Four Keys to Long-Term Parking Structure Success

Design, materials, construction, and maintenance all must come together to ensure a resilient, aesthetically pleasing, and cost-effective parking structure over the long term

— Francesco J. Genoese and Rick Petricca

Many factors go into creating a successful parking structure for both the short and long term. While owners want to create an efficient and durable structure, the definitions of these terms continue to evolve, especially with advancements in design and material technologies. This article summarizes significant aspects of parking structure design and maintenance, and also highlights important aspects that may be overlooked or misunderstood. It can also be used as a checklist to aid in any phase of parking structure design, construction, and ownership.

The four key areas of concentration—design, materials, construction, and maintenance—represent the areas of discipline involved in the life of a parking structure. You can find PCI technical resources related to the parking structure topics covered in this article: www.pci.org/Project_Resources/Parking_Structures/.

Contributing Experts

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Design Techniques

All precast concrete structures are designed with "breathable" connections that allow for movement from ordinary thermal expansion and contraction. This basic design practice reduces potential cracking and thus maintenance costs.

Precast concrete parking structures are designed to meet codes, but consideration must be made to ensure members are not overdesigned to the point that they cause tensile stress. Live loads, snow loads, and snow drift loads can be combined and reduced to better represent the realistic loads and behavior of each structure. Good design will reduce the potential for cracking and thus reduce any potential deterioration from water or chlorides. Other systems typically experience random and unpredictable cracking that leads to more extensive repair costs.

Drainage is a key part of any parking-structure design. Proper drainage details and a positive slope of a minimum of 1.5% are essential to prevent water saturation and ponding. Good design also includes sizing and location of drains, properly set elevations of landings and high points, and slope creation to shed water to low areas while maintaining clearance.

Specific design of precast structures will vary based where the structure is geographically located. Just like design, maintenance programs will have specific plans based on the environment the garage is in. The common denominator of precast is that with good design and properly prescribed and executed maintenance, life-cycle costs are minimized, consistent and predictable. Every precast producer plays a key role in helping customize a maintenance program for the garage they provide to assure that their structure has the lowest life-cycle cost of any system.

You can learn more about design specifics in the article titled *"High-Performance Parking Structures Using Precast/Prestressed Concrete,"* also in this issue of *Ascent*.

Material Selections

The manufacturing process of precast concrete inherently results in a very high-quality, high-performance concrete, ensuring the longevity of the structure beyond any other system. Factory-controlled and -cured concrete with a low water/cement ratio containing corrosion-inhibiting admixtures, fly ash, or silica fume are proven to increase durability. This concrete, typically combined with stainless-steel welded connections and hot-dipped, galvanized exposed embed plates, resists chloride ion penetration and corrosion. It is also common practice for Silane sealer to be spray applied to all horizontal surfaces of precast parking structures for added protection in climates where deicing materials are used. Field installed concrete topping and infills should always be treated with Silane sealer in such climates.

High-Performance Precast Parking Structures

Precast concrete components provide significant versatility, allowing them to be used to meet all types of aesthetic needs. This ensures that designers can be confident that any aesthetic requirement can be met while specifying the material for its other key advantages. Some of the potential benefits include:

- long spans and open floor plans;
- a compressed construction schedule due to off-site fabrication;
- high quality control of the fabrication processes, governed by certified-plant requirements;
- consistent, fast, high-quality erection processes, governed by certified field programs; and
- high strength and long-term durability due to the use of specialized, high-performance materials.

As a manufactured and engineered product, precast concrete can be fine-tuned to meet each project's specific needs. Its capabilities continue to expand as new techniques and procedures are developed to advance its properties. For example, some of the structural connections used to attach the various components during the installation process utilize stainless-steel hardware today. Where "durable" once meant a 50-year service life, material designs and maintenance programs are combining to offer the potential for a 100-year service life when desired.

Members of the Precast/Prestressed Concrete Institute discuss and evaluate the advances in material science on a regular basis and provide insight to help create a manual defining "Recommended Practices" for parking structures. Following prescribed garage practices will result in good use of space, flexibility, maintainability, reduced construction time, reduced life-cycle costs, and ultimately a better value for any project.

The 3rd Edition of "Parking Structures: Recommended Practice for Design & Construction" will be available in 2015.

Braced precast concrete wall panel during erection.

Precast Concrete double tee being installed.

Construction Techniques

Parking structures are constructed using one of several common structural systems. These include cast-in-place concrete using either conventional or post-tensioned reinforcement, prestressed/precast concrete, or hybrid systems featuring a combination of these systems and sometimes steel. While the systems have some features in common, each has specific attributes that impact construction speed, cost, aesthetics, function, durability, and long-term maintenance. As noted at the beginning, prestressed/precast concrete offers several unique benefits.

Parking structures featuring prefabricated components are assembled like an Erector® Set. The installation process involves hoisting individual components into position and using welded, grouted, and bolted connections to join them together. These connections are often concealed within the component joints and protected with joint sealants. Plant-cast or cast-in-place concrete pour strips, usually located around the garage perimeter and at pedestrian access areas, conceal reinforcing steel and connections. They also provide drainage and pedestrian transitions.

All parking structures have common elements including directional signage and line striping, lighting, drainage systems, stairways/elevators, height-restriction warning devices, and weight limits. All of these systems and features have specific needs and requirements for proper operation and service life.

Unlike enclosed buildings, parking structures are directly exposed to weather, traffic, and other environmental conditions. A variety of influences impact the durability of these structures in ways other buildings are not. These include extreme temperature changes, rain, snow, deicing chemicals, ultraviolet light, road grime, oversized vehicles, cyclic vehicular loading, and potentially abusive maintenance, like snow plowing.

Even with their inherent high durability, precast concrete parking structures (as with all such structures) require preventive and proactive maintenance to ensure long service life. Preventive maintenance should be planned and performed at regular intervals, much as with routine maintenance on a car, to minimize long-term operational costs relating to maintenance and repair and to ensure uninterrupted service.

Maintenance in parking structures is usually categorized into three key areas: housekeeping, preventive maintenance, and repairs and replacements. Housekeeping involves routine and periodic tasks meant to keep the garage clean and functioning efficiently. It typically includes tasks like lamp replacement, line striping and signage maintenance, and parking-control and security-system maintenance.

The long-term integrity of a parking structure is particularly dependent on the last two categories. Preventive maintenance usually involves longer-term maintenance intended to control deterioration, ensure safety, and maintain key systems. Repairs and replacements are required to address premature deterioration or damage and to restore systems at the end of

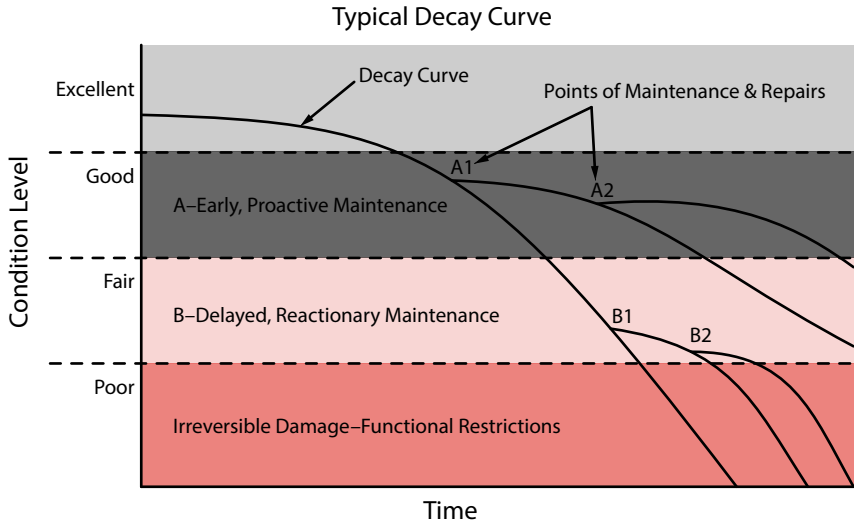

Figure: High Concrete Group LLC–StructureCare.

Stainless weld connections and proper precast joint alignment.

their service life. In precast concrete parking structures, these typically include waterproofing systems, cast-in-place concrete interfaces, and more serious damage and deterioration.

Preventive Maintenance Program

A well-developed preventive-maintenance program should start as soon as a garage is placed into service, while it is in its best condition. Early and frequent preventive-maintenance activities will maximize gains to the service life relative to the dollars spent. Delayed, reactionary maintenance provides only short-term gains that require larger expenditures at more frequent intervals. Lack of a preventive-maintenance program also can result in untimely service interruptions and unsightly and unsafe conditions.

The components of a preventive-maintenance program need to be specific to the garage and its operating conditions. For example, parking structures in colder climates have more stringent requirements due to the effects of winter. The colder temperatures and maintenance needs required to deal with ice and snow dictate a plan to remove harmful deicing chemicals from the deck surfaces in the spring time to prevent corrosion and possible moisture penetration. These regions also need a plan that deals with a review of equipment, weight restrictions, and how to avoid damage to sensitive areas.

In other regions, such conditions as sun exposure, seismic activity, and marine exposure may dictate a different approach to the maintenance plan. For example, in coastal environments, more frequent deck wash-downs will help reduce the exposure to harmful chlorides.

Regardless of location, the fundamental elements of an effective preventive-maintenance program include periodic inspections, structural audits, leak surveys, periodic maintenance training, and routine repairs and maintenance to key systems guided by the inspection process and diagnostic testing.

Annual Assessment Needed

Once the plan is developed, a re-evaluation of all components should occur every three to five years. Experience is important in this process. Periodic informal safety audits and routine weekly and monthly inspections can be completed by operations staff with some training. Annual assessments of the structural elements and protective systems in the garage, however, should be completed by a professional experienced with garage design, construction, and repair. The operations staff and the hired consultant together form the maintenance team.

These annual assessments can be informal and representative, depending on the age and condition of the garage. However, a formal, comprehensive structural audit should be completed with documented results at least once every five years. In addition to fully documenting the various observations, any developing conditions and symptoms should be evaluated for root cause. These will guide long-term repair recommendations that will help the operator/owner develop a maintenance and repair program to plan and schedule future repairs and maintenance.

Typical Multiyear Service Outline Summary and Interval of Services

Service	Year 1	Year 2	Year 3	Year 4	Year 5
Formal Assessment Structural Audit					X
Informal Assessment	X	X	X	X	
Walk-Through Monitoring–Periodic	X	X	X	X	X
Leak Survey	X	X	X	X	X
Reporting	Informal	Informal	Informal	Informal	Formal
Deicing Wash-Down (Winter Regions)	X	X	X	X	X
Misc. Repairs and Maintenance	X	X	X	X	X
On-Site Maintenance Support & Training	X	X	X	X	X
Snow-Ice Removal Training (Winter Regions)	X	X	X	X	X

Table: High Concrete Group LLC–StructureCare.

Annual leak surveys, particularly focused on areas just below the roof level, can help identify sealant failures at an early stage. This will allow smaller, selective repairs while the sealants are still repairable and avoid them contributing to a larger problem. These selective repairs can extend the overall service life of the waterproofing systems, which can include sealants, expansion joints, and membrane coatings.

Maintenance training can help the operations staff understand what to look for and how to implement their periodic inspection program. In colder environments, annual training should include winter maintenance. Diagnostic testing may assist professionals in assessing the underlying conditions and in developing recommendations for future maintenance and repair.

A well-developed preventive-maintenance program will go a long way in mitigating operations cost and extending the service life of a parking structure. It will also slow down the deterioration process. Eventually, however, repairs and replacements will be required. Root cause-based repairs should be directed by a knowledgeable professional. These repairs often involve waterproofing systems and localized concrete deterioration. Corrosion in miscellaneous hardware and railings also may need to be addressed.

Replacement of these components involves system upgrades typically relating to service-life failures. In precast concrete parking structures, these replacements usually do not involve the precast concrete components, due to their inherent durability and quality. Instead, they focus on waterproofing systems, such as joint sealants, expansion joints and membrane coatings, drainage systems, line striping, signage, lighting, and the cast-in-place concrete elements.

Positive drainage design, proper drain locations utilizing precast washes.

Systems Need Review

While parking structures are designed for service lives of 50 years or more, the systems on which they rely have a much shorter service life. For example, roof-level urethane sealants, which are typically used in garages, can last eight to 10 years due to winter-maintenance activities and ultraviolet-light exposure. These same sealants on lower levels can last 12 to 15 years. Expansion joints, depending on the joint type, can last from eight to 15 years. Drainage systems typically last 12 to 15 years, but can last longer. As a result, selective replacements will be necessary over the service life of the structure.

It's important to note that the annual inspection component of the preventive-maintenance program can help prolong the service life of these systems by identifying developing deterioration and damage early on, allowing for small and less costly repairs.

As is often the case, long-term neglect or misguided maintenance and repairs often precipitate premature failure in parking structures. The deterioration progression accelerates as conditions worsen. In these instances, simple repairs are no longer viable options. Full-scale restoration is required, which should be guided by a professional experienced in design and restoration.

If it hasn't already been completed, a thorough structural evaluation is often needed to help assess and devise appropriate repair strategies. In addition to addressing structural needs, consideration must include operational logistics, cost, and a feasible implementation time schedule. An experienced consultant can be invaluable in this process.

Parking Garages
Maintenance–Inspection Checklist

#	Inspection/Maintenance Task	D	W	M	S	A	Comments
1	Parking and Drive Aisle Debris/Trash	X					
2	Stair Tower Debris/Trash	X					
3	Elevator Debris/Trash	X					
4	Graffiti–Vandalism			X			
5	Oil Accumulation/Staining			X			Slippery Conditions at Parking Stalls
6	Floor Drains–Inspect/Clean Grates		X				
7	Ponding Conditions	X					Squeegee Water as Needed
8	Signage–Visibility, Lighting, Cleaning			X			
9	Striping–Visibility & Fading				X		Include Curbs and Directional Symbols
10	Lighting–Relamping Needs		X				
11	Lighting–Fixture Cleaning			X			
12	Lighting–Timers				X		
13	Tripping Hazards	X					
14	Slippery Conditions–Pedestrian Areas	X					Particularly Duing Wet and/or Cold Weather
15	General Safety Concerns	X					
16	Winter Maintenance Review/Training					X	Consultant Lead
17	Snow–Ice Management	X					Seasonal
18	Doors & Door Hardware		X	X			Inspect for Operation (W) and Corrosion (M)
19	Concrete Debris	X					Identify Location and Contact Consultant
20	Obvious Leaking Conditions	X					Identify Location and Contact Consultant
21	Rusting Conditions			X			
22	Concrete Deterioration			X			Identify Location and Contact Consultant
23	Deicing Removal–Deck Wash Down					X	Spring Time After Last Freeze
24	Guard Rails, Stair Rails, Cable Barriers			X			
25	Oil Stains on Underside of Floors			X			Identify Location and Contact Consultant
26	Roofing/Flashing					X	Most Likely Assigned to a Roofing Vendor
27	Ventilation Equipment			X			Stair/Elevator Towers & Parking Areas
28	Water Supply–Leak Survey			X			
29	Water Supply–Drain/Blowout					X	
30	Exterior Masonry/Concrete Inspection			X			Scan for Signs of Deterioration
31	Floor & Stair Tower Leak Survey					X	Focus on Roof Level
32	Membrane Coatings			X			Inspect and Keep Clean
33	Expansion Joints			X			Inspect for Damage, Particularly During Winter

Table: High Concrete Group LLC–StructureCare.

A common mistake made by many facility managers is to ignore or minimize preventive maintenance and ongoing repair programs following major restoration. The new appearance and considerable financial outlay provide a false sense of accomplishment and security. Unfortunately, this type of major restoration usually occurs late in the life cycle of the structure, providing a short-lived extension of service life, particularly in the absence of proactive maintenance. Now more than ever, a proactive and well-developed maintenance program is essential. Re-evaluation of this program is particularly important following major restoration.

To help with the implementation of the maintenance program, it's helpful to develop an annual implementation schedule and checklists to guide the effort. The following table can be used to outline the components and timing of various tasks.

The following inspection checklist is an example of the type of document that can be used for operations and professional staff.

In summary, an effective parking garage maintenance program should follow five key points:

1. Be proactive and sustained.
2. Identify and address deterioration and damage early.
3. Be guided by experienced eyes—engage a parking structure professional.
4. Be based on root-cause assessment and solutions.
5. Be re-evaluated every three to five years and after major repairs and restoration.

Precast concrete parking structures are the most durable, fastest to construct, and most cost-effective designs possible, offering service lives that can reach 100 years. But their durability should not lead owners and designers to consider them to be impervious. Routine, regular maintenance will ensure no weak links develop that can result in long-term and costly problems down the road. A small amount of time, money, and effort spent at regular intervals will ensure the parking structure continues to be attractive and fully functional throughout its life.

For more information on these or other projects, visit www.pci.org/ascent.