Evaluation and improvement of bridge foundations

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Evaluation et amélioration des fondations de ponts

Beurteilung und Verbesserung von Brückenfundamenten

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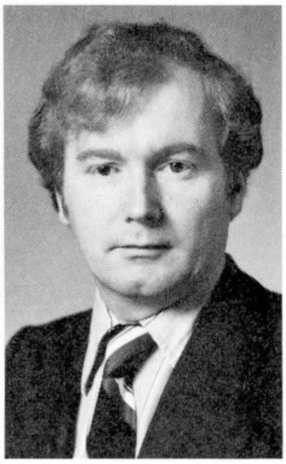

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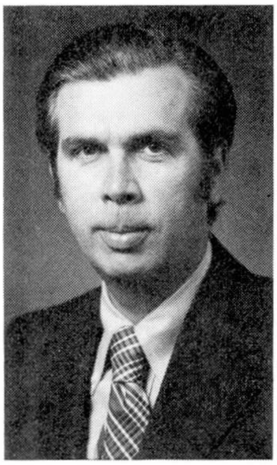

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SUMMARY
This paper reviews methods for evaluation and improvement of bridge foundations. A brief review of causes for damage in concrete structures is presented. Guidelines are provided for making a systematic evaluation of concrete substructures. Evaluation techniques including laboratory tests on concrete cores, and nondestructive test methods are described. A brief discussion of recent developments in nondestructive testing is included.

RESUME
Ce rapport traite des méthodes pour l'évaluation et l'amélioration des fondations de ponts. Un bref résumé est présenté sur les causes des dommages de constructions en béton. Des directives pour une évaluation systématique des structures en béton sont données. Des techniques d'évaluation comprenant des essais en laboratoire d'éléments en béton et des méthodes d'essai non-destructifs sont décrits. Les récents développements d'essais non-destructifs sont présentés.

ZUSAMMENFASSUNG
Dieser Bericht fasst die Methoden zur Beurteilung und Verbesserung von Brückenfundamenten zusammen. Ein kurzer Überblick über Schadenfälle an Betonbauwerken wird gegeben. Richtlinien für eine systematische Berechnung von Betonunterbauten werden aufgezeigt. Beurteilungsverfahren einschliesslich Laborversuche an Betonbohrkernen und Versuchsmethoden werden beschrieben. Weiter werden die neueren Entwicklungen in der zerstörungsfreien Materialprüfung beschrieben.

1. INTRODUCTION

There is a great need for rehabilitation, upgrading, or replacement of bridges throughout North America. Because bridge superstructures normally deteriorate faster than substructures, it is frequently possible to retain the existing substructure for supporting a replacement or upgraded bridge.

To determine the feasibility of reusing the substructure, an evaluation must be made of its present condition, need for and method of repair, load bearing capacity, and methods of increasing load bearing capacity if required. Such an evaluation can provide the basis for a decision on the technical and economical feasibility of reusing the bridge substructure.

This paper reviews causes of damage and deterioration in concrete foundation elements for bridges. A systematic approach to evaluation of condition is described. In addition to reviewing available evaluation techniques, recent developments in nondestructive testing are discussed.

2. CAUSES OF DAMAGE IN BRIDGE SUBSTRUCTURES

Damage in concrete structures can be categorized as follows:

- Freezing and thawing
- Aggressive chemical exposure
- Abrasion
- Corrosion of embedded materials
- Chemical reactions of aggregates
- Fire
- Mechanical overloading

The first five causes are discussed in detail by ACI Committee 201 [1]. Mather [2] suggests that the last two can be added to the list given by ACI 201. Concrete in bridge foundations, piers, and abutments can be affected by each of these causes.

3. STRUCTURAL EVALUATION

To determine existing condition of a concrete bridge substructure, a detailed evaluation should be made. The purpose of the evaluation is to determine the condition of the structure so that a judgment can be made of the need for and possibility of repair to return the structure to its design capacity. A judgment can also be made of the estimated life of the repaired structure. Based on the capacity of the repaired structure and requirements for the replacement superstructure, determination can be made of the need for increased load bearing capacity of the substructure.

3.1 Visual Examination

A thorough visual examination of all components of the bridge substructure is the first step in engineering evaluation. Sketches, drawings and/or photographs should be utilized so that no part of the substructure components will be overlooked in the visual examination. All accessible surface areas of the structures should be examined closely to detect signs of distress. A complete record of all observations should be made using photos, sketches, and notes describing observations. All conditions that deviate from those expected in a new structure should be reported. These include surface discoloration, surface erosion, surface deterioration, surface cracking, popouts and spalls.

Original drawings and specifications of the structure should be obtained if available. Comparison of information found in these original documents should be made with information developed during evaluation of the structure.

A general examination of the substructure should be made to determine measurements and over-all alignment of members. This can be done by use of a level and transit. Notes should be made of any evidence of settlement, deflection, misalignment of joints, or any other unplanned movements of members of the superstructure.

3.2 Tests on Cores

To analyze the substructure and determine its suitability for future use, it is necessary to develop data on concrete strength, cracks, and voids within the concrete members. In addition physical or chemical deterioration that would affect long time durability should be determined.

Direct measurement of compressive strength of concrete in an existing structure is determined by testing cores taken from the structure. Testing of cores provides a direct measurement of the in-place strength of the concrete. This procedure should be done in accordance with requirements specified in ASTM Designation C42, "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete"[3]. In addition to compressive strength, the method describes procedures for determining splitting tensile strength and flexural strength if information on these properties is desired.

Enough cores should be obtained to permit petrographic and, if required, chemical analysis. Testing of drilled cores will yield information on condition of concrete to the depth of the core. For thick concrete members, it is usually more cost effective to supplement core test with nondestructive test methods that yield information on properties of concrete in the interior of a member.

3.3 Nondestructive Tests

Several procedures are available for relatively rapid determination of concrete quality near the surface of a structure. Currently available methods can be classified as rebound, penetration, and pull-out techniques [4]. Accuracy of these procedures is considerably improved if the equipment is calibrated frequently on concrete of known compressive strength and of materials similar to the concrete being evaluated.

To evaluate soundness of relatively massive concrete members such as bridge piers and foundations, knowledge of condition of concrete throughout the volume of the member is necessary. Currently available techniques used in field applications include ultrasonic pulse velocity methods and radiographic methods [4]. Corrosion activity can be evaluated by taking electrical potential measurements in the structure.

4.0 RECENT DEVELOPMENTS IN NONDESTRUCTIVE TESTING METHODS

New evaluation techniques currently under development, include pulse-echo, tomography, acoustic emission, radar, and electrical earth-resistance techniques.

4.1 Pulse-Echo

The pulse-echo method, also known as microseismic technique, is based on the properties of sound waves in solids. The major difference between this procedure and ultrasonic testing using through-transmission techniques is that access is required to only one side of the member.

Test arrangements for through transmission and pulse echo methods are shown schematically in Fig. 1. In the through transmission techniques, a mechanical pulse is generated at one face of the member and picked up by a receiving transducer at the opposite face of the member. In the pulse echo method, a receiving transducer is placed against the face of the member. The member is struck with a hammer adjacent to the receiver. The first wave to reach the receiver by the shortest path available produces a signal on the oscilliscope screen. A second wave reflects from the back face of the member, is picked up by the transducer, and produces a second signal on the oscilloscope screen. An electronic time measuring circuit measures the delay between the first and second signals representing the time taken for the signal to pass through the member twice. Total distance traveled divided by time taken gives the pulse velocity for the member.

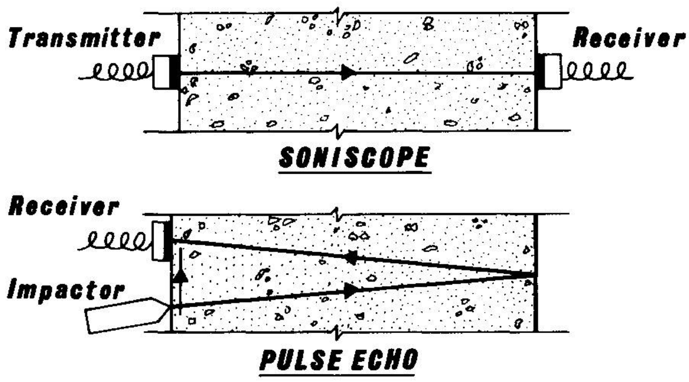

Fig. 1 Test Set-up for Through Transmission (Soniscope) and Pulse-Echo Techniques

In addition to reading of pulse velocity, discontinuities such as cracks and voids can be identified by examining the signal displayed on the oscilloscope screen. As the sound wave passes through an interface between materials of different density, part of the energy is reflected at the interface and the remainder passes through to the back face of the member. The location of the discontinuity is identified by the position of the intermediate signal on the oscilloscope screen.

The strength of the signal received from the back face gives an indication of relative crack widths. As the width of crack increases, less energy is able to penetrate to the back face. At a particular crack width, all of the energy will be reflected at the interface.

Attenuation of signal strength with no evidence of discrete discontinuities indicates porosity or low density of the cement paste causing gradual absorption and scattering of energy as the signal passes through the member.

Pulse-echo equipment for concrete testing is not widely available. However, the method has been successfully applied in evaluating many types of concrete structures including nuclear power facilities [5]. Development work is underway at a number of organizations including the U.S. Army Engineer Waterways Experiment Station [6].

4.2 Other Methods

Other methods that may have application to evaluation of bridge substructures include computerized tomography (CT) [7], acoustic emission [4], radar [8], and earth-resistance technique [9] for pile-soil systems.

5. Repair Methods

A decision to proceed with repair of concrete or strengthening of a bridge substructure should be based on a thorough evaluation using techniques and procedures described under the heading "STRUCTURAL EVALUATION". Methods for repair and strengthening of concrete structures are described in detail in Refs. [1] and [10]. Repair methods applicable to bridge foundations, piers and abutments include:

- Dry-pack mortar
- Replacement concrete
- Replacement mortar
- Preplaced aggregate concrete
- Thermosetting plastic (epoxy)
- Reinforcement installation
- Addition of new members
- Post-tensioning

Case histories of repair projects are described in Refs. [11] through [19].

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