Research Communication in Engineering Science & Technology

Journal homepage: <http://www.asianscientificresearch.com/journals/RCEST>

Potential Recovery of a Textile Wastewater Treatment Plant Sludge into Clay Bricks

Jegalakshmi Jewaratnam ^{1*}, Nurul Fatin Nabilah Abdul Samat ¹

¹ Department of Chemical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Received:
13 February 2020

Received in revised form:
14 February 2020

Available Online:
15 March 2020

Keywords:
Textile Sludge
Clay Bricks
Wastewater Treatment
Compressive Strength
Cement Bricks

ABSTRACT

As the country started to become an export-oriented country since the early 1970s, the growth of Malaysia's textile industry has increased greatly. In 2011 alone, the country has provided a total of RM10.8 billion of exports of textile products and RM6.6 billion of imports. This valuable improvement has led to several environmental impacts involving land and water pollution. The current trend in waste management is to examine the feasibility of using textile sludge generated in wastewater treatment plants of textile industry as a partial replacement for clay as building materials. The chemical and physical properties of clay and textile have been analysed. The effects of sludge proportion (0%-10%) and firing temperature (950°C and 1180°C) on the quality of the clay bricks were examined. The tests were conducted as per British Standard (BS) codes to investigate the potential of the textile sludge to be incorporate into clay for use as engineering blocks and load bearing bricks. According to the results, sludge addition and firing temperature are the important factors to determine the quality of clay bricks. All clay samples satisfied the requirement of British Standard norms in term of compressive strength and water absorption. It is seen that all bulk density of clay samples did not comply with the good quality of clay brick, but they can be categorized as lightweight building materials. Textile sludge was also tested for substitution into cement bricks. Cement samples with 10% textile sludge substitution comply with the requirement of British Standard norm for load bearing class 3. In summary, this study provides a preliminary research output that will contribute to expanding a new area of research in the recycling of textile sludge.

Corresponding author at Department of Chemical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.

Email addresses: jegalaxmi24@um.edu.my

Asian Scientific Research™ by Galaxy Tech Solutions. 2018. All rights reserved.

Abbreviations

BS	British Standard
OPC	Ordinary Portland Cement
TCLP	Toxicity Characteristic Leaching Procedure
TG-DTA	Thermogravimetry-Differential Thermal Analysis
XRD	X-ray Diffraction
XRF	X-Ray Fluorescence

1. Introduction

The textile industry involves a complex activity, from processing materials to finishing the fabrics. This is due to the modern living style and fashion. To fulfil all the customers' demand, these industries have created millions of job opportunities and have become one of the major incomes to many countries all over the world (Liew et al., 2004). Unfortunately, the expanding of textile industries gives negative impact to the environment. In Malaysia, an act has been established to encourage investments in textile industries under the Promotion of Investment Act, 1986 (MIDA, 2012). This industry has become one of the major contributors to water pollution. For instance, Malaysia textile industry generated about 80 to 217 m³ per ton of product wastewater from dyeing and finishing operations (Ahmed et al., 2007).

Generally, textile industry uses high concentration chemicals and dyes in order to get satisfied characteristics like brightness, softening and colour to textiles. By this method, this industry generates a large amount of hazardous wastewaters that contain sand, grit, heavy metals, volatile organic compounds and emulsified oil (Barredo-Damas et al., 2010). In common textile wastewater treatment plants, effluents from various textile units are collected and homogenized. Coagulants are added to agglomerate the particles agglomerated from a micro emulsion. Then these particles flocculated together into larger particles. The flocculants are added to destabilize particle and remove dyes. After all these processes, the sludge thus formed and undergoes the biological treatment (Herek et al., 2012). Next stage, the sludge which generated from primary and secondary clarifiers is collected to be dried in sludge drying beds (Jahagirdar et al., 2013).

Most of the industry uses chemicals and coagulants to treat the effluents. A huge quantity of a hazardous textile chemical sludge is generated after physic-chemical treatment in most common effluents treatment plants treating textile wastewater (Shathika Sulthana Begum et al., 2013). The toxic metals and inorganic salts in the sludge will expose the residents a threat. In recent years, demand for alternative ways to dispose the textile waste in a good method is getting higher because nowadays people in the world have been exposed to concern about the environment (Algin & Turgut, 2008). This situation is due to worldwide regulations about land filling of wastes are becoming more restrictive (Reis, 2009). Many textile industries faced problem to dispose

those textile waste without include more money (Monteiro, S.N. et al., 2006).

For the past 15 years, researchers have conducted researches in recovery sludge. There is an innovative and creative trend in recovery textile industry sludge. In 2013, Shathika Sulthana Begum et al. investigated that the bricks with sludge up to 15% satisfied the prescribed norms while Jahagirdar et al. replaced 35% of clay using textile mill sludge in burnt clay brick. In 2012, Herek et al. solidified chemical sludge generated and made cement blocks. Jeihanipour & Taherzadeh used this sludge as a source for the ethanol production in 2008. Moreover, Rosa et al. (2007) used this textile sludge as a fertiliser in soil since because of high nutrient content. In 2004, Williams & Reed modified natural fibre textile waste into high grade activated carbon matting. C.-H. Weng et al. (2003) used up to 20% sludge added to the brick materials. Balasubramanian et al. (2006) employed 10% textile sludge into clay matrix.

Textile sludge recycling into building material is the best alternative rather than land disposal in the contact of economic and environmental perspective. Due to ascending population which causing a critical shortage of materials of building, the building material industry becomes large demand industry (Ahmadi & Al-Khaja, 2001). Nowadays, the increasing popularity for using low-cost, environmentally friendly and materials of lightweight construction in the industry of building has been exposed to the world. These characteristics must be fulfilling in order to gain more profit and clean environment (Jayasinghe et al., 2010).

Generally, there are 2 types of brick commonly used as building materials which are concrete brick and clay brick. Both types of bricks have advantages and disadvantages. Clay brick are 3 times stronger than concrete brick. The average compressive strength of clay brick within range from 55 to 68 MPa while for concrete brick within range from 20 to 27 MPa. In term of water absorption at the same duration of time, clay brick absorbs 2 to 3 times less moisture than concrete brick. Movement joints are important for those materials of building move with changing weather condition. Clay brick homes do not require any use of movement joints while concrete brick homes may require reinforcing steel of joint to reduce cracking when shrinkage take place. Therefore, clay brick is chosen to be incorporating with textile sludge for this research (Monteiro & Vieira, 2014).

The recovery of the textile sludge as materials of building converts it into useful products and problems to disposal can be eliminated. The conservation of natural resources like clay can be applied (Shathika Sulthana Begum et al., 2013). Besides, the use of textile sludge as an additive to clay brick can immobilize heavy metals in the matrix during firing process, destroy any pathogens, oxidize organic matter and reduce the damage of frost (Baskar et al., 2006). Manufacturing of brick mixture of textile sludge with clay can be considered as environmentally feasible since open dumping and land filing are found to have some negative impacts to environment like loss of soil fertility and high cost of disposal (Kantarli & Yanik, 2010). This is also economically feasible because instead of the manufacturers use the money for textile waste disposal, they can increase the

company's profit by producing clay bricks from these wastes.

The aim of this study is to investigate the feasibility of the textile industry waste into building materials. This an experimental study to determine the effect of percentage addition textile sludge with clay brick on water absorption and strength of compression. Characteristic studies of the sludge have been carried out. Compressive strength, density, water absorption, and linear shrinkage of clay bricks have been analysed for the textile sludge replaced clay bricks.

2. Methodology

2.1 Raw Material

The clay is the main materials used in this study and the sample shown in Figure 1 (a) was purchased from local brick manufacturer. The sample was purchased in bulk and the samples were in brownish white in colour. The samples were tightly wrapped and stored at room temperature before testing in the laboratory. Textile sludge shown in Figure 1(b) is a waste product from textile manufacturing in local textile factory.

(a)

(b)

Figure 1: Physical structure sample of (a) clay (b) textile sludge

2.2 Raw Material Preparation

The samples of sludge and clay are dried at a temperature of 105°C for 2 hours. As per standard BS3921:1985, drying process takes 24 hours but as the samples are dried for 24 hours, the samples came in very dry form. The purpose of drying is only to remove the moistures inside samples. Since it was in dry form, the drying process is conducted for 2 hours. 2 hours drying is deemed sufficient. The dried samples are then crushed to reduce the large size and narrow the distribution of various sizes which from small to big chunk

(Balasubramanian et al., 2006). Then, directly used as clay substitute.

2.3 Characteristics of Sludge Clay and OPC

The sludge and clay samples are used in the dry form for chemical analysis. X-Ray Fluorescence (XRF) investigation of the presence of major and minor metals in the form of oxide in textile sludge and pure clay samples are conducted in a PW 1480 Philips x-ray fluorescence spectrometer operated at 40Kv and 60Ma and crystal PE-C LiF220 is used. The results are in dry weight percent. The fundamental principles of the XRF method are interactions between x-rays and electron beams with samples which includes wavelength dispersive spectroscopy, X-ray diffraction (XRD) and X-ray spectroscopy (Bennet & Graham, 1992). Laboratory investigations were performed on raw material samples at the Geology Laboratory of Science Faculty in University Malaya. The chemical composition of Ordinary Portland Cement (OPC) used in this research is based on average of several journals that used OPC from Malaysia (Deboucha & Hashim, 2011; Kartini et al., 2010). The results for chemical composition of clay, textile sludge and OPC are shown in Table 1.

Table 1: Physico-chemical properties of clay and textile sludge.

Properties	Value (w%)		
	Clay	Textile Sludge	OPC
Colour	Brown	Black	Grey
Appearance	Big chunk of solid	Hard solid	Fine particle
Na ₂ O	0.077	11.244	-
MgO	1.477	1.296	0.890
Al ₂ O ₃	21.829	4.531	6.280
SiO ₂	66.601	29.075	21.60
P ₂ O ₅	0.201	8.408	0.090
SO ₃	0.15	29.241	0.020
K ₂ O	2.462	3.887	0.720
CaO	0.379	2.558	66.230
TiO ₂	0.789	3.573	0.220
Cr ₂ O ₃	0.033	0.146	-
Fe ₂ O ₃	5.78	3.275	3.700
NiO	0.036	0.066	-
ZnO	0.019	0.09	-
SrO	0.006	0.014	-
SeO ₂	-	0.011	-
CuO	-	0.439	-
PbO	0.01	0.018	-
BaO	0.023	0.042	-
F	-	0.271	-
Cl	0.029	1.193	-
Br	-	0.583	-
MnO	0.042	-	0.080
YrO ₃	0.007	0.013	-
ZrO ₂	0.0042	-	-

2.4 Formation of Brick Clay Specimen

The dried textile sludge is mixed with clay and homogeneous mixtures of textile sludge and clay at different proportions are made. 5 different mixtures of textile sludge; 0%, 5%, 10%, 15% and 20% are used to mix with clay. The various mix ratios of clay and textile sludge used in the study is shown in Table 2. The samples are made with adequate amount of water and then moulded at 10cm x 10cm x 1.5cm. A constant pressure is applied to the mixtures during the moulding process. This is to avoid uneven structure and cracking (Shathika Sulthana Begum et al., 2013). For this study, control bricks using pure clay is prepared and kept as a reference. After that, the samples are dried in the oven for 24 hours at 105°C and then fired at 950°C in the chamber furnace. At firing temperature 950°C, sample A, B and C are well formed but sample D and E are brittle and cracked. This is due to the particles of clay and textile sludge not fused together to form a well shaped clay mixture sample.

Thus, another firing temperature at 1180°C is introduced to sample C. For further experiment, 10% sludge proportion is incorporated into cement in order to determine the compressive strength and also percentage of water absorption. In preparing mixtures of cement and textile sludge, each composition of the cement, sand and textile sludge are mixed in the mixer according to the volume ratio for three minutes. Specified amount of water was added to obtain homogeneous mixtures for 1 minute. Then, cement pastes are formed and 50mm x 50mm x 50mm of 12 cubes mould are prepared. The cement pastes are placed into the 1/3 mould from the total height of the mould and vibrated by the mechanical vibrator. This step is repeated two times until the mould is completely filled with the cement pastes. All block samples are allowed to dry for 24 hours in the dry room and cured with water for 21 days.

Table 2: Clay sludge mixture

Clay (wt %)	Sludge (%)	Sample
100	0	A
95	5	B
90	10	C
85	15	D
80	20	E

2.5 Testing of Bricks Specimens

The clay samples are examined for compressive strength, water absorption, linear shrinkage and density. The tests are carried out at Pilot Plant Workshop of Chemical Engineering Department in University of Malaya.

2.5.1 Compressive strength

A compression testing machine in Civil Department of Faculty of Engineering is used to test the compressive strength of the clay samples. This test is carried out based on standard general brick specification BS 3921:1885.

2.5.2 Water absorption

The samples are soaked for twenty four hours and the difference in weight is measured. This test is carried out based on standard general brick specification BS 3921:1885. For each tile, the water absorption, W_a ,

expressed as a dry mass's percentage, is calculated by the following equation:

$$W_a = (m_2 - m_1) / m_1 \times 100 \quad (1)$$

where

m_1 is the mass of the dry tile

m_2 is the mass of the wet tile

W_a represent water penetration into the easily fill able pores.

2.5.3 Linear shrinkage

Linear shrinkage determines the initial size of the mould required, in order to produce the desired finish product with the right dimensions. The dimensions of the tiles were measured before and after firing process. For each tile, the shrinkage, S_c , expressed as a percentage of the before firing, is calculated using the equation below:

$$S_c = (l_2 - l_1) / l_1 \times 100 \quad (2)$$

where

l_1 is the dimension before firing

l_2 is the dimension after firing

S_c represents the shrinkage value expressed as percentage.

2.5.4 Density

Densities of the fired samples are calculated using the conventional equation as shown below:

$$\rho = M / V \quad (3)$$

where,

ρ is density in kg/m^3

M is mass in kg

V is volume in m^3

The samples are weighed in a digital balance to obtain their mass. Then, the width, length and thickness of each sample are obtained to calculate the volume.

3. Results and Discussion

3.1 Characteristics of sludge, clay and OPC

According to XRF Analysis data shown in Table 1, clay sample contains high amount of SiO_2 which is 66.6%. In order to manufacture good quality brick, SiO_2 content needed must be more than 50 to 60%. The content of AlO_3 is significant which means clay has potential to be used as building material (Jahagirdar et al., 2013). The clay sample contains traces of Cl, NiO, Cr_2O_3 , Na_2O , BaO, ZrO_3 , SrO, ZnO, PbO, SO_3 and significant quantities that are Fe_2O_3 and K_2O .

Textile sludge sample contains significant amount of SiO_3 which indicates this sludge is a good binding property if it is incorporated in building material. The significant content of SO_3 represents the oxide composition in it. Traced quantities of Ni, S, Ba, Br, Zr, Pb and Zn are derived from process of dyeing take part in the textile industry (Herek et al., 2012).

According to literature review, the ratio of CaO and SiO_2 should not be less than 2 in the cement ingredients. CaO, as well as SiO_2 , acts as the major component which makes the cement sound and gives

strength. The small amount of Al_2O_3 provide quick level quality of cement while Fe_2O_3 and MgO give colour and hardness to cement (Lakshmi et al., 2008).

3.2 Firing temperature

The clays are made up of silica and alumina. The silica in the clays will turn to a glassy phase once fired at 900°C to 1200°C . The temperature plays an important role. The bonding between the clay and sludge particles will be poor if under fired and if the firing temperature is too high, the clay brick samples will melt. The vitrification does not have to be a complete process, but it does occur enough to give sufficient strength to the clay brick (Campbell & Pryce, 2003).

3.2.1 Heating and cooling curve at 950°C

Figure 2 shows the heating and cooling curve at 950°C . This temperature is used according to the minimum firing temperature of the most journals in production of sludge incorporate with clay.

The firing is divided into 4 stages. The first stage is final drying, which takes place at temperature up to 200°C , followed by dehydration from about 200°C to 550°C , oxidation from 550°C to 750°C and vitrification from 750°C to 950°C . For each stage, it takes 60 minutes to increase the temperature. The vitrification process allows brick clay samples to become hard and solid mass. The cooling process begins after the temperature has peaked and soaked for 20 minutes. This is the critical stage since the rate of cooling has a direct effect on structure and colour of the clay brick (Campbell & Pryce, 2003).

Figure 2: Heating and cooling curve at 950°C

3.2.2 Heating and cooling curve at 1180°C

Figure 3 shows the heating and cooling curve at 1180°C . The textile clay samples will soften gradually and eventually melts, as it is subjected to the rising temperature. Melting process takes place in three stages. First stage, which is just below the maximum firing temperature, is where the particles of clay and textile become sufficiently soft to fuse together in a mass. This phenomenon is called as incipient fusion. Then, the vitrification process takes place. Here, the mass becomes tight, solid and extensive fluxing occurs. Last stage is

viscous fusion when the mixture of textile and clay mass breaks down then molten. This leads to a deformation of shape. The key to the process of firing is to maintain and control the temperature in the furnace to ensure the occurrence of incipient fusion and partial vitrification and viscous fusion is prevented.

Figure 3: Heating and cooling curve at 1180°C

Structure of samples

The structure of clay brick samples according to the proportion of textile added which are 0%, 5%, 10%, 15% and 20%. From the observation, it is found that the structure of these clay samples can be explained into 3 aspects; structure, ease of handling and the fusion between clay and textile sludge particles.

(a)

(b)

Figure 4: Structure of (a) 0%, (b) 5% and 10% mixture textile clay brick samples

At firing temperature 950°C , structure of sample A (see Figure 4(a)) was still in shape and the clay particles

of sample A are fused together. It was very easy to handle since there was no textile sludge incorporated into it. For sample B (see Figure 4(b)), the structure was still in shaped. The surface structure of sample B was rough due to the bonding between the clay and textile particles were not sufficient fused together in mass. Thus, ease of handling this sample is moderate. Next, for sample C (see Figure 4(b)), the structure also was still in shaped, but the surface structure was rougher than sample B. This indicates that the bonding between the clay and textile particles were highly not sufficiently fused together. The ease of handling is low.

The structure of sample D and E (see Figure 5) were brittle and cracked. There was a weak bonding between clay and textile particles in sample D because the sample still in shape even though had cracked around the sample but it was brittle and easily broken even handled gently. While for sample E, the structure was totally cracked. This was viscous fusion as the clay and textile mixture mass broken down and became molten. According to these observations, sample C were further subjected to higher firing temperature at 1180°C. This is because structure sample C just undergo process oxidation and required higher temperature to reach vitrification stage at which the bonding between clay and textile sludge particles became tight (Campbell & Pryce, 2003).

Figure 5: Structure of (a) 0%, (b) 5% and 10% mixture textile clay brick samples

At firing temperature 1180°C, it is found that the structure of sample C was well form, solid and the mass is fused together than sample C at firing temperature at 950°C. The sample C at this firing temperature was very easy to handle. This show that at higher firing temperature, the clay and textile particles were fused together so the solid and rigid mass was formed. The comparison structure of sample C at different temperature was presented in Figure 6.

Figure 6: Structure of 10% mixture textile clay samples subjected to firing temperature (a) 1180°C and (b) 950°C

3.3 Compressive Strength

In The strength of clay bricks is greatly depending on the proportion of the textile sludge and firing temperature. The variation in compressive strength of the clay and textile mixture brick samples is shown in Table 3.

Table 3: Compressive test

Firing Temperature (°C)	% Sludge composition	Compressive strength (N/mm ²)
950	0	52.77
	5	43.11
	10	36.18
1180	10	50.51

Table 4: General Brick Specification as per MS 7.6:1972/BS 3921:1985

Designation	Class	Average Compressive strength (N/mm ²)
Engineering Brick	A	69.0
	B	48.5
Load bearing Brick	15	103.5
	10	69.0
	7	48.5
	5	34.5
	3	27.5
	2	14.0
	1	5.0

The test results showed that the strength of clay samples decrease as the amount of sludge addition increase but it increases with the increase of the firing temperature. As the weight of sludge addition increase and

firing temperature decrease, the strength of clay sample is lesser due to large number of voids are created in the structure of clay sample and become porous clay structure (Jahagirdar et al., 2013). Sample A and sample C (1180°C) has compressive strength above 48.5 N/mm² can be categorized as engineering brick class B (see Table 4). For sample B and sample C (950°C) has a compressive strength that acceptable in load bearing brick class 5 requirement from BS 3921(see Table 4). The compressive strength for 10% sludge proportion incorporated into cement is 27.53 N/mm² at 21 of curing day. According to Table 4, this cement sample can be categorized as load bearing class 3. The compressive strength of cement sample increase as the cement content increase and period of curing (Meukam, 2004). Based on Ling & Teo (2012), the maximum curing period was 28 days and the highest compressive strength for the cement sample was obtained. So, it is highly recommended to cure this cement sample at 28 days to obtain the maximum compressive strength.

3.4 Water Absorption

One of the important factors affecting the durability of clay brick is water absorption (Alonso-Santurde et al., 2012). The variation in water absorption of the clay and textile mixture brick samples is shown in Table 4.

Table 5: Water absorption test

Firing Temperature (°C)	% Sludge composition	Water absorption (%)
950	0	23.4
	5	26.11
	10	30.5
1180	10	13

Table 6: General Brick Specification as per MS 7.6:1972/BS 3921:1985

Designation	Class	Water absorption (%)
Engineering Brick	A	4.5
	B	7.0
Load bearing Brick	15	No Specific Requirement
	10	
	7	
	5	
	3	
	2	
	1	

Table 4 shows that as the sludge addition increase, the water absorption increase but at fixed proportion, as the firing temperature increase, the water absorption is decrease. The mixture of clay contains a higher sludge proportion, the clay mixture's adhesiveness of decreases but increases the internal pore size of the clay bricks due to burning of organic matter preset in the textile sludge (Williams & Reed, 2004). As a result, the amount of water absorbed increase. For load bearing brick requirement from BS 3921(see Table 6), there is no specific requirement for water absorption so all clay samples comply the requirement. The water absorption

for 10% sludge proportion incorporated into cement is 0.73% at 21 of curing day. The percentage of water absorption for cement sample decrease as the duration for curing increase (Kartini et al., 2010). The cementations systems' durability is quantified by water absorption. When a longer curing period is used, the percentage of water absorption decreased due to develop a denser of internal structure thus reducing the connectivity and size of the network of pore. (Henkensiefken et al., 2009).

3.5 Firing Shrinkage

The firing temperature plays an important role in which it influences the firing shrinkage. This is due to sintering mechanisms. These mechanisms promote between particles and causing shrinkage (Karaman et al., 2006). Table 5 gives the percentage shrinkage in clay and textile mixture brick samples for compositions of sludge addition at the firing temperature 950°C and 1180°C.

Table 7: Linear shrinkage test

Firing Temperature (°C)	% Sludge composition	Linear shrinkage (%)
950	0	3.2
	5	6.6
	10	16
1180	10	23

From Table 5, it is observed that as the sludge composition increase, the linear shrinkage increase. Similarly at fixed proportion, as the firing temperature increase, the linear shrinkage also increases. When the textile sludge composition and firing temperature increase, the linear shrinkage is more due to existing of more inorganic and organic matter burnt off during firing (Baskar et al., 2006). The increasing addition of sludge in the mixture of clay enlarges the linear shrinkage's degree since the swell ability and the organic content in the sludge are higher than the clay. Thus, the grade quality of the clay brick is lowered. The proportion of the textile sludge and firing temperature in corporate into clay are the two important factors need to be concerned to reduce and minimize the linear shrinkage (C. H. Weng et al., 2003).

3.6 Density

Generally, the good clay bricks have a bulk density from 1.8g/cm³ to 2.5 g/cm³. The density of different composition of textile sludge fired at 950°C and 1180°C are presented in Table 8.

Table 8: Effect of sludge addition and firing temperature on bulk density

Firing Temperature (°C)	% Sludge composition	Bulk density (g/cm ³)
950	0	1.703
	5	1.481
	10	1.095
1180	10	1.523

As shown table 8, the bulk densities of the clay samples were inversely proportional to the composition of textile sludge added. As higher textile sludge addition, more pores were created in the clay brick after firing so lowering density. It is clear that the bulk density of the clay

samples is affected by firing temperature (Liew et al., 2004). As the firing temperature increase, the bulk density increase too. The results showed that all the bricks had bulk density which does not comply with the range of good quality clay brick. However, all clay samples can be categorized as lightweight building materials as the bulk density of lightweight building materials from 0.3 g/cm³ to 1.84 g/cm³ (Taba & Anshul, 2015).

3.7 Colour

The colour of clay brick depends to three elements which are firing temperature, the chemical composition and the method of firing control.

Figure 7: Fired clay bricks at different proportion of textile sludge

Figure 8: Fired clay bricks at different firing temperature

From the observation (see Figure 7), as the textile sludge added increase, the colour of fired clay brick become darker. This is due to presence of black textile sludge in it. Darker colours always associated with higher firing temperature, higher compressive values and lower water absorption value. As shown in Figure 8, fired clay brick at 1180°C was darker than fired clay brick at 950°C. However, there is no direct relation between water absorption and colour or compressive strength and colour for fired clay bricks made from different raw materials (Campbell & Pryce, 2003).

4. Conclusion

Based on the laboratory work conducted in this research it can be concluded that the textile sludge has potential for recovery and can be successfully utilized as a replacement in clay brick for building materials. For compressive strength, 5% and 10% sludge addition at firing temperature 950°C has compressive strength that acceptable in load bearing brick class 5 requirements from BS 3921 while for 0% at firing temperature 950°C and 10% at 1180°C have compressive strength above 48.5

N/mm² that can be categorized as engineering brick class B. For water absorption, as sludge addition increase, the water absorption increase but at fixed proportion, as the firing temperature increase, the water absorption is decrease. All clay samples complied for load bearing brick requirement of water absorption from BS 3921 since there is no specific requirement for water absorption. Furthermore, all clay samples can be categorized as lightweight building materials as the bulk density of clay samples fulfilled the lightweight density specification. The firing shrinkage up to 10% sludge addition at firing temperature 950°C were considered as lower which is less than 20%. The compressive strength for 10% sludge proportion incorporated into cement is 27.53 N/mm² at 21 of curing day and can be categorized as load bearing class 3 while for water absorption only 0.73% which is low. This research indicates that the recovery of textile sludge has positive effects on the environment through recycle the sludge.

5. Recommendations

Toxicity Characteristic Leaching Procedure (TCLP) should be carried out for the further researches. The purpose of performing the test of toxicity characteristic leaching procedure is to investigate the leachability of heavy metals. It is a requirement to ensure the leachability potentials of heavy metals are below the acceptable limits of environmental so that it will not contribute any sources of hazard to people. In addition, TG-DTA analysis should also be conducted in order to study the effect of temperature textile sludge and clay.

6. Acknowledgements

The support of the Department of Chemical Engineering, Faculty of Engineering, University of Malaya, Malaysia in providing the facilities is gratefully acknowledged. A sincere gratitude to the Faculty of Engineering for providing Research University Grant (RU019P-2017).

7. References

- [1.] Ahmadi, B., & Al-Khaja, W. (2001). Utilization of paper waste sludge in the building construction industry. *Resources, Conservation and Recycling*, 32(2), 105–113. [https://doi.org/10.1016/S0921-3449\(01\)00051-9](https://doi.org/10.1016/S0921-3449(01)00051-9)
- [2.] Ahmed, M., Idris, A., & Adam, A. (2007). Combined anaerobic-aerobic system for treatment of textile wastewater. *Journal of Engineering Science and Technology*, 2(1), 55–69.
- [3.] Algin, H. M., & Turgut, P. (2008). Cotton and limestone powder wastes as brick material. *Construction and Building Materials*, 22(6), 1074–1080. <https://doi.org/10.1016/j.conbuildmat.2007.03.006>
- [4.] Alonso-Santurde, R., Coz, A., Viguri, J. R., & Andrés, A. (2012). Recycling of foundry by-products in the ceramic industry: Green and core sand in clay bricks. *Construction and Building Materials*, 27(1), 97–106. <https://doi.org/10.1016/j.conbuildmat.2011.08.022>
- [5.] Balasubramanian, J., Sabumon, P. C., Lazar, J. U., & Ilangoan, R. (2006). Reuse of textile effluent treatment plant sludge in building materials. *Waste Management*, 26(1), 22–28. <https://doi.org/10.1016/j.wasman.2005.01.011>
- [6.] Barredo-Damas, S., Alcaina-Miranda, M. I., Bes-Piá, A., Iborra-Clar, M. I., Iborra-Clar, A., & Mendoza-Roca, J. A.

- (2010). Ceramic membrane behavior in textile wastewater ultrafiltration. *Desalination*, 250(2), 623–628.
- [7.] Baskar, R., Begum, K., & Sundaram, S. (2006). Characterization and reuse of textile effluent treatment plant waste sludge in clay bricks. *Journal of the University of Chemical Technology and Metallurgy*, 41(4), 473–478.
- [8.] Bennet, H., & Graham, O. (1992). *XRF analysis of ceramics, minerals and allied materials*. J Wiley and Sons.
- [9.] Campbell, J. W. P., & Pryce, W. (2003). *Brick: a world history*. Thames & Hudson.
- [10.] Deboucha, S., & Hashim, R. (2011). Correlation between total water absorption and wet compressive strength of compressed stabilised peat bricks. *International Journal of the Physical Sciences*, 6(10), 2432–2438. <https://doi.org/10.5897/IJPS10.551>
- [11.] Henkensiefken, R., Castro, J., Bentz, D., Nantung, T., & Weiss, J. (2009). Water absorption in internally cured mortar made with water-filled lightweight aggregate. *Cement and Concrete Research*, 39(10), 883–892. <https://doi.org/10.1016/j.cemconres.2009.06.009>
- [12.] Herek, L. C. S., Hori, C. E., Reis, M. H. M., Mora, N. D., Tavares, C. R. G., & Bergamasco, R. (2012). Characterization of ceramic bricks incorporated with textile laundry sludge. *Ceramics International*, 38(2), 951–959. <https://doi.org/10.1016/j.ceramint.2011.08.015>
- [13.] Jahagirdar, S. S., Shrihari, S., & Manu, B. (2013). Reuse of Textile Mill Sludge in Burnt Clay Bricks. In *International Journal of Advanced Technology in Civil Engineering* (Issue 2).
- [14.] Jayasinghe, I., Basnayake, B., Amarathunga, K., & Dissanayake, P. (2010). Environmental Conservation Efforts in Developing Textile Waste Incorporated Cement Blocks. *Tropical Agricultural Research*, 21(2), 126. <https://doi.org/10.4038/tar.v21i2.2594>
- [15.] Jeihanipour, A., & Taherzadeh, M. J. (2009). Ethanol production from cotton-based waste textiles. *Bioresource Technology*, 100(2), 1007–1010. <https://doi.org/10.1016/j.biortech.2008.07.020>
- [16.] Kantarli, I. C., & Yanik, J. (2010). Activated carbon from leather shaving wastes and its application in removal of toxic materials. *Journal of Hazardous Materials*, 179(1–3), 348–356. <https://doi.org/10.1016/j.jhazmat.2010.03.012>
- [17.] Karaman, S., Ersahin, S., & Gunal, H. (2006). Firing temperature and firing time influence on mechanical and physical properties of clay bricks. *Journal of Scientific & Industrial Research*, 65, 153–159.
- [18.] Kartini, K., Mahmud, H. B., & Hamidah, M. S. (2010). Absorption and permeability performance of selangor rice husk ash blended grade 30 concrete. *Journal of Engineering Science and Technology*, 5(1), 1–16.
- [19.] Lakshmi, M., Suguna, B. N., & Reddy, B. S. R. (2008). Enhanced thermal stability and structural characteristics of different MMT-Clay/epoxy-nanocomposite materials. *Polymer Degradation and Stability*, 93(1), 201–213.
- [20.] Liew, A. G., Idris, A., Samad, A. A., Wong, C. H. K., Jaafar, M. S., & Baki, A. M. (2004). Reusability of sewage sludge in clay bricks. *Journal of Material Cycles and Waste Management*, 6(1), 41–47. <https://doi.org/10.1007/s10163-003-0105-7>
- [21.] Ling, I. H., & Teo, D. C. L. (2012). Compressive Strength and Durability Properties of Lightweight Concrete Bricks under Full Water Curing and Air-Dry Curing. *International Journal of Sustainable Energy Development*, 1(1), 14–20. <https://doi.org/10.20533/ijised.2046.3707.2012.0003>
- [22.] Meukam, P. (2004). *Characterization of local materials for the thermal insulation of buildings (Doctoral dissertation)* [University of Yaounde I]. <http://www.u-cergy.fr/theses/04CERG0287.pdf>
- [23.] MIDA. (2012). *Malaysian External Trade Development Corporation*.
- [24.] Monteiro, S. N., & Vieira, C. M. F. (2014). On the production of fired clay bricks from waste materials: A critical update. *Construction and Building Materials*, 68, 599–610.
- [25.] Reis, J. M. L. dos. (2009). Effect of textile waste on the mechanical properties of polymer concrete. *Materials Research*, 12(1), 63–67.
- [26.] Rosa, E. V., Giuradelli, T. M., Corrêa, A. X., Rörig, L. R., Schwingel, P. R., Resgalla Jr, C., & Radetski, C. M. (2007). Ecotoxicological evaluation of the short term effects of fresh and stabilized textile sludges before application in forest soil restoration. *Environmental Pollution*, 146(2), 463–469.
- [27.] Shathika Sulthana Begum, B., Gandhimathi, R., Ramesh, S. T., & Nidheesh, P. V. (2013). Utilization of textile effluent wastewater treatment plant sludge as brick material. *Journal of Material Cycles and Waste Management*, 15(4), 564–570. <https://doi.org/10.1007/s10163-013-0139-4>
- [28.] Taba, P., & Anshul, G. (2015). *To study the lightweight concrete by using silica fume, fly ash, brick ballast and aluminium powder (Doctoral dissertation)*. Lovely Professional University.
- [29.] Weng, C.-H., Lin, D.-F., & Chiang, P.-C. (2003). Utilization of sludge as brick materials. *Advances in Environmental Research*, 7(3), 679–685.
- [30.] Weng, C. H., Lin, D. F., & Chiang, P. C. (2003). Utilization of sludge as brick materials. *Advances in Environmental Research*, 7(3), 679–685. [https://doi.org/10.1016/S1093-0191\(02\)00037-0](https://doi.org/10.1016/S1093-0191(02)00037-0)
- [31.] Williams, P. T., & Reed, A. R. (2004). High grade activated carbon matting derived from the chemical activation and pyrolysis of natural fibre textile waste. *Journal of Analytical and Applied Pyrolysis*, 71(2), 971–986. <https://doi.org/10.1016/j.jaap.2003.12.007>