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Parking Structure Structural Maintenance—Guide

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Parking Structure Structural Maintenance—Guide

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Parking Structure Structural Maintenance—Guide

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This guide assists parking structure owners, operators, and the consultants who advise them and who develop maintenance recommendations as required by ACI 562, 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. Refer to ACI 362.1R for more complete information regarding design issues related to the performance of a parking structure.

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

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CHAPTER 1—INTRODUCTION

This guide is intended for owners, operators, and consultants of parking structures who seek advice on developing and implementing a proper maintenance program. All parking structures require regular maintenance to provide a satisfactory level of service and to meet service life expectations without premature deterioration, such as scaling, spalling, leaking, and cracking. Deterioration and distress due to inattention to maintenance increases the likelihood of further distress and deterioration to the structure, which can lead to undue repair expense, interrupted service, inconvenience to patrons, damage to vehicles, personal injury, and loss of revenue. Parking structures can develop more distress and deterioration than most types of buildings because they are directly exposed to traffic, environment, deicing chemicals, and snowplows. An appropriate maintenance program includes timely preventive actions to reduce system failure and premature deterioration, which can reduce the need for significant and expensive repairs.

It is incumbent on an owner interested in maintaining the service life of a parking structure to see that appropriate maintenance is performed. The owner can have this maintenance performed under contract with the parking structure operator, or under contract with a third party. Maintenance actions typically recommended and performed for parking structures are itemized and discussed in Chapters 4 and 5, which also provide a recommended frequency and timeframe for these actions. For a structure that has been repaired, ACI 562 requires that maintenance recommendations be developed by the design professional. These recommendations can be developed through the use of this

document in conjunction with the repair documents for a parking structure.

The use and management of deicing chemicals are an important part of routine parking structure maintenance, as they can directly affect long-term structural maintenance. Unless protection from deicing chemical intrusion is provided, the use of chloride-bearing chemicals such as deicing salts on a parking structure may accelerate corrosion of the embedded reinforcing steel and hasten its deterioration. Deicing salts that are used on streets and highways can also be carried into parking areas by vehicles. If the owner chooses to defer maintenance, improperly manage deicing chemicals, or both, the service life of the structure can be shortened, and costly repairs will become more likely.

This guide emphasizes the maintenance of structural components of parking structures to reduce risks associated with structural deterioration. The types and frequency of maintenance recommended for a structure are directly related to the durability features incorporated into the structure during design and construction. Deterioration problems commonly associated with parking structures are discussed in [Chapter 2](#), while protection systems available for use in parking structures are reviewed in [Chapter 3](#). Operational maintenance, housekeeping, and aesthetic maintenance are discussed in [Chapter 4](#). [Chapter 5](#) provides guidance on developing a maintenance program and a checklist for maintenance tasks and recommended frequencies of these maintenance tasks. Service life considerations and the effect of maintenance on service life are discussed in [Chapter 6](#). Appendixes [A](#) and [B](#) contain information about snowplowing and deicing procedures. [Appendix C](#) contains a worksheet that can be used as a guide for making a visual inspection.

Each type of structural system commonly used in parking structures can develop different deterioration-related problems and may have unique maintenance requirements as a result. By following the recommendations of this guide, a maintenance program can be tailored to address the typical and unique deterioration issues of a particular parking structure. Following such a program will extend the service life of the facility. Further discussion of durability considerations for parking structures can be found in [ACI 362.1R](#). An understanding of these considerations will prove helpful in developing an appropriate maintenance program. Refer also to [Bhuyan \(1993\)](#), [Chrest et al. \(2001\)](#), [ACI 562](#), [ACI 546R](#), and the *Maintenance of Precast Concrete Parking Structures* (PCI 2004).

CHAPTER 2—DETERIORATION ASSOCIATED WITH PARKING STRUCTURES

The implementation of a proper maintenance program is important to provide for the long-term durability and performance of a parking structure. This chapter is intended to provide an understanding of the reasons for a maintenance program and the potential deterioration that can occur without proper maintenance for parking structures. Chapter 5 provides detailed information regarding the development of a maintenance program.

Parking structures are frequently subjected to significant exposure conditions, including thermal changes, moisture, and chloride contamination that, when combined with the dynamic and unbalanced loads created by vehicles in the facility, will require maintenance repairs be performed to address deterioration. Understanding the deterioration mechanisms and their symptoms will give the parking structure owner the ability to recognize why and when a maintenance program is necessary and also will allow the owner to understand the ramifications of not performing regular preventative maintenance.

Problems that are left unattended during the early stages of their development can lead to safety hazards for users, increased liability for owners, expensive repair programs to address, and an eventual reduction in the serviceability and load-carrying capacity of the structure. A maintenance program includes those actions necessary to preserve and restore the structure, and to improve or enhance the protective functions of various waterproofing and anti-corrosion systems.

2.1—Deterioration of concrete

Deterioration of concrete members in a parking structure generally consists of scaling, delamination, spalling, or cracking. Sections 2.1.1 through 2.1.8 discuss various deterioration mechanisms common to concrete parking structures. Refer to ACI 201.1R, 222R, and 224R for additional information regarding the deterioration mechanisms briefly described in this guide.

2.1.1 Scaling—Scaling is the disintegration of cement paste at the surface of a concrete member or slab. It is commonly associated with saturated concrete that has inadequate air entrainment and experiences cycles of freezing and thawing. Scaling can result in progressive deterioration of a concrete structure or member. Severe scaling can result in a loss of concrete surface integrity to depths of more than 1 in. (25 mm). Scaling in deck slabs can create depressions that pose tripping hazards and create ponding areas that can lead to further deterioration (Fig. 2.1.1).

2.1.2 Corrosion—Corrosion is an electrochemical process that results in the deterioration of steel reinforcement and

other metals embedded in the concrete in the presence of sufficient moisture and oxygen. Chloride ions from road salts, carbonation, or other deleterious airborne chemicals can initiate and accelerate the corrosion process. Corrosion can lead to serious concrete deterioration that may require extensive repairs if left unaddressed. As corrosion progresses, the corrosion by-products occupy a greater volume than the original metal, creating internal pressure on the concrete that will eventually lead to cracking, delamination, and spalling of the concrete (Fig. 2.1.2). Additionally, corrosion will result in the loss of cross-sectional area of the steel reinforcement and, if not addressed, eventually a reduction in load-carrying capacity. Refer to ACI 562 and 546R.

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 to reduce or eliminate moisture penetration into the structure during the life of the structure. Refer to ACI 222R for a more complete discussion of the corrosion process and its causes.

Corrosion of unbonded post-tensioning tendons, especially non-encapsulated systems, represents a special case. Post-tensioning tendons can corrode or even fail without cracking or delaminating the surrounding concrete. In some cases, a post-tensioning tendon failure is accompanied by eruption of the strand either at the tendon end anchorage or through the concrete slab surface at a location of shallow cover. Therefore, possible indicators of a tendon failure include exposed strand or dislodged post-tensioning anchors. Other possible visual indications of tendon corrosion include cracking along the line of a tendon, delaminations or spalling at tendon locations, and rust staining on the concrete surface at a tendon location, such as on the soffit of slabs and beams near midspan at tendon low points. For more information on the corrosion, evaluation, and repair of unbonded single-strand tendons, refer to ACI 423.4R and PTI DC80.3.

2.1.3 Delaminations—Delaminations are internal cracks in the concrete, parallel to the surface of a structural member,



Fig. 2.1.1—Area of scaling on concrete surface.



Fig. 2.1.2—Corrosion of reinforcement can lead to the formation of delamination and spalling of concrete.



Fig. 2.1.3—Loose delaminated concrete on slab underside.

usually resulting from corrosion of the embedded reinforcing steel. Extensive concrete delaminations (greater than 5 to 10 percent of the surface area delaminated or spalled) are an indication of advanced deterioration. Delamination on the underside or soffit of a parking deck (slabs or framing members) can be a safety hazard due to the possibility of the delaminated concrete becoming loose and falling. Refer to Fig. 2.1.3.

2.1.4 Spalling—Spalling is the fracturing and separating of a portion of the outer surface of concrete from the main portion of a concrete member or structure. 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 that correspond to the depth of the reinforcing steel. 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. Figure 2.1.4 shows how corrosion-induced stresses can lead to concrete deterioration and spalling.

2.1.5 Cracking—There are many possible causes of cracking in concrete. For most parking slabs, well-distrib-

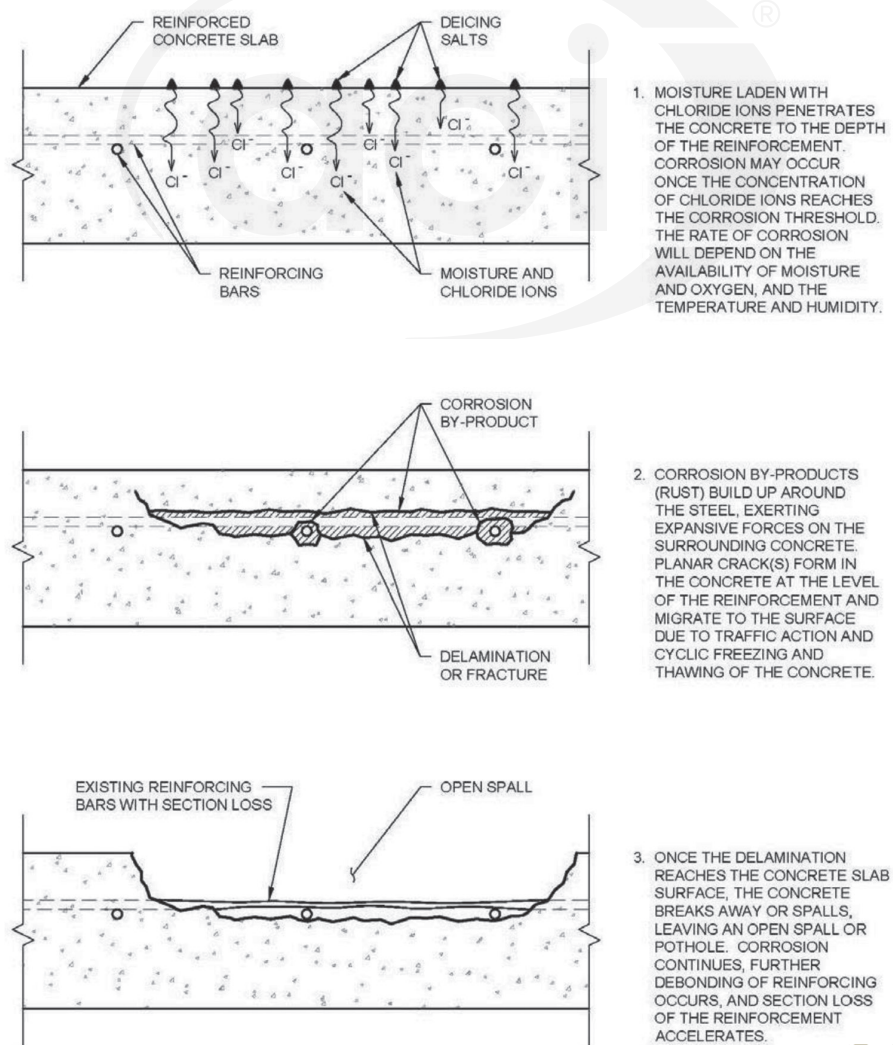


Fig. 2.1.4—Corrosion-induced delamination and spalling process.



Fig. 2.1.5—Cracks in concrete allow accelerated absorption of water and chlorides.

uted 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 (Fig. 2.1.5). 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. Refer to ACI 546R and ACI 562 for additional information.

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 assessment. A structural crack can appear in the slab, beam, column, bearing area, or other location essential to supporting the applied loading. Cracks can be moving (cracks that change in width in response to applied loads or thermal cycles) or static (cracks that do not change in width), both types of which could result in leakage.

2.1.6 Leaking—Leaking cracks, which are marked by moisture staining, efflorescence, mineral deposits, or corrosion staining, 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. Leaks are most frequently related to improperly sealed cracks or joints. Leakage can accelerate deterioration by



Fig. 2.1.7—Leaking and leaching can result in extreme deterioration conditions if cracks are not sealed.



Fig. 2.1.8—Ponded water can contribute to leakage problems and lead to accelerated deterioration.

providing a direct path for chloride-laden moisture to penetrate the concrete to the level of the embedded steel reinforcement; therefore, it should be addressed promptly. Additionally, through-slab leakage can be a nuisance by dripping on pedestrians and staining automobiles if the water contains dissolved minerals or corrosion by-product.

2.1.7 Leaching—Leaching occurs when water passes through cracks or the concrete itself, dissolving the cement constituents and transporting them to the concrete surface where dripping or evaporation occurs. The dissolved constituents precipitate at the surface as the water evaporates, appearing as efflorescence or as calcareous deposits on the surface of the concrete. The dissolved constituents can combine with each other or with atmospheric chemicals. One common example is calcium carbonate, which is produced by atmospheric carbonation of calcium hydroxide leachate. Mineral deposits can also form along cracks as crystals, stalactites, or stalagmites below where water with dissolved minerals passes through slab cracks for extended periods. (Fig. 2.1.7).

2.1.8 Ponding—Ponding (Fig. 2.1.8) can be a cause of deterioration because of the concentrating of water and deicing salts. The presence of standing water for extended

periods indicates that inadequate slopes to the drains have been provided. Improper drainage allows water laden with chlorides or other deleterious minerals to penetrate the concrete surface and increase in concentration rather than flow off the top deck surface. In the northern climates, ponding water can freeze and become a slip-and-fall hazard.

2.2—Deterioration of specific structural elements

A parking structure's most significant structural elements are the supported structural slabs and underlying structural frame elements. Therefore, these elements should be examined on a regular basis to determine their condition as an important part of an ongoing maintenance and repair program.

2.2.1 Concrete deck surface—A common cause of deterioration of structural slabs and surfaces is the penetration or saturation of water, which can cause damage when it freezes. Additional damage can occur when the water is laden with chlorides, creating a chemistry that promotes the corrosion of the embedded steel. The sources of chlorides typically include deicing salts applied directly to the slab, automobiles bringing deicing salts into the parking structure, and airborne sources near the ocean.

A parking structure should be monitored annually for concrete deterioration. Open spalls and delaminations in the structural slab should be assessed and appropriately repaired to reduce progressive deterioration and maintain serviceability. Temporary repairs can be performed if there are time or weather constraints until the source of the problem can be identified and long-term repairs accomplished. Delaminated concrete on the underside of slabs and framing members should be removed before it can loosen and become a safety hazard. 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.

2.2.2 Beams, columns, and walls—Beam, column, and wall deterioration can adversely affect a structure's integrity and load-carrying capacity, so those members should be examined periodically for cracking and spalling. In addition to delaminations, spalling, and cracking in conventional concrete members, deterioration can take various forms including, but not limited to, corroded and failed precast double-tee beam flange-to-flange or precast wall connectors; cracked and delaminated corbels; corroded embedded reinforcing and bearing plates on corbels; ineffective bearing pads supporting precast elements; cracking of double-tee beam stems parallel to the prestressing strands; loss of bearing; or any combination of these. Although deterioration of these underlying members is primarily attributed to water leakage through failed joints and deck-slab cracks, it can also be caused by inadequate design or detailing for movement of the structure.

Vertical surfaces of columns and vehicle barrier walls are also susceptible to damage by airborne chlorides, ponded water laden with chlorides, and salt water splashed from moving vehicles. In addition, vertical surfaces such as

concrete barrier walls, spandrel beams, and columns are vulnerable to vehicle impact.

Beams and columns adjacent to and below expansion joints are especially susceptible to deterioration if the joint seals are not properly maintained (Fig. 2.2.2a). Failed joint seals allow water to run down the faces of beams and columns, which can result in delaminations and, potentially, a reduction in the member capacity. Beam and column deterioration can be minimized by maintaining joint sealant systems, and by applying sealers and elastomeric membranes on the deck surfaces above and on column concrete and bumper walls just above the deck surface. Connections of exposed steel elements and members containing embedded steel connections should be inspected regularly for corrosion and distress, and any protection provided for those connections should be maintained.

If the parking structure is below grade, wall cracks are susceptible to through wall leakage, which can result in deterioration. Injection of these cracks with polyurethane grout or the installation of a membrane on the exterior of



Fig. 2.2.2a—Delamination and spalling on beam beneath leaking expansion joint.

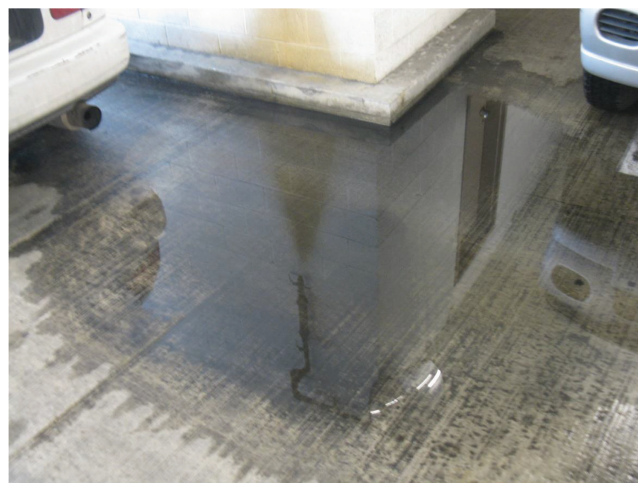


Fig. 2.2.2b—Water can collect and pond along vertical concrete surfaces such as walls and columns, resulting in premature deterioration of those elements.