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Public Services Procurement Canada – Alaska Highway

Concrete Repairs Action Plan:

Tetsa River Bridge No. 1 – km 584.6
MacDonald Creek Bridge – km 628.0
Racing River Bridge – km 641.1

Project No. BB3529

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Table of Contents

Introduction

This Action Plan is in regards to the concrete deterioration in the substructures of the Tetsa River Bridge No. 1 (km 584.6), MacDonald Creek Bridge (km 628.0) and Racing River Bridge (km 641.1) along the Alaska Highway. These three structures are of similar construction with concrete piers and abutments. The main span superstructures are trusses while the approach spans are simply supported girder spans. The objective of this Action Plan is to outline the repair method and performance specifications applicable to this concrete deterioration, to which qualified contractors are to bid on.

Existing Information/Project Inputs

Parsons has conducted regular bi-annual bridge inspections along the Alaska Highway since 2001 up to 2015, including these three specific structures. Our understanding of the concrete deterioration is based on the inspection reports from these inspections.

The Contractor who carries out the repair work is responsible for ensuring that adequate depth is achieved when removing spalled concrete, in order to reach a sound structure.

Review of Concrete Deterioration

The concrete is suffering from wide spread surface deterioration. The following are typical surface defects observed in the concrete substructures of all three structures:

- Spalls
- Spalls near bearings
- Concrete delamination
- Scaling
- Map cracking
- Cracks, with up to 1.0 mm width
- Cracks with efflorescence
- Previous concrete patches which are now failing
- Deterioration exposing rebar, leading to corrosion.

Some examples are shown in Photo 1 to 7 below from Parsons 2015 inspection. The following are repairs which are especially critical and/or may be more involved to carry out.

MacDonald Bridge Critical Repairs

- **Underside of south pier cap (Photo 1)**, Spalling ~50mm deep with exposed stirrups is occurring. Longitudinal rebar must be protected from corrosion otherwise this could compromise the capacity of the pier cap. The challenge will be to apply a patch from underneath, likely requiring form-and-pump methods. The Contractor will also need to ensure concrete removals do not disengage the tension rebar significantly from the sound concrete resulting in compromised capacity.
- **Spalls near bearings (Photo 2),** Large areas of severe scaling and spalls on the top of the south pier cap are not noted to be under the bearings yet. Contractor will need to protect against

further deterioration which will compromise support to the bearings. The north pier and abutment also have spalls and severe scaling near the bearings that must be addressed.

Tetsa Bridge Critical Repairs

- **Spalls, Scaling and Delaminations near bearings (Photo 3),** These are mostly repaired in 2011 but there are still some spalls and delamination noted near the bearings. This must be repaired to prevent further concrete deterioration to the point where support to the bearing is compromised.

Racing River

- **South Abutment Significantly Deteriorated Between Bearings (Photo 4),** This area displays the most significant concrete deterioration. This has lead us to ask if the concrete here is of poor quality or is there an environmental factor specific to this location which is accelerating deterioration compared to the rest of the structure. It may be due to the open deck above leaking salt and other contaminants to the abutment below.

Photo 1 – MacDonald Bridge, Underside of south pier cap, spall with exposed stirrups.

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Photo 2 – MacDonald Bridge, south pier cap, spalls near bearings.

Photo 3 – Tetsa Bridge, south abutment, spall near bearing 1.

Photo 4 – South abutment bearing seat of the Racing River structure. Severe scaling with exposed rebar

Photo 5 – Delaminated concrete patch repairs in the pier cap of the MacDonald bridge. exposed rebar.

Photo 6 – Wide vertical crack pier 2 of the Tetsa structure, with rust staining from corroded rebar within.

Photo 7 – North abutment of Tetsa structure with scaling in the backwall.

Previous Repairs

Latex modified patches were placed on the MacDonald structure in the winter of 2003/2004 and were first noted to be failing during Parsons 2011 inspection (Photo 1). This early failure is attributed to placement of the patches during winter where the proper environmental conditions were not maintained resulting in poor curing. Epoxy crack injections were also carried out at the same time on the MacDonald Bridge.

Proposed New Repairs

REPAIR OBJECTIVES

There are two primary objectives to any reinforced concrete repair:

1. To arrest deterioration of the structure by preventing further corrosion of reinforcing rebar.
2. To restore structural integrity.

Considering most of the observed defects are surface defects (typically not under bearings and not exposing structurally significant rebar), the goal of these repairs is to arrest deterioration to protect the capacity of the structural member from further deterioration. For defects where the depth of deteriorated concrete is below the top layer of rebar and/or there is rebar with over 10% section loss, then the repair also needs to restore structural capacity.

REPAIR TYPES

The basic repair types and criteria for undertaking this repair type are:

1. **Deep concrete patches** – Any spalls, delaminations or scaling that have a depth greater than 25 mm.
2. **Shallow concrete patches** – Any spalls, delaminations or scaling that has a depth between 25 and 10 mm

Surface defects less than 10 mm (i.e. scaling) are not necessary to repair currently, unless it is a large area where further deterioration is anticipated.

Concrete cover for these structures is generally in the 50-75 mm range based on the original design drawings.

Concrete Patches

Concrete patches will be the predominate repair throughout the structures. This will involve:

1. Removal of the existing deteriorated concrete to sound concrete,
2. Chasing of rebar corrosion,
3. Saw cutting around extents of removal,
4. Drill and epoxy dowels into the existing concrete (if removals do not go below existing rebar),
5. Install wire mesh attached to the dowels or existing rebar,
6. Splice in additional rebar for existing rebar with significant section loss,

7. Sand blasting the remaining concrete surface and exposed rebar to receive a patch,
8. For added durability, apply a coating to the existing rebar to protect against further corrosion,
9. Apply a bonding agent (mixed opinions on the effects of bonding agents' ability to enhance the bond),
10. Apply patch material.
11. Cure patch as appropriate for material used.

The dowels and mesh will help in securing the concrete patch to the new concrete and help control cracking from temperature and shrinkage. The dowels shall be made of FRP instead of rebar, as FRP dowels will not corrode and they will have minimal cover. For the same reason, the wire mesh shall be made of stainless steel or galvanized steel to prevent corrosion.

There is a distinction between shallow and deep concrete patches. In shallow concrete patches, especially where dowels and wire mesh cannot be used, there is more need for high bond strength between the substrate and patching material.

There are a wide range of materials that can be used for concrete patches. Most of these materials can be used as a *concrete* which has coarse aggregates or a *mortar* which does not have coarse aggregates. The quantity of coarse aggregate can have an effect on the behavior of the repair material such as shrinkage and cracking.

Concrete or Repair Mortar – Regular concrete mix and repair mortar will be the cheapest and easiest materials to source and produce on site. Attention needs to be placed on controlling plastic and drying shrinkage to avoid the development of cracks within the repair material, which lead to early repair failure. It is also preferable to include supplementary cementing materials which will reduce the permeability of the patch material and prevent further corrosion of the rebar.

Fiber reinforced concrete – Fiber reinforced concrete has the added benefit of fibers, typically carbon, added to the mix which aid in maintaining the integrity of the patch and minimizing cracking in the patch itself. The cost of the additional material is relatively inexpensive however there are challenges to dispersing the fibers in the mix and issues with workability.

Polymer-Modified Concrete – This is a concrete with a blend of Portland cement with polymer modifier added. Typical polymer modifiers include styrene butadiene, acrylic, vinyl acetate-ethylene or epoxy for example. Compared to conventional concrete, they have improved mechanical properties, improved bond strength and reduce permeability. It is more difficult to place and finish than conventional concrete and has short work times, approximately 15 to 30 minutes. It typically requires 1-2 days of moist curing followed by air-drying and is more sensitive to plastic shrinkage when not cured properly.

Latex modified concrete is an example of a polymer-modified concrete. It is typically used for deck overlays because of its low porosity and it is also well suited to application in thin layers. However, it typically requires to be wet cured for at least 24 hours. Recommended temperature placements are typically between 5-30^{o} C, making environmental control during winter placement a critical factor in the success of the repair.

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Polymer Concrete – Polymer concert replaces Portland cement with an organic polymer such as epoxy or polyester. It has low shrinkage as it cures, good bond strength to substrate concrete, high mechanical properties, low permeability and good resistance to chemical attack. It has quick setting time, but this is dependent on polymer type and agents used.

A downside to polymer concrete is that it has significantly higher coefficient of thermal expansion compared to regular concrete which can lead to compatibility issues in large temperature service ranges. The negative effects from differences in thermal expansion can be somewhat offset by a polymer concrete with significantly lower modulus of elasticity. This would only be applicable to non-structural repairs.

Another issue with polymer concrete is that typically contractors are not experienced in working with polymer concrete, therefore specialists are required which add additional costs. In general, polymer concrete as a repair material is relatively expensive and only used in very specific circumstances.

Project Approach to Concrete Patches

Instead of directing Contractors as to what product is required, Parsons approach to these concrete patch repairs is to use a performance-based specification which will allow the contractor to use their expertise and experience to choose the best material based on the specified performance.

This requires that the selected contractor be experienced and knowledgeable, and demonstrate this in their bids (by referencing previous projects and writing a methodology section).

The following are basic performance characteristics recommended for a typical concrete mix used for concrete repairs. These concrete properties are highly dependent on the test methods and the concrete age when the testing is conducted. Additional material properties may be needed depending on the repair procedures, size of repair patches, ambient conditions etc.

The concrete mix for the repair patches shall have properties of CSA A23.1 Exposure Class C-1 concrete, including the properties below. These properties shall be achieved by the concrete by the time the repair patches are exposed to structural and environmental loads, or sooner if the acceptance ages of Exposure Class C-1 governs.

- Compressive strength = _Min 35 MPa (CSA A23.2-9C)
- Chloride ion penetrability = Max 1,500 coulombs (ASTM C1202)
- Tensile bond strength = Min 1.0 MPa, or per structural requirements (CSA A23.2-6B)
- Thermal coefficient of expansion = To match substrate, 7 to 12 x 10^{-6}/°C (AASHTO T 336)
- Modulus of elasticity = To match substrate, 25 to 35 GPa (ASTM C469)
- Resistance to freeze thaw = Min 95% Durability Factor (ASTM C666)
- Drying Shrinkage = Max 0.04% (CSA A23.2-21C)
- Deicing Salt Scaling = Max Category 1 (CSA A23.2-22C)

For crack control in repair patches, it is also possible to specify acceptable crack criteria, such as maximum crack width, crack density, crack depth etc. when the cracks are measured at certain baseline conditions (repair age, temperature, moisture etc.).

If repair mortar is used instead of ready-mixed concrete, the above-noted material properties will also be applicable except the test methods for repair mortar would vary. The contractors should submit the test data and test methods of the proposed repair mortars for review prior to construction.

While Parsons feels like the above performance specifications are all attainable in a single product, we welcome discussion from industry experts who may choose to disagree with us, as long as it is backed up with research and data sheets.

Quantity and Cost Estimations

Based on our 2015 inspection reports and defect maps, the tables 1 to 3 give very approximate repair quantities. Actual repair quantities should be measured on site identifying specific areas to receive repairs.

Table 1 - MacDonald Bridge				
Defect Type	**Units**	**Estimated Quantity**	**% Assumed Needing Repair**	**Qty of Repair**
Delaminations	m^2	0.2	100%	0.2
Spalls	m^2	12.1	100%	12.1
Scaling	m^2	0.1	10%	0.0
Existing Patches	m^2	18.5	25%	4.6
Total Qty of Patch Repair (m^2)				**16.9**

Table 2 - Tetsa Bridge				
Defect Type	**Units**	**Estimated Quantity**	**% Assumed Needing Repair**	**Qty of Repair**
Delaminations	m^2	0.9	100%	0.9
Spalls	m^2	4.6	100%	4.6
Scaling	m^2	4.8	10%	0.5
Existing Patches	m^2	19.0	25%	4.8
Total Qty of Patch Repair (m^2)				**10.8**

Table 3 - Racing River Bridge*				
Defect Type	**Units**	**Estimated Quantity**	**% Assumed Needing Repair**	**Qty of Repair**
Delaminations	m^2	1.2	100%	1.2
Spalls	m^2	9.2	100%	9.2
Scaling	m^2	2.0	10%	0.2
Existing Patches	m^2	7.4	25%	1.9
			Total Qty of Patch Repair (m^2)	**12.5**

**estimated quantities for Racing River only considered the north abutment, south abutment and north pier. We do not have defect maps for the remaining substructure.*

Recommendation

Concrete patches, complete with drilled and epoxy FRP rebar + mesh are to be undertaken on concrete substructures of the Tetsa River Bridge No. 1 (km 584.6), MacDonald Creek Bridge (km 628.0) and Racing River Bridge (km 641.1) along the Alaska Highway. The goal of these repairs is to arrest further deterioration of the concrete and steel reinforcement.

Parsons has prepared the above performance-based specifications to undertake this work. There are a wide range of repair materials available on the market today, therefore by developing a performance-based specification, contractors qualified and experienced in the work can assess the damage and use the most appropriate materials based on their experience and expertise.

Quantities are estimated based on the latest available reports, and contractors are to price out their repairs in unit-price details, so as to easily allow for calculations of exact invoice amounts once the project has commenced.

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