Factors affecting the durability of concrete repair: the contractor's viewpoint

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1.0 Introduction

Despite the large and expanding repair and rehabilitation market, little has been done to establish the methodology of design for repair durability and to establish performance criteria for selecting and specifying repair materials. The object of any repair project should be to produce adurable repair, which means to produce a repair at relatively low cost with a limited and predictable degree of changeover time and without deterioration and/or distress throughout its intended life and purpose. Lack of durability of repaired structures is manifest inthe form of spalling, cracking, scaling, loss of strength.

2.0 Factors affecting the durability of concrete repair

The factors relevant to the durability of concrete repairs are given in Fig.1:

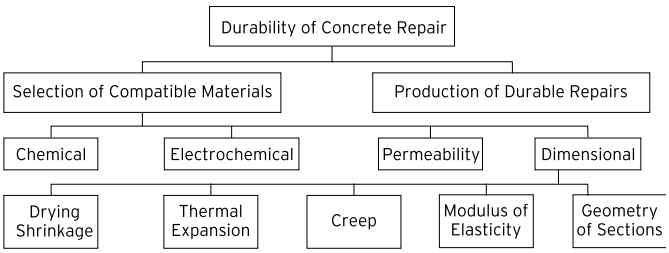

Fig. 1: Factors affecting durability of concrete repairs

2.1 Compatibility of repair materials with existing concrete

It is mostly due to overemphasis on strength rather than on long-term durability that a majority of repairs suffer from cracking due to drying shrinkage, creep, excessive heat of hydration, and other causes. Compatibility of the repair materials with the existing substrate and durability under various conditions in service are of much greater importance. In practical applications of repair materials, the emphasis in many cases has to be shifted from compressive strength and/or low permeability to other properties or combinations of properties of the repair material collectively called compatibility with the existing substrate.

Compatibility is the balance of physical,chemical and electrochemical properties and dimensionsbetween repair materials and existing substrates that ensures that a repair withstands all stresses induced by volume changes, chemical and electrochemical effects without distress and deterioration in a specified environment over a designed period of time.

2.1.1 Dimensional compatibility

Dimensional compatibility is the phenomenon of volume changes and the major problem of concrete repairs. It adversely affects the durability of repair and/or load-carrying capacity of structural repairs. It may lead to the inability to carry the expected portion of the load and to overstressing in the existing structure, but would not necessarily affect durability.

The most important of them with regard to dimensional compatibility isdrying shrinkage. At the same time, drying shrinkage is the most ignored property of repair materials. Thermal compatibility is another critical property to consider when specifying and selecting any repair material, regardless of its chemical composition.

2.1.2 Chemical compatibility

Chemical compatibility properties to consider may include alkali content, C_3A content, chloride content, etc. All aspects of chemical compatibility must be considered in the selection of repair materials. For instance,when concrete that is being repaired includes potentiallyreactive aggregates, a repair material with low alkalinity must be specified.

The reactivity of the repair material to reinforcing steeland other embedded metals or to specific protective coatings or sealers applied over the surface repair must also be considered. Repair materials with moderate to low pH may provide little protection to reinforcement. Moreover, certain repair materials are not compatible with waterproofing membranes required as protection following a repair. Therefore, the reactivity of the various repair materials with both the substrate and surface protection product should be considered.

2.1.3 Electrochemical compatibility

For each reinforced concrete repair case, electrochemical compatibility must be considered, and an evaluation of the electrochemical behaviour of local (substrate) and potential (repair material) macrocell must be carried out.

2.1.4 Permeability compatibility: a revised viewpoint

It is widely accepted that very low permeability is desirable for a repair material, which is actually not true in many cases. This concept may, in some cases, lead to a false sense of security, and unsuitable materials incapable of providing lasting performance can be specified.

The concept of using low-permeability repair materialsregardless of the situation is a fallacy. It is correct that permeability is the key to durability of concrete, a composite material. A number of major points, including one that a repaired structure is not a composite material but a composite system of materials, have been ignored, not because they do not matter,

but largely because they do not conflict with the general concrete durability theory. Therefore, it appears advisable that this concept be abandoned because of altogether too much conflicting evidence. It iscompletely conceivable that in the cases discussed, repairmaterials with permeability compatible with the existing concrete should have been specified and used.

2.2 Properties of the environment

It can be noted that the repair failures manifested in cracking, delamination and spalling. Some force has imposed tensile stress on the repair beyond its capacity to resist that force. Cycles of wetting and drying due to sun and rain cause dimensional expansion and contraction and may generate stresses in excess of the tensile capacity of the repair and thus cause cracking. Temperature changes also cause expansion in hot weather and contraction in cold weather. That again may create tensile stresses beyond the resistance capability of the repair and thus cause cracking.

If the properties of the environment in which the repaired structure is to serve are known, the levels of the relevant properties that repair materials must have in that environment to yield the desired performance may be selected. When the specifications are properly prepared and complied with, the repair possesses such properties that as it interacts with the elements of the environment, it will not deteriorate.

2.3 Load conditions

Concrete repair problems are diverse in nature. Each deterioration condition requires a clear understanding ofwhat is expected of the repair.Three general performance requirements are protection, appearance and load carrying. The process of repairdesign and specification consists of determining the exactfunction of the repair so that the correct repair materialscan be specified. A concrete repair must replace damaged concrete around the damaged areas. To recreate the ori-ginal load distribution, full load relief must be provided during the surface repair process. Repair material must be installed and cured. After the material reaches the specified strength, loads would be allowed on the member. Load relief from members is typically provided with temporary shoring and jacking.

2.4 Condition of the interface (concrete-repair bond)

Concrete repair is a composite system consisting of repair material and concrete substrate. In composites the bond between the individual constituents (phases) is most critical for the properties of the composite. Assuming the properties of the constituents are good, any improvement of the bond will improve the properties of the composite system.

Achieving an adequate bond between repair materials and existing concrete is a critical requirement for durable surface repairs. The bond at the interface between the repair material and concrete substrate is likely to be subject to considerable stress from volume changes, force of gravity and, sometimes, impact andvibration.

2.5 Production of durable repair

The best methods and materials specified for the repair project will be entirely deprived of their merits if there is even the slightest neglect in construction practices. The placement technique must deliver the selected repair material to the prepared substrate with specified results. The repair material must achieve a satisfactory bond to the existingsubstrate, must fill the prepared cavity without segregation, and must fully encapsulate the exposed reinforcingsteel. Without achieving the above requirements, the surface repair may not perform its intended structural, protective and aesthetic duties. The bond of the repair to the substrate depends to a large degree on mechanical interlocking with the prepared concrete surface. For this to occur, an adequate force should be applied to the repair material to bring it into intimate contact with the prepared surface. The repair material must also have an adequate amount of binder to interact with the prepared surface.

All operations involved in concrete repair are equally important. An issue relevant to many current problems with concrete durability is corrosion of steel reinforcement, which can be attributed, in most cases, to faulty design, material specifications and selection, and work-manship. When considering the protection provided by acement-based material to embedded reinforcing steel, the condition of the interface between the steel and the cement-based material is of paramount importance.

Among the various technological factors affecting the production of concrete repairs, the curing process employed has the greatest influence on durability. It should also be recognized that the curing process is possibly the least controlled process in the production of concrete repair owing to a lack of understanding that only adequate curing will allow the achievement of suit-able hydration of a repair material and designed levels of durability.

3.0 Conclusions

The architect and engineer need to apply engineering principles in the design of repair projects with the same professionalism as they do in designing new structures. The presented methodology defines the most important factors to be considered when designing for repair durability. When details are properly designed and specifications are properly prepared and complied with, the repair will possess such properties that, when interactive with the environment, will have the serviceability and durability required for the intended use.