BACKGROUND

The deterioration of existing concrete highway bridges is proceeding at an alarming rate. Life-cycle cost analyses of viable alternatives are necessary in order to develop rational strategies for the repair, rehabilitation, and replacement of concrete bridge components. This, in turn, necessitates the acquisition of reliable information on the level and rate of deterioration of the concrete bridges.

Under SHRP contract C-101, a procedure for the acquisition of critical data for assessing the condition of concrete bridge components was developed. The procedure (SHRP product 2032) incorporates thirteen existing tests or procedures and seven new test methods. The thirteen present methods include ten ASTM standard test methods, one American Concrete Institute (ACI) standard practice, a recently published test method for alkali-silica reactivity from SHRP, and the widely used method for measuring reinforcement cover using magnetic flux devices. The investigation that led to the choice of the existing methods is covered in Volume 1 (SHRP-S-323) of the report series titled Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion. The development of the seven new test methods is covered in Volumes 2 through 7 (SHRP-S-324 through SHRP-S-329). The eighth volume, Procedure Manual (SHRP-S-330) provides details of the procedure and includes descriptions of the new test methods, in ASTM format, in its appendices. Excerpts from the procedure manual are reproduced in this technical brief.

SELECTED PRACTICES AND METHODS

Based on a review of the technical literature and telephone interviews with maintenance and materials engineers in 47 states and 9 provinces, the best of existing testing procedures for evaluating conditions and causes related to concrete bridge component deterioration were identified. In addition, an ACI committee report procedure was added to fill a void relative to cracking. Also, a test procedure for alkali-silica reactivity, which was only recently developed and published by SHRP, was included. The resulting 13 methods are summarized in Table 1.

Seven new test procedures were developed under SHRP contract C-101 to cover perceived weak areas regarding equipment or methodology for the acquisition of data on concrete bridge component deterioration condition or rate. Table 2 summarizes the new methods and indicates the source SHRP report number. AASHTO standard status, as of June 1995, is also indicated in the table. A full standard number (T-), provisional standard number (TP), or a date

The Strategic Highway Research Program (SHRP) was established by the United States Congress in 1987 as a five-year, $150 million research program to improve the performance and durability of highways and to make them safer for motorists and highway workers. As a follow-on program to SHRP, Congress established in the Intermodal Surface Transportation Efficiency Act of 1991 programs to implement SHRP products and to continue SHRP's long-term pavement performance (LTPP) program. The Canadian Strategic Highway Research Program (C-SHRP) is directed at extracting the benefit of the US work for Canada.
Table 1 – Existing Practices Adopted for Bridge Condition Assessment Procedure

<table>
<thead>
<tr>
<th>Subject</th>
<th>Standard Practice Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Reinforcement cover depth using covermeters (magnetic flux devices)</td>
<td>none</td>
</tr>
<tr>
<td>2  Concrete strength from test cylinders</td>
<td>ASTM C39</td>
</tr>
<tr>
<td>3  Concrete strength from drilled cores</td>
<td>ASTM C42</td>
</tr>
<tr>
<td>4  Concrete strength from pullout tests</td>
<td>ASTM C900</td>
</tr>
<tr>
<td>5  Concrete strength/quality indication from rebound hammer tests</td>
<td>ASTM C805</td>
</tr>
<tr>
<td>6  Concrete strength/quality indication from penetration tests</td>
<td>ASTM C803</td>
</tr>
<tr>
<td>7  Characteristics of the air-void system in hardened concrete</td>
<td>ASTM C457</td>
</tr>
<tr>
<td>8  Microscopic evaluation of the quality of hardened concrete (petrographic exam)</td>
<td>ASTM C856</td>
</tr>
<tr>
<td>9  Identification of alkali-silica reactivity</td>
<td>Proposed ASTM Standard (SHRP C/FR-91-101)</td>
</tr>
<tr>
<td>10 Delamination detection by sounding</td>
<td>ASTM D4580</td>
</tr>
<tr>
<td>11 Damage assessment by pulse velocity</td>
<td>ASTM C597</td>
</tr>
<tr>
<td>12 Assessment of cracking</td>
<td>ACI 224.1R</td>
</tr>
<tr>
<td>13 Assessment of the probability of the existence of active reinforcement corrosion (half cell method)</td>
<td>ASTM C876</td>
</tr>
</tbody>
</table>

of balloting for provisional standard qualification is provided as appropriate.

PROCEDURE

The twenty methods listed in Tables 1 and 2 constitute the tools used in the procedure for the assessment of concrete bridge components. The procedure, laid out in the flow diagram in Figure 1, consists of three major parts, and these are 1) an initial (baseline) evaluation survey, 2) subsequent evaluation surveys, and 3) evaluation surveys for special conditions. The initial evaluation survey consists of acquiring initial property data (including, for example, compressive strength, permeability, air-void characteristics), which will provide a relative measure of initial overall quality. Most of this information is routinely collected at the time of construction, or shortly thereafter. Subsequent evaluation surveys are carried out periodically to monitor the condition of the concrete bridge components. It is the data from these surveys, primarily, that define the condition and the rate of deterioration at any point in time. Evaluation surveys for special conditions include asphalt covered decks, pretensioned and post-tensioned prestressed concrete members and rigid deck overlays.

INITIAL (BASELINE) EVALUATION SURVEY

Data on certain parameters that should not change with time need to be obtained only once, and

Table 2 – New Methods in Bridge Condition Assessment Procedure

<table>
<thead>
<tr>
<th>Subject</th>
<th>Development Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Determining instantaneous corrosion rate of uncoated steel in reinforced concrete</td>
<td>SHRP-S-324</td>
</tr>
<tr>
<td>2  Assessing the condition of asphalt-covered bridge decks using pulsed radar</td>
<td>SHRP-S-325</td>
</tr>
<tr>
<td>3  Determining the condition of preformed membranes on concrete bridge decks using pulse velocity</td>
<td>SHRP-S-326</td>
</tr>
<tr>
<td>4  Determining the relative effectiveness of penetrating concrete sealers by electrical resistance method</td>
<td>SHRP-S-327</td>
</tr>
<tr>
<td>5  Evaluating penetrating concrete sealers by water absorption</td>
<td>SHRP-S-327</td>
</tr>
<tr>
<td>6  Chloride content in concrete using the specific ion probe</td>
<td>SHRP-S-328</td>
</tr>
<tr>
<td>7  Indication of relative concrete permeability by surface air flow</td>
<td>SHRP-S-329</td>
</tr>
</tbody>
</table>

TP 36-93
TP 37-93
TP 38-93
TP 35-93
TP 35-93
Figure 1 - Flow diagram of the procedure for assessing the condition of concrete bridge components.
these appear on the flow diagram under "Initial (Baseline) Evaluation Survey." Ideally, the tests for these parameters should be carried out as part of the acceptance testing of new concrete bridge components. While these characteristics will not change with time, their significance relative to the condition of the concrete does, and therefore the testing needs will vary depending on when they are carried out. If particular faults would normally be evident by the time a test for those faults is conducted, then that test is not normally conducted. For example, air-void analyses would not be carried out on a structure over five years old because if the air-void system is not adequate to prevent freezing and thawing damage, it would already be evident in the condition of the structure.

**SUBSEQUENT EVALUATIONS**

Information on deterioration rates, as well as updates on condition, must be obtained by periodic subsequent evaluations. These are essential for the development and execution of rational bridge management policy. The initial step in the subsequent evaluations is a visual inspection for obvious signs of deterioration. Four types of deterioration may be observed, and these are 1) spalling of the layer of concrete between the surface and the reinforcing bars, 2) scaling and/or popouts, 3) concrete disintegration, and 4) cracking.

If there is no visible deterioration or only spills, a delamination survey should be carried out. Other testing for the ingress of chloride ions and resulting reinforcement corrosion should be carried out in concert with delamination testing. First, a corrosion potential survey should be conducted in accordance with standard test methods and chloride content should be tested as per the new recommended method. If used, the effectiveness of penetrating sealers should be evaluated. Corrosion rates should also be determined. Note that corrosion potential and corrosion rate tests should not be carried out where galvanized or epoxy-coated reinforcement is used.

If deterioration other than, or in addition to, spalling are observed then the emphasis on reinforcement corrosion is dropped. The rationale is that other types of deterioration are seated within the concrete mass, are progressive, and are probably not amenable to corrective action.

Scaling and/or popouts indicate freeze-thaw damage. In such instances, air-void analyses and petrographic examinations should be carried out according to ASTM methods.

General concrete disintegration covers a host of concrete materials-related problems. There are several tests which should be conducted to identify the problem and its extent. Air-void analyses and petrographic examinations should be conducted. In the possible presence of susceptible aggregates, alkali-silica reactivity testing should be undertaken as established by the SHRP procedure. Pulse velocity measurements may be used to assess the extent of the damage. Relative strength indications may be obtained with the rebound hammer or by penetration tests. A quantitative measure of strength can be achieved through compressive strength tests conducted on drilled core specimens.

The evaluation of cracking deterioration is beyond the scope of the SHRP procedure manual. Concerned practitioners are referred to the ACI manual, * Causes, Evaluation, and Repair of Cracks in Concrete Structures* (ACI 224.1R).

**MEMBERS CONTAINING EPSOY-COATED REINFORCEMENT**

The development of epoxy-coated reinforcing steel at first suggested that corrosion of steel in concrete due to chloride penetration should no longer be a problem. However, this is not the case in all applications. There is extensive evidence that corrosion sometimes occurs. The epoxy coating in these instances appears to disbond from the steel at imperfections.

Routine inspection of structures containing epoxy-coated steel should be conducted. The procedure should involve a visual inspection to locate any cracking, and it should also involve sounding of the concrete to locate any delaminations. These are the only two actions that are recommended because any other tests performed might not provide information that is useful or conclusive.

Chloride ion profile tests are not recommended because the locations of the imperfections cannot be predicted. Potential surveys and corrosion rate measurements
require connection to the reinforcement and electrical continuity among all reinforcement in the concrete. Since the epoxy coating acts as an electrical insulator, electrical continuity is prevented. In order to use potential surveys and corrosion rate devices, connections would have to be made to every reinforcing bar. This would be prohibitively expensive and would provide numerous sites for the initiation of corrosion.

EVALUATION SURVEYS FOR SPECIAL CONDITIONS

Special evaluation surveys are needed for asphalt-covered decks, pretensioned and post-tensioned concrete members, and rigid deck overlays. Where the asphalt overlay provides a traffic surface for a membrane deck protective system, the primary concern is the condition of the membrane. Membrane integrity should be evaluated and if the condition of the membrane is suspect, the condition of the deck should be evaluated using ground-penetrating, pulsed radar. Installations with asphalt overlays on bare decks should also be monitored using ground-penetrating radar.

Condition assessment of prestressed members is a critical issue. There are still no suitable, effective, non-invasive techniques to do this. For the present, the only alternative is to continue the current practice of visual inspection for rust stains and cracks. At these signs of distress, damage assessment should be carried out using pulse velocity techniques.

The condition assessment of bonded, rigid deck overlays should consist of a visual examination for cracking, spalling, wear, and testing for delamination/ debonding.

For full details of the procedure manual see:

SHRP-S-326
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 4: Deck Membrane Effectiveness and a Method for Evaluating Membrane Integrity

SHRP-S-327
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 5: Methods for Evaluating the Effectiveness of penetranting Sealers

SHRP-S-328
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 6: Method for Field Determination of Total Chloride Content

SHRP-S-329
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 7: Method for Field Measurement of Concrete Permeability

SHRP-S-330
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 8: Procedure Manual


For full details of the research into existing and new test methods see the following reports:

SHRP-S-323
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 1: State of the Art of Existing Methods

SHRP-S-324
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 2: Method for Measuring the Corrosion Rate of Reinforcing Steel

SHRP-S-325
Condition Evaluation of Concrete Bridges Relative to Reinforcement Corrosion, Volume 3: Method for Evaluating the Condition of Asphalt-Covered Decks
SHRP reports are available for sale at reasonable prices ($5 to $35 USD):

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