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Variation Analysis of Compressive Strength and Dry Density of Cellular Lightweight Concrete (CLC) Brick with Replacement of Sand by Fly Ash

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Abstract

The alternatives of conventional bricks are being searched widely due to heavy dead load and environmental issues during the manufacturing process of these bricks. This study aims to produce and analyze the properties of Cellular Light Weight Concrete (CLC) brick in terms of compressive strength and density at different compositions of the constituents. Sand is replaced by fly ash in the composition of CLC brick as 0, 20, 40, 50, 60, 80, and 100% and tested to optimize the fly ash to sand ratio. In the tested samples, compressive strength of CLC brick found as 2.4, 2.59, 3.84, 4.11, 5.29, 6.39 and 7.87 MPa respectively. The compressive strength of the randomly selected red clay brick in market found as 8.78 MPa. When compared with the red clay brick the compressive strength of CLC brick was found to be less by 10.26%. The dry density of above composition was found as 988, 1005, 1041, 1094, 1122, 1176 and 1210 kg/m^3 respectively, whereas the dry density of randomly selected red clay brick was 1584 kg/m^3. Experiment showed that CLC brick has less compressive strength than that of red clay brick; however compressive strength to density ratio of CLC brick is better than that of conventional brick, which ultimately results to choose CLC brick over conventional brick.

Keywords

Brick, CLC, Compressive strength, Density, Fly ash, Red clay brick, Mould

1. Introduction

Brick is one of the most extensively used construction material used in various load bearing and non-load bearing structural elements. A brick can be composed of clay-bearing soil, sand, and lime, or concrete materials [1]. The red clay brick have higher dead weight thus contribute to the unnecessary load on the buildings and construction projects. The use of these types of brick deteriorates and decreases the agricultural lands and overall agricultural productivity of the country.

These traditional bricks are being substituted by recent Cellular Light Weight Technology which is an economical and environmentally sound alternative to the red bricks. Furthermore energy consumed in the production of the Cellular Light Weight (CLC) Brick is only a fraction compared to the production of red bricks [2]. It is produced by initially making slurry of cement, sand, fly ash, foam and water.

CLC bricks are taken as better alternatives to red clay bricks in the construction market in terms of quality, reliability and environmental and social impact. CLC are deemed to have better sound insulation, thermal insulation, no pollution to the environment, less density, less weight, easy to use, less water absorption.

Assumptions:

- Temperature and humidity are assumed to be consistent in preparing all samples of each type
- Mixture of all ingredients of brick is homogeneous.
- No admixtures have been used while preparing of brick.
- Properties are same in manual and machine mixing.
- Ambient conditions are constant.

Despite of increasing use of CLC bricks in the markets, there is a serious lack of extensive research to optimize the mix ratio and various properties of the brick. However some experiments were already carried out by researchers mainly to increase strength and other mechanical properties [3].

studied the influence of filler type on the properties of foam concrete and concluded that the reduction of particle size of sand caused improvement in strength of the foam concrete and finer filler resulted in higher strength to density ratio.[2] concluded the red clay brick production industry was the major source of air pollution and recommended CLC as the potential replacement to clay brick because of its environmental friendliness and enhancement of overall quality. In 2014 research about effect of admixtures on the physical properties of non-autoclaved light weight blocks using pond ash were conducted and concluded that when no additive was used the compressive strength of the blocks decreases as the percentage of fly ash increases upto 90 days of curing [4] . Other experiments found that strength values of steam curing are slightly better and water absorption values are less than that of water curing [5] . Study by [6] showed that the mixture of fly ash and cement provides better strength and less water absorption compared to conventional bricks. In 2015, research about thermal behavior of expanded polystyrene based light weight concrete sandwich panel at various heat input was conducted and concluded that thermal conductivity at room temperature is found to be nearly three times less than that of common building brick [7].

2. Research Methodology

To analyze the variation of compressive strength and density of Cellular Lightweight Concrete (CLC) brick with composition and compare it with red clay brick following process (as shown in figure 1) was followed. Before starting production the literatures regarding the production and properties testing of CLC brick were reviewed from different sources. After reviewing previous researches then the production site was selected by visiting the different factories regarding the production of CLC brick production within the country Nepal. Material collection was done after finalizing the problem regarding CLC bricks and our research objective was set. Mould was prepared to achieve our standard size (8” × 4” × 2.5”) of the sample. Wooden mould was prepared manually and size was thoroughly checked to get precise dimension of the brick. The mixture has been prepared using a research study by [8].

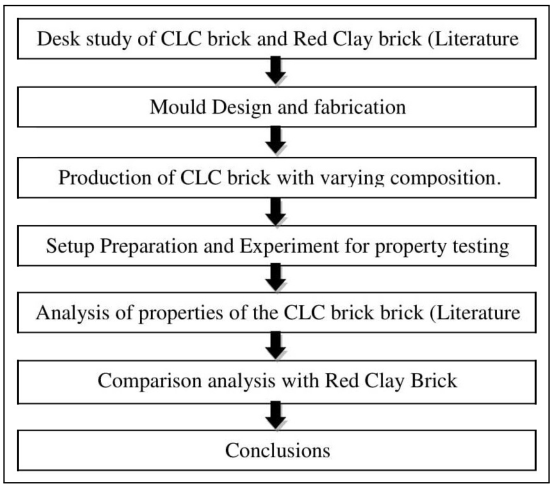

Figure 1: Methodology

They have achieved optimum strength with sand cement ratio of 1.43 keeping other ingredients constant. Our experimental samples also comprise of same materials and ratios except we replaced weight of sand with sand and fly ash in different proportions. The mixture proportions are shown in the table 1.

Table 1: Composition of the CLC samples

S.N.	% Replacement of sand by fly ash	Composition in kg				
		Cement	Water	Foam	Fly ash	Sand
1	0	5.25	3.5	0.5	0	7.5
2	20	5.25	3.5	0.5	1.5	6
3	40	5.25	3.5	0.5	3	4.5
4	50	5.25	3.5	0.5	3.75	3.75
5	60	5.25	3.5	0.5	4.5	3
6	80	5.25	3.5	0.5	6	1.5
7	100	5.25	3.5	0.5	7.5	0

Seven Samples of each composition was prepared for different properties test. Different amount of fly ash was used to replace sand and properties were checked to obtain optimum fly ash to sand ratio. The amount of cement, water and foam was kept uniform in all samples to get unbiased results for fly ash content. All the materials for each sample were mixed in a specially designed manual mixture bucket as shown in fig 2. A steel hand stirrup is used to get homogenous mixture of the slurry.

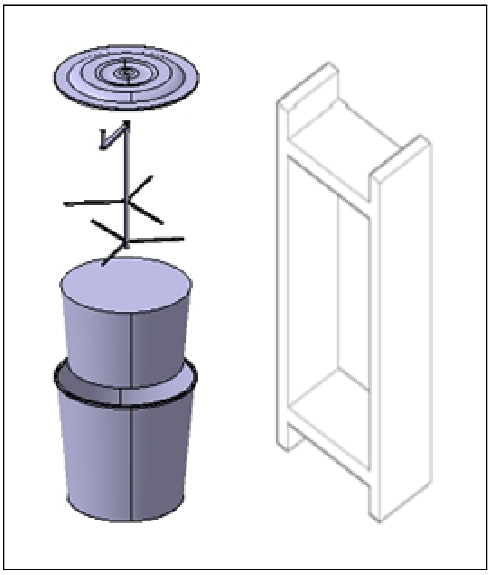

Figure 2: Designed mixture bucket, rotor and mould

All the samples were water cured for 28 days and kept in uniform room temperature. After 28 days, all samples are ready to test for density and compressive strength. The figures of fabricated brick mould and produced bricks are as shown in Figures 3 and 4.

Figure 3: Brick Mould

Figure 4: Produced CLC Bricks

2.1 Dry Density

Each samples were weighted in a digital weighing machine after drying and the density was calculated as below.

$$\rho = \frac{\sum\left(\frac{m}{v}\right)}{n} \quad (1)$$

Here, m is the weighted mass and V is the volume of the sample. Average density (ρ) is calculated using the mean of all n number of samples of same composition.

2.2 Compressive Strength

Compressive strength of each sample is tested in hydraulic compressive strength testing machine as shown in figure 5. The load applied to break the sample during test was noted and compressive strength of each composition was calculated using following equation.

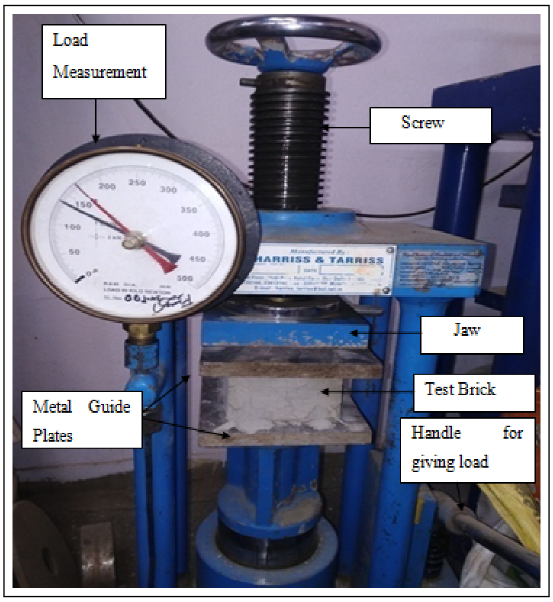

Figure 5: Experimental Set up for Compression Test

$$\sigma_c = \frac{\sum\left(\frac{F}{A}\right)}{n} \quad (2)$$

Above equation shows that the compressive strength of each block is calculated by dividing the load applied by area of contact. Average compressive strength is calculated using arithmetic mean of each sample.

3. Result and Discussion

Various physical and mechanical properties of the samples were tested and averaged with respect to composition. Dry density and compressive strength of each composition are calculated and compared along with randomly bought red clay brick from the market.

3.1 Dry Density

The figure 6 as shown below shows the densities of different samples when sand is replaced by fly ash with different ratios.

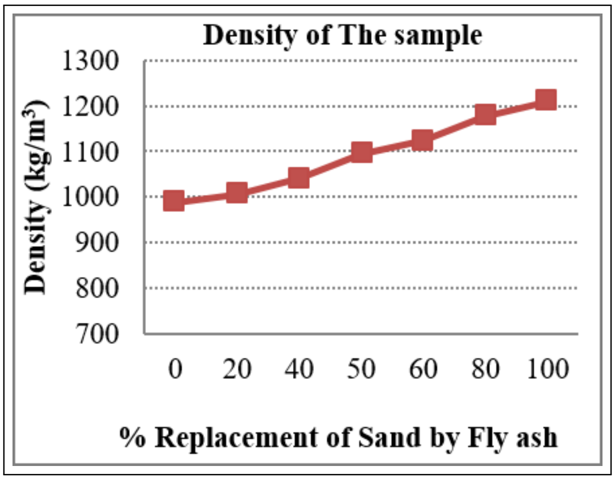

Figure 6: Dry Density of the Samples

The density of CLC is increased slightly with increase in fly ash content in the mixture. This may be due to the tight filling of voids and better bonding between ash, sand and cement. Although the density of the CLC sample ranging from 988 to 1210 kg/m^3, it's still very lower than that of red clay brick which is 1584 kg/m^3.

3.2 Compressive Strength

Our result on compressive strength shows the CLC brick gains considerably high compressive strength with increase in the fly ash content as shown in figure 7. The compressive strength without fly ash is 2.41 MPa and that of the sample with all sand replaced by fly ash is 7.88 MPa. Compressive strength of 100% fly ash in place of sand is nearly equal to the red clay brick which is found to be 8.78 MPa, other samples have inferior compressive strength compared to red clay brick.

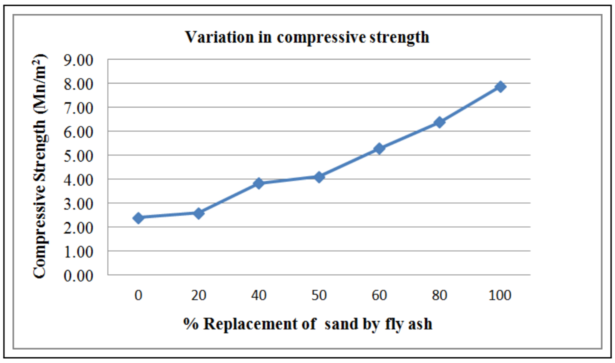

Figure 7: Variation of Compressive Strength of CLC brick samples

Figure 8 as shown below represents the relation of compressive strength with dry density of the sample. Compressive strength is being increased with increase in dry density. However, in the real practice, high dry density results in the increase in dead load, which means, lower density brick will face lower loads with similar external conditions. Hence, even the brick with lower compressive strength may be stronger than that of heavier brick.

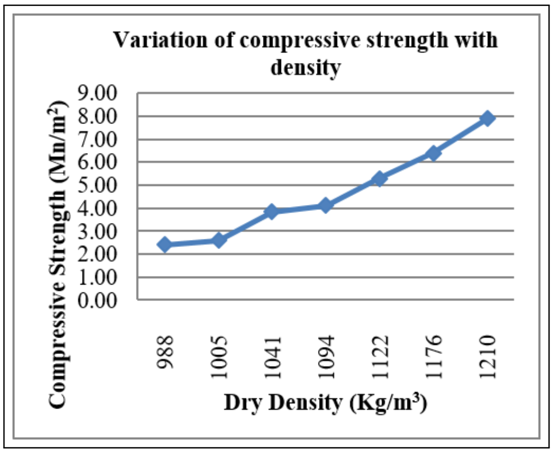

Figure 8: Variation of Compressive Strength with Density

4. Conclusion

Manual production and testing of CLC bricks to compare with randomly selected red clay bricks from the market have been carried out successfully. Experiments showed that dry density of the composition found as 988, 1005, 1041, 1094, 1122, 1176 and 1210 kg/m^3 for different seven compositions. Compressive strength of those CLC brick found as 2.4, 2.59, 3.84, 4.11, 5.29, 6.39 and 7.87 MPa respectively. When compared with the randomly selected red clay brick, dry density of CLC brick was found to be less by 23.61% and maximum compressive strength was found to be less by 10.26%. However the compressive strength of CLC brick is less than that of red clay brick, it will have less dead load due to lower dry density, so it will be more effective due to better strength to density ratio. Since the manufacturing process of CLC brick is more environment friendly than that of conventional bricks, more use of CLC brick is recommended for the market.

This experiment showed the inferiority of CLC brick in compressive strength, so further study and research is necessary to increase the strength without losing other properties of the brick. Other admixtures and materials may help to increase the strength of the CLC brick.

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