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Strength and Durability of Cement Sand Brick Containing Palm Oil Fuel ash (POFA) and Fine Recycled Concrete as Partial Cement Replacement

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Abstract: Nowadays, the growths of the construction industry are increasing directly proportional to the human population to fulfil their living needs. The consumption of construction and industrial wastes have grown rapidly across the world, which leads to creating large quantities of wastes. It reflected to the problem of having a limited number of landfills due to a huge amount of waste produced. One of the alternatives is recycle the waste and make a good product that is can reduce the landfill. Following a through literature review, recycled aggregates are aggregates derived from the processing of materials previously used in a product or in construction industry and palm oil fuel ash (POFA) is a by-product in palm oil mill. Therefore, this study promoted utilization of recycled concrete aggregate (RCA) and POFA as suitable materials to be partial cement replacement materials in the construction industry. Furthermore, POFA has pozzolnic material that has high value of silica. It is highly reactive and used as an additional material to cement for building construction materials. The main objective of this study is to determine the sand cement brick properties containing POFA, fine recycled concrete wastes, such as compressive, and water absorption tests. The mix design for the modified sand cement brick is 5%, 10% and 15% of RCA and POFA. Water cement ratio that used in this research is 0.6. Testing for compressive strength would be measure at 7 and 28 days and for water absorption only at 28 days. This research finds that with combination of 10% and 5% of POFA with 31.8 MPa for compressive strength and 5.4% for water absorption was the optimum mix design to replace cement in sand cement brick. This research helps to improve the knowledge, increase the level of environmental awareness and understanding the importance and recycling the construction waste generated.

Keywords: Palm Oil Fuel Ash, Fine Recycled Concrete Aggregate

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1. Introduction

A sand cement brick is widely used in the civil engineering field almost all the infrastructure needs a sand cement brick as a building material. It is in accordance with the construction situation in Malaysia where most of the wall structure of a building in this country is constructed using brick, whether for residential or commercial buildings [1]. A sand cement brick is a block, or a single unit of a cement material used in masonry construction. Cement and sand brick are commonly used in low and medium cost housing development and other commercial constructions in Malaysia due to easy and inexpensive production as mentioned by Ismail *et al.* [2]

As the demand of sand cement brick is high, the use of natural resources is high also. Due to the limitation production of the brick, the market price of brick is also increase dramatically. This is due to the manufacturers, especially in Malaysia are limited to get the natural resources for production of brick. Then, it will rise the market price of brick and may affect low cost buildings. The replacement of cement as palm oil fuel ash (POFA) and fine recycled concrete wastes) will helps the natural resources from depletion and also get benefit from waste production before thrown away just like that. According to Mohammed *et al.* [3] stated that the awareness on saving the natural sources, recycling of demolished concrete and palm oil will provide other benefits, such as create an additional business opportunity, saving cost of disposal, friendly with environment and help government to meet the goal of reducing disposal. Furthermore, POFA has pozzolanic material that has high value of silica. It is highly reactive and used as an additional material to cement for building construction materials.

2. Assessment of RCA and POFA

Recycled concrete aggregate (RCA) is a very popular replacement for natural aggregates. It is aggregate made from used concrete from demolition sites. Recycling demolition concrete is eco-friendly as it preserves natural aggregate resources. The process uses less energy than mining and reduces the carbon footprint. Based on previous study shows that the brick with average 50-55% of recycled fine aggregate is the best percentage of replacement of RCA in new concrete or brick. According to Ismail and Yaacob *et al.* [2] claimed that the bricks with 50% recycled fine aggregate content shows a well gradation between the coarser and finer particles of recycled fine aggregate compared with natural sand and the show the highest strength, which is greater than that of the control bricks.

The by-product of the palm oil mill is palm oil fuel ash (POFA). It is a by-product of burning palm oil fibres, shells, and empty hit bunches as fuel to generate steam, which was use to power the palm oil extraction process [4]. It is extremely reactive and used as a supplement to cement in the construction of buildings. POFA thought of as an additional environmental substance in the cement used to make concrete. The sample was tested by comparing concrete with a combination with cement and concrete with a combination of 20% of POFA. The studies found that it has the highest strength compared to any other replacement. Afterwards, POFA aerated concrete is used to make panels that will be tested for compressive strength. The results show that continuous water curing is the most effective way for assisting POFA aerated concrete in achieving higher strength than standard Portland cement concrete (OPC) [5].

3. Materials and Methods

Laboratory includes compressive strength test and water absorption test had been conducted to find the compressive strength and water absorption of cement sand brick containing combination of POFA and fine recycled concrete as partial cement replacement materials. The data is analyzed to determine the workability, strength and relationship between compressive strength and water absorption had been analyzed.

3.1 Materials

The materials used in this study are sand, cement, fine recycled aggregate and palm oil fuel ash. The size of the brick is 215 mm long, 103 mm wide and 65 mm deep.

3.2 Methods

The mixtures designed in accordance with the requirement of the British standard (BS-5628-3). In general, the ratio of cement: sand in sand cement bricks is 1:6 [6]. The water-cement ratio used in the sand cement brick mix design is 0.6. The total number of brick specimens were 60 that are 30 brick specimens for the compressive strength and water absorption tests, respectively. The production of brick specimen control by mixture content of combination of RCA and POFA as partial cement replacement materials on sand cement brick. All material weighed according to the mix design before mixing. The bricks would moulded with a mould size of 215 mm in length, 103 mm in width, and 65 mm depth. The design replacement of RCA is 0%, 5%, 10% and 15% and POFA is 0%, 5%, 10% and 15%.

The compressive strength (BS EN 12390-3-2009) calculated using the following Equation 1 and Equation 2 used to determine the percentage of water absorption of brick.

$$\text{Compressive strength} = \frac{P}{A} \quad (1)$$

$$\text{Percentage of water absorption} = \frac{Mass\ of\ the\ wet\ brick}{Mass\ of\ the\ dried\ brick} \times 100\% \quad (2)$$

4. Results and Discussion

For this study, the performance of sand cement brick is determined by looking at its compression value and percentage of water absorption. To obtain this result, several test had been conducted which is compressive strength test to obtain compression value and water absorption test to obtain the percentage of water absorption.

4.1 Compressive strength

The result compressive strength of normal sand cement brick at 7 and 28 days of curing age was 20.3 MPa and 23.7 MPa respectively. It achieved target strength of the sand cement brick according to British standard must above than 7 MPa. The highest compressive strength of concrete for 7 days age curing was concrete containing 10% of RCA and 5% of POFA at 26.6 MPa. It has the lowest compressive strength was 15% RCA and 15% POFA at 18.3 MPa. [7] suggest that POFA is an effective pozzolan to replace cement at low percentages. The 2.5% and 5% POFA replacements had remarkable high early strength concrete compared to the control one.

The highest compressive strength of concrete for 28 days age curing was brick containing 10% of RCA and 5% of POFA at 31.8 MPa. It has 29.2 % different from the control brick. The lowest compressive strength was sample containing 15% RCA and 15% POFA at 21.8 MPa. According to [8], the early age strength is due to the hydration of cement, with POFA acting as a filler of voids and contributing to the strength gain. It has -8.4% different compared to control brick. The higher the difference amount of compressive strength between brick modified (RCA and POFA) and control brick was the optimum ratio of combination of RCA and POFA in sand cement brick. It concluded that the combination of replacement at 10% of RCA and 5 percent of POFA was the highest compared to other combination [9]. Table 1 and Figure 1 shows the result obtained based on the testing of sample.

Table 1: Comprehensive strength of sand cement brick

RCA (%)	POFA (%)	Compressive Strength (MPa)					
		7 Days			28 Days		
		Strength	Average	Percentage different compared to Control brick (%)	Strength	Average	Percentage different compared to Control brick (%)
0	0	20.8 20.1 19.9	20.3	-	23.9 23.9 23.3	23.7	-
	5	24.8 22.2 23.9	23.6	15.0	28.2 30.3 29.9	29.5	21.8
5	10	21.7 22.8 22.3	22.3	9.4	27.4 26.9 27.1	27.1	13.4
	15	21.9 22.0 19.3	21.1	3.9	26.1 26.4 23.4	25.3	6.5
	5	26.4 27.1 26.3	26.6	26.9	32.4 31.2 31.9	31.8	29.2
10	10	22.9 23.2 24.1	23.4	14.2	29.4 28.9 27.8	28.7	19.1
	15	20.2 20.4 21.1	20.6	1.5	23.1 23.3 23.4	23.3	-1.7
	5	21.8 21.7 22.2	21.9	7.6	26.9 27.3 28.3	27.5	14.8
15	10	21.1 20.3 19.5	20.3	0	26.2 24.1 26.8	25.7	8.1
	15	18.4 19.3 17.3	18.3	-10.4	22.2 21.9 21.3	21.8	-8.4

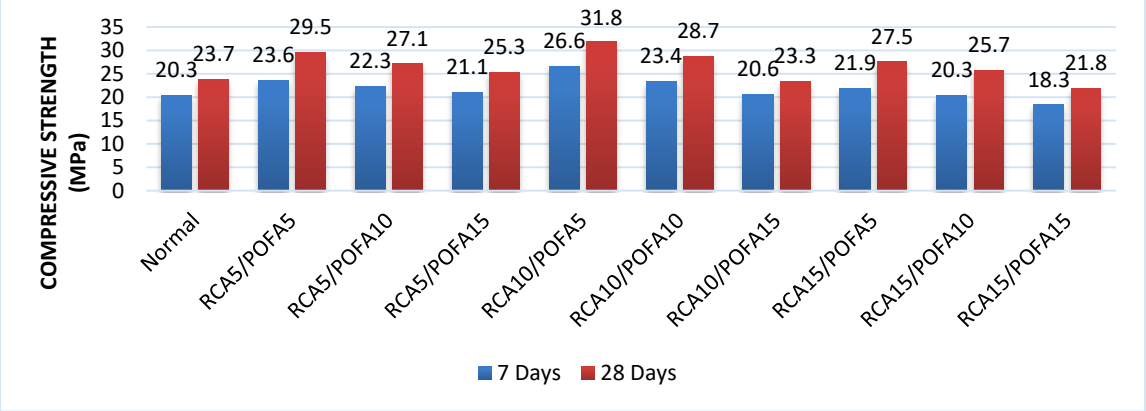

Figure 1: Compressive strength of sand cement brick for 7 and 28 days

4.2 Water absorption

Based on Table 2 and Figure 2, the percentage of water absorption for the normal sand cement brick is 4.9%. The highest water absorption obtained for the sand cement brick containing 15 % of RCA and 10% of POFA is 5.72% that has 0.82% differences normal sand cement brick. The lowest water absorption in this study was sand cement brick containing 5 % of RCA and 5% of POFA is 5.03% that has 0.13% differences compared to normal sand cement brick [10]. Study by [11] the high porosity of the recycled aggregates mainly attributed to the residue of mortar adhering to the original aggregate. It concluded that all the modified sand cement brick has higher percentage than the control sand cement brick. Besides, the water absorption percentage is lower than 7% gives better protection from harm.

Table 2: Average water absorption result and percentage of different strength between modified brick and control brick

RCA (%)	POFA (%)	Water absorption (%)	Average water absorption (%)	Percentage different compared to Control brick (%)
0	0	4.91 4.91 4.89	4.9	-
5	5	5.08 4.99 5.02	5.03	2.62
5	10	5.21 4.99 5.00	5.07	3.41
10	15	5.29 5.17 5.22	5.23	6.52
5	5	5.49 5.37 5.33	5.40	9.71
10	10	5.61 5.73 5.42	5.59	13.16
15	15	5.63 5.78 5.46	5.62	13.67
15	5	5.71 5.64 5.69	5.68	14.74
15	10	5.68 5.73 5.75	5.72	15.44
15	15	5.72	5.71	15.27

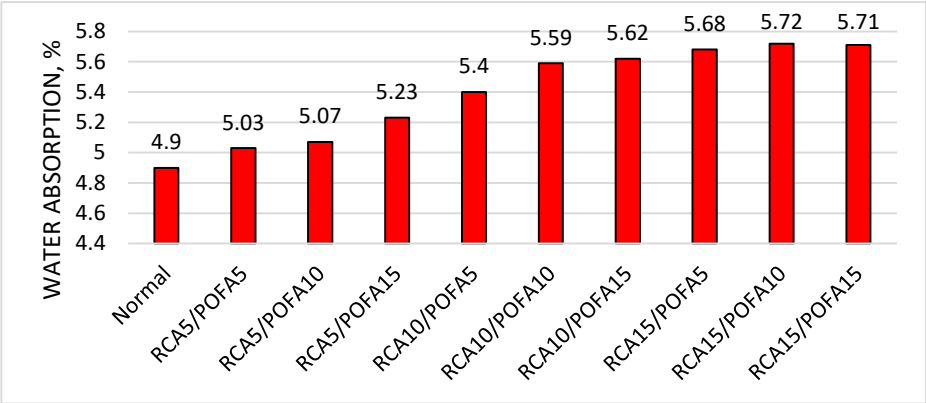

Figure 2: The average percentage water absorption for sand cement brick

4.3 Optimum mix design

Based on figure 3, it concluded that the best percentage for replacing the OPC with RCA and POFA as cement replacement materials was sand cement brick containing 10% of RCA and 5% of POFA. This confirmed by the compressive strength that reach maximum value of 31.8 MPa. Besides, the water absorption for sand cement brick containing 10% of RCA and 5% of POFA has only 0.4% difference than the control brick. Therefore, mix design with 10% of RCA and 5% of POFA is the most suitable to be used in this study.

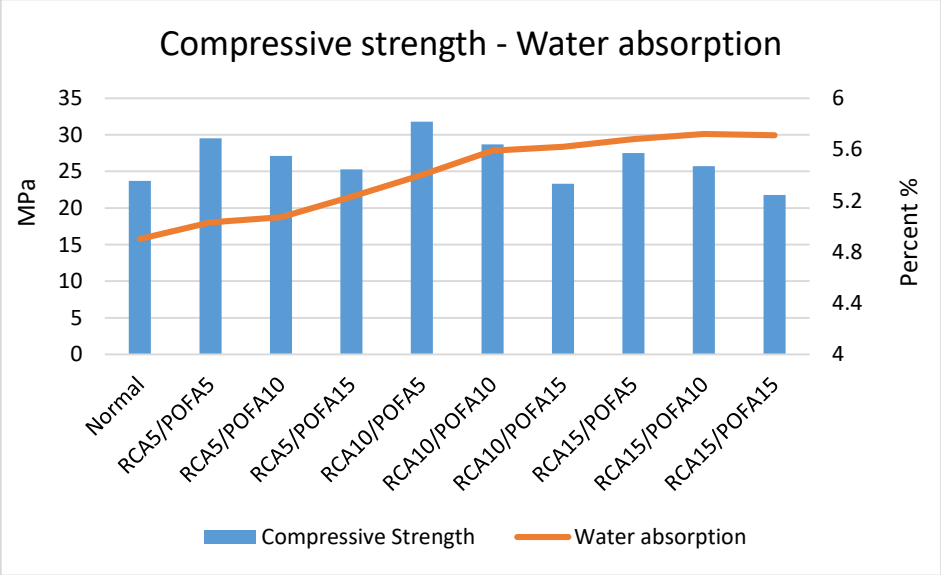

Figure 3: Sand cement brick strength and water absorption against the percentage of cement replacement

5. Conclusion

Water absorption and compressive strength of the sand cement brick were successfully investigated and achieved all the objectives. The compressive strength of the concrete showed a fluctuating condition as the percentage of RCA and POFA was added into the sand cement brick increased. The overall results for the compressive strength test showed that every mix designation of sand cement brick mix passed or above the target of normal strength of sand cement brick which was 7 MPa.

The value of water absorption become increase as the percentage of RCA and POFA was added into the sand cement brick increased. However, the test results for all percentages of RCA and POFA that was added, showed no significant difference compared to normal sand cement brick. The preferred combination between of RCA and POFA in sand cement brick was 10% and 5% respectively. The

suggestion to improve that study is to experiment with different water-cement ratio and conduct more percentage for mix design brick.

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