

Thermal Effect on Mechanical Characteristics of Drinking Water Sludge Brick Incorporated with Rice Husk Ash

(Kesan Suhu terhadap Ciri-ciri Mekanik Bata Sisa Rawatan Air Campuran Abu Sekam Padi)

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ABSTRACT

Brick is among the important construction materials and commonly manufactured from mixtures of clay or sand, lime and cement. Due to limited natural resources for raw materials and highly demand for brick in construction industry have gradually increased the market price of each unit. Therefore, alternative sources are required such utilization of drinking water sludge (DWS) and rice husk ash (RHA) are potentially used as base and/or incorporated materials for manufacturing alternative brick. In this study, the brick samples which had been developed from mixtures of DWS and RHA (D80 brick) were subjected to different firing temperatures of 300°C and 500°C. The results of this study were compared to that of unfired brick and bricks which developed from 100% DWS content (D100 brick). The result also shows the volume shrinkage significantly increased at firing temperature of 500°C and was more apparently affected the D100 brick if compared to that of D80 brick. As firing temperatures were increased, the density of both brick samples decreased with D100 brick more prominent than D80 brick. The effect of temperature on the water absorption and compressive strength clearly increased especially for the D80 bricks, respectively. The effect of temperature is closely related to the presence of rice husk ash as this organic matter destroyed at high firing temperature of 500°C. The results obtained in this study suggested that firing temperature can modify and enhance the studied mechanical characteristics.

Keywords: Brick; compressive strength; shrinkage; sludge; temperature

ABSTRAK

Bata adalah antara bahan binaan yang penting dan sering dihasilkan daripada campuran liat atau pasir, kapur dan simen. Akibat daripada terhadnya sumber semula jadi sebagai bahan mentah dan permintaan yang tinggi bagi bata di dalam industri pembinaan menyebabkan peningkatan harga pasaran setiap unit bata. Oleh itu, sumber alternatif diperlukan seperti penggunaan sisa perawatan air minuman (DWS) dan abu sekam padi (RHA) adalah berpotensi digunakan sebagai asas dan/atau bahan tambahan bagi penghasilan bata alternatif tersebut. Kajian ini menggunakan sampel bata yang dihasilkan daripada campuran DWS dan RHA (D80) telah dibakar pada suhu 300°C dan 500°C. Hasil kajian ini dibandingkan dengan bata tanpa bakar dan bata yang dihasilkan daripada 100% kandungan DWS (D100). Hasil kajian juga menunjukkan pengecutan isi padu meningkat dengan suhu bakaran 500°C dan kesannya lebih ketara terhadap bata D100 berbanding bata D80. Kesan suhu terhadap penyerap air dan kekuatan mampatan masing-masing jelas meningkat bagi bata D80. Kesan suhu sangat berkait terhadap kehadiran abu sekam padi memandangkan bahan organik ini musnah pada suhu yang tinggi 500°C. Hasil daripada kajian ini mencadangkan bahawa suhu bakaran boleh mengubah suai dan meningkatkan ciri-ciri mekanik yang dikaji.

Kata kunci: Bata; kekuatan mampatan; pengecutan; sisa; suhu

INTRODUCTION

As population has steadily increased, the need for development is paramount, new infrastructures such as residential areas, administrative offices, health centers, transportation networks and industrial estates. Subsequently, basic raw materials for construction such as sand, cement, lime and metals soar dramatically every year. In construction industry, brick can be classified is one of an important material and based on Department of Statistics Malaysia (2015), reported that the price of brick has increased to 4.3% a unit. The increasing demand for this material, the price is expected to continue higher in the future which will be imposed to the cost of particular

infrastructure development. Therefore, an alternative measure need to lessen this impact through shifting an alternative resources or efficient and more economic technologies.

Clay soil is the main natural resource that many soil brick industries are depending on and this kind of raw material is available but limited to cope with the rising demand in construction industry. Therefore, alternative resources are needed to be explored to develop sustainable brick that more economic and safer. As a result of development in technology, industrial sectors has gradually increased the quantity of multiple sources from agricultural, mining and domestic factories (Maduwar

et al. 2012). It is estimated that annually Asia generates 4.4 billion tons of solid wastes (Yoshizawa et al. 2013). A proper waste disposal is strictly imposed to evade potential environmental pollution. Incorporating these waste materials into a new product can be a solution to the environmental problem as well as to give added value for the waste as raw material for alternative products. Many attempts have been made to examine the prospective of certain wastes in making an alternative brick (Hegazy et al. 2012; Kadir & Mohajerani 2011; Yadav et al. 2014). Various kind of wastes have been embedded partially for development of brick such as fly ash (Cultrone & Sebastian 2009; Kumar & Hooda 2014; Malik & Arora 2015), rice hush ash (Hegazy et al. 2012; Hwang & Huynh 2015; Johari et al. 2011) and drinking water sludge (Fungaro & da Silva 2014; Palanisamy 2011; Rodrigues & Holanda 2013).

Drinking water sludge (DWS) and rice husk ash (RHA) are among the prospective materials for brick production. Recycling of these materials are still low, subsequently resulting in stockpiling the environments. SPAN (2014) indicated that 5500 tons of wastes were annually generated from the drinking water treatment facilities around the country. According to Breesem et al. (2014), the presence of huge stockpile of DWS was caused by the increasing demand for clean water, cost of disposal and stringent policy imposed by landfill operators. Associating this waste with recycling program if not almost, can minimize the problem of waste disposal nationwide. The occurrence of silica content in DWS and RHA known as among the pozzolanic component for cementation can be beneficially used to improve then strength properties bricks (Chindaprasirt et al. 2007; Eberemu et al. 2011; Kartini et al. 2008; Obilade 2014). Khan et al. (2015) reviewed the potential utilization of RHA as a sustainable material for construction. RHA has also been extensively studied to develop nano-crystalline for catalyst application and soil improvement (Ahmad Rusmili et al. 2012; Basha et al. 2005; Wong et al. 2018). In ceramic application, RHA can be potentially synthesized to produce nano-wollastonite which is vital raw material for ceramic making which offers good strength, low dielectric loss, good bioactivity and biocompatibility (Ismail et al. 2013). It was also reported that DWS can improve the visual appearance of brick in terms of the color and texture (Dunster et al. 2007).

In production of soil or clay brick, high temperature firing involved is between 1000°C and 1100°C to develop a good quality brick (Fernando 2017; Krishnan & Jewaratnam 2017; Tsega et al. 2017). Ordinary Portland cement (OPC) can apparently improve the strength of treated earth materials such as sandy and peat soils (Ali Rahman et al. 2016; da Fonseca et al. 2009). Previous attempt has been performed to develop brick based on DWS incorporated with RHA (0, 5, 10, 20%) without firing, however, it ended up with brick of low mechanical strength (Ali Rahman et al. 2015). It was also found that the amount of RHA corresponded to increase in compressive strength. The tests showed that

the unconfined compressive strengths (UCS) for brick with 100% DWS content (no RHA) up to 80% DWS with 20% of incorporated RHA were between 0.41 and 0.83 MN/m². These results were lower than the standard strength value that should be achieved (48.5 - 69 MN/m²; MS 76: 1972 & BS 3921: 1985). It was also reported that firing of brick at high temperature can improve its water absorption and compression strength (Hegazy et al. 2012; Ramadan et al. 2008). Krishnan et al. (2017) also found that the increase in firing temperature positively corresponded to the compressive strength with optimum DWS content of 40% in laterite-DWS mixture. Meanwhile Fugaro and Silva (2014) had examined the brick produced from a mixture of soil, cement and fly ash reported that 20% of DWS is the optimum amount with satisfactory results regarding to compressive strength and absorption of water. Therefore, the aim of this study was to examine the effect of different temperatures on mechanical characteristics of brick developed from mixture of DWS and RHA. The results were also compared between fired and unfired brick samples.

MATERIALS AND METHODS

MATERIALS USED

The base material used in this study was DWS which was collected from a raw water treatment facility. This sample was obtained at designated dumping area adjacent to treatment plant. At hand sample, DWS is semi dried with fine texture, yellowish to greyish colour and usually found in aggregated forms. Approximately 100 kg of bulk sample was collected for basic characterization of DWS and preparation of brick samples for further mechanical testing. Prior to that, DWS sample was initially dried under room temperature for several days. Then, it was manually crushing to break down the aggregates and finally sieved through 2 mm sieve. Rice husk ash (RHA) was collected from paddy processing plant (BERNAS), Tanjong Karang Selangor, Malaysia. This sample was used as an additive material in development of an alternative brick from DWS. RHA was also dried under room condition for a week and stored in airtight plastic container. The summary of the basic characteristics of the wastes used in this study is shown in Table 1. DWS is of pH6.03, classified as weak acidic whilst RHA is alkaline of pH9.11. The organic content in DWS is lower than RHA which is originated from the coagulation process of suspended solids in raw water treatment. The use of alum (aluminium hydroxide) and PAC (poly aluminium chloride) may associated with the presence of silica (SiO₂) and alumina (Al₂O₃). Trace of ferrum oxide (Fe₂O₃) found in the DWS sample responsible for the rustic discoloration (Anyokora et al. 2012). Based on the particle size analysis, silt fraction was found higher than the sand and clay contents (Figure 1(a)). Figure 1(b) shows the SEM images of the DWS sample indicating the presence of flaky shape of kaolinite minerals. Mineral quarts were also present but usually rare in occurrence. SEM image of RHA sample is shown in Figure 1(c).

TABLE 1. Physical and chemical characteristics of DWS and RHA

Parameters	DWS	RHA
pH	6.03	9.11
Organic content, %	14.56	34.31
Specific gravity, G_s	2.46	1.47
Particle size distribution, %		
Sand	5.1	-
Silt	66.7	-
Clay	28.2	-
XRD analysis	Kaolinite, Quartz	Quartz, Cristobalite
XRF analysis	SiO ₂ (43.5%) Al ₂ O ₃ (28.6%) Fe ₂ O ₃ (7.8%) K ₂ O (2.1%)	SiO ₂ (84.3%) K ₂ O (2.4%) P ₂ O ₅ (1.3%) MgO (0.6%)

not available

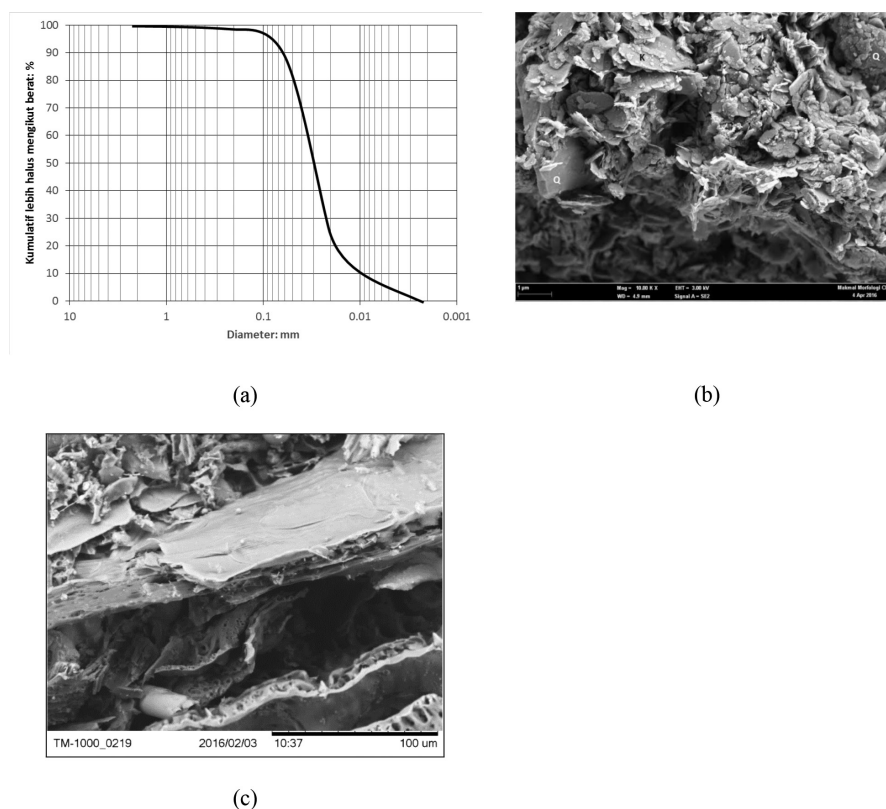


FIGURE 1. (a) Particle size distribution of DWS (b) SEM image of DWS and (c) SEM image of RHA

BRICK PREPARATION

The brick samples were developed according to the standard brick dimension of 215 mm × 102.5 mm × 65 mm (MS 76: 1972). As stated earlier, the increase in unconfined compressive strength (UCS) values was associated with the increase in the added RHA content in the brick samples, however, the UCS values still lower than that of the standard strength of conventional brick (Ali Rahman et al. 2015). Two sets of brick samples in terms of RHA content were prepared with 100% of DWS content (no RHA) and a mixture of 80% DWS and 20% RHA, labelled as D100 and

D80, respectively. In order to assess the effect of firing temperatures, the brick samples were later treated at different firing temperatures of 300°C and 500°C.

The base materials of DWS and RHA were initially mixed in dry state with mechanical mixer before distilled water was added and it was found that approximately between 950 and 1000 mL adequate to form workable mixture and the amount of water used is controlled by the amount of added RHA contents. The mixture was then thoroughly mixed again before was poured into the mould. The mould was gently vibrated to let air bubbles seep out

from the wet mixture. The mixture was then permitted to dry for 3 days before further drying off mould for another week. Later, the brick samples were carefully shifted into a furnace for firing at different high temperatures (300°C and 500°C) for 3 h. For reference, set of unfired brick samples were also prepared that involved drying process under room temperature without firing.

LEACHING TEST

Utilization of waste as base and/or incorporated materials in alternative brick manufacturing can potentially release some unwanted chemical elements of heavy metals such as arsenic, chromium, nickel and cadmium. A series of leaching tests were performed to examine the concentration levels of heavy metals from base material of WDS. For a long-term leaching characteristic, a solid sample of DWS (D100) was prepared and suspended in a tank of leachant, represented by ordinary tap water. This method was a modification of the static leachate test (ANSI/AN-16.1-2003) that generally performed for examining the mechanism of leaching from solidified waste forms (Dutre & Vandecasteele 1995; Singh et al. 2006). The leachant was not renewed with fresh solution to achieve the maximum leachate concentrations. The leachant then was collected after cumulative leach times of 24 h, 7, 14, 28, 42, 63 and 91 days. The concentrations of heavy metals in leachant samples were analyzed using Inductive Coupled Plasma Mass Spectrophotometer (ICPMS).

MECHANICAL CHARACTERISTICS

Some mechanical characteristics involved in examining the brick samples namely volume shrinkage, density, water absorption and compressive strength. Firing shrinkage was performed based on the dimension tolerance approach. This parameter aims to visualize the effect of drying or firing temperature on the change in dimension of brick which will result with the overall volume of the final product. Brick samples were allowed to cool down gradually by decreasing temperature of the furnace (Karaman et al. 2006). This would involve the measurement of the overall length, breadth and height of a row of bricks (12 pieces) and individual dimension (6 pieces) of each brick sample (BS 3921: 1985). The flat and clean surface was chosen to array the brick samples. Measurements were conducted using inextensible steel tape and vernier calliper was used for individual dimension to measurement up to two decimal places. As drying or firing of brick, the original volume, V_o will reduce due to shrinkage process. Therefore, the shrinkage volume, DV of the brick was calculated based on the different between the original volume, V_o and final volume, V_b against V_o is given by:

$$\Delta V = (V_o - V_b) / (V_o) \times 100\% \quad (1)$$

The density of the brick sample was determined in accordance to the AS/NSS 4456.8 (1997). Each sample

was labelled and the mass of dried brick, m_d was weighed prior to immersion in water for 2 h. Sample was taken out from the water tank and allowed to drain within a minute, any excess water on the surfaces was wiped out with cloth and the mass of wet brick, m_1 was weighed. Then the brick sample was transferred onto the weight scale submerged in the water, again the submerged weight, m_2 was recorded. The same procedures were repeated for all 6 brick samples. The brick density is determined based on an Archimedes principle as follows:

$$\text{Volume, } V = (m_1 - m_2) \times 1000 \quad (2)$$

$$\text{Density, } D_s = (m_d / V) \times 100 \quad (3)$$

Determination of the water absorption of brick was conducted by submerging the brick samples for 24 h (MS 76: 1972). The dried brick samples were weighed, m_d before all the bricks were immersed in the water for 24 h. Later, the brick samples were weighed again and the saturated mass of each brick, m_{sat} was recorded. The water absorption, W (%) was determined from the following equation:

$$\text{Water absorption, } W(\%) = 100 \frac{(m_{sat} - m_d)}{m_d} \quad (4)$$

The compressive strength of the brick samples was tested using the unconfined compressive strength test (UCS). The test was carried out according to the BS EN 772-1 (2011). In this study, the bed face of the brick was examined using the compressive machine model Autocon with a capacity of 5000 kN. The brick sample was placed between two pieces of wooden sheet that cut 10 mm larger than all round dimensions of the brick in order to lessen friction caused by irregularities of the brick surface. The constant rate of loading applied in this test was 15 N/mm². At higher rate of loading was permitted simply to shorten the time of testing however, as stated in BS that higher rate of loading at this stage has no influence on the ultimate strength (Arman Ali 2005). As brick sample failed, the machine would automatically stop. From the recorded maximum load, the strength was calculated by dividing the maximum load with the area of the bed face (i.e. length × breadth).

SOLUBLE SALT CONTENTS

Brick can be deteriorated as a result of salt formation which effect the durability of the studied brick. Salts either present in masonry at the time of building or are absorbed from environments during the life of building (Jordan 2001). They also naturally occur in the materials that are used in the making of the stone, brick clay or mortar sand (Young 1995). As salt solution evaporates, salt crystals develop in the pores and can generate crystallization pressure in the brick. Once the pressure exceeds the

existing tensile strength, it is sufficient to deteriorate the brick microstructure which leading to spalling and cracking (Abu Bakar et al. 2011; Hendry et al. 1981).

In this study, the preparation of sample for soluble salt content was carried out from the crushing methods (BS: 3921 1985). About 25 g of brick sample of each type of brick was initially powdered and sieved through 150 mm sieve size. The samples then were collected and dried in the oven at 110°C. The determination of soluble salt content includes water-soluble salts of calcium, magnesium, sodium and potassium and acid-soluble sulphate. The extractions of acid-soluble salts and water-soluble salts were performed in accordance with BS 3921 Appendix B.3.1 and BS 3921 Appendix B.4.1. The sulphate content was then determined by gravimetric method.

RESULTS AND DISCUSSION

LEACHING TEST

The results from the static leaching test (SLT) of the DWS sample is shown in Table 2. The concentration values of the heavy metal determined were compared with USEPA (1996) and conform with the concentration limits set by the standard. The concentration level of Al is expected high as alum and PAC were used in water treatment facility for flocculation process. It is clearly seen that the amount of Al lower than the permissible limit. Similarly, other heavy metals also comply with the standard limit while Cr value was undetected in this leaching test.

VOLUME SHRINKAGE

The measurement of the overall length, breadth and height of the brick samples that were arranged in a row and individual brick aimed to examine the change in the volume as a result of drying and firing at different set up temperatures. The change in volume (in percentage) for unfired brick, fired at 300°C and 500°C samples are shown in Figure 2. It is expected that once bricks experience drying process, their volume will reduce due to water removal through evaporation or seepage process. In terms

of change in volume among unfired (drying) and fired bricks at 300°C and 500°C, it was clearly shown that D100 exhibited lesser value if compared to that of D80 sample. As the RHA content was increased in brick sample, the firing at high temperature has caused burnt out of organic content as in RHA contains higher organic matter than DWS (Table 1). However, the change in volume was not significantly displayed between unfired brick and fired brick at 300°C. The change in volume was apparently seen for fired bricks at 500°C which associated with volume reduction. At this firing temperature, most of the organic matter in both types of bricks (D100 and D80) might be destroyed causing apparent shrinkage to final volume. At this high temperature level, the present organic matter in both DWS and RHA mostly if not all, partly burnt out causing a further shrinkage of the brick samples (Figure 2). These results were also an agreement with Weng et al. (2003), mentioning that the firing shrinkages of the brick samples as the functions of temperature and the different in the RHA contents.

DENSITY

The effect of different temperature treatments on the density is shown in Figure 3. The influence of the RHA content on the density of the brick samples clearly seen between unfired and fired brick samples. For D100 brick

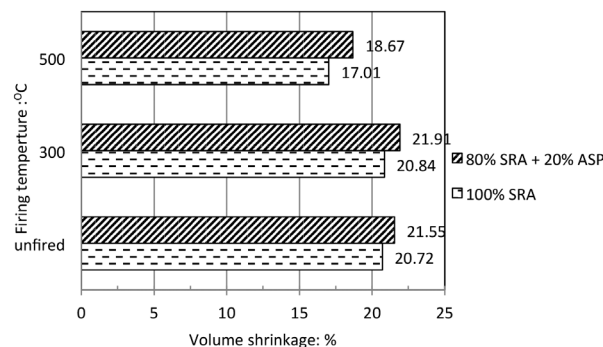


FIGURE 2. Volume change for unfired brick and bricks treated at different temperatures

TABLE 2. The concentration levels of heavy metal in DWS sample

Heavy metals	Concentration limit* mg/L	Concentration mg/L
Al	0.05-0.2	0.037
As	5	0.012
Cr	1	n.d
Cd	5	0.003
Cu	100	0.091
Pb	5	0.052
Ni	1.34	0.022
Zn	500	0.059
Fe	0.3	0.267

* United States Environmental Protection Agency (USEPA) 1996
n.d - not detected

samples (100% DWS brick), the density values higher than the D80 brick samples (20% of added RHA). For unfired brick samples, the density value for D100 brick was 2.57 g/cm³ higher than the D80 brick (2.05 g/cm³). Meanwhile for fired brick samples, the effect of firing temperature significantly decreased the density of the brick samples. As temperatures of firing were set up at 300°C and 500°C, the density values of D100 brick dropped to 2.14 g/cm³ and 1.45 g/cm³ (Figure 3). The changes in density reductions for the fired D100 bricks at 300°C and 500°C of firing temperatures equivalent to 16.7% and 43.6%, respectively. For D80 brick samples, the reduction in density can be seen slightly smaller than D100 brick sample. The changes in density reductions for brick fired at 300°C and 500°C equivalent to 3.4% and 17.1%, respectively. The effect of high temperature can be related to the presence of organic content in the brick samples. As temperature was up to 500°C, most of the organic components in DWS and RHA would burn out which end up of more pores created inside the fired bricks. The pores left by diminished organic matter attribute to the formation of brick with loose state. Chiang et al. (2009) and Tonayopas et al. (2008) also concluded that the addition of RHA which presence as organic matter can easily diminish during application higher temperature firing. Previous studies exhibited a similar result that the presence of RHA has contributed to overall decrease of density due to low specific gravity, G_s of RHA (Ali Rahman et al. 2015; Demir 2008). It also noted that the organic content was also high in DWS and RHA (Table 1). The presence of RHA can be substituted material for sand to achieve a lightweight brick production as the density decrease by increasing in the amount of RHA contents (Saleh et al. 2011).

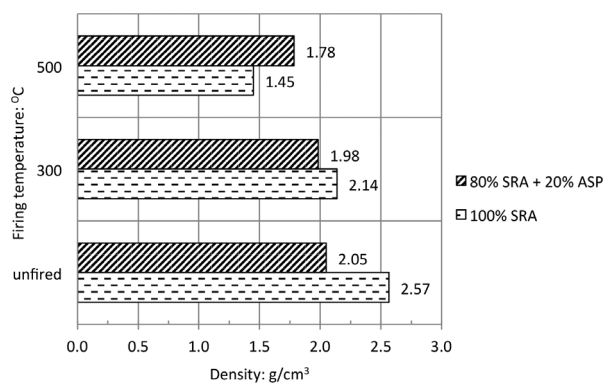


FIGURE 3. Density of the unfired and fired brick samples at different temperatures

WATER ABSORPTION

The effect of different temperature treatments on the water absorption is shown in Figure 4. The D100 brick sample displayed significantly higher water absorption compared to that of D80 brick sample. For unfired bricks, the water absorption value for D100 brick was 31.5% which was lower than D80 brick sample (50%). While for

fired brick samples, the water absorption value for D100 brick fired at 300°C and 500°C increased to 37.4% and 39.4%, respectively. For D80 brick samples, the values of water absorption also increased to 59.4% and 63.0%, respectively. These values are higher than that of brick samples from D100. The presence of organic matter in RHA is higher than DWS and both are considered high in organic content (Table 1). Therefore, at a higher firing temperature of 500°C, the organic matter in combined mixtures of DWS and RHA in D80 brick will burn out which end up with more micro pores left within the bricks if compared to that of D100 brick samples. Therefore, more RHA content in brick will create more pores that contribute to higher value of the water absorption rate. Similar conclusion was also made by Hegazy et al. (2012) showed that the increase in the amount of RHA content caused the increase in water absorption for a particular firing temperature.

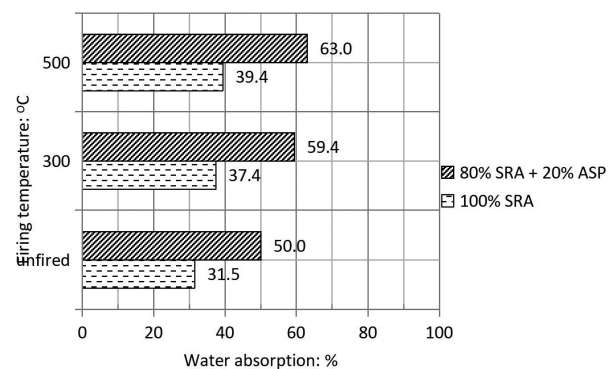


FIGURE 4. Water absorption of the unfired and fired brick samples at different temperatures

COMPRESSIVE STRENGTH

The mechanical characteristics of compressive strength from the D100 brick and D80 brick samples are shown in Figure 5. Both type of brick samples, the effect of temperature clearly increased the compressive strength. For D100 brick samples, the unfired brick exhibited lower compressive strength value compared to that of fired bricks at temperatures of 300°C and 500°C. The increase in compressive strength from unfired to fired bricks at 300°C and 500°C equivalent 10% and 32%, respectively. However, the increase in the mechanical strength was slightly small compared to that of D80 bricks. The compressive strength increased from 0.41 MN/m² (unfired) to 0.58 MN/m² and 0.83 MN/m² for fired bricks at 300°C and 500°C, respectively. The increase in compressive strength from unfired to fired bricks at temperature of 500°C equivalent to 102% which was triple if compared to that of D100 brick. The burning out of RHA at this temperature has attributed to development of silicon dioxide (SiO₂) which a vital component in extent the strength of the brick (Sutas et al. 2012). This is an agreement with the higher content of SiO₂ in RHA than WTS (Table 1). These clearly indicated the couple effects of RHA content and temperature have

significantly contributed to improvement of mechanical strength of brick developed from drinking water sludge. Chiang et al. (2009) found that the presence of rice husk of more than 15% fired at high temperature between 1050°C and 1100°C formed brick with larger open pores which reduced bulk density and strength. Hegazy et al. (2012) also found that effect of temperature and RHA contents on strength improvement but as RHA content up to more than 25%, the compressive strength decreased below the control brick from water treatment residue (WTS). In clay brick incorporated with RHA, the optimum content of RHA was 2% which resulted with the maximum value of compressive strength (Sutas et al. 2012). In another studied by Mohan et al. (2012), 30% of RHA to clay was good proportion to achieve high compressive strength. Therefore, the amount of RHA addition should be properly selected otherwise the strength of brick continue to decrease as it passes the optimum content.

SOLUBLE SALT CONTENT

Soluble salt can originate from raw materials used to manufacture brick. Salt crystallization within brick can internally disintegrate brick microstructures. The results of soluble contents in the brick samples are shown in Table 3. According to maximum limit of the salt contents as given by BS 3921: 1985, the content of the soluble salt in the brick samples can be classified as low salt content. Therefore, the recycling of the drinking water sludge can

be potentially used for raw material for alternative brick since the amounts of soluble salt contents are within permissible standard.

CONCLUSION

The effects of temperature on the mechanical characteristics of brick developed from combined mixtures of wastes was investigated in this study. Based on the experimental results, the following conclusions are drawn: Leaching test on drinking water sludge (DWS) has not been found to associated with leach out of heavy metals and comply with the standard concentration limit. The soluble salt contents in different brick samples were low in comparisons with the maximum limit classified in BS 3921: 1985. The applied firing temperature has a significant effect on the mechanical characteristics especially for bricks which were developed from the combined mixtures of DWS and RHA (D80 bricks). At high firing temperature of 500°C has responsible in burning out of the organic contents in both types of bricks (D100 and D80) which can be reflected by the studied mechanical properties. This can be related to the addition of RHA in development of the studied brick. The improvement of compressive strength of brick significantly improved for brick D80 if compared to that of D100 brick as firing temperatures were increased up to 500°C. It concluded that firing temperature has significantly contributed to the strength of the studied brick.

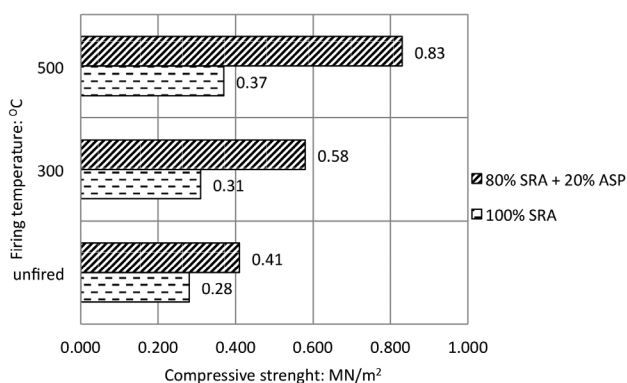


FIGURE 5. Compressive strength of the unfired and fired brick samples at different temperatures

TABLE 3. Percentage of soluble salts in brick samples

Salts	*Percent. limit, %	D100			D80		
		40°C	300°C	500°C	40°C	300°C	500°C
Ca	0.3	0.01	0.01	-	0.01	0.01	0.08
Na	0.03	0.05	0.03	0.03	0.04	0.03	0.03
K	0.03	0.04	0.03	0.03	0.05	0.03	0.03
Mg	0.03	0.03	0.03	0.04	0.02	0.03	0.03
SO ₄	0.5	0.08	0.07	0.05	0.05	0.03	0.02

* BS 3921: 1985

- Not detected

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Kebangsaan Malaysia for the financial assistance in supporting this research project under grant code ETP-2015-003. Special thank is also due to the laboratory staffs at the School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, UKM for the sample preparation and testing facilities.

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Received: 21 March 2019

Accepted: 15 August 2019