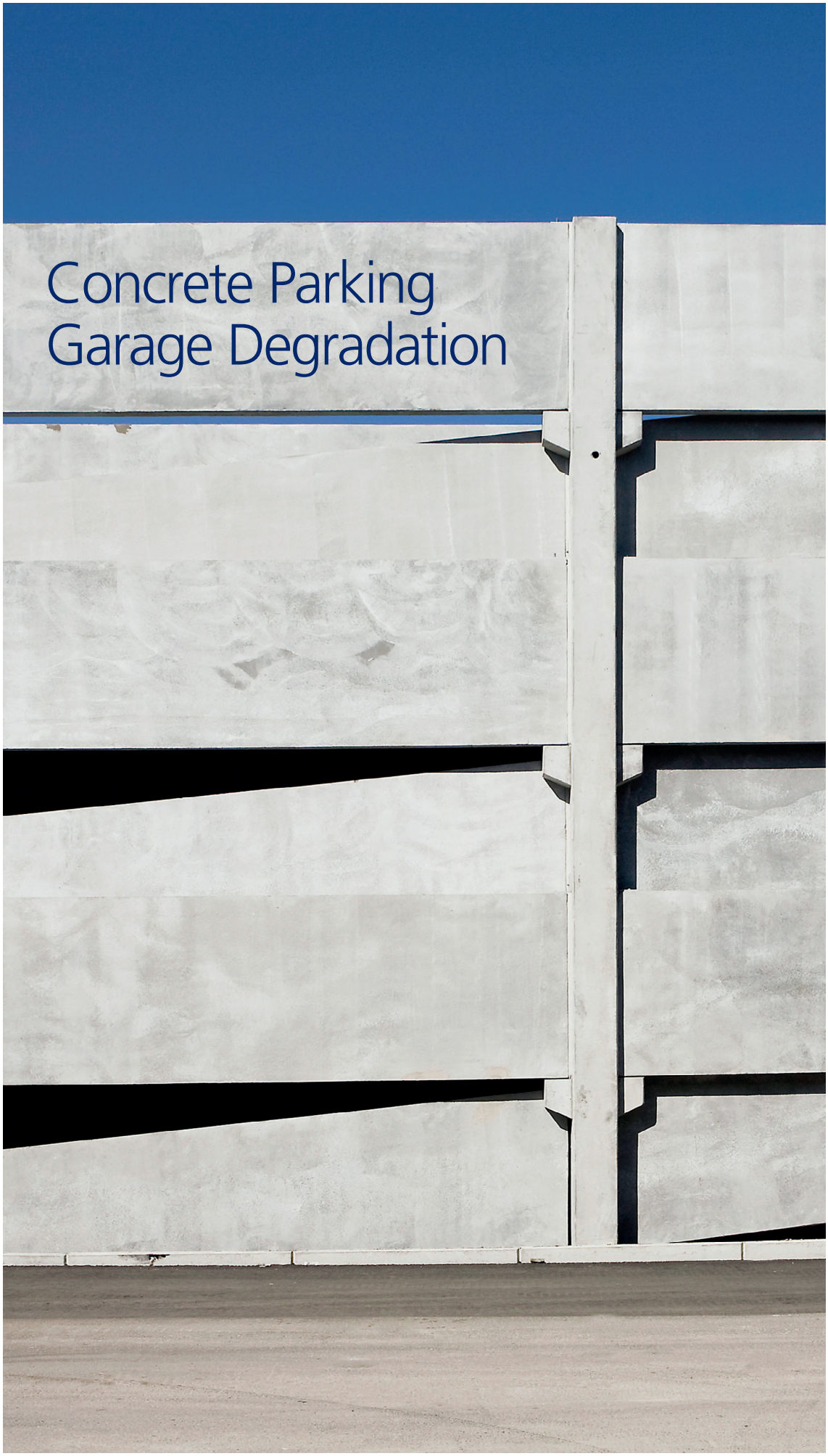
Concrete Parking Garage Degradation



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With proper care and maintenance, the life of a concrete parking garage can span several decades.

> **“Zurich offers an overview of the common causes of concrete garage deterioration, methods of inspection, types of testing, and guidelines for preventative maintenance.”**

The integrity and strength of structural concrete relies heavily on both its concrete and reinforcing steel components; the failure of either component could lead to failure or loss of strength of the structure. Zurich offers an overview of the common causes of concrete garage deterioration, methods of inspection, types of testing, and guidelines for preventative maintenance.

Concrete parking garages are typically constructed as cast-in-place conventionally reinforced concrete, cast-in-place post-tensioned concrete, or precast pre-stressed concrete. Cast-in-place concrete is concrete that is poured into forms at the final location whereas precast concrete is fabricated at a location off-site. Conventional reinforcement utilizes steel bars, wires, and strands to provide additional strength to the concrete structure. Post-tensioned concrete has reinforcing steel tendons that are tensioned after the concrete is placed as opposed to pre-stressed concrete which has reinforcing steel tendons that are tensioned before the concrete is placed.

Common Causes of Degradation

Degradation of concrete garages can occur due to extreme temperature variations, impact loading conditions and corrosion due to chemicals such as de-icing materials.

Multi-level garages experience significant temperature differentials between the top level, which is exposed and therefore more vulnerable to outside temperature, and the lower levels, which are a little more insulated and, as such, do not vary in temperature as much. This difference in temperature between levels causes additional stress on the connecting concrete members, which can contribute to delamination and ultimate failure of the structure due to reinforcing steel damage. This assumes the garage is open and unheated.

Figure 1 - Scaling

Freeze-thaw cycles can also cause scaling of the concrete, which creates a rough surface due to the shallow disintegration of cement paste at the concrete surface.

Thermal movements can also cause cracking of the concrete. These cracks should be monitored during inspections to see if they spread and/or deepen. Temperature variations may also cause distress between connections in precast members. This distress could be at welds, bolts, plates, or bearing pads. Connection distress should also be addressed during inspections.

Figure 2 - Crack in concrete

Impact loads can cause spalling of the concrete, which is a fracturing of the outer surface of the concrete. These concrete chunks are generally several inches across and at least one inch deep. Spalling can also occur due to freeze-thaw cycles or poor design mix quality. The spalling could lead to reinforcement steel exposure and subsequent deterioration of the reinforcement steel by de-icing chemicals.

Impact forces can be created when snow removal equipment damages the structure. Additionally, dumping of snow into storage piles on decks can cause impact loads. Apart from impact loads, snow removal procedures using plows can often damage expansion joints. The damaged joints could lead to water infiltration, which may deteriorate the concrete or the reinforcing steel.

The damaged expansion joints could also allow for de-icing chemicals to more easily and quickly reach the reinforcing steel. These chemicals can then cause corrosion of the reinforcing steel.

Figure 3 - Exposed, corroded reinforcing steel

Corroded reinforcing steel can lead to delaminations, which are fractures of the concrete that occur below and parallel to the surface and can lead to the corrosion of the reinforcing steel. These areas should be repaired as soon as practical to minimize the loss of integrity of the reinforcing steel and maintain the original structural design parameters. Extensive delamination may require expensive and significant remedial work.

Figure 4 - Delaminated concrete removed to expose corrode reinforcing steel

Inspection Methods

Owners and property managers of concrete parking garages are encouraged to conduct annual inspections of their structures. These structures should be inspected by individuals who are knowledgeable of the structural aspect of concrete structures. Spring is generally considered the best time to conduct these inspections because damage from winter conditions will be observed, snow and salt will not obstruct the view and spring rains can demonstrate leakage conditions. Inspections should include both written and photographic documentation.

Specific areas that should be observed during inspections are at structural connections, recessed connections, bolted connections, slotted connections, ledges, pockets, joint sealants, bearing pads, mortar joints and exposed reinforcement steel.

Visual inspections should include observing the concrete surface for signs of delamination, spalling, cracking, and scaling. Connections should be inspected for weld failures/distress, bolt failures/distress, rust and corrosion damage. Expansion joints, sealants, and caulk joints should all be checked for signs of damage, deterioration and leaks. Drains should be inspected for leaks, adequate drainage, and clogs. The quantity and depth of cracks should also be monitored during the annual inspections.

Visual inspections that uncover areas of concern may then require further testing to determine the level of damage and remedial steps that may need to be taken. A qualified engineer should get involved, if they have not already been included in the annual inspections. Additionally, owners may wish to consider full engineering evaluations on all older structures and when accurate maintenance records are not available.

> **“Good practices in house-keeping and preventative maintenance will help extend the life and reliability of concrete parking structures.”**

Testing

Listed below are some tests that can be performed to determine the level of degradation of a concrete parking garage. This list is by no means exhaustive as it is meant to provide an introduction to the types of additional work that could be performed either during an annual inspection or due to the observations that come out of annual inspections. They have been listed in order of increasing destructiveness.

Impact-Echo

This is a non-destructive test used to find internal flaws such as cracks or honeycombing. Transient stress waves are used on concrete structures that have a fairly smooth surface. The maximum effective testing depth is 3 feet. This test could be performed annually or could be performed if there are concerns with the quantity and depth of cracks observed during an annual inspection.

Ground Penetrating Radar (GPR)

This test uses pulsed electromagnetic waves to measure the difference in materials. The differences it detects are internal flaws, reinforcement, and thickness of members. It is useful for large areas. Results do not include determination of bar size. Similar to the Impact-Echo test, this test is also non-destructive and can be performed annually or for further investigation of areas of concern.

Reinforcement Location

The amount of concrete that is placed over the reinforcing steel is the concrete cover. The greater the cover; the better the protection for the reinforcing steel from corrosion. Electro-magnetic methods are used in this test to determine the location of the reinforcing steel and thus determine the concrete cover. The devices used are specialized metal detectors that have been calibrated for concrete reinforcement. However, the devices have a limited penetration of about 12 inches and cannot differentiate between closely spaced bars or nearby non-structural steel. The previous test, GPR, can also be used to determine reinforcement location.

This test can be conducted during an annual inspection to determine the level of protection that existing reinforcing steel has from exposure to corrosive elements. This would help to determine the vulnerability of the reinforcing steel to degradation. This is also a non-destructive type of test.

Sounding

For delamination that has occurred near embedded reinforcing steel, concrete can be impacted with a rock hammer and the resulting sound is sampled for “hollowness”. Hollow sounds can indicate the presence of delamination. This is a non-destructive test that can be conducted during an annual inspection. The results would help to determine if more destructive methods of testing should be utilized in areas of concern.

Carbonation

Carbonation is a test that measures the pH of the concrete. When pH levels are below 11.5, the concrete is considered carbonated and susceptible to corrosion. The test is performed by exposing the concrete either through chipping off a small piece or by drilling a hole. The exposed face is washed and an indicator solution is sprayed on it. If carbonation is found, the probe is deepened further to determine the depth of carbonation.

If corrosion of reinforcing steel is suspected, this test would help to determine if further investigation is necessary. Some of the concrete will be destroyed during testing through either chipping or drilling.

Chloride Ion

Testing can be performed to determine the Chloride Ion content in concrete. Chloride Ions are generally present due to de-icing. Values of chloride content about 300 ppm or higher are considered conducive to corrosion of any uncoated embedded reinforcement. Note that this 300 ppm threshold will be lowered if the concrete is also considered carbonated. This test is performed by taking powder samples from various locations and at various depths. Samples are then analyzed in a lab for chloride content.

This test would also be destructive to the concrete at the sampled areas because several areas will have concrete removed and at various depths. It is also useful in deciding if further investigation is necessary due to a higher potential of corroded reinforcing steel.

Half-Cell Potential Testing

This test determines the vulnerability of the reinforcing steel to corrosion activity. The test is conducted on top or on the underside of a concrete structure. The test area must contain reinforcement that is electrically continuous throughout. Holes are drilled to the reinforcing mat, the concrete surface is wetted down and readings are taken with electrodes to determine the probability of corrosion activity. The test cannot be conducted if waterproofing membranes or sealers are covering the concrete surface.

The level of destructiveness varies depending on the presence of membranes or sealers. For the readings, only two holes need to be drilled in the concrete. However, if membranes are present, they will need to be removed. The test is useful in determining in further detail if the reinforcing steel may have corroded.

Preventative Maintenance

Good practices in housekeeping and preventative maintenance will help extend the life and reliability of concrete parking structures. Good practices include the following activities on a regular and frequent basis:

- Sweeping of all areas to remove items that could cause physical damage to the concrete.
- Pressure washing all decks to remove chemicals that could break down the concrete or the reinforcing steel.
- Repairing any coating issues where the coating is designed to prevent water penetration (especially decks with epoxy coating).
- Trash pick-up to avoid either physical damage or chemical corrosion.
- Control joint and expansion joint cleaning. This helps to prevent damage to the joints so that water does not infiltrate into the reinforcing steel.
- Oil stain removals to help prevent transfer of chemicals to the reinforcing steel.
- Floor drain cleanings, which will help to prevent clogs or leaks. This helps avoid water damage to reinforcing steel.
- Controlled snow removal, particularly to avoid snow plow damage to joints and impact loads to the concrete structure.
- Monitored de-icing to minimize the amount of exposure concrete has to the de-icing chemicals.
- Maintenance of any traffic coatings. This also includes the regular re-application of traffic coatings as required by the manufacturer.
- Posted signage to restrict access to the garage by abnormally heavy vehicles.

An additional best practice for owners is to obtain and securely archive all records that were produced during construction. These documents include but are not limited to QA/QC records, testing reports, daily logs, as built drawings, and MSDS. This information is very useful in determining the existing conditions of the structure.

Degradation of concrete garages can occur due to temperature variations, impact conditions, and corrosion. Annual inspections and additional testing can help to determine the extent of degradation, if any. Preventative maintenance practices should decrease the possibility of degradation.

This report provided an overview of the causes of degradation, how to maintain concrete parking structures, and methods of inspection and testing. With the proper program in place, owners should be able to benefit from their structures for several decades.

Checklist for Annual Visual Inspections of Concrete Parking Garages

Areas to be visually inspected:

- ☐ Structural Connections
- ☐ Recessed Connections
- ☐ Bolted Connections
- ☐ Slotted Connections
- ☐ Ledges
- ☐ Pockets
- ☐ Joint Sealants
  - ☐ Control Joints
  - ☐ Expansion Joints
  - ☐ Mortar Joints
- ☐ Bearing Pads
- ☐ Exposed Reinforcement Steel
- ☐ Drains
- ☐ Overall Cleanliness
- ☐ Oil stains (removal)
- ☐ Coatings
- ☐ Posted Signage
- ☐ Other: _____

Photographs to be Attached:

- ☐ Connections
- ☐ Joints
  - ☐ Control
  - ☐ Expansion
  - ☐ Mortar
- ☐ Areas of concern
- ☐ Other: _____

Review Maintenance Records

- ☐ QA/QC Records
- ☐ Testing Reports
- ☐ Daily Logs
- ☐ As-built Drawings
- ☐ MSDS
- ☐ Other: _____

Areas of Concern:

Observation	Location(s)	Further Investigation Recommended?
Delamination		
Spalling		
Cracks		
Scaling		
Leaks		
Water Damage		
Weld Failures/Distress		
Bolt Failures/Distress		
Corrosion Damage, Rust		
Joint Sealant – Damage, Deterioration, or Leaks		
Drains – Leaks or Clogs		
Other:		

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A1-112000682-B (06/15) 112005439

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