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Effect of Fibre (Polypropylene) Volume in Mortar Mixed With POFA

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Abstract: High strength fibre reinforced concrete is envisaged to exhibit high compressive and tensile strength under loadings. In this study, experimental studies are conducted to assess the mechanical behavior of fibre reinforced mortar and comparing them with normal concrete. For this experiment, the aspect ratio of fibre (polypropylene) volume inclusion is fixed to 33. Palm Oil Fuel Ash (POFA) is also included as partial cement replacement. The compressive strength and split tensile strength tests are conducted. This paper presents the results of mechanical strength for fibre reinforced mortar mixed with POFA. It is indicated that the volume of fibre inclusion in concrete have significant impact in compressive and tensile strength. In this study, the optimum fibre dosage inclusion is 20 kg/m^3 that exhibit 82.4MPa and 78.7 MPa stresses at 56 days of curing for both 100% OPC and 40%POFA inclusion samples, respectively. The findings of this study can be applied to construction in coastal areas.

***Keywords*: Fibre reinforced mortar, palm oil fuel ash (POFA), flexural and tensile strength**

I. INTRODUCTION

Fibre reinforced concrete is a type of concrete made of cement, fine and coarse aggregates and discontinuous discrete fibres. Fibre is made up of various shapes, size and types such as steel, glass, plastics, and natural materials. The top advantage of fibre reinforced concrete is the improvement of flexural toughness. The presence of fibres also helps to further increase tensile strength of concrete since the stretching ability of the under load reinforced fibre is higher compared to normal concrete (Bright Hub engineering, 2016; Ibnul *et al*., 2016). Similar to concrete, it is known that mortar is weak in tension but good in compression.

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This is why addition of fibre helps in enhancing the ductility of concrete.

Flexural strength has significant effect when it comes to the orientation of fibres. A study has been conducted by Yu *et al*., (2017) stated that flexural strength of Ultra High Fibre Reinforced Concrete (UHFRC) casted at one side of mould is higher than UHFRC that is casted randomly. When large amount of fibre is placed perpendicular to flexural force direction, steel fibres helps in enhancing the resistance toward cracks formation and growth as this will lead to increase the flexural strength of concrete. Ramli and Dawood, (2011) also justified that homogeneity of fibre distribution in High Strength Fibre Reinforced Mortar (HSFRM) significantly has improved the flexural strength of mix. These studies showed that flowing direction of fibres is crucial to control the orientation of fibre in concrete. Application of HSFRM in infrastructure such as bridges is beneficial since it requires high ductility materials that exhibit good tensile and compressive strength to maintain the bridge structure and prevent it from collapse when force acting upon it.

Palm Oil Fuel Ash (POFA) is the industrial by product from palm oil mill that can be used as partial replacement for cement as it also exhibits pozzolanic properties. Generally, POFA is disposed in open fields and this has cause traffic hazard besides becoming potential hazard to human health and also environment (Skariah *et al*., 2017).

Moreover, solid wastes from POFA increase every year due to usage of palm oil as major raw material in bio-diesel production. Good efforts have been shown by researchers as this waste material can be utilized as cement partial replacement.

POFA is proved to increase the strength of concrete up to 20% replacement by weight (Sujivorakul *et al*., 2011; Al-mulali *et al*., 2015; Islam *et al*., 2016). According to Awal and Abubakar, (2011) pozzolanic properties that exist in POFA could replace Portland cement in making mortar with relatively high strength and also with good resistance towards chloride expansion.

In this research, high strength fibre reinforced mortar is envisaged to exhibit high compressive and tensile strength under loadings.

Thus, experimental studies are conducted to assess the mechanical behavior of fibre reinforced mortar and comparing them with normal concrete. It is expected that this high strength fibre reinforced mortar can help to improve the durability of houses in coastal area in Sarawak which are exposed to corrosion.

II. MATERIALS AND METHODS

A. Material Used

The materials used in this research are POFA, cement, sand, water and Polypropylene fibre. Aspect ratio of fibre volume inclusion is a control aspect in the research which is 33. The raw material POFA was collected at Rimbunan Hijau (RH) Palm Oil Mill, Lundu Sarawak. The cement used for this research was Ordinary Portland cement (OPC) which is produced by Cahaya Mata Sarawak and Polypropylene fibre were produced by SikaFibre Force MY and cut to the length of 20mm.

B. Preparation of Raw Materials

Firstly, POFA undergo drying process of water removal to ease and shorten the time during sieving process. POFA was dried under 100°C temperature. POFA samples were sieved using 300μm sieve vibrating machine. The final sizes of POFA samples after sieving were in the range 300μm and below. POFA was burned in the electric kiln under temperature of 500 °C for 90 minutes. This process helps in eliminating the excess carbon and moisture present in POFA. Initially before burning and drying process, POFA contain alumina, silica and carbon which give dark colour to POFA. The elimination of carbon helps POFA to act as cement replacement material since the replacement of cement by POFA needs alumina and silica to exhibit same properties as cement. Grinding process of POFA was conducted by using 25000 rpm electric power grinder. POFA samples were initially placed into the grinder and undergo 8 cycles of grinding. It took 3 minutes for the grinding process to complete 1 cycle. Each cycle took 1 minute rest to prevent overheat of grinder. Stand fan was used to cool down the grinder by facing the stand fan towards grinder. This process is important for the production of ultrafine POFA so that it has sizes ranges from 1-10μm. CILAS Particle Size Analyzer (Model: 1090L) is used to the sizes of POFA falls in the range 1μm - 10μm to make sure the procedures of grinding process of POFA is successful. This is also to ensure that more ultrafine POFA sizes ranging from 1μm-10μm can be produced. For the POFA particle that does not falls in the required sizes, it needs to undergo grinding process again so that POFA achieved the required size.

C. Preparation of Mortar Samples

Mortar samples for mechanical test were mixed according to design that is tabulated in Table 1 and poured into 50mm^3 cube mould for compressive test whereas cylinder mould size of 100mm diameter and 200mm height for split tensile test.

D. Compressive Strength Test

The compressive strength of the mortar samples were tested after curing of 7, 14, 28 and 56 days.

E. Split Tensile Test

The split tensile strength of the mortar samples were tested after curing of 7, 14, and 28 days.

Table 1: Mortar samples and mix proportions

Sample	Mix proportion		
	OPC(%weight)	Fibre (kg/m3)	Ultrafine POFA (%weight)
A (control)	100	-	-
B	100	10	-
C	100	15	-
D	100	20	-
E	60	-	40
F	60	10	40
G	60	15	40
H	60	20	40

III. RESULTS AND ANALYSIS

A. Compressive Strength Test

Strength development of mortar blended with ultrafine POFA is different from mortar that is mixed with Ordinary Portland cement (OPC). It can be observed from Figure 1 that mortar that mixed with ultrafine POFA has slower early strength compared to mortar that contain 100% OPC. This is due to the fact that there was a prolong hydration process of ultrafine POFA. Lower cement content in the mix and pozzolanic behaviour were the main cause for reducing heat of hydration in concrete that containing POFA.

High fineness of ultrafine POFA particles aids in filling the voids between cement and aggregates. While hydration process takes place, $Ca(OH)_2$ is generated and then react SiO_2 that exist in POFA and forming excess calcium silicate hydrate. This excess calcium silicate hydrate helps in improving the interfacial bonding between aggregates and pastes at later ages (Karim *et al*., 2016). This characteristic has been shown to improve compressive strength of concrete as well as density of concrete.

The effect of fibre dosage inclusion on compressive strength has been presented in Figure 1. It can be seen in Figure 1 that inclusion of polypropylene fibre has little effect in mortar compressive strength. As can be observed in the inclusion of 10 kg/m^3 polypropylene fibre, there is increase in the compressive strength 80.5 Mpa (100% OPC-56 days) and 79.5Mpa (40% POFA as partial cement replacement-56 days). The increase in compressive reading for 10 kg/m^3 fibre inclusion may be due to transverse confinement effect of polypropylene fibre that restrained the lateral expansion of mortar cube samples (Lee *et al*., 2015).

Inclusion of fibre may aid in arresting the development of microcracks which leads to higher value of compressive strength. Though the main propose of fibre is to improve energy absorption capacity after macrocraking takes place, it also depends on the number of fibre, deformity and bonding of the matrix. The higher the number of fibre inclusion in the mortar cube, the higher the probability of microcracks are being intercept by fibre. When the mortar cube is stiff enough and those fibres are well bonded to the matrix, microcracks can be prevented.

In addition to the fibre quantity, perturbation also depends on the ability of matrix to accommodate fibre (Neves & De Almeida, 2005). Therefore, addition of fibre is a balancing between microcracks bridging and additional voids that is caused by fibre addition.

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In this study, the optimum fibre dosage inclusion is 20 kg/m^3 that exhibit 82.4MPa and 78.7 MPa compressive strength at 56 days of curing for both 100% OPC and 40% POFA inclusion samples, respectively.

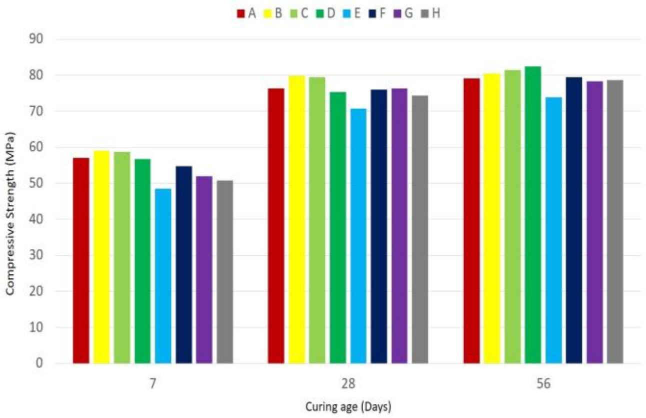

Figure 1: Compressive strength development for all mortar samples

B. Split Tensile Strength Test

Fineness of POFA used in this study is at d_{50}, 4.33µm. The filling effect from ultrafine POFA particles is contributed to form higher contact area between fibre and past-aggregate mix which is resulting from increased amount of hydration product due to high pozzolanic reaction in ultrafine POFA which increase with time (Awal & Abubakar, 2011). Higher fineness of POFA can reduce permeability of concrete towards water where it shows smaller degrees of expansion and loss in compressive strength compared to sample mix that contain 100% of OPC (Tangchirapat *et al*., 2007).

Figure 2 shows the readings for split tensile test strength for 100% OPC cylinder mortar and 40% POFA as partial cement replacement with fibre inclusion of 10 kg/m^3, 15 kg/m^3 and 20 kg/m^3, respectively. The 10 kg/m^3 fibre inclusion gives the highest reading for both type of mixes, 6.3MPa (100% OPC) and 6.6 MPa (40% POFA inclusion). The results show that fibre inclusion is controlling the strength behaviour of mortar that contain fibre. Fibre inclusion helps bridging the micro cracks and therefore slowly supported full tensile stress. Transferred stress to fibre eventually enhanced tensile strain capacity of concrete matrix and improved tensile strength of fibrous mixture compared to non-fibrous mixture (Awal & Abubakar, 2011).

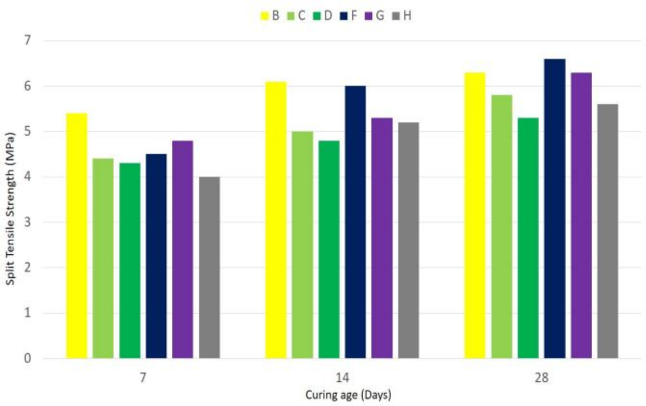

Figure 2: Split tensile strength development for all mortar samples

IV. CONCLUSION

The experimental results and analyses showed that the optimum polypropylene fibre volume of 20kg/m^3 in both 100% OPC and 40% ultrafine POFA samples give average reading of 82.4MPa ad 78.7MPa compressive strength at 56 days of curing, respectively. Mix sample that contains 40% ultrafine POFA as partial cement replacement mixed with 10kg/m^3 of polypropylene fibre volume has the highest average reading of tensile strength at 28 days of curing, 6.6 MPa.

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Professor Mohammad Abdul Mannan, BEng (Civil Eng), MEng and PhD, served as academician at Universiti Malaysia Sabah, UMS for 13 years (1999 to 2012). Now, he is at Universiti Malaysia Sarawak, UNIMAS, Malaysia since May 2012. He has more than 130 publications and obtained h-index of 15, i10-index of 21 with citations of more than 1,600. He is the sole author of Book, 'Oil Palm Shell: Lightweight Concrete and Structures', ISBN 978-1-53610-878-1, Publisher: NOVA Science Inc., USA. Based on 33 years of experience in teaching, professional practice and research, his vision is to be excellent in research on Innovative Construction Material and Structure.

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