Guide for Structural Maintenance of
Parking Structures
Reported by ACI Committee 362

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This guide is intended to assist parking structure owners, operators, and the consultants who advise them in developing preventive maintenance programs for parking structures. It presents typical maintenance concerns and suggests ways of addressing them.

The guide summarizes information regarding structural, operational, aesthetic, and routine maintenance for parking structures. Design suggestions to minimize maintenance are also included. A structural maintenance checklist of specific recommended tasks and references to other publications with information related to the structural maintenance of parking structures is included.

See ACI 362.1R for more complete information regarding design issues related to a parking structure’s performance.

Keywords: concrete durability; condition appraisal; construction joints; contraction joints; corrosion; cracking; expansion joints; isolation joints; leakage; maintenance; membrane; parking structure; post-tensioning; precast; prestressed; ramp; scaling; sealant; sealer; snow removal; spalling.

CONTENTS

Chapter 1—Introduction, p. 362.2R-2

Chapter 2—Developing a maintenance program, p. 362.2R-2

Chapter 3—Deterioration problems associated with parking structures, p. 362.2R-3

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3.3.3—Stair and elevator towers
3.3.4—Exposed metals

Chapter 4—General maintenance considerations, p. 362.2R-9
4.1—Housekeeping and cleaning requirements
4.2—Snow removal and ice control
4.3—Other operational maintenance
4.4—Aesthetic-related maintenance
4.5—Precast/prestressed concrete
4.6—Post-tensioned concrete
4.7—Cast-in-place, conventionally reinforced-concrete structures

Chapter 5—Parking facility structural maintenance tasks and frequencies, p. 362.2R-11

Chapter 6—References, p. 362.2R-11
6.1—Referenced standards and reports
6.2—Cited references

Appendix A—Snow removal, p. 362.2R-12
Appendix B—Deicing procedures, p. 362.2R-13
Appendix C—Checklist for structural inspection of parking structures, p. 362.2R-13

CHAPTER 1—INTRODUCTION
All parking structures require regular maintenance to provide a satisfactory level of service and meet service-life expectations without premature deterioration, undue repair expense, interrupted service, inconvenience to patrons, or loss of cash flow. Parking structures can develop more distress and deterioration than most types of buildings because of their direct exposure to traffic, weather, deicing chemicals, and snowplows. Poor maintenance increases the likelihood of distress and deterioration and is a potential cause for damage to vehicles and personal injury. A maintenance program includes timely preventive actions to reduce system failure and premature deterioration, which can reduce the need for significant and expensive repairs. This guide is intended for owners, operators, and consultants for parking structures who seek advice on developing and implementing a maintenance program.

This guide emphasizes the maintenance of structural components to reduce risks associated with structural deterioration. The types and frequency of maintenance required for a structure are directly related to the durability features incorporated into the structure during design and construction. Deterioration problems associated with parking structures are discussed in Chapter 3. Operational maintenance, housekeeping, and aesthetic maintenance are discussed in Chapter 4. Chapter 5 provides a checklist for maintenance tasks and recommended frequencies. Appendices A and B contain information about snowplowing and deicing procedures. Appendix C also contains a worksheet for making a visual inspection. Different types of structural systems can develop different types of deterioration-related problems. ACI 362.1R contains discussion of durability considerations for parking structures. An understanding of these issues will prove helpful in developing an appropriate maintenance program. Refer also to Sound Maintenance Extends Life Spans of Parking Facilities, by Bhuyan.

CHAPTER 2—DEVELOPING A MAINTENANCE PROGRAM
2.1—The project maintenance manual
For many projects, a maintenance manual is developed at the completion of construction as part of the close-out process. The manual can contain the project specifications; a set of as-built drawings; product information, including warranty and maintenance information from the manufacturers of various components; and specific maintenance requirements. If a project maintenance manual exists, it is a good idea to become familiar with the manual to develop a comprehensive maintenance program.

2.2—Periodic inspections
A walk-through visual inspection should be made at least annually to provide an overview of the structure’s general condition. Problems should be noted in a concise report, recommending further investigation of specific items if required. The inspection should be conducted by an engineer experienced in structural condition assessment of parking structures. A visual inspection does not involve physical testing. Maintenance personnel with proper checklists and day-to-day experience of operating the structure can also conduct a visual inspection of nonstructural maintenance concerns. Appendix C provides a checklist of specific items that should be observed during a visual maintenance inspection.

2.3—Preventive maintenance
Preventive maintenance should reduce life-cycle repair expenses and extend the service life of the structure. This is accomplished by ensuring that the structure’s protective systems are functioning properly to reduce the intrusion of water and deicing chemicals. Regular cleaning to remove debris, wash-downs with water, sealing cracks, spot repairs of sealants and expansion joints, protective coatings and membranes, and periodic reapplication of sealers are all features of an active preventive maintenance program.

2.4—Condition appraisals
A condition appraisal should be performed if extensive deterioration or unexplained problems are observed during the walk-through visual inspection. The appraisal should evaluate and define the extent of deterioration, the associated problems observed, their causes, the causes of the problems observed, and the corrective options available. Typically, the appraisal focuses on the deterioration of deck slabs and their supporting structural elements that can reduce structural capacity or cause safety hazards.

Material samples can be taken and a variety of tests performed. The most important tests are those that determine the extent of corrosion and bond loss of the reinforcement and those that quantify the amount and extent of chloride ingress into the concrete. See ACI 201.1R for additional information regarding concrete durability. Testing may include compressive strength, chain dragging, and half-cell testing to locate
active corrosion and delamination, and chloride-ion content. In addition, petrographic analysis can be done to identify specific concerns regarding the makeup of the concrete.

Information gathered from the condition appraisal, along with resulting lab analyses, should be reviewed by an engineer experienced with structural-condition appraisals. If necessary, a materials consultant can confirm the causes of deterioration. These experts should provide a report with specific recommendations, including restoration priorities, options, and repair budgets.

The owner should maintain accurate maintenance and inspection records to provide historical information that can assist in future appraisals of deterioration and identify potential problems observed.

CHAPTER 3—DETERIORATION PROBLEMS ASSOCIATED WITH PARKING STRUCTURES

The implementation of a proper maintenance program requires an understanding of the deterioration mechanisms and their symptoms. Most deterioration involves water intrusion and corrosion of reinforcement.

Problems that are left unattended during the early stages of their development can lead to safety hazards for users, increased liability for owners, and can require expensive repair programs for correction. Structural maintenance requirements are those actions necessary to preserve, restore, and enhance structural members and improve or enhance protective functions of various waterproofing and anticorrosion systems. See ACI 201.1R, 222R, and 224R for additional information regarding deterioration mechanisms briefly described in this guide.

3.1—Concrete-related deterioration

Concrete-related deterioration is often associated with scaling, spalling, joint failure, or cracking of the concrete members. Delamination of concrete, however, is not a prerequisite for concrete-related deterioration. Sections 3.1.1 through 3.1.7 discuss various deterioration mechanisms.

3.1.1 Scaling—Scaling is the disintegration of cement paste at the concrete surface. Commonly associated with cycles of freezing and thawing, it results in progressive deterioration. Severe scaling can result in a loss of concrete surface integrity to depths of more than 25 mm (1 in.). Scaling in deck slabs can create depressions that pose tripping hazards and create ponding areas that can lead to further deterioration. See Fig. 3.1.

3.1.2 Corrosion—Corrosion is an electrochemical process that results in the deterioration of reinforcement and other metals embedded in the concrete or exposed to the weather. Chloride ions from road salts or other deleterious airborne chemicals accelerate the corrosion process. Moisture and oxygen also play a direct role. Corrosion can lead to serious deterioration and repair problems. As corrosion progresses, the corrosion byproducts occupy a greater volume than the original metal, creating internal pressure on the concrete that can eventually lead to cracking, delamination, and breaking of the concrete substrate. Corrosion of unbonded post-tensioning tendons represent a special case.

Post-tensioned tendons can corrode or even fail without cracking or delaminating the surrounding concrete. A post-tensioned tendon failure is often accompanied by the eruption of the tendon either at the tendon end or through the concrete slab. Other post-tensioning problems to look for include exposed tendon sheathing or dislodging of post-tensioning anchors.

Mitigating the corrosion process should be a priority of any maintenance program. The most practical way of controlling corrosion is to incorporate corrosion-protection systems into the original construction and then to reduce or eliminate moisture penetration into the structure (Fig. 3.2). See ACI 222.R for a more complete discussion of the corrosion process and its causes, and ACI 423.4R on corrosion and repair of unbonded single-strand tendons.
3.1.3 Delaminations—Delaminations are fractures of the concrete, parallel to the surface, usually resulting from corrosion of the reinforcing steel parallel to the surface in the concrete. Extensive concrete delaminations (5 to 10% of the surface area visually deteriorated) are an indication of advanced deterioration.

3.1.4 Spalling—Spalling is the fracturing of the outer surface of concrete. It can be caused by corrosion of embedded reinforcement, which can produce internal pressures exceeding the tensile strength of the concrete. It can also be caused by impact. Spalling typically creates cavities 25 mm (1 in.) or more in depth with rough surfaces. Spalling tends to create conditions conducive to progressive deterioration of the structural concrete. Spalling on the top surfaces of the deck can lead to rapid deterioration due to the ponding of water combined with the reduced concrete cover over the reinforcing steel. Fig. 3.3 shows how corrosion-induced stresses can lead to concrete spalling and deterioration.

3.1.5 Cracking—There are many possible causes of cracking in concrete (Fig. 3.4). For most nonprestressed deck systems, well-distributed fine cracks are considered normal and no treatment is required. Refer to ACI 224R for discussions of crack width.
Detrimental cracks can be construction or service related. Construction-related cracks can be caused by rapid moisture loss due to improper curing, placing, or finishing practices. Cracking can also be caused by corrosion of embedded metal. Service-related cracks can result from thermal movement, structural loads, or differential settlement. Cracks can lead to leaking, leaching, corrosion, and delamination. Regardless of their cause, cracks should be investigated and, if necessary, repaired promptly, especially if they are leaking, to reduce the possibility of future deterioration.

Deciding whether a crack compromises structural integrity is important. A proper understanding of the underlying causes of the existing cracking is a prerequisite for a proper repair, which can require an engineering appraisal. A structural crack can appear in the deck, beam, column, bearing area, or other location essential to supporting the load. Cracks can be moving or stable and may or may not leak. Leaking cracks are indications that water is entering the structure. The source and cause of the leakage should be investigated and repaired and the leaking cracks sealed promptly.

3.1.6 Leaking—Leaks are most frequently related to improperly sealed cracks or joints. Leakage is a nuisance and also can accelerate deterioration; it should be addressed promptly.

3.1.7 Leaching—Leaching occurs when water passes through concrete dissolving the cement constituents. The dissolved constituents can combine with each other, or with atmospheric chemicals, and can crystallize on the surface of the concrete. The crystallized leachate is referred to as “efflorescence.” One common example is calcium carbonate, produced by atmospheric carbonation of calcium hydroxide leachate. Efflorescence can drip onto and damage vehicle finishes (Fig. 3.5).

3.2 Sealants and waterproofing

Some combination of joint sealants, isolation joint seals, concrete surface sealers, or traffic deck membranes is typically used in parking structures to prevent penetration of water and chloride ions into the concrete deck surface. Isolation, construction, and contraction joints in parking structures accommodate differential movement due to concrete shrinkage, seasonal temperature variations, elastic shortening, axial creep in post-tensioned structures, or creep of concrete. Sealant and waterproofing systems should be monitored and maintained as part of a preventive maintenance program.

Preventive maintenance, such as applying a protective sealer, elastomeric coating, or sealants, is most effective when applied to a new slab. On existing structures with chloride-ion contamination, the corrosion-suppressing capabilities of sealers and elastomeric coatings can vary depending on their ability to substantially reduce the concrete moisture content. Coatings normally reduce moisture absorption more effectively than sealers, but do not stop ongoing corrosion completely.

3.2.1 Contraction and construction joint sealants—Contraction joints are provided in a concrete slab or wall to create weakened planes for the formation of cracks at predetermined locations rather than allowing random cracks to develop. Construction joints at the end of a concrete placement separate it from other placements. Leakage can develop at these joint locations unless they are properly sealed and maintained. Joint sealant systems have a typical life expectancy of seven to ten years and should be replaced as necessary. Refer to ACI 504 for additional discussion regarding joint sealants. Localized repairs should be anticipated before complete replacement is necessary. A common failure mechanism of joint sealants is deterioration of the surfaces to which the sealant is bonded, allowing the intrusion of water and subsequent progressive failure of the sealant along the length of the joint. Spot repair of these conditions is an effective means of reducing joint leakage problems and reducing progressive failure. Joint sealants can also fail in adhesion, requiring repair or replacement.

Contraction joints, construction joints, and joints around drains are typically sealed with a flexible sealant to minimize leakage and slow deterioration of the structure. In addition to deteriorating joint sealants, random deck-slab cracking can contribute to leakage and the deterioration of structural

Fig. 3.4—Cracks in concrete allow accelerated absorption of water and chlorides. If left unaddressed they can lead to leakage and deterioration of surrounding substrates.

Fig. 3.5—Leaking and leaching can result in extreme deterioration conditions if cracks are not sealed.
members. If they leak, random cracks should be routed and sealed with flexible sealants (Fig. 3.6 and 3.7).

3.2.2 Seals for isolation joints and expansion joints—Isolation joints and expansion joints pass all the way through the structure. They allow structural movement due to volume changes often associated with seasonal temperature changes. They are designed to accommodate a significant amount of movement. Leakage at these locations is a common problem. Refer to Appendix A for additional information regarding controlling damage related to snow-removal procedures.

Early detection and correction of leakage at isolation joints or expansion joints provides the best protection against progressive deterioration and expensive repairs. If problems persist despite corrective measures, consider a more effective sealing device. An experienced engineer, specialty waterproofing manufacturer, or contractor should help resolve sealing problems with isolation joints and expansion joints. Refer to ACI 504R for additional information regarding sealing joints (Fig. 3.8).

3.2.3 Concrete sealers—Concrete sealers are frequently used to reduce the permeability of concrete surfaces and their susceptibility to water and chloride-ion penetration. Concrete sealers are typically designed to penetrate the surface and may not be visually detectable. Reapplication on a five to seven year cycle, perhaps more frequently in high-traffic or exposed areas, will be necessary and should be budgeted accordingly.

Although no standard test exists to evaluate sealer performance, several techniques have been devised. One such test, commonly called a water-uptake test, is performed by sealing a graduated, open tube to the deck, filling it with water, then measuring how much of the water is absorbed into the concrete over a specified time period, usually 20 min to 1 h. A baseline reading should be established when the sealer is applied, and comparable readings taken at time intervals from one to three years to measure reduction in sealer effectiveness. Moisture content of the concrete should be noted when readings are taken and held constant for future readings, such as with surface-dry concrete.

Another method of evaluating sealer performance is to take initial samples of the concrete and determine the chloride-ion content, then take comparative samples at time intervals from one to three years. Resealing should be considered when tests indicate that performance is declining, as evidenced by an increase in chloride-ion content. This can be necessary every three to five years in high-exposure areas, but may not be required as often in parking stalls or other areas subject to less
traffic exposure. See Fig. 3.9. See ACI 515.1R for additional information.

3.2.4 Elastomeric, traffic-bearing membranes—Elastomeric, traffic-bearing membranes (traffic coatings) are frequently used in parking structures. The membrane waterproofs the surface and allows moisture penetration only at localized imperfections, such as holes and tears. The flexibility of the membrane allows it to bridge small cracks effectively, provided that the crack opening does not exceed the deformation limit of the membrane. Figure 3.10 shows the installation of a typical elastomeric traffic-bearing membrane. Large cracks can be routed and filled with sealant, then coated with an additional membrane to provide increased membrane thickness to accommodate moving crack conditions (Fig. 3.11).

The condition of these membranes is easier to monitor than that of sealers because the membrane is visible and damage can be seen easily. If damaged, the membranes should be repaired as soon as possible to prevent progressive deterioration. These membranes can be expected to be effective for 10 years or more in parking structures. Areas exposed to direct sunlight, traffic lanes, turns, or areas where vehicles stop and start can have a reduced service life. Although more expensive than surface sealers, elastomeric, traffic-bearing membrane systems provide more effective protection against moisture and chloride-ion penetration.

3.3—Structural elements and related items

3.3.1 Concrete deck surface—A parking structure’s most significant maintenance needs are associated with supported deck slabs and underlying structural frame elements. The most common cause for deterioration of deck slabs and surfaces is the penetration of water and deicing chemicals into and through the deck slab.

A parking structure should be monitored annually for concrete deterioration. Open spalls and delaminations in the deck slab should be assessed and appropriately patched to reduce progressive deterioration and maintain serviceability. Temporary repairs may be required because of time or weather constraints until the source of the problem can be identified and long-term repairs accomplished. Spalls and delaminations in concrete should not be patched with tar or asphaltic materials because they allow migration of water and chloride ions into the concrete below, prevent them from being flushed out during wash-downs, and hide potential deterioration from view.

Long-term repairs require removing all deteriorated concrete. Before patching, corroded reinforcement should be replaced or cleaned and given a protective coating. The area to be repaired should then be patched appropriately. Repair materials may be cementitious or modified by a variety of polymers and additives. Figure 3.12 shows a properly prepared patch area awaiting placement of the patching material. Proper curing of portland-cement-based patches is imperative to obtain a durable surface, minimize shrinkage of the patched area, and enhance serviceability. Consult with an experienced structural engineer for guidance on repair options. Refer to ACI 546.1R for additional information.

The most effective method of repairing a crack in a deck slab is to rout it out and seal it with a flexible, traffic-grade sealant (rout-and-seal method). If numerous cracks are closely grouped, a traffic-bearing membrane should be installed over the area after the leaking cracks have been repaired with
the rout-and-seal method or otherwise repaired in accordance with recommendations from the membrane manufacturer. Brushing a low-viscosity penetrating sealer into fine cracks can provide a temporary repair. If there is concern that the cracks compromise the integrity of the structure, they should be evaluated by a qualified professional engineer experienced with structural restoration before undertaking repair.

Ponding is also a significant cause of deterioration. The presence of standing water for extended periods indicates that inadequate slopes to drains have been provided. Ponding can be corrected by installing supplemental drains. Resurfacing to re-establish proper drainage lines can be required if the problem is widespread, but adding supplemental drains at low points can be the most economical approach to correcting poor drainage situations. Refer to ACI 515.1R for additional information (Fig. 3.13(a)).

Concrete sealers and elastomeric coatings are frequently used to reduce water intrusion into and through deck slabs. For maximum protection, these systems should be applied during initial construction, but they can also improve performance when applied at a later date. High-traffic areas, such as entrance and exit lanes, turn areas, and ramps can be expected to require more maintenance than parking stalls and flat drive lanes and should be monitored accordingly.

3.3.2 Beams, columns, and walls—Beam and column deterioration can adversely affect a structure’s integrity and load-carrying capacity. Deterioration of these underlying members is primarily attributed to water leakage through failed joints and deck-slab cracks. Vertical surfaces of columns and bumper walls are also susceptible to damage by ponded water and salt water splashed from moving vehicles. Beams and columns adjacent to and below expansion joints are especially susceptible to deterioration. Beam and column deterioration can be controlled by maintaining joint sealant systems and deck surfaces, and by applying sealers and elastomeric membranes on the column base and bumper wall.

Concrete walls and columns are also vulnerable to vehicle impact and should be examined periodically for cracking and spalling. Connections of exposed steel elements and areas containing embedded steel connections should be inspected for corrosion and distress.

Ponded areas and drainage areas adjacent to walls (Fig. 3.13(b)) and columns can contribute to corrosion of those walls connections and their connected elements. This can lead to unsightly rust staining, and in extreme cases, safety concerns about the performance of wall connections. These adverse conditions can require installing new curbs, supplemental drains, or sloped concrete to move water away from the face of the affected column or bumper wall.

3.3.3 Stair and elevator towers—Leaks often occur through joints between the deck slab and stair and elevator towers. This problem can often be attributed to poor drainage around the towers. Drainage can be improved by providing curbs that will divert water away from the towers and reduce deterioration of underlying elements such as doors, light fixtures, electrical conduits, metal stairs, exposed structural steel members, and connections. In addition, rust stains, efflorescence, and peeling paint are not aesthetically pleasing. Frequent inspections and repair of damaged isolation- and ex-
pansion-joint seals between the tower and the deck surface also will reduce distress caused by leaking.

Stairs and landings are exposed to chloride-ion contamination, and these concrete surfaces require periodic resealing. Metal-pan stairs with concrete treads can be particularly susceptible to corrosion-related deterioration. Cracking of stair and elevator walls should be evaluated and repaired to control moisture penetration. Door and window glazing, if present, should be repaired or replaced when damaged or leaking (Fig. 3.14(a) and (b)).

3.3.4 Exposed metals—A parking structure can have exposed steel in the form of connections, stairs, pedestrian railings, vehicular guardrails, or primary structural components, such as columns and beams. Premature deterioration of metal components can be caused by atmospheric exposure, neglect, or the chemical reaction between the metals and a corrosive environment. The condition of all exposed metals should be visually monitored on a regular basis. Treating metals with proper surface preparation and appropriate paint or anticorrosion coatings will reduce corrosion and resultant problems.

Corrosion at the attachment point of metal items to concrete is a particular concern because the distress can spall the concrete and lead to progressive deterioration of the concrete member, failure of the attachment point, or both.

CHAPTER 4—GENERAL MAINTENANCE CONSIDERATIONS

4.1—Housekeeping and cleaning requirements

Housekeeping involves regular inspection, repair, and maintenance of items required to keep the structure functional for users. This maintenance includes routine cleaning, sweeping, washdowns, snowplowing, and ice control. See Fig. 4.1.

Regular cleaning is one of the most important aspects of good housekeeping practice. A clean environment makes the parking structure more pleasant and can reduce maintenance and extend service life. Sweeping can be done using hand brooms, mechanized sweepers, or vacuums designed for use in parking structures. Sweeping should be done at least monthly. All dirt and debris should be removed from the facility. Special attention should be paid to keeping dirt and debris out of drain basins, pipes, expansion joints, and other openings. Grease buildups should be removed regularly using appropriate degreasers.

Road salt accumulates over winter months in freezing climates and should be removed each spring by flushing the surface with large volumes of water under low to moderate pressure. A second washdown in the fall also is recommended to remove surface debris and contaminants. Parking structures should be equipped so that a 1-1/2 to 2 in. diameter hose can be used to wash the deck. Critical areas that tend to get a higher buildup of salts, such as entrances, exits, and flat or ponded areas, should be rinsed more frequently. Care should be taken not to damage joint sealants, expansion joints, or deck-coating materials with pressure-water cleaning. Drains should be flushed carefully to avoid rinsing sand, dirt, or debris into the drainage system.

4.2—Snow removal and ice control

In cold climates, it can be necessary to remove snow and ice to maintain a safe, functional facility. Snowplows can damage joint sealants, isolation-joint seals, and deck coatings. Columns, curbs, walls, and even the decks themselves can be damaged by snow-removal activities. Piles of snow also can create a reservoir of salt-contaminated water, contributing to leakage and chloride buildup over extended periods (Fig. 4.2).
A variety of deicing chemicals are commonly used to control ice buildup and reduce slipping and skidding hazards for pedestrians and vehicles. The most common chemical deicers can cause detrimental physical effects to concrete structures. See Appendices A and B for additional information on these subjects.

4.3—Other operational maintenance

Other operational systems in a parking structure that require maintenance but do not affect structural performance include mechanical and electrical systems, lighting, elevators, signage, parking control equipment, security systems, graphics, and striping. Refer to the Parking Garage Maintenance Manual (Parking Consultants Council of the National Parking Association 1996) for additional information on these items.

4.4—Aesthetic-related maintenance

In addition to the structural and operational aspects, maintenance also should address the aesthetic features of a parking structure. These features include landscaping, painting, and general appearance.

4.5—Precast/prestressed concrete

Precast/prestressed concrete is composed of many individual structural components and has good resistance to cracking and corrosion-related surface deterioration due to the consistently high quality of plant-produced concrete components. Precast concrete is characterized by the many sealed joints, which should be maintained to control leakage and avoid related problems (Fig. 4.3). Precast/prestressed parking structures may have a cast-in-place concrete topping that can also exhibit cracking and leakage and require maintenance. Connections between precast elements may exhibit evidence of corrosion which may also require corrective maintenance. Refer also to Concrete Parking Structure Maintenance, by the Precast/Prestressed Concrete Institute.

4.6—Post-tensioned concrete

A cast-in-place, post-tensioned concrete frame and slab has few joints and usually few cracks that leak. It can be vulnerable, however, to restraint-induced cracking, reinforcement corrosion, anchorage deterioration, and related surface deterioration. The integrity of the corrosion-protection system for post-tensioning tendons should be
maintained because of the structural significance of the post-tensioning function. Additional information regarding corrosion of unbonded, post-tensioned tendons is given in ACI 423.3R (Fig. 4.4).

4.7—Cast-in-place, conventionally reinforced-concrete structures

Cast-in-place, conventionally reinforced-concrete structures are more susceptible to damage related to the corrosion of embedded reinforcement because they exhibit more cracking than precast/prestressed or post-tensioned structures. Figure 4.5 shows the interior of a cast-in-place structure.

CHAPTER 5—PARKING FACILITY STRUCTURAL MAINTENANCE TASKS AND FREQUENCIES

See Table 1.

CHAPTER 6—REFERENCES

6.1—Referenced standards and reports

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

**American Concrete Institute**

201.1R Guide for Making a Condition Survey of Concrete in Service

222R Corrosion of Metals in Concrete

224R Control of Cracking in Concrete Structures

362.1R Guide for the Design of Durable Parking Structures

423.3R Recommendations for Concrete Members Prestressed with Unbonded Tendons

504R Guide to Sealing Joints in Concrete Structures

515.1R Revised 1995 A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete
APPENDIX A—Snow removal

It is possible to damage concrete deck surfaces, joint sealants, isolation joint seals, and traffic-deck membranes while clearing snow and using equipment to vacuum or clean the deck. The four most common causes of damage are:

1. Dropping heavy or sharp objects onto the surface;
2. Dragging heavy or sharp objects across the surface;
3. Operating snow-removal equipment with direct contact between the steel plow blade and the deck; and
4. Using studded tires or chains.

To minimize damage, follow these guidelines:

- Make the persons responsible for snow removal or cleaning the structure aware of the potential damage that can occur from their activities. Develop a specific plan that recognizes the problems and reduces the potential for damage. Use equipment that can accomplish the task without relying on excessive speed;
- Clearly mark the locations of isolation-joint or expansion-joint seals in a way that will be visible to the equipment operator when the deck is covered with snow. Colored stripes, flags, or other markings should be placed at each end of the joint to indicate its location. Isolation joint and expansion joint seals should be installed flush, or slightly recessed, to the driving surface to minimize damage from snow-removal equipment;
- Establish a snow-removal pattern so that the plow blade approaches the expansion joints at an angle not greater than 75 degrees. Plowing parallel to the length of the joint is preferable. This will reduce the probability of catching the plow on the edge of the joint. Snowplow damage normally is not covered by the seal system warranty, and the expense associated with any necessary repairs will probably be the owner’s responsibility;
- Plow snow with a gross vehicle weight that can be accommodated by the load-bearing capacity of the deck (4,000 lb axle loads are typical maximum). Equip snowplow blades and bucket loaders with shoes or rubber guards that prevent direct contact with the deck surface. Use a power brush to remove light snow;
- Take special care during snow removal at large, open structures, such as those frequently found at shopping centers. These areas are particularly vulnerable to damage due to the use of high speeds to clear them. Structures with multiple levels and fewer bays are less likely...
to experience significant damage because of the frequent turns required;
• Do not collect or pile snow in corners or other locations. Piled snow can exceed the rated load capacity and cause cracks in the deck, allowing the intrusion of chloride ions into the structure from the meltwater. This can accelerate the deterioration process and result in additional repair expense. Remove excess snow by blowing or off-loading from the structure. Some structures have snow-gates or chutes to accommodate this procedure; and
• Inspect the deck every spring to determine if any damage has occurred during the previous winter. Make repairs as soon as possible.

APPENDIX B—Deicing procedures
Using chemical deicers to control ice buildup is common practice for winter maintenance of parking structures. These chemicals can have major negative effects on the durability of concrete and should be used sparingly. The effectiveness of deicing chemicals is significantly reduced in very cold temperatures.

Some of the common chemicals used for ice control are:
• Sodium chloride (halite, table salt, or road salt) has little chemical effect on concrete itself. It can, however, promote corrosion of reinforcement and other metals in the concrete, and can also damage lawns and shrubs. Using sodium chloride, even with a corrosion inhibitor, is not recommended;
• Calcium chloride, a major active ingredient in many proprietary deicers, has little chemical effect on concrete, but it promotes corrosion of metals. Using calcium chloride is not recommended;
• Ammonium nitrate or ammonium sulfate will not harm most vegetation. Its use may lead to serious concrete deterioration due to direct chemical attack on reinforcement, and is not recommended;
• Calcium magnesium acetate (CMA) helps break the bond between the ice and the driving surface. Its deicing effects are similar to salt, but it requires more time to melt ice, typically 10 to 15 min or longer for equal quantities. CMA has no known adverse effects on concrete or embedded reinforcement. It will not damage lawns or shrubs, and, like road salt, will perform at temperatures down to 20 F (–7 C). Although currently more expensive than rock salt, the price and availability of CMA should improve over time as mass production processes are developed and improved. Other acetates, such as sodium and potassium, are also available. CMA is generally used in a granular form but is also available as a liquid; and
• Prilled urea does not damage concrete, lawns, shrubs, or metal. Prilled urea behaves differently from common road salt; it attracts moisture and will stay “mushy” longer than salted areas. It will take longer to penetrate and melt ice and works best at breaking up ice in combination with solar action. Prilled urea has little effect after dark, in covered areas, or in temperatures lower than 24 F (–4 C). For best results, use prilled urea to break up ice and then remove the ice. Urea is a fertilizer and can create environmental concerns. It should not be used near streams and lakes.

A durable parking structure requires a concrete mixture that is properly designed, air-entrained, and cured. As time progresses and concrete cures, it becomes less permeable. It is important to minimize the amount of deicing chemicals used during the first two years because early exposure can allow these chemicals to migrate into the concrete more rapidly. Avoid the use of sodium chloride, calcium chloride, ammonium nitrate, or ammonium sulfate on the concrete surface.

Ice buildup can be controlled by using heated sand or a mixture of sand and CMA. Avoid applying deicing chemicals containing chloride directly to the concrete. Small amounts of sodium chloride (3 to 5% by mass) added to sand can be very effective to increase traction and prevent skid problems. Apply the sand and sodium chloride mixture to ice only as needed. As soon as weather permits, flush the deck with a large volume of water under low to moderate pressure.

Drain systems should be protected against runoff-related sand accumulation during ice-control operations. Temporary burlap or straw filters can be used to prevent clogging and possible damage to drain systems.

The following deicing measures are recommended in order of decreasing preference:
1. Clean, plow, and scrape off ice and snow; do not use deicing agents;
2. Use sand to increase traction; when washing down the deck, protect the drainage system;
3. Deice with urea or CMA; and
4. Use a mixture of sand and calcium or sodium chloride, but protect the drainage system.

APPENDIX C—Checklist for structural inspection of parking structures
A regular visual inspection of the structural and waterproofing components of the parking structure is an essential feature of a preventive maintenance program. The inspection should be conducted in conjunction with a wash down of the structure so that any active leakage can be noted and its source identified. A report of the inspection should be placed on file for future reference.

Inspect the structure systematically, taking notes to identify the nature of problems observed as well as their location and severity. It is helpful to have a notebook-sized plan sheet of each floor to make notations or diagrams of problems and their locations during the inspection. This process can be simplified if a legend identifying various anticipated conditions is also developed and used to take field notes.

While most problems can be observed by lay persons familiar with the structure, an inspection should be performed by a qualified engineer every three to five years or when new or advanced deterioration conditions are observed.

Visual inspection of the parking structure should include the items listed in Table 1.
Table 2—Checklist

<table>
<thead>
<tr>
<th>DECKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any cracks? Do they leak? What is the location, direction, width, and depth?</td>
</tr>
<tr>
<td>Is the surface sound, or are there areas where surface scaling is present?</td>
</tr>
<tr>
<td>Is any steel reinforcement exposed?</td>
</tr>
<tr>
<td>Is there any evidence of concrete delamination?</td>
</tr>
<tr>
<td>Is there any evidence of corrosion of reinforcing steel or surface spalling?</td>
</tr>
<tr>
<td>Are there any signs of leakage? Describe conditions and location.</td>
</tr>
<tr>
<td>If there is a traffic-bearing membrane are there any tears, cracks, or loss of adhesion?</td>
</tr>
<tr>
<td>Are there low spots where ponding occurs?</td>
</tr>
<tr>
<td>Are the water stains on the underside (soffit) of the deck?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>BEAMS AND COLUMNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any cracks? If so, what is the location, direction, width, and depth?</td>
</tr>
<tr>
<td>Are there any signs of leakage? Describe conditions and note location.</td>
</tr>
<tr>
<td>Is there any concrete spalling?</td>
</tr>
<tr>
<td>Is any steel reinforcement exposed?</td>
</tr>
<tr>
<td>Are bearings in good condition?</td>
</tr>
<tr>
<td>Are bearing plates rusted?</td>
</tr>
<tr>
<td>If bearing pads have been used under beams, are they present and in good condition? Are bearing pads squashed, bulging, out of place, or missing?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STAIR AND ELEVATOR TOWERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any signs of a leaking roof?</td>
</tr>
<tr>
<td>Are there any cracks in the exterior finish?</td>
</tr>
<tr>
<td>Are there any signs of corrosion-related deterioration with the stairs and railings?</td>
</tr>
<tr>
<td>Is any other corrective action required?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ISOLATION JOINTS AND EXPANSION JOINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any leaks through isolation-joint seals and expansion-joint seals?</td>
</tr>
<tr>
<td>Are leaks related to failure of seals or adjacent concrete?</td>
</tr>
<tr>
<td>Could the cause be snowplows?</td>
</tr>
<tr>
<td>What type of isolation joint or expansion joint seal is installed?</td>
</tr>
<tr>
<td>Who is the manufacturer?</td>
</tr>
<tr>
<td>Is there a warranty in force?</td>
</tr>
<tr>
<td>Consult the manufacturer for repair recommendations if applicable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>JOINT SEALANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there any signs of leakage, loss of elastic properties, separation from adjacent substrates, or cohesive failure of the sealant?</td>
</tr>
<tr>
<td>If bearing pads have been used under beams, are they present and in good condition? Are bearing pads squashed, bulging, out of place, or missing?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXPOSED STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there any exposed steel (structural beams, handrails, door frames, barrier cable, exposed structural connections)?</td>
</tr>
<tr>
<td>Is there any exposed embedded reinforcing steel or connections due to the spalling or chipping of concrete cover?</td>
</tr>
<tr>
<td>Is rust visible?</td>
</tr>
<tr>
<td>Is it surface rust or is there significant loss of section?</td>
</tr>
<tr>
<td>Is repainting required?</td>
</tr>
<tr>
<td>What is the condition of attachment point and surrounding concrete?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the drains functioning properly? When were they last cleaned?</td>
</tr>
<tr>
<td>Are the drains properly located so that they receive the runoff as intended?</td>
</tr>
<tr>
<td>Is the seal around the drain base in good condition?</td>
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</tbody>
</table>
## Table 2 (cont.)—Checklist

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PREVIOUS REPAIRS</strong></td>
<td></td>
</tr>
<tr>
<td>Are previous repairs performing satisfactorily?</td>
<td></td>
</tr>
<tr>
<td>Are the edges of previous patches tight?</td>
<td></td>
</tr>
<tr>
<td>Does the patch sound solid when tapped?</td>
<td></td>
</tr>
<tr>
<td><strong>GENERAL COMMENTS</strong></td>
<td></td>
</tr>
<tr>
<td>Are records of previous inspections available? Have they been reviewed?</td>
<td></td>
</tr>
<tr>
<td>Are there previous engineering reports available? Have they been reviewed?</td>
<td></td>
</tr>
<tr>
<td>Has the concrete been tested for chloride content? Are reports available? Have they been reviewed?</td>
<td></td>
</tr>
<tr>
<td>Other comments:</td>
<td></td>
</tr>
</tbody>
</table>

Project: 
Inspected by: 
Date: 

Note: A copy of the inspection report should be added to the operations/maintenance manual each time an inspection is undertaken.