CONTROLLING CRACKS IN REINFORCED CONCRETE BEAM USING POLYMER MODIFIED MORTAR BY DIFFERENT METHODS

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A report submitted in partial fulfillment of the requirements for the award of the degree of B. Eng (Hons) of Civil Engineering

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2014

ABSTRACT

The most common defect in concrete structures is the cracks. Cracking in concrete will affect the appearance, workability and the strength of the concrete structures. It may indicate the occurrence distress of the structure or less of durability, thus it will make not safe for application. The structure that damaged must be repaired to bring back its structure strength. This research investigates the efficiency of polymer modified mortar as a material for repair cracks. For this study of controlling crack, three beams of grade 20 strength were casted and repaired by three different methods. All the beam samples were tested by one point load test until first crack appear. The repair methods covered for this study were using polymer modified mortar by injection, patching and underlay coating. The beams were tested for second time until failure to get the deflection, ultimate load and pattern of cracks. Between this three methods of repairing cracks in beam using polymer modified mortar, underlay coat method showed the less differences of load and deflection between repaired and initial beam which were 83.1% and 26.8% respectively. Patch method resulted the least of 69.9% of load and 3.4% of deflection differences while inject method indicated 78% and 8.6% of differences in load and deflection respectively between initial and repaired beam. Most of cracks happened at the same places after they were repaired in flexural and shear patterns. For this study, less of polymer modified mortar was used for remove cracks due to less than 1 mm width of cracks. However, in real situation of the structures are remaining under condition of permanent forces, polymer modified mortar will apply more into cracks for the good results.

ABSTRAK

Masalah yang biasa berlaku pada struktur konkrit adalah keretakan. Masalah keretakan akan mengganggu ketahanlasakan,kebolehkerjaan dan penampilan struktur bangunan. Sesetengah kes keretakan yang serius akan menyebabkan sesebuah bangunan tidak sesuai untuk didiami. Oleh yang demikian, kerja-kerja pembaikan perlu dijalankan untuk memperkukuhkan semula struktur bangunan tersebut. Kajian ini adalah untuk mengetahui kesesuaian mortar terubahsuai berpolimer sebagai bahan baikpulih bagi keretakan. Untuk tujuan tersebut, tiga rasuk gred konkrit 20 disediakan di mana rasuk di baiki dengan kaedah tiga cara yang berbeza. Kesemua contoh rasuk di uji dengan kaedah satu titik beban sehingga retak pertama wujud. Kemudian, contoh rasuk di baiki dengan cara yang berbeza. Mortar terubahsuai berpolimer digunakan bagi kaedah penampalan, penyuntikan dan lapisan pelapik. Rasuk-rasuk kemudian akan di uji untuk kali kedua sehingga kegagalan untuk mendapatkan beban, kelenduran dan jenis keretakan Antara tiga kaedah membaiki retak menggunakan mortar terubahsuai berpolimer, kaedah lapisan pelapik menunjukkan kurang perbezaan beban dan kelenduran antara rasuk yang di baiki dengan rasuk awalan yang mana 83.1% dan 26.8% keduanya. Kaedah penampalan memberikan keputusan terendah iaitu perbezaan 69.9% beban dan 3.4% kelenduran sementara kaedah penyuntikan memberikan 78% dan 8.6% perbezaan dalam beban dan kelenduran antara awalan dan rasuk yang di baiki. Kebanyakkan retak yang berlaku di tempat yang sama selepas ia di baiki dalam keadaan lendut dan ricih. Untuk kajian ini, hanya sedikit mortar terubahsuai berpolimer telah digunakan untuk membuang keretakan yang kurang dari 1 mm lebar. Walau bagaimanapun, dalam situasi yang sebenar struktur di bawah keadaan beban tetap, mortar terubahsuai berpolimer akan digunakan lebih ke dalam retak untuk keputusan yang bagus.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter will focus on the introduction, background, problem statements, objectives, scopes and research significance. Its also introduce to the basic things of the concrete, repair material and cracks due to relate with the chapter. Other view of this chapter will discuss about the situation happened related to the topic and the main objectives of this study. It is explained also about the scopes that will do in this research to achieved the objectives.

Concrete is an important material in construction industry. Combination of concrete with steel for reinforcement bar, a complete building structure material can be created. The tensile strength is provided by reinforcement steel in the concrete structure and some of the shear strength. Meanwhile, the strong compression of the concrete will protect the steel and provide durability. Reinforced concrete also most frequently applied structural material because its strength and durability which has been used for many years to build a wide of structure construction from houses to bridges(Ahmad et. al, 2012)

Reinforced concrete structure often show its vulnerability to the time dependent phenomena that is including weathering, well before reaching the service life of the structure. This phenomenon is widely used in replacement of existing structures is not a possible measure. Thus, interest in rehabilitation and strengthening of reinforced concrete structural elements has been rapidly increase around the world. In this

situation, development and methods for improving the safety and reliability of existing concrete structures are in researched.

The damage of structural component is needed to be repaired for effective use of the structure. A crack may cause serious failure of the structure, therefore it must be detected in the early state since it is small. Concrete repair is a complex process which is very different field with the new concrete construction. In scope of the time and environment, it should be able to concrete structures in the capability to endure the exposures of use.

An important component of structure repair industry is crack repairing which needs to be comprehensive. Occurrence of cracks in concrete structures is very common. The durability and appearance of structure is affecting from the cracks. It is important to study methods of controlling cracks to prevent further deterioration of concrete structures. In this study, reinforced concrete beams will be focus on crack repair.

1.2 BACKGROUND

Crack happened in concrete structure due to many factors. They may affect the appearance only or indicate significant structural distress and lack of durability. The effects of cracks depend on the type of structure and the nature frequency of the cracking. Suitable crack method repair depends upon the knowledge on the causes of cracking. It will influence the selection of repair procedures, repair materials and types of repairing.

In this study of controlling crack for reinforced structural beam, polymer modified mortar (PMM) was used. Polymer modified mortar is made by partially replacing the cement hydrate binders of conventional cement mortar or concrete with polymers such as polymeric admixture or cement modifiers and by strengthening the binder with the polymer. The polymeric admixtures or cement modifiers include latexes, emulsified polymers, redispersible polymer powders, water soluble polymers, liquid resins and monomer.

Different types of repair crack are to find the serviceability aspects appear after beam will be failed. The good repair method of the structure between their performance and strengthening compared to the controlling crack behaviours. Proper guidance and support should be emphasis in the selection of crack repair method and repair material for preferable result in concrete crack repair.

1.3 PROBLEM STATEMENTS

Cracking and spalling are common phenomenon appears in concrete structure. The appearances of cracks may cause the strength of the structural member such as beam decreased. There are many methods to repair such fault likeinjecting material and underlay coating. Therefore, suitable repair technique of beam is important to restore its strength. Polymer modified mortar is selected in controlling cracks and able to increase the strength, stiffness and ductility of the structure. Besides, factors of drying shrinkage, chemical reaction, and settlement are deterioration can cause cracks.

1.4 OBJECTIVES OF THE STUDY

- To identify the performance of polymer modified mortar to control cracks in reinforced concrete beam.
- To compare effectiveness between three methods of this study to repair damaged reinforced concrete beam.
- To determine the load, deflection, and pattern of cracking to the reinforced concrete beam.

1.5 SCOPES OF STUDY

The limitation of this research on controlling crack works of reinforced concrete beam by using polymer modified mortar. The scope of this research include prepare of 3 reinforced concrete beams for flexural test using concrete grade 20 and 2Y12 at bottom bar. The length of the beam is 1500mm with cross section of 150 x 200 mm. Preparation suitable proportion of patching materials using polymer modified mortar.

This study also include the repairing the cracks by using crack injection method and patching method. Beam 1 repaired by using patching material of polymer modified mortar into the cracks, beam 2 will patch with the injection and beam 3 will patch and inject with the additional of an underlaying coating at the bottom of the beam. Analysing the mechanicals properties of polymer modified mortar such as ultimate strength, deflection and pattern of cracks.

1.6 RESEARCH SIGNIFICANCES

Nowadays, epoxy resin injection is widely use for repairing works of structural concrete member such as beam and column. Flexural test on repaired reinforced concrete beams have shown that the epoxy resin injection not only eliminates the unsightly appearance of wide cracks but also increase the flexural strength and stiffness of the repaired member higher than the original beam (H. W. Chung, 1981). In spite of the advantages, economical of application epoxy resin injection is quite expensive. Therefore, focusing on application of polymer modified mortar which is cheaper than epoxy resin injection in this study.

Polymer modified mortar is environmental friendly and it is can be classified as construction materials that support the sustainability aspects of construction (Ahmad, Elahi, Barbhaiya & Farid, 2012). Ohama, 1995 also said that polymer modified mortar (PMM) have superior properties such as high tensile and flexural strengths, excellent adhesion, high waterproofness, high abrasion resistance and good chemical resistance compared to ordinary cement mortar. There were many strong interests focused on the suitability of polymer modified mortar as repair materials. Then, we need to identify the most appropriate method to introduce polymer modified mortar into the cracks of the reinforced structural beam.

1.7 CONCLUSION

This chapter was indicated the introduction of the title which is include the background of the study, problem statement, objectives of the study, scopes of the study

and research significance.Three important objectives was discuss in order to finished this research and achieved it at the conclusion.

Basically, the introduction of the polymer modified mortar as a controlling crack in reinforced concrete bar was discussed in this chapter.The introduction of the main title is to explain about why this research is done. Next chapter will tell the literature review about this study. It will explain more specific and related about the title of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will provide the review from previous study that is related to the final year project. It will explain about the controlling crack, repairing crack and repair material. The full understanding of the concept is important in order to choose the best way of controlling cracks and types of method repairing cracks.

Besides, the explaination of polymer modified mortar as a suitable material for controlling cracks in this chapter. The mechanism properties of polymer modified mortar compare to another materials. Then, the selection of the best methods that can be used will choose based on the literature review of this chapter.

2.2 TYPES OF CRACKS

Cracks in a structure can be broadly classified as either active or dormant. If they are active, they show some movement in direction, width or depth over a measured period of time. However, the crack of dormant or unactive crack, they remain unchange. Some dormant cracks are not dangered but if left without repaired, cracks provide channels for moisture penetration which can lead to future damage.

Cracks can be more specifically classified based on three factors which is direction, width and depth of the crack. They may be longitudinal, transverse, vertical, diagonal or random. Pattern cracking, checking, hairline cracking and d-cracking are

some crack classifications. All these types of cracks may range in size form less than 1 mm for fine to between 1 and 2 mm in medium to over 2 mm wide.

For pattern cracking, it is commonly happened. In this pattern, fine openings in common pattern which due to contant volume of concrete that near below to the surface. It can be seen at Figure 2.1 clearly showed the pattern cracking in the structure. Checking cracking happened when shallow openings, too close and not regularly spaced. Small cracks and placed randomly in expose of areas is the hairline cracking. Basically, it happened in flexural to the angle of shear pattern which is shown in Figure 2.2. Lastly, d-cracking is defined as fine cracks at near intervals in a progressive random features. Figure 2.3 was showed the d-cracking pattern which it mostly in circle pattern(U.S. General Services Administration, 2012).

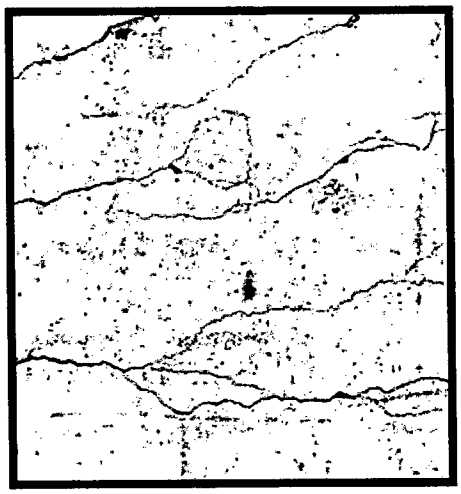

Figure 2.1: Pattern cracking

Source: U.S General Services Administration (2012)

Figure 2.2: Hairline cracking

Source: Home Design Magz (2013)

Figure 2.3: D-cracking

Source: Seal Green (2011)

2.3 FACTORS OF CRACKS

Most of concrete cracks usually happen due to not proper design and construction works. Due to the construction process, cracks can occur in unhardened concrete which is also called as plastic concrete and hardened concrete. National Ready Mixed Concrete Associate, 1998 stated that for the concrete surfaces crack, there are some factor crack happened:

a) Gap of contraction and isolation joints and not proper practices of jointing.

b) Inappropriate preparation of subgrade.
c) More slump concrete used or excessive addition of water on the task.
d) Unsuitable finishing.
e) Less or no curing

The use of concrete during construction can define that much variables involved in the product of finished concrete which directly give impacts to strength and appearance. Most important of these things likes kind of cements, ratio of water to cement, size and type of aggregate, type and proportionate amount of materials mixture and various situations or actions happening during the mixing, replacement, finishing and curing process (Hall and Foreman, 2013). One advantages of using concrete as a building materials are the fact that a certain amount of cracking is bound to occur.

2.3.1 Cracking of Plastic Concrete

A plastic cracking is a type of shrinkage crack that only happens in wet concrete. It is often seen in the top of a structure as diagonal lines. It is usually caused by delays in applying the curing process due to rapid drying of the surface. (U.S. General Services Administration, 2012).

2.3.1.1 Plastic Shrinkage Cracking

Plastic shrinkage cracking is usually produced when fresh concrete in its plastic state which is subjected to rapid moisture loss. Rdso (n.d) has indicated that plastic shrinkage cracking caused by factors of combination that include concrete temperatures and air, relative humidity and velocity of wind at the concrete surface . All this factors can be combined to factor high rates of evaporation surface in either cold or hot weathers.

Figure 2.4 above shows the plastic shrinkage cracks pattern on the structure. When evaporation of moisture form fresh placed concrete to the surface faster than it is replaced by bleed water, then the surface concrete will shrink. When no bleed concrete will shrink due to the provide of restraint by the concrete below the surface drying

layer, stress of tensile developed in the weak, stiffening plasticity of concrete, resulting in shallow cracks of various depth that may form a random, polygonal features or may be appeared as essentially parallel to the other.

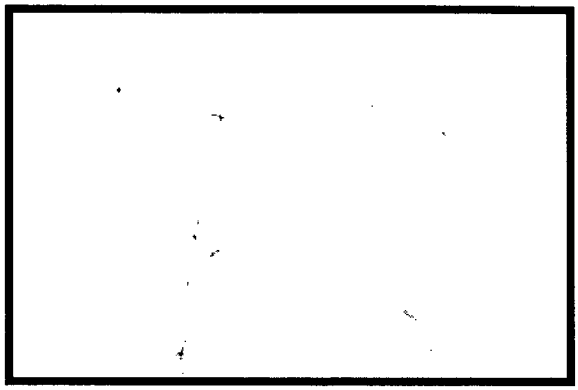

Figure 2.4: Plastic shrinkage crack

Source: Foundation, concrete and earthquake engineering (n.d)

2.3.1.2 Settlement Shrinkage

After first placement of the concrete, vibration and finishing concrete has done to continue the consolidate. During this time, the wet concrete may restraint locally by steel reinforcement, initially placed to hard concrete or formwork. This local restraint may be resulted in voids cracks above and under the obstruction.

When bound with steel reinforcement, plastic settlement cracking will increase with rising bar sizes, bigger slump and lower cover. The angle of settlement cracking may intens by vibration insufficient or by use of leaking or flexible forms highly. The Figure 2.5 below shows the settlement cracks at the surface of the concrete structure (Rdso, n.d.).

Figure 2.5: Plastic settlement crack

Source: Rdso (n.d)

2.3.2 Cracking of Hardened Concrete

Holcim, (2010) mentioned that hardened concrete crack happens the performance of concrete for shape that no longer can be altered without damage. It tells that the cracks factored by drying shrinkage which resulted from movements of temperature that can be taken place in all materials exposed to the structures. Unless the member concerned movements permits of its structures without development of extensive cracking, excessive stresses rare may be occurred.

2.3.2.1 Chemical Reactions

Chemical reactions may cause cracking of the concrete. Rdso (n.d.) explained the reactions of the materials used to make the concrete or materials which is coming to contact with the concrete after it has being hardened. Concrete may be cracked with the period of time as the produce of moderately developing high reactions between contain aggregate active alkalis and silica which obtained from hydration of cement, admixtures or outer sources. The another sources likes water curing, ground water, solutions of alkaline kept or used in the structure that finished.

The alkalinity of silica reactions resulted in the structure of a swelling gel, that be inclined from another portions of the concrete to draw water. These will cause to local accompanying and expansion stresses of tensile and may be resulted in the complete defection of the concrete structure.

Some rocks of carbonate take part in reactions by alkalis, which is certain ingrediants make cracking and detrimental expansion. They are mainly assisted with argillaceous dolomite limestone. For the observed crack pattern, multiple fine cracks were observed along the length of the reinforcement concrete beam. Kamal et. al (2008) said that the number of cracks also depended on the fiber content of the material as shown in Figure 2.6 below. The higher of fiber content in materials, then, higher cracks will occur.

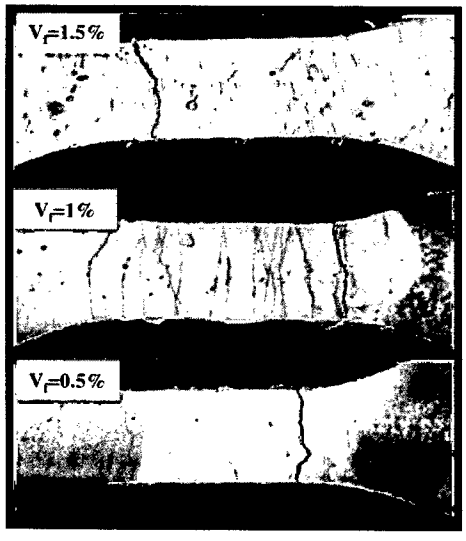

Figure 2.6: Crack pattern due to percentage of fiber content

Source: Kamal et. al (2008)

2.3.2.2 Corrosion of Embedded Metals

Corrosion of steel produces iron oxides and hydroxides, which have a volume much greater than the volume of the original metallic iron. This can increase in volume

causes high radial bursting stresses around reinforcing bars and results in local radial cracks.

These splitting cracks can propagate along the bar, resulting in the formation of longitudinal cracks or spalling of the concrete. A broad crack may also form at a plane of bars parallel to concrete surface resulting in delamination. Cracks is actually provided not difficult enter by oxygen, chlorides and moisture then little splitting cracks may create a situation in which cracking and corrosion are accelerated. Figure 2.7 shows one of the example of cracks caused by the corrosion.

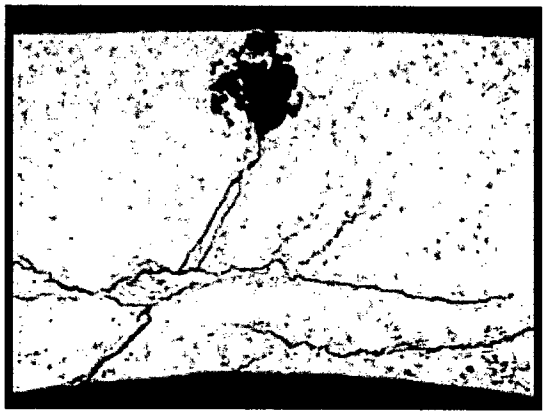

Figure 2.7: Crack caused by corrosion

Source: Corrosion Technology Laboratory (n.d)

Malumbela et. al (2010) was indicated that it is difficult to associate corrosion crack patterns with level of sustained load. Table 2.1 below gives corrosion crack patterns that were exhibited by beams in this research called as crack pattern A, crack pattern B and crack pattern C. The three kinds of crack are different type of patterns which unsimilar with the compressive strength of the concrete.

In crack pattern A, one crack that propagared parallel to the corroded steel reinforcement bars was remarked on the face of tensile to a beam which corrosion agents were produced into the concrete structure. In crack pattern B, initially a beam cracked on its face of tensile as in crack pattern A. Besides, when the corrosion