Quantification of Non-conventional Brick's Characteristic Compressive Strength

Jyoti Prakash Giri¹ and Monalisa Priyadarshini²

¹Assistant Professor, Department of Civil Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India, 532127, Email: jyotiprakash.g@gmrit.edu.in.

²Assistant Professor, Department of Civil Engineering, Government College of Engineering Kalahandi, Bhawanipatna, Odisha 766002, India, Email: monalisa@gcekbpatna.ac.in.

Abstract. Now-a-days researches are concentrating on the utilization of waste materials in construction industry. Fly ash is one of the waste originated from industrial, is the main concern in the present study for brick manufacturing. As fly-ash is a by-product, its properties may vary from source to source resulting variation in strength of the brick. To confirming this, the main focus of the present study was to fabricate a hydraulically operated semi-automatic brick pressing machine followed by preparation of fly ash brick using that and study on the variation of brick strength. Later on, a statistical analysis is conducted based on the experimental compressive strength data for the fly ash bricks. The normal distribution curves are plotted followed by the estimating the constraints of normal distribution, which is the most common adopted distribution function in concrete. From the analysis, the characteristic compressive strength at 95% probability level is obtained as 3.46 and 5.42MPa respectively for the bricks (M1 and M2 type).

1. Introduction
Brick industry is one of the oldest one and popular for burnt block achieved after burning of clay in a kiln. As brick is a major construction material in the construction industry, it is also considerable that use of clay bricks creates a depletion of natural resources. Hence, numbers of researchers were explored the use of different waste materials to produce brick and try to conserve the natural clay. Generally, fly ash (FA) is a fine waste material obtained from power plant after coal combustion. This waste usually retains pozzolanic properties and offered advantages by enhancing the strength of concrete. This same pozzolanic behaviour when reacts with lime also found that helps in improvement of the quality of bricks compared to conventional clay brick [1]. The usage of fly ash in non-conventional bricks has been confirmed by different researchers and observed that, different source of fly ash offering different performance [1-8]. Similarly compaction process of brick also plays an important role for their quality. Keeping all point in mind, the objective of the study is to fabricate a semi-automatic brick pressing machine followed by a probabilistic analysis on compressive strength of compacted bricks based on the experimental result at 95% level.

2. Semi-Automatic Brick Pressing Machine
As fabrication of brick pressing machine comprises a part of the present study, it was proposed to prepare the fly ash bricks imparting with other binding materials with desired pressure which resulting a dense compacted bricks for further observations in economical way. This machine marked as semi-automated, i.e. the functions of pressing and extraction from the brick mould are automated, whereas feeding of material into the machine is manual. The details of the pressing machine are summarized in Table 1 and Figure 1.
Table 1. Detail specification of machine

| Machine capacity     | 300 numbers of ‘bricks 8 hours |
|----------------------|---------------------------------|
| Mould size           | 190mm x 90mm x 90mm             |
| Brick /stroke        | 2                               |
| Power of reciprocal  | 2kW                             |
| type motor           |                                 |
| Load                 | 12-15 kN                        |
| Cylinder (Hydraulically operated) | inner diameter of 125mm with outer diameter of 145mm, a shaft of diameter 60 mm |
| Table                | cast iron with 850mm x 300 x 800mm size |
| Hopper capacity      | 13590 cc                        |
| Die                  | 200 x 200 x 100 mm.             |
| Hydraulic oil tank   | 45 lit. capacity                |
| Mixer                | Manual                          |

Figure 1. Semi-automatic hydraulically operated brick pressing machine

3. Experimental Programme

3.1 Materials

The main aim of this experimental programme involves with the casting and testing the fly ash bricks. For this, the fly ash was collected from two different sources such as NALCO, Damonjodi and NTPC, Kaniha. The specific gravity of both the fly ash was found in laboratory as 2.28 and 2.19 respectively. The raw materials used to prepare these non-conventional bricks were fly ash, sludge lime, sand and gypsum based on the proportions suggested by NTPC report (Table 2). The sand was collected from a local river bed of Sagada. The fineness modulus and specific gravity of the sand was found as 2.37 and 2.65 in the laboratory respectively. The sludge lime was obtained from a nearby waste water treatment plant having specific gravity of 2.53 and the gypsum was collected from local source having specific gravity of 2.34. In the present study, two types of mixes were compacted using the fabricated pressing machine marked as M1 (fly ash from NTPC, Kaniha) and M2 (fly ash from NALCO, Damonjodi). After compaction, the average strength at 21 days for both the mixes were recorded to do the probabilistic analysis and to obtained the characteristic compressive strength at 95% confidence level.
Table 2. Details of the composition taken in bricks

| Mix Id | Fly ash | Sand | Sludge Lime | Gypsum |
|--------|---------|------|-------------|--------|
| M₁     | 45%     | 30%  | 20%         | 5%     |
| M₂     | 45%     | 30%  | 20%         | 5%     |

3.2 Preparation of Bricks

First the materials were weighted (Table 2) as per the requirement and then mixed homogenously by adding required amount of water. After a homogenous mix it was fed into the hopper which is placed just above the brick mould. From the hopper the required quantity of materials was led into the mould and the mould was uniformly pressed hydraulically to formed dense bricks [Figure. 2(a)]. Then the moulds were hydraulically released and uplifted to release the pressed bricks. Using another hydraulic cylinder, the bricks were pushed to a ply board and allowed for an air curing for 1 day followed by 1 day sun dry. After 2 days, the same was transferred to water curing for 21 days. Figure.2 (b) and Figure.2 (c) represent the bricks before and after curing respectively.

![Figure 2](image)

4. Experimental Results

Fifty numbers bricks were casted using the machine for the each type mixes. The bricks after required curing were tested to observe the compressive strength using compression testing machine as shown in Figure.3. The average compressive strength of M₁ and M₂ fly ash brick samples are presented in Table 3.

![Figure 3](image)

Table 3. Compressive strength of bricks

| Mix Id | Average compressive strength (MPa) |
|--------|-----------------------------------|
| M₁     | 3.22                              |
| M₂     | 5.18                              |
5. **Probabilistic Analysis**

The real-world engineering situations are to mainly minimize with the uncertainty through an appropriate probabilistic model [9]. The normal distribution (Eq.1) which is the most commonly used distribution in statistics and it also applicable to a wide range of events in Civil Engineering applications [6-7].

\[
f(x)=\frac{1}{\sigma \sqrt{2\pi}} \exp \left[-\frac{1}{2} \left(\frac{x-\mu}{\sigma}\right)^2\right]
\]  

(1)

Where \( \mu \) and \( \sigma \) are represented as the mean and standard deviation.

![Figure 4. Normal distribution curve](image)

The probability is obtaining randomly and it is a score to be evaluated from a normal distribution using an empirical rule. From Figure 4, it can be observed that 95% of values fall within the two standard deviations from the mean. The compressive strength of hundred numbers of non-conventional fly ash bricks after 21 days were the initial data for the normal probabilistic analysis. From this compressive strength, the estimated constraints were evaluated for normal distribution summarized in Table 4. By considering these estimated constraints, the normal distribution curves for brick M1 and M2 was presented in Figure 5. From the Figure 6, the characteristic compressive strength value at 95% probability level for mixes M1 and M2 bricks were estimated and shown in Table 5.

| Table 4. Estimated constraints of normal distribution |
|----------------------------------------------------|
| Estimated Parameters | M1 | M2 |
|----------------------|----|----|
| Minimum value        | 1.97 | 2.73 |
| Maximum value        | 5.86 | 8.22 |
| Mean                 | 3.22 | 5.18 |
| Standard deviation   | 0.52 | 0.58 |
| Variance             | 0.30 | 0.47 |
| Skewness             | 0.00 | 0.00 |
| Kurtosis             | 0.00 | 0.00 |

![Figure 5. Normal distribution plot for the bricks (M1 and M2)](image)
6. Conclusions

Based on the above experimental and probability analysis, the non-conventional bricks compacted with fly ash, sand, sludge lime and gypsum, the highest compressive strength was observed during the experimental work for the brick (M2) prepared with fly ash collected from NALCO. From the statistical analysis evaluated for the normal probability distribution at 95% of confidence level were observed highest strength for the same M2 mix. The reason behind the highest characteristic compressive strength for M2 mix may be due to the aluminum content available in the fly ash as it was obtained from NALCO whereas another one from coal. However, both the mixes were offered acceptable result (> 3.5MPa) according to codal provision [10]. From this it can be concluded that the strength behavior of bricks may vary with the source of fly ash. Addition to this, all source of fly ash used in brick preparation are confirming their performance requirement as per Indian specification which helps to conserve the natural resources as well as protecting the environment.

7. References

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