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NRC Research on Field Performance of Rehabilitated Concrete Bridges

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INTRODUCTION

Many of North America's bridges are in urgent need of rehabilitation: nearly one of every three bridges is rated structurally deficient or functionally obsolete. According to a recent survey,[1] US$80 billion is the estimated cost of bringing those bridges to an acceptable level of repair.

Significant discrepancies between claimed laboratory performance and the actual field performance of repair and protection systems for concrete bridges are frequently observed. Field performance is one important criterion for the selection of repair and protection materials, but the lack of comprehensive data and suitable guidelines makes the selection process difficult.

To address this problem, the National Research Council Canada and partners from the private and public sectors have joined effort to investigate the long-term field performance of various repair and protection systems for concrete bridges. This paper presents a brief description of major projects.

THE VACHON BRIDGE (Laval, QC)

Field study of corrosion inhibitors

This is an on-going 5-year study[2] in which the field performance of corrosion inhibiting systems is being evaluated on a highway bridge owned by the Ministry of Transportation of Quebec (MTQ). Ten consecutive 34-metre long spans of barrier wall were demolished in the summer of 1996 and rebuilt with standard concrete to which various types of corrosion inhibiting systems were applied (a different system for each span). Test sections were instrumented with temperature/humidity sensors, reference electrodes and strain gages; the data collected is transmitted to NRC by data loggers using cellular phone technology. Corrosion surveys of the barrier wall are conducted annually.

Analytical study on early-age concrete cracking

Extensive transverse cracking in the newly reconstructed concrete barrier walls of the bridge was observed soon after construction. The study,[3] which combined measured field data and comprehensive computer simulations, has provided valuable insight into this problem. The main findings were as follows:

- Thermal stress was found to be the main factor in early-age cracking. Uneven distribution of heat through the wall appeared to have been brought about by the use of concrete with a high cement content and by the use of formwork with different thermal properties, and by the removal of the forms before full curing had taken place.
- Autogenous shrinkage due to non-uniform hydration of the cement (typical of high-strength concrete) was also shown to have contributed significantly to the cracking.
- Movement of traffic on the bridge during construction, which causes deck deflection and strain, may have contributed in a smaller way to the cracking of the walls at mid-span.
- High-strength concrete does not, by itself, assure durability of bridge barrier walls. The use of appropriate construction techniques is essential to improve concrete durability.

THE RENFREW BRIDGE (Renfrew, ON)

A 4-year partnership with the Ministry of Transportation of Ontario was formed in 1999 to study the deterioration mechanisms and to evaluate the long-term performance of different concrete patching systems under field conditions on a highway bridge (Figure 1).

Figure 1: View of the west half of the Renfrew bridge

This study[4] is being done by monitoring the repaired barrier walls of the bridge with non-destructive corrosion surveys and automated remote monitoring. Sensors were installed in the concrete patches and in the old concrete to measure relative humidity, temperature, electrochemical potential, electrical resistance, and strain. An automated data acquisition system complete with solar power and cellular modems for data transmission was installed on site (Figure 2).

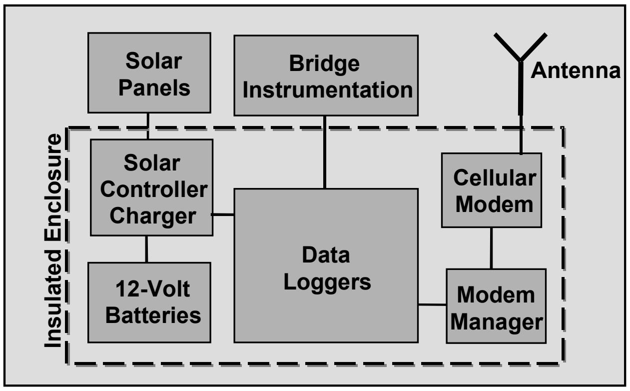

Figure 2: Data logging system at the Renfrew bridge

THE PERLEY BRIDGE (Hawkesbury, ON)

The key objective of this 1-year study completed in 2000 was to evaluate the adequacy of current corrosion measurement techniques for concrete bridge decks under various moisture conditions. Repaired slab sections of the old Perley bridge owned the Public Works and Governmental Services Canada (PWGSC) were cut and transported to NRC laboratories for testing. They were conditioned and surveyed in the lab to monitor corrosion activity over a period of time. After completion of the corrosion surveys, a visual corrosion inspection of the top reinforcement followed the removal of the concrete cover. The major findings of this study are:

- A statistical analysis of a large number of half-cell potential readings measured under similar conditions allowed the relative corrosion condition of the slabs to be predicted reasonably well.
- Significant fluctuations in the corrosion rate measured by linear polarisation was found to be a good indicator of active corrosion. Reliable predictions of the rebar corrosion condition were achieved by considering both the half-cell potentials and corrosion rates simultaneously in the analysis of the corrosion results.

FUTURE PROJECTS

The following field projects are presently under discussion with bridge owners and industry partners.

Early-age cracking in bridge barrier walls

A number of construction techniques to reduce or prevent early-age cracking will be selected to evaluate the field performance of reconstructed sections of bridge barrier wall. These techniques may include the use of fibre-reinforced concrete, precast concrete, curing and shrinkage-reducing admixtures, surface coatings and crack sealers, as well as special forms and reinforcement.

The study will be composed of 4 major components: (i) the field evaluation of the barrier wall sections including the short-term cracking performance and the long-term corrosion performance, (ii) a comprehensive numerical study to simulate conditions not tested in the field, (iii) structural testing to confirm theoretical assumptions, and (iv) materials testing to provide critical data to the computer model. The data and information developed under this project will be used to prepare guidelines for the prevention of early-age cracking in newly constructed bridge barrier walls.

Stainless steel reinforcement in bridge decks

This project will study the long-term corrosion performance of an innovative technique, in which regular carbon steel reinforcement is substituted with stainless steel reinforcement in sections of the bridge prone to chloride-induced corrosion (top layer, splash zones). If proven adequate, this approach will help extend the service life of reinforced concrete bridges for a small increase in the initial construction cost. However, there is a concern regarding the controversial issue of galvanic coupling of dissimilar alloys used as reinforcement in concrete and the possible formation of macro-cell current. Instrumentation will be embedded in concrete during construction to monitor corrosion activity.

SUMMARY

The strategy selected for the bridge rehabilitation projects presented in this paper is to evaluate the long-term performance of concrete repair and protection systems under field conditions, using external monitoring (non-destructive test methods) as well as internal monitoring (embedded instrumentation).

The use of field instrumentation and remote data loggers allows accurate and frequent monitoring of the long-term field performance of rehabilitated bridges. This innovative technology is extremely useful for remote bridges or for busy highway bridges on which the traffic can not be disrupted.

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