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Burnt-Bricks Production Using Extracted Finer Particles from Soil with Fly Ash Addition

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Abstract: Earthen building materials, including mud, adobe, rammed earth, and bricks, have a long history of use in civil engineering construction all throughout the world. Burnt bricks are one of these materials that is important. However, the availability of raw materials for making bricks is limited. As a result, numerous alternatives have been investigated as raw materials for making bricks. These substitutes include fly ash, rice husk and ash, industrial, and agricultural waste. The current study suggests a novel method for producing burnt bricks using extracted finer and fly ash. Finer particle extraction was done through soil washing. Since the extracted finer is having high plasticity index and high linear shrinkage, extracted finer was mixed with 20%, 25%, 30%, 40% and 50% fly ash. Fly ash is an industrial waste; hence the use of fly ash for this kind of production would give a sustainable solution for waste management. Every finer-fly ash combination underwent an Atterburg test to evaluate its qualities, particularly its plasticity index and linear shrinkage. Standard-type mold (220 x 115 x 75 mm) was used to produce the handmade bricks. Compressive strength, flexural strength, water absorption, density, and dimension variations of burned bricks were all examined. Results were compared with SLS 39: Specification for burnt clay bricks. Further, these properties were compared with the same properties of bricks made with soil taken from the brick-making industry mixed with fly ash and industrial available burnt-bricks. Additionally, wire-cut bricks were produced using extracted finer and 25% fly ash. The dimensional variation of finer-fly ash mixed burnt bricks is decreasing when the fly ash % is increased relative to the mold size. Compressive strength of the Grade 2 category was demonstrated using bricks manufactured with a 25% fly addition, according to SLS 39. According to the aforementioned findings, burnt bricks composed of extracted finer and fly ash have higher desirable qualities when 25% more fly ash is added. Additionally, it shows that using fly ash results in lightweight bricks. The wire-cut bricks made with this selected mixture give 10.64 N/mm^2 of compressive strength and it satisfies the SLS 39 requirements for wire-cut bricks. Also, its water absorption was nearly 16% which is below the SLS required value (18%).

Keywords: Burnt-bricks, extracted clay, fly ash

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1. Introduction

Earthen materials have been used in civil engineering construction worldwide in different forms, such as mud, adobe, rammed earth and bricks. The present situation in the construction industry provides evidence that the use of burnt-bricks and cement sand blocks are comparatively high. The use of Sun-dried clay bricks as a building material has a history of more than 6,000 years. Sun-dried bricks have been replaced by burnt-bricks to enhance the strength and durability properties of the masonry. The availability of raw materials for the production of bricks is short; hence, many alternatives have been developed as walling materials(Jayasinghe, 2007). Baiden, Agyekum and Ofori-Kuragu, (2014) have shown that there are many barriers to use traditional burnt-bricks and most of them are due to lack of materials. The heterogeneous property of bricks due to clay can incorporate a significant percentage of waste material to its body (Dondi *et al.*, 2009). Suitable clay for these products is hard to find due to environmental issues. Therefore, reusing the waste matter in the production of clayey products would be a sustainable alternative as the raw materials and also it would be a way for industrial waste management.

The utilization of different types of waste in brick production has been investigated by many researchers. Those are: fly ash (Aakash Suresh Pawar, 2015), rice husk and ash (Sutas, Mana and Pitak, 2012), (Silva and Perera, 2018) waste crushed glass (Ikechukwu and Shabangu, 2021), (Akinyele *et al.*, 2020), waste marble powder (Sutcu *et al.*, 2015), ceramic sludge (Subashi De Silva and Hansamali, 2019) and water treatment plant sludge (Heniegal *et al.*, 2020). Kazmi *et al.*, (2016) has shown that the use of waste sugarcane bagasse and rice husk ashes lead to not only relieves the environmental burden but also results in more sustainable and economical construction. Other than that, some studies have shown that the use of rice husk and ash leads to lightweight burnt bricks (Rahman, 1987), (Tonnayopas and Tekasakul, 2014). Murmu and Patel, (2018) with their extensive literature study, have shown the usage of industrial and agricultural waste for bricks production has been investigated by many researchers. All these researchers aimed to find some alternative raw materials for clay-based building materials. The present study suggested clay extraction from clayey soil through washing as a new approach for finding raw materials for burnt-bricks production.

Since the extracted finer consists of a high plasticity index and linear shrinkage, extracted finer was mixed with fly ash to form a more desirable mixture for bricks production. Since fly ash is an industrial waste, the use of fly ash for this kind of production would give a sustainable solution for waste management. With this background, this paper aims to propose a new approach for burnt-bricks production. To achieve this aim, the properties of burnt-bricks were tested for different extracted finer and fly ash mixtures.

1.1 Properties of Burnt Bricks and Its Raw Materials

In the modern construction industry, different types of bricks are in use. Those are; burnt clay bricks, sand-lime bricks, concrete bricks, fly ash bricks, etc. These names are given based on the materials used and the method of manufacturing. Out of that burnt clay bricks usage is common. Bricks are one of the oldest construction materials, and it continues to be one of the most popular building materials because it is durable, easy to handle, aesthetic in look, and inexpensive (Phonphuak and Chindaprasirt, 2014). Clay bricks are made by shaping suitable clays or shales into units of standard size, which are then fired at a temperature of 900–1150°C for 8–15 hours (Ingham, 2013). Usually, the particle size of clay is the most important factor to check the suitability of raw materials. As per (Fernandes, 2018), particle size lower than 0.1mm is the most suitable size. But, some researchers have used particle sizes of more than 0.1 mm also in smaller quantities in the raw material (Silva and Perera, 2018). Colour is another main important aspect and it is determined according to the chemical composition (Ingham, 2013). Usually, burnt bricks properties are determined according to the standards available. In Sri Lanka, SLS 39: 1978 defines the properties of burnt clay bricks (Sri Lanka Standard Institution, 1978). Table 1 gives the requirements for burnt bricks.

Table 1 - Specific requirements of burnt clay bricks (Sri Lanka Standard Institution, 1978)

Characteristic	**Type 1 (Machine made bricks**	**Type 2 (Hand-made bricks)**	
		Grade I	**Grade II**
Characteristic compressive strength average not less than (MPa)	10	4.8	2.8
Water absorption not more than	18%	28%	28%
Efflorescence- highest permissible rating	Slight	Moderate	Moderate

2. Soil Washing

The separation of sand, silt and clay fractions from soil has been described by (Genrich, 1972), (June, 1969), (Mann and Groenendijk, 1996). This was done by sieving, sedimentation procedure and electrophoresis. The present study considered soil washing together with sedimentation to extract finer particles from the soil. Washing was first done manually to check the feasibility of separating finer through washing. Then the commercially available concrete mixer was used for soil washing. The 20-*l* bucket was used to measure the soil and water. One 20-*l* bucket of soil and the same amount of water were put into the concrete mixer and the mixer was functioned for a known time and one soil bucket was washed for different times. **Error! Reference source not found.**1 shows the use of a concrete mixer for soil washing. It was mixed well and the clay slurry was removed. To make the sedimentation process of finer accelerated, Alum was used.

After keeping the slurry for a few hours, some amount of clear water could be removed. The remaining clay slurry was put into a cloth to filter the remaining water to separate the clay. Then the clay was kept under the Sun to completely dry (Figure 2). The remaining larger particles are also can be used for other products such as soil cement blocks (Malkanthi, 2019).

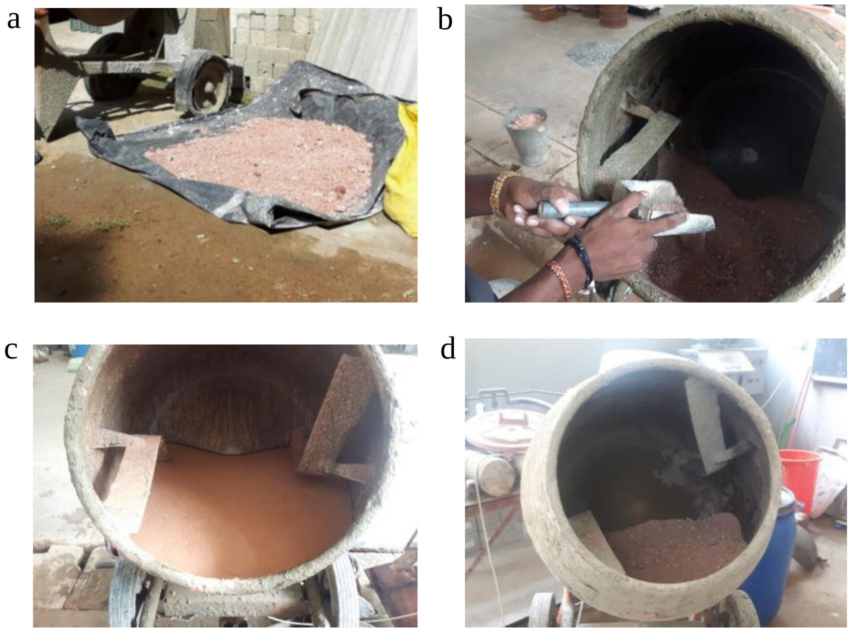

Fig 1 - (a) Dry soil; (b) put in the concrete mixer; (c) mix with water; (d) clay slurry after washing

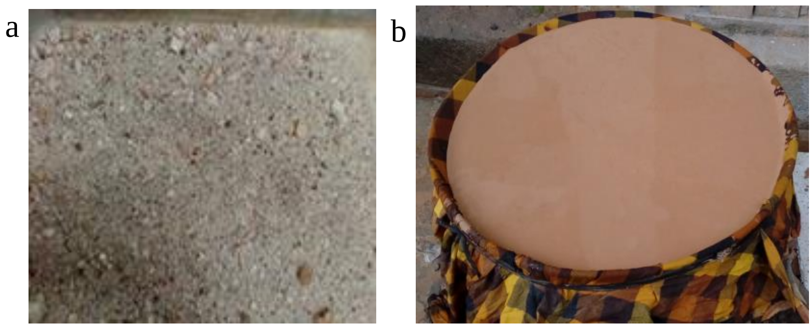

Fig 2 - (a) Coarse particles; (b) separated finer

3. Burnt Bricks Production

The main consideration for this study is to find new raw materials for burnt-bricks production. The extracted finer from the soil through soil washing was the generated new raw material. This extracted finer was mixed with 20%, 25%, 30%, 40% and 50% fly ash since the extracted finer did not show sufficient texture and plasticity to produce burnt-bricks (Figure 3). Atterburg test was performed for every finer-fly ash mixture to check the mixture properties mainly the plasticity index and the linear shrinkage. Another set of bricks was made using market-available clay mixed with the same fly ash percentages for comparison purposes.

Fig 3 - Preparation of clay mix for burnt bricks production (a) extracted clay; (b) add fly ash; (c) mix of clay and fly ash; (d) mix with water

For the handmade bricks, standard-type mould (220 x 115 x 75) *mm* was used. The dimensions are slightly larger than the standard brick size. This tolerance was kept to allow for shrinkage. Bricks were kept for drying without direct sunlight. After drying sufficiently, bricks were kept in the furnace for firing for about eight hours at 1000^{0}C. After cooling, bricks were taken out. Burnt-bricks were tested for compressive strength, flexural strength, water absorption, density, and dimension variations. Results were compared with SLS 39: Specification for brunt clay bricks. Also, these properties were compared with the same properties of industrial available burnt-bricks. Figure 4 shows the used mould and the final product after burning.

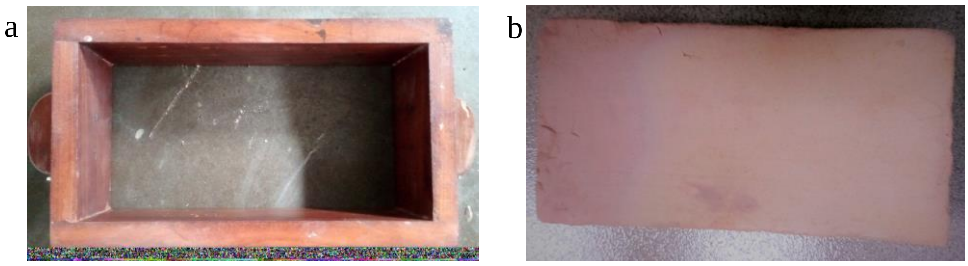

Fig 4 - (a) Size of the mold: (220 x 115 x 75) mm; (b) burnt brick made with extracted clay + fly ash

After firing and testing the bricks made with different fly ash addition, it was identified that the 25 % fly ash addition gave the optimum properties for bricks. Therefore, wire-cut bricks were made with extracted clay with 25% fly ash addition. **Error! Reference source not found.**5 shows prepared wire-cut bricks.

Fig 5 - Wire-cut bricks

Bricks were tested for strength properties and durability properties. Tests were performed as per the guidelines given in SLS, IS, ASTM and past researches. The compressive strength of bricks was determined as per SLS 39. First, bricks were filled flush with 1 cement: 1 clean sand to obtain a smooth flat surface. Then the brick was placed into the compression testing machine and compressive force was applied until the brick fails. The compressive strength was determined as in Equation (1) and the average compressive strength was calculated. For wire-cut bricks capping on the bricks was not necessary since their surfaces are nearly flat. A flexural bending test was conducted for bricks as per ASTM C 90-11a and strength was calculated as in Equations (2). The schematic diagram in **Error! Reference source not found.**6 shows the all strength testing procedures.

$$Compressive\ Strength = {}^{P}/_{A} \quad (1)$$

$$Flectural\ Strength = 1.5Pl/(bd^2) \quad (2)$$

Where P= ultimate applied load, A = the area of the bearing surface, l = span length, b = width of the brick at the mid-span section, d = depth of the brick at the mid-span section

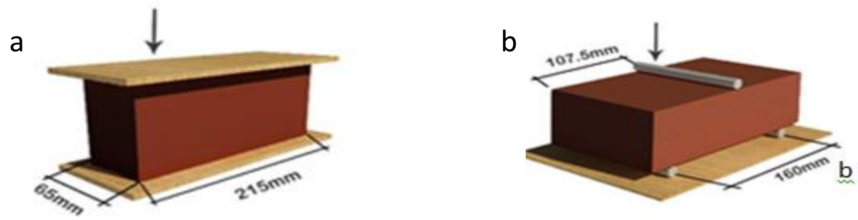

Fig 6 - Schematic diagram for (a) compression test; (b) flexural test

4. Results and Discussion

Clay bricks made with extracted clay with different compositions of fly ash were tested for strength, durability and insulation as explained in section 4. According to the Atterberg test results, 25% fly ash addition to extracted clay gave the lowest shrinkage. For other percentages also, shrinkage is not significantly large compared to some literature (Silva and Perera, 2018), (Rahman, 1987). Therefore, the bricks were made with up to 50% fly ash addition.

First, the prepared bricks were checked for dimension variation after firing and Table 2 shows the dimension variation results. These variations were calculated based on the dimensions of the brick mould used (220 x 115 x 75) mm. Bricks were made with the clay available in the brick-making industry with fly ash addition also for comparison purpose.

Table 2 - Dimension variation of bricks

Brick specimen	Fly ash %	Variation in length (%)	Variation in Width (%)	Variation in Height (%)
ECB-F20	20	5.9	9.6	9.3
ECB-F25	25	4.5	8.7	9.3
ECB-F30	30	3.6	6.1	9.3
ECB-F40	40	3.2	4.3	7.1
ECB-F50	50	2.3	4.3	7.1
MCB-F00	0	11.82	18.26	21.33
MCB-F20	20	9.55	13.04	17.33
MCB-F25	25	8.18	9.57	16.00
MCB-F30	30	7.73	8.70	13.33
MCB-F40	40	2.73	6.09	10.67
MCB-F50	50	2.27	4.35	9.33
MCB-F60	60	1.36	4.35	6.66

ECB: Extracted Clay Bricks; MCB, Market Clay Bricks

These dimension variations are visible in burnt bricks. Fig7 shows a few burnt bricks with different fly ash contents.

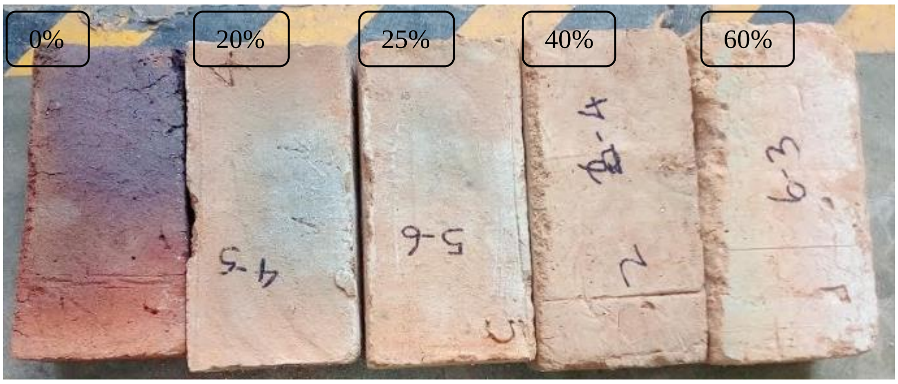

Fig 7 - Burnt bricks with different fly ash contents

According to these dimension variations, it is clear that the fly ash addition helped to lower the shrinkage. So, the number of bricks needed is reduced for a unit wall area construction compared to that built with normal bricks. Hence, these burnt bricks help to reduce the cost of wall construction. However, with the increase of fly ash, bricks are not rigid and it can be seen the appearance of the bricks.

Table 3 shows the strength values of bricks for different fly ash percentages. Bricks strengths were compared with randomly taken market bricks. Also, bricks made with clay taken from the brick-making industry and mixing with fly ash were considered for the comparison. These compressive strengths and flexural strengths variations are presented in **Error! Reference source not found.**8 and

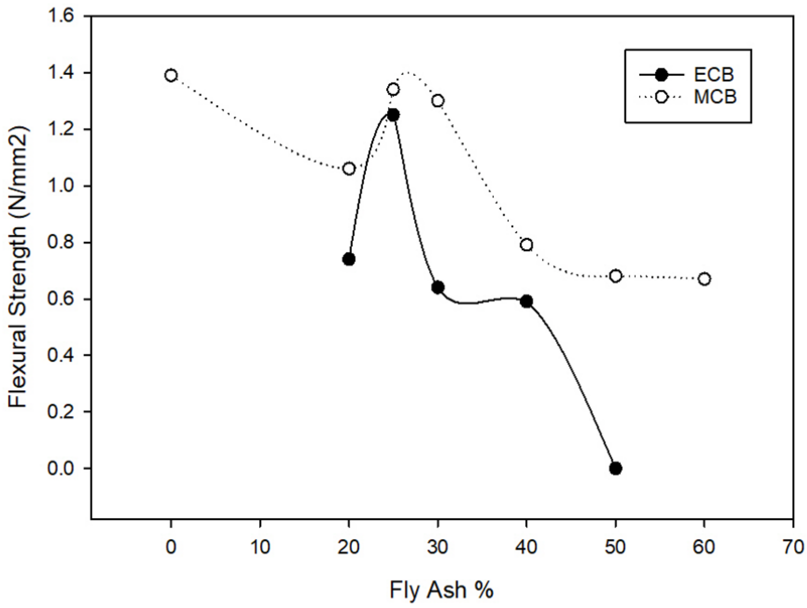

Fig 9 respectively.

According to the results of the strength of the two bricks categories, 25% fly ash addition helps to achieve the maximum strengths for both compressive and flexural strengths.

Table 3 - Compressive strengths and flexural strengths of bricks

Brick specimen	Fly ash %	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)
ECB-F20	20	2.51	0.74
ECB-F25	25	3.99	1.25
ECB-F30	30	2.32	0.64
ECB-F40	40	1.52	0.59
ECB-F50	50	0.97	0
MB	-	3.85	1.51
MCB-F00	0	6.02	1.39

MCB-F20	20	4.02	1.06
MCB-F25	25	4.13	1.34
MCB-F30	30	2.42	1.3
MCB-F40	40	1.38	0.79
MCB-F50	50	2.17	0.68
MCB-F60	60	0.91	0.67

ECB: Extracted Clay Bricks, MB; Market Bricks, MCB: Market clay Bricks

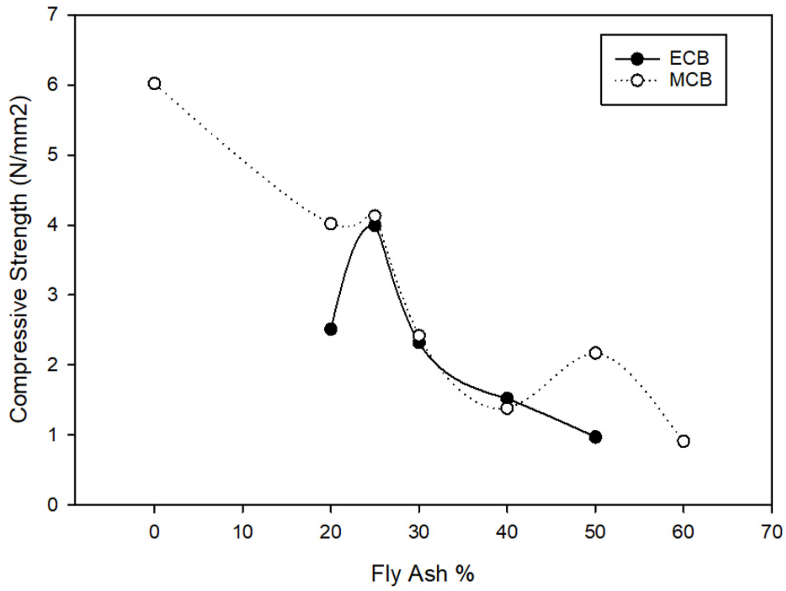

Fig 8 - Compressive strength variation of burnt bricks with fly ash %

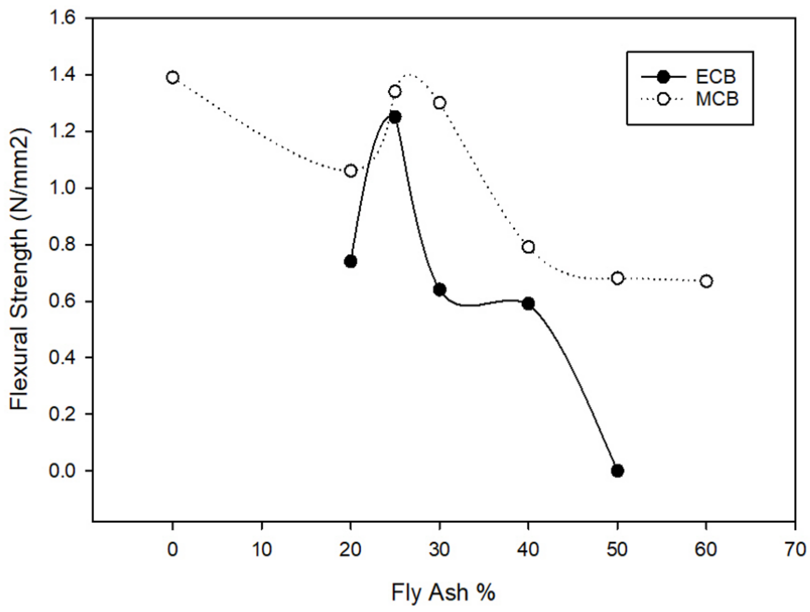

Fig 9 - Flexural strengths variation of burnt bricks with fly ash %

For the above-mentioned brick specimens, dry density and water absorption were calculated and those are shown in Table 4.

Table 4 - Density and water absorption of bricks

Brick specimen	Fly ash %	Dry Density (kg/m^3)	Water Absorption (%)

ECB-F20	20	1230	33.93
ECB-F25	25	1183	33.28
ECB-F30	30	1156	37.19
ECB-F40	40	1083	39.87
ECB-F50	50	1059	42.14
MB-1	-	1891	13.11
MCB-F00	0	1453	32.77
MCB-F20	20	1332	33.87
MCB-F25	25	1243	33.81
MCB-F30	30	1234	34.81
MCB-F40	40	1146	36.88
MCB-F50	50	1088	39.07
MCB-F60	60	1019	41.23

ECB: Extracted Clay Bricks, MB; Market Bricks, MCB: Market clay Bricks

According to the above test results, the most dominant feature is the reduction of density with fly ash addition. This will be a good feature in masonry construction since the handling of lightweight bricks requires less labour ending with unit rate reduction for masonry work. Considering the water absorption ratio, 25% of fly ash addition helps the lowest water absorption even though it is high compared to the market-available bricks. Finally, it can be concluded that the addition of 25% of fly ash would give the optimum results for burnt-bricks properties. Efflorescence test also was conducted for the bricks made with 25% fly ash addition. Results show that the bricks do not show any type of Efflorescence.

Wire-cut bricks made with 25% fly ash addition to extracted clay were tested for relevant properties and those are shown in Table 5.

Table 5 - Properties of wire-cut bricks

Property	Result	SLS 39 Requirement
Dry Compressive Strength	10.64 N/mm^2	10 N/mm^2
Flexural Strength	2.09 N/mm^2	-
Density	1708 kg/m^3	-
Water Absorption	16.25 %	18%

5. Conclusion

Clay bricks have been used as a key building element in the history of the construction industry. With the heavy usage of bricks with the rapid growth in the construction industry, raw material shortage for brick production is a severe problem. Alternative materials have been introduced by many researchers as a solution. Clay can be extracted from soil with high clay content. This would give a reasonable solution for materials shortage for burnt-brick production. The use of fly as to mix with extracted clay will be another benefit in two-fold. It will give a solution to the management of this industrial waste. Also, fly ash contributes to the burnt-bricks properties improvement. The study showed that the use of 25% fly ash with extracted clay for burnt-bricks production is a fair solution for the scarcity of material for burnt-clay bricks production. The present study can be extended further by researching the performance of wire-cut bricks for different fly ash percentages.

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