

Analysis of Parking Garage Repair

By Stephen A. Johanson, P.E.

In recent years, the repair and renovation of parking structures has become highly specialized. Parking structures, which are classified as buildings, are unique structures. Typically open to the environment, garages are often subject to freeze-thaw cycles, moving loads, excessive moisture conditions, and inherent high stresses contributed by rotational forces produced by vehicle wheel loads. Older parking garages were normally considered non profit-producing structures, setting the initial pretense that a garage's economic resourcefulness is often dependent upon low construction and maintenance costs. Major concrete repairs to parking facilities can be costly and disruptive; however, avoiding repairs can hamper the efficiency of the garage's operation, create tenant discontentment, or lead to possible legal action due to pedestrian or vehicular accidents (see Figure 1).

Recently, it has become increasingly common to utilize the design and repair approach, where a single contract is awarded for the analysis, design, and repair of a parking structure. This approach maximizes efficiency, develops a single source of responsibility, maintains high quality control, and develops the most cost-effective solution. Design and repair projects are done either by engaging a specialty concrete repair contractor with engineering capability, or through a joint venture between a contractor and consulting engineer. A contracted scope of work should typically consist of the following:

1. A condition survey;
2. Structural design review, repair details, and material specifications;
3. Owner inspection, coordination, and control;
4. Contractor quality control; and
5. Continuing maintenance program.

Condition Survey

Once a problem in a parking structure has been detected, a condition survey should be performed to define and understand the distress (problem) in order to properly recommend a repair solution. Concrete deterioration, cracking, joint failure, corrosion, leakage, and thermal expansion and contraction can be both aesthetic and structural concerns. Performing a condition survey can identify and categorize the problems and place them into their proper perspective.

The condition survey will define the existing conditions, the quantity and scope of the repair work,

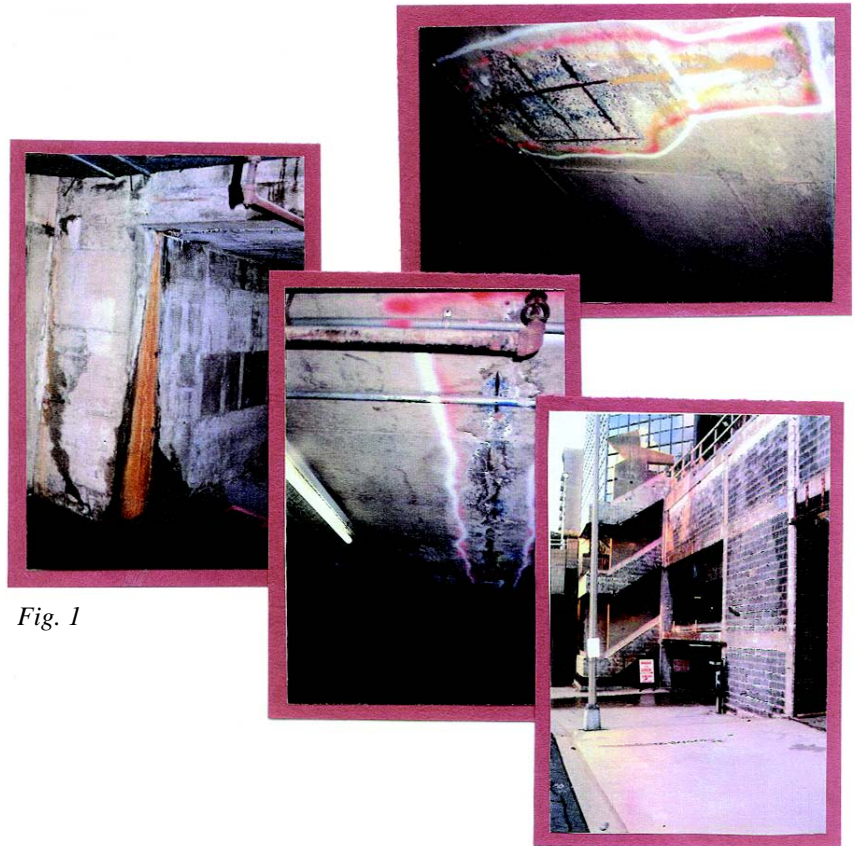


Fig. 1

recommend repair procedures, and, if necessary, recommend specialized repair materials. The condition survey can act as the basis for cost-estimating and bidding purposes. Primary and secondary problems are identified to allow the client to develop a budgeted repair program. The condition survey typically consists of the following:

EXHIBIT A

Condition Survey Practices for the Evaluation of Existing Concrete Structures

- A. Preliminary introduction:
 1. Site visit
 2. Field orientation
 3. Ambient/environmental review
- B. Review of preconstruction and construction data and operation and maintenance records:
 1. Preconstruction requirements
 2. Design criteria
 3. Concrete laboratory records
 4. Batch plant and field inspection records
 5. Construction techniques
 6. Operation and maintenance records
 7. Change orders



Fig. 2



Fig. 3

- C. Review of client inspection/maintenance programs:
 1. General
 2. Routine inspections
 3. Periodic inspections
 4. Inspection reports and records
- D. Condition survey field analysis:
 1. Crack survey
 2. Surface spalls and scale mapping
 3. In-situ stress determinations
 4. Supplemental instrumentation
 5. Seepage monitoring
 6. Surface damage
 7. Joint survey
 8. Concrete contamination analysis
 9. Reinforcing steel rust/corrosion analysis
- E. Nondestructive testing:
 1. Scope
 2. Surveying techniques
 3. Pachometer (R-meter)
 4. Acoustic (V-meter)
 5. Infrared
 6. Electrical potential
 7. Electrical resistance
 8. Moisture meter
 9. Ground surface radar
 10. Crack/joint monitors
 11. Dye test
 12. Bore scope
 13. Schmidt hammer
- F. Destructive testing:
 1. Petrographic examinations
 2. Chemical analysis
 3. Physical analysis
 4. Mechanical analysis
 5. Core drilling
 6. Partial demolition
 7. Strength testing
- G. Evaluation and recommendations:
 1. Determining the origin of distress
 2. Repair and rehabilitation analysis
 3. Review of material selection
 4. Cost vs. benefit relation

- H. Condition survey report:
 1. General description
 2. Evaluation of concrete deterioration
 3. Quantity of deteriorated concrete
 4. Cost analysis
 5. Repair details
 6. Prioritize repairs
 7. Estimate duration of repairs

Note: ACI Committee 364 has published "Guide for Evaluation of Concrete Structures Prior to Rehabilitation (ACI 364.1R-94)."

Structural Design, Repair Details, and Material Specifications

The majority of problems associated with parking garage deterioration and distress are often attributed to lack of proper consideration in the original structural design, repair details, and material specifications. Omissions and/or oversights, however slight, in these important design features, have the potential to create premature failure of structural members and repairs that can result in serious operational and maintenance problems (see Figures 2 and 3).

The most important consideration in the design and analysis of parking garage structures is recognizing the fact that the loading conditions, the design criteria, and the environment of these structures are distinctly different from those of conventional structures. Parking garages are constantly exposed to extreme weather changes in terms of moisture, temperature, and wind. Parking garages are also continually exposed to harsh and corrosive conditions caused by rain, snow, ice, and road salts. These conditions are significant where special design considerations need to account for the following:

1. Volume changes in the structure;
2. Cracking and spalling of concrete;
3. Corrosion of embedded steel;
4. Leakage;
5. Drainage; and
6. Concrete contamination.

In order to develop a detailed repair plan, one needs to understand the type of deterioration that has occurred, what the causes were, which preventive measures can be included in the design and construction, and the methods of repair for the correction and prevention of further deterioration. The entity recommending the repair details needs to be specialized in the repair of existing concrete structures and knowledgeable of current “state-of-the-art” engineering repair (see Exhibit B).

Emphasis needs to be given to the use of proper repair materials and the implementation of repair materials with construction details. Quality repair materials and proper placing, curing, and finishing techniques are necessary to assure durability. The use of admixtures is an important factor in the repair of concrete structures and should be used to assist in the workability of the repair material, increase its strength, and in some cases reduce material and installation costs (see Figure 4).

Various repair materials that have been recommended in the rehabilitation parking structures are as follows:

1. Portland cement mortars;
2. Portland cement concretes;
3. Polymer concrete;
4. Methylmethacrylate concrete;
5. Epoxy-modified concrete;
6. Magnesium phosphate concrete;
7. Late x-modified concrete;
8. Epoxy resins;
9. Sealants;
10. Sealer coatings;
11. Membrane coatings; and
12. Gunite (shotcrete).

Inspection, Coordination, and Control

Coordination with the owner, owner’s representative, subcontractors, material suppliers, and service forces is the responsibility of the contractor. Any operation that might affect or interrupt the use of a parking facility, unduly inconvenience the tenants, or disrupt their workstations must be carefully coordinated with the Building Manager.

Inspections render valuable services to both owner and contractor. A thorough inspection assists the owner in obtaining what has been specified and also helps the contractor avoid costly mistakes. Inspectors, whether the contractor’s or the owner’s, need to be present continuously, assisting the contractor in adjusting or correcting important out-of-specification materials and procedures. A good job requires adherence to a set time schedule, conscientious inspectors, overall coordination, and the

proper work environment in which to accomplish it. The professionalism that the contractor maintains in the project areas will be directly reflected in the coordination and control that exists in his office.

The owner should permit the contractor to do a good job. The Project Manager is concerned primarily with keeping a project on schedule and within budget, and at times may regulate quality to a lower priority. A quality job requires sufficient time, proper compensation, and the right atmosphere in which to work.

Deterioration	Cause	Investigation/Testing Techniques								Repair Techniques				
		Petrographic Analysis	Strength Analysis	Historical Research	Quantity Survey	Pachometer	Pulse Velocity Meter	Design Re-Evaluation	Coring	Concrete Removal & Replacement	Grouting	Strengthening	Joints	Coating/Sealers/Membranes
Weathering	Heat	X	X	X	X					X	X			X
	Thermal	X	X	X	X						X		X	X
Mechanical Spalling	Rust			X	X	X					X	X	X	X
	Stress			X	X				X		X	X		
Discontinuities	Honeycombs				X		X		X	X				
	Cracking		X	X	X				X	X		X	X	
Leaks	Embedded Metals				X	X				X			X	X
	Joints			X	X				X		X	X		

EXHIBIT B

Contractor Quality Control

Enough cannot be said concerning the qualifications of the contractor. Besides having impeccable credentials, the contractor should be intimately familiar with the type of repairs being initiated. Far too often, the respective contractor lacks the knowledge of proper surface preparation or application techniques, which results in premature failures. Today, with high interest rates, inflation, union restrictions, and government regulation, contractors are aggressively bidding for future work. Unfortunately, due to these circumstances, some contractors are bidding for work that would normally not be of interest. A roofing contractor bidding on structural repairs in a parking garage would be an example of this. When all is said and done, the owner of a facility is going to get what he has paid for, problems as well as benefits.

Specifications should state explicitly the requirements that all bidding contractors need to comply with. The following contractor quality control specifications have been utilized in rehabilitation construction projects, with excellent results:



Fig. 4

1. The contractors are required to have a minimum of five years' experience in the repairs, as stated within these specifications;
2. The contractors are required to submit with their bid five previous jobs (names, addresses, phone numbers and descriptions) similar in nature of the repairs, as stated within these specifications;
3. The contractors are required to have trained technicians who have attended specialized training courses in the preparation and application of the required repair materials;
4. Throughout the progression of the work, at least one person who is thoroughly familiar with the specified requirements and completely trained and experienced in the necessary skills shall be present at the site at all times; and
5. The contractor is required to submit a certified statement from the manufacturer indicating that he is qualified to install the specified repair materials.

Maintenance Program

Parking garages should be recognized as structures with unique characteristics, subject to severe environmental conditions. Budget, design, and construction requirements will reflect the garage's life-cycle performance. It is more economical to protect an existing structure and to require periodic checking and maintenance than to await advance deterioration before taking appropriate action.

Owners of parking facilities, who have all gone to great expense to build or purchase their property, need to develop a preventive maintenance program at the birth of their facility. A human baby's problems are easy to deal with when it is an infant; however, if the infant's problems are not corrected until it is an adolescent, complications develop that can have a devastating impact. A

parking facility currently requiring major renovation at one time would have only required remedial repairs. Shrinkage cracks, for example, in a concrete deck, should be routed and sealed. If left unattended, moisture, salts, and contaminants could turn an inexpensive repair into a major one. Preventive maintenance begins with a post-construction survey and continues for as long as the parking facility maintains its useful service.

The design and implementation of a maintenance program should be discussed with a consulting entity. Programs can be developed which allow the owner's maintenance staff to inspect and repair construction materials having limited service life, or to be trained to observe the warning signs of more complex problems.

Specialty concrete repair contractors with engineering capability have developed client maintenance programs, instructing owner's employees in a turnkey approach designed to last 5, 10, and even 30 years. In this manner, parking facility owners can increase the useful services of their facility while eliminating high rehabilitation costs, which are eminent to parking facilities without maintenance programs.

The maintenance program for a particular garage facility needs to be custom-designed. Its activity level, location in the country, and present physical condition will affect the type and extent of the preventive maintenance or structural programs required. A sound maintenance program should include, at a minimum, the following:

- Annual structural review;
- Water infiltration analysis;
- Housekeeping;
- Snow removal;
- Graphic/Line painting; and
- Maintenance of plumbing, lighting/electrical systems, security systems, attendant booths, doors and hardware, and elevators.

By following a detailed and well-thought-out plan, whether for major renovation or minor maintenance and repairs, parking garage owners can keep their facilities running smoothly, cost-effectively, and with only minor inconveniences to the normal flow of traffic.



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