A Study of Sludge from Treatment Plant and Coir Fiber as Additive for Fire Protection Brick

Nor Muslaili Binti Mokhtar, Norizan Binti Zakaria & Rozilaili Binti Mustapa

Jabatan Kejuruteraan Awam, Politeknik Sultan Idris Shah, Sungai Lang,
45100 Sungai Air Tawar, Selangor Darul Ehsan,

norlyzaidy@yahoo.com

ABSTRACT

Building material is any material which is used to a construction purpose, clay and red soil are natural material that have been used to construct building. It is used for bricks and among oldest material in the world. Based on the act for making material, most of the bricks only have 2 hours for fire resilience. Moreover, the cost of making this type of bricks is more expensive compared with other materials. In order to make of the bricks more resilience, this study is aim to determine a new material using waste materials. For this study, red soil, cement, sludge and coir fiber as a new mixture have been used with a certain ratio for making the new brick. From heat resilience test, it shows that 30% of red soil, 15% of cement, 10% of sludge and 45% of coir fiber is the best ratio. Meanwhile, this ratio took 6 hours before it cracked.

Key Words: Brick, Sludge, Fly Ash, Fiber, Fire.

1.0 INTRODUCTION

The uses of common clay brick of the building as a filler material are common in various buildings of the past until now. These materials, until now seems to still be chosen by the public despite the many discoveries in the field. Common clay bricks can only withstand to the fire for 1 to 2 hours. The selection of bricks cost also play an important role for the purchase of bricks. The clay brick requires high cost because of its quality. Therefore, many people use the ordinary bricks to construct the house because the price of the ordinary brick is lower than clay brick. But the lack of the ordinary brick is fire resistant low.The important of Fire Protection Brick is to reduce the spread of fire when burning happen at building. Based on Fire and Rescue Department, statistics shown the total death because of fire increased from 139 victims in 2014 to 153 victims in 2015. Increasing about 10% of death because of fire was in a concern level and need to take seriously. Fire and Rescue Department also receive 80183 emergency call or average is 220 call in a day. It is shown that a number of death causes by fire is higher. It is also can minimize the damage occurs at the building when burning happen. Other building will be affected and loss of property will occur when fire happen and using this brick it can decrease the loss and damage of the building. Almost 4.4 billion cost of property loss because of fire cases across the country along this 2015. The amount of loss increased 57% than on 2014 it was 2.8 billion (General Director of fire and Rescue Malaysia, 2016).

One of waste material are sludge are made of solid materials separated from the waterline during wastewater treatment. Sludge contains a high percent of water. According to Lara P. Rodrigues, et al (2015), large amount of municipal sludge that must be discarded were generated from water treatment plant. It becomes an issue when it is hard to find an ecological destination for its final disposal. This statement has been supported by Ali Yacine Sahnoun, et al (2012) stated that the sludge production increase with the development of water treatment plant and the major problem is to find a solution to eliminate these residues in the most economical conditions while respecting the environment. Thus, according to S.V. Sverguzova, et al (2016) around 7 billion tons of solid waste only was produced in the world annually. One of the widespread and big-volume wastes is sludge generated during wastewater treatment. The sludge are used or sent for recycling only in small quantities, sent to industrial landfills for their long-term storage and so on. A lot of attention is paid to

recycling or disposal of this waste production. Sludge can be used for making a brick since it have the similar chemical properties as clay. It can be seen as Bength Hultman, et al (2014) stated in Sustainable Sludge handling 'Div of Water Resources Engineering' that the organic component in sludge can be used for the producing bricks. This statement was supported by Mohammed, et al (2008), stated that there are similarity between Alum sludge and normal clay. The use of water treatment sludge in various industrial and commercial manufacturing processes has been reported in UK, USA, Taiwan and other parts of the world. Successful trial have been undertaken in brick manufacture, cement manufacture, and commercial land application. The mineralogical composition of the water treatment sludge is particularly close to clay and shale. This fact encourages the use of water treatment sludge in brick manufacture. This can be seen based on a research carried out in UK mentioned by Godbold, et al (2003), assessed the potential of incorporating aluminium and ferric coagulant sludge in various manufacturing processes including clay brick making. A mixture consists of about 10 percent of the water treatment sludge and sewage sludge, incinerated ash was added to about 90 percent of natural clay to produce brick.

Coir fiber has the highest concentrations of lignin, a natural polymer. Therefore most suitable for applications such as geotextiles, where slow biodegradability is required. Coir fiber is used in a wide range of applications such as floor coverings/carpets, door mats, furniture padding and as filling for mattresses. Traditionally also in brushes, ropes and twines. Due to its resilience and high elongation properties coir fiber and natural latex are combined, as biobased composite, to be used in automobile seat production. None woven rubberized coir sheets are used as insulation and as packaging material. It has high degrees of surface abrasion resistance and resists contraction/ expansion due to variations in temperatures. Coir fiber are made up of small threads, each less than 0.05 inch (1.3 mm) long and 10 to 20 micrometres in diameter. White fibre is smoother and finer, but also weaker. The coir fibre is relatively waterproof and is the only natural fibre resistant to damage by salt water (Coir Board Ministry of MSME, Govt. of India).

A Study Of Sludge From Treatment Plant And Coir Fiber As Additive For Fire Protection Brick were presented and discuss consist of property such as compressive, density, water absorption and heat resilience compare with common brick.

2.0 MATERIAL

The Fire Protection Brick was designed according to the MS 7.6 : 1972. There are four (4) ratios are used to produce the Fire Protection Brick which is red soil (kg), cement (kg), sludge (kg), coir fiber(kg) and water(l). The design of ratio are (1:2:5:3), (3:1.5:1:4.5), (6:1:2:1) and (2:5:1:2). The materials used in Fire Protection Brick are sludge. Sludge made of solid materials separated from the water line during water treatment. Sludge contains a high percent of water. Alum Sludge is a waste resulting from the freezing process water treatment plant in Malaysia that used alum in the water treatment process. It is extremely close to brick clay in chemical composition show in Table 1.

Table 1: Chemical composition of Alum Sludge

Ingredient	Ratio by Weight (%)
SiO_2	43.12
Fe_2O_3	5.26
Al_2O_3	15.97
CaO	5.56
MgO	0.85
SO_3	1.49
Na_2O	0.52
K_2O	0.25
Cl	0.012
LO.I	26.79

Source : Waste Water Sludge Processing, 2006

Red soil or also known as laterite soil is red or brown colour soil which was shaped in humid environments, cold and may have a deep soil profile, easy to absorb water that contain organic materials and has neutral pH to acidic and also high content of iron and aluminium till it is good to be use during building construction because easy to absorb water. The texture of red soil usually compact and strong to bear load on it.

Ordinary Portland Cement is the most usually use in construction industry, It is suitable to use for all kind of works either for rough work, construction of structure, finishes work, and so on. In terms of price, this cement is much cheaper compare to other types of cement.

Coir fiber is the outer part of the coconut fruit. They are moth-proof, resistant to fungi and rot provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean.

Water used must be clean and do not contain any impurities. Water containing salt will reduce the strength of the brick structure and cause non-slip surface.

3.0 METHODS

The Fire Protection Brick was designed according to the MS 7.6 : 1972. There are four (4) dimension and design mixes ratio are used to produce the Fire Protection Brick which is A(1:2:5:3),B(2:5:1:2),C(6:1:2:1) and D(3:1.5:1:4.5) show on Table 2 and 3.

Table 2: The dimension of the Fire Protection Brick

Brick Sample	Width (mm)	Length (mm)	Height (mm)	Mass of Sample (kg)	Volume of Sample (m^3)
Fire Protection Brick A	103	215	65	2.56	1.429×10^{-3}
Fire Protection Brick B	105	217	65	2.56	1.466×10^{-3}
Fire Protection Brick C	103	214	66	2.22	1.457×10^{-3}
Fire Protection Brick D	102	215	64	2.07	1.413×10^{-3}
Common Brick	102	215	65	2.65	1.420×10^{-3}

Table 3: Design mix proportion of Fire Protection Brick

Materials	Fire Protection Brick (A)	Fire Protection Brick (B)	Fire Protection Brick (C)	Fire Protection Brick (D)
Red Soil (kg)	0.20	0.41	1.22	0.59
Cement (kg)	0.46	1.18	0.23	0.34
Sludge (kg)	1.00	0.21	0.41	0.20
Coir Fiber (kg)	0.29	0.20	0.10	0.43
Water (l)	0.62	0.58	0.26	0.51

Water cement ratio in mixes proportion are average 0.2 to 0.3 with all design mix ratio by weight. The mixture proportion are dried alum sludge from the water treatment plant disintegrated into small pieces and the coir fiber size using between 4mm to 5mm. All of the materials was mixed together thoroughly according to the mixture ratios. Water was added slowly so that will get the accurate amount of water used in the mixture .The mixture of the brick was pour into the mould of the press machine.

There are four (4) test in terms of compression, density, water absorption and heat resilience. Compression test is to evaluate the strength of Fire Protection Bricks that produced using the method set in MS 7.6 : 1972.

Brick density test is to ensure or compare the strength of ordinary red soil bricks and the Fire Protection Brick made of alum sludge and coir fiber as additive. The size of Fire Protection Brick using vernier caliper to find its height, width and length. The mass of the Fire Protection Brick can determine using weighing scale. The density of the Fire Protection Brick can defined as the ratio of the mass of a fluid to its volume (kg/m^3).

Water absorption test are used to determine the rate of water absorb in Fire Protection Brick. It also intended to ensure appropriate water is used to bind the brick. The permeability of the brick can indicate the nature of the absorption by the surface of the brick is important during the brickwork. Weighing scales is using to define the mass of a dry Fire Protection Brick. Fire Protection Bricks was soak in soaking basin containing water for 24 hours.

Heat resilience test are used to determine the extent of the brick resilience to withstand heat and the time taken for the brick crack in a high temperature. The heat resilience test were conduct by put the Fire Protection Bricks to the drying oven and set the temperature by 250°C. Cracking effect of

the bricks was checked every 1 hour. The period time was taken when the crack occur on the Fire Protection Brick.

All the data analysis will present the results of the tests that were conducted to know the workability of the brick. The data acquired was processed and analysed. The result was shown in Table 4 and bar graphs was shown in Figure 1 to 4.

4. DISCUSSION AND RESULT

The purpose of dimension test is to ensure that the size of the brick follow the standard specifications according to MS 76:1972 show at Table 2 and Table 4 show the result of data obtained in terms of compressive strength (N/mm^2), density (kg/m^3), water absorption (%), and heat resilience (hr). The data will be analysed to determine whether the mixture and the ratio of the raw material are suitable for the use in the manufacture of brick. The process of making brick and test methods were mostly based on MS 76:1972 and BS 3921:1985. The strength of brick was compare that contain of red soil, cement, sludge and coir fiber with common brick.

Table 4: The difference test results for testing the sample

Test	Fire Protection Brick A (1:2:5:3)	Fire Protection Brick B (2:5:1:2)	Fire Protection Brick C (6:1:2:1)	Fire Protection Brick D (3:1.5:1:4.5)	Common Brick (7:3)
Compressive Strength (N/mm^2)	6.73	16.60	5.13	17.48	6.37
Density (kg/m^3)	1793	1744	1476	1468	18.66
Water Absorption Test (%)	9.65	9.81	15.61	14.99	11.94
Heat Resilience (hr)	4.33	2.82	2.56	6.00	6.04

4.1 Compressive Strength Test

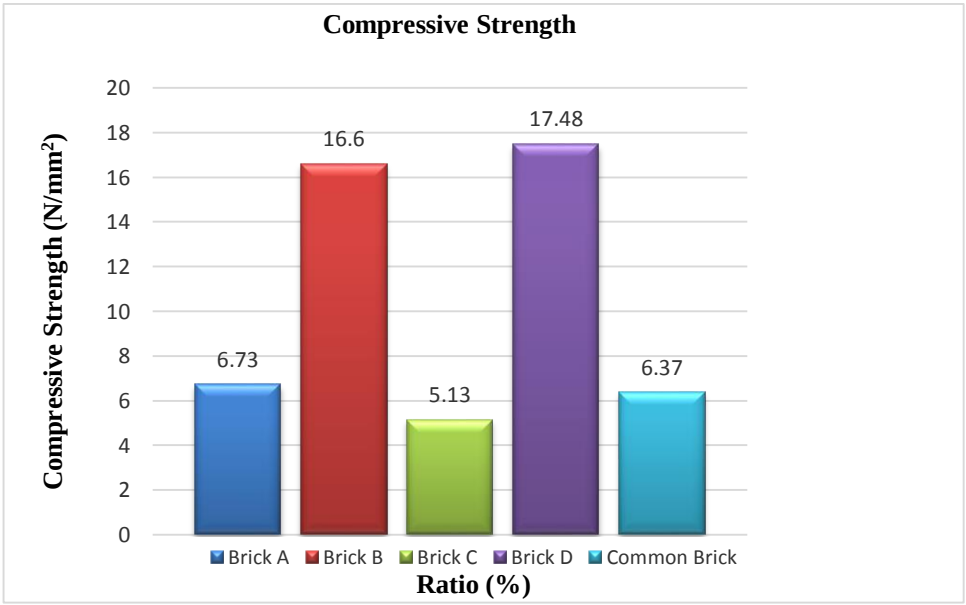

Figure 1: Compressive Strength (N/mm^2)

The Figure 1 show that bricks used sludge from treatment water and coir fiber as additive surpasses the standard of compressive strength. Fire Protection Brick A was imposed with maximum load between 142kN to 160kN until the brick were crack. Fire Protection Brick B was imposed with load between 135kN to 400kN. While Fire Protection Brick C was cracked when the imposed load is between 105kN to 120kN. In this test, Fire Protection Brick D can bear the highest imposed load which is between 390kN to 450kN. This study was found that the Fire Protection Brick A, B and D shows the maximum load imposed is higher than the common brick that can withstand when the imposed load is between 130kN to 150kN only. The Fire Protection Brick samples passed the limit of compression

strength in MS 76:1972 .The higher compressive strength was brick D that used 30% of red soil, 15% of cement, 10% of sludge and 45% of coir fibre with the reading 17.48 N/mm^2. The result was because the used of 45% of coir fibre. Coir fibre act as adhesive between the materials contains in the brick that affect the strength of the brick. The lowest compressive strength was brick C that used 10% of red soil, 20% of cement, 50% sludge and 20% of coir fibre with 5.13%.

4.2 Density Test

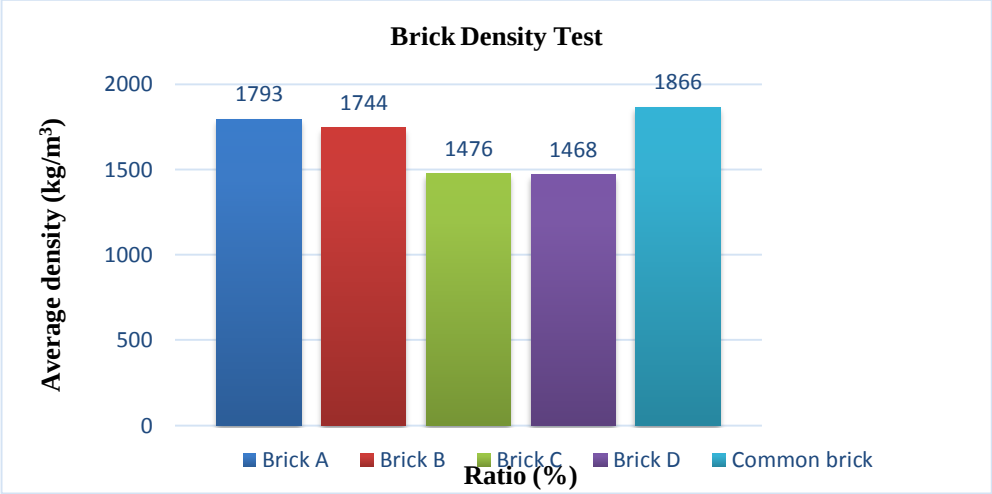

Figure 2: Density (kg/m^3)

Based on Figure 2, it shown the density of common brick was the higher that the other ratio of the brick with the reading 1899 kg/m^3. Brick D was the lowest density with ratio 30% of red soil, 15% of cement, 10% of sludge and 45% of coir fiber with the reading 1468 kg/m^3. The lowest density was Fire Protection Brick D because the used of 45% of coir fiber influences the mass of the brick. The difference between brick A and brick B was just 0.58% because the used of red soil and the cement was equal in both ratio.

4.3 Water Absorption Test

Water absorption test was conducted to determine the percentage of water absorption and also intended to ensure appropriate water used to bind the brick. The result was taken after 24 hours soaked the brick in water. This experiment was important to determine the content of water that seeps into the bricks if it used in the construction that exposed to water or rain.

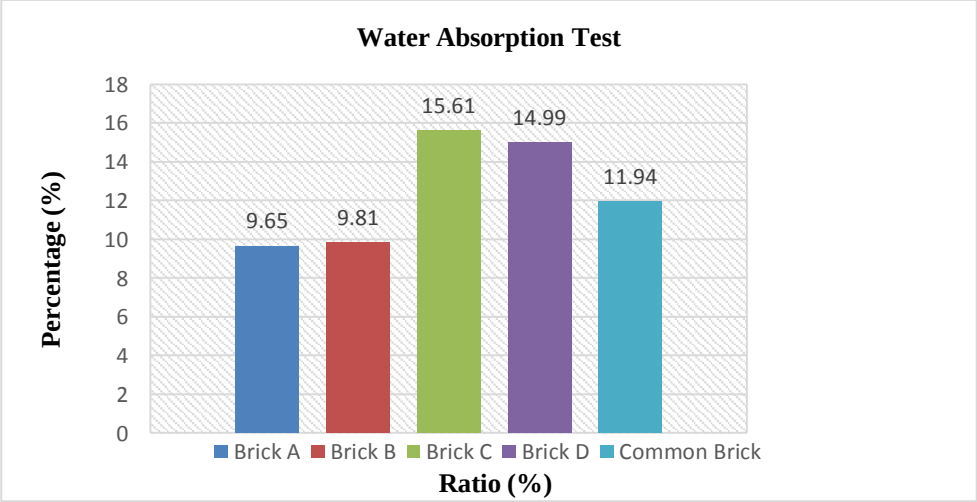

Figure 3: Water Absorption Test (%)

Fire Protection Brick C contain are high percentage of water absorption which is 15.61%. While the percentage of water absorption rate of common brick was 11.94%. This shows that difference of the rate of water absorption between Fire Protection Brick C and common brick is 3.67%. The result of water absorption test for Fire Protection Brick A, B and D are 9.65% , 9.81% and 14.99%. However the results of this four mixture ratios in this test does not exceed 1/6 of the volume of brick. Based on Figure 3, it's shown that brick C that used 10% of red soil, 20% of cement, 50% sludge and 20% of coir fiber compared with other ratio has a higher water absorption with 15.61%. Its shows that brick D was not compacted properly that caused the brick has airspace that influences water absorption. The lowest water absorption was brick A that used 60% of red soil, 10% of cement, 20% of sludge and 10% of coir fiber with reading 9.65%. The difference between the higher and the lowest percent (%) water absorption is 5.96%.

4.4 Heat Resilience Test

Heat resilience test is to get the duration for the brick to crack under a certain temperature to measure its heat resilience. It also to compare the time taken for the common brick and Fire Protection Brick crack in term of heat resilience. This test was carried out is intended to test the durability of brick against the heat at the temperature of 250°C and time taken for the bricks to crack. Fire Protection Brick A can withstand with the heat is about 4 hours 30 minutes. While Fire Protection Brick B and C can withstand the heat only for 2 hours before crack and this shows that the Fire Protection Brick B and C can withstand the heat below that 2 hours. Fire Protection Brick D takes about 6 hours to crack. This test shows that Fire Protection Brick D which contains higher percentage (45%) of coir fiber can withstand the heat 4 hours more than common brick.

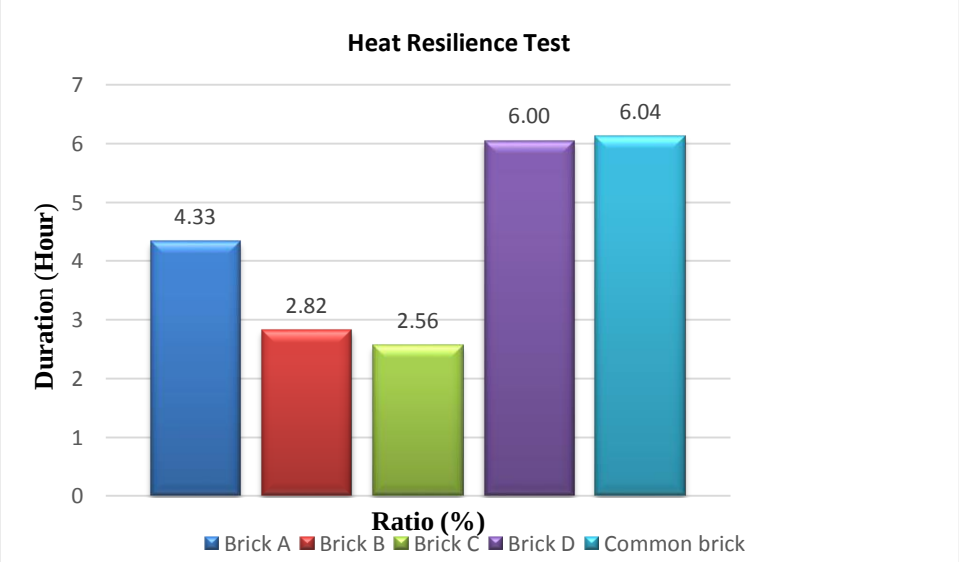

Figure 4: Heat Resilience Test (Hr)

Based on Figure 4, the longer time taken for the brick to crack was common brick that takes 6.04 hours and followed by Fire Protection Brick D that used 30% of red soil, 15% of cement, 10% of sludge and 45% of coir fibre with 6.00 hours. Fire Protection Brick C that used 10% of red soil, 20% of cement, 50% sludge and 20% of coir fibre was the shortest time taken for brick to crack with 2.56 hours. The difference between the longer and shorter time for brick to crack was about 6 hours. Its shows that used of coir fibre as additive in a brick has the more retention time heat resilience compare with common brick.

5. SUMMARY

Data analyses show that, red brick with the additive of coir fiber and sludge from treatment plant is lighter than the conventional red brick. There are four different percentage that was tested which is high contain of red soil (6:1:2:1) cement (2:5:1:2), sludge (1:2:5:2) and coir fiber (3:1.5:1:4.5). All of these mixture ratios were used to test and compare in terms of density, water absorption, compressive strength and heat resilience of brick. The density test proved that Fire Protection Brick A is heavier

which is 1793 kg/m^3 compared to Fire Protection Brick B, Fire Protection Brick C and Fire Protection Brick D. However, Fire Protection Brick D is the lightest with the density 1468 kg/m^3. More contain of coir fiber added during the process of manufacturing the brick, given low density of the brick.

Generally, the brick is very widely use especially in the construction of the building. Compressive strength of brick is an important criteria in determining the strength. The absorption rate of water will affect the bond strength during brick work. While heat resistant did influence the durability of brick during in high temperature condition.

Strength of bricks produced is dependent on the raw materials and manufacturing methods. Brick has a high content of cement has higher compressive strength than the brick that has less content of cement. To produce a strong brick is to emphasis the use of appropriate water.

The sludge and coir fiber was the additive materials in Fire Protection Brick and the durability of heat was tested for size of the brick is 215mm x 102.5mm x 65mm and it was according to MS 76: 1972.

The results show that the Fire Protection Brick D possess a high compressive strength which is 17.48 N/mm^2 and higher than common brick. This is due to the high fiber content of coir. Coir fibers have very strong ties with each other. The content of red soil and cement also helps to enhance the compressive strength of the brick. Therefore the strength of Fire Protection Brick D is higher and passed the minimum strength of brick (7.0 N/mm^2) . Besides, Fire Protection Brick D can withstand the heat on temperature of 250°C for 6 hours which is the same duration with common brick. The ratio of Fire Protection Brick D with ratio (3:1.5:1:4.5) is suitable because the strength is high and the duration to crack in high temperature is more than 2 hours.

REFERENCES

British Standard BS 3921 – 1985*. Spesification for Clay Bricks*.The authority of the Board of BSI, 29 November 1985

Coir Board Ministry of MSME, Govt. of India. Retrieved 27 September 2016.For more information, please visit: http://www.coirboard.gov.in/?page_id=60

Hultman B. & Levlin E. *Sustainable Sludge Handling,* Div. of Water Resources Engineering Royal Institute of Technology (KTH) S-100 44 Stockholm, Sweden

Malaysian Standard MS 76 : 1972. *Specification for Bricks and Blocks of Fired Brickearth, Clay or Shale Part 2 : Metric Units, Standard & Industrial Research Institute of Malaysia*.

Rodrigues, L.P, Nilson, J. & Holanda, F. (2015). *Recycling of Water Treatment Plant Waste for Production of Soil Cement Bricks*, Procedia Materials Science, 8 (2015) pp 197-202

Sahnoun. A.Y et al. *Comparative Study of Characteristics of Three Types of Sludge from Wastewater Treatment Plants*. Energy Procedia 18 (2012) 99 – 109

S.Somayaji, (2001). *Civil engineering materials*. Upper Saddle River, N.J.: Prentice Hall.

Sverguzova, S., Sapronova, Z., & Starostina, I. (2016). Disposal of Synthetic Surfactants-Containing Wastewater Treatment Sludge in the Ceramic Brick Production.*Procedia Engineering*,*150*, 1610-1616

Shakir A., A. & Ahmed Mohammed, A. (2013). *Manufacturing of Bricks in the Past, in the Present and in the Future*: A state of the Art Review. *International Journal Of Advances In Applied Sciences*,*2*(3).

Statistics Fire & Rescue Department Kuala Lumpur. For more information, please visit: http://rehdainstitute.com/wp-content/uploads/2016/11/10.-Slides-1-Khiruddin-Drahman.pdf

Ramadan M. O, et al. *Reuse of Water Treatment Plant Sludge in Brick Manufacturing,* Department of Civil Engineering, Faculty of Engineering, Banha University, Egypt. J. Appl. Sci. Res., 4(10): 1223-1229, 2008