TEST Engineering & Management

November-December 2019
ISSN: 0193-4120 Page No. 3121- 3126

The Effect of Textile Fine Grained Mortar Layers on Reinforced Concrete Beam

Suraya Hani Adnan*[1], Mohamad Hairi Osman[2], Mohammad Ashraf Abdul Rahman[3], Kamaruzzaman Musa[4],
Zalipah Jamellodin[5] , Wan Yuslinda Wan Yusof[6], Noor Shuhada Mohammad[7]

[1,2,3,4]*Faculty of Engineering Technology, University Tun Hussein Onn Malaysia, BatuPahat, Johor*
[5,6,7]*Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, BatuPahat, Johor*
**Corresponding author E-mail:suraya@uthm.edu.my*

Article Info
Volume 81
Page Number: 3121- 3126
Publication Issue:
November-December 2019

Article History
Article Received: *5 March 2019*
Revised: *18 May 2019*
Accepted: *24 September 2019*
Publication: *14 December 2019*

Abstract:
Textile fine grained mortar (TFGM) is combination of Palm Oil Fuel Ash (POFA) in Fine Grained Mortar (FGM) and Alkali Resistant Glass (AR glass) fibres. TFGM serves as a new innovative of structure technology, which is to strengthen and repair concrete structures with thin layered mortar that can sustain load. This study investigated the effect of using TFGM layers when applying on reinforced concrete (RC) beams. This study aims on replacing the normal mortar with TFGM in order to enhance both the ultimate load carrying behaviour as well as the serviceability and delaying the extension of cracking. Two (2) of RC beams with dimension 150 mm x 200 mm x 2500 mm were strengthened with TFGM made of selected proportioning with 4 and 8 layers. Unstrengthen RC beams were also included as a control specimen with the same dimension. All specimens were tested for the flexural strengthening at 28 days by using BS EN 196-1:2005. The result indicates that TFGM increased the load carrying capacity of RC beams which is about 10 % increment comparison with control specimen. The layers of TFGM were significantly delaying the crack.

Keywords: *Textile fine grained mortar; palm oil fuel ash; alkali resistant glass; reinforced concrete; flexural strength*

1. Introduction

In buildings, it is well known that reinforced concrete (RC) beams represent a large percentage of structure reinforcement in order to avoid excessive loading, poor design and corrosion [1]. Nevertheless, the construction industry gives a larger impact on the environmental pollution due to the utilization of Ordinary Portland Cement (OPC) which is compulsory in every structure development [2]. This unfortunate event occurs due to carbon dioxide (CO2) produced by the OPC that can harm the atmosphere [3]. Also, the increasing in global warming by approximately 5 % from OPC manufacturing affected by carbon emission resulting in ozone depletion, acid rain and greenhouse effect [4]. The environmental sustainability improvement need to be done by replacing the cement with waste that has features in enhancing the strength of materials [5].

Palm Oil Fuel Ash (POFA) is a waste that have potential to be used as a partial replacement of OPC because it has pozzolans features which complement the cementing properties[6–8]. An effort was made to evaluate the usefulness of fine grained mortar (FGM) containing POFA and fine sand less than 1 mm for producing the high strength mortar. The utilization of POFA in FGM is significant with 10 % of OPC replacement [9, 10].

Modern structures need an improvement towards the sustainable development of a building which emphasizes the quality of the construction materials in line with advances in technology. Textile reinforcement is one of the ideas to improve strength development [11,12]. The utilization of textile fibres is a new innovative of structure technology which is to strengthen and repair concrete structures with thin layered composite materials that can sustain load carrying capacity [13]. Textile fibres have great properties which are lightweight, freeform structure, modular, rid the risk of corrosion and can be utilised to build slender [14]. Furthermore, it is also functioning as a reinforcement in order to increase the durability for preventing the poor impact strength [13]. The addition of textile fibres enhances the properties of OPC and both the ultimate load carrying behaviour as well as the serviceability thus delaying the extension of cracking [15,16].

Therefore, this study focused on the combination of textile fabrics and FGM containing POFA which known as TFGM system as a layer reinforcement for flexural strengthening on reinforced concrete beams. The aim of this study is to investigate the effect of using TFGM layers when applying on RC beams.

2. Methodology

2.1.Materials

TFGM system was made by combining FGM as a composite material and textile fibres. The structure of FGM comprises of a cementitious material, a mixture of water, sand with a size less than 1 mm, superplasticizer, OPC and 10 % of POFA. POFA was collected from palm oil mill located in Kluang, Johor. In this study, POFA was utilised in TFGM as a cement replacement material due to the POFA properties which can enhance the mortar strength compared to the use of cement concrete mix thoroughly. Textile fibres from Alkali Resistant Glass type (AR Glass) were used as textile reinforcement.

2.2.Mix Proportion

The OPC was partially replaced by POFA at 10 % due to the great percentage in strength development which had been conducted in past researches[9,10]. The volume ratio of cementitious material (OPC + POFA) to sand was 1:2 with 0.45 water ratio. There are three (3) of RC beams with dimension 150 mm x 200 mm x 2500 mm. The control specimens with one (1) specimen were made and another two (2) specimens are laminated TFGM for a strengthening system with 4 and 8 layers. The workability was modifiable with 1 % of superplasticizer. All materials and mixture proportions of TFGM for each specimen are shown in Table 1.

Table 1: Mix proportions of TFGM on RC beams

Mix no.	Layers	Binder (g)		Fine sand	Water
		Cement	POFA	(g)	(mL)
1	4	900	100	2000	450
2	8	1800	200	4000	900

2.3.Mix Process

Firstly, the existing RC beams surface was roughened to ensure that the mortar and beam are greatly tied and stuck to. After that, the combination of ground POFA, OPC, fine sand less than 1 mm with the additional of water and superplasticizer

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ISSN: 0193-4120 Page No. 2732 - 2742

were mixed uniformly to produce the FGM. The first layer of FGM was strengthened on RC beams with a maximum thickness of 2 mm followed by one layer of AR Glass. Lastly, the step was repeated by using AR Glass and FGM combined layer by layer to produce TFGM in order to laminate the RC beams in a strip way until reaching the 4 and 8 layers. The RC beams were strengthened by TFGM with externally strengthened on flexural strengthening in order to investigate the effect of layer. The sample was flattened once by using u-plate and cured for 28 days.

2.3.Experimental Setup

The experimental setup for RC beams strengthened by TFGM was conducted in four bending point test using the test set up shown in Figure 1 based on specification in BS EN 196-1 [16]. The instrumentation comprised of load cells and three set of linear variable differential transducers (LVDT) notch in centre of span. The distance between the two lower rollers was 2000 mm while the other two upper rollers were set at 150 mm from the centre of span with the distance between two upper rollers of 300 mm.

The sample was placed in the apparatus where the two rollers bending machines acted as helpers at the bottom and another roller at the top of the point of the applied load. During the running test, load was applied gradually which was 3 mm/min. The test aimed on achieving the failure of mortar where the reading was decreased. Lastly, digital reading was taken in unit kilo newton (kN) when the mortar and beam became failure. This step was repeated for all samples. The flexural strength was calculated and the mean value was reported.

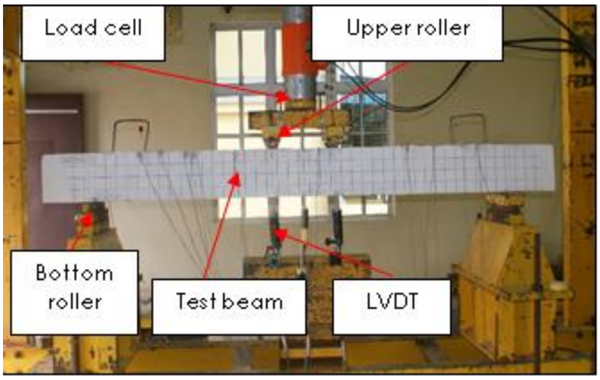

Fig. 1: Four bending point test for RC beams strengthened by TFGM

3. Result and Discussion

3.1. Load Carrying Capacity

According to the load-deflection curve on the mid span of RC beams as presented in Figure 2, there were three specimens comprised of control specimens represented as BC1, 4 layers and 8 layers of TFGM strengthened on RC beams as BPOFA-4 and BPOFA-8. Based on the graph, BPOFA-4 shows the highest of load carrying capacity with 41.5 kN followed by BPOFA-8 which is 40 kN and the lowest of load carrying capacity is BC1 with 38 kN. From the graph, the result shows that BPOFA-4 and BPOFA-8 were higher than BC1 due to the great effect of TFGM layers on RC beams which enhanced the strength. Besides that, BPOFA-8 has resulted in poor load carrying capacity compared to BPOFA-4. The strength of BPOFA-8 was rapidly developed but it failed in a short time.

The TFGM layers on RC beams also reduced the deflection of RC beams. From the Figure 2, BC1 shows the highest of deflection followed by BPOFA-4 and BPOFA-8. The combination of POFA as OPC replacement and AR glass as textile reinforcement in TFGM reduced the deflection and resulted in an increment of the serviceability thus delaying the extension of crack on RC beams. AR glass in TFGM layers also functions reducing the deflection rate of RC beams. The deflection rate on RC beams is important to develop a safety state and increase the life expectancy of the buildings.

This indicates that, the combination of POFA in FGM and textile fibres from AR glass types are verified increased the load carrying capacity of RC beams with 10 % increment.

Several failures occurred as the test were conducted. Textile slippage failure occurred on BPOFA-8 within the matrix in the maximum bending moment region at mid span as shown in Figure 3. After textile slippage occurred on BPOFA-8, the load carrying capacity of RC beams dropped and failed. It can be observed that depending on layers of TFGM, the load capacity and stiffness of BPOFA-4 was increased significantly. The mode of failure occurred was textile rupture as shown in Figure 4. This failure means the layers of AR Glass was broken ultimately during the enhancement of the deflection caused by the formation of wide flexural cracking in a maximum moment and stress strain [17]. From Figure 5, it can be seen that the BC1 specimens is under concrete crushing failure. The failure of BC1 occurred at compression zone under reinforced concrete beams due to the yielding of steel[1].

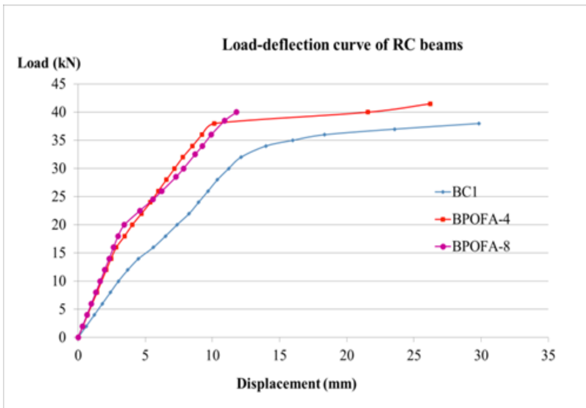

Fig. 2: Load-displacement graph on mid span of RC beams

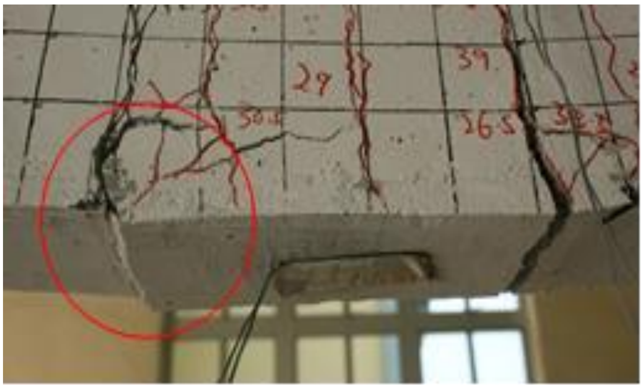

Fig. 3: Slippage failure on BPOFA-8

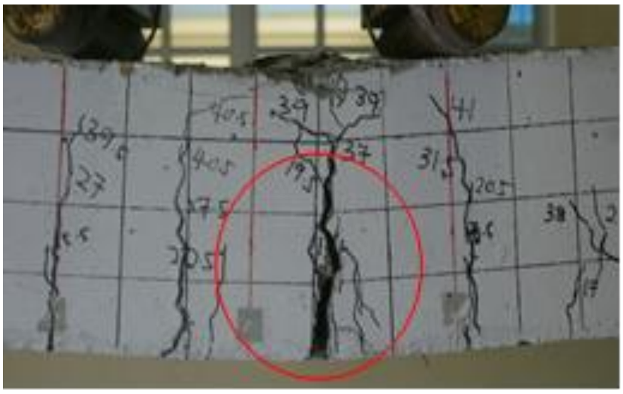

Fig. 4: Textile rupture failure on BPOFA-4

Fig. 5: Concrete crushing failure on BC1

3.2. First Crack

Figure 6 shows the first crack for BC1, BPOFA-4 and BPOFA-8. During the flexural testing of RC beams, the load-deflection reading was considered in determining the first cracking based on visual observation from beam cracking. From the graph, it can be seen that the first crack occurred in the mid span region. The first crack for control specimens represented by BC1 failed rapidly when load reached at 11.5 kN. However, after the application of TFGM layers strengthened on RC beams, it shows a significant difference compared to BC1. For BPOFA-4, the first crack was about 14 kN when the maximum tensile stress in concrete was achieved the modulus of rupture. Other than that, the first crack for BPOFA-8 occurred when load reached 16.5 kN and resulted in highest first crack pattern compared to BC1 and BPOFA-4.

The lowest first crack pattern of BC1 was due to the specimen's brittleness after yielding under compression zone. Other than that, the first crack for BPOFA-4 and BPOFA-8 were increased due to the fineness of fine sand and POFA. The minimum thickness of fine sand which is less than 1 mm can filled the pores and increase the ultimate loading carrying capacity[18]. POFA react with OPC were produced calcium silica hydrate (C-S-H) and calcium alumina hydrate which serves to cover up cracks and pores thus gives a strong bond between the particles in concrete [19]. Also, it was due to the high performance of AR Glass fabric in elasticity that is great on brittle stress that give more durability and ability to RC beams as a structural component.

When the first crack occurred at higher loading applied in BPOFA-8, it shows that the RC beams have low deflection. It is good in increasing the serviceability of the beam in a state limit. Based on the elaborated result, it was determined that the application of POFA in FGM combined with AR glass as textile reinforcement in TFGM was significant to be used for strength development of RC beams.

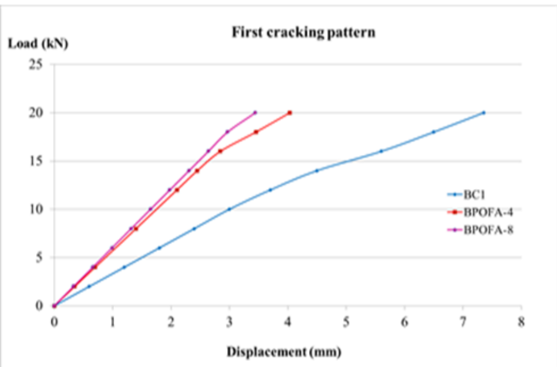

Fig. 6: First Crack Pattern

4. Conclusion

From the results that obtained from this study, it can be concluded that:

1) The new innovations to improve strength development of RC beams were successfully achieved by using TFGM and enhancing the flexural capacity with 10 % increment.
2) The 4 layers of TFGM are effective layers in increasing the flexural strength on RC beams due to the ultimate load carrying capacity of the strengthened beams is higher compared to control beams.
3) The test results on RC beams identified the three failures modes, namely, textile rupture, textile slippage and concrete crushing. The failure modes are depending on the amount of TFGM layers in RC beams and also were caused by the loss of strengthening action

Acknowledgement

The authors gratefully acknowledge the UniversitiTun Hussein Onn Malaysia and Ministry of Higher Education for providing the financial support through the Fundamental Research Grant Scheme (FRGS), Vot 1618.

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