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Delamination tendency of repair mortar incorporating crumb rubber

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Abstract

The success of repair material to extend the service life of infrastructures will be determined by its performance and durability. The delamination tendency of this material may be a crucial factor that governs its performance and durability. This paper investigates the delamination tendency of repair mortar incorporating crumb rubber at various contents. The beneficial effect of incorporating crumb rubber to reduce the risk of delamination is discussed. A simulation of shear stress due to differential shrinkage in the interface between repair mortar and substrate concrete is accomplished to highlight the important of material properties (elastic modulus, creep and shrinkage) with regards to delamination tendency.

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Keywords: creep; crumb rubber; delamination; elastic modulus; repair mortar; shrinkage; shear stress

1. Introduction

Reinforced concrete is one of the main materials used in the construction and development of various infrastructures. There are many reasons why this material turns out to be a preferable choice in the construction of countless infrastructures around the world. The widespread availability of concrete ingredients and the versatility of this material to be manufactured into any shapes and sizes could be those of the considerations. In spite of its advantages, it should be aware that a reinforced concrete will eventually deteriorate due to a number of factors. A reinforced concrete structure may experience some extreme circumstances during its service life. In the seismic zone for example, earthquake could trigger excessive loading on the structure causing structural damage. In aggressive environment, the service life of the structural concrete may be shortened due to the accelerated degradations. All of

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these situations should remind civil engineers that in addition to the creation of new infrastructures, there is a great challenge to maintain and rehabilitate the existing infrastructures.

Maintenance and rehabilitation are important schemes to extend the service life of existing reinforced concrete structures. A longer service life means preserving and limiting an exploitation of natural resources that would be utilized to replace the out of use structures. Thus, maintenance and rehabilitation are part of the holistic strategies to promote sustainable infrastructures. The type and technique of maintenance or rehabilitation are vary and these depend on the forms of degradations that would be tackled. Degradations of structural reinforced concrete element in the forms of spalling and delamination of the concrete cover may be repaired by patching method. The success of this method relies on the performance and durability of the repair material being used.

Experience shows that the design of durable concrete repair material can be more complex than the design of new structures, because each damaged structure imposes its own necessities. Mistakes in design, selection of materials, and execution of repair work lead to crack formation, with a drastic consequence on the durability of the repaired structure [1]. Matthews [2] investigated performance of repair materials via case histories and found a variety of modes of repair failure. The principle modes of repair failure were cracking (32 %), debonding (25 %), continues corrosion of embedded reinforcement (22 %), alkali aggregate reaction (4 %) and others (17 %). Most of the failures i.e. cracking and debonding (delamination) could be initiated by a dimensional incompatibility between the repair material and the substrate concrete. This dimensional incompatibility could be explained as follows: when a cement-based repair material is applied to seal the patching zone of concrete element, hydration of the repair material will promote adhesion in the interface between repair material and substrate concrete. After the repair material attains a hardened state, the two components become a composite system. Differential shrinkage and thermal expansion will exist due to the new repair material tends to exhibit higher shrinkage and thermal expansion than those of the old substrate concrete. For the case of differential shrinkage, the deformation of the repair material will be restrained by the substrate concrete which induces tensile stress in the repair material and compressive stress in the substrate concrete. The induced tensile stress could result in the formation of cracking in the repair material [3, 4]. In addition to these stresses, shear stress in the interface and tensile stress in the direction normal to the interface plane are also induced which may cause delamination and peeling [5-7].

Understanding the mechanisms in which cracking and delamination of a repair material may occur is a key to identify the influencing parameters. As explained in the previous paragraph, cracking and delamination of repair material are initiated by the development of shrinkage stresses. These stresses are controlled by the magnitude of differential shrinkage between the repair material and the substrate concrete. Thus, limiting the shrinkage of the repair material could be one of the approaches to obtain durable repair material. However, it is recognized that creep of the repair material also plays important role in releasing the shrinkage stresses. A repair material with a higher creep coefficient will be a better choice than that of a lower creep coefficient. Another parameter that must be taken into account is an elastic property of the two components of the composite system. A lower elastic modulus of the repair material will decrease the induced shrinkage stresses. A lower elastic modulus of the substrate concrete will reduce the degree of shrinkage restraint, which in turn minimizing the shrinkage stresses [4, 8-11]. Based on the above identified parameters and other relevant properties, Beushausen and Alexander [12] proposed design considerations for obtaining durable concrete patch repair. Meanwhile, Li and Li [13] proposed a repair material with special mechanical characteristics i.e. high strength and high ductility. These two characteristics are other important parameters to promote a higher resistance of repair material against cracking and delamination. Cracking can only occur when the induced shrinkage stress has attained the tensile strength of the repair material. The ductility of the repair material which is provided by a large inelastic strain capacity under tensile stress is beneficial to offset the shrinkage demand and so lowering a risk of delamination.

The effect of all the influencing parameters on the induced shrinkage stresses in the patch repair system could be formulated in the analytical model. A number of models to compute shrinkage stresses for this case have been developed by many authors [1, 5-7, 9-12, 14]. In the development of the models, the initiation and then the progress of shrinkage stresses can be divided into several stages. Firstly, it is assumed that the repair material can freely shrink. At this stage, there are two distinctive approaches in the consideration of the shrinkage of the repair material. Most of the models assume that shrinkage is constant across the depth of the repair material. It may be argued that as a result of drying, the surface of the repair material tends to experience higher shrinkage than the layers below. Hence, there exists a shrinkage gradient throughout its thickness. Wittmann and Martinola [1] proposed a model that