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Knoll, H.; Qian, S. Y.; Cusson, D.

Ottawa Construction News, 12, November 11, p. 8, 18, 2002-11-01

National Research Council Canada
Conseil national de recherches Canada

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Knoll, H.

IRC-VISI-358

A version of this document is published in / Une version de ce document se trouve dans :
The Ottawa Construction News, v. 12, no. 11, Nov. 2002, p. 8, 18

www.nrc.ca/irc/ircpubs

NRC Studies Corrosion Inhibitors for Reinforcing Steel in Concrete

By Henry Knoll

Submitted to *Ottawa Construction News*

Abstract

This article discusses a five-year research project recently completed by IRC in which a number of corrosion inhibitors were evaluated on the barrier wall of the Vachon bridge in Laval, Quebec.

Résumé

Cet article traite d'un projet de recherche que l'IRC a mené pendant cinq ans au cours duquel un certain nombre d'inhibiteurs de corrosion ont été évalués sur le parapet du pont Vachon à Laval au Québec.

Scientists at the National Research Council's Institute for Research in Construction (IRC) are analyzing the results of a five-year study of the effectiveness of corrosion inhibitors in reinforced concrete structures.

Corrosion of reinforcing steel in concrete is a serious problem, one that affects structures of all kinds, including bridges. Dr. Daniel Cusson, the project manager and one of the IRC researchers involved in the study, says that in Canada and the United States, the total cost of corrosion-induced damage to the concrete of bridges has been estimated at billions of dollars a year.

"Corrosion inhibitors have been considered one of the most cost-effective and user-friendly solutions to the wide-spread corrosion of steel reinforcement in concrete," says Dr. Shiyuan Qian, one of the lead investigators involved in the study. "They have increasingly been used as concrete admixtures for new structures and restorative applications for repairing existing reinforced concrete during the last 15 years."

Dr. Cusson and Dr. Qian are both researchers in IRC's Urban Infrastructure Rehabilitation program. The program addresses a wide range of infrastructure issues, concrete structures, roads and buried utilities. Much of the research effort in concrete concerns bridges.

The Vachon bridge in Laval, Quebec.

Before calcium nitrite became commercially available in the 1970s, some chemicals used as corrosion inhibitors not only performed poorly but often produced detrimental effects on the strength development of concrete. Corrosion inhibitors may be inorganic compounds, such as calcium nitrite, or organic compounds, or both. For example, during the 1990s, organic inhibitors composed of amines and their salts were developed.

When added in required concentrations to concrete, a corrosion inhibitor brings about changes at the metal-concrete interface. Some inorganic compounds are thought to act as anodic inhibitors, that is, they increase the rate at which an oxide film barrier is formed on the surface of the reinforcing steel. Some organic compounds, in turn, may inhibit corrosion by attaching themselves to the steel surface where they become a protective coating that then prevents the breakdown of a passive film already formed there.

Commercially available corrosion inhibitors include rebar coatings, concrete admixtures and coatings for application to concrete surfaces. Very little information is at hand, however, for engineers and bridge owners about the effectiveness of these systems in field applications, especially about their long-term performance.

NRC technical officer measures the corrosion rate of the reinforcement in the barrier wall of the Vachon bridge.

“We still have some basic questions to answer,” says Dr. Qian. “Which inhibitors promise to be most effective in the long term for new concrete structures, for example? And which are compatible with the repair materials and original concrete in restorative applications?”

Because of the lack of solid information on the performance of corrosion inhibitors and the sometimes serious problems that can occur because of misuse, scientists at IRC launched a research project to find some answers. The Ministry of Transportation of Quebec (MTQ) and manufacturers of corrosion-inhibiting systems collaborated with them. The purpose of the research project was to assess the effectiveness and field performance of several commercially available corrosion-inhibiting systems. The researchers therefore tested corrosion-inhibiting systems normally used in the construction of reinforced-concrete structures that are subjected to de-icing salt and our typically severe climatic conditions. They also conducted laboratory studies on samples of the corrosion-inhibiting admixtures and coatings to corroborate the field data.

The test site for the project was a concrete barrier wall at the Vachon Bridge, a six-lane, 21-span highway bridge in Laval, Quebec, owned by MTQ. During the summer of 1996, ten 35-m long spans of the bridge barrier wall were reconstructed by using standard, medium-strength concrete that contained corrosion-inhibiting systems, including one, two or three of the following products: concrete admixtures, reinforcement coatings and concrete coatings/sealers. One control span was similarly constructed with the same standard concrete and carbon-steel reinforcement – but without any corrosion inhibitor.

The concrete barrier wall was instrumented with over a hundred sensors embedded in concrete for the measurement of various parameters for the duration of the project. There was corrosion monitoring, continuous remote data acquisition and periodic visual crack surveys conducted on the ten spans of the barrier wall. A laboratory program included material tests on cores taken from the bridge at different occasions.

On-site measurements on the special rebar ladders embedded in the spans indicated that relatively high corrosion activity had occurred where the concrete cover over the rebars was thin. However, where the concrete cover was of regular thickness – on the main spans, in particular – on-site corrosion measurements showed that the overall corrosion rates were low.

Analysis of the performance results obtained from the annual field corrosion surveys indicates that the system with an inorganic-based corrosion-inhibiting admixture offered the best field performance over five years of testing. Certain laboratory tests of inhibitors showed one of the organic-based and one of the inorganic-based concrete admixtures to be very effective for increasing the chloride threshold and reducing the corrosion rate. Overall, the inorganic-based concrete admixtures inhibited corrosion of the reinforcing steel better.

Dr. Cusson cautions that these results are all based on measurements taken during a relatively short time. The performance of the various corrosion-inhibiting systems will

certainly change after a period longer than five or six years. The researchers are planning to continue the project for another five years.

NRC's Institute for Research in Construction conducts research in three other pivotal areas: the Building Envelope and Structure, the Indoor Environment, and Fire Risk Management. Most of the laboratory work is carried out at the NRC campus on Montreal Road.

Henry Knoll is a freelance writer and editor in Ottawa.