SUBSTRUCTURE CONSIDERATIONS FOR SUCCESSFUL ACCELERATED BRIDGE REPLACEMENT PROJECTS

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ABSTRACT

Accelerated bridge replacement techniques have the capability of reducing traffic closures to mere hours compared to traditional bridge replacement projects which may require lane closures for many months or even years.

In order to realize the full benefit of accelerated bridge replacement, serious consideration must be given to the existing substructure - its structural capacity, existing condition and the options available to repair and/or extend its service life. Within the context of a superstructure replacement project, it is a reasonable objective that substructures are rehabilitated such as to achieve a service life which meets or exceeds the service life of the new bridge deck or superstructure.

INTRODUCTION

Accelerated bridge construction, and accelerated bridge replacement in particular, have been successfully utilized for at least 15 years and have been accepted as an advanced bridge repair technique. As the bridge stock continues to age, accelerated bridge replacement is increasingly being utilized.

The accelerated bridge replacement technique often hinges on the use of prefabricated superstructure components or using an entire superstructure that is built off site. These components can be placed one section at a time overnight, such as using individual precast deck panels, or the entire superstructure can be replaced over a weekend using self-propelled modular transport (SPMT) units or other heavy lifting techniques (1).

The benefits of accelerated bridge construction may include items such as:

- Reduced construction time
- Reduced environmental impact
- Reduced road closures

- Reduced lane restrictions
- Reduced impact on the travelling public
- Improved community relations
- Increased worker and the public safety
- Increased construction quality (2).

While the public may be focused on the high profile superstructure lift, bridge professionals understand that accelerated construction success is dependent on many other factors, one consideration being the reuse of existing abutments and piers. If the existing substructure can be reused as is, or rehabilitated concurrently with other construction operations, a substantial savings in schedule duration, project cost or both can be achieved.

One aspect of the decision to reuse existing abutments and piers are their current condition and estimated residual service life. Ideally, the substructure (as is or rehabilitated) should meet or exceed the service life of the new bridge deck or superstructure and not require any significant premature repairs, rehabilitation or in the worse scenario replacement.

SUBSTRUCTURE EVALUATION

A general review of the substructure normally verifies that the existing components are compatible with the replaced superstructure. This process will expose limitations in the approaches, foundations, load carrying capacity or substructure dimension if for example the new bridge is to be widened.

On major rehabilitation projects such as superstructure replacement, it is prudent that the existing substructure undergoes a condition assessment and environmental characterization to understand its current condition. A typical assessment may include actions such as visual inspection, confirmation of as-built reinforcement placement via ground penetrating radar, confirmation of concrete compressive strength, petrographic examination to detect concrete abnormalities such as improper aid voids or reactive aggregates, concrete cover over the reinforcing steel, chloride ion profile, carbonation depth, mapping of cracks, spalled concrete, and concrete delaminations, corrosion potential mapping, and corrosion rate.

This information will provide a thorough overview of the current condition of the structure. In addition, service life modeling may also be warranted. A service life analysis can be accomplished by gaining an understanding of the structure's natural environmental exposure conditions compared with the structure's innate resistance to corrosion and concrete degradation (3).

SUBSTRUCTURE REHABILITATION

In most cases, an aged substructure can be rehabilitated even if it has been exposed to corrosive conditions. Chloride contamination from deicing salts is common in northern climates. Substructures on marine bridges often suffer from corrosion due to chlorides as well. Historically, corrosion due to concrete carbonation is not a major concern although it should be tested during the investigative phase.

Substructure deterioration caused by deicing chemical exposure can often be isolated to specific weak points in the structure such as improperly maintained expansion joints, construction (cold) joints in concrete or concrete cracks whereby soluble chloride ions from deicing salt penetrates the weak point and contaminates the substructure. An example of this phenomenon is when pier caps under a failed expansion joint are corrosion-damaged and pier caps underneath maintained expansion joints or location where there is no joint at all are in good condition.

Chloride-contamination can be more general in nature if the substructure has plowed snow pushed upon it or splashing from passing traffic leaves salt on the entire concrete surface. General contamination can also occur in marine environments to some degree by exposure to the tidal zone and airborne salts.

Once the condition assessment is complete, and a determination that substructure rehabilitation is the preferred option in terms of schedule or cost, a repair and protection strategy can be developed. There are several corrosion mitigation technologies available that have been deemed cost effective when "applied to the appropriate bridges at the appropriate time" (4). Answering two fundamental questions can point the bridge engineer in the right direction when developing a substructure rehabilitation strategy.

A. Is the concrete damage localized or widespread?
B. What is the degree of risk for future corrosion?

If the answer to Question A is that the structure suffers from localized concrete damage, then a targeted concrete patch repair strategy should be considered. An excellent reference for completing concrete repairs on corrosion damaged structures is available from the International Concrete Repair Institute (ICRI) (5). If the answer is that the concrete damage is more widespread across the entire substructure, or within a specific structural element, then a global protection plan may be necessary. If the capacity of the structure has been compromised, structural strengthening may be required. This could be accomplished with large area concrete replacement with supplemental surface-applied FRP strengthening or by utilizing a reinforced concrete encasement where the section is built out with additional reinforcing steel. As indicated on Figure 1, as the as the percentage of surface area with concrete damage increases, the likelihood of using reinforced encasements or structural replacement increases.

The answer to Question B regarding corrosion risk lies within the information gathered during condition assessment. For this purpose, corrosion risk is defined as the percentage of area with concrete damage and high corrosion potentials as measured by a reference electrode. As the risk of future corrosion increases, it is more likely to move from a strategy of targeted protection to globally protecting large areas of the structure.

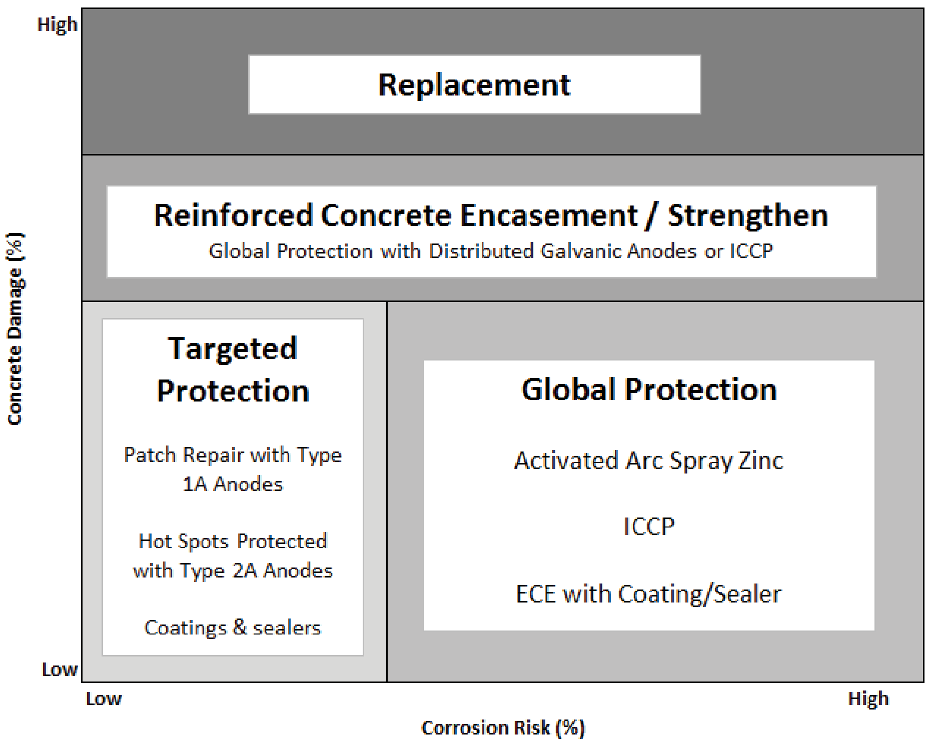

Figure 1: Matrix of Concrete Rehabilitation Strategies

CORROSION REPAIR STRATEGIES

The following information details potential concrete rehabilitation strategies that incorporate various corrosion mitigation technologies. An overview of cost effective electrochemical corrosion mitigation technologies can be found in the FHWA Bridge Preservation Guide (4) and the ICRI Guide for Electrochemical Techniques for Corrosion Mitigation (6).

Patch Repair with Targeted Protection

When corrosion damage is low and the risk of future corrosion is low, then a Patch Repair with Targeted Protection strategy can be considered. This approach would include concrete repair by ICRI Guidelines (5) with Type 1A Embedded Galvanic Anodes. Sound concrete areas with high corrosion potentials (hot spots) would be protected with Type 2A Embedded Galvanic Anodes (7). If the structure remains in a corrosive environment then it can be coated or sealed for more general protection.

Patch Repair with Global Protection

If corrosion damage is low but the risk of future corrosion is high, then a strategy of Patch Repairs with Global Protection should be considered.. Examples of global protection include electrochemical chloride extraction (ECE), activated arc spray zinc galvanic protection and impressed current cathodic protection.

Reinforced Concrete Encasement with Cathodic Protection

For structures with more substantial concrete and corrosion damage, a reinforced concrete encasement containing additional reinforcing steel provides a one-step repair, corrosion protection and strengthening option. This technique can be accomplished on abutments, columns or pier caps.

Figure 2: Pier Cap Repair Using Reinforced Concrete Encasement with Distributed Galvanic Anodes, George Wade Memorial Bridge Rehabilitation, 2011

To provide cathodic protection to both the existing corroded steel and the new reinforcing in the encasement, distributed galvanic anodes or impressed current cathodic protection are an important consideration.

Replacement

When structures are substantially damaged and deemed impractical or cost-prohibitive to repair, a full structural replacement is an appropriate option. Life cycle considerations should be taken into account in the design of the replacement substructure including concrete mix design, type of reinforcing, and cathodic prevention.

EXAMPLE PROJECTS

There are many examples of Accelerated Bridge Replacement projects that reuse existing substructures to speed the schedule or extend project budgets. We will provide two examples below:

I-480 Viaduct, Omaha, Nebraska, USA

In the summer of 2002, the Nebraska DOR undertook a large rehabilitation project on a 1.5 mile elevated section of Interstate 480 in downtown Omaha. Constructed in the early 1970's, the viaduct had experienced significant chloride induced corrosion and deterioration to the concrete deck and substructure.

The rehabilitation project included a complete replacement of the concrete deck but the long-term performance of the repair substructure was a concern. After the corrosion investigation was completed on the 66 hammerhead piers, it was determined that 23 were in a low concrete damage, high corrosion potential condition. The repair strategy for these piers was Patch Repair with Global Protection using Norcure electrochemical chloride extraction, a technique that removes chloride ions from concrete and restores the rebar to a passive condition.

Thirty-two of the piers were determined to have low concrete damage and low corrosion risk and as such utilized Patch Repair with Targeted protection using Type 1A embedded galvanic anodes to extend the life of the patch repairs.

Since the hammerhead piers were to remain in a corrosive environment, all 66 were protected from future chloride contamination with a chloride-resistant coating.

Figure 3: Bridge Deck Replacement

Figure 4: Removal of Damaged Concrete

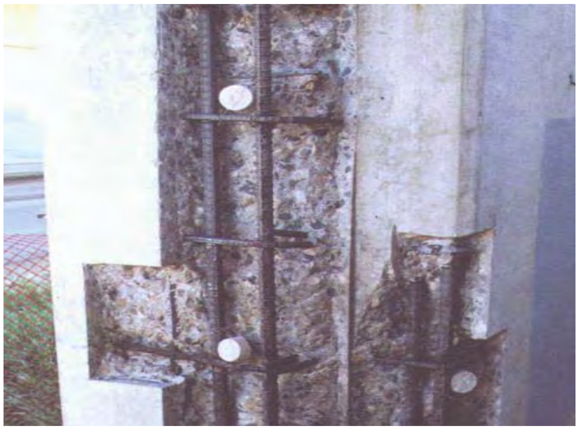

Figure 5 Patch Repair with Type 1A Anodes

Figure 6: Concrete Repairs

Figure 7: Temporary Anode Placement

Figure 8: Temporary Electrolyte Installation

Figure 9: Norcure ECE Treatment in Progress

Figure 10: Replacement of Drains and Coating Application

Figure 11: Completed I-480 Viaduct Rehabilitation

Highway 417 Island Park Bridge, Ottawa, Ontario, Canada

In August 2007, the Ontario Ministry of Transportation (MTO) completed a rapid lift replacement of the Island Park Bridge which carries Highway 417 in Ottawa. At 150,000 vehicles per day, the structure is on a heavily used artery in the national capitol.

The project design was to rapidly remove and replace the 48-year old eastbound and westbound superstructures while reusing the existing (rehabilitated) concrete abutments. The new prefabricated superstructures, consisting of steel girders and concrete decks, were built on a site adjacent to the Island Park Bridge.

While the new superstructures were under construction, the concrete abutments were rehabilitated. The abutments were substantially damaged with high risk of future corrosion. The engineers selected a Reinforced Concrete Encasement with Cathodic Protection strategy for the abutments. This was accomplished by re-facing the abutment walls with a structural overlay containing additional reinforcing steel. To protect the reinforcing steel in the existing chloride-contaminated concrete, Galvanode DAS distributed galvanic anodes were placed in the overbuilt section.

Both bridges were replaced in a 16 hour period from Saturday, August 11th at 8:00pm until the bridge was reopened Sunday August 12th at 12:00pm. SPMT units were used to rapidly remove and replace the superstructures.

The Island Park Bridge replacement was the first accelerated bridge replacement project completed in Canada. This successful accelerated bridge replacement project was estimated to have saved $2.4 million and 2 years compared to conventional techniques. Due to the benefits of tis accelerated bridge replacement project, MTO has used this approach on 4 additional bridge replacement projects.

Figure 12: Construction of New Prefabricated Superstructures

Figure 13: Condition of Existing Abutments

Figure 14: Re-facing of Existing Abutments

Figure 15: Distributed Galvanic Anodes and Additional Reinforcing Steel

Figure 16: SPMT Moving a New Prefabricated Superstructure

Figure 17 New Superstructure In-place

To see a complete detailed video of the Island Park Bridge Rehabilitation project, view the project video courtesy of McCormick Rankin Corporation https://www.youtube.com/watch?v=9JZ02f-SmAw (8)

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