MnDOT Service Life Design Guide for Bridges

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Section 1 Introduction

1.1 Background

This document addresses the service life design of bridges and retaining walls. Bridges designed in accordance with the *AASHTO LRFD Bridge Design Specifications* provide for an estimated 75-year design life. However, there are times where the most economical life cycle solution for a bridge is a longer design life. This guide provides recommendations and strategies for determining the recommended target service life and the design options to achieve it for MnDOT projects. The guidance in this document is based on the framework developed in NCHRP Project 12-108 and published in the *AASHTO Guide Specification for Service Life Design of Highway Bridges*. Bridges in Minnesota have many environmental demands, more than an average bridge, therefore some revisions from the national guidance are needed. This document serves to provide Minnesota-specific recommendations and is to be used instead of the AASHTO guide specification. The document is written with MnDOT owned facilities in mind; it can be used for local agency structures as well, and local owners are encouraged to use these principles on projects.

With the renewed focus on redundancy, robustness, and resilience that is under discussion within the bridge industry, service life design will play a larger role in the future. While initial design for strength and serviceability is important in ensuring a robust structure, bridge elements that do not suffer a capacity reduction due to deterioration will also increase the robustness of a structure. This may provide the benefit of reduced life cycle costs as well as fewer and more predictable traffic closures for future repairs.

1.2 Target Service Life Categories

There are three target service life categories which are described in the following sections. There are also renewable elements of a bridge that can and will need to be replaced during the service life of the bridge. Renewable elements include bearings, expansion joints, wearing courses, paint and surface coatings, and non-structural elements that can be easily repaired or replaced. These items do not affect the target service life category, but their replacement schedule should be considered along with the service life category. To minimize the life cycle cost, a sound asset management approach is needed for timely maintenance, preservation, and rehabilitation work.

1.2.1 Normal Service Life

Normal service life is the minimum design life for a new bridge. MnDOT policy is consistent with AASHTO bridge design specifications, which provides for a 75-year design life. For typical bridge types, the deck can be replaced. However, the expectation with normal service life design is that the deck will not need to be replaced for the full 75-year service life.

Elevated risk, such as exposure to water or chlorides, may require the use of enhanced or maximum service life materials or detailing practices to ensure normal service life is obtained.

1.2.2 Enhanced Service Life

Enhanced service life gives an extension to the normal service life, but it does not provide the maximum service life available. Service life designs that are extended beyond the normal service life often come at an initial cost premium, although they may ultimately provide the lowest life cycle cost. The goal of this category is to provide a deck that will exceed a 75-year service life or that will provide normal service life duration with lowered maintenance needs.

Elevated risks, such as exposure to water or chlorides, may require the use of enhanced service life materials or detailing practices to ensure a normal service life is reached.

The criteria for enhanced service life are described in Article 2.2.2.

1.2.3 Maximum Service Life

Maximum service life provides the longest life for a structure, but it also typically comes at the highest initial cost. Although a specific service life cannot be defined in the number of years, maximum service life design uses the best options available at the time of design to maximize the life of the elements. Despite the often-high initial costs, maximum service life designs may provide the lowest life cycle costs. It is anticipated that all non-renewable structural elements will exceed 100 years of service. A bridge specific set of design criteria should be considered for any bridge designed for maximum service life design to ensure all expected permit vehicle loading is enveloped.

Elevated risks, such as exposure to water or chlorides, may require the use of maximum service life materials or detailing practices to ensure a normal service life is reached. The criteria for maximum service life are described in Article 2.2.3.

Section 2 Service Life Identification

2.1 Philosophy

Determination of the target service life required is based on a variety of factors, including the potential to replace the deck of the bridge in the future, initial and life cycle cost, ramifications to the traveling public, and environmental conditions that cause more rapid deterioration such as high chloride exposure or frequent wet/dry cycles.

The target service life should be established during the scoping phase of the project. Because design for enhanced and maximum service life often require more costly technologies and materials to be used, it is important to ensure that enough funding is dedicated for a project. It is also important to understand long-term plans for the area surrounding the structure. It is not prudent to invest for a maximum service life if the structure will need to be replaced due to upgrades, such as for traffic capacity, alignment improvements, or additional pedestrian facilities before the service life is expended. Ideally, owners would design structures based on life cycle cost decisions, and replacements would only be driven by poor condition. However, due to constrained budgets and unknown future plans at the time of initial construction, balancing initial investment and life cycle costs are a necessity.

Service life applies to the whole structure; however typically only certain critical elements, such as the deck or piers, may need the higher-level materials or detailing to allow them to last as long as other elements on the bridge. For example, a bridge with pier columns in the roadway splash zone may warrant different rebar or increased cover on the columns to ensure that the pier lasts as long as the other elements of the bridge. This represents a significant change from the AASHTO Guide Specification for Service Life Design of Highway Bridges, but it is based on MnDOT experience with service life and deterioration rates of bridge elements.

Typical deck replacement costs are approximately 40% of a new bridge. Also, on some bridge types, including concrete box girders, it is not possible to replace the deck without costly temporary superstructure support. For bridges with large river crossings or over large inaccessible areas like high traffic corridors, concrete box girder temporary support is not a viable option.

Deck replacements on some structure types may be possible, such as curved steel girders, but it may be prohibitively expensive. Likewise, curved steel girder bridges may require full closure for deck replacement rather than staged construction due to the original design.

Deck replacement on very high-volume traffic routes can also be problematic. Bridges without enough width to stage traffic movements may require significant traffic volumes to be detoured or temporarily rerouted. When there is room, staging bridges can require detailing or construction issues, such as longitudinal joints, vibrations due to adjacent pours, or differential deflection, that leads to maintenance issues.

Structure components other than the deck that are exposed to elevated chloride levels may justify the use of materials or detailing practices of a higher service life design category to obtain the target service life. These include substructure or retaining wall elements located under joints, drainage systems that may leak in the future, and elements located within the splash zone of a roadway.

In addition to providing a longer service life, enhanced or maximum service life materials or detailing practices may be used to allow for a reduction in future operational resource needs, particularly in areas with poor access or where repair projects can only be scheduled reactively.

Unless noted otherwise, bridges should be designed for normal service life. Do not design new or replacement bridges for less than standards identified in the MnDOT *LRFD Bridge Design Manual* (BDM) for normal service life without the approval of the State Bridge Design Engineer. Follow the guidance in the BDM for temporary bridges.

For rehabilitation and preservation projects, see the *Bridge Preservation and Improvement Guidelines (BPIG)*.

Designing for a particular target service life is intended to ensure that the bridge can remain fully functional with an anticipated level of service interruption for preservation and maintenance activities. However, timely preventive maintenance, reactive maintenance, and preservation projects will all be necessary to achieve the desired design life.

2.2 Service Life Selection

2.2.1 Normal Service Life

All bridges are to be designed for normal service life unless there is a compelling reason for another approach. A target service life of 75 years is a sufficient, cost-effective selection for the majority of bridges. This includes bridges that are potential candidates for enhanced or maximum service life but are likely to be removed before 75 years due to expansion or other needs unrelated to bridge condition.

2.2.2 Enhanced Service Life

Use enhanced service life for:

- Decks of bridges which have superstructure types where staged deck replacement is problematic, such as curved bridges, steel girder bridges with deflection concerns, or where staging is not practical due to limited access and the option to close the bridge for construction is not preferred.
- Decks of any individual bridge with a bridge construction cost exceeding $20 million (2022 dollars).
- Decks of bridges with AADTs greater than 60,000

Consideration should be given to bridge elements that may be prone to deterioration where maintenance access may be challenging. Discuss with the Bridge Preservation Unit and State Bridge Design Engineer.

Areas below expansion joints are at increased risk of deterioration and may require enhanced service life techniques to achieve normal service life practice. See articles below that address particular bridge components.

2.2.3 Maximum Service Life

Use maximum service life for:

- Decks of bridges with superstructure types that prohibit deck replacement such as concrete box girders.
- Decks of any individual bridge with a bridge construction cost exceeding $35 million (2022 dollars).
- Decks of bridges where minimizing user delays is crucial, such as on border crossings or bridges with long detours.

Areas below expansion joints are at increased risk of deterioration and may require maximum service life techniques to achieve normal service life practice. See articles below that address particular bridge components.

2.2.4 Approval Process

For new bridges, the target service life category and the reasons identified in Articles 2.2.2 or 2.2.3 that enhanced or maximum service life is required should be noted on the preliminary bridge plan. For bridges with decks that require enhanced or maximum service life, the Preliminary Bridge Plans Engineer, District, and State

Bridge Design Engineer will collaborate and identify the deck and rebar requirements to be approved by the State Bridge Engineer on the preliminary plans.

Use normal service life for the majority of bridge repair projects. For rehabilitation and preservation of existing bridges, any enhanced or maximum service life requirements should be noted in the Bridge Repair Recommendations. The Regional Bridge Construction Engineer in collaboration with the District will determine if any elements require enhanced or maximum design service life. Any elements with enhanced or maximum design service life requirements on bridge repair projects need approval by the State Bridge Construction and Operations Engineer.

Any deviations from the guidance provided in this document need approval of the State Bridge Design Engineer.

Section 3 Materials

3.1 Concrete

Concrete deterioration is driven by many factors. These include chloride induced corrosion, freeze-thaw cycles, surface wear, and non-load induced or load induced cracking.

Concrete mix design plays a crucial role in minimizing cracking in concrete elements. Likewise, minimizing chloride intrusion through less permeable concrete contributes to longer service life of concrete components.

Standard MnDOT concrete mixes identified in the MnDOT *Bridge Design Manual* Table 5.1.1.1 provide normal service life for all bridge components except for decks. More details on deck mixes can be found in Section 4 of this document.

In addition to concrete mix design, the concrete cover, reinforcing types, coatings, and curing methods play a significant role in the service life of concrete. Those topics will be discussed later in this document.

3.2 Fiber Reinforcing

Micro and macro fiber reinforced concrete uses discrete fibers that are uniformly and randomly distributed to control cracking, primarily due to shrinkage. The fibers decrease the concrete's overall permeability due to early age cracking, which improves the overall service life. Fibers are a standard part of the HPC mixes identified in Section 5 of the BDM.

3.3 Reinforcing Bar

3.3.1. Black Reinforcing Bar

Standard carbon steel reinforcing bar, also called black rebar, has the lowest initial cost of the reinforcing bars used in MnDOT bridges. However, it is relatively quick to corrode when exposed to chlorides, water, and oxygen. Only use black bar in fully buried components or in limited applications where service life expectation is much less than normal. Example locations are buried footings or bars secured with epoxy adhesives in an existing structure with less than 25 years expected remaining service life. Use ASTM A615 Grade 60 reinforcing bars that satisfy MnDOT Spec 3301.

3.3.2 Epoxy Coated Reinforcing Bar

The vast majority of rebar used on MnDOT bridges is epoxy coated rebar, which meets the requirements for normal service life. The epoxy coating provides protection from chloride-based corrosion at an initial cost slightly higher than black rebar. Protecting the coating during installation and repairing minor damage to the coating is imperative for the coating to provide adequate protection to the steel. Damaged epoxy coating can lead to more rapid localized deterioration of the rebar than having black rebar. Epoxy coated reinforcing bar must meet ASTM A615 Grade 60 in accordance with MnDOT Spec 3301 with epoxy applied per ASTM A775.

3.3.3 Epoxy Coated 4% Chromium Reinforcing Bar

Steel rebar that meets the requirements of ASTM 1035 with 4% chromium and is epoxy coated can provide an enhanced service life with less initial cost than some other more corrosion resistant materials. A study done by the University of Kansas shows that the epoxy coated 4% chromium bars have a higher chloride threshold to initiate corrosion, take longer to start corroding, and have a slower corrosion rate than ASTM A615 epoxy coated bars. Although they have a higher initial cost than ASTM A615 epoxy coated bars, the design strength is higher than typical rebar, which allows for a potential reduction in overall steel weight compared to typical reinforcement.

3.3.4 Stainless Steel Reinforcing Bar

Stainless steel rebar provides the longest anticipated service life due to lowest corrosion potential. MnDOT allows the use of stainless steel that meets ASTM A955 with specific Unified Numbering System (UNS) designations as defined in the latest version of the special provisions for stainless steel reinforcement bars. These bars can be expected to meet the maximum service life category even in relatively high corrosion potential environments, but also have the highest initial cost compared to other rebar types. The design yield strength for stainless steel rebar is 75 ksi. This higher yield strength combined with a reduced concrete cover of 2 ½" to the top deck bars allows for potential reduction in overall steel weight compared to typical reinforcement. Care must be taken in development of details to prevent potential corrosion issues related to the use of dissimilar metals that would reduce the service life of the structure.

3.3.5 Glass Fiber Reinforced Polymer Reinforcing Bar

Glass Fiber Reinforced Polymer (GFRP) rebar is a non-metallic option for reinforcing concrete that can provide an enhanced service life. Because it is not steel based, it does not corrode like other reinforcement. It is also much lighter, making handling of rebar bundles much easier. Because of the low density, GFRP bars need to be tied down much more rigorously than steel bars to avoid becoming buoyant in wet concrete. GFRP bars are also much less ductile than steel bars. The design methodology is very different than steel rebar. Designs are almost entirely controlled by crack control provisions rather than strength design provisions. GFRP rebar cannot be bent in the field, nor can it be bent to all shapes that steel rebar can. Proper detailing in the plan is key to the success of a project that uses GFRP rebar. Unlike steel rebar which can remain undamaged when concrete is removed from around the bars, GFRP bars are much more sensitive to adjacent concrete removal and will require special techniques for repair. Like 4% chromium epoxy coated rebar, GFRP rebar can provide enhanced levels of service life compared to epoxy coated rebar at a lower cost than stainless steel rebar.

Most uses of GFRP rebar have not been in place long enough to document future rehabilitation costs. Should there be damage to the structure, either due to deterioration or impact, rehabilitation may not be possible using typical methods, because the GFRP rebar is susceptible to damage in ways that typical steel rebar is not. Decisions regarding the use of GFRP rebar should include consideration of the risk of future rehabilitation or widening challenges and costs.

3.3.6 Galvanized Reinforcing Bar

Although galvanized reinforcing bar is not the preferred material for MnDOT bridge decks based on cost and availability, it does appear to behave similarly to the more regularly used ASTM A615 epoxy coated reinforcement. Bridges that have galvanized reinforcing would be considered to meet the normal service life design as a replacement for epoxy coated rebar.

3.3.7 Other Types of Reinforcing Bar

Uncoated rebar that meets the requirements of ASTM 1035 with 4% chromium was considered as an alternative to typical epoxy coated rebar. However, given that the uncoated high-chromium bar does not perform substantially better than typical epoxy coated rebar and comes at a higher cost, it is not recommended for use as a replacement for epoxy coated rebar.

Dual coated steel reinforcing bars that meet ASTM A1055 also may not perform better than typical epoxy bars and come at a higher premium and are not recommended for use.

3.4 Structural Steel

Requirements for structural steel materials are found in the MnDOT *LRFD Bridge Design Manual*, Section 6.

All steel that meets MnDOT specifications is adequate for normal, enhanced, or maximum service life design. The MnDOT standard for structural steel used in beams and diaphragms is weathering steel, which provides longer service life than non-weathering steel due the patina that develops and prevents further deterioration.

Although galvanizing of steel beams or the use of stainless steel beams could theoretically extend the service life of beams, they are not practical alternatives. Galvanizing tanks are not typically capable of handling the pieces. Stainless steel is still prohibitively expensive for structural steel.

3.5 Coatings

3.5.1 Galvanizing

Hot-dip galvanizing is the process of coating fabricated steel by immersing it in a bath of molten zinc thus providing a bonded cathodic protection. Common elements that are galvanized include drains and drainage systems, metal railings, diaphragms for prestressed concrete beam superstructures, expansion devices, bolts and anchorages, sign supports, light poles, utility supports, and steel bearing assemblies. Depending on exposure, the galvanizing should last at least 40 years. Metalizing is occasionally offered as an alternative to galvanizing, but we do not yet have sufficient history to confirm the service life expectations compared to galvanizing. Unless galvanizing is impractical, metalizing should not be substituted where galvanizing is required.

3.5.2 Primary Element Steel Paint

For the past 40 years, all steel beam superstructure members have been designed with weathering steel per MnDOT Spec 3309. A thin, protective, oxidized layer called patina is formed on the surface of weathering steel that prevents further corrosion and pitting. MnDOT performed an internal research study in 2004 and again in 2013 that found weathering steel did not need painting except near deck joints. Painting beams and secondary members near joints prevents corrosion and pitting due to high chloride exposure.

For enhanced or maximum service life, consider the use of thermal spray-applied zinc (metalizing) on beams and secondary members near joints in lieu of paint. Contact the State Bridge Construction and Operations Engineer prior to inclusion on a project.

Painting does provide additional protection and extend the service life of beams for non-weathering steel. Periodic repainting is needed near leaking deck joints and is considered a renewable element needing attention throughout the bridge service life. Typically, fascia steel beams are painted due to aesthetic needs of project and not because of service life extension.

For guidance on repainting, see the BPIG.

3.5.3 Secondary Element Steel Paint

Secondary steel elements, including but not limited to metal railings, diaphragms for concrete beams, and expansion devices, are always galvanized. For aesthetic reasons, metal railings may also be painted with one of two approved systems after being galvanized. The first is a duplex wet paint process. This is more prone to field damage but can be repaired more easily in the field. The other approved process is powder coating, which is more durable against installation and transportation damage but harder to do field repairs when damage does occur. The Regional Bridge Construction Engineer specifies which paint system to use on a project. Based on a limited sample size, powder coated rail appears to have a longer service life. Paint systems on railings do deteriorate over time. For maintenance and long-term aesthetic reasons, bridge owners are encouraged to use unpainted galvanized metal railings wherever possible.

Painting over galvanizing marginally increases the service life of the component and should not be used to provide a higher level of service life for the bridge. Paint adhesion over galvanized members is challenging and should be limited to high aesthetic areas only.

3.5.4 Concrete Coatings

Exposed surfaces of concrete can also be coated for aesthetic and protective benefits. Special surface finish (SSF) coatings hide imperfect form surfaces, provide uniform appearance and a nominal amount of protection. SSF is a mixture of paint and mortar that is applied in multiple coats. SSF is used on barriers, fascia beams and deck copings over roadways, and on substructures near roadways to protect those surfaces from deterioration. Other locations where SSF is used, including the bottom of interior beams and copings over waterways are exclusively for aesthetics.

For concrete surfaces not requiring aesthetic treatments, a spray applied or rolled on waterproofing coating can be applied. For substructures or concrete beam ends under deck joints, this is an option for maximum service life level protection.

Section 4 Bridge Components

4.1 Decks

4.1.1 Cast-in-place Decks

Decks are the component that most often drives the service life of a bridge and has the highest risk for service disruption. Determining the right combination of materials for a deck can maximize the service life of a bridge.

There are three primary components that determine the design service life of a bridge deck: concrete type, rebar type and coating, and cover to the top rebar.

Typical MnDOT practice includes using high performance deck concrete (HPC), epoxy coated rebar, and 3 inches of cover to the top rebar. That combination of materials, along with a 7-day wet cure, is the standard for new and redecked bridges and can be classified as normal service life design.

To reach enhanced service life design, MnDOT recommends one of the following combinations:

- HPC deck mix design, epoxy coated ASTM 1035 with 4% chromium deck and barrier reinforcement, 3” cover to the top rebar, and 14-day wet cure
- HPC deck mix design, GFRP deck and barrier reinforcement, 2½” cover to the top rebar

For maximum service life design, MnDOT recommends the following combinations:

- For monolithic decks of structures other than concrete box-girders: HPC deck mix design, stainless steel deck and barrier reinforcement, 2.5” cover to the top rebar, and 14-day wet cure
- For two stage decks (structural slab plus wearing course) of structures other than concrete box-girders: HPC deck mix design, stainless steel deck and barrier reinforcement, 3” cover to the top rebar, and 14-day wet cure
- For concrete box girder structures: job mix formula with performance-based deck mix design, stainless steel deck and barrier reinforcement, 3½” cover to the top deck rebar (to facilitate milling for future wearing courses) with a ½” allowance for deck profiling, and 14-day wet cure

Other combinations may be permitted at each of the service life design categories with the approval of the State Bridge Design Engineer or the State Bridge Construction and Operations Engineer. For remote areas of the state where HPC concrete may not be an option, specify the low cement high performance concrete (LCHPC) mix that minimizes cracking.

Use the traditional deck design in the *AASHTO LRFD Bridge Design Specifications* for normal service life. It is unclear at this time whether decks designed using the empirical method will meet the normal service life design requirements. MnDOT does not use empirical deck design due to a history of excessive cracking.

For phased deck pours where the rebar in the deck is typical epoxy coated bars, use a more corrosion resistant bar type at the longitudinal joint.

Although they provide a significant extension of service life, deck replacements should typically follow normal service life design guidance.

4.1.2 Full Depth Deck Panels

Full depth deck panels may provide a longer service life than a traditional cast-in-place deck because of the better ability to control the casting and curing process, provided the joints are carefully detailed and constructed. However, due to the number of variables, service life design categories for full depth deck panels will be decided on a case-by-case basis by the State Bridge Design Engineer and State Bridge Construction and Operations Engineer.

4.2 Wearing Courses

Wearing courses provide protection to the structural deck from damage due to chlorides. Wearing courses can be placed with initial construction of a bridge, as is often the case for low slump concrete wearing courses. In addition to protection of the structural deck, wearing courses placed at initial construction can be used to improve profiles with complex geometry. Wearing courses can also be placed soon after initial construction, typically one to three years after the bridge is complete. Near-initial wearing courses are more typically epoxy or polyester polymer concrete. Placing these on the deck after the deck has been able to age enables more years from initial construction until a re-overlay is needed without sacrificing any life of the structural deck. Ultra-high-performance concrete (UHPC) wearing courses are still being studied. While they are likely able to provide maximum service life, the cost may be prohibitive. Discuss any potential use of UHPC wearing courses with the State Bridge Construction and Operations Engineer. For superstructure types with limited redeck options, a proactive wearing course program is essential for extending the bridge's service life.

4.2.1 Low Slump Concrete Wearing Courses

Due to advances in full-depth deck mix designs, curing requirements, and the use of fibers, the amount of deck cracking has been significantly reduced allowing for more full depth decks. See Article 2.4.1.1.2 in the BDM for more guidance on when wearing courses are appropriate.

MnDOT is currently studying a new concrete low slump wearing course mix with the goal to eliminate cracking and provide better performance. Deck wearing courses are a critical bridge preservation strategy for the best the cost-benefit ratio and following sound asset management principles.

4.2.2 Polymer Wearing Courses

Polymer wearing courses can be a valuable tool in providing a longer service life for a bridge deck. Polymer wearing courses consist of adhesives and aggregate to form an impermeable layer on over the structural slab. They can be applied during initial construction, at a set time in the life of the bridge prior to deterioration, or in response to deterioration.

The use of polymer wearing courses as part of initial construction, either epoxy or polyester based, should be discussed with District staff and the State Bridge Construction and Operations Engineer.

As part of new construction, traditional low slump, epoxy chip seal, and silica fume wearing courses provide an expected normal service life. The use of a polyester polymer concrete (PPC) wearing course applied during initial construction may extend service life compared to other wearing course options. It is recommended to apply a PPC wearing course for post-tensioned bridges or full-depth deck panel bridges during initial construction to help ensure the structure can reach its target service life.

4.3 Metal Railings

While metal railings are replaceable items, the work and cost to replace can be significant. All metal railings, regardless of service life category must be galvanized. The galvanization is what provides the cathodic protection to the metal and is the most cost-effective option. Painting with either duplex or powder coating is a way to provide aesthetic benefits to a metal railing. Painting without galvanizing is not sufficient to provide even a normal service life design for a railing. Galvanized railings are appropriate for all target service life categories, because metal railings are replaceable elements.

4.4 Beams and Girders

4.4.1 Prestressed Concrete Beams

Prestressed concrete beams can be used for all service life design categories with the standard MnDOT procedures: epoxy mild steel, uncoated strand, and beam end coating. Regardless of which service life design category is used, use the tension limit for prestressed concrete beams identified in the BDM.

4.4.2 Concrete Box Girders

Concrete box girders are a significant investment and are used primarily for major bridges. The box girders must be designed for maximum service life. All concrete box girder bridges must be designed for tension limits identified in the BDM.

When designing new box girders, use an electrically isolated tendon (EIT) system. EIT systems allow for construction verification and non-destructive evaluation and monitoring of the post-tensioning (PT) system in a box girder bridge over its entire life. Additionally, the PT system and ducts required for an EIT system are less susceptible to corrosion damage and mitigate the risk of stray current corrosion.

FHWA is developing a post-tensioned concrete reliability assessment tool. This tool will quantify aspects of post-tensioning systems including tendon type and profile, tendon joint type and closures, system and component materials, installation quality, and environmental demands. When the reliability assessment tool is available, MnDOT will determine a minimum score acceptable for maximum service life.

Do not use automated anti-icing systems on post-tensioned boxes. Leakage from the anti-icing system can cause deterioration to the galvanized post tensioning hardware.

4.4.3 Steel Girders

Like prestressed concrete beams, steel girders can be used on bridges in any service life design category. For all new steel superstructures, weathering steel is required.

Design for infinite fatigue life. Use the requirements of BDM Article 6.3.3 for deflection, and follow BDM Article 9.2.1 requirements for deck pour sequence to ensure adequate service life design.

See Article 3.5.2 of this document for guidance on coating steel girders.

4.5 Substructures

The superstructure is most likely to drive the service life of the bridge, but depending on exposure, substructures can play a significant role in premature deterioration of a structure. A deck service life design category of enhanced or maximum does not necessarily require the substructure to be designed to the same level. Piers with typical exposure as defined in Article 4.5.1, not under a joint, and without a drainage structure attached that are designed according to the requirements of the BDM are expected to meet all service life categories. Likewise, substructures that warrant enhanced or maximum service life do not necessitate that same level for the superstructure components. For example, a box girder bridge requires maximum service life design for the box girders, but the piers may not require that same level of protection and could meet normal or enhanced criteria.

4.5.1 Piers

4.5.1.1 Pier Columns

Pier columns or pier walls that are in bodies of water or are immediately adjacent to roadways and thus subjected to chlorides due to snow removal activities are at increased risk for deterioration. These are more critical than abutment front faces or retaining walls, where the bars closest to the chlorides are design bars, unlike with abutment or wall front faces. Single column piers are at increased risk due to lower redundancy than multicolumn piers or wall piers. A wall pier has an aspect ratio of 5:1 (length:width) or greater.

There are three exposure categories for piers based on proximity to the roadway or water: normal, moderate, extreme.

Typical – Piers are not in standing water and are 25 feet or more from the edge of the driving lane.

Moderate – Piers are in standing water or are between 15 and 25 feet of the driving lane or when the pier has a drainage system attached to a column.

Extreme – Bridges are within 15 feet of the edge of the driving lane.

The target service life for piers is based on the risk and severity of a service interruption as follows:

Normal – The route underneath has an AADT < 60,000.

Enhanced – The AADT for the route underneath is greater than or equal to 60,000.

Maximum – The pier is a single column pier.

The following table indicates which design paradigm to use based on the combination of target service life and exposure category.

		Service Life Categories		
		Normal	Enhanced	Maximum
Exposure categories	Typical	Design 1	Design 2	Design 2
	Moderate	Design 2	Design 3	Design 3
	Extreme	Design 3	Design 3	Design 4

Table 1 Design Requirements for Pier Column or Pier Wall Design

Use the following table for pier columns or pier walls.

	Design 1	**Design 2**	**Design 3**	**Design 4**
Column Concrete Cover [inches]	2	3	3	3
Column Rebar Type	Epoxy Coated	Epoxy Coated	Epoxy Coated 4% Chromium Reinforcing Bar	Stainless

Table 2 Pier Column or Pier Wall Service Life Category Requirements

For very tall piers, such as piers in water on major river crossings, consider using Design 1 in the columns to at least 10 feet above the water line.

Only the columns with drainage systems attached must be designed for the higher design. Other columns within the pier can be designed based on the pier's exposure conditions not including the drainage system.

4.5.1.2 Pile Bents

Pile bents, particularly where the piles are not encased in a pier wall, are another pier type that need additional attention to ensure that the intended service life can be reached. Currently, there is no configuration of pile bents that meets enhanced or maximum service life design. For guidance on when and how to address potential pile bent deterioration, see Section 10 of the BDM.

4.5.1.3 Pier Caps Under Deck Expansion Joints

For all pier types under deck expansion joints, additional attention is needed for the pier caps and beam seats to ensure that adequate service life can be achieved. Good detailing practices, including double stirrups, proper development of bars, use of hooked bars, and adequate cover, will help pier caps achieve their intended service life. Use epoxy coated 4% chromium reinforcing bar for shear stirrups, end ties, and top longitudinal bars. This will help reduce corrosion of the bars should the joint above the substructure fail. GFRP bars are not acceptable for pier cap shear ties or longitudinal bars. Use epoxy coated 4% chromium reinforcing bars or GFRP bars in pedestals. Stainless steel bars may be used in lieu of epoxy coated 4% chromium reinforcing bars or GFRP bars for projects where stainless bars are already being used in significant quantities. Use 3 inches of cover for normal service life on pier caps under expansion joints.

Similar guidance is warranted for localized areas where drainage systems attach to pier caps.

4.5.2 Abutments

Abutment beam seats and the front face of abutment back walls are prone to more rapid deterioration when located under expansion joints. To enable the abutment risk zones to reach the desired service life of the bridge, use GFRP or epoxy coated 4% chromium reinforcing bars for ties or longitudinal bars for parapet style abutment beam seats and pedestals. Use 3 inches of cover on front face of back wall, seat, and pedestal for normal service life when there is an expansion joint at the abutment. See Figure 1 for GFRP or epoxy coated chromium reinforcing bar locations. For all other abutment design methodology, see the BDM.

Integral abutments have a single line of piles and face many of the same risks as pile bent piers. See Section 10 of the BDM for guidance on when and how to address potential deterioration.

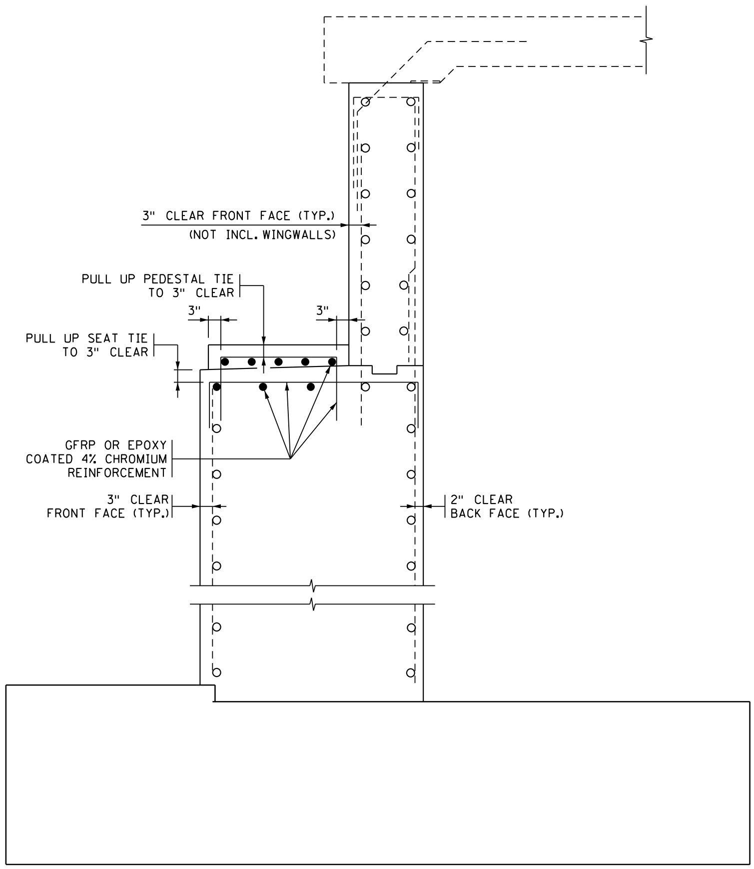

Figure 1 Abutment Seat Reinforcing

4.6 Deck Expansion Devices

With only a typical 20- to 35-year service life, failed deck expansion devices are the most common location for chloride intrusion into below-deck superstructure and substructure elements. Design bridges for jointless decks wherever possible.

Incorporate details in the original design which will allow for future replacement of expansion devices, as all joints are renewable components and will likely need to be replaced during the life of the bridge.

For all bridge deck rebar types, use ASTM A615 epoxy coated rebar for transverse bars within 2 feet of strip seal or modular expansion devices. Also use ASTM A615 epoxy coated rebar for longitudinal bars added under modular expansion devices as shown in Figure 2.

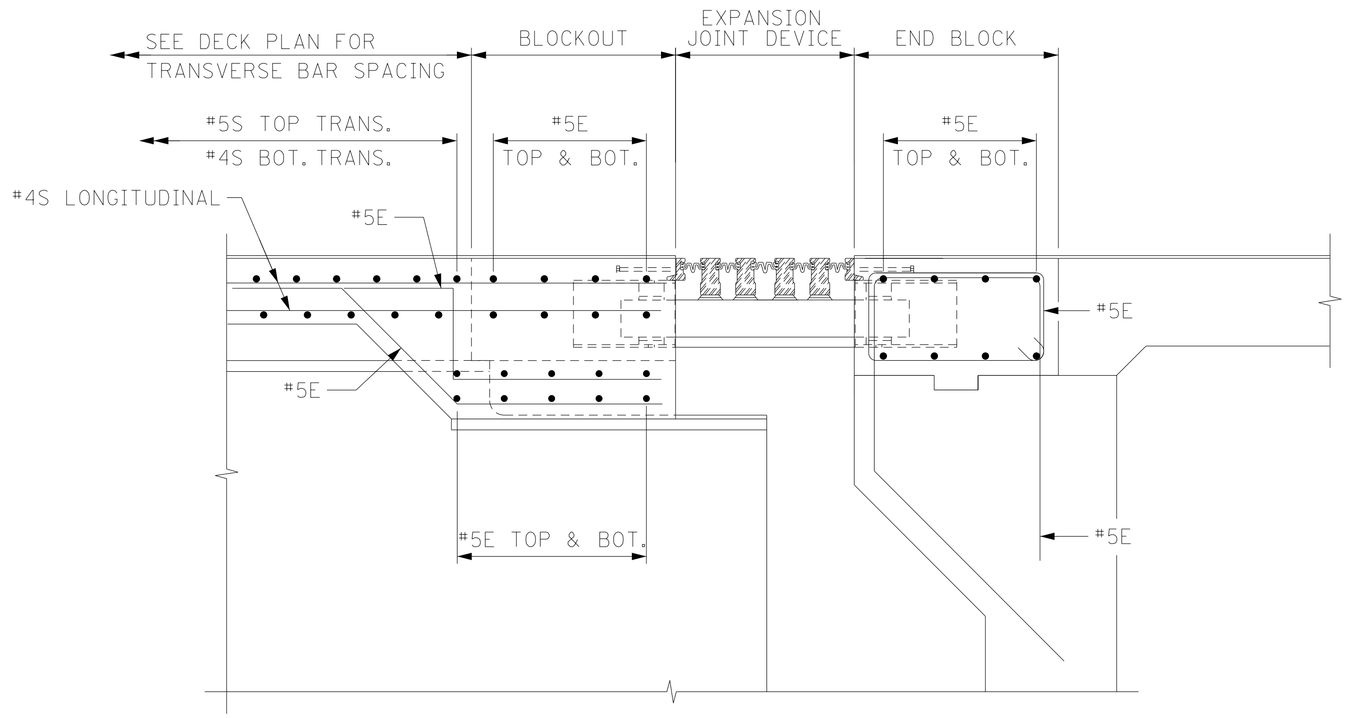

Figure 2 Modular Expansion Device Rebar Details

Do not provide stainless steel expansion devices even on maximum service life bridges. The life span of the expansion device is only 25 years, even with steel that is less likely to deteriorate, due to gland deterioration.

Movable parts of modular expansion devices are tested for fatigue, but there are still issues with long term performance. Like strip seals, modular expansion devices need to be replaced approximately every 20-25 years.

Finger joints may perform better than modular expansion devices. To reduce potential damage to the substructures, finger joints need to include a neoprene trough below the fingers with adequate slope to drain properly. These troughs also need to be replaced on a regular schedule, so they do not leak onto the substructure below. Finger joints may last longer than a modular device, but drainage issues can lead to deterioration of the substructure below. Work with District Bridge Maintenance and the State Bridge Construction and Operations Engineer prior to using finger joints on a project.

4.7 Bearings

Good detailing and routine maintenance may allow for bearings to last for the entire service life of the bridge. This includes the use of jointless bridges, maintaining joints where present, and selecting bearing types that provide better service life. Where possible, use elastomeric bearings with curved plate assemblies. If the loads do not allow for elastomeric bearings, use disc bearings. Do not use pot bearings due to a history of early failure.

4.8 Foundations

Foundations are not typically the first component to reach the end of its service life, but consideration of foundation details is still important to service life design. Footings that are exposed to cycles of water and/or chloride as well as air can experience premature deterioration.

In the rare case where ground cover over the footing is not at least 1'-0", use epoxy coated rebar instead of the typically required black rebar.

4.9 Retaining Walls

MnDOT standard cast-in-place (CIP) and mechanically stabilized earth (MSE) retaining walls are designed for a 75-year (normal) target service life. If there is reason to believe that an enhanced or maximum service life may be warranted, contact the Structural Wall Engineer in the Bridge Office.

4.10 Aesthetics

Use aesthetic details that match the desired service life of the bridge as much as possible. If an aesthetic detail cannot be expected to last the entire service life, ensure that repair or replacement is possible with minimal cost to the rest of the structure. Otherwise, do not use the aesthetic detail. Do not include aesthetic features on the bridge that prohibit or impede access for maintenance or inspection. Before adding aesthetic features, consider the ramifications to water flow across the bridge. Do not use elements that will direct water to bearings or substructure beam seats.

4.11 Other Structures

The philosophy identified here applies to all structural assets, even the ones not directly addressed in this document.

4.12 Slopes and Scour Protection

Scour calculations are done for the lesser of a 100-year flood event or the overtopping event, and riprap is designed for that situation. Bridge foundation and riprap stability is checked for the lesser of a 500-year flood event or the overtopping event. If there is a need to provide even greater protection, contact the Waterway Engineer.

Section 5 References

AASHTO. AASHTO LRFD-8 AASHTO LRFD Bridge Design Specifications; 9th Edition. 444 North Capital Street NW, Washington, DC 20001, USA; The American Association of State Highway and Transportation Officials, 2020.

AASHTO. AASHTO HBSLD-1 AASHTO Guide Specification for Service Life Design of Highway Bridges; 1st Edition. 444 North Capital Street NW, Washington, DC 20001, USA; The American Association of State Highway and Transportation Officials, 2020.

Farshadfar, O., O'Reilly, M., and Darwin, D., "Corrosion Performance of Plain and Epoxy-Coated MMFX Bars," SL Report 18-4, University of Kansas Center for Research, Inc., Lawrence, KS, October 2018, 114 pp.

MnDOT LRFD Bridge Design Manual. (2021, October 19). Retrieved from https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=2955578

MnDOT Bridge Preservation and Improvement Guidelines. (2015, July 6). Retrieved from http://www.dot.state.mn.us/bridge/pdf/bridge-preservation-and-improvement-guidelines-2016-2020.pdf.

Durability Assessment of a Bridge Substructure. (2015, August 20). Retrieved from https://www.fhwa.dot.gov/goshrp2/Content/Documents/Factsheets/R19A_DurabilityAssessmentReport.pdf.