An Experimental Study of Bricks Made with Different Mineral Additives

Harsimranjit Singh¹, Mudasir Nazeer², Aditya Kumar Tiwary³

¹Lovely Professional University, Phagwara, India
²Dr B R Ambedkar National Institute of Technology Jalandhar, Ind
³Chandigarh University, Mohali, India

Abstract. Large numbers of bricks are required to meet the needs of increasing population for both residential and commercial sectors. The overall development and industrial development lead to the use of the traditional bricks at a very hefty rate. The traditional bricks are commonly made up of clay as its main component as a result it is on the verge of exhaustion. To standardize its broad, utilize and discovering its auxiliary one is the need of the hour. In this study, bricks were made by using different proportions of alternative materials like fly ash (FA), sand, lime and plaster of Paris. The size of specimen 230×110×70 mm was manufactured and quality constraints like compressive strength and water absorption were tested at different curing ages. The cost-effective mix design of the bricks for optimum compressive strength and rate analysis was also the part of this study. It was detected from the observation of results that the compressive strength decreases with increasing percentage in fly ash and increases with increasing percentage of sand and lime in fly ash-based bricks. Increment in water absorption was observed as fly ash content is increased and decrement of water absorption is seen with increasing percentage of sand and lime in fly ash-based bricks.

Keywords: Fly Ash, Water Absorption, Lime, Rate Analysis

1. Introduction
Brick is one of the most extensively used building material in the world of construction all over the world. It is the oldest building materials and still very popular and is widely used in construction as it is cheap, durable and easy to handle. About 25% of construction of building or houses is done by either brick masonry or block masonry [1]. The bricks have been manufactured since the dawn of
civilization all over the universe. In the beginning periods mud bricks were formed with the help of hands rather than the moulds of wood or metal, belong to the late Neolithic period and were found in Jericho [2–4]. The examples include one of the major structures of the period was the Neolithic long house. The world largest Great Wall of China was constructed by using both sun dried and fired bricks. The Ramesseum at Thebes, Egypt provides the finest example of mud bricks construction. Qutab Miner is one of the tallest bricks constructed structure minaret in the world. Furthermore, India is at the second number as producer of brick after China at number one in the world [5–7].

The clay brick has the advantages that it has good compressive strength, absorbs less water and are most popularly used in construction now a days. But while manufacturing these bricks, we are disturbing the environment by using the valuable soil or top most layer of soil which is useful for farmers to grow crops due to its fertility. Secondly during manufacturing of these bricks air get polluted during burning process of these bricks [8–10].

Moreover, boost in construction activities prove deficiency of conventional building materials and abundantly available industrial waste have endorsed the development of innovative building materials. So, to overcome these problems an economical alternative is to manufacture bricks by using fly ash as a raw material mixed with sand, lime or cement. Due to speedy upsurge in the capacity of thermal power generation in India, production of massive quantity of fly ash arises, which is almost 50 million tons per year. Fly ash is basically a fine graded material obtained from the combustion of coal, transported by flue gases and collected by electrostatic precipitators. It comprises of insignificant amount of un-burnt carbon which is acidic in nature. Its key ingredients are silica, aluminium oxide and ferrous oxide. These bricks have many advantages like proper utilization of fly ash [11–13], good strength, less water absorption and cheaper than clay bricks. These bricks are also called Eco friendly bricks because these bricks are manufactured without burning process and hence cause no air pollution. Fly ash bricks are manufactured using fly ash as a raw material mixed either with sand, lime or cement. Fly ash-cement bricks as the name indicate these bricks are manufactured by mixing fly ash as a raw material with sand and cement. Fly Ash Lime Gypsum Bricks abbreviated are manufactured by mixing fly ash with sand, lime and gypsum with desire quantity [14–16].

In this study, brick specimens of size 230x110x70 mm were made and quality constraints like compressive strength and water absorption were tested at different ages of curing. The cost-effective mix design of bricks which also shows optimum compressive strength was also performed in this study [17–19].

2. Experimental Program and Methodology

The experimental program involves two parts. In first part different bricks samples were collected from different manufacturing units of state of Punjab. 20 numbers of bricks were collected from each unit. Their ratios and material cost were compared. In second part different ratios samples were
manufactured. Total 19 samples are manufactured with different ratios each sample have 25 number of bricks. Methodology adopted is listed below:

i. Information was collected about fly ash bricks manufacturing units in the state of Punjab. Samples were collected and tested for various design parameters (Dimension test, Compressive strength test, water absorption and Dry density).

ii. Based on results obtained from collected samples and literature review different ratios were decided and the samples were manufactured and tested for quality parameters.

iii. From the test results of manufactured samples material ratios were decided corresponding to maximum strength.

iv. Considering the above selected ratio as standard ratio different design samples were again manufactured and tested for optimal values/ratios.

3. Material used
The different samples collected were manufactured using fly ash as a raw material mixed with sand, lime, POP and cement with different ratios of materials.

3.1 Fly ash
Fly ash as a raw material used in manufacturing fly ash bricks. Class C fly ash was taken from the nearby thermal Power Plant (Guru nanak dev thermal Power Plant) which is located in Bathinda Punjab. The various ingredients present in this ash are listed below in Table 1.

| S. No | Ingredients      | (%)  |
|-------|------------------|------|
| 1     | Silica           | 57-60|
| 2     | Alumina          | 24-25|
| 3     | Iron Oxide       | 7-8  |
| 4     | Lime             | 4    |
| 5     | Magnesium Oxide  | 2    |

3.2 Coarse Sand
Local coarse sand obtained from river bed was used and various properties, see table 2 and 3.

Table 2. Properties of sand
Table 3. Detail of ratios used in different collected samples

| Sr. No. | Name of Manufacturing Unit | Fly ash | Sand | Lime | POP | Cement |
|---------|-----------------------------|---------|------|------|-----|--------|
| 1       | MJ Bricks                   | 55      | 25   | 15   | 5   | -      |
| 2       | Paras Bricks                | 60      | 30   | 8    | 2   | -      |
| 3       | Power Fly ash Bricks        | 55      | 20   | 20   | 5   | -      |
| 4       | Ritika Fly ash Bricks       | 55      | 25   | 15   | 5   | -      |
| 5       | Ritika Fly ash Bricks       | 50      | 30   | 15   | 5   | -      |
| 6       | Bhucho Bricks               | 50      | 27   | 18   | 5   | -      |
| 7       | Vivek Bricks                | 60      | 10   | 25   | 5   | -      |
| 8       | Singla Bricks Industry      | 65      | 10   | 20   | 5   | -      |
| 9       | Garg Bricks Plant           | 50      | 30   | 15   | 5   | -      |
| 10      | Royal Bricks                | 50      | 35   | -    | -   | 15     |
| 11      | Khalsa Bricks               | 60      | 30   | -    | -   | 10     |
| 12      | Brawny Bricks Construction  | 45      | 50   | -    | -   | 5      |
| 13      | Ramjee Construction         | 15      | 50   | 30 (Slag) | 5 |

4. Design mix and manufacturing of bricks
From the help of collected samples, their ratios and with the help of literature review different ratio bricks were manufactured. Total three category bricks were manufactured. In first category fly ash by
weight is increased. In second category coarse sand increased by weight and in third category hydrated lime by weight is increased Total 9 numbers of samples were manufactured which consisted of 25 bricks each.

In category 1, fly ash variation is done by keeping coarse sand, hydrated lime and pop constant by Percentage. In category 2, variation of coarse sand done by keeping fly ash, hydrated lime and pop constant by Percentage. In category 3, variation of hydrated lime by weight is done by keeping fly ash, coarse sand and POP content constant (by Percentage), see table 4

| Sample | FA (%) | Coarse sand (%) | Hydrated lime (%) | POP (%) |
|--------|--------|-----------------|-------------------|--------|
| Fly ash variation (Category 1) |
| 1      | 38     | 33              | 24                | 5      |
| 2      | 42     | 31              | 22                | 5      |
| 3      | 46     | 29              | 20                | 5      |
| Coarse sand variation (Category 2) |
| 4      | 39     | 26              | 24                | 5      |
| 5      | 42     | 31              | 22                | 5      |
| 6      | 45     | 36              | 20                | 5      |
| Hydrated lime variation (Category 3) |
| 7      | 40     | 33              | 17                | 5      |
| 8      | 42     | 31              | 22                | 5      |
| 9      | 45     | 29              | 26                | 5      |

5. Results and Discussions

5.1 Compressive strength, water absorption and density

The test results of various samples collected from site were tested for different parameters like compressive strength, water absorption and dry density. It is detected from the result that the highest strength brick (power fly ash brick) having compressive strength of 24 N/mm², where the ratio of fly ash, sand, lime and POP were 55%, 20%, 20% and 5% respectively. The least compressive strength was observed as 3.28 N/mm², where the percentage of fly ash, sand, lime and POP was 60, 10, 25, and 5. Furthermore, the highest water absorption rate was observed as 25.15% and the lowest water absorption rate was observed as 13.8%. Moreover, the dry density was found maximum for 14 N/mm² compressive strength sample whereas lowest value of dry density was observed in 3.28 N/mm² compressive strength sample. The cost of per unit brick varies from 1.33 rupees to 3.00 rupees.
However, the cost of high strength brick was only 1.47 rupees and Table 5 presents all the result of samples.

Table 5. Results of different collected samples

| Sample No. | Name of Unit     | Water absorption (%) | Dry density (Kg/m³) | Compressive strength (N/mm²) | Material cost per brick (Rs.) |
|------------|------------------|----------------------|---------------------|-------------------------------|-----------------------------|
| 1          | MJ Bricks        | 17.40                | 1460.19             | 10.87                         | 1.33                        |
| 2          | Paras Bricks     | 15.10                | 1643.13             | 22.19                         | 1.33                        |
| 3          | Power FA Bricks  | 13.81                | 1560.36             | 24.00                         | 1.47                        |
| 4          | Ritika FA Bricks | 15.87                | 1482.77             | 6.04                          | 1.35                        |
| 5          | Ritika FA Bricks | 10.27                | 1533.59             | 10.27                         | 1.44                        |
| 6          | Bhucho Bricks    | 12.39                | 1449.15             | 18.00                         | 1.55                        |
| 7          | Vivek Bricks     | 25.15                | 1330.69             | 3.28                          | 1.43                        |
| 8          | Singla Bricks    | 10.39                | 1626.35             | 12.64                         | 1.59                        |
| 9          | Garg Bricks      | 10.03                | 1749.00             | 11.74                         | 1.83                        |
| 10         | Royal Bricks     | 15.32                | 1559.94             | 15.33                         | 3.00                        |
| 11         | Khalsa Bricks    | 19.67                | 1442.99             | 13.80                         | 1.91                        |
| 12         | Brawny Bricks    | 14.89                | 1593.14             | 12.32                         | 2.01                        |
| 13         | Ramjee Construction | 7.29              | 2089.22             | 14.00                         | 2.79                        |

5.2 Manufactured samples results

5.2.1 Compressive strength
The strength test (compressive strength) was conducted on the brick samples of all the three categories at 7- and 28-day of curing age. It is evident from the graph between fly ash (FA) content and compressive strength (CS) that with increase in content of fly ash, compressive strength of brick gets decreased. However, 28 day curing strength is higher than the 7-day curing strength. Furthermore, Figure 1 and 2 represented between sand content and compressive strength shows inverse parabolic curve path which suggests that with increase in sand content, initially compressive slightly decreases and then it increases with age. Moreover, with increase in content of lime compressive strength of brick sample increases.

5.2.2 Water Absorption

Water absorption test was conducted on all the brick samples after 28-days of curing age. It was observed that water absorption rate increases with increase in the percentage of fly ash. However, on increasing the sand content in the mix, rate of water absorption decreases. Furthermore, water absorption shows gradual increment when lime content is increased in the mix as shown in Figure 3 and 4.
5.2.3 Dry Density

The observations of dry density shows that the density (dry) decreases with increasing percentage of fly ash content but with increase in sand content dry density of brick sample starts increasing. Furthermore, a steep increase in density was observed when lime content of the mix was increased as shown in Figure 5 and 6.

![Figure 5. Dry density Vs Fly ash](image)

![Figure 6. Dry density Vs Lime](image)

6. Conclusion

This investigation was done in two different stages, in first stage the strength parameters like compressive strength, water absorption rate and dry density of 13 ready-made brick samples were conducted and in second stage different sample of mix were made to find the optimum sample of design mix. The self-made brick samples were prepared in three different stages with change in content of fly ash, sand and lime content. It was observed that with increase in content of lime in mix, compressive strength of mix increases and compressive strength decreases with increasing percentage of fly ash in the mix. Furthermore, rate analysis was performed in which it was observed that the brick having maximum strength need only proper proportion of mix content. The rate per piece of brick of high strength was only 1.47 rupees.

References

[1] Hany E, Fouad N, Abdel-Wahab M and Sadek E 2021 Investigating the mechanical and
thermal properties of compressed earth bricks made by eco-friendly stabilization materials as partial or full replacement of cement *Constr. Build. Mater.* **281**

[2] Gencel O, Kazmi S M S, Munir M J, Sutcu M, Erdogmus E and Yaras A 2021 Feasibility of using clay-free bricks manufactured from water treatment sludge, glass, and marble wastes: An exploratory study *Constr. Build. Mater.* **298**

[3] Wang W, Gan Y and Kang X 2021 Synthesis and characterization of sustainable eco-friendly unburned bricks from slate tailings *J. Mater. Res. Technol.* **14** 1697–708

[4] Ibrahim J E F M, Tihtih M and Gömze L A 2021 Environmentally-friendly ceramic bricks made from zeolite-poor rock and sawdust *Constr. Build. Mater.* **297**

[5] Akinyemi B A, Orogbade B O, Ogheneyome A, Abeer M A, Khan A, Mahmoud A H and Asiri A 2021 Influence of alkali activators on thermo-physical properties of ecofriendly unfired clay bricks from anthill mounds *Eur. J. Environ. Civ. Eng.*

[6] Asfora V K, Bueno C C, de Barros V M, Khoury H and Van Grieken R 2021 X-ray spectrometry applied for characterization of bricks of Brazilian historical sites *X-Ray Spectrom.* **50** 45–52

[7] Yugasini S, Uma Maguesvari M, Muthaiyan P and Ammaippan M 2020 Comparative study of conventional bricks with Padobe *IOP Conference Series: Materials Science and Engineering* vol 989, ed H S M Vasugi V. (IOP Publishing Ltd)

[8] Arsyad M, Umar M Z and Faslih A 2020 Physical testing of concrete brick material made by community in Petoaha Village Nambo District Kendari City Southeast Sulawesi Province *AIP Conference Proceedings* vol 2255, ed N I G D Kusrini E. (American Institute of Physics Inc.)

[9] Ongpeng J M C, Inciong E, Sendo V, Soliman C and Siggaot A 2020 Using waste in producing bio-composite mycelium bricks *Appl. Sci.* **10**

[10] Li K, Wang X, Li H, Zheng M, Peng B, Kong F and Zhang Z 2020 Analysis on energy saving and thermal insulation performance of improved straw brick in northern cold area *Arab. J. Geosci.* **13**

[11] Dontriros S, Nooaek P and Supakata N 2020 Geopolymer bricks from concrete residue and palm oil fuel ash: Evaluating physical-mechanical properties, life cycle assessment and economic feasibility *EnvironmentAsia* **13** 150–62

[12] Retno Susilorini M I, William S S, Rianto, Kartikowati S, Setiawan M H, Ludfie Hardian P
and Kurniawan E 2020 Masonry walls retrofitting with eco-concrete bricks in tidal flooding prone area *Int. J. Eng. Res. Technol.* **13** 560–9

[13] Yedri A B, Ammari M and Allal L B 2020 Assessment of Mechanical and Thermal Performances of a Ceramic Product Incorporating an Industrial Waste ed E M. *Adv. Intell. Syst. Comput.* **1104** AISC 86–97

[14] Ajam L, Ben El Haj Hassen A and Reguigui N 2019 Phosphogypsum utilization in fired bricks: Radioactivity assessment and durability *J. Build. Eng.* **26**

[15] Gowthami N R, Sivaji A and Ajay Kumar Reddy K 2019 Geopolymer brick by using flyash, GGBS, Silica Fume and Kadapa slab dust *Int. J. Recent Technol. Eng.* **8** 2541–5

[16] Parashar A K 2019 Augmentation of compressive strength of bricks made of various materials by adding molten plastic waste *Int. J. Innov. Technol. Explor. Eng.* **8** 3249–54

[17] Kumar R, Chohan J S, Goyal R and Chauhan P 2020 Impact of process parameters of resistance spot welding on mechanical properties and micro hardness of stainless steel 304 weldments *Int. J. Struct. Integr.* ahead-of-p

[18] Gairola P, Gairola S P, Kumar V, Singh K and Dhawan S K 2016 Barium ferrite and graphite integrated with polyaniline as effective shield against electromagnetic interference *Synth. Met.* **221** 326–31

[19] Abbas A T, Gupta M K, Soliman M S, Mia M, Hegab H, Luqman M and Pimenov D Y 2019 Sustainability assessment associated with surface roughness and power consumption characteristics in nanofluid MQL-assisted turning of AISI 1045 steel *Int. J. Adv. Manuf. Technol.* **105** 1311–27