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Compressive and flexural strength of concrete containing palm oil biomass clinker and polypropylene fibres

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Abstract. This paper presents the effects of using palm oil biomass (POB) clinker with polypropylene (PP) fibres in concrete on its compressive and flexural strength performances. Due to infrastructural development works, the use of concrete in the construction industry has been increased. Simultaneously, it raises the demand natural sand, which causes depletion of natural resources. While considering the environmental and economic benefits, the utilization of industrial waste by-products in concrete will be the alternative solution of the problem. Among the waste products, one of such waste by-product is the palm oil biomass clinker, which is a waste product from burning processes of palm oil fibres. Therefore, it is important to utilize palm oil biomass clinker as partial replacement of fine aggregates in concrete. Considering the facts, an experimental study was conducted to find out the potential usage of palm oil fibres in concrete. In this study, total 48 number of specimens were cast to evaluate the compressive and flexural strength performances. Polypropylene fibre was added in concrete at the rate of 0.2%, 0.4% and 0.6%, and sand was replaced at a constant rate of 10% with palm oil biomass clinker. The flexural strength of concrete was noticed in the range of 2.25 MPa and 2.29 MPa, whereas, the higher value of flexural strength was recorded with 0.4% polypropylene fibre addition. Hence, these results show that the strength performances of concrete containing POB clinker could be improved with the addition of polypropylene fibre.

1. Introduction

Concrete is versatile and widely being used as construction material due to its desirable engineering properties. In the twenty-first century, it has emerged as the dominant construction material for infrastructure needs. However, it is strong in compression and weak in tension. Therefore, the innovative materials such as fibres and admixtures is being introduced for better performances of concrete [1, 2]. Considering the environmental sustainability, the waste materials need to be utilized in the concrete production. One of such waste is the palm oil waste, which is very abundantly available in Malaysia. While, comparing the globally palm oil production, the Malaysia is one of the largest palm oil producer in the world. It creates large amount of waste in the form of fibres, nutshells, kernels and empty fruit bunches. The wastes such as kernels, nutshell and fibres are used to generate steam by burning them in boilers to run a turbine to generate electricity. Palm oil biomass clinker is obtained when these wastes are incinerated. It was reported by Zarina [3] that palm oil mill industry in Malaysia has been producing solid waste in large quantities around 4 million tons per year. Now a days



Malaysia also considered as second largest producer of palm oil in the world, the production of 18.6 million metric tons has been reported in the year 2010 [3]. Ultimately, the wastes are disposed-off and do not serve any purpose. According to the particle size the palm oil biomass clinker are very similar to sand and having low specific gravity which makes it suitable to be utilized as sand replacement material. Therefore, the wastes that are produced can be utilized as construction materials to act as partial replacement of sand in concrete.

The term Fibre Reinforced Concrete (FRC) can be used to describe concrete with the addition of fibre. Addition of polypropylene fibre which is one type of synthetic fibres is being used due to its high ductility. According to Saeed [4], lower dosage rate of polypropylene fibres from 0.18% to 0.40% increases the compressive strength of concrete by about 5%. While the addition of 0.20% Polypropylene fibres can rise the flexural strength about 80% [4]. Hence, the aim of this study is to investigate the effect of polypropylene fibre on the flexural strength of concrete containing palm oil biomass clinker as a sand replacement.

2. Materials and Method

2.1. Fine and coarse aggregate

Fine and coarse aggregates conforming to the standards BS EN 12620 [5] was used for this study. The coarse aggregates were sieved passing from size 20 mm and retained in size 10 mm and passing in 5 mm for fine aggregate. The aggregates that are sieved and collected were kept in safe place.

2.2. Palm Oil Biomass (POB) Clinker

Palm oil biomass clinker used in this study was a waste by-product from the steam generation process of Tanjung Langsat Biomass Steam Plant. Palm oil biomass (POB) clinker was first being washed to wash off the impurities of palm oil biomass clinker and dried before sieving to pass the size of 5mm. The percentage of palm oil biomass (POB) clinker as partial replacement of sand in concrete used are 10%, 20% and 30%. The figure 1 shows that the particle size distribution of fine aggregates and palm oil biomass clinker. The gradation of palm oil biomass clinker appeared to be similar to sand.

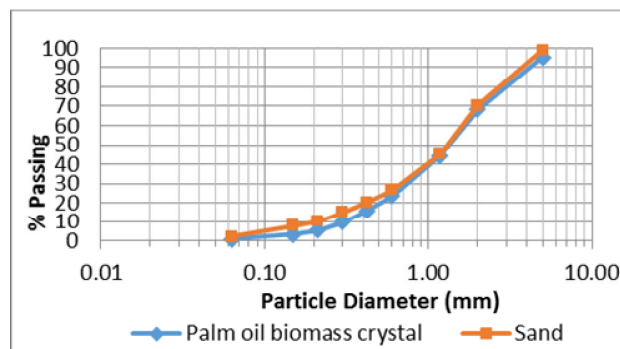


Figure 1: Particle size distribution of sand and palm oil biomass clinker

2.3. Specific Gravity

Specific gravity is a dimensionless parameter that relates the density of the soil particles to the density of water. It was carried out to determine the weight-volume relationships. Table 1, shows the specific gravity of palm oil biomass (POB) clinker and sand. It was experimentally perceived that the specific gravity of palm oil biomass (POB) clinker is about 21% lesser than natural sand, which indicate that palm oil biomass (POB) clinker is porous material.

Table 1: Specific gravity of sand and palm oil biomass clinker

	Sand			Palm oil biomass (POB) clinker		
Specific Gravity	2.54	2.66	2.68	2.07	1.98	2.17
Average	2.63			2.07		

2.4. Polypropylene (PP) Fibres

The type of synthetic fibre used is polypropylene macro synthetic fibre as shown in figure 2. Different proportions of fibres such as 0%, 0.20%, 0.40% and 0.60% were used in this research with replacement of optimum percentage of palm oil biomass clinker to replace sand. Table 2 shows the detailed properties of polypropylene fibres.

Table 2: Properties of polypropylene fibre

Description	Result
Length	55mm
Diameter	0.85mm
Aspect ratio	65-70
Specific Gravity	0.90kg/dm ³
Tensile strength	425 N/mm ²
Young Modulus	7 288 N/mm ²

From the above mentioned result, the properties of polypropylene macro synthetic fibre considering the length of 55 mm, diameter of 0.85mm with aspect ratio of 65-70 and tensile strength of 425 MPa.

**Figure 2:** Macro synthetic polypropylene fibres

2.5. Water and Cement

There are no specific requirements according to BS EN 1008 [6] for the water used to produce concrete as long as it is potable water, therefore water tap was used as long as the water is not severely contaminated. In this study, the Ordinary Portland Cement complying with standard of BS EN 197-1 [7] was used and water to cement ration were used as 0.50 for all the mix proportion. Whereas, Table 3 shows the chemical composition of Ordinary Portland Cement.

Table 3: Chemical composition of ordinary Portland cement [2]

Material	Chemical Composition	Percentage Limit
Lime	CaO	60-67
Silica	SiO ₂	17-25
Alumina	Al ₂ O ₃	3-8
Iron Oxide	Fe ₂ O ₃	0.5-6
Magnesium	MgO	0.1-4
Alkalis	Na ₂ O, K ₂ O	0.2-1.3
Sulphur Trioxide	SO ₃	1-3

2.6. Mix Proportions

The concrete mix design was based on Design of Experimental (DoE) British standard method. There were four different percentage of polypropylene fibre with labels as PP0, PP0.20, PP0.40 and PP0.60 for 0%, 0.20%, 0.40% and 0.60% of replacement percentage respectively were prepared. The amount of palm oil bottom clinker was chosen as optimum percentage of 10% and water-cement ratio was kept constant as 0.50 for all the mixes. Table 4 shows the mix proportions for one batch with six concrete cube of size of 100 mm x 100 mm x 100 mm and another six concrete prisms of size 100 mm x 100 mm x 500 mm.

Table 4: Mix proportions of concrete for one batch

Mix notation	Cement (kg/m ³)	Sand (kg/m ³)	Palm oil biomass clinker (kg/m ³)	Water (kg/m ³)	PP Fibre (kg)	Water-cement ratio
PP0	18.22	34.13	3.79	9.11	0	0.5
PP0.20	18.22	34.13	3.79	9.11	0.07	0.5
PP0.40	18.22	34.13	3.79	9.11	0.14	0.5
PP0.60	18.22	34.13	3.79	9.11	0.21	0.5

The samples preparation started with the 24 concrete cubes samples of size 100 mm x 100 mm x 100 mm were casted to find the optimum percentage of palm oil biomass clinker as partial replacement of sand in concrete. The overall 48 specimens were prepared, 24 for compressive strength test and 24 for flexural strength test. After getting the optimum percentage of palm oil biomass clinker, the other specimen was prepared for the addition of polypropylene fibre for the curing period of 7 and 28 days. The experimental work was divided into sets, one is the fresh concrete and second is the hardened concrete. For fresh mix concrete the workability was evaluated with the help of slump test following the BS EN 12350-2 [8]. While, for the determination of compressive and Flexural strength test the standard BS EN12390-3 [9] and BS EN 12390-5 [10] followed respectively.

3. Results and Discussions

3.1. Workability of concrete

It was observed that the slump value tends to decrease from 20mm to 10mm with the addition of polypropylene fibre. The figure 3, represents the slump value of concrete, which indicates the slump values were decrease with the increase of polypropylene fibre. This phenomena expresses that the workability of concrete decreases with addition of polypropylene fibre. It was also reported by Payam [11] that palm oil biomass clinker while used as fine aggregates in concrete can absorb more water with even three times to the normal weight of sand. The addition of palm oil biomass clinker decreases the workability of concrete due to the porosity of palm oil biomass clinker grain which absorbs more water.

The decreasing values of slump can be associated with the formation of network structure in concrete due to high volume of polypropylene fibres as stated by Machine [12], the high content and large surface area of fibres also causes more cement paste to wrap around the fibres thus increasing the viscosity and reducing the slump value. Whereas, the non-homogenous distribution of fibre also leads to decrease in the workability of concrete. In addition, in research conducted by Mohod [13], it is shown that with usage of polypropylene fibres in concrete decreases the workability of concrete.

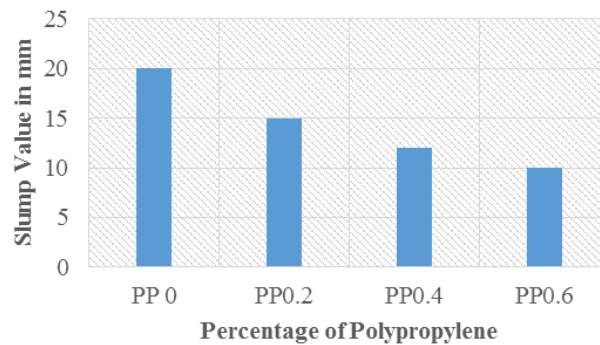


Figure 3: Slump value of concrete

3.2. Compressive Strength

Generally, it was perceived that the compressive strength of concrete tends to decrease when sand is replaced with palm oil biomass (POB) clinker. The figure 4, represents the compressive strength values at 7 and 28 days. Whereas, at the age of 28 days, the compressive strength of concrete shows decreasing as compared to the control samples of 10% replacement of palm oil biomass clinker is 7.44%, for 20% replacement is 9.94% and for 30% replacement is 37.43%. It was observed that there is no any considerable difference in the strength for the 10% and 20% replacement percentage, which is 27MPa and 26.27MPa respectively with difference of 0.73MPa. On the basis of performances, it is concluded that the percentage of sand replacement increase the concrete strength decrease with significant reduction especially for 30% palm oil biomass clinker replacement for sand.

This is mostly due to the high water absorption and low specific gravity of palm oil biomass clinker as compared to sand. The porosity nature of palm oil biomass clinker causes high water absorption, which eventually reduces the strength of concrete.

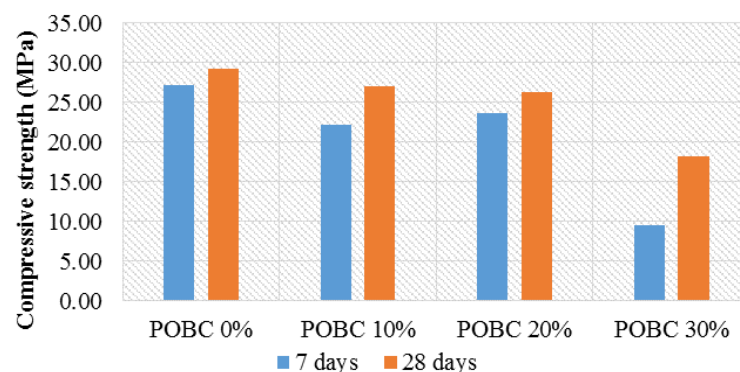


Figure 4: Compressive strength of concrete with POB clinker

The compressive strength shows increase from 7 days curing age to 28 days curing ages with 0.6% polypropylene fibres addition the lowest compressive strength as compared to other percentage of fibres. As observed from the figure 5, the compressive strength of concrete with 0.4% polypropylene fibres addition shows highest strength of 27.71MPa as compared to 0% polypropylene addition of 27.23MPa. However, as compared to the control the compressive strength of 0.4% addition of polypropylene fibres is still lower.

According to Saeed [4], the addition of polypropylene (PP) fibre at low values such as 0.18% to 0.40% the compressive strength increases but when the values are high like 0.55 % to 0.60%, compressive strength decreases by 3 to 5%. Higher dosage rate of polypropylene (PP) fibre can also decrease the strength of concrete due to the high volumes of polypropylene fibres interfering with the cohesiveness of the concrete matrix.

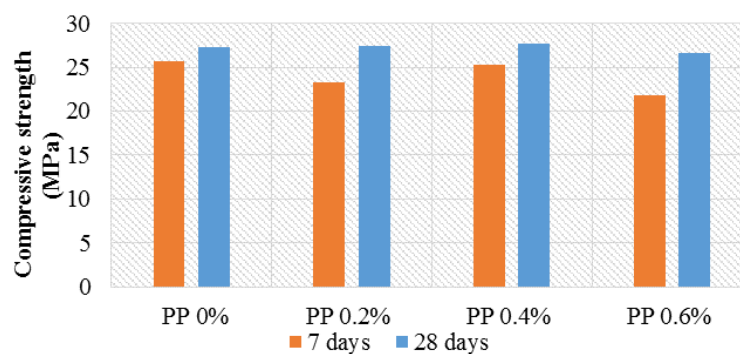


Figure 5: Compressive strength of concrete with POB clinker and PP fibres

3.3. Flexural Strength

The flexural strength of concrete or control without any replacement of sand and polypropylene fibres is the highest as compared to the concrete after 10% replacement of palm oil biomass clinker and addition of polypropylene fibre with different percentages of 0%, 0.2%, 0.4% and 0.6%. While the value of flexural strength of 10% replacement of palm oil biomass clinker without addition of polypropylene fibre is 21.50% which shows reduction as compared to the control samples. However, when the addition of 0.2% of polypropylene fibre concrete with palm oil biomass clinker replacement were tested, the flexural strength value shows an increase to 2.265MPa and continue to increase to 2.297MPa for 0.4% of addition of polypropylene fibre. However, when the polypropylene fibre addition reached to 0.6%, the flexural strength started to decrease to 2.251MPa. Fibres reinforcement tends to increase the ductility of concrete. This is because the capability of fibres to transfer tensile stress across a cracked section. Fibres tend to decrease the crack depth [11]. It was indorsed by Wan Ibrahim [14] that the flexural strength of foamed concrete is not much rise with the addition of polyolefm fibers.

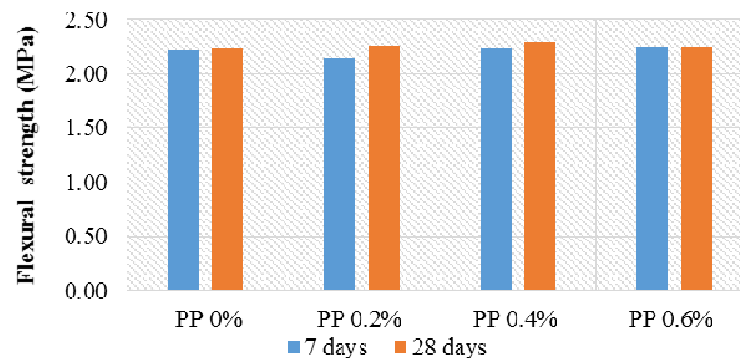


Figure 6: Flexural strength of concrete with POB clinker and PP fibres

4. Conclusion and Recommendations

Based on the results obtained, the palm oil biomass clinker considered as a potential material of construction. It was observed that the addition of polypropylene fibre can considerably be improved the flexural strength performances of concrete, about 8% raise in flexural strength was noticed at 0.4% fibre addition. Although the increase of the flexural strength is not in high percentage, but it is still proven that addition of polypropylene (PP) fibres can increase the flexural strength of concrete. Other than that, the concrete containing palm oil biomass (POB) clinker as sand replacement causes decrease in compressive strength due to the porosity of the clinker. Even though the target strength of concrete has been achieved and flowing conclusions has been drawn:

- i. The concrete containing palm oil biomass (POB) clinker as sand replacement along with polypropylene (PP) fibres, decreases the workability of the concrete.
- ii. The compressive strength of concrete at 28days was recorded as 27.40MPa, 27.71MPa and 26.61MPa for 0.2%, 0.4% and 0.6% respectively, with 10% of palm oil biomass (POB) clinker as sand replacement along with addition of polypropylene (PP) fibres.
- iii. The highest flexural strength of concrete was noticed with 10% oil biomass (POB) clinker as sand replacement and 0.4% addition of polypropylene (PP) fibres, which about 8% higher than the control specimen at the curing period of 28days.
- iv. According to the compressive and flexural strength performances, the 0.4% addition of polypropylene (PP) fibres in concrete with 10% palm oil biomass (POB) clinker as sand replacement could be considered as optimum content.

Hence, it is recommended for the future works that the in-depth research is required to investigate the strength and durability performances of concrete containing ground palm oil biomass (POB) clinker with polypropylene (PP) fibres.

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