STRENGTH PROPERTIES OF SELF-HEALING MORTARS

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To my Family
For your companionship, understanding and
Continuous encouragement over the years.

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ABSTRACT

Cementitious materials are the most widely used in building materials all over the world. However, deterioration is inevitable even since in the very beginning of the service life. In addition, the maintenance and repair work which are often labor- and capital-intensive, would be followed. Thus, self-healing of the affected cementitious materials is of great importance. Self-healing phenomenon in cementitious materials has been noticed and been studied for a long time. Self-healing of micro cracks by introducing bacteria at the time of formation of mortar or concrete is gaining momentum these days. However presumably self-healing with polymeric admixtures might be relatively more durable and faster process. The development and characteristics of self-healing synthetic polymeric materials have been inspired by biological systems in which damage triggers an autonomic healing response. This is an emerging and fascinating area of research that could significantly extend the working life and safety of the polymeric components for a broad range of applications. In this research an epoxy resin (diglycidyl ether of bisphenol A) without any hardener is used as polymeric admixture to prepare polymeric-cementitious materials and their self-healing function is evaluated. Epoxy-modified mortars are prepared with various polymer-cement ratios subjected to initial wet/dry curing plus long term dry curing and tested for strength properties. The fundamental properties such as workability, influence of curing, strengths, strength development, porosity, permeability and water absorption are investigated. The ultrasonic pulse velocity (UPV) and compressive strength test were conducted to determine the ability of self-healing of Mortar by used liquid polymer. The result shows that 10% of polymer is the best percentages of polymer - cement and wet dry curing was the best mechanism to heal the hairline crack in mortar.

ABSTRAK

Simen adalah yang paling banyak digunakan dalam bahan membuat bangunan di seluruh dunia. Walaubagaimanapun , kecacatan struktur tidak dapat dielakkan sejak dari mula bahan digunakan. Di samping itu, penyelenggaraan dan kerja-kerja pembaikan yang yang memerlukan modal dan tenaga kerja yang tinggi telah menjadi masalah dalam sektor pembangunan. Oleh itu, rawatan penyembuhan automatik oleh bahan tambahan dalam simen adalah amat penting. Rawatan penyembuhan automatik telah dikaji sejak dahulu lagi. Rawatan penyembuhan automatik untuk membaiki keretakan mikro dengan menggunakan bakteria didalam komponen simen sangat popular di kalangan penyelidik. Walaubagaimanapun, rawatan penyembuhan automatik dengan bahan tambah polimer adalah proses yang lebih tahan lama dan lebih cepat. P embentukan dan ciri-ciri bahan sintetik rawatan penyembuhan automatik dari polimer telah diilhamkan oleh sistem biologi di mana kerosakan mencetuskan suatu gerak balas penyembuhan autonomi. Ini adalah rawatan baru dan menarik dalam penyelidikan yang boleh melanjutkan hayat kerja dan keselamatan sesuatu struktur bangunan. Dalam kajian ini, resin epoksi (diglycidyl ether bisphenol A) tanpa pengeras digunakan sebagai bahan tambah polimer untuk menyediakan bahan polimer-simen dan fungsi rawatan pemulihan secara automatik dikaji. Mortar epoksi diubahsuai disediakan dengan pelbagai nisbah polimer-simen tertakluk kepada pengawetan basah-kering ditambah pengawetan kering jangka panjang dan diuji untuk ciri-ciri kekuatan. Sifat-sifat asas seperti kebolehkerjaan, pengaruh keadaan pengawetan, kekuatan, keliangan, kebolehtelapan dan penyerapan air dikaji. Ultrasonik halaju (UPV) dan ujian kekuatan mampatan telah dijalankan untuk menentukan keupayaan diri penyembuhan mortar oleh bahan tambah polimer. Hasilnya menunjukkan bahawa 10% tambahan polimer ke dalam mortar adalah peratusan yang terbaik dan pengawetan kering basah adalah mekanisme yang sesuai untuk menyembuhkan keretakan halus dalam mortar.

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INTRODUCTION

1.1 General

Over the past 20 centuries the properties of structural materials at our disposal have improved tremendously in every aspect. The early improvements were due to a slow trial and error process, appropriately called “black magic” at the time, guided by just the appraisal of the final material, or more importantly the resulting product performance. The development took place without real knowledge of the material itself, or of the internal changes taking place during materials processing. In the nineteenth, and in particular, in the twentieth centuries, however, the pace of material development accelerated greatly. Two major factors played a role in this development: the notion of a microstructure in combination with physicochemical techniques to quantify it, and the availability of (semi empirical) models linking the microstructure to the final material properties and vice versa. Both factors led to a real acceleration of material development and today material properties can be tuned precisely, and to very high levels, sometimes even approaching the theoretical limits.

Concrete constructions are currently designed according to set norms that allow cracks to form up to 0.2 mm wide. Such micro cracks are generally considered

acceptable, as these do not directly impair the safety and strength of a construction. Moreover, micro cracks sometimes heal themselves as many types of concrete feature a certain crack-healing capacity. Research has shown that this so called 'autonomous' healing capacity is largely related to the number of non-reacted cement particles present in the concrete matrix. On crack formation, ingress water reacts with these particles, resulting in closure of micro cracks. However, because of the variability of autonomous crack healing of concrete constructions, water leakage as a result of micro crack formation in tunnel and underground structures can occur. Concrete will continue to be the most important building material for infrastructure but most concrete structures are prone to cracking. Tiny cracks on the surface of the concrete make the whole structure vulnerable because water seeps in to degrade the concrete and corrode the steel reinforcement, greatly reducing the lifespan of a structure. Concrete can withstand compressive forces very well but not tensile forces. When it is subjected to tension it starts to crack, which is why it is reinforced with steel; to withstand the tensile forces. Structures built in a high water environment, such as underground basements and marine structures, are particularly vulnerable to corrosion of steel reinforcement. Motorway bridges are also vulnerable because salts used to de-ice the roads penetrate into the cracks in the structures and can accelerate the corrosion of steel reinforcement.

1.2 Problem Statement

In many civil engineering structures tensile forces can lead to cracks and these can occur relatively soon after the structure is built. Repair of conventional concrete structures usually involves applying a concrete mortar which is bonded to the damaged surface. Sometimes, the mortar needs to be keyed into the existing structure with metal pins to ensure that it does not fall away. Repairs can be particularly time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height.

1.3 Objectives

This research aims to develop a self-healing polymeric-cementitious material using polymeric admixture such as an epoxy resin (diglycidyl ether of bisphenol A type) without any hardener which can be applied as repair materials for reinforced concrete structures or manufacturing of precast concrete products.

This study embarks on the following objectives:

1. To determine the mix proportions of mortars using various polymer-cement ratios (epoxy resin content).
2. To investigate the engineering properties of epoxy-modified mortars as self-healing materials.
3. To investigate the mechanism of degree of hardening and self-healing function of epoxy resin in hardened mortars.

1.4 Scope

In this research an epoxy resin (diglycidyl ether of bisphenol A) without any hardener is used as polymeric admixture to prepare polymeric-cementitious materials and their self-healing function is evaluated. Epoxy-modified mortars using an epoxy resin without any hardener are prepared with various polymer-cement ratios, subjected to initial wet/dry curing plus long term dry curing and tested for strength properties. The fundamental properties such as workability, influence of curing, strengths, strength development, porosity, permeability and water absorption are investigated. The self-healing function and hardening of epoxy resin are evaluated by preloading and drying of specimens, chemical analysis, and ultrasonic pulse velocity test.

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