The Effect of Water Cement Ratio on Cement Brick Containing High Density Polyethylene (HDPE) as Sand Replacement

Noorwirdawati Ali^{1,*}, Nor Fazlin Mohd Yusup², Faisal Sheikh Khalid¹ Shahiron Shahidan¹ and Siti Radziah Abdullah¹

¹Repair, Strengthening and Rehabilitation of Structure Focus Group, Jamilus Research Centre, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

²Abd Manas Bin Abd Wahab, No. 3A, MARA Building, Iskandar Street, 33100 Pengkalan Hulu, Perak, Malaysia

Abstract. Waste disposal can contribute to the problem of environmental pollution. Most of the waste material is plastic based, because the nature of difficult of plastic degradable by itself. In order to overcome the problem, many study has been conducted on the reuse of plastic material into various field such as civil engineering and construction. In this study, municipal solid waste (MSW) in the form of High Density Polyethylene (HDPE) plastic was used to replace sand in cement sand brick production. The HDPE used in this study was obtained from a recycle factory at Nilai, Negeri Sembilan. 3% of HDPE replacement was applied in this study, with the cement-sand mix design of 1:6 and water-cement ratio 0.35, 0.40, 0.45 and 0.50 respectively. All specimens were tested for compressive strength and water absorption at 7 and 28 days. The density of the bricks was also recorded. The finding show that brick with 3% HDPE content and 0.45 of water-cement ratio at 28 days of age curing show the highest compressive strength, which is 19.5N/mm² compared to the control specimen of 14.4 N/mm².

1 Introduction

Increased waste from day to day cause the management of waste disposal a major problem to the world. Inefficient management of waste disposal can contribute to the problem of environmental pollution. Most of the waste material is plastic based, because the nature of difficult of plastic degradable by itself.

Plastics are divided into two categories, namely thermo-plastic and thermosetting plastics. Thermo-plastic such as polyethylene (PE), polystyrene (PS), polypropylene (PP), polyethylene terephthalate (PET) and high density polyethylene (HDPE) which can be melted by heating and hardened by cooling. Whereas, thermosetting plastics cannot be melted or softened by heating.

In effort to an increase demand of brick production, the brick industry continues to search and explore the alternative markets to improve their brick's quality and productivity. On top of that, many research have been conducted on the use of recycle materials into construction or building material [1 - 7]. Plastic is one of the materials that receive great attention among researcher to be used to substitute sand in the production of brick or concrete. Since plastic is non-biodegradable, study on the use of this recycle material become crucial as it can helps in reducing plastic wastes to be dumped to landfills.

In this study, high density polyethylene (HDPE) is used as a sand replacement in the production of cement-sand bricks. In the experimental work conducted, 3% HDPE was used as sand replacement. 3% replacement was chosen because from literature review conducted, 3% of plastic material to substitute sand in brick or concrete was found to be the optimal value for replacement. Meanwhile, the ratio of water to cement used is varied by 0.35, 0.40 (as a control sample), 0.45 and 0.5. These various value chosen also from the literature review conducted. This study aimed to investigate the effect of water-cement ratio on the compressive strength and water absorption of cement-sand bricks containing HDPE.

2 Material and methods

The materials used in the preparation of specimens were Ordinary Portland cement, river sand and high density polyethylene (HDPE) obtained from a recycle factory at Nilai, Negeri sembilan. The HDPE used is in the shape of plastic seed that is used as materials to produce plastic-based products as shown in Figure 1. The HDPE average size was 3mm in shape. In this study, 3% HDPE was used as sand replacement in the cement-sand production. The mix design of HDPE cement-sand brick are shown in Table 1 while Table 2 shows the density for

* Corresponding author: wirda@uthm.edu.my

each raw materials used in this study. For each mix design, a total of 12 specimens were prepared where 6 specimen for water absorption test and another 6 specimen for compressive strength test. For each test, 3 specimens were tested at 7 day of curing while another 3 specimen were tested at 28 day of curing. The specimen for compressive strength test was also used to determine the brick density. Before specimens were placed for compression test, it will be weighed to determine the weight of the brick. Figure 2 and 3 shows the process of specimen production.

Fig. 1. HDPE used in this study

Table 1. Mix design

HDPE (%)	Water : cement (w/c)
3	0.35
0 (Control)	0.4
3	0.4
3	0.45
3	0.5

Table 2. Density of raw materials

Density	Value
Cement	1506kg/m ³
Sand	1600kg/m ³
Water	1000 kg/m ³
High Density Polyethylene (HDPE)	625 kg/m ³

Fig. 2. Brick specimen production

Fig. 3. Compaction of the brick

Specimen were left for air curing. They were placed at indoor environment and left for 7 dan 28 days of curing as shown in Figure 4. Specimens were then tested to determine the density, water absorption and compressive strength. Figure 5 shows water absorption test on specimen. The results were analyzed and compared with control specimen. Conclusions were drawn based on the test result.

Fig. 4. Curing of specimen

Fig. 5. Water absorption test on specimen

3 Results and discussions

3.1 Density

The density of cement bricks affected by the raw material and the manufacturing process. Cement bricks must meet the standards of BS EN 771-3: 2003 [8] in order to meet the needs of a satisfactory compressive strength and high durability. This is because the mechanical properties of cement brick containing HDPE affected by its density. The results of the density of the brick are displayed in Table 3 and Figure 6.

Table 3. Results of density of bricks

Water : cement (w/c)	Average density at 7 day (kg/m ³)	Average density at 28 day (kg/m ³)
0.35	1730	1690
0.4 (control)	1900	1840
0.4	1550	1840
0.45	1870	1930
0.5	1940	1850

Fig. 6. Results of density of bricks

Based on the results obtained, the density of brick containing 3% of HDPE with various water cement ratio showed no significant difference with the control sample. From the graph of the results obtained, 0.50 water-cement ratio recorded the highest density at 7 days of curing with the value of 1940 kg/m³, while the water-cement ratio of 0.45 recorded the highest average density at 28 days of curing with the value of 1930 kg/m³. The lowest density was recorded for brick with water-cement ratio of 0.4 for 7 day at 1550 kg/m³ while brick with water-cement ratio of 0.35 recorded the lowest density at 28 day with 1690 kg/m³.

Water-cement ratio is the key factor in determining the strength and workability to be achieved in the production of bricks. Workability is an important element for determining the density of a brick. Low water-cement ratio will increase the strength and hardness, but it will reduce the workability while high water-cement ratio will increase the workability of the mix during the production process of bricks. A brick with good workability will encourage the production of high-density brick. These factors explain the existence of differences in density that occurs between all the samples tested.

3.2 Water absorption

Water absorption is important to determine the quality of bricks produced. Water absorption rate of a unit brick is closely related to the porosity. High water permeability by a brick will cause swelling of the soil particles in the bricks that have been stabilized and will cause a decrease in strength.

Table 4 and Figure 7 shows the average water permeability for cement bricks sample produced. Specimens with water cement ratio of 0.5 showed the lowest reading at the age of 7 and 28 days of curing which are 2.17% and 1.89% respectively. Meanwhile, the water-cement ratio of 0.35 recorded the highest value at the age of 7 and 28 days of curing, at 6.85% and 10.33% respectively.

Table 4. Results of water absorption test

Water : cement (w/c)	Average water absorption at 7 day (%)	Average water absorption at 28 day (%)
0.35	6.85	10.33
0.4 (control)	2.94	5.32
0.4	6.79	4.18
0.45	3.36	2.17
0.5	2.17	1.89

Fig. 7. Results of water absorption test

Based on the results obtained, it can be concluded that the use of water-cement ratio in the production of bricks have an impact on increasing the percentage rate of water absorption in the brick. This is because water is the agent of chemical reactions in cement to bind all the raw materials in mixing a brick.

The use of 3% HDPE in cement bricks did not leave much impact on improving water permeability. This situation can be evidenced by the rate of water absorption of cement brick with 3% HDPE which was lower than the control specimen.

3.3 Compressive strength

Compressive strength of a brick is much influenced by the cement content in the mix, the type of raw material and the water content of a cement brick. The compressive strength is an important aspect in assessing the load bearing capability of a brick. Based on the analyzed data, it is found that compressive strength of bricks containing HDPE meets the standards set in MS 76: 1972 [9-10].

From Table 5 and Figure 8, it was found that the average compressive strength of brick at age 7 and 28 days with an addition of 3% HDPE and 0.45 water-cement ratio recorded the highest compressive strength of 15.5 N/mm² and 19.5 N/mm² respectively. This mix also recorded the highest density at the age of 28 day.

Table 5. Results of compressive strength test

Water : cement (w/c)	Compressive strength at 7 day (%)	Compressive strength at 28 day (%)
0.35	7.4	9.8
0.4 (control)	11.7	14.4
0.4	11.1	15.9
0.45	15.5	19.5
0.5	12.5	14.4

Fig. 8. Results of compressive strength test

The content of water-cement ratio in the brick plays an important role in determining the compressive strength of the brick. This is because it affects the air voids in the brick and affect the strength. Based on the results obtained, the compressive strength at 28 days of age showed and increased of compressive strength with the increased of water cement ratio up to 0.4 w/c. Beyond water cement ratio 0.4, the compressive strength of the brick decreased as shown in Figure 4.

Meanwhile, the use of 3% of HDPE in the cement brick does affect the compressive strength of bricks produced. Figure 8 above shows the reading of compressive strength using 3% of HDPE with a 0.40 ratio of cement was higher than the control specimen at 28 days of age the curing with the value of 15.9 N/mm². It shows that with the same water-cement ratio, the value of compressive strength recorded almost similar value with the added of 3% of HDPE into the mix.

From the experimental results, it is also noted that the lowest compressive strength was recorded by brick with water-cement ratio of 0.35 which is the lowest water-cement ratio used. It can be deduced here that low water-cement ratio not only reduce the workability but also reduce the compressive strength of the brick. This results can also be supported by the results from water absorption test where the specimen with the lowest water-cement ratio which is 0.35, recorded the highest water absorption and therefore it also can be deduced that with high water absorption resulted in decreased of compressive strength of the brick. This mix also recorded the lowest density at the age of 28 day and the second lowest of density at the age of 7 day.

4 Conclusions and Recommendations

From the results presented above, some conclusion can be deduced as follows:

- 1) Water-cement ratio of 0.45 is the optimal ratio for cement bricks containing 3% HDPE because it recorded the highest compressive strength and the second lowest of water absorption at 28 day.

- 2) This study also shows that HDPE can be use as sand replacement in brick production where the utilization of HDPE can reduce the waste dump at the landfill.
- 3) The ratio of water used in the production of cement bricks affect the percentage of water absorption. From the results of experimental work that have been carried out, the percentage of water absorption decreases with increasing water cement ratio in the production of the bricks.
- 4) Results also shows that compressive strength increased with the increased of water cement ratio up to water cement ration of 0.45. This shows that the use of excessive water-cement ratio can reduce the compressive strength of bricks produced.

In order to enhance the research of using HDPE in cement brick, there are several recommendations that is suggested to be investigated. The recommendation includes:

- 1) Percentage of replacement can be varied to get more range of data.
- 2) Study the effect of different mix design ratio should also be considered.
- 3) Other type of testing can be conducted for example thermal testing.

This research is funded by Short Term Grants (STG) U340, Universiti Tun Hussein Onn Malaysia and Fundamental Research Grant Scheme (FRGS) 1576.

References

- [1] J. Hadipramana, A.A.A. Samad, A.M.A. Zaidi, N. Mohammad, A. Wirdawati. Influence of Polypropylene Fiber in strength of foamed concrete. *Advanced Materials Research*, **488-489**, pp. 253-257 (2012)
- [2] N. Ali, K.Y. Yaacob, M.K. Burhanudin, S. Shahidan, S.R. Abdullah. Investigation of compressed earth brick containing ceramic waste. *ARPN Journal of Engineering and Applied Sciences*, **11** (8), pp. 5459-5462 (2016)
- [3] F. S. Khalid, M. I. Juki, N. Othman, M. H. Wan Ibrahim. Pull-out strength of polyethylene terephthalate bottle fibre in concrete matrix. *Malaysian Construction Research Journal*, **21**(1), 2017, pp. 75-85 (2017)
- [4] A.S. Leman, S. Shahidan, M.Y. Yusuf, S.S. Mohd Zuki, and N.A. Misnon. Workability and compressive strength for concrete with coconut shell aggregate behaviour of concrete with coconut, MATEC Web of Conf., **87**, no. 1017, pp. 1–6 (2017)
- [5] M. Frigione. Recycling of PET bottles as fine aggregate in concrete. *Waste management*, **30**(6), 1101-1106 (2010)
- [6] N. Saikia and J. de Brito. Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate. *Construction and building materials*, **52**, 236-244 (2014)
- [7] F. S. Khalid, H. S. Herman, N. B. Azmi, and M. I. Juki. Sand cement brick containing recycled concrete aggregate as fine-aggregate replacement, MATEC Web of Conferences. **103**, 01016 (2017)
- [8] BS EN 771. Part3: Aggregate concrete masonry unit (dense and light-weight aggregates) (2003)
- [9] MS76:1972.Malaysian Standard. Specification for bricks and blocks of fired brick earth, clay or shale, (1972)
- [10] J.C. Morel, A. Pkla, and P. Walker. Compressive strength testing of compressed earth blocks. *Construction and Building Materials*, **21**(2), pp.303–309 (2007)