FLEXURAL PERFORMANCE OF TEXTILE FINE GRAINED MORTAR CONTAINING RICE HUSK ASH AS A PARTIAL CEMENT REPLACEMENT IN REINFORCED CONCRETE BEAMS

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DEDICATION

I dedicate this thesis to my beloved angel which are my father and my late mother for giving full of support in this journey.

I also dedicated this thesis to my two prettiest women, which is my supervisor and my co-supervisor Assoc. Prof. Dr Suraya Hani Adnan and Madam Zalipah Jamellodin. Also to my most supportive co supervisor, Assoc. Prof. Dr Haziman Wan Ibrahim.

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ABSTRACT

External strengthening of RC beam become a popular method to reduce deterioration. Due to highest demanding on external strengthening, a new innovation was introduced called as textile fine grained mortar (TFGM). TFGM is a composite material which is combined fine grained mortar (FGM) that utilized rice husk ash (RHA) as a partial cement replacement material of FGM and textile reinforcement made from glass fibre reinforcement called as alkali resistant (AR) glass. Characteristic of the binder were firstly performed by conducting X Ray Fluorescence, X Ray Diffraction, particle size distribution and surface morphology. From characterization of RHA, it is categorized as a pozzolanic material from chemical composition, amorphous form of RHA and fineness of RHA. FGM with different percentage of RHA replacement varies from 0 %, 10%, 20 %, 30 % and 40% was investigated under compressive and flexural strength. Optimum replacement of RHA in FGM also determined. 20 % of RHA replacement in cement consumption of FGM gave excellent of compressive and flexural strength. Utilization of 20 % RHA in FGM was continuing to use when FGM combined with AR glass as textile reinforcement and produced new composite material TFGM. Several layers of TFGM were selected in this study, namely 2 layers, 4 layers, 6 layers and 8 layers. Flexural strength was conducted to determine the prism increment in flexural when externally bonded with TFGM. After flexural prism were done, 4 layers and 8 layers of TFGM were selected as desired layer to be applied on RC beams. Flexural test was perform on RC beams and resulted 4 layers of TFGM shown highest in flexural compared to control RC beams. But, 8 layers of TFGM were resulted failed due to delamination at the end of TFGM. As a conclusion, TFGM were very excellent in strengthening of RC beams. RHA is a highly promising in increments of flexural strength and AR glass also reduced the deflection of RC beams.

ABSTRAK

pengukuhan luaran bagi rasuk konkrit bertetulang menjadi satu kaedah yang popular untuk mengurangkan kemerosotan pada rasuk. Permintaan tinggi pada pengukuhan luaran menyebabkan inovasi baru diperkenalkan iaitu mortar berbutir halus bertekstil (TFGM). TFGM adalah bahan komposit yang menggabungkan mortar berbutir halus (FGM) menggunakan abu sekam padi (RHA) sebagai bahan pengganti separa simen dalam FGM dan tetulang tekstil daripada tetulang gentian kaca dipanggil sebagai *alkali resistant (AR) glass.* Ciri-ciri pengikat dikaji menggunakan *X Ray Fluorescence, X Ray Diffraction*, taburan saiz zarah dan *surface morphology*. Dari pencirian RHA, ia dikategorikan sebagai bahan pozolana dari komposisi kimia, bentuk amorfus RHA dan kehalusan RHA. FGM dengan peratusan penggantian RHA berbeza-beza dari 0%, 10%, 20%, 30% dan 40% dikaji mengikut kekuatan mampatan dan lenturan. Penggantian optimum RHA dalam FGM menunjukkan bahawa 20% penggantian memberikan kekuatan mampatan dan lenturan yang tinggi. Penggunaan 20% RHA dalam FGM diteruskan menggabungkan FGM dengan *AR glass* sebagai fabric tetulang. Beberapa lapisan TFGM telah dipilih dalam kajian ini, iaitu 2, 4, 6 dan 8 lapisan. Ujian kekuatan lenturan dijalankan untuk menentukan kenaikan kekuatan lenturan apabila TFGM diaplikasikan. Selepas kekuatan lenturan pada prisma dilakukan, 4 lapisan dan 8 lapisan TFGM telah dipilih sebagai lapisan yang sesuai untuk digunakan pada rasuk. Ujian lenturan dijalankan pada rasuk dan menunjukkan bahawa 4 lapisan TFGM memberikan kekuatan lenturan tertinggi berbanding rasuk tanpa TFGM. Tetapi, 8 lapisan TFGM menunjukkan kegagalan ikatan pada hujung TFGM. Kesimpulannya, TFGM sangat berpotensi dalam pengukuhan rasuk. Penggunaan RHA boleh meninggikan kekuatan lenturan dan *AR glass* juga mengurangkan pesongan rasuk RC.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Repairing the structural concrete elements become more economical and sustainable which is less cement consumption. This method were more considered than reconstruction. This is also agreed by previous study conducted by (Truong *et al*., 2017) Textile Fine Grained Mortar (TFGM) is a mineral based composite which is combined Fine Grained Mortar (FGM) and Alkali Resistant (AR) Glass as a textile reinforcement. FGM produced in this study were utilized fine grained size sand which have maximum 1mm. Utilization of fine grained sand were also have been used by several researchers (Brückner, Ortlepp & Curbach, 2006), (Hegger & Voss, 2008) and (Daskiran, Daskiran & Gencoglu, 2016). FGM were also utilized Rice Husk Ash (RHA) as a partial cement replacement. RHA utilized in this study is one of waste material that came from combustion of rice husk. Not only in repairing process, construction of the building also must considered to utilized waste material in constructing every structural element (Mohanraj, Rajkumar & Kandasamy, 2011).

In building, every structural element has their function to carry loads from upper until foundation. It involved trusses, beams, columns, slabs and foundation. These elements play their own role ensure the building can functioning and safe.

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Beams is a horizontal structure element used to carry vertical load, shear load and sometimes horizontal load. The beam can be made from timber, stone or steel Utilization of reinforced concrete as a material in beams have been established over the world due to the various applications. Normally, RC beams were designed to carry load for 10 years (Eurocode, 2002). To increase the service life of RC beams, a few research conducted by Duthinh & Starnes (2001) and Rambabu, Prudhvija & Kumar (2016) on the strengthening of RC beams were performed. Strengthening method is the effective method due to increase the capacity in terms of ductility, stiffness and strength itself (Frascadore *et al.*, 2015). There are various methods that have been used for strengthening RC beams such as steel plates (Su, Siu & Smith, 2010) and (Vilnay, 1988), fibre reinforced polymer (Ombres, 2011; Duthinh & Starnes, 2001 and Patel & Parikh, 2016) and RC jacketing (Raval & Dave, 2013) and (Jamil & Zisan, 2014). Recently, textile reinforced concrete with mortar binder has become favourable method of strengthening RC beams Srinivasa, 2012; Elsanadedy *et al.*, 2013 and Jabr, Ragaby & Ghrib, 2016). However, there is a lack of study on the utilization of pozzolanic materials as a cement replacement in mortar binder.

Thus, in this study were focusing on the utilization of pozzolanic materials came from agricultural waste called rice husk ash (RHA). Other than that, utilization of fine grained size sand with maximum 1mm were introduced and combined with RHA in FGM. After that, alkali resistant (AR) glass were used as a textile reinforcement with FGM to produce new method strengthening of RC beams called as TFGM.

1.2 Background of study

Strengthening of reinforced concrete structure, especially RC beams is the newest innovation to increase the service life. Several methods were introduced, but in this study, for improving the method of beam strengthening, a new formulation of mortar binder was introduced in this study. This mortar has been categorized as a special mortar due to the utilization of fine grained sand with smaller size less than ≤ 1 mm. Normally, previous researchers (Elsanadedy *et al.*, 2013) and (Brückner, Ortlepp & Curbach, 2006) used normal mortar containing fine grain sand with maximum size 5 mm. This study

also introduced the application of pozzolanic materials as a cement replacement in mortar binder. Several researchers Obilade (2014), Shalini *et al*. (2016) and Hossain *et al.*, (2016) have identified that the utilization of RHA as a pozzolanic material in cement replacement for concrete and mortar with percentage 10 to 20 percent could enhance the performance of concrete and mortar in terms of flexural strength.

Rice husk is one of the waste material from the agriculture industry and produced from rice milling industries. The outer shell of rice grain is called rice husk. RHA is obtained from controlled or uncontrolled burning of rice husk. It consists of non-crystalline silicon dioxide (SiO_2) with high specific surface area and high pozzolanic reactivity (Karim *et al*., 2012). It was estimated that 1000 kilograms of rice grain will produce 200 kilograms of rice husk. After controlled or uncontrolled burning of rice husk about only 20 percent of the rice husk would become as rice husk ash. Rice husk ash from controlled burning, contains high silica content in amorphous form of silica up to 100 percent (Jamil *et al*., 2013); (Patil, Dongre & Meshram, 2014) and (Bakar, Yahya & Gan, 2016). For this study, RHA was used with OPC in a mortar binder to strengthen RC beams. The combination of OPC, fine grained sand and RHA were namely as fine grained mortar (FGM).

From the observation, it can be seen that textile fibre could improve the flexural strength of concrete structure due to the result that obtained by Bernat-Maso *et al.*, (2014) and Hegger, Will & Rüberg (2007). Thus, to increase the flexural strengthening of RC beams, AR glass also used in this study. AR glass worked as a textile reinforcement to strengthen concrete structure (Brückner *et al.,* 2006; Hegger & Voss, 2008 and Barhum & Mechtcherine, 2012). AR glass is designed to be functioned as reinforcement to reinforce normal mortar. For becoming an effective reinforcement, AR glass was constructed layer by layer with FGM on RC beams. Hence, the application of FGM and AR glass in this study known as textile fine grained mortar (TFGM).

1.3 Problem statement

Recently, RC beams became one famous concrete element that have been selected to be repaired. Repairing method were selected because it is reducing the consumption of cement. RC beams usually facing with flexural strengthening problems and it leads to reducing of working life (Truong *et al.*, 2017). Therefore, several researchers (Elsanadedy *et al*., 2013; Raval & Dave, 2013 and Brückner *et al*., 2006) have conducted studies on RC beams strengthened by using various method and materials. From previous researcher such as Hegger *et al*., (2007), Feng *et al*., (2013) and Daskiran *et al*., (2016), they found that TFGM were the new method of strengthening of RC beams and can increase the flexural strengthening.

TFGM is a new strengthening method applied on RC beams which combine fine grained mortar and additional of textile reinforcement. In construction industry, utilization of sustainable material become trending and much recommended. sustainable cementitious system were introduced to reduce the negative environmental impact due to the utilization of OPC as fully binder material like stated by Hossain *et al*., (2016). It is include the utilization of waste material to partially replace the utilization of cement as a binder materials.

Agriculture waste like rice husk disposed on open field and usually uncontrolled combusted were given negatively impact to our environment. It can lead to pollution and also increase demanding on more landfill to disposed rice husk. If there were no properly handled in early stage, it were lead to disastrous of agriculture waste. Therefore, to provide an alternative solution for this problem, this study were conducted to employ the optimum usage of rice husk after through control combustion and become RHA as a binder in FGM. Other than that, the wrong percentage selection of RHA were also can lead to reducing in strength as agreed by (Antiohos, Papadakis & Tsimas, 2014). So, this study were conducted to identify the optimum utilization of RHA in FGM as a partial cement replacement.

In civil engineering, most commonly used as reinforcement is steel reinforced concrete as a composite materials in construction and also in repairing work. Utilization of textile reinforcement become a new development eventhough biaxial or multiaxial

and it were combined with FGM to produce TFGM. This method were promoted new thin layer of strengthening and repairing. Some of researchers before have been proposed different types of textile reinforcement such as AR Glass, polyethylene (PE), carbon, poly-p-phenylene benzobisoxazole (PBO) in production of TFGM. However, utilization of carbon and PBO were very expensive. It is also stated by researcher (Daskiran *et al*., 2016). Therefore, some previous researchers were utilized AR Glass as textile reinforcement such as (Hartig, Häußler-Combe, & Schicktanz, 2008), (Scheffler *et al.*, 2009) and (Ombres, 2011). So, this study were focusing on utilization of AR Glass as a textile reinforcement in TFGM.

1.4 Objectives

The objectives of this study are as follows:

1. To develop and identify optimum content of RHA in mixes proportion containing RHA as cement replacement materials in Fine Grained Mortar (FGM).
2. To establish and design TFGM system containing optimum FGM with RHA through textile layer optimization
3. To evaluate flexural performance of TFGM developed on RC beams

1.5 Scope of study

There are three major phases that have been conducted in this study. The first phase was the development of optimum mix proportion of Fine Grained Mortar (FGM). The second phase is to apply TFGM on concrete prism with size 100 mm x 100 mm x 500 mm with 2 layers, 4 layers, 6 layers and 8 layers. Third phase of this study is to apply the selected layer from the second phase on 150 mm x 200 mm x 2500 mm reinforced concrete (RC) beams.

For the first phase of this study, material used were RHA, fine sand, water and OPC. RHA were replaced the cement content on FGM with 0 %, 10 %, 20 %, 30 % and 40 % by weight of cement. Three ratio mixes were designed in this study which were

1:2, 1:2.5 and 1:3 and based on (BSI, 2016). RHA is produced by burning the rice husk in control combustion of 600°C. After control combustion, RHA is ground using a grinder and sieved. Particle size of RHA has been analyzed by using particle size analyzer (CILAS). Scanning electron microscopic (SEM) and X-Ray Diffration machine were used in Faculty of Mechanical and Manufacturing Engineering at University Tun Hussein Onn Malaysia (UTHM) to identify surface morphology of materials. Chemical properties of RHA were tested by using an X-Ray Fluorescence machine at Faculty of Civil and Environmental Engineering, UTHM. The maximum grain size 1 mm of sand were introduced in FGM. FGM mix were combine OPC, fine grained sand, RHA and water. Additional superplasticizer were used 1% of cement consumption to increase the workability. FGM strength has been obtained by using flexural and compressive testing apparatus in Civil and Environmental Engineering Faculty, UTHM. The prism specimens of size 40 mm x 40 mm x 160 mm were used at the age of 7 days, 28 days and 90 days. Number of FGM specimens used in this phase are 135 specimens.

After the optimum percentage of RHA used in FGM were obtained, second phase conducted which is TFGM preparation and work. TFGM that produced from a combination of FGM with optimum RHA consumption and textile reinforcement called AR Glass were applied on concrete prisms with selected layers 2 layers, 4 layers, 6 layers and 8 layers. Total of 39 concrete prism with size 100 mm x 100 mm x 500 mm were utilized in this study. The flexural strength test was conducted on concrete prism at Civil and Environmental Engineering, UTHM laboratory.

After analysis on selected layer in phase two, the best layer of TFGM was used to be conducted the third phase of this study. Total of 7 reinforced concrete beam with size 150 mm x 200 mm x 2500 mm were used in this phase. The flexural strength test was conducted at Civil and Environmental Engineering, UTHM laboratory. Figure 1.1 shows every work conducted in this study.

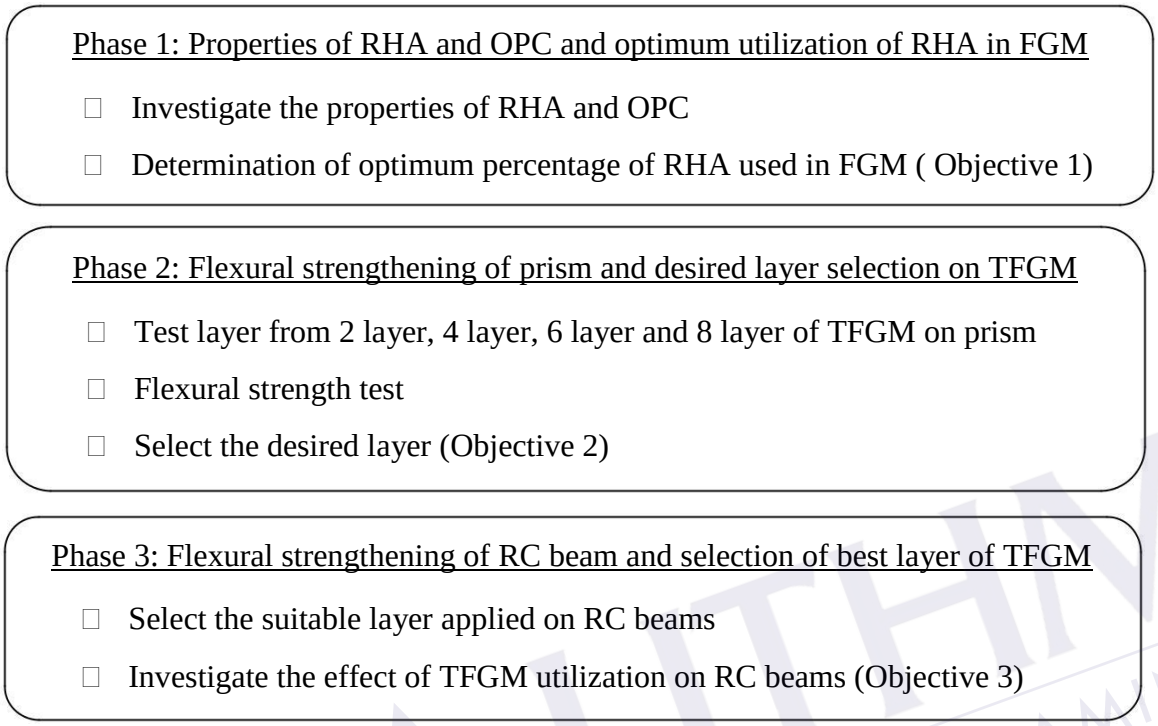

Figure 1.1: Research framework of this study

1.6 Limitation of Study

- This study only focuses on externals strengthening of RC beams in terms of flexural which is on tension surface. This is due to the several problems occurred on flexural strengthening of RC beams in construction field and it were involved the repairing process.
- RHA used in this study were controlled burned with temperature range 500 to 700 degree Celsius. Temperature chosen were based on (ASTM, 2010) and previous study that was stated that RHA in temperature in between 500ºC to 700ºC were produced higher of silica content.
- RHA were used 10 %, 20 %, 30 % and 40 % of OPC consumption in FGM. The percentage were chose to determine the optimum consumption of RHA in FGM to increase the strength of TFGM
- Fine grained sand used with maximum size 1 mm.

- This study only applied TFGM on RC beams with selected layer which are 2 layers, 4 layers, 6 layers and 8 layers. Different layer were selected to obtain the best and appropriate layer that can applied on RC beams.
- All the casting and testing process were conducted at UTHM laboratory.

1.7 Significance of study

i. From this study, the comparison can be made between FGM by using an Ordinary Portland Cement (OPC) and OPC plus RHA as partial cement replacement in compressive and flexural strength.

ii. The improvement of mortar application in the construction industry by using textile reinforcement and fine sand in FGM.

iii. The usage of RHA as a partial cement replacement in Fine Grained Mortar will be reduce the cement used in mortar application in the construction industry.

iv. The usage of waste material produced from agriculture such as RHA in mortar application.

1.8 Organization of thesis

Chapter 1

This chapter was discussed about the introduction of TFGM, FGM and RHA. Another discussion in this chapter is the problem arises from the previous issue, several objectives to achieve this study and the significance of this study.

Chapter 2

This chapter was discussed about the previous study for RHA usage in the construction industry, the fact about RHA, and the result obtains from the previous study in terms of compressive strength, flexural strength of normal mortar using RHA, other testing for normal mortar, previous study about TFGM, Alkali resistant glass and FGM.

Chapter 3

This chapter was discussing about the methodology in this study. This chapter were wrote about the types of material used, the method preparation of FGM with 0 %, 10 %, 20 %, 30 % and 40 % replacement, TFGM with 2 layers, 4 layers and 6 layers, rectangular concrete beams and RC beams. In this chapter also wrote about all the testing method that applied to the RHA, FGM and TFGM.

Chapter 4

In this chapter, all the results coming from several testing of material were analyzed. Result from X-Ray fluorescence, X-Ray Diffractometer, Scanning Electron Microscopy and Particle Size Analysis are analyzed to know the suitability of RHA used as cementitious materials. The analysis included the summary of data and graph for analysis. Compressive and flexural strength results obtained from FGM analysis was performed in this chapter. The suitability of RHA utilization also revealed in this chapter. This chapter was answered objective one in this study.

Chapter 5

This chapter represented the data and analysis of Textile Fine Grained Mortar. The result consists of flexural strength of TFGM on concrete prism and flexural strength of TFGM on RC beams. These all result were elaborated and determined the suitability of AR Glass used in TFGM improve the flexural strength of RC beams. In this chapter, objective two and objective three were discussed.

Chapter 6

This chapter were included the conclusion writing, the best and optimum replacement of RHA are mentioned again. The objectives of this study were concluded and revealed whether it is proven or not. The recommendation for future study of this material also provided to improve the properties of RHA.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter were discussed about the study conducted by previous study in development of strengthening method on reinforced concrete (RC) beams. Explanation on material used and their performance in strengthening of RC beams also were deliberated in many kind of application.

Textile fine grained mortar (TFGM) is a composite construction material using textile fibre and fine grained mortar (FGM). TFGM is one of the alternative for strengthening and repairing the existing concrete structure. The strengthening approach is significantly increases both the ultimate load bearing behaviour and the serviceability (Brückner *et al*., 2006). FGM is a combination of cement, fine sand and water. Utilization of pozzolanic material as a partial cement replacement material can reduce the cement consumption in FGM. In this study, FGM is using rice husk ash (RHA) as partial cement replacement material. RHA is highly pozzolanic material (Rajput *et al*., 2013). RHA is the agricultural waste coming from rice milling production. It is obtained by burning rice husk in controlled manner.

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