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Evaluation and Repair of Deteriorated Garage Floors

Please note

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In the past, the potential for corrosion in indoor parking garages has not been sufficiently appreciated and construction techniques were utilized that did not give adequate protection against this. Consequently, major repairs became necessary, often after only a few years of service. The causes of deterioration were the subject of a previous CBD, while the present Digest describes the methods used for the assessment of damages and how these tests can aid in the selection of the repair method.

Evaluation

In order to arrive at the best and most economical repair strategy, a thorough examination of the garage is indispensable. This task should be handled by an independent consultant experienced in garage repairs rather than relying on the opinion of a contractor in selection of the repair technique. Contractors who specialize in a particular type of repair, may focus their attention on aspects of their specialty, and perhaps underestimate the importance of defects falling outside their field. As a result, their report might lack proper balance.

Visual inspection

A visual survey, if done by an expert, is the key element in the evaluation process. The first objective is to detect possible structural defects, cracks in the deck, the conditions of beams and columns, and to decide whether consultation with a structural engineer is necessary. Beyond that, an expert will advise whether the structure can carry additional load in the form of overlay if such a mode of repair is contemplated.

Another purpose of the survey is to identify as accurately as possible the cause of deterioration. Conclusions can be reached on the basis of these observations, such as the quality of concrete, the depth of cover over the reinforcing bars, the type and extent of the damages, etc.

The location of defects, including those found on the underside of the slab, should be marked on the site plan. Normally, the degree of scaling is expressed in terms of depth, as follows:

light scaling	0 to 5 mm
medium scaling	5 to 10 mm
heavy scaling	10 to 25 mm
severe scaling	over 25 mm

Cracks are classified according to their widths:

hairline (H)	less than 0.1 mm
narrow (N)	0.1 to 0.3 mm
medium (M)	0.3 to 0.7 mm
wide (W)	greater than 0.7 mm

Because the edges tend to break off, cracks appear wider at the surface level than below it. This difficulty is overcome by reporting the crack width at a depth 5 mm below the surface.

If the deck is covered with a wearing course, such as asphalt, the condition of the concrete must be assessed from signs of deterioration, such as rust stains, cracks, water spots and efflorescence, on the underside of the slab.

The distance between floor drains should be noted, as well as the condition of the drain pipes, the effectiveness of the slopes and the likelihood of puddle formation.

Expansion joints have to be carefully examined and, if defective, repair or replacement ordered. This is quite often overlooked and the penetration of salt laden moisture seriously shortens the lifespan of the repaired deck. Of particular concern are the expansion joints over ledge beams, a location of structural importance.

The observations noted on the site plan serve as the basis for developing a repair strategy.

Delamination survey

Delamination is the separation of the slab usually at the level of reinforcement in a plane roughly parallel to the upper surface, and is caused by corrosion of the steel. Whether visible on the surface or not, delaminations should be repaired as they indicate a high level of corrosion activity and may lead to significant structural weakening.

Delamination can be detected by a dull sound heard when the slab is struck. A variety of tools may be used for the test but the most efficient and simple one developed is the chain drag. It can be in the form of a 1.5 m long single heavy chain, with 50 mm links made of 10 mm diameter steel, which is swung from side to side. Another, more popular form, is constructed from four 0.5 m long chain (25 mm links) segments attached with rope to 0.5 m long copper tubing. The operator holds the handle, attached to the midpoint of the tube to form a T, and pulls the chain from side to side in a swinging motion which, unless delamination is encountered, results in a ringing sound.

If the concrete is covered with an overlay, detection of the sound indicating the presence of delamination may be difficult. Also, the dull sound could be due to loss of bond between the concrete and the overlay. If the asphalt overlay is thicker than 30 mm, it is necessary to remove it in certain areas to perform the test. Differentiation between debonding of an overlay and delamination in the concrete can be made by coring in the dull-sounding areas.

Cover meter survey

The reinforcing steel in parking garage decks should be protected with a 50 mm thick concrete cover, a minimum requirement which is unfortunately seldom met. To obtain reasonably long service life for the repaired deck, those areas where the cover is less than 25 mm have to be identified and corrective measures taken.

The thickness of the concrete over the steel can be measured with a cover meter, also known as pachometer. Several types are available. The accuracy is in the range of ± mm for a cover less than 25 mm.

Measurement of corrosion potentials

Corrosion of metals is an electrochemical process in which the deteriorating area of the metal is the anode, the positively charged electrode of the galvanic cell. Positive potential of the metal

indicates corrosion activity, i.e., the metal in this region is converting from the metallic to the ionic state. The value of the potential depends on the tendency of the metal to go into solution and, based on the concentration of ions around the electrode, is a good measure of the corrosion that has taken place.

The potential of the steel is measured against a copper/copper-sulfate half cell, as reference. If a water-proofing membrane is present, it has to be punctured to establish electrical continuity before the test can be performed. With galvanized steel, interpretation of the results is difficult and, if epoxy-coated, the measurement cannot be made at all for lack of electrical continuity.

Measurement of chloride content

Steel in concrete, due to the prevailing high alkalinity, corrodes very little, unless the chloride concentration of the pore solution exceeds a critical value. The chloride content of concrete is, therefore, an important factor to consider when evaluating the causes of deterioration. Samples for the test are obtained from the level of the reinforcement by drilling or coring and, after indicating the location and the depth of origin on the label, are sent to the laboratory for chemical analysis.

In evaluating the result, differentiation has to be made between the harmful soluble and innocuous nonsoluble chlorides. Certain aggregates, for example those from the Niagara escarpment, contain a significant amount of non-soluble chlorides. To arrive at the chloride concentration of interest, the "background" chloride content, originating from the mixing water, portland cement and admixtures, has to be subtracted from the total.

Interpretation and Significance of Test Results

The visual inspection and the delamination survey are, perhaps, the most important tests; based on these, the repair strategy can be formulated. From these tests information is obtained on structural aspects, on the condition of the expansion joints and the drainage facilities. The extent of delamination expressed as percentage of the total area is a good measure of the corrosion activity. These two tests must always be performed; the others are performed according to the needs. For example, if there are indications of insufficiently thick cover over the reinforcing steel, a survey to clarify this aspect is useful. In evaluating the result, it should be kept in mind that if the cover is in excess of 3.5 cm thick, corrosion seldom results in delamination, while with less than 2 cm cover, or unless some other protection is provided, problems will probably recur after repair.

The potential of the copper/copper-sulfate half cell is another good indicator of corrosion activity. Corrosion is considered to be active if the potential is a greater negative value than -0.35 volt, with spalling expected to occur above -0.50 volt. The numerical value of the potential is proportional to the extent of corrosion but not necessarily to the rate.

The threshold value of chloride concentration above which corrosion of the reinforcing steel is expected to occur is 0.20% chloride by weight of cement. In concrete with 400 kg/m³ cement content and 2300 kg/m³ unit weight this concentration value is equivalent to 0.035% chloride by weight of concrete. Unfortunately, corrosion can take place even with lower concentration if the conditions are favourable. To remove all salt-contaminated concrete is seldom practical but the corrosion rate can be greatly reduced by installing an effective waterproofer. All delaminated concrete should, of course, be replaced.

Repair Strategy

If a weakening of the structure has occurred, restoration of structural integrity is the first objective of the repair. The second objective is to restore functional integrity in the most cost-effective way. To do so, the cause of the deterioration has to be identified.

Deterioration itself is evidence that the protection provided was insufficient for the prevailing conditions. In many cases the concrete is not dense enough, the cover over the reinforcing steel is inadequate, no waterproofing membrane is installed and, due to inadequate drainage facilities, excessive ponding occurs. The severity of the conditions can be mitigated by

improving drainage but to replace the deck with better quality concrete is prohibitively expensive. Increasing the cover thickness is also expensive and not really feasible as few decks have the reserve load-carrying capacity required by such additions. Thus, only by providing further protection can the service life of this inherently nondurable deck be lengthened.

Installation of a waterproofing membrane is a technically effective solution to the problem, the cost of which is reasonable. Obviously, the extent of repair work and the provision of additional protection depends on the characteristics of the particular case. Availability of funds, the economic loss caused by interruption of garage service, inconvenience and other considerations will also greatly influence the decision.

It is advisable to develop a plan that includes:

1. the repair of concrete in all delaminated areas;
2. the installation of a waterproofing membrane or an overlay, if such is not in place;
3. the repair of the expansion joints; and
4. any necessary upgrading of the drainage system.

Restoration of parking decks is usually carried out according to one of the following three approaches:

1. sealing the cracks in the concrete slab with epoxy injection and installing a waterproofing membrane with a wearing course;
2. removing the deteriorated concrete and, after cleaning the reinforcing steel, repairing the areas by patching with concrete. Again, a waterproofing membrane with a wearing course should be installed;
3. as described under 2, but installing a 5 cm thick dense concrete overlay instead of a waterproofing membrane. To reduce the weight of the extra load of the overlay, removing the existing concrete to some depth is often necessary.

The first method is best suited for repairs required for structural purposes where advantage is taken of the great strength of the costly epoxy binder. The second and third methods have been widely used in recent years with apparently good success but the experience gained to date is insufficient to make any statement on their long-term durability. Evaluation is made difficult also as every job has unique characteristics and compromises might have to be made for technical or economic reasons.

Concrete Repair Technique

The perimeter of a concrete repair should be sawcut to a depth of at least 15 mm to avoid feather edges, and preferably the concrete should be undercut to "key in" the patch. Only light jackhammers or other chipping tools should be used to avoid damaging the surrounding areas and to prevent loss of bond in the remaining concrete. If removal of the deteriorated concrete exposes more than half the perimeter of a reinforcing bar, it is advisable to completely expose the bar allowing sufficient clearance underneath to ensure encasement and good bond. The steel has to be cleaned to bare metal by sand blasting. All debris must be removed and the surface cleaned of loose material with high pressure air or water.

The new concrete should be compatible with the concrete in place. The cement content should be in excess of 360 kg/m^3; the water/cement ratio should be less than 0.45 and contain air-entraining admixture. Between the old and new concrete a portland cement bonding agent should be used which consists of equal parts of cement and fine aggregate, with water added in a quantity to produce cream consistency. Alternately, latex-modified portland cement grout or epoxy resin bonding agents can be used, and applied according to the manufacturer's directions.

Inspection and Testing

In repairs, unforeseen situations often develop which require judgement, inventiveness and experience. To rely solely on material and procedure specifications prior to the work is not a sound practice. The contractor should be very carefully selected and, if feasible, an independent consultant for inspection engaged.

Maintenance

In indoor garages, it is beneficial to maintain low temperatures (above freezing) and good ventilation. Salt-containing mixtures must not be stored there. Slabs should be washed periodically and drains maintained in a free-running condition. After repair, the garage should be inspected regularly, and any necessary steps taken to correct problems that develop.

Sources for Further Reading

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