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Journal

How to Assess Your Parking Garage

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With contemporary designs that highlight parking structure architecture with living facades, graphic artwork, sculptural lighting, and eye-catching metal scrims, today's parking garages merit mention in design journals and debut to architectural fanfare. As designers embrace the possibilities of garages' open plan for everything from traditional parking to al fresco dining and integrated retail, the architecture of what once was the humble parking structure has become a showpiece for innovation and creativity. Investing in such inventive designs, however, means that building owners are all the more compelled to stay on top of parking garage maintenance, which, with a structure that is exposed to the weather inside and out, can be demanding.

A Unsightly deterioration can quickly devolve to hazardous conditions if left unchecked. Routine parking structure inspection can identify and correct problems before they become unsafe.

Whether the parking facility is a free-standing multi-level garage or a few below-grade levels under a high-rise building or plaza, the imperative is the same: proactive condition assessment and diligent maintenance are a must. If problems are ignored, the harsh environment in garages, including corrosive deicing chemicals, freeze-thaw cycling, and the stress of thousands of vehicles traversing the deck, will quickly accelerate deterioration into hazardous conditions. With the integrity of the garage and the safety of users at stake, owners and managers are compelled to prioritize parking structure evaluation and maintenance to preempt problems and avoid possible liability.

Recognizing the critical importance to public safety of parking garage stability, some jurisdictions have passed legislation requiring periodic assessment and repair of parking facilities. These regulations typically entail a comprehensive initial evaluation, followed by assessments at intervals, usually every few years. For many garage owners and managers, these requirements codify practices similar to those already in place at their parking facilities; for others, the new laws require an unprecedented allocation of time

Robert A. Marsoli, Jr., PE, Senior Engineer with Hoffmann Architects, provides assessment, remediation design, and construction administration services for parking structure distress, treating each garage with sensitivity to usage demands, budget, logistics, and longevity.

and resources to parking garages. For those facilities where maintenance has been deferred, problems may be advanced enough to require expensive and disruptive repair.

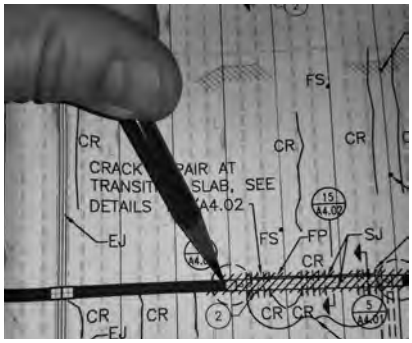
To keep from getting to that point, owners and managers of parking facilities are advised to follow a preventive approach to garage upkeep. That begins with a comprehensive assessment, typically conducted by an architect or engineer experienced in parking structure evaluation. By establishing a baseline of garage conditions, an assessment guides maintenance and repair efforts and serves as a reference point for ongoing evaluation.

The Initial Visit

Whether prompted by a government mandate, observed distress, or preventive efforts, the condition assessment process begins with ***an information-gathering initial visit***. After receiving an inquiry, the architect or engineer will meet with the building owner, manager, and/or facility maintenance staff to discuss reasons that initiated the assessment. Typically, these might include:

- Observed distress, such as spalls, cracks, corrosion, staining, or other deterioration;
- Leaks, condensation, and ponding water;
- Structural and safety concerns;
- Need for maintenance plan development; and/or
- Ordinance or mandate requiring garage assessments.

After establishing the history of problems, past repair efforts, previous investigations, and the original design and construction of the facility, the design professional will conduct ***a brief visual walkthrough of the garage.*** In this initial stage, the architect or engineer is looking to establish the type of construction and identify typical defects, as well as classify existing conditions.



Drawings are useful for marking locations of distress, past repairs, and other conditions.

This information aids in determining the level and type of investigation warranted.

Existing documentation, including previous reports, construction documents, record drawings, maintenance and repair records, and manufacturer documents, are extremely useful. Having information about the original construction and past repair projects can reduce expenses by taking the guesswork out of establishing the history, condition, and underlying construction of the parking structure.

Planning the Assessment Approach

After a review of information gathered during the initial visit, the architect or engineer will propose an approach to assessing the parking structure, customized to the needs, age, and construction type of the facility. In general, parking garage assessments may include:

- Visual observation and photo documentation;
- On-site testing and evaluation;
- Laboratory material sampling and analysis; and
- A condition assessment report, summarizing findings.

A key part of the planning process is ***coordinating among trades***, as parking garage investigation typically includes testing and exploratory probes that may require various subconsultants. Unless the services of contractors, testing agencies, specialists, and other parties are solicited early in the process, coordination may substantially delay the assessment. Timing of disruptive testing to ***avoid peak usage hours*** is also critical to scheduling.

With this information, the design professional will provide a proposal, including detailed information about recommended testing, sampling, invasive probes, and analysis, with necessary subcontractors and consultants. The timeframe between receipt of this proposal and the onset of the investigation depends on the turnaround for the agreement, as well as the time to retain subconsultants. For an architecture and engineering firm experienced in parking garage assessment, this should not take too long, as longstanding relationships with subconsultants often means faster turnaround. Once all parties have agreed to the terms, the garage assessment can begin.

Visual Observation and Photo Documentation

Comprehensive visual evaluation is the cornerstone of a parking structure condition assessment. Design professionals look for conditions, such as cracks, spalls, corrosion, delamination, condensation, displacement, and deterioration, but they also, perhaps more importantly, look for ***patterns in the observed distress***.

If, for example, a precast concrete garage shows signs of water infiltration and corrosion at parking deck joints, the design professional may suspect failure of the embedded steel connections and protective sealant, prompting invasive testing to observe concealed conditions. At a cast-in-place concrete garage, the architect or engineer might identify areas of widespread concrete

MATERIAL SAMPLING – *What Tests Are Necessary?*

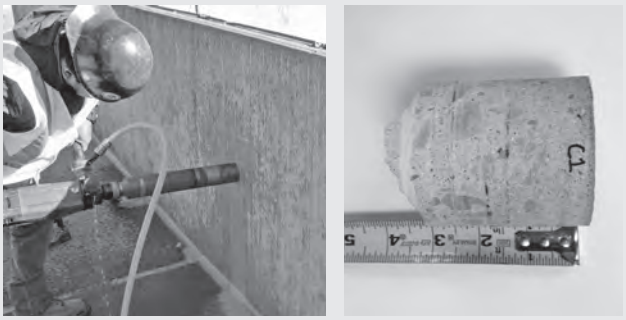
As part of the parking structure assessment, the architect or engineer may specify on-site testing, material sampling, and laboratory analysis to evaluate the condition of concrete and embedded steel elements.

Non-invasive tests, which require minimal or no removal of materials, may include:

Chain drag survey: Used to detect delaminations in concrete parking decks. Involves pulling heavy chains along the parking deck surface to listen for the characteristic hollow sound of subsurface voids.

Joint movement survey: Identifies joints between precast concrete members that contain fractured connections. As a vehicle drives across a joint, the joint is monitored for discernable movement that would indicate fractured connections.

Half-cell potential testing: Determines the electrochemical properties of embedded steel by measuring its electrical potential. The greater the difference in charge from one point on the steel bar to the next, the greater the risk that corrosion is occurring. Requires removal of the concrete cover over reinforcing, to access the steel bars.



Extraction of concrete cores for testing is important to evaluating the composition and quality of the material.

Invasive tests demand some degree of destructive probing, whether to extract materials for off-site analysis, or to reveal concealed conditions. These often include:

Probes: Removal of existing materials (concrete, sealant, etc.) to observe underlying construction details and conditions.

Chloride sampling: Determines chloride concentrations within the concrete, which indicate the potential for corrosion of embedded steel elements. Dust samples may avoid the need for destructive testing, but in some cases, concrete core extraction may be specified, to obtain additional information on concrete strength and composition.

Petrographic analysis: Using concrete cores, petrographic analysis evaluates concrete strength, air entrainment, aggregate type and distribution, and evidence of shrinkage, settlement, corrosion, secondary deposits, and deleterious products of chemical reactions. Also offers insight into concrete composition, including water-to-cement ratio, porosity, binder and paste content, and depth of carbonation, all of which indicate the overall soundness and durability of the concrete.

Welding analysis: For precast concrete garages, where connection failure is a common concern, extraction of welded assemblies may be warranted, to determine the quality of welding and/or the materials used.

Turnaround time for laboratory tests can vary, so it is best to obtain samples early in the investigation process. Typically, chloride ion testing takes just one or two weeks, but a full petrographic analysis can take four to six weeks or more. When determining the overall timeline for a parking garage condition assessment, it is important to consider how the lead time for sample analysis impacts production of the final report. ■

spalling and corrosion of embedded reinforcing, suggesting poor concrete cover or quality and prompting laboratory analyses to determine the concrete composition.

Identifying pervasive problematic conditions allows the design professional to focus the assessment on problematic areas and make best use of available resources. Indiscriminate testing in the absence of visual evidence can waste time and money. Moreover, knowing where in a many-thousand-square-foot garage to best obtain samples for analysis is critical to obtaining useful data.

An experienced design professional will walk the entire garage to observe existing conditions, document defects and areas of distress, and identify locations for testing. Existing floor plans and elevations are helpful for notating locations of observed conditions, but if these are not available, the architect or engineer can create basic drawings for this purpose. ***Testing and sample extraction locations*** should be marked on the drawings for future use.

A key part of the visual evaluation is ***photographic documentation*** of observed conditions. Photographs provide a record of defects and deterioration, establishing a reference point to

monitor emerging conditions. Photos also assist in identifying patterns of deterioration at sites that may be far apart yet experiencing similar distress.

Testing and Material Sampling

The type and extent of testing can vary by construction type, by the existing documentation available, and by the conditions present within a garage. If little is known about the original construction of the garage, more testing will be required to observe concealed conditions and details, and to establish a baseline for future investigations. Different types of parking structures demand different types of testing; what is appropriate for a precast concrete garage is not necessarily required or appropriate for a cast-in-place or steel-framed structure.

Precast Concrete Garages

Precast members are cast in a factory and must be moved and assembled in the field, which means that precast decks have a far greater number of joints than their cast-in-place counterparts. Each time a car traverses one of these joints, the connections undergo ***stress reversals*** from the up-and-down motion. After millions of these reversals, the welded steel connections along the joint may become fatigued, and the joint "unzips" along its length as connections fracture. As this happens at more and more connections, the structural integrity of the parking structure is compromised.

Connection failure at this precast concrete deck led to leaks, requiring supplemental support.

Design professionals accustomed to evaluating precast parking garages are aware of this Achilles heel and make it a point to thoroughly investigate parking deck joints for signs of distress and failure. First, the architect or engineer conducts a ***joint movement survey*** to identify locations of concern. Next, he or she specifies ***probes***, or investigative openings, at connection locations, notably at joints where two ***flanges*** (parking decks composed of the horizontal arms of precast single or double "T"-shaped units) abut, as well as at flange-to-spandrel and spandrel-to-column intersections.

The number of joint probes is based on the observed level of distress. Probes to reveal concealed conditions are essential at ***moving joints***, where the connections have likely failed, but they are also important at some ***non-moving joints,*** where the intact connections provide a baseline for what the original connection was supposed to be. While, ideally, the welds and steel elements would be consistent with the original design intent, investigatory probes sometimes reveal deficient conditions that likely contributed to the premature ***connection failures***.

If the quality of materials or workmanship used in the original construction appear to be contributing to observed distress or are potentially vulnerable to premature deterioration, a ***metallurgical/welding analysis*** of representative connection elements may be warranted.

Information about the configuration and condition of precast concrete connections provides the design professional with an understanding of the seriousness of the structural distress. Stable, intact connections are essential to the integrity of precast concrete

Fireproofing coats this steel-framed parking garage with composite deck.

parking garages and, in their absence, the capacity of the garage to safely bear traffic and resist lateral loads is compromised. Thorough investigation of connections, along with all other structural elements, is therefore of critical importance to the accurate assessment of a precast concrete garage.

Cast-in-Place Concrete Garages

While cast-in-place garages don't suffer from the connection failures that can plague precast construction, they possess their own set of typical problems. Since the concrete is mixed in a plant and then transported to and cured on site, where conditions are variable, there is potential for error in creating a long-lasting and durable product. If the concrete properties are affected by transporting, placement, and/or finishing activities, the finished concrete may be more susceptible to cracking and chloride intrusion from deicing chemicals or freeze-thaw cycling from winter weather, leaving it prone to premature deterioration.

Prior to concrete placement, ***steel reinforcement*** must be placed on site in forms. Placement of reinforcement is critical not only to achieving the specified structural capacity of the members, but also for durability. Insufficient concrete cover can result in steel that is too close to the surface, increasing potential for corrosion from

chloride-laden moisture. Corrosion can lead to expansion of the steel, lamination of the concrete, and ultimately ***spalling***, where the surface of the concrete breaks apart.

While spall locations are visually identifiable, ***delaminations*** are not readily visible. To identify these incipient defects on the decks of the garage, the design professional may conduct a ***chain drag survey***. Areas of deterioration can be marked directly on the deck for repair, as well as on a plan drawing of the parking structure for future use.

At locations where there is concern about the condition, configuration, or size of the existing reinforcement, the design professional may specify invasive probes. The number and location of these exploratory openings depends on the type of observed distress, as well as on the level of existing documentation available. Where little is known about the composition of the garage, more probes may be necessary.

Steel-Framed Garages

Unlike their concrete counterparts, steel-framed parking structures contain structural steel framing members (columns and beams or sometimes joists) which support concrete parking decks. These decks are either formed and cast as conventionally reinforced concrete slabs, or they are cast on ***galvanized metal forms*** or ***composite deck*** (corrugated steel). Since these decks are formed and cast on site, they are susceptible to similar quality-control issues and deterioration mechanisms as cast-in-place decks and are often evaluated using comparable investigative techniques. While the metal deck components within steel-framed garages are subject to deterioration via chloride-laden moisture from above, they are also directly exposed to atmospheric moisture from humidity and condensation.

Steel is susceptible to corrosion in wet, chloride-rich environments, which are often present in coastal regions or in areas where deicing chemicals are used. Steel deck typically contains a ***sacrificial galvanized coating***, and structural steel is coated with paints for protection. Nonetheless, these coatings can become worn or compromised over time, allowing exposure to moisture and initiation of the corrosion process. On exposed structural steel elements, this corrosion can be readily visible and evaluated. However, exposing the extent of deterioration on concealed framing or metal decking can require invasive probes.

> “Knowing how and why a parking facility is experiencing distress is valuable information. Knowing what to do about it is even more important.”

In garages where form deck is used to the support the slab, corrosion of the deck is only of aesthetic concern, as the main structural reinforcing is concealed within the slab. However, where composite deck is used, the integrity of the deck is critical, as it often serves as the slab's main reinforcement. Where deterioration is observed at composite decks, probes are often warranted to determine the extent of section loss.

Structural steel framing may be coated with ***fireproofing***, particularly if the garage is located beneath a building. This fireproofing is critical to protecting against loss of steel strength in the event of a fire and should be visually reviewed for integrity. Locations of fireproofing failure may also highlight areas of concealed deterioration.

Concrete Composition and Quality

Subjected to the most abuse of any garage component, parking decks are generally constructed of concrete, the quality and condition of which is critical to withstanding this abuse and protecting embedded reinforcing. To evaluate resiliency and potential for future deterioration, ***petrographic analysis*** and ***chloride testing*** are commonly used to identify in-situ concrete properties. Both require sample extraction and laboratory analysis.

While the decks of parking structures often experience the most wear and, therefore, deterioration, other structural elements, including columns, spandrels, vehicle and pedestrian guards, and stair towers, are of significant importance from a structural and life-safety perspective and warrant review during a typical assessment. Probes and testing of these elements are sometimes recommended, based on visual observations or signs of distress. Depending on the scope and need of the assessment, mechanical/electrical/plumbing (MEP) systems may also be included.

What's Included in a Condition Assessment Report

At the culmination of a parking garage condition assessment, the design professional will compile the findings into a report, which can then guide further action. Typically, such a report will begin with a summary of the conditions prompting the investigation, whether due to observed distress, an inspection mandate, or proactive routine evaluation.

From the information-gathering phase of the project, the architect or

Mandated Parking Garage Inspections

In some jurisdictions, routine parking garage assessments may be more than just a good idea – they may be required.

The State of New York, for example, adopted a rule in late 2018 requiring garage condition assessments, performed by a qualified professional engineer, at least every three years.

While New York State stipulates what should be included in such an assessment, the basics are consistent with typical parking garage surveys, including an evaluation and description of:

The author on site to assess conditions at a hospital parking garage.

- *Unsafe conditions*
- *Conditions that should be remedied immediately*
- *Deterioration and distress that could result in unsafe conditions*
- *Problems that are leading to deterioration and hazards*
- *Corrective options*
- *Recommended timeframe for remediation*
- *Risks of not addressing the deterioration and defects*
- *Recommended timing of the next parking garage assessment*

Since the new regulation places the burden of instituting, administering, and enforcing the parking garage assessment program on cities, towns, counties, and other authorities having jurisdiction (AHJ), rather than on the State, program filing procedures are still being established. The rule suggests that the first assessment report will be due as soon as October 2019 for garages built prior to 1984; for garages constructed between 1984 and 2002, the deadline is a year later, and newer garages have until 2021 to complete the assessment. New parking structures must undergo an initial condition assessment before being issued a certificate of occupancy.

The New York City Department of Buildings announced in June 2019 that buildings located in the city are exempt from the state code, but that similar requirements for periodic parking garage inspections in NYC have been recommended for adoption as a local law.

Just as New York became a national model for facade inspection ordinances and energy conservation codes, it may serve as a paradigm for other jurisdictions nationally, as more states and cities recognize the importance of parking structure safety. Be on the lookout for similar regulations to come. ■

For more information, see the New York State Fire Marshals & Inspectors Association announcement, *http://www.nysfma.org/parking-garage-inspections/*, or the New York State Building Standards and Codes announcement, *https://www.dos.ny.gov/DCEA/pdf/2018-12%20Final.pdf*.

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engineer will provide a description of the garage construction, age, repair and modification history (as available), and other pertinent information.

Observations and Documentation of Existing Conditions

Photographic documentation of the current condition of the parking structure forms the backbone of the report, with descriptive notes explaining observed construction and distress. Locations and types of cracks, areas of corrosion, displacement, spalling, structural movement, moisture, and other signs of deterioration are noted and paired with illustrative photographs of typical conditions.

Evaluations

Next, the design professional discusses each of the reported conditions in the context of probable cause. Incorporating visual evaluation, as well as exploratory probe findings and testing results, the report opines on underlying conditions that led to observed distress.

Recommendations

Knowing how and why a parking facility is experiencing distress and deterioration is valuable information. Knowing what to do about it is even more important. The parking structure assessment concludes with the design professional's opinion of advisable corrective action for the conditions detailed in the report.

Repair strategies are generally accompanied by an opinion of probable cost, to guide planning and budgeting. The report may also provide recommended prioritization and phasing of corrective work, based on safety concerns, budget, and logistical considerations. Sometimes, a maintenance plan and schedule may be included, along with recommended frequency of inspection and upkeep activities.

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representative projects

Parking Structure Assessment and Rehabilitation

Identifying and responding to emerging conditions is critical to parking garage longevity, yet many garages fall prey to deferred maintenance. Regular assessment of parking structures provides a baseline to monitor incipient issues and properly allocate repair resources. Unless problems are detected, they cannot be solved.

Hoffmann Architects provides garage assessment and rehabilitation design services to diverse clients and facilities. Our work includes:

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MacDougall-Walker Correctional Institution
Suffield, Connecticut
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Foxwoods Resort Casino, Mashantucket, Connecticut, *Grand Pequot Parking Garage Assessment and Repair.*

MasterCard Headquarters
Purchase, New York
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New York Police Department
Brooklyn, New York
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The architect or engineer will typically schedule a meeting with the owner or manager to review the report and offer guidance for further action.

How to Make Best Use of Information from a Parking Garage Assessment

Deterioration or distress that creates unsafe conditions, or that is at risk of resulting in unsafe conditions, should be addressed as a matter of priority. While the condition assessment report provides useful recommendations for repair, these guidelines do not take the place of detailed project drawings and specifications, which should be prepared before repair work is initiated. The design professional's contract documents and construction administration services provide critical guidance to the contractor in carrying out the repairs, direction that can make the difference between a repair that solves the problem and one that soon fails.

The assessment also provides timelines for re-inspection, which is important to monitoring conditions that do not yet require corrective action, but which may become problematic. By routinely evaluating parking structures, building owners and managers can save time and resources, identifying and treating conditions before they become pervasive and require costly and disruptive remediation.

Probe to assess embedded reinforcing steel.

For garage users, unsightly and troubling deterioration does not make a desirable impression and can create a sense of an unsafe environment. Whether an innovative multi-purpose design, a sleek nod to the automobile age, a utilitarian facility, or some combination, a parking garage is only as good as its maintenance and reliability. ■

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