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## Rehabilitation of Parking Garages

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Predrag L. Popovic, born 1944, received his structural engineering degrees from the University of Belgrade and the Illinois Institute of Technology. He has investigated distressed conditions and designed repairs for over 200 parking structures.



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## Summary

Millions of dollars are spent annually to address deterioration and maintain or restore serviceability in reinforced concrete parking structures. Investigation of distressed conditions in hundreds of parking structures and subsequent design and installation of repairs have revealed the most common causes of distress and the most effective ways to repair and extend the life of these structures. This experience has also led to the development of maintenance priorities that can improve the serviceability of parking structures and reduce the probability that future major repairs will be required.

### **1. Visual Signs of Problems**

The most common signs of potential problems in parking structures are cracking and spalling of concrete and leakage of water through cracks and joints.

Cracking in concrete structures is not unusual and occurs for a variety of reasons. One of the most common is the stresses caused by restraint to ordinary volume changes in the structure. Loadings that exceed the cracking strength of the concrete are another cause. Cracking can also be an indication that corrosion of embedded reinforcement is occurring or that a structural deficiency exists.

While most cracks are not an immediate structural concern, all cracks should be assessed by an engineer or other qualified person to verify their cause. If the cracking is not related to a structural deficiency, the cracks should be evaluated for their impact on serviceability. If exposure to moisture and salts is not severe, no further action may be necessary. On the other hand, in a high moisture or salt environment, the presence of any cracking can accelerate penetration of moisture and salts into the concrete causing reinforcement to corrode. Water penetrating through cracks in overhead slabs can also drip onto vehicles and damage finishes.



Concrete spalling is usually caused by corrosion of steel reinforcing embedded in concrete that is exposed to moisture and chlorides (from de-icing salts). Since the volume of corrosion by-products (rust) is significantly greater than the volume of the original steel, corrosion of embedded bars creates expansive forces which can cause the concrete to crack and spall.

Cracking and debonding of sealants used in the joints of certain types of concrete parking structures are a sign that maintenance or repair is needed. Visible distress in expansion joint seals, which may not have been designed to accommodate structural movements or which have been damaged by snowplows or vehicular traffic, are also a sign of problems.

Visible signs of distress should be evaluated. This is usually done by performing a condition survey which may be supplemented by structural analysis or testing. The specifics of a typical condition survey, which include document study, visual examination, delamination survey, core sampling, and nondestructive testing, are discussed.

## **2. Repair Techniques**

The results of the condition survey are used to develop repair documents. Repair strategy depends on the condition of the structure. In addition to technical issues, selection of the appropriate strategy will be dictated by costs, the owner's future plans, and availability of funds. Scheduling of repairs will depend on the need to maintain partial occupancy during the work.

Proven techniques for patching floor delaminations and overhead and vertical distress, installing full-depth slab repairs, sealing cracks, adding bonded concrete floor overlays, installing membranes and sealers, and addressing expansion joint and drainage problems are covered.

Specifics on each technique and useful tips based on successful experience are provided. A recommended maintenance program for a reinforced concrete structure in reasonably good condition, and located in an environment with moderate to heavy moisture and salt exposure is also provided.

## **3. Conclusions**

The causes of distress and deterioration in reinforced concrete parking structures are common and well known. Experience proven procedures are available to successfully repair the common types of distress and deterioration. Once repairs are completed, establishing a routine and reasonably inexpensive maintenance program can prolong the useful life of the structure and minimize the need for costly additional repairs.