Performance of composite sand cement brick containing recycle concrete aggregate and waste polyethylene terephthalate with different mix design ratio

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Abstract. This study is focuses to the performance of composite sand cement brick containing recycle concrete aggregate and waste polyethylene terephthalate. The objective is to determine the mechanical properties such as compressive strength and water absorption of composite brick containing recycled concrete aggregate and polyethylene terephthalate waste and to determine the optimum mix ratio of bricks containing recycled concrete aggregate and polyethylene terephthalate waste. The bricks specimens were prepared by using 100% natural sand, they were then replaced by RCA at 25%, 50% and 75% with proportions of PET consists of 1.0%, 1.5%, 2.0% and 2.5% by weight of natural sand. Based on the results of compressive strength, it indicates that the replacement of RCA shows an increasing strength as the strength starts to increase from 25% to 50% for both mix design ratio. The strength for RCA 75% volume of replacement started to decrease as the volume of PET increase. However, the result of water absorption with 50% RCA and 1.0% PET show less permeable compared to control brick at both mix design ratio. Thus, one would expect the density of brick decrease and the water absorption to increase as the RCA and PET content is increased.

1. Introduction

Brick is one of the important material in the construction of which is widely used and highly demand in the construction of a structure in the civil engineering sector. However, the consumption of natural resources such as sand in brick production resulted in resource depletion, environmental degradation, and energy consumption [1]. Three main material of sand cement brick including cement, aggregates and sand have been considered for replacement with another recycle product to further reduce the amount of natural resources. Recycle concrete aggregate (RCA) is more recently use as aggregate in brick. Basically the aggregate which are classified as coarse aggregate and fine aggregate (sand). Recycle aggregate is obtain from the processing of construction and demolition waste has been applied increasingly.

Waste bottles are among major cause of solid waste disposal. It is non-biodegradable products that been used and thrown out which leads to the environmental pollution. Polyethelene Terephthalate (PET) is commonly used for carbonated beverage and water bottles [2-3]. These polymer wastes are almost non-degraded in the natural environment even after a long period of exposure. The slow degradation property of waste polymer materials causes a waste disposal crisis from environmental view point, but it may appear to be valuable property as constructional material [3]. Utilization of waste PET as aggregates in masonry mortar/ concrete would be good solution to this environmental hazard [4].

This study aims to determine the mechanical properties such as compressive strength and water absorption strength of composite brick containing recycled concrete aggregate and polyethylene terephthalate waste. Many researchers found that the compressive strength of concrete is influenced by the physical and the mechanical properties of RCA materials. It has been observed from a number of experimental investigations that using the same water-cement ratio, the compressive strength of concrete using RCA is greatly influenced by the increment in the replacement percentage less than 50% of RCA as compared to concrete using natural aggregates [5-7]. According to O'Mahony [8], when RCA is crushed from masonry, content of the fine particles is much more than that form concrete. This leads to decrease workability and strength of concrete containing recycled fine aggregate [9]. Boltryk, [10]

studied the possibility of using RCA in the concrete mixture. Four series of concrete specimens with the percentage of 0%, 25%, 50% and 75% of recycled concrete aggregate was prepared. The water-cement ratios for all mixtures are different due to high content of dust fractions in RCA causing high water demand in concrete mixtures with aggregates.

The use of waste PET particles as the partial substitution of an equivalent 5% weight of natural sand in concrete was also investigated by previous researcher [11]. The substitution however limited only to the fine aggregate fraction by 5% weight for particles in the fraction 0.1 to 5mm which possess similar grading curve to that substituted natural sand. For 0.45 and 0.55 water-cement ratio, the waste PET concrete characterized the same workability and no segregation with respect to the reference similar concrete. The specific gravity for PET is in low value compared to natural aggregate. Also, the plastic waste is found to have very low water absorption and it usually less than 7%. However, many researchers presented that an increase in fibre content of waste PET increases the concrete strength. Previous study shows that the compressive strength of concrete increased up to 2% replacement of the fine aggregate with waste PET fibres [12]. The replacement of waste PET improved the ductility of the concrete where PET fibres exhibit impressive performance compared to the plain concrete [13].

As the conclusion, RCA itself has a great properties and performance as fine aggregates. As stated by researchers, RCA is a well-graded materials, have greater porosity and higher in water absorption compared with natural aggregate (NA). Also, PET contributes as recycling target as it is non-biodegradable materials. Its low density, strength, user-friendly designs, fabrication capabilities, long life, lightweight, and low cost are the factors behind such phenomenal growth.

2. Methodology

As stated in chapter one, this study involved a series of experimental tests to obtain the physical and engineering properties of sand cement composite brick containing RCA and PET. In this chapter, a detail discussion is presented on the material preparation and the experimental methods to achieve the objectives of the research. The activities involved in this chapter can be summarize as material preparation, sieve analysis, design mix, brick preparation, physical and mechanical properties testing. The bricks were then moulded with a mould size of 215 mm in length, 103 mm in width, and 65 mm depth. The ratio of 1:4 and 1:5 will be use as mix design ratio of sand cement brick and water cement ratio is 0.6. The design mix was prepared according to BS 5628-3 design method. In order to get the suitable mix design ratio, pilot tests will be conduct by using three different mix design ratios (1:4 and 1:5) in the production of brick and will be tested through compressive and water absorption test. The optimum design mix used to produce sand cement composite brick with 25%, 50% and 75% of RCA and 0.5%, 1.0%, and 1.5% of PET waste as fine aggregate replacement.

All specimens that include RCA, PET waste bottle, cement, sand and water was been prepared in laboratory at Universiti Tun Hussien Onn Malaysia. A series of laboratory cured brick was prepared during the mixing mortar and there was also considered the sample for 7 days and 28 days. Brick was prepared according to 24 different mix proportions with different mix design ratio. There is about 156 number of specimen that was provided to perform compression test and 78 specimens were prepared for water absorption test. The brick will be moulded with a mould size of 215mm in length, 105mm in width, and 65mm in depth. The process involve in casting the brick is by added the mixtures that have been prepared earlier using scoop into the mould for three layers and the mixture was tamped for 25 times for each layer. For identification, each of the specimens will be labeled according to its mixture proportion and date of fabrication.

In the mechanical property test of the brick, compressive and water absorption were examined. For each test, three specimens were prepared according percentage of 25%, 50% and 75% for RCA and 0.5%, 1.0%, and 1.5% for PET with different mix design ratio. Testing durations for all samples include 7 and 28 days, respectively. The procedure for testing the compressive strength was consistent with BS EN 772-1:2011 “Methods of test for masonry units”. The procedure for water absorption test followed BS 3921:1985.

3. Result and discussion

The overall results for material testing of composite brick from the experimental works are presented, analysed and discussed in detail in this study. The results and analysis are divided in two parts, namely physical and mechanical properties. All collected data presented in table and graph to assure for a better and clear understanding of the results.

3.1. Water absorption

Water absorption was carried out to determine the percentage of water absorption of the brick. The details results of water absorption against ages for each percentage of RCA and PET were given in Figure 1 and Figure 2. It shows the evolution of water absorption from 7 days to 28 days for all mixtures with two different mix design ratio 1:4 and 1:5. The results illustrated that the water absorption increased with the replacement percentage of fine aggregate by the RCA and PET wastes for all mixtures. However, up to RCA50%PET1.0% replacement in mix design ratio 1:4 and 1:5 were slightly decreased of water absorption of composite cement brick for both 7 and 28 days. The results indicate that the sample with RCA50%PET1.0% was less permeable when compared to other samples. Then, the percentages of water absorption start to increase at RCA 50% PET 1.5%. Furthermore, the highest water absorption coefficients were obtained in composite sand cement brick with RCA75%PET2.5%. Samples with 75% of RCA absorbed more water than did samples containing 50% and 25% of RCA.

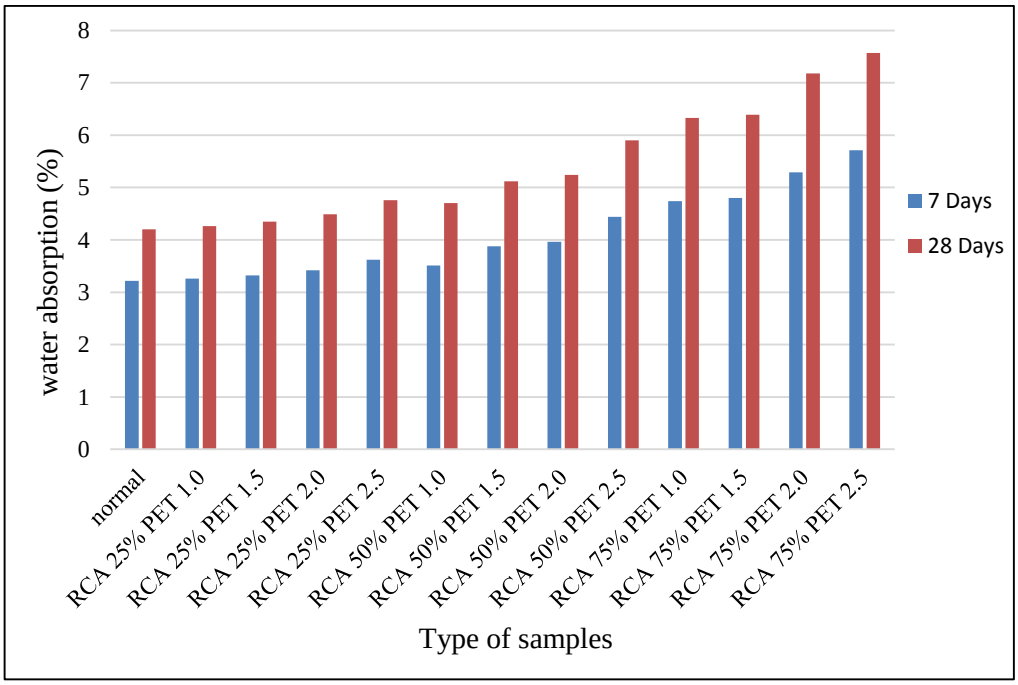

Figure 1. Water absorption test at 7 and 28 days with mix design ratio 1:4

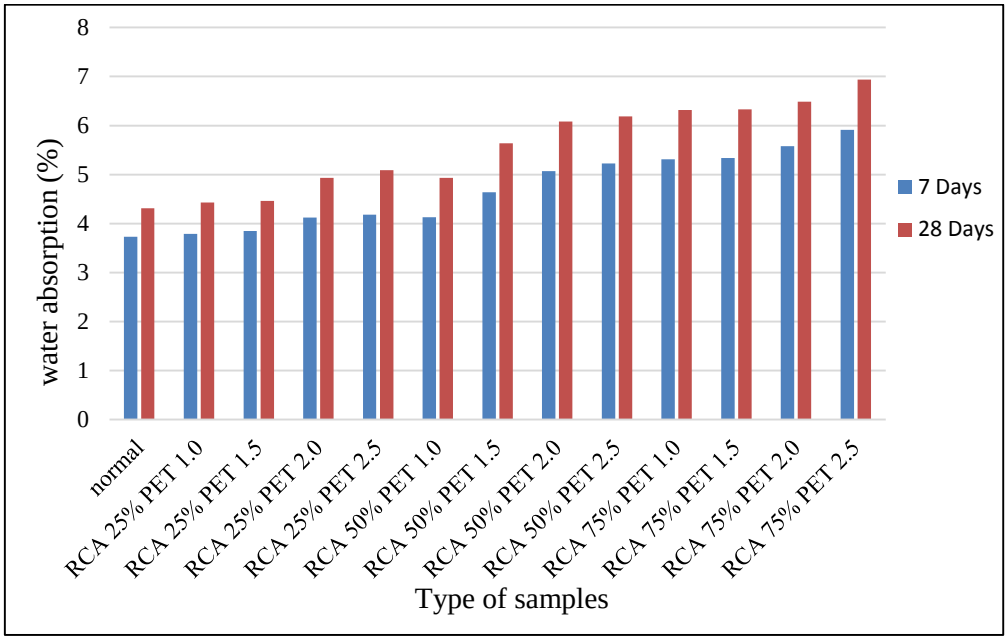

Figure 2. Water absorption test at 7 and 28 days with mix design ratio 1:5

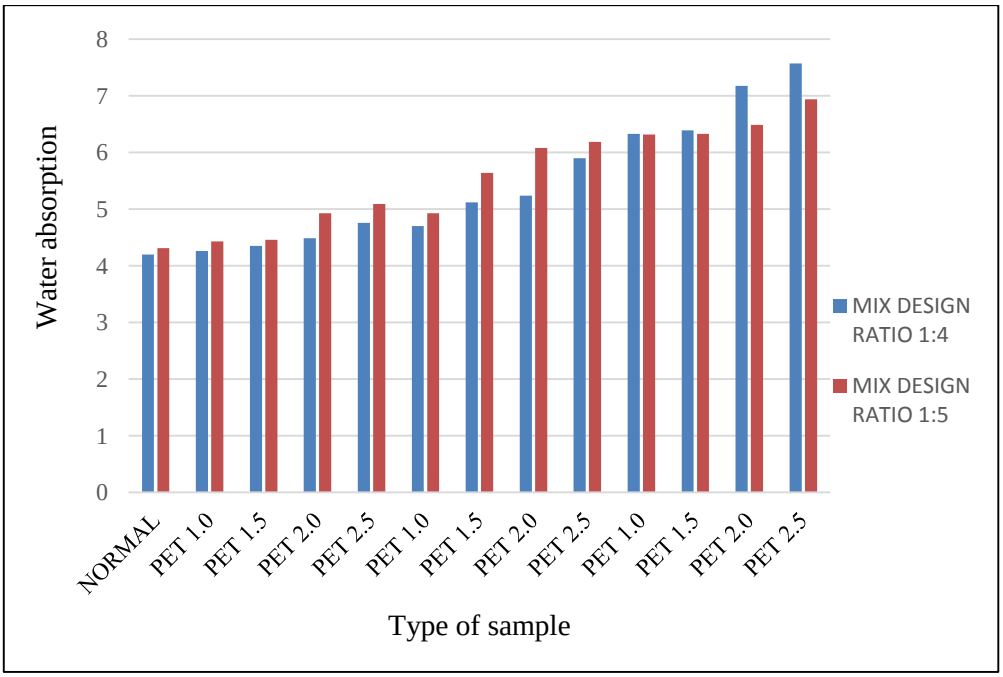

Figure 3. The water absorption between mix design ratio 1:4 and 1:5

It can be summarized in Figure 3 above, that the water absorption of composite sand cement bricks with recycled fine aggregate significantly affected the increased water absorption characteristic of bricks [14]. From the results, only bricks with 50% RCA and 1.0% PET show less permeable compared to control brick. Thus, one would expect the density to decrease and the water absorption to increase as the RCA and PET content is increased.

3.2. Compressive strength

Compressive strength of bricks was tested at age 7 and 28 days. The investigation was done on the twelve types of bricks samples which contain 25%, 50% and 75% RCA with an addition of 1.0%, 1.5%, 2.0% and 2.5% of PET. From the Figure 4, the highest strength is 33.3 MPa for the samples that contain

RCA 25% and PET 2.0% as sand replacement whereas the strength for normal bricks is 29.9 MPa. However, the samples of RCA 75% and PET 2.5% attained a lower strength about 14.4 MPa reductions from the control brick. After a while, the strength starts to decrease for samples RCA 25% and PET 2.5% when the sample contain of high percentage of RCA and PET.

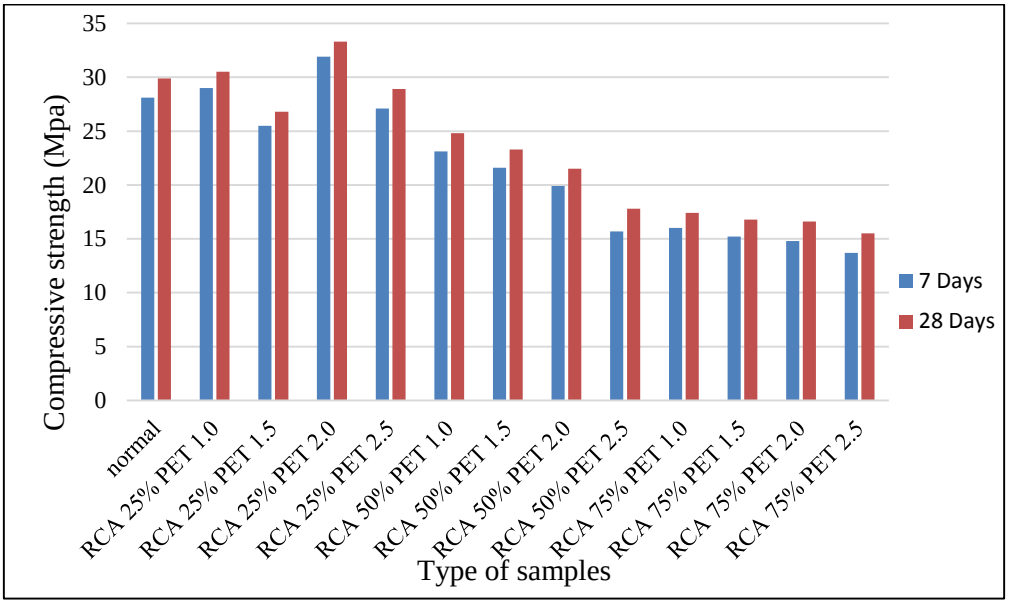

Figure 4. Compressive strength at 7 and 28 days with mix design ratio 1:4

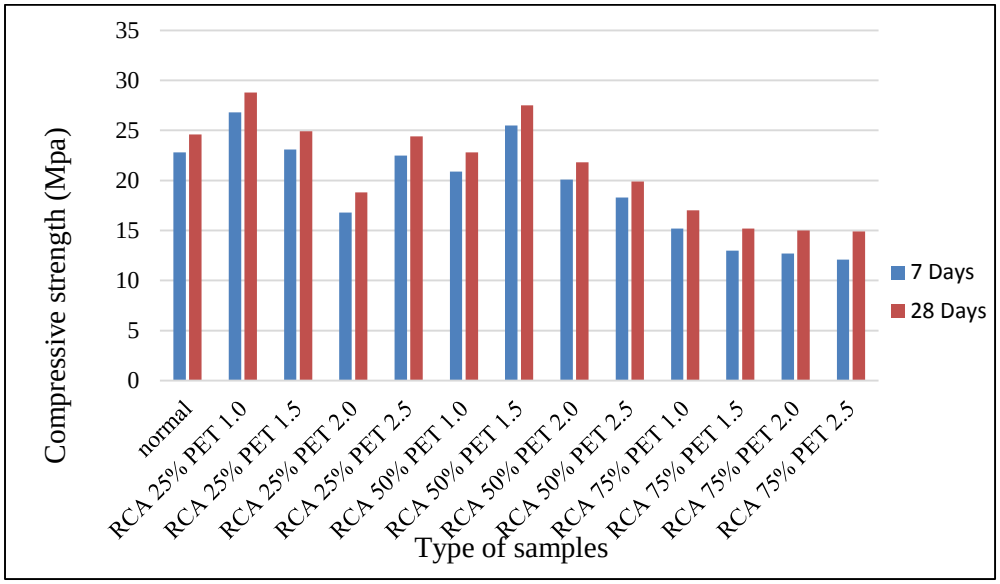

Figure 5. Compressive strength at 7 and 28 days with mix design ratio 1:5

The increasing average compressive strength between curing age of 7 days to 28 days with mix design ratio 1:5 is shown in Figure 5. All the samples achieve strength more than the minimum strength for both 7 Days and 28 Days. The sample with RCA 25% with PET 1.0% exhibit the highest strength with 28.8 MPa, which is higher strength rather than normal brick. Nevertheless, the specimen with RCA of 50%, it shows the strength increased in line with the increasing of PET volume for 1.0% and 1.5% and start to decrease at 2.0% and 2.5% of PET content. However, the strength for both curing age starts to decrease for brick containing 50% and the increasing volume of 2.0% and 2.5% of PET also reduced the strength of the composite brick. It shows that RCA in brick has siginificant effect on the compressive

strength of specimen but higher levels of replacements of these materials reduced the compressive strength significantly [15-16].

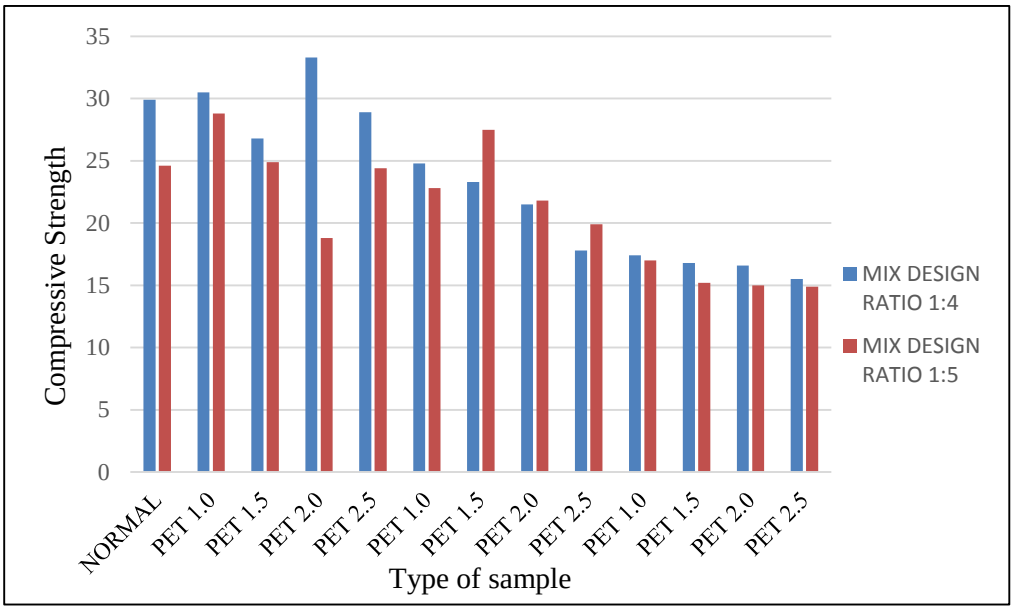

Figure 6. The compressive strength between mix design ratio 1:4 and 1:5

For overall results on compressive strength in Figure 6 above, it indicates that the replacement of RCA shows an increasing strength as the strength starts to increase from 25% to 50% for both mix design ratio. Meanwhile, the strength of specimen containing RCA 50% shows a reduction percentage of strength from 2.0%of PET replacement. However, an addition of PET fiber in the specimen demonstrate that the increasing replacement of PET as sand in the composite brick shows an increasing strength for RCA 25% and RCA 50%. But, the strength for RCA 75% volume of replacement started to decrease as the volume of PET increase.

4. Conclusion

As the conclusion, the analysis of data and discussion that has been carried out. Overall, from all the studies, they founded the decrease of density was influenced by the addition of RCA and PET. The result can be concluded that the reduction in bricks density was attributed by the lower unit weight of RCA and PET. From the result of water absorption, composite sand cement bricks with recycled fine aggregate and PET significantly affected the increased water absorption characteristic of bricks. However, only bricks with 50% RCA and 1.0% PET show less permeable compared to control brick. Thus, one would expect the density to decrease and the water absorption to increase as the RCA and PET content is increased.

The test result on the compressive strength roughly shows the replacement of sand by RCA and PET increase as the volume started to increase. The sand replacement ratio of RCA and PET at levels 25% and 1.0% has good effects on the compressive strength of the bricks. It can be discussed that the high percentage of RCA can increase the strength of the bricks RCA whereas the lower volume fraction of PET is seen to be suitable added when the volume of RCA is high but whenever the high volume of PET is used, the strength for 25% of RCA indicates the high strength.

The overall result based on two different mix design ratio shows instability in compressive strength of bricks when RCA and PET were added. When the compressive strength of the mixtures values were compared at different mix design ratio (1:4,1:5), it showed that the compressive strength for control brick at mix design ratio 1:4 was higher than mix design ratio 1:5 at ages 7 days and 28 days. Overall result of different percentages of RCA and PET compared at different mix design ratio, the lowest value of compressive strength were obtained for a mix design ratio 1:5.

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