Manual

Precast/Prestressed Concrete Institute

Maintenance Manual for Precast Concrete Parking Structures

MNL-136-19

Second Edition

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CHAPTER 1—INTRODUCTION

Parking structures, more than other building types, require routine maintenance and occasional repair throughout their service life. This manual is intended to assist owners, architects, engineers, contractors, and operators in preserving and extending the life of precast concrete parking structures. The recommendations, guidelines, and procedures contained in this manual serve as a resource for architects and engineers during the design phase, and for operators and owners after construction has been completed.

Unlike other buildings, the above-grade components of parking structures are directly exposed to weather and other environmental conditions. Extreme temperature changes, rain, snow, ice, road debris, and atmospheric moisture can progressively deteriorate the structure, potentially contributing to performance problems. In addition, exposure to deicing salts, vehicle fluids, and concentrated vehicle loads can also contribute to deterioration of the deck and other structural components. The rate and degree of the deterioration depend on the geographic location of the structure, design and construction features, the use of the facility, the quality of maintenance, and other factors.

A well-designed and well-constructed precast concrete parking structure offers superior resistance to deterioration. Plants certified by the Precast/Prestressed Concrete Institute (PCI) are monitored for quality control, fabrication, and operating procedures. As a result, these plants manufacture concrete elements with a high degree of quality and uniformity. The plant-controlled environment also facilitates the use of durable concrete mixtures and specialty curing processes, which are more difficult to achieve with field-placed concrete. These inherent advantages of precast concrete help the owner and operator control maintenance costs from the date the structure is placed into service. However, without development and implementation of a proper maintenance program, the long-term performance of any type of structural system will be compromised.

A proper maintenance program will result in a cleaner, safer, and more user-friendly atmosphere within the structure. In addition, a well-maintained structure (Fig. 1.1) promotes user satisfaction, presents a positive image, and discourages littering and loitering. A well-maintained parking structure also reflects positively on the facility owner/operator and adjacent businesses. Thus, it is essential for a maintenance program to be a major component in the design and operation of all parking structures. The program should be established before initial occupancy and adjusted as appropriate over the structure's service life.

Figure 1.1. Well-maintained parking structures provide a user-friendly atmosphere. Photo: University of Mississippi.

This manual contains guidelines for maintaining precast concrete parking structures. It is common for a variety of nonprecast materials such as cast-in-place concrete, steel, and masonry, to be incorporated into precast concrete parking structures. Most guidelines contained in this manual are generally applicable to nonprecast materials and systems. However, some of the nonprecast components may require maintenance procedures that are not covered in this manual. In addition, mechanical/electrical, security, and revenue control systems, elevators, and other nonstructural systems have specific maintenance requirements that are typically developed by the manufacturer or supplier. These additional requirements should be incorporated into the facility's maintenance program.

Numerous PCI technical documents contain detailed information regarding the design and construction of precast concrete parking structures, including topics related to materials, durability, and maintenance. Selected documents are listed below.

- PCI Parking Structures Committee Fast Team. 2007. "Joints in Precast Parking Structures." *PCI Journal* 52(5): 124–139.
- PCI Parking Structures Committee. 2015. *Prestressed Concrete Parking Structures: Recommended Practice for Design and Construction*. MNL-129. 3rd ed. Chicago, IL: PCI.
- PCI Industry Handbook Committee. 2017. *PCI Design Handbook: Precast and Prestressed Concrete*. MNL-120. 8th ed. Chicago, IL: PCI.

The following documents published by organizations other than PCI include design and maintenance guidelines for a broad variety of structural systems and components:

- American Concrete Institute (ACI) Committee 362. 2012. *Guide for the Design and Construction of Durable Concrete Parking Structures.* ACI 362.1R-12. Farmington Hills, MI: ACI.
- ACI Committee 362. 2000 (reapproved 2013). *Guide for Structural Maintenance of Parking Structures.* ACI 362.2R-00. Farmington Hills, MI: ACI.
- National Parking Association (NPA). 2016. *Parking Facility Maintenance Manual*. 5th ed. Washington, DC: NPA.

CHAPTER 2—TYPES OF MAINTENANCE

Parking structures require a diligent maintenance program to ensure proper operation and achieve reliable long-term performance. Broad categories for maintenance of parking structures are often described as *housekeeping maintenance, preventive maintenance,* and *structural repairs.* Within these categories are specific items that require periodic attention. For example, snow removal is a special type of housekeeping maintenance for structures located in areas with frequent winter precipitation.

In addition, maintenance should include traffic control and other means of limiting the weight and speed of vehicles within the structure.

2.1 Housekeeping Maintenance

Housekeeping maintenance involves routine, scheduled tasks that address the aesthetic appeal and functional performance of the facility. Users of a parking structure tend to consider their parking experience to be satisfactory if the facility is clean and safe. Housekeeping maintenance involves the following tasks:

- General cleaning: Trash removal, drain cleaning, sweeping, and window cleaning
- Floor washing: High-pressure wash-down and removal of road salts and oil stains
- Expansion joints and control joints: Cleaning of debris (Fig. 2.1)
- Painting: Touch-up of painted surfaces
- Landscaping: General upkeep of irrigation system and plants
- Doors and hardware: Checking for proper operation
- Striping and graphics: Repainting parking stripes and graphics
- Lighting fixtures: Cleaning lenses and replacement of lamps
- Emergency lighting: Checking for proper operation
- Elevators: Cleaning, inspection, and maintenance
- Signs: Cleaning and repair
- Graffiti: Removal
- Snow and ice control: Plowing and snow removal; deicing of traffic areas
- Security system: Checking for proper operation
- Parking equipment and revenue control system: Checking for proper operation
- Janitorial services: Cleaning and maintaining lavatories, offices, lobbies, and other areas
- Heating, ventilation, and air-conditioning (HVAC) system: Replacement of filters and other routine scheduled maintenance

The housekeeping items listed previously should be performed on a periodic basis, as suggested in Table 2.1. The parking operator is typically responsible for carrying out these duties because good housekeeping tends to increase parking revenue, facilitate day-to-day operations, and achieve user satisfaction.

The cleanliness of surfaces and the absence of litter are direct indications of the amount of attention that an operator has committed to caring for the facility. Lack of attention is an invitation to loiter in the facility and may reduce the safety of users. Maintaining clean, odor-free, and sanitary stairwells is especially important given the frequent pedestrian traffic in these areas of the facility. Sweeping should include removal of debris from drains, expansion joints, and control joints. Cleaning should include removal of litter from overhead ledges.

Figure 2.1. Housekeeping should include frequent cleaning of joints. The joint shown in the left photo contains debris. Clean joints (right photo) will increase service life. Photos: Michael Lee.

Highly visible parking striping promotes the centering of vehicles within designated spaces. If striping is changed, do not paint over existing striping. It is better to remove existing striping completely so that two sets of striping do not create confusion and a cluttered appearance. Removal can be achieved by abrasive, water, or sodium bicarbonate (baking soda) blasting.

Uniform, functional lighting correlates with user security. Therefore, a high priority should be placed on maintaining the lighting system. Lighting fixtures lose much of their effectiveness when dirt accumulates on lenses of clear covers. Therefore, it is recommended that all fixtures be cleaned annually. It is important that lamps be replaced before they burn out. A schedule of relamping based on the estimated lamp life is recommended. Burned-out lamps should be replaced in a timely manner.

Security systems, battery-operated emergency lighting, and emergency generators should be checked frequently to ensure that they function properly. Ventilation and carbon monoxide monitoring systems in enclosed structures must be checked regularly.

Light to moderate oil stains are generally not detrimental to the structure, but their removal improves facility appearance. Heavy stains should be removed immediately to eliminate slippery and hazardous conditions.

2.2 Snow Removal Maintenance

In areas where winter weather affects the operation of a parking facility, timely removal of snow and ice is essential for public safety and the functional performance and long-term durability of the structure. The method, equipment, and materials needed to remove snow and ice depend on the characteristics of the storm, the area to be maintained, and other factors. Special care must be taken during removal operations to avoid damaging the structure.

Table 2.1. Housekeeping schedule

Housekeeping Items	Frequency							
	Daily	Weekly	Monthly	Quarterly	Semiannually	Annually	As required	Other
Sweeping	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Localized	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Overall	n/a	X	n/a	n/a	n/a	n/a	n/a	n/a
Trash pickup	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cleaning	n/a	n/a	n/a	n/a	X	n/a	n/a	n/a
Control joints	n/a	n/a	n/a	n/a	X	n/a	n/a	n/a
Elevators	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Expansion joints	n/a	X	n/a	n/a	n/a	n/a	n/a	n/a
Floor drains	n/a	O	n/a	n/a	X	n/a	n/a	n/a
Graphics	n/a	n/a	n/a	n/a	n/a	X	n/a	n/a
Office, lavatories, cashier booths	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Light fixtures	n/a	n/a	n/a	n/a	n/a	X	n/a	n/a
Stains	n/a	X	n/a	n/a	n/a	n/a	n/a	n/a
Windows	n/a	n/a	n/a	n/a	X	n/a	n/a	n/a
Elevator maintenance	n/a	n/a	n/a	n/a	n/a	X	n/a	n/a
Parking space restriping	n/a	n/a	O	n/a	n/a	n/a	X	n/a
Remove oil stains	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Relamping	O	X	n/a	n/a	n/a	n/a	n/a	n/a
Check light fixtures and exposed conduits and repair	n/a	n/a	O	n/a	n/a	n/a	X	n/a
Graffiti removal	n/a	X	n/a	n/a	n/a	n/a	n/a	n/a
Graphics repair and maintenance	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nonilluminated	n/a	n/a	n/a	O	n/a	n/a	X	n/a
Illuminated	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Parking equipment maintenance	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Security system check	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Landscaping	n/a	X	n/a	n/a	n/a	n/a	n/a	n/a
Doors and hardware	X	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ventilation (cleaning and testing)	O	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Snow removal	X	n/a	n/a	n/a	n/a	n/a	X	n/a
Ice removal	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Safety checks	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Carbon monoxide monitor	O	n/a	n/a	n/a	n/a	n/a	X	O[1]
Exit lights	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Emergency lights	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Tripping hazards	O	n/a	n/a	n/a	n/a	n/a	X	n/a
Handrails and guardrails	n/a	O	n/a	n/a	n/a	n/a	X	n/a

Source: Partially based on information from *Parking Facility Maintenance Manual* (National Parking Association, 2016).

Note: See text for additional information. n/a = not applicable; O = inspect; X = perform operation.

[1]Schedule is for enclosed parking structures (warning to management office is recommended before monitor is tested).

2.2.1 Planning

Parameters for snow and ice removal should be established and addressed during the design phase so that snow storage and removal features can be properly incorporated during construction. The anticipated maximum amount and frequency of snowfalls will influence planning strategies.

Removal of snow is typically handled by using plows, shovels, or other equipment to move the snow, to snow chutes or designated openings ("gates") in exterior spandrels. Alternatively, use of snow melting equipment can be an effective option. Snow should not be temporarily stored in piles unless specific parameters have been provided by a structural engineer. Critical parameters include pile height, dimensions, and location. Piling up snow in a manner that exceeds the design capacity of the deck can result in structural damage, and significant overloading can cause collapse. In addition to considering the structural aspects of storing snow, consideration should be given to the effect of snow piles on sight lines, the possible loss of parking spaces, and the potentially deleterious effect of deicers that may be present in the snow.

Protected snow-dumping zones are required beneath snow chutes and gates to ensure the safety of workers, pedestrians, and vehicles. Multilevel parking structures also require special procedures to prevent the penetration of falling snow onto lower parking levels. The number of dumping locations depends on the structure size, anticipated snowfall rate, and adjacent property locations.

Once a removal plan has been developed, discussions between the owner and operator of the parking structure regarding responsibility for snow and ice removal are recommended. Contracted services and in-house maintenance staff represent two common options for removal. The developed procedures should be clearly communicated to the personnel performing and overseeing the work.

Components that could be damaged during removal operations should be identified in the removal plan. Examples include expansion joints, joint sealants, membranes, signage, lighting, and floor drains. Markers highlighting such obstacles can be installed before the beginning of the winter season and removed when the season is over.

Adequate drainage is a critical component of proper snow and ice removal. Before the arrival of freezing weather, areas of ponding water should be identified and remedial measures implemented to eliminate them. Drains should be inspected and cleaned of debris or other obstructions. Water lines used for surface cleaning should be drained to avoid damage from frozen water.

2.2.2 Equipment

Removal of snow and ice is accomplished using specially designed equipment that is available in various sizes, weights, and systems. The type of equipment will affect the efficiency of the removal operation. Skid-steer loaders (for example, Bobcats®) are not recommended for snow removal. Plows and other snow removal equipment that contact the deck should be equipped with well-maintained rubber-tipped blades to minimize damage to the concrete structure.

The weight of the snow removal equipment should not create a condition that exceeds the live load for which the deck was designed. Before equipment is chosen, the structure should be evaluated by a structural engineer to ensure that the deck can safely support the equipment's maximum working weight and associated concentrated loads. Special attention should be given to one-level parking structures that are situated at or near grade level. Because one-level structures may not have the inherent height restrictions common with multilevel structures, it is important to prevent inadvertent use of removal equipment that might be appropriate for use on adjacent surface parking lots but is too heavy for the parking structure.

2.2.3 Chemical Deicers

The use of chemical deicers can affect the structure's efficiency, safety, and longevity. Deicers must be chosen carefully with consideration given to their chemical potency, availability, and cost. Improper use of deicers may be deleterious to the structure, harmful to the environment, or both.

Many types of chemical deicers are available. Some, like chlorides, are relatively inexpensive but are much more harmful to the structure than ureas or calcium magnesium acetate. Sodium or calcium chloride (rock salt) deicers are not recommended.

Deicers work by chemically lowering the freezing temperature of water. They should melt snow at several degrees below 32°F but may not be effective at very low temperatures. Chemical deicers also reduce the surface tension of water and can promote saturation of the underlying concrete. When deicing chemicals form a slush from ice or snow, that slush should be removed to limit saturation that can cause surface scaling and to prevent melted liquids from refreezing at colder temperatures. Removing slush is especially important in pedestrian walkways.

Chemical deicing equipment must be capable of distributing deicers uniformly, efficiently, and in a controlled manner. As with snow removal equipment, the weight of deicing equipment should not exceed the live load for which the deck was designed.

To avoid scaling of the concrete surface, deicers should not be used until the structure is at least one year old. Mitigation measures within the first year include manual removal of snow or ice or use of noncorrosive material (for example, sand). A design professional should be consulted for recommendations based on job-specific conditions.

Deicers can adversely affect the environment. Transportation agencies minimize use of sodium or calcium chloride because of the detrimental environmental effects of these products.

The deck surface should be washed immediately following the winter season. Use of high water volume from a 1¼-in.-diameter or larger hose is recommended. The design of the facility should include provision for sufficient water to clean all surfaces that can be contacted by deicers (that is, all floor levels in addition to the roof). A specialty contractor with a truck-mounted pressure washer can also be employed.

2.2.4 Snow Removal Procedures

The following guidelines should be followed during the snow removal process:

- Snow plows must be equipped with rubber-tipped blades to minimize impact and abrasion damage to the structure. During snow removal, the blades should not come into direct contact with expansion joints, deck membranes, or joint sealants. The blades should be kept a minimum of ½ in. above these easily damaged items and should not impact vertical offsets between adjacent deck surfaces. Grinding of uneven edges of adjacent deck surfaces may be necessary.
- Equipment driving speed should be reduced at changes in floor slopes, such as the ends of ramps, washes, the ends of double tees, and wheelchair ramps.
- Impact forces caused by pushing snow into walls or spandrels should be avoided. Additionally, dumping snow into storage piles should be avoided to minimize impact forces on decks.
- Snow must not be stored directly over floor drains. The area over drains must be kept clear so melt water will not pond.
- Frozen pieces of snow or ice that have fallen from vehicles should be removed daily, along with hanging icicle formations.
- Frozen pieces of snow or ice that have accumulated on facade elements should be removed daily. Alternatively, personnel can cordon off pedestrian pathways at risk for falling snow or ice.
- As previously mentioned, excessive snow piling can result in structural damage and even collapse. Snow should be piled only on decks or portions thereof that have been specifically designed for the additional weight of snow piles. The snow removal team must be aware of pile limits and take precautions not to exceed them.

Keeping a parking structure free of snow and ice and removing deicing salts are essential maintenance tasks to ensure public safety as well as the proper performance and long-term durability of the facility. The safety of stairs, landings, and other areas of pedestrian egress must be a top priority. Planning, selection of proper equipment and deicers, and adherence to proper procedures are necessary for a successful snow and ice removal program.

2.3 Preventive Maintenance

Preventive maintenance involves periodic inspection, cleaning, and restoration of all components of the parking structure. This type of maintenance will prolong the useful service life of the structure. In addition, it helps personnel to detect and address minor problems at an early stage before they can develop into potentially significant issues.

If an owner chooses to invest in durability-enhancing features during the original design and construction of the facility, preventive maintenance and future repair costs will be lower. Examples of durability-enhancing features include corrosion-resistant reinforcing steel and low-permeability concrete. Therefore, it is recommended that the owner, not the operator, be primarily responsible for preventive maintenance.

Preventive maintenance should include a periodic inspection of structural, architectural, mechanical, electrical, communication, and other components to verify proper performance. For the structural system, the inspection should include a visual observation of the structural components conducted by an engineer experienced in the design, construction, and restoration of parking structures. Drainage and sealants are important in structural system maintenance. Over time, diminished performance of these elements can contribute to material degradation and associated structural distress.

Some equipment maintenance may be performed by the owner or operator in accordance with the manufacturer's recommendations. However, in general, only trained technicians should service revenue control equipment, life safety systems, elevators, security systems, and other specialized equipment.

The primary components of the recommended periodic inspection are listed in sections 2.3.1 to 2.3.3.

2.3.1 Structural Systems Maintenance

- **Double-tee floor members:** Visually inspect for delamination, spalling, cracking, and scaling. Check flange connections for signs of weld failure or corrosion damage.
- **Floor and roof deck members:** Visually inspect for spalling, cracking, and scaling. For field-applied concrete topping, also inspect for delamination and indications of corrosion.
- **Beams, spandrels, and columns:** Visually inspect for spalls, cracks, and delamination as well as indications of corrosion.
- **Stair and elevator towers:** Check handrails, treads, landings, metal or precast concrete stair members, walls, and roofs for deterioration. Check concrete adjacent to handrails and at the interface with concrete framing at the main parking structure for signs of distress.
- **Exposed steel:** Check bearing plates and welded connections for corrosion. Check grouted connections for rust stains.
- **Bearing pads:** Visually inspect bearing pads for distress or displacement (Fig. 2.2).
- **Sealers and deck coatings:** Check for tears, abrasions, delaminations, debonding, or other deterioration. Identify areas where slip resistance of coatings may be compromised.
- **Joint sealants:** Check for deterioration and leaks.
- **Expansion joints:** Check for deterioration and leaks.
- **Drainage:** Check for leaks, inadequate drainage, or clogged drains. Check stair and elevator roofs for deterioration, standing water, or leaks.
- **Vehicular barrier systems:** Inspect cables for tightness and anchorages for damage. Review condition of attachments to panels serving as barriers.
- **Tripping hazards:** Check curbs, stair thresholds, and floor surfaces for vertical offsets in walking surfaces that may represent potential hazards. Any identified tripping hazards should be addressed immediately.

Figure 2.2. Proper double-tee bearing pad position on support surface reduces the potential for distress. The photo on the left shows a pad that is properly centered with respect to stem width. A misplaced or displaced pad (right photo) can cause spalling. Photos: Michael Lee.

2.3.2 Equipment Maintenance

- **Parking access and revenue control equipment:** Check system components in accordance with the owner's manual; retain trained technicians as required.
- **Lighting:** Replace lamps, check and calibrate timers and photocells, and visually inspect conduit and electrical panels.
- **Exit and emergency lighting:** Check and replace lighting as necessary. Periodically test the battery pack and emergency lighting system. Inspect the emergency generator in accordance with the manufacturer's recommendations and local ordinances.
- **Security systems:** Inspect and test surveillance cameras, audio monitoring devices, emergency phones, panic alarms, door panic hardware, and other security-related systems.
- **Fire protection systems:** Inspect standpipes and sprinkler systems as well as fire extinguishers, hoses, and cabinets.
- **Elevators:** Inspect and maintain elevators in accordance with the manufacturer's recommendations and local ordinances.
- **Plumbing system:** Check drains, piping, and risers for blockage or other damage. Flush the system periodically. Check heat-tracing elements for proper performance.
- **Ventilation equipment:** Inspect fans, ductwork, and support systems in accordance with the manufacturer's recommendations.
- **Snow removal equipment:** Check gates, chutes, and heating elements.
- **Photovoltaic panels:** Inspect, clean, and maintain panels as recommended by the manufacturer.
- **Electric vehicle charging stations:** Inspect and maintain stations as recommended by the manufacturer.
- **Wayfinding systems:** Inspect systems for proper operation.

Deficiencies or deterioration uncovered during checks should be addressed in a timely manner. Minor items may be addressed as part of preventive maintenance, while more serious deterioration or malfunction may need more detailed evaluation and repair by specialized personnel.

2.3.3 Protective Systems Maintenance

2.3.3.1 Semiannual or Annual Maintenance

A semiannual or annual inspection should include a review of protective systems to minimize the intrusion of water and deicing salts into the concrete and prevent future deterioration. The following should be done semiannually for parking structures in areas where deicing salts are used and those in areas near coastal seawater. They should be done annually for structures in areas where deicing salts are not used and those more than 15 miles from coastal seawater.

- Flush floor surfaces with sufficient water volume and pressure to remove dirt and debris. In general, a 1¼-in.-diameter hose is adequate. Garden hoses are not adequate for cleaning decks. Flushing should start by cleaning at the top level. For parking structures located in geographic areas where deicing salts are used, flushing should be performed immediately after the last freeze. Flushing should be performed with floor drains protected by screens to prevent clogging. Care should be taken to avoid damaging sealants and coatings with high-pressure water jets. Flushing could include horizontal surfaces of bearing ledges, corbels, and similar items below the top surface of the deck that have the potential to accumulate dirt, debris, and contaminants.
- Inspect floor surfaces for wear and cracking. An increase in the number and severity of cracks, or any other significant surface deterioration (Fig. 2.3), such as fractured and displaced concrete, should be brought to the attention of a structural engineer experienced with concrete restoration. If appropriate, spalls in floor surfaces should be patched and worn spots leveled with suitable repair materials. If reinforcing steel or steel plates are exposed because of deteriorated concrete, the steel should be cleaned and suitably prepared by abrasive blasting, hydroblasting, or power wire brushing. The engineer should review distressed conditions and specify materials, anticorrosion coatings, and other repair products. Cracking noted during periodic inspections should be documented to aid in determining whether cracks are “moving” or enlarging. Moving cracks are typically sealed with an elastomeric sealant after routing. Studies have shown that very narrow cracks (less than 0.008 in.) are typically regarded as nondetrimental to the serviceability of the deck and have little influence on the corrosion process. Studies have also shown that where cracking is perpendicular to the reinforcement, the possibility of corrosion is greatly diminished. Application of a penetrating silane sealer creates a thin hydrophobic protective layer on the surface and provides additional protection against corrosion. The potential value of such a sealer is project-specific. If a silane sealer is used, periodic reapplication is required to maintain effectiveness.

Figure 2.3. Comparison of a deck surface exhibiting excessive deterioration (left) and a deck surface in pristine condition. Left Photo: Michael L. Lee. Right Photo: Ted O'Shea.

- Inspect deck expansion joints (Fig. 2.4) and control joints for deterioration, wear, and damage. Expansion joints are particularly susceptible to damage from snowplows and vehicles. Many expansion joint manufacturers have specific requirements and conditions that must be satisfied to maintain warranty coverage.

Figure 2.4. Comparison of a debonded and torn expansion joint seal (left) and a seal in excellent condition. Photos: Michael Lee.

- Inspect and clear floor drains (Fig. 2.5) and downspouts. Remove barriers that impede proper water flow to drains. Cleaning of drains and drainpipes should include removal of grates and cleaning of pipes.

Figure 2.5. Comparison of a clogged and unclean floor drain (left) and a clean floor drain. A clean drain promotes surface drainage and therefore mitigates deterioration of concrete deck. Photos: Michael Lee.

- Elastomeric traffic-bearing membranes should be patched when visual inspection reveals ripping, tearing, bubbling, or excessive wear. Discoloration can be an early indication that the membrane is approaching the end of its useful life.

2.3.3.2 Annual (Spring) Maintenance

- Inspect structural connections. The following connection types should be monitored and maintained as required:
  - **Recessed connections** (Fig. 2.6): It is common practice for welded connections between members to be recessed and covered with a grout or sealant to conceal and protect the connection plates. Cracks and separations may form along edges of the recess. These conditions can often be addressed, if needed, by grouting and applying a sealant along the perimeter. Cracking within the patch, corrosion of concealed metal, weld damage, or distress in the surrounding substrate should be evaluated by an engineer.

Figure 2.6. Comparison of a recessed connection exhibiting cracking along perimeter and spalling of grout cover (left) and a grouted connection in excellent condition. Photos: Michael Lee.

- **Bolted connections:** Bolted connections are often used between precast concrete members, such as spandrel-to-column connections. Recessed areas at these connections are often covered with a plastic cap or filled with grout. If signs of water penetration are present, the connection should be checked for corrosion. Remedial measures should be implemented to treat any corrosion and prevent future water ingress. These connections should also be checked to ensure proper engagement of the nut onto the threaded rod or bolt.
- **Slotted connections:** In areas where allowance for vertical or horizontal movement is provided, slotted connections are often used. Where accessible, these connections should be inspected for binding, corrosion, proper engagement, and distress. Any accumulated debris that inhibits free movement should be removed.

- Inspect joint sealant (Fig. 2.7). Typically, water leakage through the joint, separation of the sealant from the concrete substrate, cracking of the substrate, or tearing of the sealant indicates a need for sealant replacement. Several types of joint sealants are available. The most common are polyurethanes and silicones. Silicones should be used to replace silicone sealants. Installation procedures and specifications depend on the sealant material and manufacturer. It is recommended that only experienced installers be retained for surface preparation and sealant installation. Critical issues to consider include the following:
  - Sealants should be installed at times when the seasonal temperature is near average, if possible. Sealant should not be installed during periods of extreme heat or cold.
  - The sealant depth should be a minimum of $\frac{3}{8}$ in. An ideal sealant width-to-depth ratio is 2, but acceptable ratios may vary between 1 and 3. Special precautions may be required at large or narrow joints. Manufacturer's specifications should be followed.
  - Backer rods or bond breakers should be used to prevent bonding at the bottom of the sealant reservoir.
  - Joint preparation is critical to ensure sealant performance. Joints must be clean and free of defects such as spalls and unsound concrete. In addition, remnants of old sealants should be removed. Grind, clean, and prime concrete surfaces that will directly contact the sealant. Also grind surfaces that have the potential to create a joint failure, such as sharp edges exposed to wheel pressure.

  Additional guidance relating to installation and maintenance of joint sealants is provided in the PCI Parking Structures Committee Report, "Joints in Precast Parking Structures," cited in Chapter 1 of this manual.

Figure 2.7. Comparison of debonded and torn joint sealant (left) and sealant in good condition. Photos: Michael Lee.

- Inspect bearing pads. The function of a bearing pad is to distribute load between two precast concrete elements and allow horizontal and rotational movement to occur through small deformations of the pad. Typically, pads are functioning adequately if direct contact between the precast concrete elements has not occurred and the effective bearing area of the pad is able to transfer the load. Close-up inspection will help identify distressed conditions or displaced pads not visible while walking on the deck. If cracking has occurred in the pad or in the adjacent bearing surface, or if the pad is not in its proper position, an engineer should evaluate the condition.
- Inspect slide bearing pads and assemblies at expansion joints. Proper joint performance relies on uninhibited movement and proper component alignment. Damaged or displaced components should be evaluated by an engineer.
- Inspect steel components. Clean unprotected or corroded steel, and apply a corrosion-inhibiting coating system. Proper surface preparation is critical to optimizing the service life of the coating. Surface preparation should include removal of oils, dirt, salts, rust, loose paint, and contaminants by solvent cleaning, hand cleaning, or blast cleaning. The Society for Protective Coatings (www.sspc.org) provides additional surface preparation and coating guidelines.

2.3.3.3 Periodic Maintenance

- If a surface sealer such as polyurethane, epoxy, or other material was applied during construction as a floor surface water repellant, it will need to be reapplied periodically. The frequency of reapplication will depend on numerous factors, including material properties, substrate condition, and exposure. In the absence of specific information provided by the manufacturer or an engineer, consideration should be given to budgeting for reapplication every five years. Areas of heavy abrasion, such as turn and acceleration lanes, may require more frequent reapplication.
- If a penetrating silane or siloxane sealer was applied, it generally should be evaluated for effectiveness after approximately five years. Reapplication may be needed at that time, depending on substrate type and orientation, exposure to abrasion and ultraviolet light, and other factors.
- Traffic-bearing membranes will need to be recoated over the service life of the facility. They should be inspected twice a year, repaired as required, and planned for recoating and replacement at least every 10 years. Top-coating and other isolated maintenance may be necessary more frequently in high-traffic areas.
- Metallic electrical conduit exposed to moisture can corrode. Periodic painting may extend its life. If damaged, conduit should be immediately repaired, and all sources of water ingress should be corrected.

Other elements of parking structures that need periodic maintenance are identified in Table 2.2.

Table 2.2. Preventive maintenance schedule

Maintenance Items	Frequency						
	Daily	Weekly	Monthly	Quarterly	Semiannually	Annually	As required
Floor wash-downs					X[1]		
Repair floor potholes and cracking		O			X		
Scaling repairs		O			X		
Repair deterioration in expansion joints					X		
Joint sealant installation or reapplication						X	
Repair damaged bearing pads						O	X
Inhibit rust and correct rust damage (exposed steel)				O		X	
Repaint			O				X
Drain water systems for winter						X	
Apply surface sealer							X[2]
Stair repairs	O						X
Plumbing repairs		O				X	
HVAC equipment repairs[3]			O				X
Fire protection system repairs			O				X
Clear floor drains		O			X		
Check lavatory facilities operation (commodes, sinks, changing stations)	X						O
Roofing and flashing repairs			O			X	
Patch or repair floor membranes			O				X
Check for water leakage		O			X		
Check for rusting concrete reinforcement		O			X		
Repair mortar joints						O	X
Repair concrete cracks					O		X

Source: Partially based on information from *Parking Facility Maintenance Manual* (National Parking Association, 2016). Note: See text for additional information. HVAC = heating, ventilation, and air conditioning. O = inspect; X = perform operation.

[1]Wash-downs are required twice per year (spring and fall) in snowy or coastal regions, and at least once per year elsewhere.

[2]Surface sealer: Apply every three to five years. Penetrating sealer: Apply every five to seven years; apply more often in abrasive areas.

[3]Inspect daily for enclosed parking structure. Management office should be notified immediately when repairs are needed..

2.4 Structural Repairs

Even well-designed, properly constructed, and regularly maintained facilities require structural repairs over their lives due to exposure to harsh environments, dynamic and concentrated loads, and chemical attack from deicing and other fluids. When repairs are needed, they should be designed and specified by a structural engineer experienced in parking structure evaluation and restoration. Typical repairs that are implemented in older precast concrete parking structures are described in sections 2.4.1 to 2.4.3.

2.4.1 Concrete Deterioration

Concrete deterioration is more common in cast-in-place portions of the structure (for example, field-placed topping and pour strips) than in precast concrete components. Deterioration mechanisms include the following:

- **Scaling:** Scaling refers to disintegration of cement paste at the concrete surface. Usually associated with freezing and thawing cycles, it produces an unsightly and rough surface and can create tripping hazards and areas of ponding water. It is commonly repaired with a surface overlay.
- **Spalling:** Spalling, or the fracturing of the outer surface of concrete, can be caused by corrosion of embedded steel reinforcing bars or be due to impact loads. Spall repair should include a structural evaluation to determine the cause of the distress along with specification of repair materials compatible with properties of the concrete substrate.
- **Cracking:** Well-distributed, fine cracks are not uncommon, especially in concrete elements that are not prestressed. In precast concrete units, cracks can be caused by improper stripping, handling, and erection. Cracks can also be caused while the unit is in service by corrosion of embedded metal, stresses due to restrained volume change, or loading in excess of anticipated design live loads. In some instances, differential or excessive foundation movement can cause cracks. Minor, nonmoving cracks in decks typically do not have structural significance. These types of cracks often need to be addressed only with a surface sealer to prevent water intrusion. However, large and readily perceptible cracks, especially if accompanied by faulting, corrosion, or movement under traffic, should be evaluated by an engineer.
- **Delaminations:** Delaminations are fractures that occur below and parallel with a surface. In precast concrete parking structures, delaminations are typically caused either by corrosion of reinforcing steel or by debonding between field topping and underlying precast concrete as a result of improper surface preparation. Extensive delamination should be evaluated by an engineer before repairs are undertaken.

Concrete repairs, even when installed using accepted methods, can exhibit shorter-than-expected service lives due to many factors. Visual examination of repaired areas should be supplemented with mechanical sounding to identify incipient spalls or delaminations.

2.4.2 Expansion Joints

Expansion joints are often necessary in structures that are relatively large or irregularly shaped. In some cases, expansion joints are provided to isolate the deck from vertically stiff elements such as stair or elevator towers. The purpose of expansion joints is to reduce the magnitude of stresses caused by restrained volume change, such as that related to the customary drying shrinkage of concrete and temperature variations. At expansion joints, adjacent portions of the structure are intentionally isolated so that free movement can occur in the desired direction. A wide range of proprietary products and seals are available to fill or cover the deck openings created by expansion joints.

When expansion joints deteriorate or malfunction, water leakage will contribute to deterioration of the adjacent concrete. Frequent monitoring and timely cleaning and repair of damage will extend the service life of expansion joints and mitigate damage in the adjacent concrete elements. Recurring problems, significant concrete damage, or excessive vibration may require a thorough evaluation by an engineer.

2.4.3 Connection Distress

Excessive stresses caused by restrained volume change or external loading can cause cracking, distortion, and other forms of distress in connections. Connections typically involve welded steel plates, bolted steel plates, through-bolts, bearing pads, threaded rods, and other assemblies. In addition, some connections are propri-

etary products designed for specific applications. Because of the considerable variety of types and applications of connections, indications of notable distress should be evaluated by an engineer.

A common example of distress requiring evaluation is cracking and spalling adjacent to double-tee flange-to-flange connections (Fig. 2.8). Deferred maintenance of such damage can lead to excessive deck deflections (causing bounce and vibration), deterioration of adjacent connections, flange cracking, and development of overhead debris. Distress at these connections may be an indication of weld damage or concrete distress concealed by joint sealant. Cracks, spalls, and other distress at these connections, especially if accompanied by readily perceptible movement under traffic, should be evaluated by an engineer.

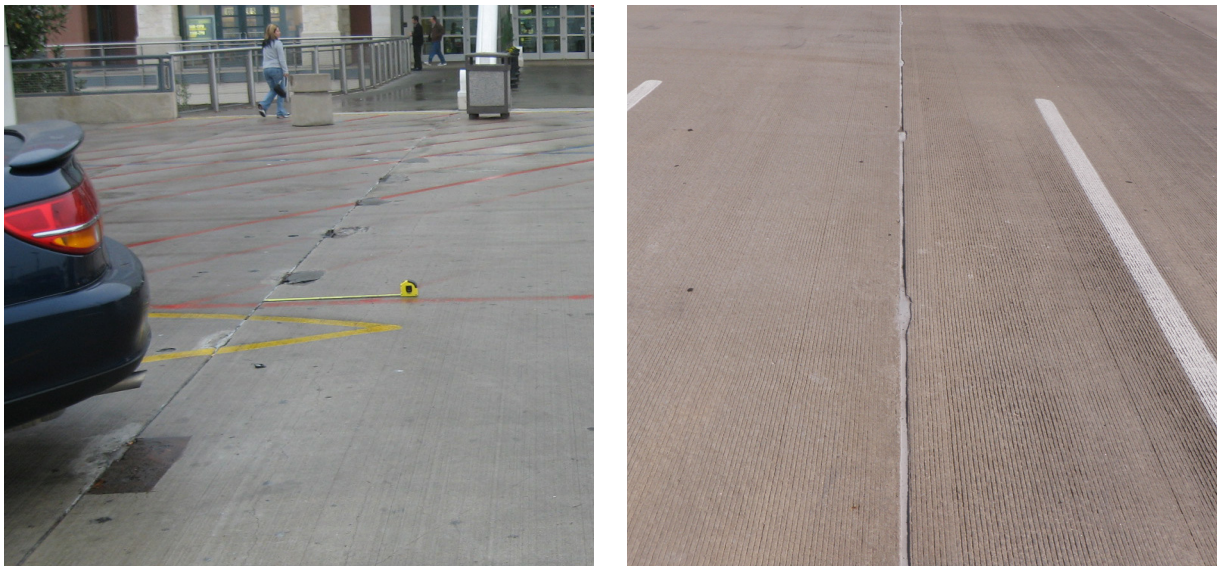

Figure 2.8. The photo on the left shows spalled and repaired concrete at connections along a flange-to-flange joint. The photo on the right shows no distress. Photos: Michael Lee.

2.5 Traffic Control

Most parking structures are designed for storage of passenger vehicles. Building code design criteria for passenger vehicle parking structures are simplified to provide for normal vehicular traffic using a uniform live load of 40 lb/ft^2, which is intended to account for vehicle weight and the dynamics of vehicles moving at 10 mph. A concentrated live load of 3000 lb is also included in the design criteria to account for the load from a jack used to change a flat tire. The 40 lb/ft^2 load criteria does not include allowance for heavy vehicles such as tow trucks or rescue vehicles. The 2018 *International Building Code* includes specific provisions for heavy vehicles. Floors that are intended to support vehicles with a gross vehicular weight rating greater than 10,000 lb require specific design for the heavier vehicular live loads including impact and fatigue.

It is important that weight and speed limit signage be posted and enforced. Height restriction bars can help prevent overweight vehicles from entering a structure. When a facility has long, straight aisles, it may be necessary to include traffic control devices (such as raised surfaces or pads) to limit vehicular speed.

Floors subject to excessive loads or high speeds, particularly at changes in slopes such as level-to-ramp transitions, may be subject to extreme wear. This can result in premature connection failure from overload, fatigue, or both. Broken connections may cause excessive cracking in the double-tee flanges. Control of traffic to the bounds anticipated by the design criteria is an important aspect of parking structure maintenance to ensure that a long, effective, useful life for the structure is achieved.

CHAPTER 3—PERIODIC STRUCTURAL AUDIT

While most aspects of a preventive maintenance program (section 2.3) do not require the skill of an engineer or other licensed design professional, it is prudent for a structural engineer experienced in precast concrete design and evaluation to be periodically retained to perform a structural audit. Such an individual has the training and expertise to identify actual or potential problems that might not be apparent to others. These issues can typically be addressed with less effort, cost, and disruption when they are discovered early. For example, delamination can be identified using mechanical sounding or reinforcing steel corrosion can be assessed using specialized testing.

For the purposes of this manual, the term “audit” refers to a general condition assessment of the portions of the structure that are essential to its serviceability, durability, and structural integrity. An audit is generally proactive in nature whereas most other types of evaluations are undertaken primarily to investigate a specific condition known to need attention.

The scope and frequency of structural audits are determined by the structure's age, design features, geographic location, and prior repair history, as well as other factors. An initial audit should take place immediately upon completion of construction. The structural engineer of record, precast or specialty engineer, and general contractor should participate in the initial audit, which will serve as a baseline against which future audits will be compared. Participation of the architect and owner can also be beneficial while documenting conditions observed during the initial audit. Findings from the first several audits will determine the frequency of future audits over the remaining service life of the facility; every three to five years is a common range.

Findings from the initial audit, including photographs, should be retained along with all critical documents related to the design and construction of the structure, such as structural and architectural design drawings, project specifications, precast-related submittals (including shop drawings and calculations), test reports, field changes, and product warranties. This collection of documents should be maintained in a readily accessible location so that it can be reviewed by others during subsequent audits. All items of concern identified during audits should be documented and recorded with photographs, measurements, and narrative, as required to allow full understanding of the performance and maintenance history of affected areas.

The structural audit should include items listed in section 2.3, as modified and enlarged based on characteristics of the structure, performance expectations of the owner, geographic location, and other factors.

CHAPTER 4—PLANNING AND DOCUMENTATION

The development of an overall maintenance program should include documentation and recording of materials, systems, and procedures used in the design, construction, and maintenance of the facility. These documents are beneficial for planning, scheduling, and developing future maintenance and repair procedures. Time and resources can be used more effectively when design, fabrication, erection, and maintenance records are available.

An organized data management system should be created that includes hard and electronic copies of the following documents:

- Construction documents
    - Architectural drawings
    - Civil drawings
    - Structural drawings
    - Mechanical/electrical/plumbing (MEP) drawings
    - Project specifications
    - Precast concrete production and erection shop drawings
    - Part drawings for plate and other assemblies embedded in precast concrete elements
    - Design documents for elevators, lighting, MEP, and other nonstructural items
- Modifications to construction documents
    - Change orders
    - As-built documents
- Catalogs and manuals for equipment such as
    - Expansion joint seals
    - Sealants
    - Coatings
- Maintenance records for
    - Routine inspections, housekeeping, and repairs
    - Elevators, light fixtures, guidance systems, and other nonstructural items
    - Structural repairs

An appropriate maintenance program can be developed based on review of the above documents and input from the owner or operator. Assistance from the original design and construction team is beneficial, as input from these parties may enable efforts to be directed to specific components or systems. For example, stainless steel should require little to no maintenance, whereas painted steel surfaces will need regular attention. Maintenance of mechanical equipment such as elevators and entry/exit control systems will depend primarily on the recommendations of their manufacturers.

A specific maintenance program should include the following primary elements:

- Establishment of an annual maintenance budget
- Assignment of personnel for implementation of the program
- Development of recording procedures to track maintenance activities
- Creation of a management system to oversee and administer the program

Periodic assessment of the maintenance program is essential to allow adjustments to be made over the life of the structure based on interim findings, the performance of the structure, and budget objectives. Increases in the maintenance budget should be anticipated over the life of the facility to account for increased needs as the structure ages.

Manual

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