



## Experimental Investigation into the Construction of Building Blocks, using Fly Ash, Sand, and PPC, with Gypsum Added

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**Abstract:** An effort is made toward the preparation of fly ash-based building blocks with varying water binder ratios in order to achieve the goal of obtaining a building block with a high strength using both conventional and non-conventional construction materials. The purpose of the experimental program is to examine the possibility of casting building blocks using fly ash, sand, cement, and gypsum in order to meet the demand for clay bricks. 230 millimeters by 120 millimeters by 120 millimeters was the dimensions of the building block specimen that was obtained. The mix proportions that were used were fly ash (40-50 percent), sand (33-43%), cement (15 percent), and gypsum (2 percent). The water-binder ratios that were used were 0.70, 0.75, and 0.80. In addition to determining the compressive strength of building blocks in comparison to clay brick, the purpose of this research was to identify the optimal mix ratio of fly ash, sand, PPC, and gypsum for standard sizes of building blocks. Specimens were examined for a period of seven, fourteen, and twenty-eight days. The research indicates that the optimal composition for fly ash, sand, cement, and gypsum building blocks was forty percent fly ash, forty-three percent sand, fifteen percent cement, and two percent gypsum.

**IndexTerms –** Water binding ratio, optimum mix ratio, fly ash bricks, building blocks

### I. INTRODUCTION

Fly ash, which is sometimes referred to as "pulverized fuel ash" in the United Kingdom, is a result of coal combustion that is made up of the particulates, which are fine particles of fuel, that are expelled from coal-fired boilers along with the flue gases. The term "bottom ash" refers to the ash that was deposited at the bottom of the boiler. Before the flue gases reach the chimneys, fly ash is typically collected by electrostatic precipitators or other particle filtration equipment in modern coal-fired power plants. This occurs before the particles are released into the atmosphere. Coal ash is the term used to describe the mixture of bottom ash and bottom ash that is removed from the bottom of the boiler. The components of fly ash can vary greatly depending on the origin of the coal that is being burned and the composition of the coal itself; however, all fly ash contains significant quantities of silicon dioxide (SiO<sub>2</sub>) (both amorphous and crystalline), aluminum oxide (Al<sub>2</sub>O<sub>3</sub>), and calcium oxide (CaO), which are the primary mineral compounds found in coal-bearing rock strata. Prior to the implementation of air pollution control regulations, fly ash was typically discharged into the atmosphere. However, these rules now mandate that fly ash must be caught before it is discharged by installing pollution control equipment. It is common practice in the United States to either store fly ash at coal power stations or to put it in landfills. It is frequently used as a pozzolan in the production of hydraulic cement or hydraulic plaster, and it is also utilized as a substitute or partial replacement for Portland cement in the production of concrete. Approximately 43 percent of the material is recycled. Pozzolans are used to ensure that concrete and plaster will set properly, and they also give concrete with increased protection against attacks from chemicals and moist circumstances.

### II. LITERATURE REVIEW

Siddique et. al. [1] Fly ash, a byproduct of coal combustion, has significant potential as a substitute for traditional building materials. Its pozzolanic properties improve the strength and durability of concrete while reducing the environmental impact. Studies indicate that incorporating fly ash into cementitious mixtures enhances workability, reduces water demand, and increases resistance to sulfate attacks. However, its effectiveness depends on particle size, fineness, and chemical composition.

Malhotra et. al. [2] Sand serves as a primary filler material in concrete, providing bulk and influencing strength and durability. Research shows that the type and gradation of sand significantly affect the compressive strength and workability of concrete. The use of river sand, though common, is being substituted with manufactured sand and alternative materials due to environmental concerns. Optimal mixing proportions of sand with fly ash and other binders yield better compaction and strength.

Tiwari et. al. [3] PPC is a blended cement that includes fly ash as a component, offering enhanced durability, reduced permeability, and resistance to chemical attacks. It contributes to energy efficiency and sustainability in construction practices. Studies reveal that the use of PPC in fly ash-based blocks results in better long-term strength gain compared to ordinary Portland cement. PPC's slow hydration rate also helps reduce cracking and shrinkage.

Ghosh et. al. [4] Gypsum is widely used as a retarder in cement, regulating the setting time and improving workability. It also contributes to the compressive strength and durability of fly ash-based composites. Research highlights that adding gypsum to fly ash and PPC mixtures improves binding properties and reduces shrinkage. Additionally, its role in mitigating the effects of efflorescence makes it a valuable additive.

Chindaprasirt et. al. [5] The use of fly ash in building blocks reduces dependence on natural resources and mitigates waste disposal issues. Fly ash blocks exhibit better thermal insulation, fire resistance, and sound absorption properties compared to conventional clay bricks. Studies emphasize the importance of proper curing and proportioning to achieve optimal performance. Moreover, the environmental footprint of these blocks is significantly lower.

Meyer et. al. [6] Fly ash-based building blocks have shown promising results in terms of compressive strength and durability. Research demonstrates that proper blending of fly ash, sand, PPC, and gypsum achieves higher strength and resistance to environmental degradation. These blocks perform well under load and exhibit resistance to water absorption, making them suitable for various climatic conditions.

Joseph et. al. [7] Despite its benefits, the use of fly ash in building blocks presents challenges such as variability in material quality and handling issues. Innovations in mix design and curing techniques are being explored to address these limitations. Recent studies focus on optimizing fly ash content and integrating additional binders like gypsum to enhance performance and sustainability. Advances in automated production also contribute to the consistency and quality of fly ash blocks.

### III. OBJECTIVES

1. To figure out the best proportion of fly ash, sand, PPC, and gypsum to use in the mix for the conventional size of building blocks.
2. To calculate the compressive strength of the construction block.
3. To evaluate the durability of construction blocks in comparison to traditional clay bricks.
4. To conduct an investigation into whether or not building blocks can serve as a suitable substitute for clay bricks.

### IV. RESEARCH METHODOLOGY

This research assesses the mechanical characteristics and cement generated from locally sourced waste materials, including fly ash, sand, and gypsum. To attain these aims, the subsequent phases were implemented. The initial process was acquiring the components and by-products for the Fly ash blocks. In the second phase, specimens of Fly ash blocks were prepared, and in the third phase, compressive strength tests were undertaken. This chapter comprehensively examines all three periods.

#### Materials Utilized

The materials utilised in the fabrication of building blocks include fly ash (F.A.), sand, cement, gypsum and water. The fly ash utilised in this investigation was sourced from the Bara Thermal Power Plant in Allahabad. The additional materials, namely cement, sand, and gypsum, were procured from the local market.

#### Pulverised Fuel Ash

Fly ash is a finely divided residue produced from the burning of pulverised coal, carried by flue gases and collected by an electrostatic precipitator. Class F fly ash is typically generated from the combustion of anthracite or bituminous coal that satisfies the relevant specifications. This Class F fly ash possesses pozzolanic characteristics and contains a minimal of silica dioxide, aluminium oxide, and iron oxide. The physical and chemical parameters of the fly ash utilised in the studies are presented in Tables 3.1 and 3.2, respectively.



Fig 1: Fly ash class F

#### Chemical Properties of fly ash collected from Bara thermal plant

The fly ash that is used in concrete as a substitute for cement were obtained from thermal power plant. Following the completion of the chemical analysis, the results are presented in Table 3.1. Based on the findings of the tests, it is possible to draw the conclusion that the Fly Ash is classified as Class –F according to the ASTM classification system and Grade I according to IS 3812.

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**Table 1: Chemical Properties of Fly ash**

Sr. No.	Chemical compound	Requirement as per IS:3812 in %	Test Results in %
1	Silicon dioxide( $\text{SiO}_2$ )	35.0 Min.	60.21
2	Aluminium oxide( $\text{Al}_2\text{O}_3$ )	Not Specified	26.08
3	Iron oxide( $\text{Fe}_2\text{O}_3$ )	Not Specified	4.80
4	Calcium Oxide( $\text{CaO}$ )	Not Specified	1.00
5	Magnesium Oxide( $\text{MgO}$ )	5.0 Max.	0.25
6	Sulphur Trioxide( $\text{SO}_3$ )	3.0 Max.	0.25

The particles that make up fly ash can range in shape from spherical to irregular, and their diameters can be anywhere from 0.5 to 150 meters.

**Table 2: Physical Properties of Fly ash**

Properties	Result
Specific gravity	2.3
Moisture content	19.75
Fineness	0.001-0.6mm
Maximum dry density	1.53g/cm <sup>3</sup>
Permeability	4.87×10 <sup>-7</sup> cm/s
Cohesion	3-34Kpa

## Cement

During the course of the research, a single batch of Portland pozzolana cement manufactured by Prism champion was utilised. The experimentally determined chemical and physical characteristics of cement are presented in Tables 3.3 and 3.4, respectively, as a result of the testing. All of the tests are carried out in accordance with the protocol that is outlined in IS 1489 (Part 1):1991, which is applicable to pozzolana cements.



Fig 2: Cement (PPC)

## Chemical properties of cement

Four major oxides (CaO, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, and Fe<sub>2</sub>O<sub>3</sub>) occupy the volume of cement (90%). The main chemical contents of Portland cement are tabulated below .

Table 3: Chemical Properties of cement used for the experiment

Chemical content	Amount%
Calcium oxide(CaO)	60-67
Silicon dioxide(SiO <sub>2</sub> )	17-25
Aluminium oxide(AlO <sub>2</sub> )	3-8
Iron oxide(Fe <sub>2</sub> O <sub>2</sub> )	0.5-6
Magnesium oxide(MgO)	0.1-4

Sodium oxide( $\text{Na}_2\text{O}$ )	0.2-1.3
Potassium oxide( $\text{K}_2\text{O}$ )	0.2-1.3
Sulfur trioxide( $\text{SO}_3$ )	1-3

### Methods Used for Specimen Preparation

#### ➤ Setting time

Premix mortar product was usually de-molded 24 hours after casting.

#### ➤ Mixing Process

When it comes to premix, mixing is a very crucial component, and it is essential to adhere to the recommendation. The qualities and look of the finished composite 27, 27, and 27 control specimens were cast in order to determine the compressive strength at 1, 2, and 4 weeks respectively. This was done because even a minor deviation might have a significant impact on the workability of the wet mortar. The following is an explanation of the hand mixing procedure that was utilised in the establishment of the specimen:

a) When making a standard mix, proceed in a regular manner with the measured quantity of mixer.

After that, the needed amount of cement is poured onto the fine aggregate and distributed uniformly across the surface.

c) After that, the fine aggregate, sand, and cement are mixed together in a close manner using a shovel. The mixture is turned over and over again until it is uniform in colour throughout and free of streaks.

d) The entire mass ought to be mixed at least three times by shovelling and turning over by twisting from the centre to the sides, then back to the centre, and then again to the sides.

f) A hollow in the midst of the mixed pile is created at this step.

g) While the materials are being turned in towards the centre using spades, it is necessary to add three quarters of the total quantity of water that is required. A water can that has been equipped with a rose head is used to add the remaining water to the mixture, and the entire mixture is turned over and over again in a slow and steady manner until the colour and consistency of the pile are consistent throughout.

It is recommended that the mixing platform be cleaned at the end of each weeks work.

#### ➤ Mix proportion and water binder ratio

To make the building block following mix proportion are arrived by trial and error method. The Table3.7 show the various mix proportions.

### Testing of the specimens

Compressive Strength test

#### Compressive strength test

In comparison to the compressive strength of clay bricks, the compressive strength of block is three times higher. Bricks made of clay have a minimum compressive strength of 3.5 Newtons per square millimetre. The compressive strength of the block is therefore between 10 and 12  $\text{N/mm}^2$ . It is imperative that the compressive strength of the block that is going to be employed for various activities is not lower than what was indicated above. When determining the compressive strength of a block, the universal testing machine is the instrument of choice. Once the curing phase has been completed, the blocks are stored for testing purposes. In order to conduct the tests on the specimens, the block is put into a calibrated compression testing machine with a capacity of 3000 kN. A load that is uniform and applied at a rate of 2.9 kN/min is applied to the block. The maximum load at which specimens fail to produce any further increase in the indicator reading on the machine is referred to as the load at failure. The experiment consisted of testing three different numbers of blocks for each mix proportion. Different blocks may confer varying degrees of strength. As a result, the average of three blocks was calculated.



Fig 3: Compressive strength test machine

**V. RESULTS AND DISCUSSION**

Each of the results that were acquired from the compression test are presented in this chapter. It does this by presenting the results in a graphical style, which makes it simpler to comprehend the comparison between the outcomes. Also included in this chapter is a discussion and analysis of a few potential elements that may have played a role in determining the outcome.

**Table 4: Compressive strength of building blocks for W/B Ratio 0.70**

Fly Ash (%)	7days (KN)	7days (N/mm <sup>2</sup> )	14 days (KN)	14days (N/mm <sup>2</sup> )	28 days (KN)	28days (N/mm <sup>2</sup> )	W/B Ratio
50	103	3.73	223	8	300	10.86	0.70
45	120	4.34	230	8.33	306	11.08	
40	130	4.71	243	8.80	316	11.44	

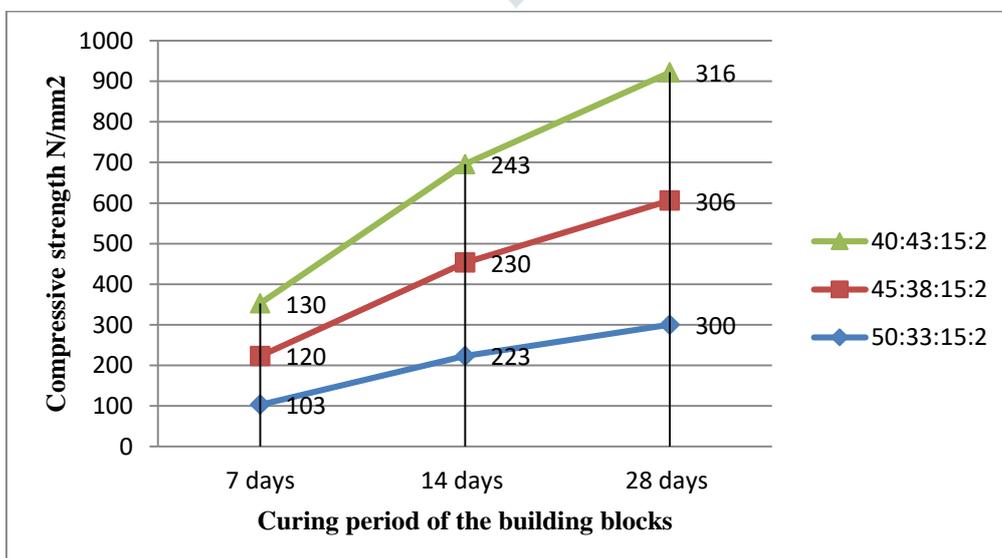


Fig.4: Compressive strength of blocks line chart (W/B=0.70)

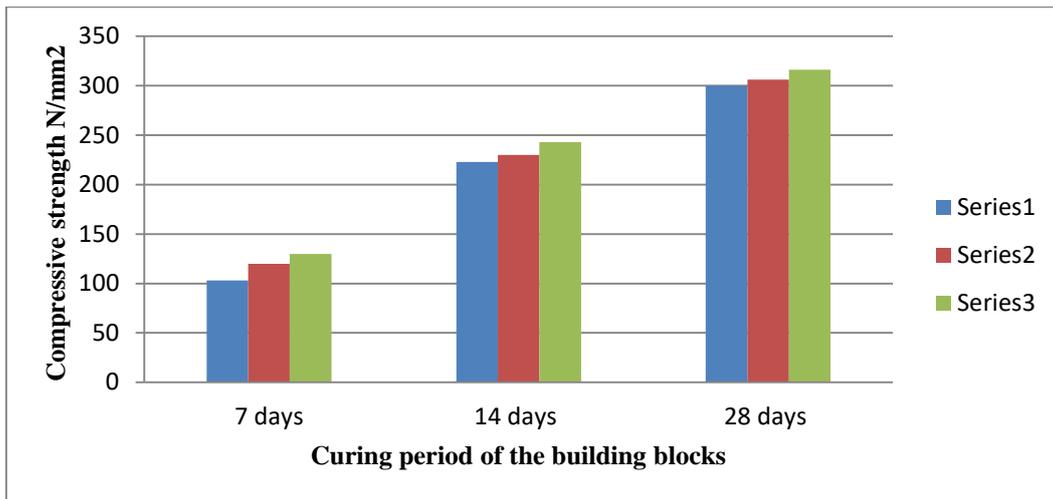


Fig.5: Compressive strength of blocks bar chart (W/B=0.70)

Table 5: Compressive strength of building blocks for W/B Ratio 0.75

Fly Ash (%)	7days (KN)	7days (N/mm <sup>2</sup> )	14days (KN)	14days (N/mm <sup>2</sup> )	28days (KN)	28days (N/mm <sup>2</sup> )	W/B Ratio
40	83	3	223	8	280	10.14	0.75
45	106	3.84	226	8.18	286	10.36	
50	123	4.45	240	8.69	300	10.86	

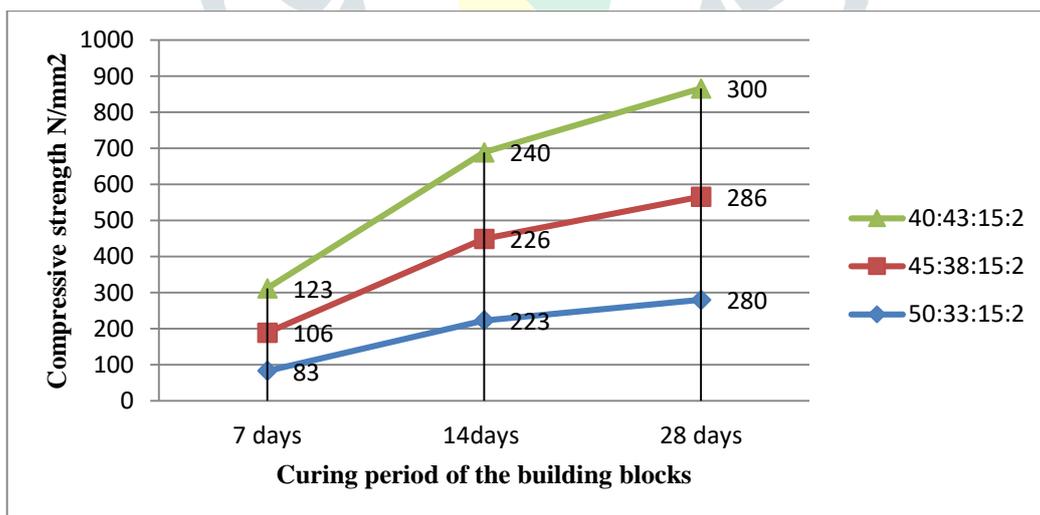


Fig.6: Compressive strength of blocks line chart (W/B=0.75)

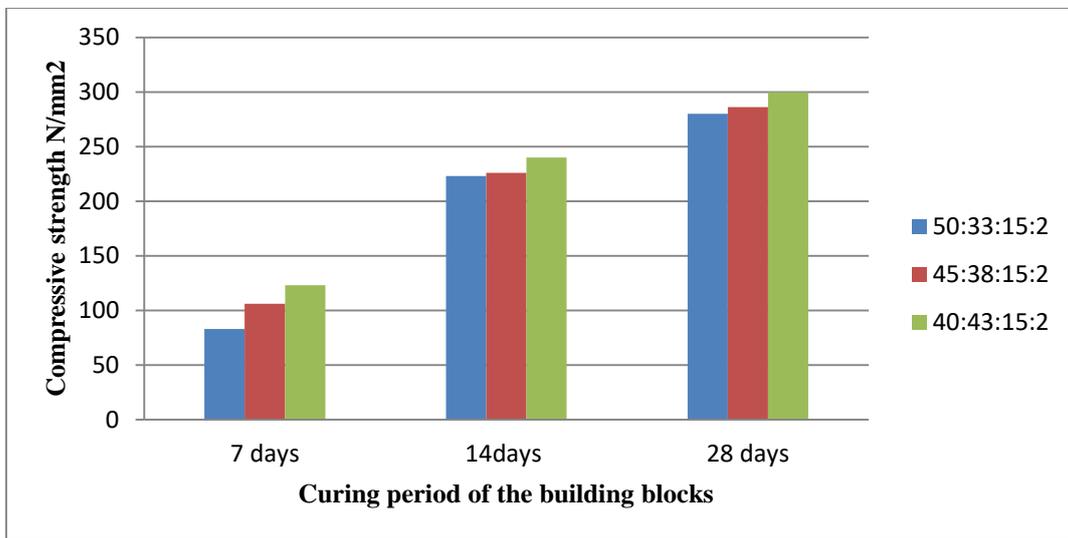


Fig. 7: Compressive strength of blocks bar chart (W/B=0.75)

Table 6: Compressive strength of building blocks for W/B Ratio 0.80

Fly Ash (%)	7days (KN)	7days (N/mm <sup>2</sup> )	14days (KN)	14days (N/mm <sup>2</sup> )	28 days (KN)	28days (N/mm <sup>2</sup> )	W/B Ratio
45	100	3.62	226	8.18	256	9.27	0.80
40	120	4.34	236	8.55	273	9.89	
50	130	4.71	253	9.16	390	14.13	

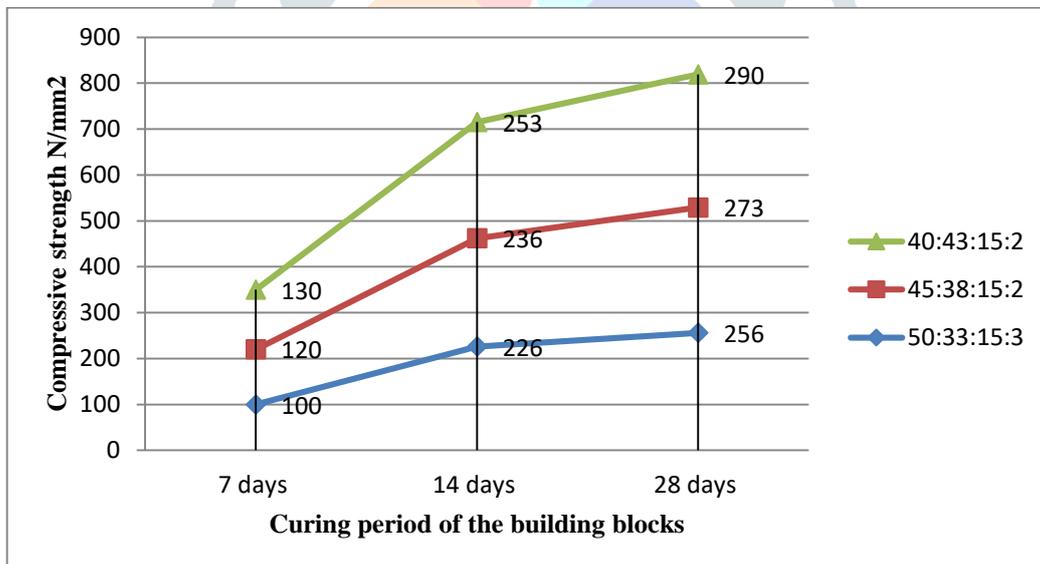


Fig.8: Compressive strength of blocks line chart (W/B=0.80)

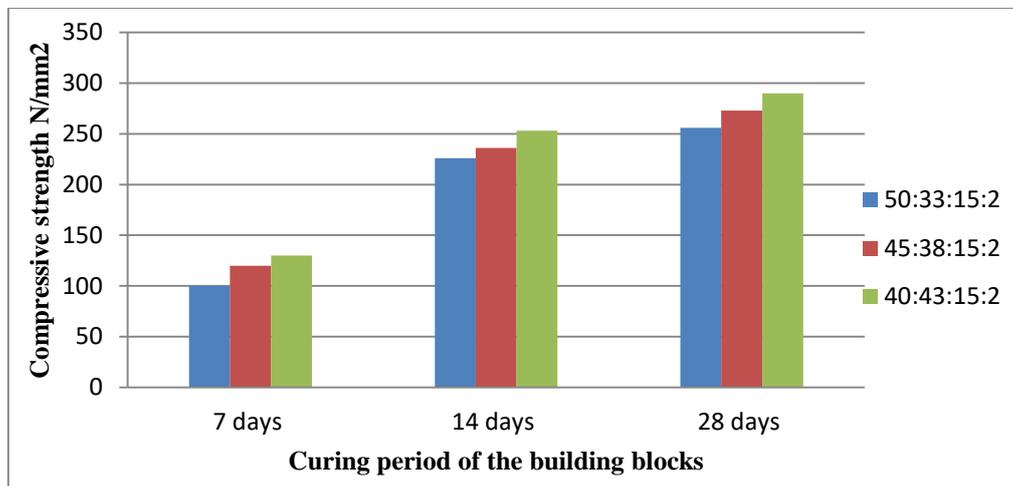


Fig.9: Compressive strength of blocks bar chart (W/B=0.80)

When it comes to construction, there is a significant demand for the introduction of alternative approaches to building materials. It is essential that the building materials be of a kind that is beneficial to the environment and possess a high level of strength with the intention of producing unique possibilities. Clay bricks were replaced by fly ash-sand-cement-gypsum building blocks, as indicated by the experimental study that was conducted on the strategy that was taken towards using these building blocks. Under the conditions that are outlined in Tables 4, 5, and 6 the production of building blocks took place. For each sort of specimen, there were at least three building blocks that were created. After being moulded, the blocks were held in place for forty-eight hours before being removed and lastly allowed to cure. Air was used for the curing process, and water was used for 7, 14, and 28 days. The results demonstrate the compressive strength of fly ash, sand, cement, and gypsum blocks for a variety of mix proportions with water binder ratios of 0.70, 0.75, and 0.80. Upon examining the compressive strength, it is evident that the water binder ratio is favorable. It has been discovered that the building blocks have already acquired a good compressive strength at a young age of 14 days, and the compressive strength at 28 days is highly impressive in all three water binder ratios. Based on the findings, it was determined that the highest compressive strength was achieved when the W/B ratio was 0.70 across all of these alternative mix proportions. This demonstrates that a low proportion of water in the mix results in an increase in compressive strength. Furthermore, it was also discovered that increasing the amount of sand in each proportion led to an increase in compressive strength.

#### Cost comparison between building blocks and clay bricks

Each masonry block is priced at approximately Rs 6.5, but a clay brick is priced at approximately Rs 7.5.

Building blocks are lighter and more economical than clay bricks.

Building bricks are composed of the waste generated from coal combustion in thermal power plants. Clay bricks are composed of clay sourced from fertile land or topsoil. This is the primary reason that renders building blocks more significant than clay bricks.

Clay bricks exhibit greater porosity than masonry blocks.

The building blocks are cement-colored, whereas clay bricks vary from burnt red to light brown, contingent upon the type of clay utilised in their production.

Building blocks are made in moulds that are consistently of regular shape. Clay bricks are handcrafted, resulting in minor variations in their shape and dimensions.

An attempt to find the approximate cost of block is made as follows:

**Basis:** 28 blocks per day

Dimension: 230mm × 120mm × 120mm

Avg. Weight of one block = 5kg

#### Mixing Ratio:

FlyAsh-50%; Sand-33%; Cement-15%; Gypsum-2%

**Fly ash** = 2.5kg for each block

For 28 blocks = 2.5 × 28 = 70kg

1kg fly ash = 0.20Rs

70kg fly ash = 70 × 0.20 = 14Rs

#### Mixing Ratio:

FlyAsh-50%; Sand-33%; Cement-15%; Gypsum-2%

1. **Fly ash** = 2.5kg for each block

For 28 blocks= $2.5 \times 28$   
 $=70\text{kg}$   
 1kg fly ash= $0.20\text{Rs}$   
 70kg fly ash= $70 \times 0.20=14\text{Rs}$

**2. Sand**= 1.65kg for each block  
 For 28 block= $1.65 \times 28=46.2\text{kg}$   
 1 Cubic fit sand= $44\text{kg}$   
 20 Cubic fit sand= $20 \times 44=880\text{kg}$   
 880kg sand= $600\text{Rs}$   
 1kg sand= $600/880=0.68\text{Rs}$   
 46.2 kg sand = $46 \times 0.68=31\text{Rs}$

**3. Cement**= 0.75kg for each block  
 For 28 block= $0.75 \times 28=21\text{kg}$   
 50kg cement= $300\text{Rs}$   
 1kg cement=  $300/50= 6 \text{ Rs}$   
 21kg cement = $6 \times 21=126\text{Rs}$

**4. Gypsum**= $0.20\text{kg}$  for each block  
 Gypsum for 28 block=  $28 \times 0.20=5.6\text{kg}$   
 20kg gypsum= $100\text{Rs}$   
 1kg gypsum= $100/20=5\text{Rs}$   
 5.6kg gypsum= $5.6 \times 5=28\text{Rs}$   
 Total cost for 28 blocks=  $(14+31+126+28)$   
 $=199\text{Rs}$   
 Cost of each block = $199/28$   
 $= 7\text{Rs}$

Now Manufacturing cost of each block= $\text{Rs } 7/-$

## VI. CONCLUSION AND FUTURE SCOPE

A study was carried out with the purpose of determining the ideal proportion of fly ash, sand, cement and gypsum in the mixture of building blocks. Fly ash (40-50%), sand (33-43%), cement (15%), and gypsum (2%), in that order, were the components that comprised the building blocks specimen, which had dimensions of 230120120. These are the W/B ratios for 0.70, 0.75, and 0.80. We can draw the conclusion that based on the results that we obtained.

- Building blocks are demonstrating a high compressive strength and have the potential to serve as an alternative to the traditional burnt clay bricks.
- At the tender age of fourteen days, the building blocks exhibit a good compressive strength in all minimal proportions.
- The compressive strength of the specimen is lower for the W/B ratio of 0.70 compared to the other W/B ratios, which demonstrate that a lower W/B ratio results in an increase in the specimen's compressive strength.
- The utilization of fly ash as a building material helps to mitigate the negative impact that fly ash has on the environment.
- The optimal composition for fly ash, sand, cement and gypsum building blocks was forty percent fly ash, forty-three percent sand, fifteen percent cement and two percent gypsum.
- According to the findings of the cost comparison between clay bricks and building blocks, it was discovered that burnt clay bricks can be used as a replacement by the construction industry.

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