Protection Systems for New Concrete Bridge Decks

Introduction

Bridge decks are the main structural component designed to carry vehicle traffic and transfer live loads to the girder system. While safely carrying vehicle loads, bridge decks are exposed to wear and tear from heavy trucks and extreme Alberta weather. They must withstand the application of anti-icing and de-icing materials necessary for safe winter driving, abrasive forces from wheel loads and snowplows, and varying climatic conditions. Bridge decks are susceptible to cracking under live loads, thermal stresses, and restrained shrinkage loads, which can significantly accelerate moisture penetration and the deterioration caused by anti-icing and de-icing materials. Measures must be taken to prevent or minimize the penetration of anti-icing and de-icing materials below the top surface of the concrete bridge deck, and to reduce the susceptibility of the reinforcing bars to corrosion and prevent subsequent concrete delamination.

Background

Over the past decades Alberta Transportation (AT) has refined its concrete deck protection system standards and maintenance policies to minimize the impact that winter roadway maintenance materials have on its bridge inventory. Since the mid 1980's, AT's standard protection system for bridge components exposed to de-icing materials has consisted of a hot rubberized membrane, protection board, and 80 mm two course asphaltic concrete pavement (ACP) system (Standard Drawing S-1443); several iterations of high performance concrete (HPC) mixes; and corrosion resistant reinforcing steel. The standard deck waterproofing system is intended to be an impermeable barrier between potentially damaging de-icing materials and the reinforced concrete deck, and to serve as an easily maintainable riding surface for vehicle traffic. The current HPC mix is designed to provide durable, low-permeability concrete with minimal cracking that will last the design life of the structure. The HPC specification calls for a 28 day compressive strength of 45 MPa and a mix design employing both fly ash and silica fume with a 14 day wet cure. Epoxy coated reinforcing steel was thought to provide improved corrosion resistance in aggressive environments, but research and field performance over the past several years has shown that epoxy coated reinforcing does not provide the improved corrosion resistance that was expected. Since 2008, AT has used alternative reinforcing materials, including a variety of corrosion resistant steels, and glass fibre reinforced polymer (GFRP) bars on a trial basis in decks, curbs and barriers. A revised standard for corrosion resistant steel reinforcing has been developed and is included in Appendix E of Version 6.2 of the AT Bridge Structures Design Criteria. The new standard shall be used on all new bridge projects moving forward. Additional background information on the standard AT bridge deck protection system can be found in the Appendix of this document.

Recommendation

The standard AT deck protection system shall consist of:

- hot rubberized membrane with protection board and ACP for bridge decks, roof slabs, and approach slabs (Standard Drawing S-1443),
- Class HPC concrete,
- corrosion resistant reinforcing (CRR)
- Spring cleaning and periodic application of penetrating sealers on exposed concrete elements such as curbs, barriers and concrete nosings of deck expansion joints.

The standard AT protection system shall be used on all Provincial Highway bridges, and on all local road bridges that are on paved roadways. Bridges on local roads that are expected to be paved in the future shall be designed with all the features that will allow for future membrane and ACP installation. When the roadway is expected to be paved in the future, consideration should be given to paving the new bridge and a short section of the approaching roadways on either end; however, it is possible for the bridge to remain unpaved for as long as it is not exposed to de-icing salt application. If left unpaved, a rub rail or transition curb is recommended to protect the exposed curb ends until the bridge is paved.

Standard SL bridges, and other bridges on unpaved low volume local roads that will not be exposed to anti-icing or de-icing materials, shall remain unpaved and shall not require membrane protection.

Designers shall consult Appendix E of Version 6.2 of the AT Bridge Structures Design Criteria for further information on designing with CRR. A supplemental construction specification for projects using CRR is available from AT's Professional Services Section upon request.

Contact

Questions or further information on this guideline may be directed to the Structural Engineering Specialist in the Bridge Engineering and Water Management Section of the Technical Standards Branch, Alberta Transportation.

Adopted:

Original Signed by, Des Williamson, P. Eng. — Mar. 13, 2012
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Appendix – Supplemental Background Information

Standard Deck Waterproofing System

The standard deck waterproofing system and 80 mm two lift asphaltic concrete pavement (ACP), as detailed on Drawing S-1443, is intended to be an impermeable barrier between potentially damaging de-icing materials and the reinforced concrete deck, and to serve as an easily maintainable riding surface for vehicle traffic. Without the rubberized asphaltic membrane between the ACP and the concrete bridge deck, the ACP will act as a sponge retaining potentially damaging anti-icing and de-icing materials against the concrete surface. When concentrated on the surface, salt-laden de-icing materials will migrate through the concrete and cause reinforcing steel to corrode. When the reinforcing steel corrodes it expands, causing delamination and cracking of the surrounding concrete. Magnesium chloride and calcium chloride based anti-icing and de-icing materials have been shown to attack the concrete directly, breaking down the cement paste and reducing the concrete's resistance to abrasion and cracking. Through many years of service, the standard hot-applied rubberized asphaltic membrane has proven itself to be user friendly and an effective barrier against de-icing materials. AT has tried other membrane types, including roll-on products, peel and stick membrane products, and hot-applied sheet products, none of which have been able to match the current AT standard in terms of constructability, durability, or performance. Ontario, British Columbia, Saskatchewan, and several other Canadian transportation agencies also use the hot rubberized membrane system.

High Performance Concrete Mix

Several high performance concrete (HPC) mix specifications have been tried since the mid 1980's to reduce the permeability and increase the durability of cast-in-place concrete decks. Initial specifications called for a portion of the portland cement to be replaced with silica fume (SF) to reduce the permeability and the potential for de-icing salts to migrate through the concrete to the level of the reinforcing steel. Although the strength of the SF concrete was increased to 35 MPa, and the permeability was reduced, the autogenous and drying shrinkage of these mixes was significantly higher, leading to extensive cracking in these decks. Further development increased the strength to 55 MPa with a further reduction in permeability, but the cracking problem persisted. The strength was then moderated to 45 MPa, flyash was added to reduce the heat of hydration, and a 14 day wet cure was implemented. This finally resulted in a high quality concrete with better crack control. This HPC mix design and placement procedure is incorporated in the current HPC concrete specification.

Corrosion Resistant Reinforcing

In situations where the membrane and/or HPC have not been totally successful in preventing de-icing materials from coming in contact with the reinforcing bars (defects in or aging of the membrane and/or HPC, or defects in exposed concrete components such as curbs and barriers), the corrosion resistance of the reinforcing bars themselves must be relied upon to prevent corrosion-related deterioration. Over the past several decades, epoxy coated reinforcing steel was thought to provide improved corrosion resistance in aggressive environments. Originally, in Alberta, only the top mat of reinforcing steel was required to be epoxy coated. The requirement was changed to include both top and bottom mats of reinforcing bars to prevent the development of potential macrocell corrosion between the two mats. Research and field performance in Alberta and throughout North America over the past several years indicates that epoxy coated reinforcing does not provide the improved corrosion resistance when exposed to de-icing materials that was originally expected. Some damage to the epoxy coating proved to be unavoidable, allowing moisture to reach the steel bars, leading to corrosion and concrete delamination. Alternative reinforcing materials, including various grades of corrosion resistant steel and a variety of fibre-reinforced polymers, have evolved significantly since the mid 1980's and can provide a substantial reduction in life cycle and user costs with minimal impact on construction costs. Since 2008, AT has used alternative reinforcing materials on a trial basis in decks, curbs and barriers. A revised standard for corrosion resistant reinforcing has been developed and is included in Appendix E of Version 6.2 of the AT Bridge Structures Design Criteria. As experience is gained and new corrosion resistant products become available and are proven, it is expected that the design criteria and construction specifications for CRR will be updated periodically.

Protection Systems for Standard Bridges

Although standard SLC bridges have been detailed for both paved and unpaved options, the unpaved option is allowed only on unpaved local roads that are not exposed to anti-icing or de-icing materials, and is expected to be rarely applicable. In almost all instances, standard SLC bridges shall receive the standard ACP and membrane system.

The standard SLW bridge was developed to provide an economical alternative to SLC bridges, for use on paved low volume Provincial Highways and local roads. The SLW bridge design is a modified version of the standard SL bridge design, which has a PL1 bridgerail with no curb. The SLW design incorporates a 75 mm high curb to control potentially damaging runoff and concrete shear keys to facilitate the application of the membrane and paving directly on top of the precast girders. The SLW design maintains the PL1 bridgerail used in the SL design so SLW bridges must meet the conditions for using a PL1 bridgerail presented in Section 12.4 of the Canadian Highway Bridge Design Code. SLW bridges cannot accommodate a PL2 bridgerail because the higher design collision forces transferred from the rail to the deck will fail the channel connectors between the girders.

Standard SL bridges are not intended for use on paved roadways and are not properly detailed to deal with the application of anti-icing and de-icing materials, even when a deck waterproofing system is used. The deck on the standard SL bridge is not detailed to accommodate the waterproofing membrane and the system will unravel along the longitudinal girder joints and fail pre-maturely. Standard SL bridges should only be used on unpaved low volume local roads that are not exposed to anti-icing or de-icing materials. Protection offered by the concrete cover is acceptable under these conditions. If it is determined that a new bridge on an unpaved roadway should be paved, and the paving results in subsequent salt application, the SLW standard bridge shall be used in conjunction with a short stretch of approach pavement on either end of the bridge. The SLW standard bridge can also be used with delayed membrane and paving, provided no salt is applied during those initial years.