Recent Trends in Civil Engineering and Built Environment Vol. 1 No. 1 (2020) 55–65

RTCEBE

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN : 2773-5184

The Study on Use of Ceramic Waste As Partial Substitute of Fine Aggregates in Cement Bricks

Johnny Anak Kapok[1], Hasniza Abu Bakar[2*], Muhamad Hanafi Rahmat[2], Emedya Murniwaty Samsudin[2], Hannifah Tami[2]

[1]No. 3, Jalan Batu Matop, 96600 Julau, Sarawak, MALAYSIA

[2]Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

* Corresponding Author

DOI: https://doi.org/10.30880/rtcebe.2020.01.01.004
Received 20 August 2020; Accepted 07 December 2020; Available online 13 December 2020

Abstract: Cement brick is a type of material used in construction work and uses sand as part of its composition. Demand for the use of sand in the construction industry is increasing every year and this can lead to a reduction in natural materials. Meanwhile, ceramic waste has been used as a recycling material in Ayer Hitam, Johor and this can be channeled as a partial substitute of fine aggregates material for future use of sand in the construction industry. This research was conducted to investigate the strength characteristics of existing cement bricks containing ceramic waste as the partial substitute for fine aggregate. The total replacement percentage of 0%, 5%, 10% and 15% of ceramic waste in a ratio of 1:9 were classified to produce 24 samples of bricks. The tests carried out on the cement brick samples were density tests, water absorption tests and compression strength tests. As a result, the cement brick sample containing 10% ceramic waste had met the standards set out in BS 3921 for the water absorption test and BS 5628 for the compression strength test. The results of the density test showed that the higher the percentage of ceramic waste added to the mix, the density and the weight of the cement bricks decreased. Therefore, cement brick with the substitution of ceramic waste has the potential to become one of the building materials in the construction industry and this helps to reduce total dependence on the sand as a mixture in the cement brick.

Keywords: Cement Bricks, Ceramic Waste, Ceramic Waste Bricks

Corresponding author: hasniza@uthm.edu.my

1. Introduction

Brick is a well-known building material used in many countries all over the world. In Malaysia, the demand for brick as the housing construction materials is increasing in the rapidly increased population urban area [1]. The use of bricks covers every structure in the building to be erected. In the field of construction, the most commonly used types of bricks are clay and cement bricks. Cement bricks are usually not used as walls in buildings compared to clay bricks due to their lack of strength to bear the load of the building. However, despite this shortage, it is still very popular among contractors in housing construction in Malaysia because of its low price and easy to produce [2].

Recently, many studies focus on the use of waste material in the production of cement brick. The production of cement bricks from recycling materials can reduce the total dependence on the use of sand as a mixture in the cement brick. For example, Sheikh Khalid *et al.* [2] in their research had explored the waste replacement material of sand aggregate for sand cement brick by using the application of recycled concrete aggregate (RCA) acted fine aggregate. On top of that, Ismail and Yaacob [3] also had done studies about recycled aggregates to replace natural aggregates in the production of cement and sand bricks. Therefore, this research was conducted to produce cement bricks made from ceramic waste mixtures as a substitution of the fine aggregate material to reduce industrial waste. In addition, replacing this material in a cement brick mixture can help to reduce construction costs and prevent the occurrence of uncontrolled waste disposal [4]. From previous studies, Carmeane *et al*. [5] stated that ceramic waste chemical composition consist of various elements that are very complex materials is shown in table 1. These complex chemical compositions have made ceramic materials to have higher high-temperature strength, higher hardness, lower density, and lower thermal conductivity than metals [6,7]. This research also developed the concept of sustainable construction using recycled materials [2,8,9,10] with the primary aim of reducing the amount of energy required and thus reducing the adverse effects of the atmosphere [11].

Table 1: Chemical composition of ceramic waste [5]

Type of chemical composition	Percentage (%)
SiO_2	63.36
Al_2O_3	18.20
Fe_2O_3	2.77
CaO	1.74
Na_2O	0.34
K_2O	3.87
MnO	0.02
TiO_2	0.80
MgO	2.04
P_2O_5	0.05
PF	6.8

2. Materials and Methods

2.1 Materials

The materials used to make cement bricks are portland cement, sand and water. The ceramic waste used in this study worked as a substitute for the sand part in the production of cement bricks. This ceramic waste was collected from the ceramic manufacturing industry located in Ayer Hitam, Johor. Figure 1 shows a flow chart of the Ceramic Waste Bricks (CWB) manufacturing process. Ceramic waste must be cleaned and dried before being crushed by a grinding machine. Then, the measurement process was performed to obtain sand size from 150 µm to 5 mm. The materials were mixed in the brick mix at an optimum ratio of 1:9 which was 1 part representing the cement and 9 parts representing the sand [12]. The materials were mixed and placed into mould size 205 mm x

102.5 mm x 65 mm in accordance with BS 6073 [13] and allowed to harden gradually for 7 days and 28 days according to the standards set out in BS 1881 [14]. Table 2 shows the design of mixtures used to produce cement bricks with ceramic waste mixtures as sand.

Figure 1 : Flow chart of fabricating process of CWB

2.2 Methods

This study used a 5%, 10%, and 15% percentage of the weight of the ceramic waste as a substitute for the sand. The same method was done by Sheikh Khalid *et al.* [1]. They have made a comparison for the result of the control specimen using 100% natural sand to the recycled concrete aggregate replacement by weight for 55%, 65%, and 75%. The result had shown that the portion of 55% provided the highest compressive and flexural strength compared to other percentage and control specimen..

BS 6073 is the design method used for the brick design [13]. Once the brick samples had passed 7 and 28 days, laboratory tests would be conducted on the sample. The brick sample was tested for Density Test by measuring the length, width and thickness of the brick using a measuring tape. Once measured, the bricks that had been dried in the oven for 24 hours would be weighted using a weighting tool. The next test was the Water Absorption Test where it was done to determine the amount of water that could be absorbed by each brick unit after being immersed in 3 mm water for 1 minute. The absorption rate test was performed to obtain the ability to determine the bonding properties of the mortar and the brick units in the absorption range between 0.25-2.0 kg/min/m^2 according to standard BS 3921 [15]. The final test performed was a Compression Strength Test in which the cement brick produced was designed to exceed 7 N/mm^2 for its compressive strength to meet the load imposed according to the BS 5628 [9]. The compressive strength of the material determines its load-carrying capacity before failure. British Standards Institution states that the compressive strength of bricks should not be less than 7 N/mm^2. The test had been carried out for the sample periods of 7 and 28 days.

Table 2: Design of ceramic waste bricks mix according to 2 kg of cement

Samples	Cement (kg)	Sand (kg)	Ceramic Waste, CW (kg)
CW 0%	2	18	-
CW 5%	2	12.6	5.4
CW 10%	2	7.2	10.8
CW 15%	2	1.8	16.2

3.0 Results and Discussion

The results of laboratory tests conducted on the use of ceramic waste as a sand substitute in cement bricks were analyzed using Microsoft Excel. This data analysis was done to find out the effectiveness of the substitute materials used in achieving the objectives stated at the beginning of the study.

3.1 Density Test

The weight of a brick unit is closely related to the amount of ceramic waste replacement in the mixture. Figure 2 shows the relationship between brick sample weight to ceramic waste percentage. From the graph, it was clear that the higher the percentage of ceramic waste mixed in the mixture, the less the unit of cement brick. Therefore, according to Ismail and Yaacob [3], subsequent weight loss would cause the density of the brick to decrease.

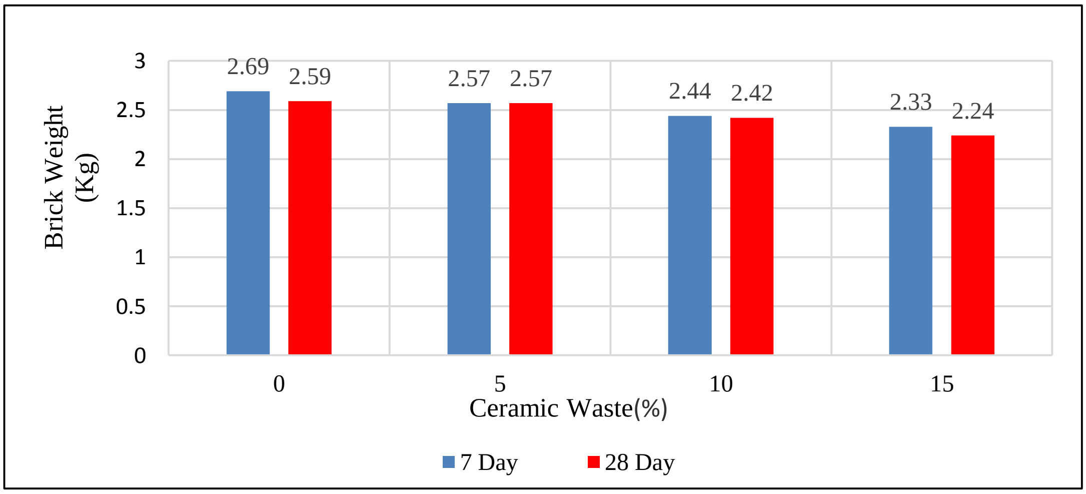
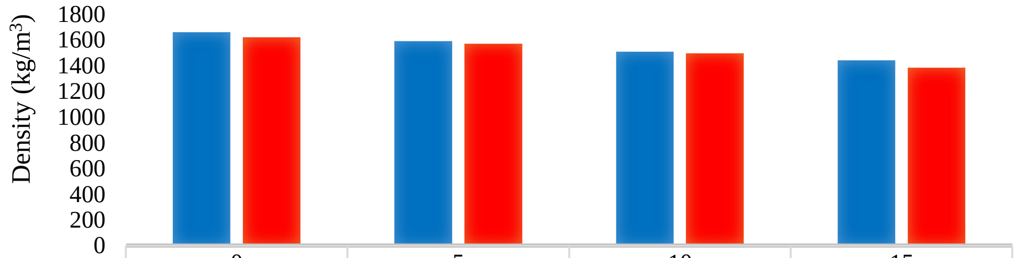


Figure 2: Relationship between brick sample weight to ceramic waste percentage

The batch of specimens was divided into 4 parts which contained 0%, 5%, 10% and 15% of ceramic waste. The density of the specimens was calculated by dividing the weight with the volume of the specimens. Figure 3 shows the relationship between density and percentage of ceramic waste.



	0	5	10	15
7 Day	1661.51	1591.42	1508.97	1440.94
28 Day	1620.28	1570.81	1496.6	1383.22

Figure 3: Relationship between density and percentage of ceramic waste

The density test concluded that the highest brick sample density values for the control sample were 1661.51 kg/m^3 for 7 days of curing and 1620.28 kg/m^3 for 28 days of curing. A similar finding had been recorded for the density control sample of 1631 kg/m^3 in producing concrete lightweight with waste clay brick as a coarse aggregate [16]. The reduction of the brick density continued decreasing due to its characteristic which was low in density [6], while the percentage of replacement materials had been increased [1]. The density of the ceramic waste samples tested were decreasing for cement bricks containing 5%, 10% and 15% of ceramic waste and could be categorized as lightweight brick as the densities were less than 1600 kg/m^3 [17].

3.2 Water Absorption Test

Based on the graph in Figure 4, it shows the value of the initial absorption of water during the 7 and 28 days of curing had increased in the brick samples containing 0%, 5% and 10% ceramic waste, while the brick sample containing 15% ceramic waste had recorded a decrease in water absorption rate. According to Sheikh Khalid *et al.* [2], the water absorption characteristic of sand cement bricks containing recycled fine aggregate increased the water absorption characteristic of bricks. According to Zimbili *et al.* [18], the ceramic bricks aggregates proved to be having high water absorption. Same with Mohamad Ibrahim *et al.* [16], with the increment of the percentage of waste applied in each mixture, the total voids distributed in the sample would be increased. This would result in a higher water absorption capacity since samples were capable to absorb more water when more voids were distributed.

. On top of that, according to Mohd Yassin *et al.* [1], the percentage of water absorption of the brick had been decreased as the percentage of EPS increased. This was due to the non-absorbent characteristic of EPS. It could be concluded that the reduction of water absorption with the 15% increment of ceramic waste was due to the non-absorbent characteristic of ceramic. However, the decreased in the absorption rate for brick samples of ceramic waste within 7 and 28 days of curing was still within the allowable standard of BS 3921 [15] between the absorption range 0.25-2.0 kg/min/m^2.

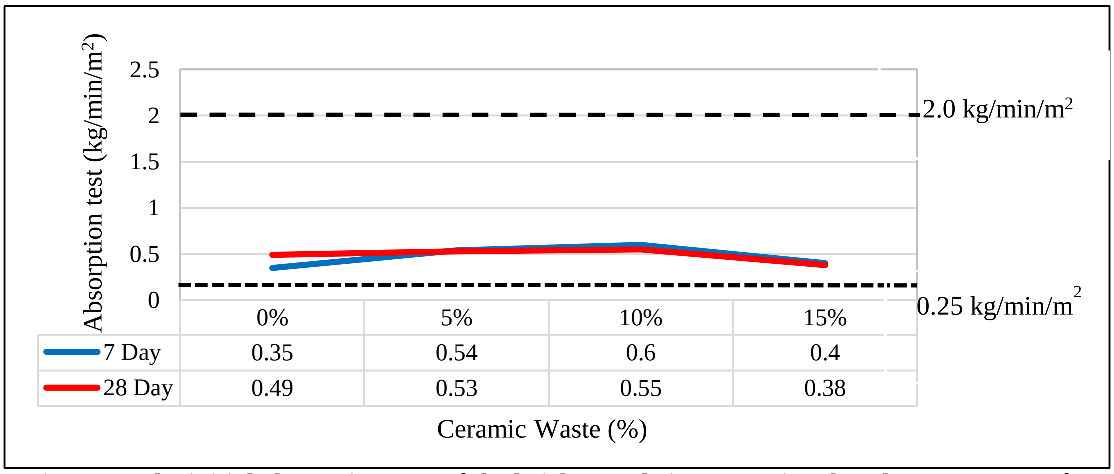


Figure 4: The initial absorption rate of the brick sample is proportional to the percentage of ceramic waste

3.3 Compression Test

Figure 5 shows the graph of the compression strength of the brick samples according to the percentage of ceramic waste. Based on the test result, there were an increment in 5% and 10% replacement. According to Sheikh Khalid *et al.* [2], it confirmed that brick with 5% and 10% replacement of the ceramic waste had good interlocking, well-graduation, and more homogeneous. The brick sample containing 5% ceramic waste increased from 8.1 N/mm^2 at 7days to 12.3 N/mm^2 at 28 days. While the brick sample containing 10% ceramic waste had recorded the highest percentage of their compressive strength for 7 days from 7.8 N/mm^2 and the number had increased to 13.2 N/mm^2 at 28 days. This had influenced the strength wherewith rough and the unequal surface had produced the high adhesion between the particle and cement matrix [2].Therefore, the compression strength values of 5% and 10% for both curing periods indicated exceeded the standard BS 5628 [9] which was 7 N/mm^2.

However, for a brick sample containing 15% ceramic waste, it showed a decreased in compressive strength for 7 days and 28 days. This was because according to [18], ceramic tile aggregate was having a rough surface on one side and smooth on another side, which was lighter in weight than normal aggregates. The surface texture of the ceramic waste aggregate was found smoother than the crushed stone aggregate [10]. That gave a decreasing result when more percentage of ceramic waste was added into the mix. Therefore, cement bricks containing 10% ceramic waste were selected as the optimum value of the ceramic waste to replace the sand in the mix.

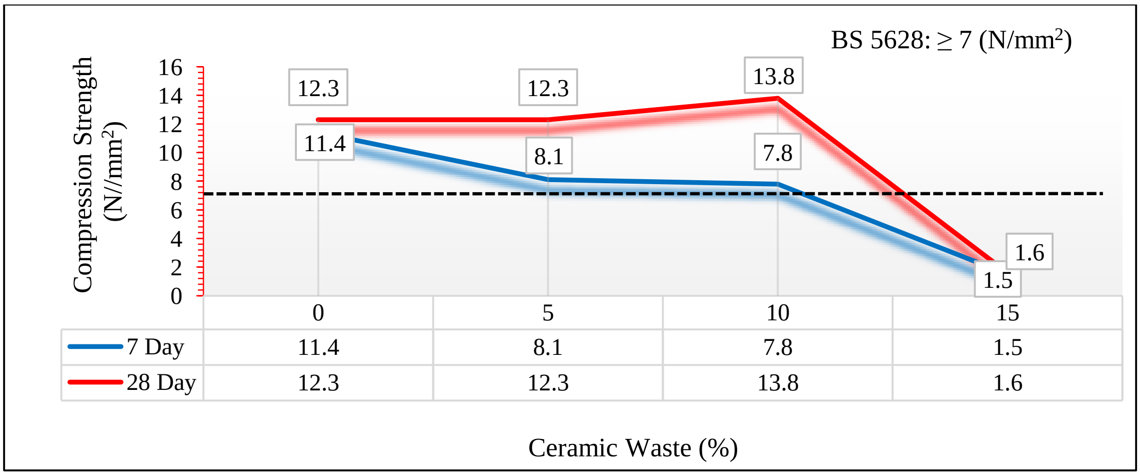


Figure 5: Compressive strength of the samples according to the percentage of ceramic waste for 7 and 28 days of curing

3.4 The Relationships between the Density, Water Absorption Rate and Compressive Strength

After analyzing all the test results from the three tests performed on the control brick sample and the brick sample containing the percentage of ceramic waste, it was found that the results were interrelated with each other according to the percentage of ceramic waste mixed in the contents of the brick sample.

3.4.1 Relationship between Compressive Strength and Density

Based on the graphs in Figures 6 and 7, it was found that the compressive strength of the brick sample was closely related to the density of the brick sample. The higher the density of a brick sample, the more the compressive strength will increase. This is due to the mixture becoming more homogeneous and having a good connection with the bonds in the mixture [3]. The opposite happened when the density of the sample brick was dropped, the compressive strength had been significantly reduced. The same observation was found by [1,2], the density and compressive strength of the brick was decreased as the percentage of the replacement increased. Therefore, the increase in the addition of ceramic waste in the cement brick mixture had affected the compressive strength and density values of the cement brick.

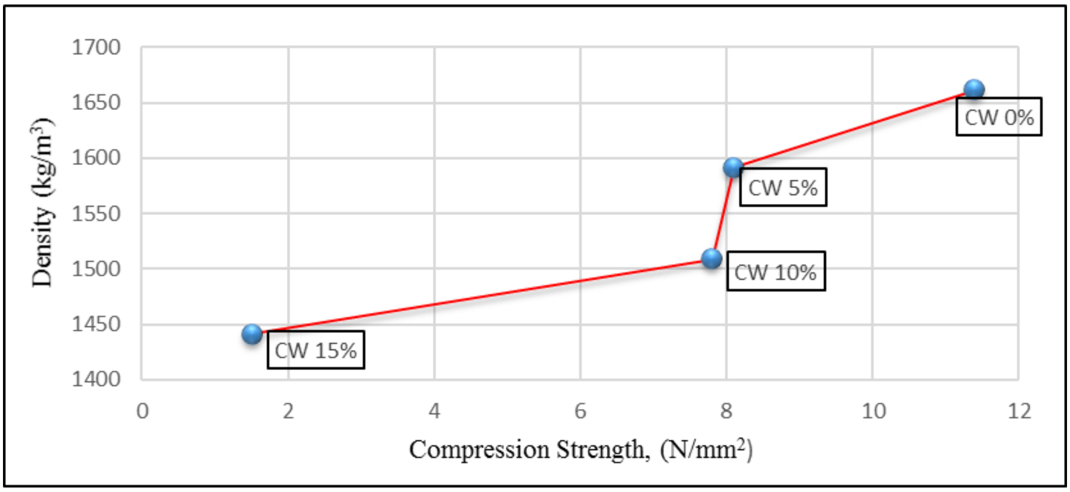


Figure 6: Relationship between compressive strength and density for 7 days

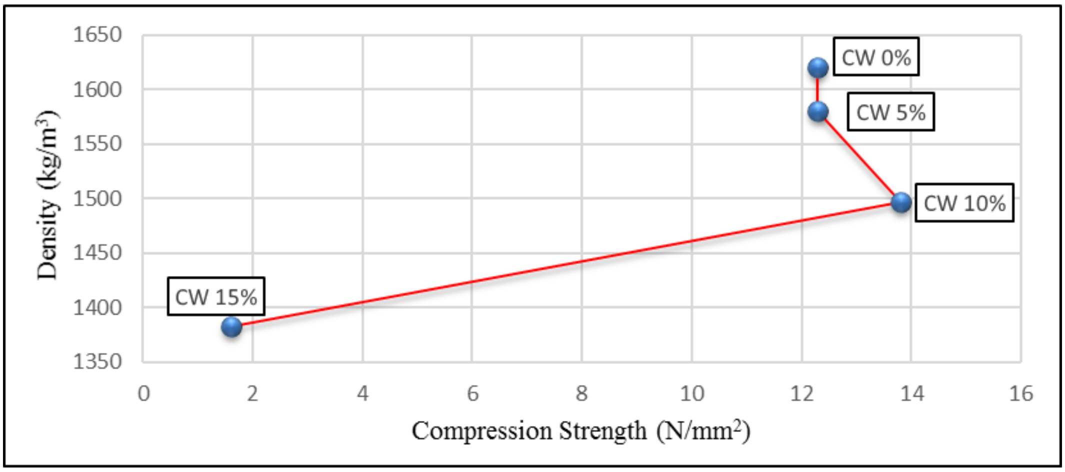


Figure 7: Relationship between compressive strength and density for 28 days

3.4.2 Relationship between Density and Water Absorption

Graphs in Figures 8 and 9 show that the density of the brick sample also affected the absorption rate of the brick sample. Brick samples containing 10% ceramic waste were high-absorption but low in density whereas control bricks had low absorption rates but high-density values for both curing periods. Based on the previous research from Sheikh Khalid *et al.* [2], the result had shown that a decreased in the density and an increased in the water absorption when there was an increased of the recycled fine aggregate content. The same observation was found by Mohd Yassin *et al.* [1], which recorded concrete containing Expanded Polystyrene (EPS) had shown lower water absorption in comparison to normal concrete. This can be concluded that the reduction of the percentage of water absorption with the increment of ceramic waste was due to the non-absorbent characteristic of the material.

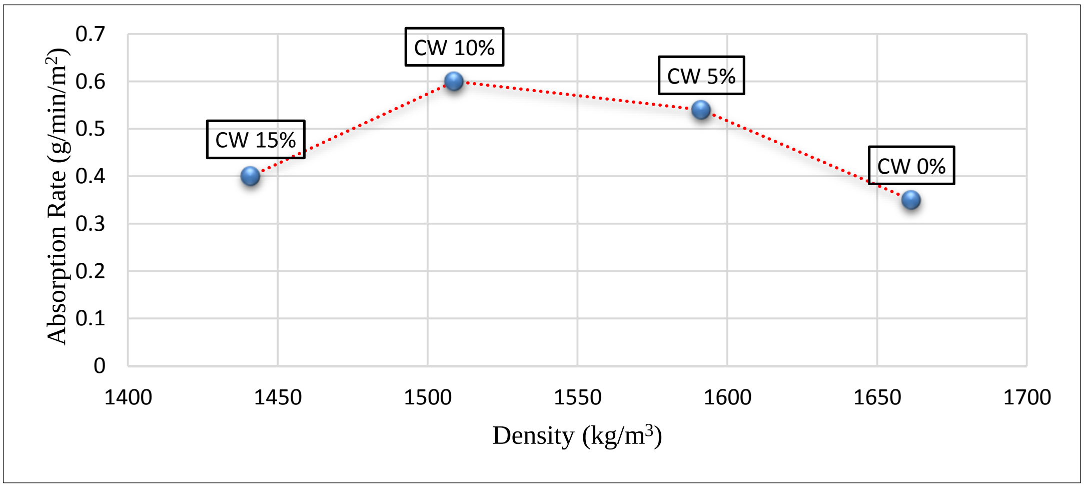


Figure 8: Relationship between the density and absorption rate for 7 days

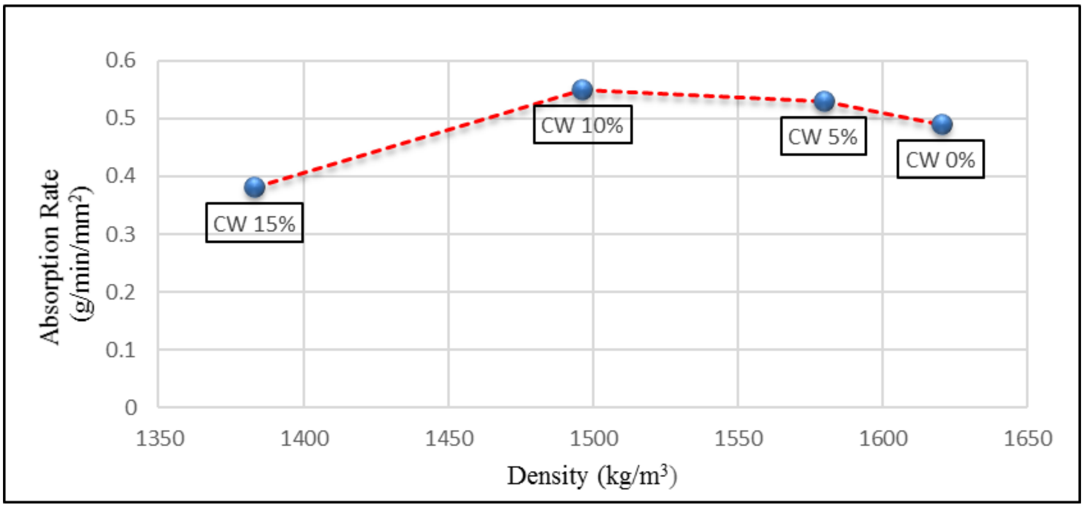


Figure 9: Relationship between the density and absorption for 28 day

3.4.3 Relationship between Compressive Strength and Water Absorption

Figures 10 and 11 show a graph of the relationship between compressive strength and absorption rate of brick samples for 7 and 28 days of curing. Through these graphs, high absorption rates of bricks have a high strength of control bricks as well as bricks samples containing 10% ceramic waste. However, 15% of ceramic waste brick samples had shown a low absorption rate and low strength. A similar finding was found by Mohd Yassin et.al [1] when the increment of EPS had reduced the brick strength and decreased the percentage of water absorption. This is believed was due to the characteristic of EPS which is non-absorbent that helps in the reduction of water absorption.

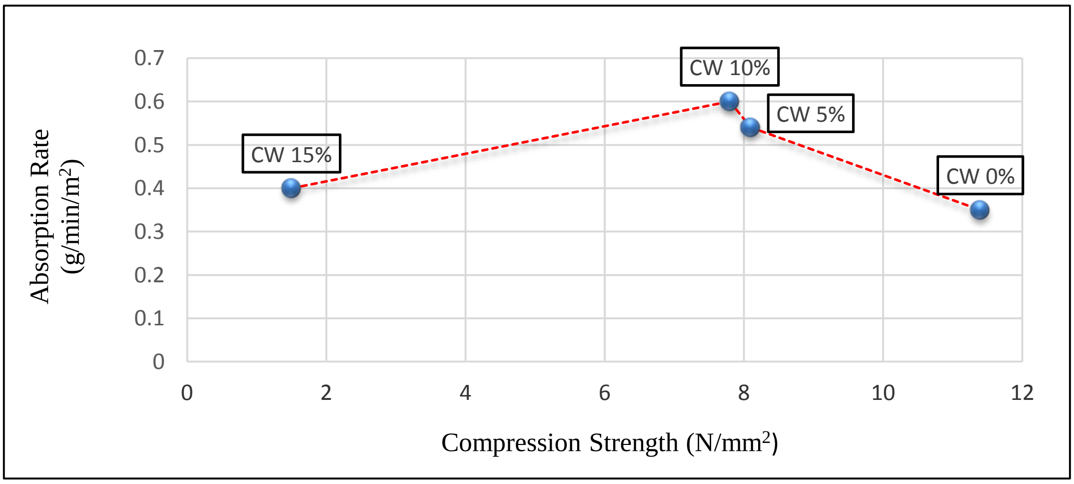


Figure 10: Relationship between compressive strength and absorption for 7 days

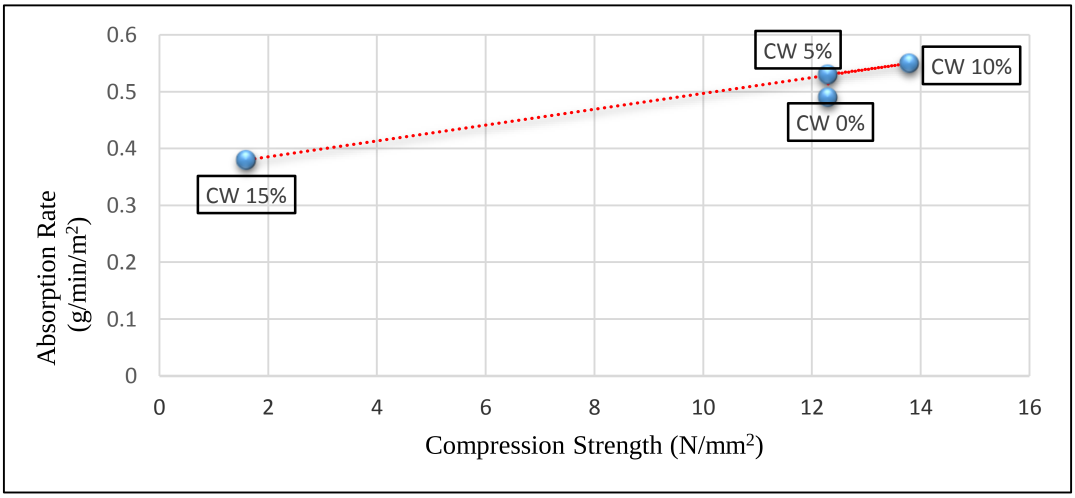


Figure 11: Relationship between compressive strength and absorption for 28 days

4.0 Conclusion

From the results of the analysis, it can be concluded that cement bricks that use ceramic waste have the potential to be one of the good building materials in the construction industry. The use of ceramic waste in cement bricks is suitable for use due to ceramic's high hardness and thermal resistance. This indicates that the higher the percentage of ceramic waste replaced, the compressive strength can also reduced due to the plasticity properties of the ceramic waste itself. Therefore, the use of ceramic waste as a substitute for sand in a mixture of cement bricks is suitable because ceramic is a non-metallic material but only limited to 10%.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for their support and assistance in making the smooth journey for this research to the end. In addition, special thanks to the Claytan Ceramic Factory in Ayer Hitam, Johor for providing the opportunity to obtain ceramic waste to make this study a success.

References

[1] N. I. Mohd Yassin, S. H. Adnan, S. Shahidan, S. S. Ayop, M. H. Osman, Z. Jamellodin, N. A. Abdul Hamid, W. A Mohamad Nor Akasyah and K. Nurul Amirah. "Strength and water absorption properties of lightweight concrete brick" in IOP Conf. Series: Materials Science and Engineering 513, 2019. 012005 IOP Publishing, doi:10.1088/1757-899X/513/1/012005.

[2] F. Sheikh Khalid, H. Shah Herman, N. B. Azmi and M.I. Juki, "Sand cement brick containing recycled concrete aggregate as fine-aggregate replacement"in ISCEE 2016 : MATEC Web of Conferences, vol. 103, 01016, 2017, doi: 10.1051/matecconf/2017103010 16.

[3] S. Ismail and Z. Yaacob, "Properties of bricks produced with recycled fine aggregate", International Journal of Civil and Environmental Engineering, vol. 4, no. 7, pp. 190-194, 2010.

[4] H. G. Shruthi, G. Prasad, M.E Samreen and S. R. Pasha, "Reuse of Ceramic Waste as Aggregate in Concrete", International Research Journal of Engineering and Technology, vol. 3, pp. 115-119, 2016.

[5] E. Carmeane, V.F. Marilena, G. Saulo & E.A. Orestes, "Microstructural Characterization of Ceramic Floor Tiles with the Incorporation of Wastes from Ceramic Tile Industries", Materials Research, vol. 13, no. 3, pp. 319-323, 2010.

[6] F. Arifin and E.S. Martomi, "Keramik (Advance Ceramics) Sebagai Material Alternatif Di Bidang Kesehatan", Jurnal Austenit, Volume 1 Nomor 1, pp : 11-17, April 2009

[7] Dietrich, Munz, Theo and Fett, "Ceramics: Mechanical Properties, Failure Behaviour, Materials Selection", Materials Science, Springer, New York, 2001. [E-book] Available: Springer-book.

[8] H. Abdul Rahman, "Penglibatan Komuniti dalam Pengurusan Sisa Pepejal di Malaysia", Malaysian Journal of Environmental Management, vol. 16, no. 1, pp 13-22, 2017.

[9] BS 5628 : Code of practise for use of masonry, Part 3: 1985 Materials and components design and workmanship, 1992.

[10] M. M. A. Abdullah, K. Hussin, C. M. Ruzaidi, S. Baharin, R. Ramly and N. K. Nisa, "Concrete Ceramic Waste Slab (CCWS)", Journal of Engineering Research & Education, vol. 3, 2006, pp 139-145, 2006.

[11] M.N. Zaini, "Laporan Tahunan 2012", Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam, 2012.

[12] A. Frasson Jr, J.M. Casali, A.L. Oliveira ,and L. R. Prudencio Jr, "A Mix Design Methodology for Concrete Block Units", 15th International Brick and Block Masonry Conference, Brazil, 2012.

[13] BS 6073 : Precast concrete masonry unit, Part 1: Specification for precast concrete masonry unit, part 1, British Standards Institution, London, UK, 1981.

[14] BS 1881. Part 116 : Methods for Determining Compressive Strengths of Concrete Cubes. British Standard Institution, 2 Park Street, London. 1983.

[15] BS 3921 : A Specilfication for Clay Bricks, 1985.

[16] N. Mohamad Ibrahim, S. Salehudin, R. Che Amat, N. L. Rahim and T. N. Tengku Izhar, “Performance of Lightweight Foamed Concrete with waste Clay Brick as Coarse Aggregate”, ICESD 2013 Procedia 5(2013) 497-501 : pp 497-501,2013,doi : 10.1016/j.apebee.2013.05.084.

[17] B. M. Febrianto, “Penelitian kuat tekan dan berat jenis mortar untuk dinding panel dengan membandingkan penggunaan pasir bangka dan pasir baturaja dengan tambahan foaming agent dan silica fume”, Jurnal Teknik Sipil dan Lingkungan, vol. 2, no. 2, 2014, pp 287-296, 2014.

[18] O.Zimbili, W. Salim and M. Ndambuki, “A Review on the Usage of Ceramic Wastes in Concrete Production”, World Academy of Science, Engineering and Technology, International Journal of Civil and Environmental Engineering, vol. 8, 2014, pp 91-95, 2014.