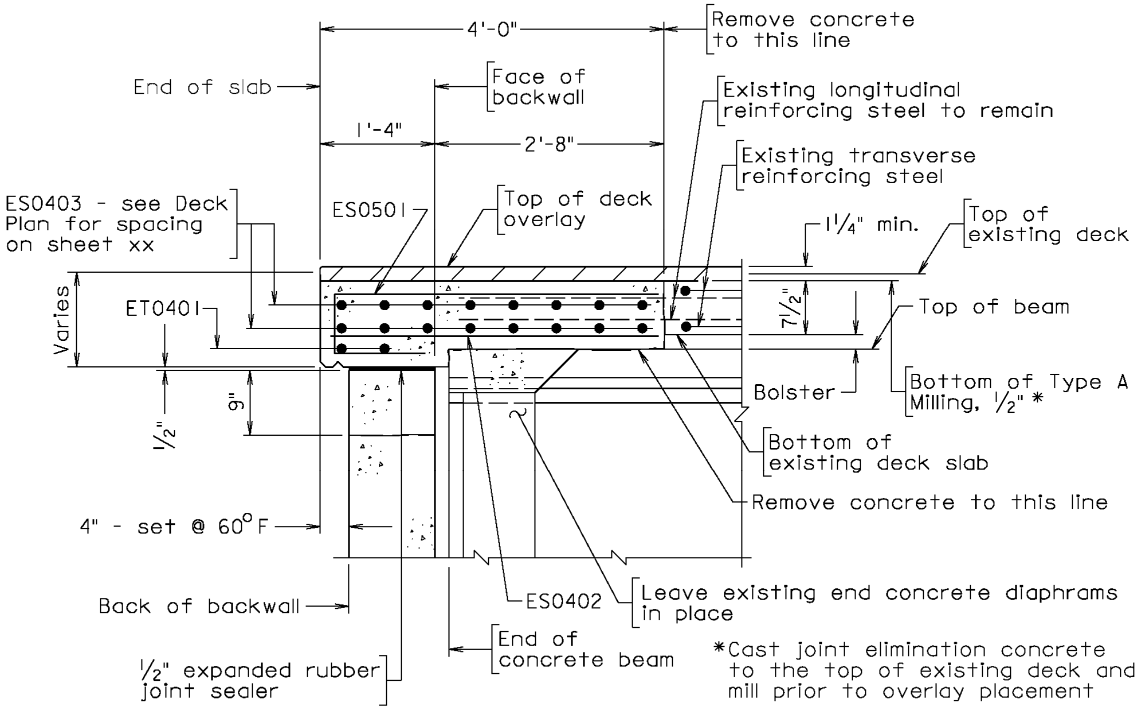
Example details for the Flexible Link Slab, Deck Extension, Virginia Micro-Abutment and Virginia Alternate Micro-Abutment are provided below:



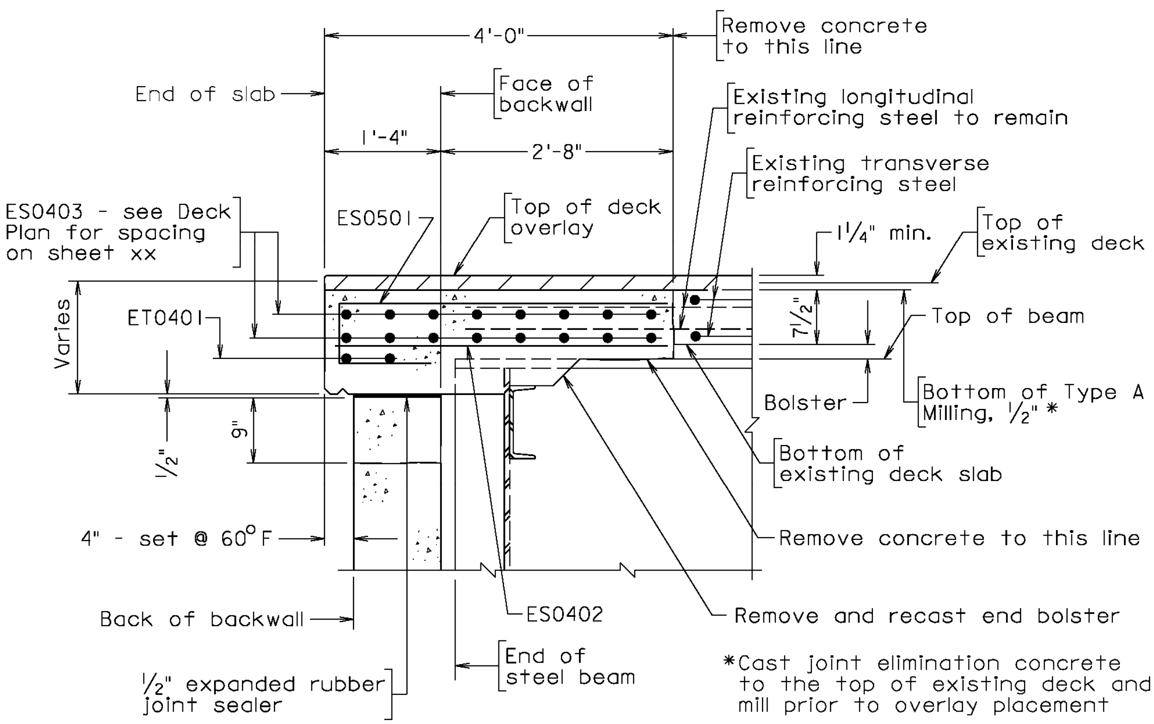
Flexible Link Slab With Epoxy Overlay Using A4 Modified Concrete Detail (concrete beam shown)



Flexible Link Slab With Concrete Overlay Using A4 Modified Concrete Detail (steel beam shown)

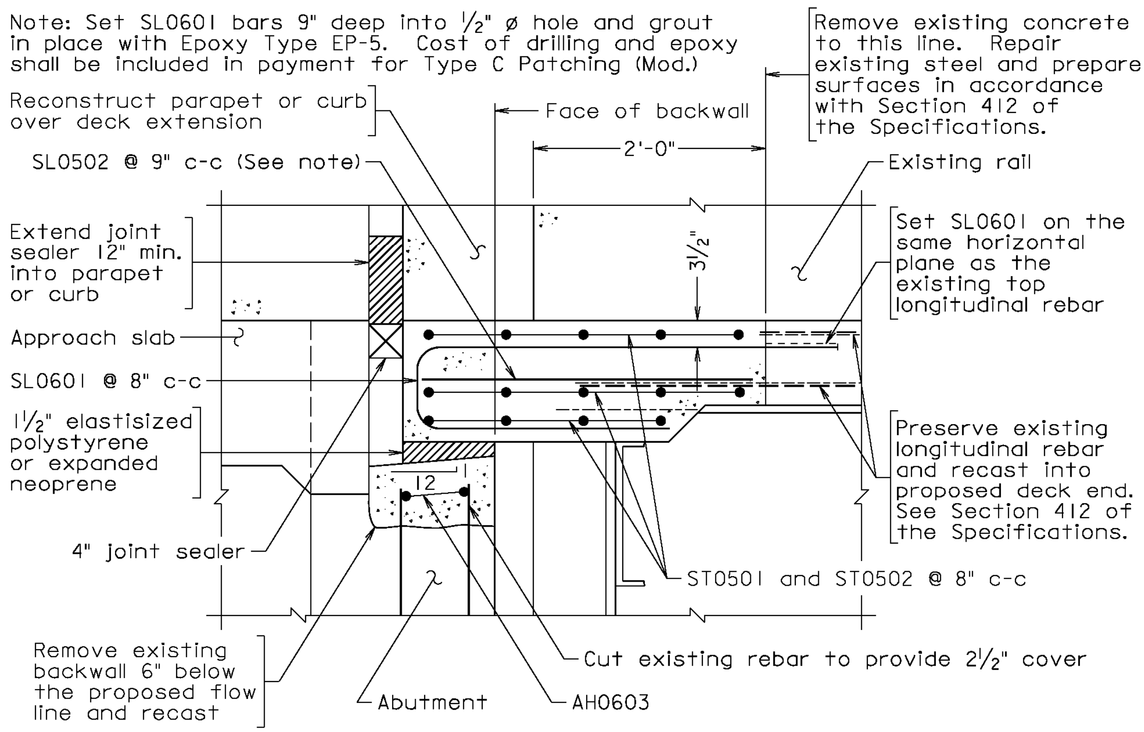


Deck Extension Detail (concrete beam shown)

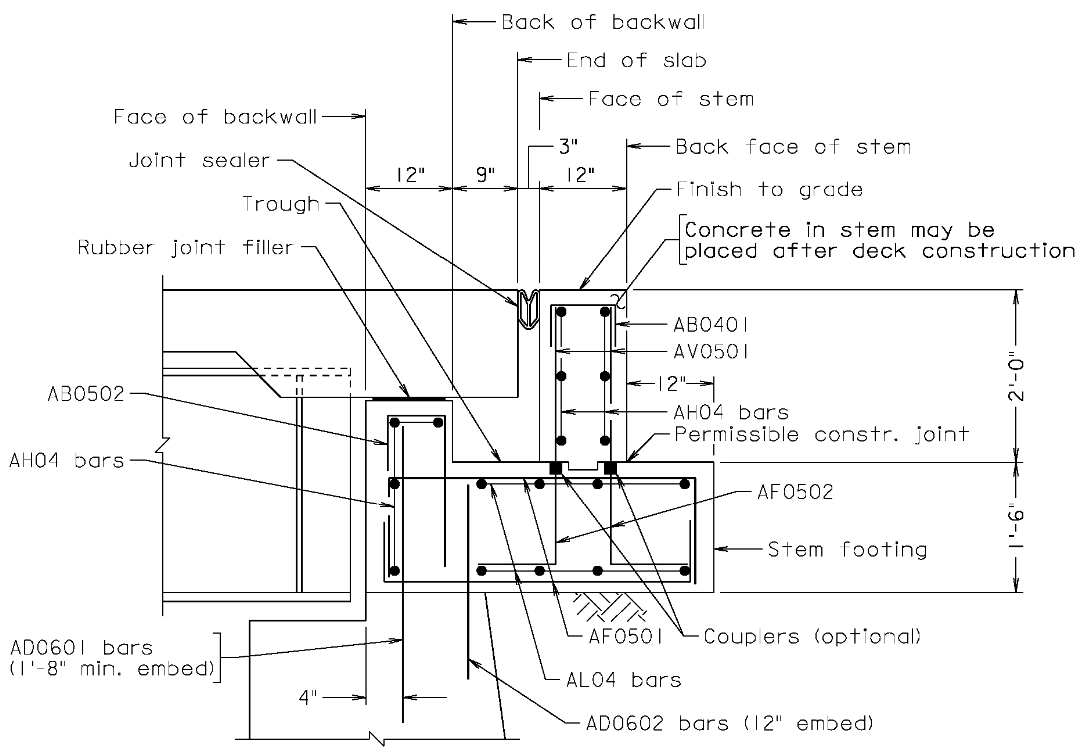


Deck Extension Detail (steel beam shown)

MAINTAINANCE AND REPAIR **BRIDGE DECK JOINT ELIMINATION** **GUIDELINES FOR BRIDGE DECK JOINT ELIMINATION**	PART 2 DATE: 08Aug2018 SHEET 3 of 8 FILE NO. 32.09-3



Virginia Micro Abutment Detail



Alternate Virginia Micro-Abutment Detail

MAINTAINANCE AND REPAIR **BRIDGE DECK JOINT ELIMINATION** **GUIDELINES FOR BRIDGE DECK JOINT ELIMINATION**	PART 2 DATE: 08Aug2018 SHEET 4 of 8 FILE NO. 32.09-4

STRUCTURAL ANALYSIS REQUIREMENTS:

Elimination of joints by any of the methods listed in the above table may cause changes to the loading of affected bridge components or elements including any affected deck, superstructure, substructure or foundation component. Any bridge element that will experience a change in loading due to the elimination of the joint(s) must be analyzed for the new loading conditions. Existing elements to remain may be analyzed in accordance with the provisions for loading, strength, serviceability and stress in the AASHTO bridge design specifications in effect when the bridge was built (either AASHTO Standards Specifications for Highway Bridges or LRFD). New components replaced as part of the joint elimination process (e.g. superstructures, decks, or parapets/rails) must be designed in accordance with the AASHTO LRFD Bridge Design Specifications and the requirements of this manual.

FHWA has sanctioned this practice (which is less stringent than VDOT's) in a memorandum, titled "Clarification of LRFD Policy Memorandum", dated January 22, 2007, which states the following: "For modifications to existing structures, States have the option of using the LRFD Specifications or the specifications which were used for the existing design." A link to this memorandum and the existing LRFD Policy Memorandum, dated June 28, 2000, are provided below.

http://www.fhwa.dot.gov/bridge/012207.cfm
http://www.fhwa.dot.gov/bridge/062800.cfm

1. **Structurally continuous structures** are generally employed on new bridges and existing bridge rehabilitation projects involving superstructure replacements. When replacing a superstructure on an existing bridge, all new bridge components (bearings, superstructure, deck, barriers) must be designed in accordance with LRFD and the requirements of this manual. Existing substructure elements to remain may be evaluated in accordance with the provisions for loading, strength, serviceability, and stress in the AASHTO bridge design specifications in effect when the bridge was built.

2. **Structures made continuous for live load** are generally employed on new bridges, existing bridge rehabilitation projects involving superstructure replacement, and existing bridge rehabilitation projects involving deck replacement. When an existing bridge is made continuous for live load as part of a rehabilitation project, all new bridge components (bearings, superstructure, deck, barriers as appropriate) must be designed and evaluated in accordance with LRFD and the remaining chapters of this manual. Existing substructure elements to remain may be evaluated in accordance with the load requirements of the AASHTO bridge design specifications in effect when the bridge was built.

3. **Flexible Link Slabs** are generally employed on existing bridges in which the existing deck is not replaced or on new decks where the superstructure is not replaced. When a flexible link slab is installed on an existing bridge, the existing deck, superstructure and substructure components to remain may be evaluated in accordance with the load requirements of the AASHTO bridge design specifications in effect when the bridge was built. The following elements must be evaluated for projects that employ flexible link slabs:

    - Bearings: evaluate fixed bearings for lateral loads associated with thermal and braking forces
    - Piers: evaluate fixed piers for lateral loads associated with thermal and braking forces
    - Joints: evaluate the remaining joints

STRUCTURAL ANALYSIS REQUIREMENTS (Cont'd):

Other bridge elements that will not be modified (deck, girders, barriers, etc.) do not require additional structural analysis.

Since VDOT has adequate field experience with the flexible link slab, individualized analysis of each use of a flexible link slab is not required for bridges with spans less than 120' as long as the following requirements are met:

- Concrete in link slab or deck extension: $f_c' \geq 4{,}000$ psi
- Longitudinal reinforcing steel from existing slab is spliced to reinforcement in link slab or deck extension (lap splice or mechanical coupler); spacing not to exceed 12".
- Transverse reinforcing steel is replaced and spliced, if necessary for staged construction.
- Link slabs extend 2' in either direction from the centerline of the existing joint location.
- Bond breaker is provided between tops of girders/beams and bottom of link slab
- Shear engagement is removed from tops of girders/beams within the area of the link slab (studs for steel girders/beams, reinforcement for concrete beams)

When spans exceed the above limits, link slabs should still be used if possible. However, analysis of the link slab will be required and the length of the link slab may exceed 4'.

Flexible link slabs are intended to be somewhat flexible and allow rotation of the girders/ beams at the piers. The flexible link slabs do not need to satisfy the cracking width requirements at the serviceability limit states. Some cracking of the deck of relatively new reinforced concrete sections has far superior performance then if an expansion joint were to be used. It is desirable to limit the length of debonding between the closure pour and girders/beams.

Flexible link slabs do not function in the same manner as structurally continuous superstructures or superstructures that are continuous for live load. They affect the bridge as follows:

- Superstructures: Flexible link slabs are not intended to significantly transmit vehicular live load effects from one span to another. Accordingly, connecting two adjacent simple spans with a flexible link slab does not require additional analysis of the capacity of the existing beams.
- Substructure and bearings: While the changes to the live load and dead load effects from flexible link slabs are usually not significant, changing the articulation of the superstructure may significantly change the thermal and braking loads on the bearings, piers and abutments. Evaluate the bearings, substructures or foundations to determine if they can accommodate the new force configurations. Existing substructure elements may be evaluated in accordance with the load requirements of the AASHTO bridge design specifications in effect when the bridge was built.

Almost all joint eliminations are done in stages. The first stage usually cracks the most due to the eccentricity of forces between the two spans. On wide bridges where the joint eliminations are done in three or more phases, it is best to start near the center to minimize eccentricities. When locking up multiple consecutive joints, it is best to start with the joint at the center of the group and proceeding to the outer joints to help minimize forces when casting the center joint.

STRUCTURAL ANALYSIS REQUIREMENTS (Cont'd):

All bearing work (i.e., converting fixed bearings to expansion), increasing capacity of expansion bearings, replacing fixed bearings to increase capacity for longitudinal forces, etc. needs to be completed for the full width of superstructure of the spans being linked together prior to casting link slabs for the first stage.

If all of the joints cannot be eliminated due to substructure limitations, then there is a distinct probability that some can be and effort should be taken to close the joints with the greatest benefit (e.g., over substructure elements with the most difficult access for repair). Use of elastomeric expansion bearings is encouraged as they help transfer longitudinal forces to the substructure and minimize the redistribution of loads due to changing fixed/expansion bearing relationships.

4. **Deck Extensions** (over backwalls at bridge abutments) do not require analysis except for bridges with skews in excess of 30º. For bridges with skews over 30º, ensure that forces applied at the ends of the deck (at rub plates) do not exceed capacity of substructure elements.

5. **General:** The following steps are required for the design and evaluation of existing bridges that are being made continuous for live load or for which a link slab is being installed.

   - Assess existing bearings and adjust fixities as necessary. In many cases the existing articulation of the bridge may need to be adjusted. Specifically, some fixed bearings may need to be freed to allow longitudinal translational movement and some expansion bearings may need to be fixed against longitudinal translation. These changes, when required, are usually prompted by additional thermal and braking loads applied to portions of the structure due to the proposed deck continuity or flexible link slab.

   - Assess strength of existing piers. As with the bearings, deck continuity changes the magnitude of applied loads to certain bridge elements. The addition of deck continuity usually increases the applied braking and thermal loads on piers. In general, taller, more flexible piers are better able to sustain additional lateral loading resulting from deck continuity.

DETAILS:

There are many acceptable versions of link slabs and deck extensions that have been used successfully in Virginia. Contact the Engineering Services Program Area of the Structure and Bridge Division for details on previous projects.

Coordinate use of these details in consultation with the Structure and Bridge District Office or the Maintenance Program Area group of the Structure and Bridge Division.

MATERIALS

Concrete for flexible link slabs must be Low Shrinkage Class A4 Modified Concrete per Section 217.12.

Material for reinforcing steel in flexible link slabs and deck extensions shall be CRR.

COMMENTARY

Function of Flexible Link Slabs: It is important to understand the fundamentally different behavior associated with flexible link slabs and other forms of structural continuity. While flexible link slabs do provide some degree of continuity to a formerly unlinked set of spans, the flexible link slab is not designed to transmit live load effects from one span to another. This is the reason that the link slabs must be flexible and not bonded to the tops of the girders.

Advantages of Jointless Decks: The most significant advantage of jointless decks is that there are no expansion joints that may leak or require maintenance and replacement. However, jointless decks also provide a smooth riding surface, eliminating the headers at either end of the bridge. Since headers are often the cause of joint deterioration, jointless decks eliminate both major causes of joint failure (header deterioration and gland failure). While flexible link slabs and deck extensions do often exhibit small cracks at cold joints or within the new slab concrete, these cracks generally cause only minimal leakage. Virginia has nearly 30 years of experience with flexible link slabs on all highway systems and with various geometric configurations, including skews. The performance record has been excellent.

PREVENTIVE MAINTENANCE BACKGROUND

VDOT faces significant challenges in addressing the needs of the aging infrastructure. Due to limited funds and increased competition for funds among highway assets, VDOT is challenged to cost effectively preserve and maintain the bridges to support overall highway mobility. However, having a “worst-first” approach to bridge management by focusing only on replacing or rehabilitating poor bridges while ignoring the maintenance needs of good and fair bridges is inefficient and cost-prohibitive in the long term.

Preventive maintenance (PM) is a cost-effective means of extending the service life of highway bridges. PM for highway bridges is a strategy of extending service life by applying cost effective treatments to bridge elements. PM activities retard future deterioration and avoid large expenses in bridge rehabilitation or replacements.

Preventive maintenance provides a high return on investment. While the benefits of PM may not be realized immediately, they still should be a high priority for each district’s bridge program as they help to ensure the long term health of the structure inventory.

Preventive maintenance includes any planned cyclical activity performed in advance of a critical need for repair to reduce or arrest the rate of future deterioration. Preventive maintenance activities consist of the following characteristics: planned and cyclical; proactive (not reactive); and activities that are condition based as determined in safety inspections.

Examples of Preventive Maintenance – Bridge Cleaning, Deck Sealing, Sealing Joints, Thin Deck Overlays, Removing Large Debris in Channels, Spot and Zone Painting and Reconstructing/ Closing Joints.

Element condition data may be used to determine preservation or rehabilitation needs. Typically, condition states 1 and 2 would indicate no action or preventive maintenance activities, while condition states of 3 and 4 indicate the need for restorative or rehabilitation activities.

Preventative maintenance is one component of the bridge preservation program. The other component of the preservation program is restorative maintenance.

Preventive maintenance can be condition based or non-condition based.

CONDITION BASED PREVENTIVE MAINTENANCE

Condition based Preventive Maintenance may correct minor defects and generally is designed to extend the useful life of the asset, without, necessarily, extending structural capacity of the assets. Condition based preventative maintenance includes minor repairs on bridges that are in overall good condition, Examples include small areas of deck patching, small areas of substructure concrete surface repair, sealing leaking deck joints, etc.

PLANNED PREVENTIVE MAINTENANCE

Non-condition based preventive maintenance is typically referred to as Planned Preventive (Cyclical) Maintenance.

Planned Preventive Maintenance (PPM) - PPM is a general term for maintenance tasks that slow deterioration and prolong the life of a maintainable structure. They do not include corrective repairs to existing damage. Any planned activity performed in advance of a need for repair or in advance of accumulated deterioration, so as to avoid such occurrences and reduce or arrest the rate of future deterioration. The activities may correct minor defects as a secondary benefit. Planned Preventive maintenance is: 1) planned, 2) cyclical and 3) not condition-based.

Examples of PPM include: joint replacement, deck washing, drain cleaning, thin-bonded deck overlays, vegetation removal, bearing cleaning and spot or zone painting. Ideally, these tasks should be performed at regularly scheduled intervals. PPM is generally performed on bridges with a minimum GCR of six or more and is an important investment in the life of existing assets. PPM is considered for elements in condition states 1 or 2 only. Elements in condition states 3 or worse are considered for restorative maintenance.

The goal of PPM is to slow the rate of deterioration of structural elements. The effectiveness of PPM treatments can only be measured over many years as deterioration is slow.

The approach to assessing PPM needs begins with a set of criteria (shown below) used to identify which bridges are candidates for PPM. The number of units (elements) meeting the requirements for treatment across all bridges meeting the selection criteria are summed by system and by district, and then multiplied by the unit cost of PPM. Finally, a frequency factor was applied that represents the fraction of the candidates that should be treated each year in order to ensure PPM treatments occur on every bridge with fixed regularity.

As an example, if District “A” has 1000 LF of pourable joints meeting the selection criteria, the annual preventive maintenance need for pourable joints for District “A” would be determined as follows: (1000 LF * $71.49/LF)/6 year frequency = $11,915)

Pourable joints cost an average of $71.49/LF to replace and should be replaced every 6 years.

Criteria used to identify structures and elements that are candidates for PPM:

The general goal is to perform PPM activities on structures that are in overall Good Condition; however, there may be cases where a component is in Poor or Fair condition and the candidate components are in Good condition, and the decision is made to perform PPM activities on the components in Good condition. For example, where the bridge deck is a 7 and the substructure is a 4 for scour (needs countermeasures), the decision may be made to clean/wash the deck. Consult the District Structure and Bridge Engineer for guidance in these situations.

- Bridge Deck Washing (Concrete) - Selection Criteria:

  VDOT maintained bridges having concrete decks or slabs without asphalt overlay

  Deck Elements – 12, 18, 22, 26, 27 (Unit – SF)

  Slab Elements – 38, 44, 48, 52, 53 (Unit – SF)

  Select bridges where 100% of the element is in State 1 or State 2 (0% in States 3 – 4)

Criteria used to identify bridges and elements that are candidates for PPM (cont.'d):

- Bridge Deck Sweeping - Selection Criteria:

  VDOT maintained bridges having concrete decks or slabs with asphalt overlay, metal decks, and timber decks and slabs

  Deck Elements – 13, 14, 28, 29, 30, 31, 32 (Unit – SF)

  Slab Elements – 39, 40, 54, 55 (Unit – SF)

  Select bridges where 100% of the element is in State 1 or State 2 (0% in States 3 – 4)

- Seats and Beam End Washing - Selection Criteria:

  VDOT maintained bridges having concrete abutment seats and concrete pier seats

  Elements – 215, 233, 234 (Unit – LF)

  Assume an average seat width of 3 feet

  Select bridges where 100% of the element is in State 1 or State 2 (0% in States 3 – 4)

- Cutting and Removing Vegetation - Selection Criteria:

  VDOT maintained bridges over waterways

  Custodian = 1, Culvert GCR = N, and Channel GCR not equal to N

- Routine Maintenance of Timber Structures - Selection Criteria:

  VDOT maintained bridges having timber components

  Elements 31, 32, 54, 55 (Unit – SF)

  Assume that most of this work will involve decks

  Select bridges where 100% of the element is in State 1 or State 2 (0% in States 3 – 4)

- Scheduled Replacement of Compression Seal Joints - Selection Criteria:

  VDOT maintained bridges having compression seal joints

  Element 302 (Unit – LF)

  Select bridges where 100% of the element is in State 1 (0% in States 2 – 4)

Criteria used to identify bridges and elements that are candidates for PPM (cont.'d):

- Scheduled Replacement of Pourable Joints - Selection Criteria:

  VDOT maintained bridges having pourable joints

  Element 301 (Unit – LF)

  Select bridges where 100% of the element is in State 1 (0% in States 2 – 4)

- Cleaning and Lubricating Bearing Devices - Selection Criteria:

  VDOT maintained bridges having moveable bearing assemblies

  Element 311 (Unit – Each)

  Select bridges where 100% of the element is in State 1 or State 2 (0% in State 3-4)

- Scheduled Installation of thin Epoxy Concrete Overlay - Selection Criteria:

  VDOT maintained bridges having bare concrete decks

  Deck Elements – 12, 26 (Unit – SF)

  Slab Elements – 38, 52 (Unit – SF)

  Select bridges where 100% of the element is in State 1 (0% in States 2 – 4)

- Beam Ends Painting - Selection Criteria:

  VDOT maintained bridges having painted steel beams or stringers

  Elements – 107, 113 (Unit – LF)

  Assume beam ends are 15% of total beam length

  Select bridges where 100% of the element is in State 1 (0% in States 2 – 4)

- Removing Debris from Culverts - Selection Criteria:

  VDOT maintained culverts

  Custodian = 1

  GCR for Deck, Superstructure, and Substructure = N

  Select culverts where 100% of the element is in State 1 or State 2 (0% in State 3-4)

Planned preventive (cyclical) maintenance should be performed on a schedule to be developed for each structure. The following table establishes a basis for scheduling planned preventive maintenance activities:

Preventive Maintenance Activity		Ideal Cycle Years	Units	Activity Description	How Activity Is Accounted for in Annual Needs Analysis
1	Bridge Deck Washing (Concrete)	1	SY	Removal & disposal of debris; pressure washing of bridge roadway surface, joints, sidewalks, curbs, parapet walls, drainage grates, downspouts, and scuppers.	All concrete decks and slabs that do not have an asphalt overlay.
2	Bridge Deck Sweeping	1	SY	Includes the removal and disposal of debris and sweeping of the bridge roadway surface, shoulders, joints, sidewalks, and curb lines.	All concrete decks and slabs with asphalt overlay, metal decks, timber decks and slabs.
3	Seats & Beam Ends Washing	2	SY	Includes the removal and disposal of debris and pressure washing of the bridge seat, bearing areas, and 5 feet of beam-ends. Use 3 feet avg. seat width for estimation purposes.	Clean all bridge seat and bearings, abutment seats, pier seats, bearing devices, end diaphragms and the last 5’ of beams and girders.
4*	Cutting & Removing Vegetation	2	EA	Cutting, removing and disposing of vegetation, brush and trees that are on, adjacent to, or under bridges.	This activity can be planned and performed on any bridge or culvert as deemed necessary.
5*	Routine Maintenance of Timber Structures	2	EA	Tightening and/or replacing fasteners for decks, railing systems, misc. connections. Sealing ends of timber elements, such as boards, bent caps, railings, posts.	All timber structures.
6	Scheduled Replacement of Deck Expansion Joint Seals	10	LF	Includes removal of existing joint material, surface preparation and installing new joint material.	Only joints that are in good condition will be considered as planned preventive maintenance needs. Needs for joints that are not in good condition are included in the condition-based preventive maintenance needs.
7	Cleaning and Lubricating Bearing Devices	4	EA	Removal and disposal of debris, and lubricating movable bearings.	All bridges with movable type bearings.
8	Scheduled Installation of Thin Epoxy Concrete Overlay	15	SY	Includes installing of new system and/or replacing existing overlay system.	Only concrete bridge decks that are in overall good condition are considered in this program.
9	Beam End Painting	10	EA	Preparing and over-coating the end 5’ of painted steel beams or girders that are located under joints, except for bridges with timber decks. Assume paint system replaced at 40 years.	Only beam ends in good condition will be considered in the annual planned preventive maintenance needs analysis. Needs for beam ends not in good condition are included in the condition-based preventive maintenance needs.
10	Removing Debris from Culverts	5	EA	Includes the removal and disposal of debris that is collected inside and/or at inlets or outlets of culverts.	All culverts except for those scheduled for replacement.

*Not eligible for federal reimbursement under the efficiencies agreement

Notes on deck crack sealing: There are two distinct schools of thought on the application of gravity sealants to seal active deck cracks. Recent research has shown that this activity has, at best a very limited functional duration and is not a cost-effective maintenance technique for active cracks. However, some districts have had good experience with the practice and have both practical and anecdotal evidence to support this position. This document does not recommend the use of gravity sealants on active cracks but recognizes that a valuable short-term maintenance activity for dormant cracks.

GUIDELINES FOR THE RESTORATIVE MAINTENANCE (RM) AND STRUCTURAL REHABILITATION (SR) OF EXISTING CULVERTS - INTRODUCTION

This section provides guidance for the evaluation, design, and installation for restorative maintenance and structural rehabilitation of existing culverts inventoried by the Structure and Bridge Division.

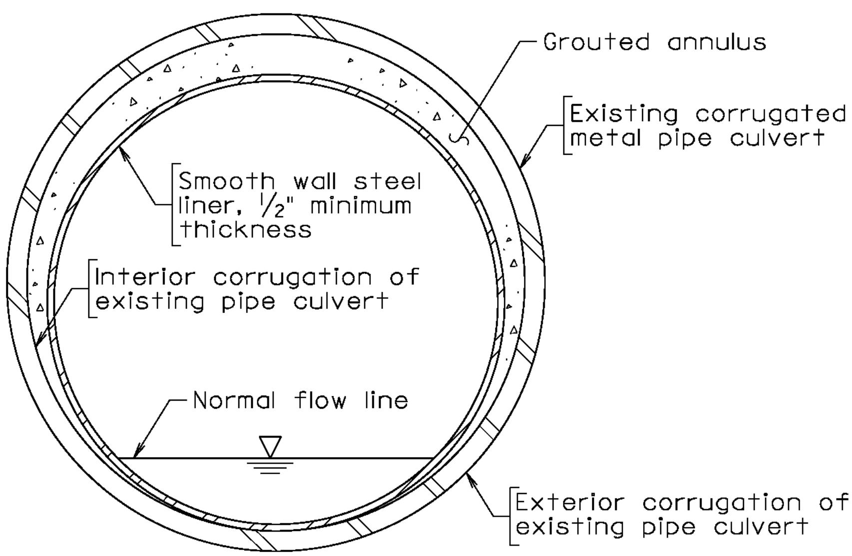
Hierarchy of Options for Restorative Maintenance and Structural Rehabilitation of Culverts (Most Aggressive to Least Aggressive)		
Rank	**Type**	**Treatment**
1	Structural Rehabilitation	Smooth Wall Steel Pipe Liner with Grouted Annulus
2	Structural Rehabilitation	Spray-On Cementitious Liner[1] (Centrifugal Spin-Cast or Shotcrete)
3	Structural Rehabilitation	High Density Polyethylene (HDPE) Pipe Liner with Grouted Annulus
4	Restorative	Paved Invert with Engineered Cementitious Composite (ECC)
5	Restorative	Repair Joints, Patch and Repair Delaminated, Spalled and Cracked Concrete

[1]Spray-On Cementitious Liners are being used on demonstration projects in Virginia but have been used successfully in other states. They are permitted in Virginia based on the performance from other states.

Spray-on polymer liners and cured-in-place pipe liners are prohibited, as they have historically displayed unsatisfactory performance and have been shown to pose environmental risks. Asphalt coatings have been shown to provide minimal protection and are therefore also prohibited.

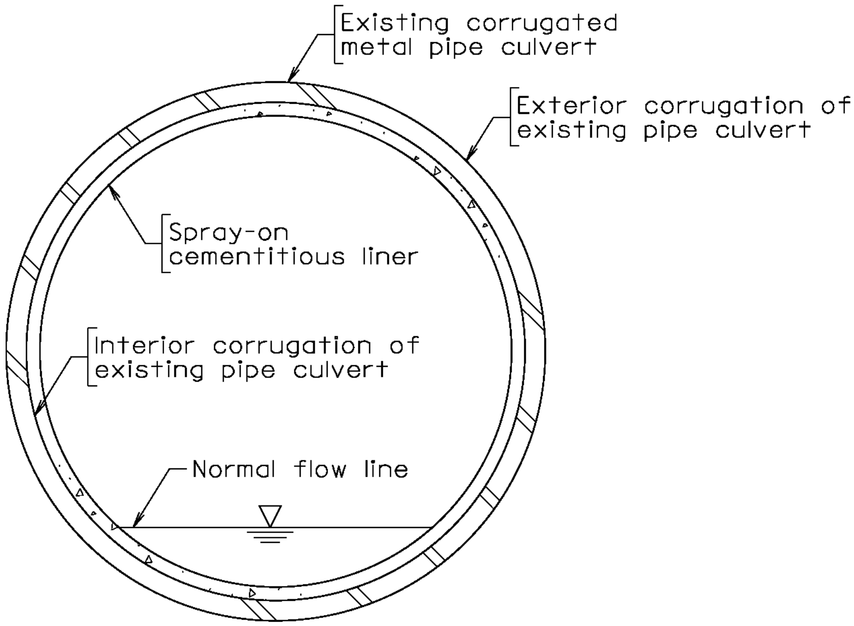
DETAILS

The following drawings show conceptual level details for culvert rehabilitation options. Circular corrugated metal culverts shown. Details for concrete and non-circular culverts are similar.

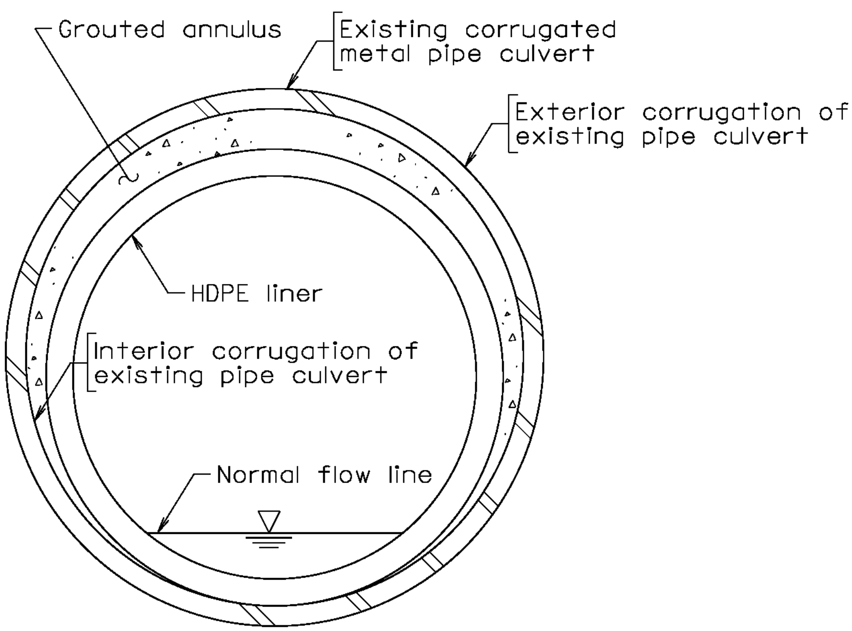


Corrugated Metal Pipe Culvert with Smooth Wall Steel Pipe Liner with Grouted Annulus

DETAILS (Cont.'d):



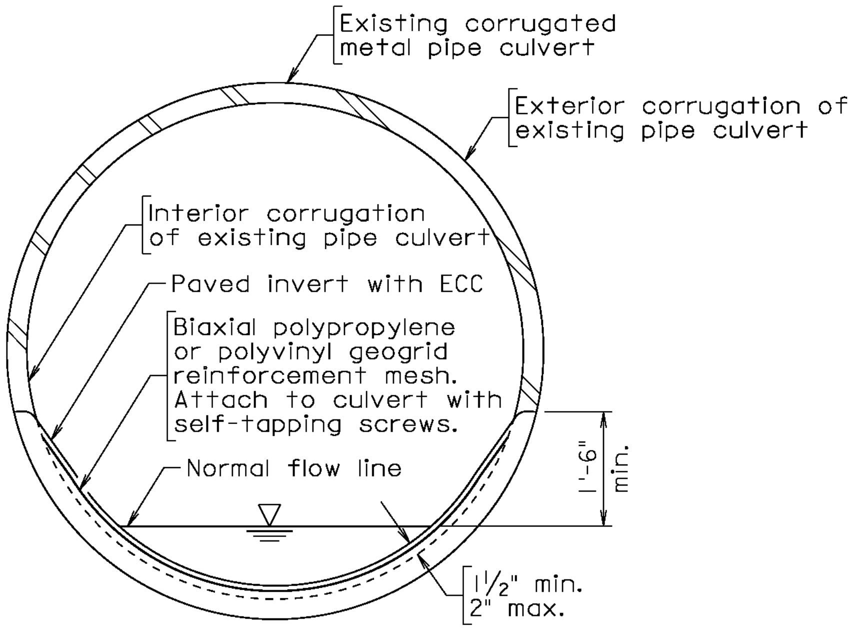
Corrugated Metal Pipe Culvert with Spray-On Cementitious Liner



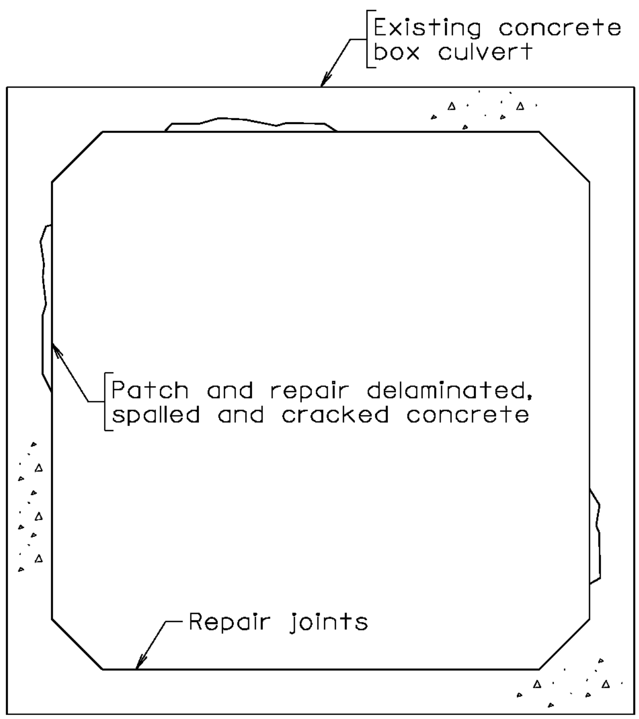
Corrugated Metal Pipe Culvert with HDPE Liner

MAINTENANCE AND REPAIR **GUIDELINES FOR THE RM AND SR OF EXIST. CULVERTS** **DETAILS**	PART 2 DATE: 05Oct2018 SHEET 2 of 11 FILE NO. 32.11-2

DETAILS (Cont.'d):



Corrugated Metal Pipe Culvert with Paved Invert with ECC



Repair Joints, Patch and Repair Delaminated, Spalled and Cracked Concrete

DESIGN AND SELECTION OF TREATMENT METHOD

Structural design: All structural rehabilitation treatments must restore the strength of the culvert and must be accompanied by design and load rating calculations, sealed by a professional engineer, registered in the Commonwealth of Virginia.

Required Actions for Culvert Treatment		
Culvert General Condition Rating (GCR)	**Culvert Type**	**Minimum Required Action**
GCR ≥ 5	Metal	Paved Invert with ECC
	Concrete	Patch Delaminations and Spalls, Repair Cracks and Joints
GCR ≤ 4	Any	Structural Rehabilitation*

* Paved inverts with ECC may be appropriate for certain metal culverts with GCR ≤ 4 if settlement, roof deformation, and/or flow line deterioration are within acceptable levels. Approval of the District Structure and Bridge Engineer is required in order to place paved inverts on any culvert with GCR ≤ 4. If roof or flow line deformation has caused significant settlement of the overburden and roadway (>7%) in any location, the structural effectiveness of the affected culvert barrel has been compromised, and replacement is the required action. Similarly, if settlement along the flow line (particularly at joints) has created a vertical discontinuity in excess of 4”, the culvert is exhibiting damage exceeding the capability of rehabilitation to correct.

REPAIR AND REHABILITATION OF JOINTS

Structural rehabilitation methods will address joint leaking and deterioration. However, restorative maintenance actions may require joint repair. In the absence of settlement at joints, any of the actions listed below may be used to repair joints in non-structural rehabilitations:

- Corrugated Metal Pipe:
  - Oakum with urethane grout
  - Internal bands of corrugated steel matching the contours of the existing corrugations
  - Internal bands of rubber and stainless steel
- Concrete Culverts
  - Polymer grout injection (epoxy or urethane)
  - Cementitious grout injection

ENVIRONMENTAL REQUIREMENTS

Culvert restorative maintenance and structural rehabilitation generally require stream diversions, which require environmental permits. Placement of scour countermeasures (including grouted or ungrouted riprap) may require permits.

Invert elevations of existing culverts may be raised more than 2” only with prior approval of the Environmental Division through permitting. In general, invert elevations may be raised more than 2” on multi-barrel pipes/culverts as long as the existing invert elevation of one or more barrels is raised by no more than 2”. The purpose of this restriction is to allow aquatic life to traverse the stream.

HYDRAULICS AND HYDROLOGY

Hydrological analysis (stream study) is not required for restorative maintenance, structural rehabilitation or in-kind replacement of existing culverts, unless the work is being performed in order to address noted deficiencies in the hydraulic performance of the culvert. When necessary, perform hydrological analysis in accordance with VDOT's *Drainage Manual* and associated Informational and Instructional Memoranda (IIMs). See link below:

http://www.virginiadot.org/business/locdes/hydra-drainage-manual.asp

Hydraulic analysis should be considered, but is not required, for culverts that have a history of repeatedly flooding over the roadway. However, since the alternatives presented in this section affect hydraulic performance, the flow capacity of the restored/rehabilitated culvert must be checked against that of the original culvert. In general, the alternatives presented in this section will improve the smoothness of the culvert but reduce its cross-sectional area.

A full hydraulic analysis is not required if the culvert restorative maintenance or structural rehabilitation does not reduce flow rate, as calculated according to Manning's Equation, shown below:

$$Q = VA = (1.49 / n) * A * R_h^{(2/3)} * (S)^{0.5}$$

Where: Q = Flow Rate; V = Velocity; A = Flow Area; S = Channel Slope

n = Manning's Roughness Coefficient (use table unless testing indicates other values may be used)

R_h = Hydraulic Radius = (Cross-sectional area of flow) / (wetted perimeter)

= b*h/2*(b + h) for a rectangular channel (b = width, h = height of flow)

= r / 2 for a circular section [$r / 2 = (\pi r^2 / 2\pi r)$]

In order to assess potential treatments for suitability, evaluate according to the procedure shown below and submit evaluations to the district hydraulic section for a hydraulic commentary to accompany permit applications.

For the intervention options included in this section, only three variables need to be considered for the Manning equation: R, A, and n. A general example is provided below establishing a simplified method for comparing flow rates before and after rehabilitation. The subscripts "1" and "2" are used to describe the culvert parameters before and after rehabilitation, respectively, so, as shown, the comparative analysis can be performed without consideration of the values of V (velocity) and S (slope):

Primary Requirement: $Q_2 \geq Q_1$

Therefore: $(1.49 / n_2) * A_2 * R_{h2}^{(2/3)} * (S_2)^{0.5} \geq (1.49 / n_1) * A_1 * R_{h1}^{(2/3)} * (S_1)^{0.5}$

Reducing terms: $(A_2 / n_2) * R_{h2}^{(2/3)} \geq (A_1 / n_1) * R_{h1}^{(2/3)}$

In some cases, a decrease in the flow rate can be tolerated (if the existing culvert has excess capacity). For cases where the proposed intervention reduces flow rate, consult district hydraulics section for potential options, including hydrological analysis.

HYDRAULICS AND HYDROLOGY (Cont'.d)

Material	Recommended Roughness Coefficient (Manning's "n")
Corrugated Metal	0.022
Smooth Wall Steel Pipe	0.010
Spray-On Cementitious Liner	0.012
HDPE Pipe	0.010
Paved Invert with ECC	0.013
Concrete Culvert	0.011

Example 1:

For a corrugated metal pipe with an original inside diameter (d_1) of 70" (r_1 = 70" / 2 = 35"), determine if flow is adequate if an HDPE liner with a 64" inside diameter (d_2) is placed in the pipe (r_2 = 64" / 2 = 32"):

Initial Conditions (A_1, n_1, R_{h1})

$A_1 = \pi * r_1^2 = \pi * (70 / 2)^2 = 3{,}848$ in^2

$n_1 = 0.022$ (see table)

$R_{h1} = r_1 / 2 = 35 / 2 = 17.5$ inches

$(A_1 / n_1) * R_{h1}^{(2/3)} = (3{,}848 / 0.022) * 17.5^{(2/3)} = 1{,}180{,}000$

Post-Rehabilitation Conditions (A_2, n_2, R_{h2})

$A_2 = \pi * r_2^2 = \pi * (64 / 2)^2 = 3{,}217$ in^2

$n_2 = 0.010$ (see table)

$R_{h2} = r_2 / 2 = 32 / 2 = 16$ inches

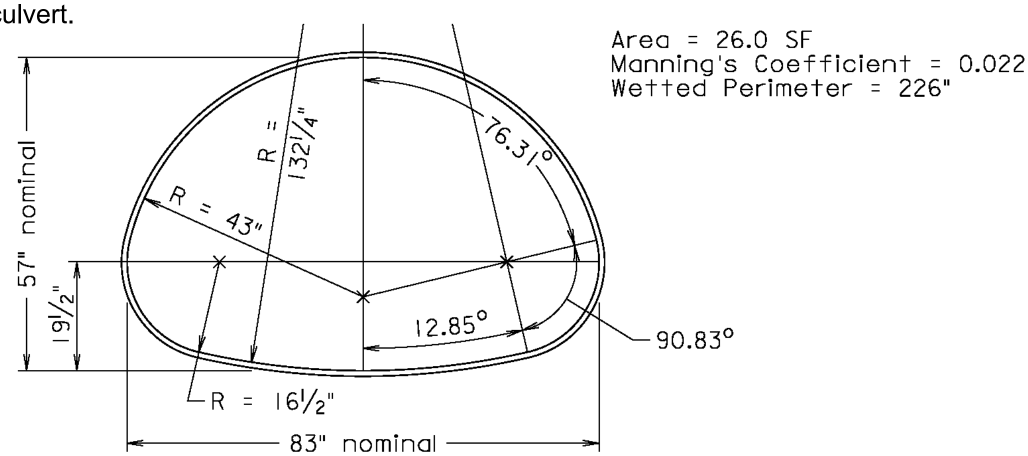
$(A_2 / n_2) * R_{h2}^{(2/3)} = (3{,}217 / 0.010) * 16^{(2/3)} = 2{,}040{,}000$

2,040,000 ≥ 1,180,000 → OK

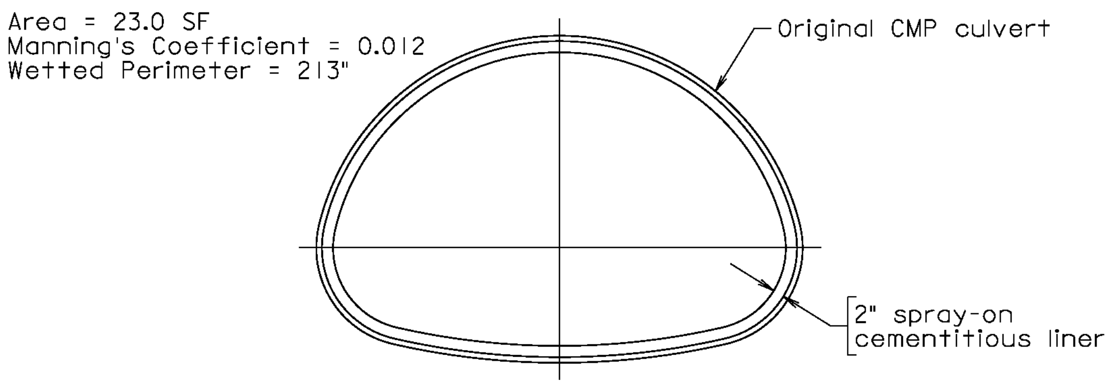
HYDRAULICS AND HYDROLOGY (Cont'.d)

Example 2:

For an arch-shaped, corrugated metal pipe (CMP) with the dimensions shown in the sketch below, determine if flow is adequate if a 2" thick spray-on cementitious liner is centrifugally cast in the culvert.



Arch-Shaped CMP Culvert Prior to Rehabilitation



Arch-Shaped CMP Culvert After Rehab. with Spray-on Cementitious Liner

Initial Conditions (A_1, n_1, R_{h1})

A_1 = 26 ft^2 = 3,744 in^2 (manufacturer's info.)

n_1 = 0.022 (see table)

Wetted perimeter = 226 inches (manufacturer's info.)

R_{h1} = 3,744 / 226 = 16.6 inches

$(A_1 / n_1) * R_{h1}^{(2/3)} = (3,744 / 0.022) * 16.6^{(2/3)}$
= 1,110,000

Post-Rehabilitation Cond.'s (A_2, n_2, R_{h2})

A_2 = 23 ft^2 = 3,312 in^2

n_2 = 0.012 (see table)

Wetted perimeter = 213 inches (measured in drawing)

R_{h2} = 3,312 / 213 = 15.5 inches

$(A_2 / n_2) * R_{h2}^{(2/3)} = (3,312 / 0.012) * 15.5^{(2/3)}$
= 1,720,000

1,720,000 ≥ 1,110,000 → OK

SCOUR AND STREAM PROTECTION

Existing and potential scour of existing streams should be addressed concurrently with culvert restoration and structural rehabilitation projects. When scour protection is warranted, the following techniques for scour mitigation should be considered:

- Class III or Class II riprap (lower classes of riprap have provided limited effectiveness in scour-prone areas)
- Precast concrete jacks
- Articulated blocks
- Grouted riprap (any class). Grouted riprap is generally discouraged, as it has a tendency to become undermined. If the district structure and bridge office considers grouted riprap to be the most viable available alternative, coordinate with district hydraulic and environmental personnel.
- Concrete riprap in bags
- Grout bags

Scour mitigation using any of the above methods must be placed over geotextile riprap bedding material.

Culvert rehabilitation presents the potential for increasing stream velocity. Changes to velocity and flow rates can create concerns for scour, stream bed erosion, and changes to flood plain elevations (both upstream and downstream of the culvert). In general, velocity increases associated with culvert rehabilitation do not tend to cause new scour problems but can exacerbate pre-existing issues. Separate evaluation of in-stream effects is not required for culverts rehabilitated in accordance with this section unless warranted by existing conditions such as development/dwellings within 200’ of the culvert or signs of significant scour.

HEADWALLS AND WINGWALLS

When funding is available, headwalls and wingwall should be repaired in conjunction with culvert restorative maintenance/rehabilitation. For culverts without headwalls, consider building new headwall(s) in conjunction with the other treatments, as headwalls tend to improve entrance head loss. Each headwall and wingwall repair is unique and requires evaluation particular to the site and performance, but the table below provides general recommendations and guidelines for headwall rehabilitation and repair:

Headwall and Wingwall Structural Rehabilitation and Repair		
Headwall or Wingwall Type	**Problem**	**Recommended Action**
Cantilevered Concrete	Spalling	Patch and inhibit source of water (coating, redirect, etc.)
	Rotation	Determine Cause. If wall stability is at risk, determine if it can be stabilized using external supports (deadman anchors, tie-backs, etc.), beams/struts, or if replacement is required.
	Sliding	
MSE Wall	Settlement	Evaluate extent of the distress. If wall stability is at risk, determine if it is possible to reduce the surcharge load at the top, or if it is possible to underpin the MSE mass. If drainage at the top of the wall has been compromised, place a ditch. If wall stability cannot be corrected, replace wall.
	Undermining	Evaluate extent of the distress. If wall stability is at risk, determine if the undermined area can be backfilled and protected with riprap. If drainage at the top of the wall has been compromised, place a ditch. If undermining cannot be stabilized, replace wall.
Laterally Supported Wall (Deadman, Soil Nails, Tie-Backs)	Rotation	Determine Cause. If wall stability is at risk, determine if it can be stabilized using external supports (deadman anchors, tie-backs, etc.), beams/struts, or if replacement is required.
	Sliding	
Steel Soldier Pile with Lagging (any Material)	Corrosion or Other Steel Damage	Evaluate need for strengthening/splice plates. Address cause of corrosion or damage
	Lagging Damage	Replace lagging if feasible, otherwise patch
Timber	Rot or Decay	Replace compromised element if feasible, otherwise provide metal splice (sleeves for piles, plates for lagging)

REQUIRED DRAWINGS AND SUBMITTALS

Drawings for culvert restorative maintenance and structural rehabilitation projects must be provided as indicated below:

1. Headwall and wingwall repairs (if applicable)
2. Permit drawings (when required by stream diversion)
3. Scour mitigation locations (plan view required)
4. Pipe rehabilitation drawings as indicated in the table below:

Drawings Required for Culvert Rehabilitation		
Rehabilitation Method	**Drawing Type***	**Required?**
Smooth Wall Steel Pipe Liner with Grouted Annulus	Supplier-provided shop drawings	Required
Spray-On Cementitious Liners (Centrifugal Spin-Cast Liners) or Shotcrete	Supplier-provided shop drawings	Required
High Density Polyethylene (HDPE) Pipe Liner with Grouted Annulus	Supplier-provided shop drawings	Required
Paved Invert with ECC (Engineered Cementitious Composite)	None – Follow Standard Detail & Specification	N/A
Patch and Repair Delaminated and Spalled and Cracked Concrete and Repair Joints	None – Delineate Locations of Patches on Culvert Walls with Spray Paint. Note Which Joints Require Repair. Specify Joint Repair Methods.	N/A

*Work for all five methods may be advertised with no plan assembly that includes specifications and pay items as long as the solicitation refers to cross-sections in VDOT's Manual of the Structure and Bridge Division, Part 2, Section 32.11.

Sealed engineer's design calculations and load ratings must be kept in project file at the district office.

SPECIFICATIONS:

Develop contracts to incorporate the following specifications:

Smooth Wall Steel Pipe Liner with Grouted Annulus:

- Special Provision for Large Metal Culvert Rehabilitation Using Smooth Wall Steel Liners

Spray-On Cementitious Liners (Centrifugal Spin-Cast or Shotcrete)

- Special Provision for Large Metal Culvert Rehabilitation using Spray-On Cementitious Liners

High Density Polyethylene (HDPE) Pipe Liner with Grouted Annulus

- Special Provision for Large Metal Culvert Rehabilitation Using High Density Polyethylene (HDPE) Liners

SPECIFICATIONS (Cont.'d):

Paved Invert with ECC (Engineered Cementitious Composite)

- Special Provision for Large Metal Culvert Invert Restorative Maintenance Using Engineered Cementitious Composite (ECC)

Patch and Repair Delaminated, Spalled and Cracked Concrete and Repair Joints

- *VDOT Road and Bridge Specifications*, Division 4 and Division 2

REFERENCES

NCHRP SYNTHESIS 303
Assessment and Rehabilitation of Existing Culverts
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_303.pdf

Decision Analysis Guide for Corrugated Metal Culvert Rehabilitation and Replacement
United States Department of Agriculture Forest Service
https://www.fs.fed.us/t-d/pubs/pdfpubs/pdf11771810/pdf11771810Pdpi72.pdf

Culvert Rehabilitation Practices
Utah DOT
https://www.udot.utah.gov/main/uconowner.gf?n=1128117589169310

Culvert Repair Best Practices, Specifications and Special Provisions – Best Practices Guidelines
Minnesota Department of Transportation
https://www.lrrb.org/pdf/201401.pdf

Culvert Rehabilitation Guidance
State of Maine Department of Transportation
https://www1.maine.gov/mdot/edi/docs/culvert_rehab_guide_final_4915.pdf

Bridge Maintenance Course Series - Chapter 14 Culverts
Florida DOT
http://www.fdot.gov/maintenance/STR/BI/Reference%20Manual/BMRM%20Chapter%2014.pdf

Bridge Maintenance Manual - CHAPTER 9 CULVERTS
Iowa DOT
https://siims.iowadot.gov/IowaDOT_BridgeMaintenanceManual.pdf

Culvert Repair Practices Manual, Volume I
FHWA
https://www.contractorexam.com/ref/FHWA-RD-95-089_Culvert_Repair_V1.pdf