CONCRETE

CORROSION - RESTORATION - REPAIR

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Many structures, especially parking garages in northern regions, are constantly exposed to wide variations in weather and harsh environments. Temperature and moisture changes, freeze-thaw cycles, de-icer salts, and poor surface drainage can rapidly deteriorate these structures and even result in structural failure. This article discusses concrete deterioration in a chloride contaminated environment and presents several repair and corrosion prevention methods.

Galvanic Corrosion:

Corrosion of embedded reinforcing steel is the most common type of concrete deterioration. Concrete usually protects embedded steel from corrosion through its high alkali environment. In addition, a light coating of rust surrounding the steel bars helps protect them from further corrosion. However, penetration of chloride-ions from de-icer salts into concrete can destroy the protective film, create a galvanic cell, and cause corrosion.

A galvanic cell is created when two metals with different electrical potentials, or a metal with different potentials at different locations, are connected together in the presence of a conducting solution (i.e. electrolyte). In this case, the electrical potential of the steel areas with a high pH are different from the steel area adjacent to chloride contamination. An electric current flows between the two areas. During this electrochemical reaction, the steel ions leave the steel bar, travel through the electrolyte (moist or wet concrete environment), combine with other ions in the concrete and are redeposited as rust. As a result, the steel bar loses its cross-sectional area. The corrosion process produces about three times the volume of rust than the volume of the steel eroded. This expansive process creates great internal stresses in the concrete, and often results in spalling of the concrete surfaces. The corrosion process will continue until the electrical connection (steel bar) is broken.

A parking structure which collapsed due to deterioration

Most parking structures built before 1980 were not adequately protected against corrosion and have not been adequately maintained. As a result, significant deterioration can be seen in almost every northern climate parking structure. Careful evaluation, design and maintenance are necessary to restore reliable, long-term services to these structures.

Restoration Programs:

The first step of a restoration program is for a restoration concrete engineer to evaluate the overall condition of the structure. The type, severity and cause of the deterioration must be identified. Depending on the evaluation results, the repairs may be limited to aesthetic defects or may involve structural elements. In addition, the direction or strategy of the restoration program may be dictated by the needs of the facility owner, property manager or operator. Factors influencing repair strategy are:

1. ***Structural concern of the affected areas .***
2. ***Future plans for use.***
3. ***Desired service life of the repair.***
4. ***Repair buget available.***

Repair Options:

Selection of repair methods is usually made based on the severity and extent of the deterioration observed as well as the desired service life of the repair. A life cycle cost analysis should be performed and the annual equivalent repair and maintenance costs for each repair option should be analyzed before selecting a specific repair program.

Aesthetic defects:

Aesthetic defects are items such as minor potholes, surface honeycombing or voids which do not poise any structural concern but are unsightly. Repair of this type of defect involves surface patching with hand packed or shotcrete (gunite) materials. The repair is limited to removing loose materials and replacing with the patch material.

Spot patching:

This repair method is used to restore the structural integrity of a concrete element at small, usually isolated areas. The repair involves removal of the deteriorated concrete areas to either partial or full depth of the member. The exposed reinforcing bars are sandblasted to remove any corrosion products. More severely corroded reinforcing bars are replaced with new epoxy coated bars or additional reinforcing steel is added. The perimeter of the repair areas should either be saw cut or square cut with a chipping hammer to a minimum depth of 1" to avoid feather edging which will accelerate deterioration of the repaired areas. The prepared areas are then replaced with a high quality patch material such as high density concrete or a polymer modified concrete. The life expectancy of spot patching is variable and depends on many factors. Based on past performance, the service life of this type of repair is generally five to eight years.

Partial Replacement:

This repair method involves more extensive concrete removal and replacement than the spot patching method. The removal process often extends to a large portion of the structural element. Removal of ten foot long sections along the beam lines is not uncommon. This repair will last longer than spot patching as a larger amount of the original concrete and steel are replaced with a better quality concrete and epoxy coated reinforcing steel. The service life of this method is estimated at eight to twelve years.

A reliable and successful restoration program requires proper evaluation and design, careful planning and proper execution to insure a quality repair job.

Bonded Overlay (Floor)

This repair system includes removal of all deteriorated and unsound concrete and installing a bonded overlay to protect the concrete floor. Bonded concrete overlays have exhibited very satisfactory performance. A study of the field performance of a bonded overlay system installed over chloride contaminated highway bridges indicates a service life of between ten and twenty years can be expected. Materials suitable for a bonded concrete overlay are latex modified concrete, low slump concrete, microsilica concrete and polymer modified concrete.

Complete Replacement:

This repair method is usually performed only when severe deterioration is encountered and the service life of the structure is to be extended more than twenty years. The method involves the complete removal and replacement of the deteriorated structural element. Epoxy coated reinforcing and high quality specialty concrete must be utilized in the replaced concrete elements.

Protection Measures:

To reduce risk of continuing corrosion and to extend the service life of repair work, the following additional protective measures should be considered individually or in combination:

1. Provide adequate concrete cover for reinforcing steel.
2. Use epoxy coated reinforcing steel.
3. Use a low water-cement ratio high density concrete mix.
4. Include a corrosion inhibiting admixture in the concrete mix.
5. Use silica fume to reduce water permeability.
6. Apply a concrete sealer or coating to reduce water and salt penetration.
7. Install cathodic protection to control galvanic cell corrosion.

In Conclusion:

A reliable and successful restoration program requires proper evaluation and design, careful planning and proper execution to insure a quality repair job. Proper attention begins when a deterioration problem becomes identifiable and restoration engineers are contacted to study the condition of the structure and analyze the repair options. Construction documents can then be prepared outlining repair techniques and materials. Finally, the repair work should be executed by a contractor experienced in concrete repair who has performed restoration work in the past and can set up a continuous mantainence program to avoid ever growing repair costs.