MUI ENGINEERING SERVICES

CONCRETE STRUCTURES

MUI's high level of engineering services provides a good understanding of the client's needs and are custom-tailored to the client with a higher level of quality requirements. **MUI's Engineers** are retained as specialists in structure design, condition survey, corrosion control techniques, and repair methods for various concrete structures.

A professional engineering evaluation is often valuable in determining both an accurate account of existing damages and in assembling the information necessary to properly select the best method to rehabilitate a particular structure. A comprehensive engineering evaluation is comprised of several test procedures, the results of which provide valuable information for determining the proper rehabilitation requirements.

MUI engineers provide expertise in the evaluation of the following conditions:

Structural Engineering Services

- Project Feasibility Studies
- Constructability Review based on project documents to facilitate risk management, change of orders, and save valuable time in construction schedules.
- Complete Structural Engineering Services with structural concepts enables integrated structural solutions and produce cost-effective innovative designs.
- Design and Construction Document Services with our unique knowledge of special structural systems and high-end analysis.
- Value Engineering to determine excessive material costs for clients and manage the cost impacts to meet project goals.

Structural Condition Survey and Assessment

MUI provides a wide range of services to evaluate and manage structural assets. MUI's tools and techniques are designed to identify deterioration trends early, determine root cause, and develop plans to maintain, repair and extend the life of structural assets using the fundamental understanding of material science for identifying failure mechanisms. CMC specialized teams can enhance the condition assessment capabilities to clients by providing specialized assessments services including:

- Structure failure investigation
- Structure condition assessment
- Field testing
- Full steel and reinforcement corrosion assessment
- Specialized Non-Destructive and Semi-Destructive testing
- Comprehensive lab testing

1. CORROSION INVESTIGATION AND EVALUATIONS

A professional engineering evaluation is often extremely valuable in determining both an accurate account of existing corrosion damage and in assembling the information necessary to properly select the cost-effective method to control rebar corrosion on a particular structure. A complete engineering evaluation of a concrete structure is comprised of a number of test procedures, the results of which provide valuable information for determining the proper rehabilitation requirements.

MUI performs comprehensive corrosion survey to determine of which structure members are experiencing corrosion. Based on the survey results, MUI determines the overall structural integrity, including corrosion conditions and provides recommendations for the most economical and effective rehabilitation method(s).

The studies include the following tests, depending upon the type and condition of the structure:

Visual Survey:

Visual examination of a structure is conducted to observe and document what prompts the civil or structural engineer to suspect that a corrosion problem exists. This survey is a vital part of the evaluation because the use of subsequent test procedures depend on the visual assessment of the structure. A visual survey is conducted in accordance with ACI 201 "Guide for Making a Survey for Concrete in Service."

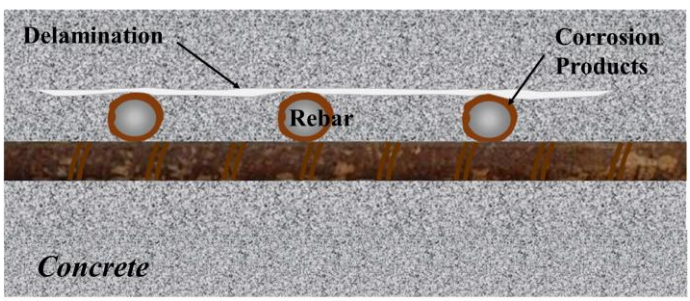
Use of Results: Design of repair method(s) and estimate the repair cost.



Concrete Delamination Survey:

The existence of cracking and spalling of a concrete structure is evidence that concrete delamination may be occurring elsewhere that may not be visible. When concrete cracks develop in the direction of the concrete surface, a de lamination plane forms. Because the cracks are located underneath the concrete surface, the extent of the delaminating areas cannot be visually detected.

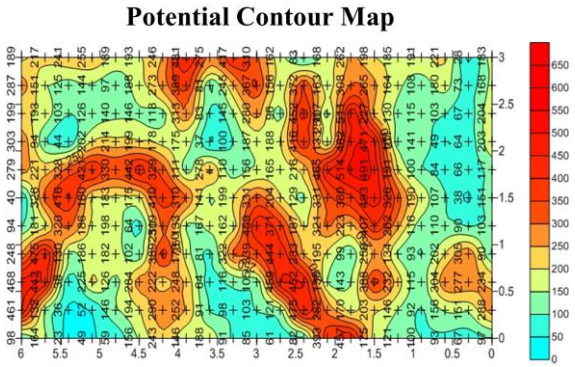
Use of Results: Design of repair method(s) and estimate the repair cost.



Half-Cell (Corrosion) Potential Measurements:

Corrosion potential measurements are another means of detecting corrosion activity affecting steel in presently sound areas of concrete. As corrosion is occurring on steel, these potential measurements are useful tools in determining the corrosion activity in the concrete. Potential measurements are conducted in accordance with ASTM C876.

Use of Results: Determine the proper corrosion control method(s) and estimate its cost.



Caution:

Electrical continuity must be performed to make sure that the selected ground rebar is electrically continuous to the majority of the rebars in the same concrete component before the measurements are performed. If the grounded rebar is not electrically continuous, the potential data are not valid.

Chloride Concentration Analysis:

Chlorides in concrete are the primary active elements that cause corrosion of steel. When the chloride ion concentration at the steel-concrete interface is greater than 0.03 percent (300 ppm) of concrete (threshold concentration), corrosion occurs. By sampling the concrete powder from different depths in concrete, the chloride profile with concrete depth can be produced.

By calculating the diffusion coefficient from the chloride profile, this accounts for all effects and provides an estimate of the effective rate of mitigation of chlorides into the concrete using Fick's second low of diffusion.

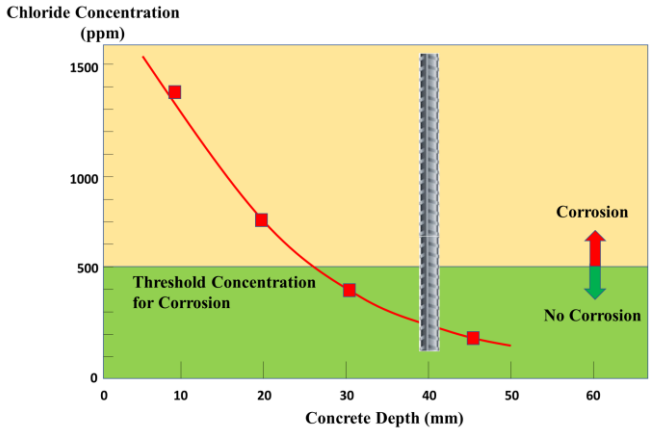
$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2}$$

Use of Results: Determine the proper corrosion control method(s) and estimate its cost.

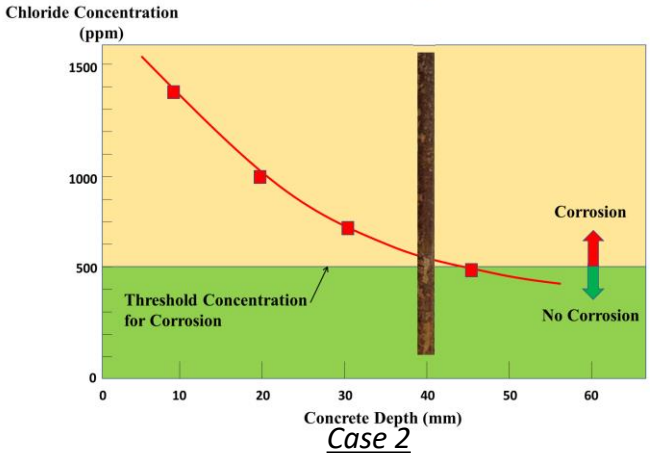
Case 1: If some structure component is not contaminated with high level of chlorides, specialized chloride barrier method is effective.

Case 2: If initial stage of rebar corrosion, pressure injection of corrosion inhibitor may be effective.

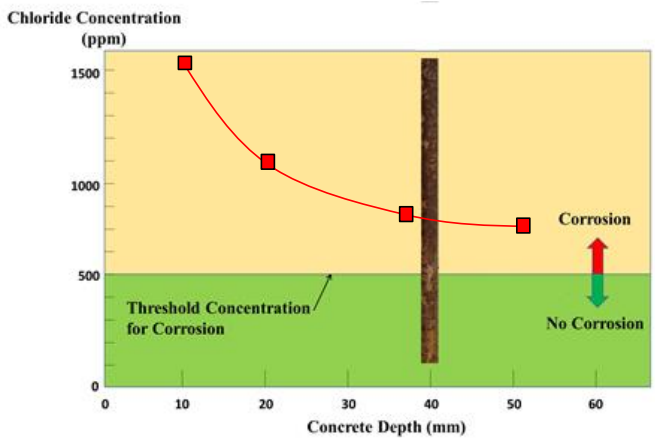
Case 3: If the rebar corrosion is severe and widely spread in the structure, cathodic protection is only the method to stop the corrosion.



Case 1



Case 2

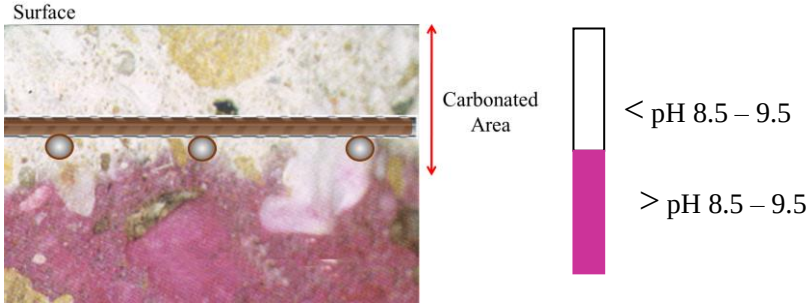


Case 3

Concrete Carbonation Analysis:

Carbonation is a process that takes place when carbon dioxide in the air penetrates into the concrete and reacts with the alkaline components of the cement paste. It is known that the pH of concrete is approximately 13. This high (alkaline) pH results in passivation of the steel surface and protecting the steel from corrosion. However, the carbonation process leads to the reduction of the pH value to below 9. This lower pH causes depassivation of the steel and allows corrosion to initiate. The concrete depth of carbonation is determined by chemical testing..

Use of Results: Determine the proper corrosion control method(s) and estimate its cost.



Electrical Continuity Testing (for Case 3 in Chloride Test Results):

Normally, rebar chairs and wire ties provide good electrical continuity throughout the concrete. However. Electrical continuity should always be verified during the condition survey. Continuity testing is performed to determine if various metallic objects (usually rebar) within the concrete are electrically continuous with each other.

Use of Results: Determine the cathodic protection can be applied if majority of rebars are not electrically continuous to each other.

2. CATHODIC PROTECTION

Cathodic Protection Design Survey

This survey determines whether cathodic protection is a viable and cost-effective rehabilitation method and what type of cathodic protection system would be most applicable/beneficial over the remaining life of the structure. The economic impact is also taken into consideration. The study consists of the following tests:

Reviewing or performing a limited condition survey.

1) Reviewing available cathodic protection options
2) Conducting electrical continuity tests on various steel components of a concrete structure.

Based on the test results, the following are determined:

1) Suitability of the structure for cathodic protection.
2) Applicable cathodic protection system(s)
3) Cost estimation to apply cathodic protection

Cathodic Protection System Design

Based on the process of developing plans and specifications for the construction/installation of a cathodic protection system, bill of quantities and a cost estimate.

Cathodic Protection System Installation

Based on the approved design, the installation of the cathodic protection is carried out with concrete repairs with communicating with the structure owner. During the installation, various tests are conducted for the proper installation.

Cathodic Protection System Maintenance

If the structure's owner does not have the capability for the maintenance of cathodic protection system, MUI will contract. MUI will issue yearly maintenance test report to the owner.

3. CORROSION MONITORING

Evaluations of all types of new and existing corrosion protection systems - including membranes, penetrating sealers, overlays are performed. Using the state of the art technology, the effectiveness of the protection systems is evaluated.

MUI provides specially designed corrosion rate probes embedded in concrete members, the corrosion rate of steel can be monitored over time for new and existing concrete structures.

4. CORROSION CONTROL SEMINAR

Understanding of rebar corrosion mechanism, proper corrosion control method(s), and application is one of the most important factors for the structure owner. MUI provides training seminar to assist the owner's engineers.

The seminar can be a couple of hours to a few days based on the program.

5. CRACKS IN CONCRETE

Crack Surveys

A crack survey is an examination of a concrete structure for the purpose of locating, marking, and identifying cracks and determining the relationship of the cracks with other destructive phenomena (ACI 207.3R). In most cases, cracking is the first symptom of concrete distress. Hence, a cracking survey is significant in the evaluation the future serviceability and safety of the structure.

Evaluation of surface, cracks are normally done during the visual inspection of structures. Crack opening on the surface of the concrete is normally measured using a crack gauge. Depending on the opening of the cracks on the surface, cracks can be described (as tiny as hairline, or cracks with a few millimeters opening);

All crack surveys must be conducted in bright environment. The air temperature must be greater than 15°C.

Plastic Shrinkage Cracks (Surface Cracks)

When the concrete is still in its plastic state (before hardening), it is full of water. As the concrete loses moisture while curing, it gets a bit smaller. As the concrete shrinks, the concrete could crack in order to retain the tension.

Crazing (Premature Drying Surface Cracks)

Crazing is a web-like series of fine cracks, usually at the surface of the concrete. These can be caused by surface shrinkage, which can occur in low humidity, hot air or sun, and wind.

Settling (also called Subsidence)

When the ground under the concrete settles, cracks could form if the settling is uneven. It can occur if the soil under the concrete gets saturated and soft, and the weight of the concrete compacts the soil.

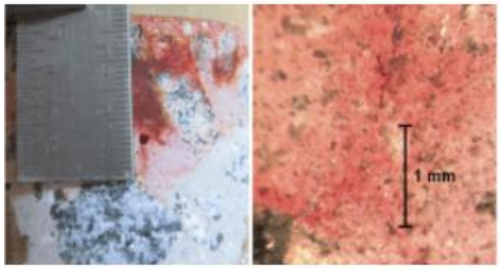
Cracks by Overload

Placing excessive amounts of weight on top of a concrete component can cause cracking. Overloading may be in shear, flexure, or tension. It may also be a result of fatigue or cyclic loading.

Crack Depth Surveys

Visual crack survey does not provide enough information about the depth of these cracks. Different techniques need to be used for the purpose of crack depth measurement in concrete. It is important to evaluate the depth of cracks, to make sure if surface cracking is well propagated into concrete or not. The effectiveness of repair methods relies on accurate prediction of crack depth. Different methods have been developed over the years to evaluate the depth of cracks in concrete.

Visual Examination of Concrete Cores



In this method, dye is injected (using pressure) into surface cracks. Later, concrete cores will be taken from the area under investigation. The sample is studied under microscope for determining the depth of cracks in concrete.

Impact Echo

In Impact-Echo test, a stress pulse is generated at the surface of the element. The pulse spreads into the test object and is reflected by cracks, flaws or interfaces, and boundaries. The surface response caused by the arrival of reflected waves, is monitored using a high precision receiving transducer. When stress waves travel within the concrete element, a part of emitted acoustic waves by the stress pulse on the surface is reflected over the boundary layers, where different the material stiffness changes. This procedure has been standardized as ASTM C1383, “Standard Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method”.

Ultrasonic Pulse Velocity

Ultrasonic Pulse Velocity (UPV) is an effective non-destructive testing (NDT) method for detecting damages in structural components. **Ultrasonic testing of concrete** is an effective way for crack depth estimation. The test procedure has been standardized in ASTM C597 “Standard Test Method for Pulse Velocity through Concrete. ”

Crack Monitoring

Cracks in concrete structures can signal underlying problems and should be monitored to avoid serious functionality or stability issues. Crack identification is one of the most important aspects in structural health monitoring, because the collapses of concrete bridges are mostly due to occurrence and propagation of initial cracks.