1.571: Design and Mechanics of Concrete
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Introduction

The service life of concrete is limited by cracks, spalling of the concrete cover, and rebar corrosion. Often repairing these problems can be as complex as designing a new structure. This is because concrete is a non-homogeneous material and each repair is different. Another major issue with repair materials is that they must be compatible with the original concrete. The repair material and the concrete must work as a single unit in order to carry the applied stresses and to protect the reinforcing steel. However, finding a compatible repair material is not an easy task. Compatibility is determined by a number of criteria. The material must have a similar modulus of elasticity, similar compressive strength, be chemically compatible, and have similar volumetric change properties. The repair materials must also provide strong bonding strength with the existing concrete, low permeability of water and chloride, and cure rapidly to limit disruption of service.

There are two categories of concrete repair: local repair and global/system repair. The most common local repair materials are epoxy resins, polyester resins, polymer latex, polyvinyl acetate, and magnesia-phosphate cement composites. The effectiveness of these materials will be investigated in this paper. This paper will not examine global/system repair schemes.

Background

Considerations Caused by Concrete Behavior

Effects of Weather

Structures that are exposed to weather are subjected to drastic seasonal temperature changes as well wetting and drying cycles. These conditions cause stains to accumulate in the concrete. However, the effects of weather are less severe in core of the section than at the surface. This implies that there is some critical depth measured from the surface that feels the greatest strains from temperature and humidity changes. The depth of this layer is not constant for all specimens, even ones in the same climate. Some surfaces are exposed to direct sunlight for long portions of the day while others are shaded for a few hours or all day. Similarly, some surfaces are protected from rain while others are not (1).

Modeling the hygral changes due to weather effects has been researched in a few studies.

Shrinkage

Shrinkage is caused by the loss of water in drying and it is mostly reversed when the specimen is wetted. It is independent of the level of stress being applied to the specimen. Therefore, it is possible to calculate the shrinkage independently of the mechanical properties of the concrete. This is an important effect to consider for local concrete repair because once the repair mix is applied to the concrete it will begin to shrink, causing stresses to build between the concrete and the repair mix.

Laboratory tests show that moist curing for three months or greater significantly reduces the shrinkage of concrete.

Creep

Creep is a time dependent deformation. Under normal conditions it has the beneficial effect of causing a relaxation of stresses in a concrete section. However, restrained shrinkage builds up tension in repaired sections, which can cause cracking or failure in the repaired section. Little is known about creep of concrete in tension (1). Modeling concrete creep is complicated by the fact that the true mechanisms of creep are not completely understood, as illustrated by Pickett's Paradox (figure 1). The strains observed in a drying specimen can be up to four times greater than in a completely saturated specimen, but there is almost no strain in a dry specimen.

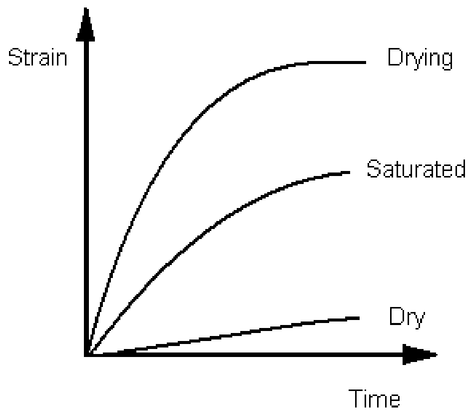

Figure 1: Pickett's Paradox

Materials

Polymer Concrete

In polymer concrete polymeric materials are substituted for Portland cement to bond aggregates. Polymer resins improve the mechanical behavior of the concrete as well as improving the durability. It reduces the water and salt permeability and offers good corrosion protection. They also cure faster than traditional concrete, which is important to reduce the down time in service life of the structure (3).

Polymer resins are not cheap however. Therefore, a lot of work has gone into studying the optimum ratio of resin to aggregate, which has been found to be from 1:7 to 1:12 (2).

1. Francios Saucier, Frederic Claireaux, Daniel Cusson, and Michel Pigeon, “The Challenge of Numerical Modeling of Strains and Stresses in Concrete Repairs”, *Cement and Concrete Research*, Vol. 27, pp 1261-1270, 1997.

2. Hisham Abdel_Fattah and Moetaz M. El-Hawary, “Flexural behavior of polymer concrete”, *Construction and Building Materials*, Vol. 13, pp 253-262, 1999.

3. MM Al-Zahrani, M Maslehuddin, S.U. Al-Dulaijian, and M. Ibrahim, “Mechanical properties and durability characteristics of polymer and cement-based repair materials”, *Cement and Concrete Composites*, Vol. 25, pp 527-537, 2003.