

# A COMPREHENSIVE ANALYSIS OF THE ADVANTAGES AND DISADVANTAGES OF USING NON-CLAY BRICKS IN CONSTRUCTION COMPARED TO THE CONVENTIONAL CLAY BRICKS

Sameer Kumar Jha<sup>1</sup>, Rakesh Sakale<sup>2</sup>, Hirendra Pratap Singh<sup>3</sup>

<sup>1</sup>PG Student, School Of Research & Technology, People's University Bhopal (M.P.), India

<sup>2</sup>Prof., School Of Research & Technology, People's University Bhopal (M.P.), India

<sup>3</sup>Asst. Prof.<sup>3</sup>, School Of Research & Technology, People's University Bhopal (M.P.), India

## ABSTRACT

Bricks are the artificial stones. These are utilised in building construction as well as for decoration work in different Civil Engineering structures. These are primary materials used in wall construction. These are widely available, inexpensive, and lightweight. They can be shaped and sized as needed. Bricks made properly are nearly as robust as stone. This thesis contains results from a laboratory investigation on several bricks constructed from various ingredients (Fly Ash, Cement, and Lime) with different proportions of these material having varied properties. Many countries throughout the world have emphasised the importance of locally created building materials made from waste and alternative materials. Utilization of waste material not only reduces the pollutant materials from the environment but also it reduces the overall cost of construction of different projects. There is a disparity between costly conventional building materials and traditional building materials. To overcome this issue, emphasis has been placed on less expensive alternative building materials with higher desired qualities. Bricks are inorganic nonmetallic masonry units that are commonly utilised as building components all over the world. The bricks could be sun-dried (unburnt) or burned. Burned bricks are typically stronger than sun dried bricks, particularly if built of clay or clayey material. Bricks are classified according to the admixtures and raw materials used in their manufacture. Certain admixtures are added to burnt brick raw mixes to achieve varied effects in the end product. Organic matter, such as fly ash, cement, and lime, is another type of additive that can be used to make bricks. The mixes were made in increasing percentages, such as 5%, 10%, and 15%. We can employ those resources in regions where these materials are abundant. The acceptability of the material used in building is determined by its compressive strength and structural requirements. In general, the compressive strength of these specimens increases with increasing percentages of cement and lime while decreasing with increasing percentages of fly ash.

## 1. INTRODUCTION

Bricks are man-made stones. These are utilised in building construction as well as for decoration. These are primary materials used in wall construction. These are widely available, inexpensive, and lightweight. They can be shaped and sized as needed. Bricks made properly are nearly as robust as stone.

### 1.1 Brick Applications

1. These bricks can be used to construct buildings as building blocks.
2. It can be utilised as a liner material for wells, canals, and so on.
3. It can be utilised as a flooring material as well.
4. It is also suitable for usage in reinforced brick concrete.
5. It can also be used to build boundary barriers.

### 1.2 Benefits

1. Because these bricks are uniform in shape and size, they use less mortar in brick work.
2. Fly ash bricks are available with or without a frog component.
3. Because of their flat surface, these bricks require less plaster than clay bricks.
4. These bricks are eco-friendly since they are created from fly ash, a byproduct of thermal power plants.
5. It conserves agricultural land that would otherwise be utilised to make clay bricks.

### 1.3 The investigation's goals

The primary goals of this research are as follows:

1. Investigate the features and engineering properties of the fly ash cement and lime samples gathered.
2. Optimisation of the proportions of fly ash, lime, cement, and other ingredients for greater compressive strength brick.

3. The goal of this thesis is to demonstrate that bricks constructed from other materials are more appropriate than clay bricks.

#### 1.4 The Research's Scope

A variety of bricks were made using varying percentages of Fly Ash, Lime, and Cement to investigate the key features such as compressive strength and water absorption.

## 2. LITERATURE REVIEW

**Kalaimani Ramakrishnan, Vigneshkumar Chellappa and Subha Chandrasekarabharathi, 2023** explained in their paper about bricks consume a massive quantity of clay. Using clay bricks causes erosion, lowers the water table, and harms the environment. This research examined various waste materials, including fly ash, quarry dust, marble dust, eggshell powder (ESP), and rice husk ash (RHA), in varying percentages to avoid using clay in manufacturing bricks. Compressive strength and water absorption tests were conducted, and the results were compared with the specifications for traditional clay bricks. It was observed that the compressive strength and water absorption values met the relevant standards needed for standard construction bricks. Furthermore, the cost of manufacturing bricks from waste materials was estimated, and the findings show that manufacturing bricks from waste materials cost less than conventional bricks. Finally, it was concluded that the brick industry could become more sustainable and economically feasible by using specific waste materials in manufacturing bricks.

**Alaa. A. Shakir et. al, 2013** explained in their paper that the large demand has been placed on building material industry especially in the last decade owing to the increasing population which causes a chronic shortage of building materials, the civil engineers have been challenged to convert waste to useful building and construction material. Recycling of such waste as raw material alternatives may contribute in the exhaustion of the natural resources; the conservation of not renewable resources; improvement of the population health and security preoccupation with environmental matters and reduction in waste disposal costs. In the review of utilization of those waste, this paper reviewed recycling various waste material in bricks production.

Fly ash can be used in manufacturing of bricks as a substitute for a portion of clay. The advantage of using fly ash is obvious: fly ash is a by-product of coal burning in power plants. There are about 125 thermal power plants in India, which form the major source of fly ash in the country (Kumar and Singh, 2006). Fly ash was found as a pozzolanic material for use in manufacturing of bricks as early as in 1914. However, the comprehensive study on the use of fly ash in brick manufacturing was conducted by Abdun Nur (1961). For clay bricks we can find a very vast literature on their investigation of thermal transformations. Lee and Mc Conville (2005), investigating micro structural development on firing clay, advised that it should be possible to predict the stage of formation for clays with other known composition burned to a given temperature. The investigations carried out on Indian fly ashes show that all the fly ashes contain silica, alumina, iron oxide and calcium N. S. Pandian and S. Balasubramanian (2000). The silica content in fly ashes is between 38 and 63%, 37 and 75% in pond ashes, and 27 and 73% in bottom ashes. The fly ash composites developed with addition of gypsum and lime have significantly contributed to the strength characteristics of the composite material (Manoj Kumar Mishra 2006).

The chemical composition of fly ash according to Tabin Rushad, Abhishek Kumar, Duggal S. K., Mehta P. K. (2011).

**Table 2.1** Chemical Composition of Fly Ash

Chemical Composition	% By Weight
Unburnt	12.00
SiO <sub>2</sub>	57.77
Al <sub>2</sub> O <sub>3</sub>	23.92
Fe <sub>2</sub> O <sub>3</sub>	9.56
TiO <sub>2</sub>	1.63
CaO	2.24
K <sub>2</sub> O	0.60
MgO	1.28
Mo <sub>2</sub> O	0.13

Cement is a binding material which used in construction industry. Cement sets well under water and hardens quickly and attains strength. Cement differs from lime by the property that it does not slake but sets readily. Cement possesses hydraulic properties to a great extent and acquires more strength on setting. The setting power of cement is more than that of lime. So we can also use the cement as a material in manufacturing of bricks.

**Table 2.2** Chemical Composition of Ordinary Portland Cement

S. No.	Oxide	Composition	Percent
1	Lime	CaO	60 – 67
2	Silica	Sio <sub>2</sub>	17 - 25
3	Alumina	Al <sub>2</sub> O <sub>3</sub>	3.0 – 8.0
4	Iron Oxide	Fe <sub>2</sub> O <sub>3</sub>	0.5 – 6.0
5	Magnesia	MgO	0.1 – 4.0
6	Sulphur trioxide	SO <sub>3</sub>	1.0 – 3.0
7	Soda and Potash	Na <sub>2</sub> O, K <sub>2</sub> O	0.4 – 1.3

Lime is produced by heating limestone which is more or less pure calcium carbonate. The lime is not generally found in the nature in the Free State but it is obtained by burning one of the following materials.

- 1- Limestone found in limestone mines.
- 2- Limestone builders found in the beds of river. J. N. Akhtar, J. Alam and M. N. Akhtar (2010).

### 3. MATERIALS USED FOR THE PRODUCTION OF BRICKS

#### 3.1 FLY ASH

Fly ash is a residue produced by coal combustion plants that consists of fine particles that ascend with the flue gases.

##### 3.1.1 FLY ASH PRODUCTION

Fly ash can be used to replace a portion of clay in the manufacture of bricks. The benefit of employing fly ash is self-evident: fly ash is a byproduct of coal combustion in power plants. India has around 125 thermal power stations, which are the country's primary producer of fly ash (Kumar and Singh, 2006). Coal-fired power and steam generating plants generate fly ash. Coal is often pulverised and blasted with air into the boiler's combustion chamber, where it burns, generates heat, and produces molten mineral waste. Boiler tubes absorb heat from the boiler, cool flue gases, and induce molten mineral residue to harden and create ash.

Coarse ash particles, known as bottom ash or slag, settle to the combustion chamber's bottom, while finer ash particles, known as fly ash, remain floating in the flue gas. Fly ash is removed from the flue gas before it is exhausted by particulate emission control devices such as filter fabric bag houses (FFBH) or electrostatic precipitators. Fly ash is created when pulverised coal is burned in industrial boilers or electric utility boilers. Coal-fired boilers are classified into four types: (i) stoker-fired, (ii) pulverised coal, (iii) cyclone furnaces, and (iv) fluidized-bed combustion (FBC) boilers. The pulverised coal boiler is the most common, particularly for generating huge electric units. Other boilers are more typically found in industrial settings. Electrostatic precipitators (ESP) or filter fabric collectors (FFC) are used to capture fly ash from flue gases. The physical and chemical properties of fly ash are affected by three factors: (i) coal source, (ii) burning methods, and (iii) particle form.

##### 3.1.3 FLY ASH CLASSIFICATION

There are basically two classes of fly ash as defined by ASTM C618 those are as follows:-

- 1- Class F Fly ash
- 2- Class C Fly ash

The difference between these two classifications is determined by the amount of aluminium, calcium, silicon, and iron in the ash. The chemical content has a significant impact on all aspects of fly ash. The ASTM C618 construction standard does not apply to all fly ash.

##### Class F Fly ash

Class F fly ash is typically produced by the combustion of older anthracite, harder, and bituminous coal. This fly ash is pozzolanic in nature, with less than 20% lime (CaO) content. The pozzolanic characteristics, alumina, and glassy silica of Class F fly ash necessitate the addition of a cementing agent, such as Portland cement, hydrated lime, or quicklime, in order for the heat of hydration to react and generate cementitious compounds. Alternatively, adding a chemical activator to a Class F ash, such as sodium silicate, can result in the creation of a geopolymer.

Properties:

- 1- Checks heat gain most effectively during concrete curing.
- 2- As a result, it is regarded as a suitable cementitious ingredient in mass concrete and high strength mixes.

3- Offers sulphate resistance comparable to sulphate-resistant cement. Class F fly ash is generally suggested for use where concrete may come into contact with sulphate ions in the soil or ground water.

#### **Class C Fly ash**

Class C fly ash is often formed from lignite and sub-bituminous coals and contains a large proportion of Calcium Hydroxide (CaO) or lime (Cockrell et al., 1970). This type of fly ash possesses pozzolanic qualities as well as cementitious properties (ASTM C 618-99).

#### **Properties:**

- 1- Especially effective in pre-stressed applications, performance mixtures, and other situations where higher early strengths are critical.
- 2- Best for soil stabilisation because Class C fly ash does not require the addition of lime.

#### **3.1.4 Benefits of Fly Ash**

- 1- It extends the life of structures by boosting brick durability.
- 2- It can be used in the production of cement.
- 3- We can lessen environmental pollution by using fly ash.
- 4- Because fly ash is lighter than clay, it reduces the structure's own weight.

### **3.2 CEMENT**

Cement is a binding material that is commonly used in the building sector. Cement adheres effectively to water, hardens quickly, and gains strength. Cement differs from lime in that it does not slake but easily sets. Cement has significant hydraulic qualities and gains strength throughout the setting process. Cement has a higher setting power than lime. Cement is a calcareous substance that is used in the creation of mortar or concrete. The Romans invented the first binding material for Civil Engineering projects. They uncovered some limestone lumps in clay beds. The Roman engineers obtained a cementing material known as Roman Cement by burning these lumps.

In 1845, I.C. White invented a cementing substance. He made a slurry of clay and finely crushed chalk ( $\text{CaCO}_3$ ), dried it, and burned it at roughly 25000 F. At this temperature, the lime and silica bonded to produce tri-calcium silicate, a chemically novel material. When finely powdered powder is combined with water, it makes a strong cement known as Portland cement. Portland cement is typically made from lime, silica, and a trace of alumina.

#### **3.2.1 MANUFACTURING PROCESS OF PORTLAND CEMENT**

Portland cement is made from calcareous materials such as limestone or chalk, as well as argillaceous elements such as shale or clay. Cement is made by grinding raw materials, mixing them, and then burning them in a kiln at temperatures ranging from 13000C to 15000C, at which point the material sinters and partially fuses to create nodular formed clinker. The clinker is cooled and pulverised to a fine powder with 2 to 3% gypsum added. Portland cement is the end product of this operation.

##### **1- Wet Process of Manufacture**

Limestone is first crushed into smaller bits in the wet process. It is then transported to a ball or tube mill and mixed with clay. The mixture is then mixed with water to form a slurry. To prevent the settling of limestone and clay particles, the slurry is pumped to slurry tanks and constantly stirred by a revolving arm or compressed air from the bottom. The slurry is then sprayed against heavy hanging chains to the upper end of a rotary kiln. When sprayed against a hot surface of flexible chain, the slurry loses moisture and becomes flakes. These flakes are dropped into the kiln's blower end and heated to 15000 degrees Celsius. Chemical reactions occur, and 20 to 30% of the components are fused. The elements lime, silica, and alumina are recombined. Clinker is dropped into a rotary cooler and chilled under controlled conditions. The cooled clinker is then pulverised in a ball mill with 2 to 3% gypsum added. Particles are crushed to fine powder and placed in bags in the ball mill. The flow chart below depicts the intricacies of the wet process in cement manufacture.

##### **2- Dry Process of Manufacture**

The raw ingredients are dried and ground to a fine powder using a grinding mill in this procedure. The dry powder is then combined and adjusted for proper composition before being mixed with compressed air. The mixture was blended and rectified for proper composition before being combined with compressed air. The mixed powder is then held in storage silos before being fed into a granulator, which consists of an inclined spinning drum or dish. A small amount of water (approximately 12% by weight) is then added to the mixed powder to form nodules. These nodules are then dried in a preheater before being fed into the rotary kiln from the top. These nodules are lowered to the lower end, where they are subjected to temperatures of around 15000 C. Chemical processes occur, and 20 to 30% of the material is fused. The elements lime, silica, and alumina are recombined. The fused substance transforms into nodular

clinker. The clinker enters the rotary cooler and is cooled under controlled circumstances. The cooled clinker is then pulverised in a ball mill with 2 to 3% gypsum added. Particles are crushed to fine powder and loaded into bags in the ball mill.

### 3.2.2 BASIC CHARACTERISTICS OF PORTLAND CEMENT

There are certain basic characteristics of Portland cement.

#### 3.2.3 Chemical Composition

Lime, silica alumina, and iron oxide are the raw components used to make cement. These oxides interact with one another to generate various chemicals. The proportions of different oxide compositions influence the various characteristics of cement. The approximate oxide compositions of regular Portland cement are shown in Table 3.1.

**Table 3.1** for the approximate oxide compositions of Ordinary Portland cement

S. No.	Oxide	Composition	Percent
1	Lime	CaO	60 – 67
2	Silica	Sio2	17 - 25
3	Alumina	Al2O3	3.0 – 8.0
4	Iron Oxide	Fe2O3	0.5 – 6.0
5	Magnesia	MgO	0.1 – 4.0
6	Sulphur trioxide	SO3	1.0 – 3.0
7	Soda and Potash	Na2O, K2O	0.4 – 1.3

When exposed to high temperatures, various oxide compositions contained in raw material combine to produce complex compounds known as "Bogue's compounds" after the work done by R.H. Bogue's to identify these compounds. Table 3.2 lists the four compounds included in Portland cement.

**Table 3.2** for Bogue's compounds

S. No.	Name of Compound	Abbreviated Formula
1	Tricalcium Silicate	C <sub>3</sub> S
2	Dicalcium Silicate	C <sub>2</sub> S
3	Tricalcium Aluminate	C <sub>3</sub> A
4	Tetracalcium Aluminoferrite	C <sub>4</sub> AF

In addition to the four major compounds, there are many minor compounds formed in the kiln. These minor compounds does not affects on the properties of cement.

**Table 3.3** Properties of Ordinary Portland Cement

S. No.	Particulars	Result values after test	Requirements of IS:1489-1991 (Part-1)	
1.	Normal Consistency (%)	32		
2.	Setting Time (minutes)			
	a. Initial Setting Time	110-125 Minutes	30 Minutes	Minimum
	b. Final Setting Time	200-250 Minutes	600 Minutes	Maximum

### 3.3 LIME

Lime is a binding material used in the building sector. It comes in handy for making mortar. Lime has been employed in the construction industry since its inception. The lime-surkhi mortar was used to construct many great temples, monuments, and historical structures.

#### 3.3.1 USES OF LIME

Lime is extremely vital in the construction sector, but it is also extremely beneficial in a variety of other industries. The following are some of the most important applications for lime:

- 1- Used to make mortar for brick and stone masonry.
- 2- In the manufacture of artificial stones and sand lime bricks.
- 3- In the production of cement, paint, and glass.



- 4- For whitewashing and plastering.
- 5- To make lean lime concrete for foundations and floors.
- 6- Used as a refractory material in furnace lining.

## 4. MANUFACTURING OF BRICKS

### 4.1 Definition

Bricks are man-made stones. These are utilised in building construction as well as for decoration. These are primary materials used in wall construction. These are widely available, inexpensive, and lightweight. They can be shaped and sized as needed. Bricks made properly are nearly as robust as stone.

### 4.2 Manufacturing process of brick

The following operations are involved in the production of bricks:

1. Site selection.
2. Material selection.
3. Material preparation.
4. Brick moulding.
5. Moulded brick drying.
6. Moulded bricks are being burned.

1- Site selection - For the manufacture of bricks, the location should be near the bank of a river, where clay, silt, and sand deposits are plentiful. The location should be easily accessible from the city. Water should be easily accessible on the location.

2- Material selection - We choose materials according on the specifications. A excellent brick soil comprises between 55 and 60% silica, 20 to 30% alumina, and the other elements are magnesia, sodium, potassium, and iron oxide.

3- Material preparation - In this phase, the prepared ingredients are combined together in appropriate proportions. A moderate amount of water is mixed so that the dumps have the correct consistency for simple mixing and workability, but the addition of water should be managed so that it does not cause problems with moulding and drying. Excessive moisture content may alter the completed brick's size and shape.

The tempering process is then completed. It entails kneading the ground with your feet to make it hard and plastic (by plasticity, we mean the ability of wet clay to be permanently distorted without splitting). It should best be done by storing the dirt in layers of around 30 cm thickness in a cool spot for at least 36 hours. This will ensure that the clay material is homogeneous for later processing.

4- Brick Moulding - This is the method of shaping tempered clay by hand or machine. The brick moulding method might be soft-mud (manual moulding), stiff-mud (machine moulding), or dry-press.

Moulding can be done in two ways: I) by hand, and II) by machine.

Hand Moulding is further subdivided into ground moulding and table moulding. We use the ground moulding method to shape the bricks. The ground is levelled and sand is poured on it during this operation. The modular bricks samples 190 mm 90 mm 90 (IS: 12894-2002) were then cast.

The sample was combined with enough water to achieve a working consistency for the moulding procedure.

5- Moulded Brick Drying - This is a technique in which the first goal is to evaporate all excess moisture contained during the moulding process without destroying the bricks.

The moulded brick was allowed to dry for two days while being protected from direct sunlight (drying was done under the shed).

6- Burning of moulded bricks - The final and most significant operation in the brick making process is burning. Bricks must be properly burned.

It serves the following functions:

- 1- It fully eliminates the water from the clay.
- 2- It gives bricks toughness and strength.
- 3- It increases the density and durability of the bricks.
- 4- It gives the bricks colour.

## 5. LABORATORY TESTS AND THEIR RESULTS

The tests and experimental results are presented in this Chapter, together with commentaries that provide an interpretation of the data. The findings of statistical studies were tabulated to help comprehend the level of variance

displayed when various attributes were examined. Specific gravity and compressive strength were among these qualities.

### 5.1 Specific gravity of the materials

Specific gravity is a ratio that compares the density of a compressed specimen to the density of water (Mindess et al, 2003). The specific gravity of fly ash is affected by its particle form, colour, and chemical makeup. It is used as an indirect performance parameter to determine the performance of fly ash in brick manufacture. The specific gravity of coal ash is generally about 2.0, but it can vary greatly (1.6 to 3.1). McLaren, R. J., and A. M. Digioia (1987). The specific gravity of cement ranges from 3 to 4.8, while the specific gravity of lime ranges from 2.2 to 3.4.

Calculations- Mass of empty Pycnometer = W1 (gm)

Mass of Pycnometer + dry sample = W2 (gm)

Mass of Pycnometer + dry sample + Water = W3 (gm)

Mass of Pycnometer + Water = W4 (gm)

Formula for the determination of Specific Gravity –

Specific Gravity =  $[(W2 - W1) / (W2 - W1) - (W3 - W4)]$

**Table 5.1** Specific Gravity of different materials those were used in manufacturing of bricks

S. No.	Material	Specific Gravity
1	Fly Ash	2.3
2	Cement	3.1
3	Lime	2.4

### 5.2 Compressive strength analysis of the bricks

The modular bricks samples of size 190 mm × 90 mm × 90 mm (IS: 12894-2002) were casted. The compressive strength tests were conducted on three Bricks from each mix. The results of the compressive strength tests are shown in Table 5.2. These results were found after testing the specimens. Before testing, the frogs of the specimen were filled up with cement sand mortar (1:1).

**Table 5.2** Compressive strength of Clay Brick

Specimen No.	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	7700	45.03
2	7800	45.61
3	7750	45.32

Average compressive strength of these specimen after testing = 45.32 kg/cm<sup>2</sup>.

**Table 5.3** Compressive strength of Brick Specimen (Mix-I)

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	4700	27.48
2	5	4650	27.19
3	5	4700	27.48

Average compressive strength of these specimen after testing = 27.38 kg/cm<sup>2</sup>.

**Table 5.4** Compressive strength of Brick Specimen (Mix-II)

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	10	3800	22.22
2	10	3850	22.51
3	10	3850	22.51

Average compressive strength of these specimen after testing = 22.41 kg/cm<sup>2</sup>.

The compressive strength tests were conducted on three specimens prepared from each mix. The results of the compressive tests are shown in Table 5.2.

**Table 5.3** Compressive strength of Brick Specimen (Mix-I)

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	4700	27.48
2	5	4650	27.19
3	5	4700	27.48

Average compressive strength of these specimen after testing = 27.38 kg/cm<sup>2</sup>.

**Table 5.4** Compressive strength of Brick Specimen (Mix-II)

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	10	3800	22.22
2	10	3850	22.51
3	10	3850	22.51

Average compressive strength of these specimen after testing = 22.41 kg/cm<sup>2</sup>.

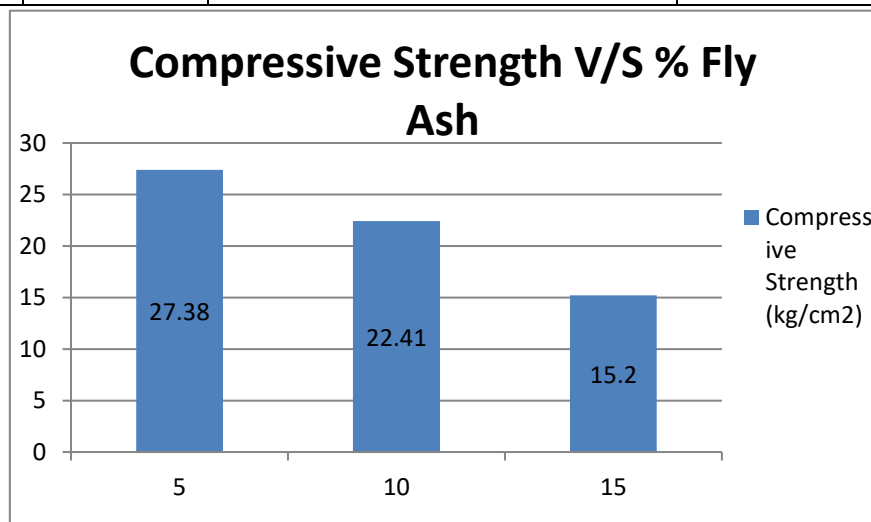
**Table 5.5** Compressive strength of Brick Specimen (Mix-III)

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	15	2600	15.20
2	15	2650	15.49
3	15	2550	14.91

Average compressive strength of these specimen after testing = 15.20 kg/cm<sup>2</sup>.

**Table 5.6** Combine table for compressive strength of Brick

Specimen No.	% of Fly Ash	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	4681.98	27.38
2	10	3832.11	22.41
3	15	2599.20	15.20



**Figure 5.2** Compressive strength v/s Fly ash

**Table 5.7** Compressive strength of Brick Specimen (Mix-IV)

Specimen No.	% of Cement	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	10250	59.94
2	5	10200	59.64
3	5	10300	60.23

Average compressive strength of these specimen after testing = 59.93 kg/cm<sup>2</sup>.



**Table 5.8** Compressive strength of Brick Specimen (Mix-V)

Specimen No.	% of Cement	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	10	12000	70.17
2	10	12100	70.76
3	10	12150	71.05

Average compressive strength of these specimen after testing =70.6 kg/cm<sup>2</sup>.

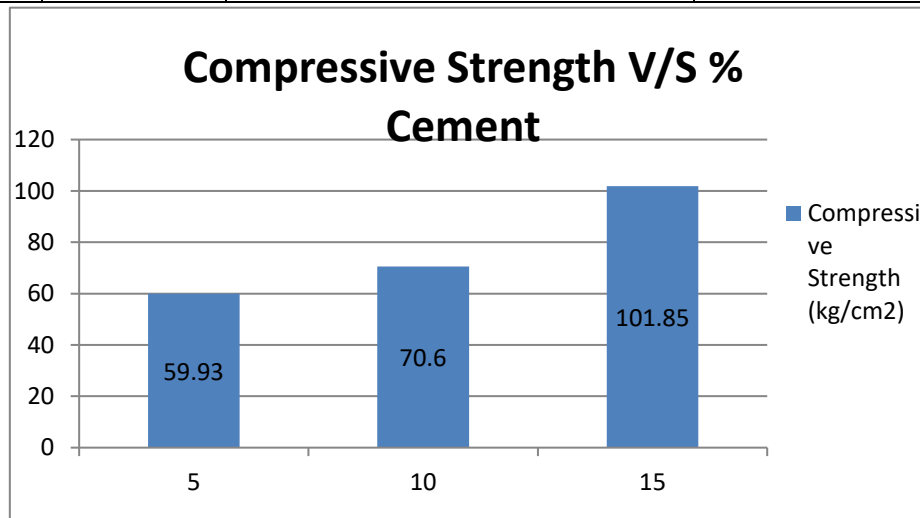
**Table 5.9** Compressive strength of Brick Specimen (Mix-VI)

Specimen No.	% of Cement	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	15	18000	105.26
2	15	17000	99.42
3	15	17250	100.88

Average compressive strength of these specimen after testing =101.85 kg/cm<sup>2</sup>.

**Table 5.10** Combine table for compressive strength of Brick

Specimen No.	% of Cement	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	10248.03	59.93
2	10	12072.60	70.60
3	15	17416.35	101.85



**Figure 5.3** Compressive strength v/s Cement

**Table 5.11** Compressive strength of Brick Specimen (Mix-VII)

Specimen No.	% of Lime	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	8000	46.78
2	5	8100	47.37
3	5	8150	47.66

Average compressive strength of these specimen after testing = 47.27 kg/cm<sup>2</sup>.

**Table 5.12** Compressive strength of Brick Specimen (Mix-VIII)

Specimen No.	% of Lime	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	10	10100	59.06
2	10	10000	58.47
3	10	10200	59.65

Average compressive strength of these specimen after testing = 59.06 kg/cm<sup>2</sup>.

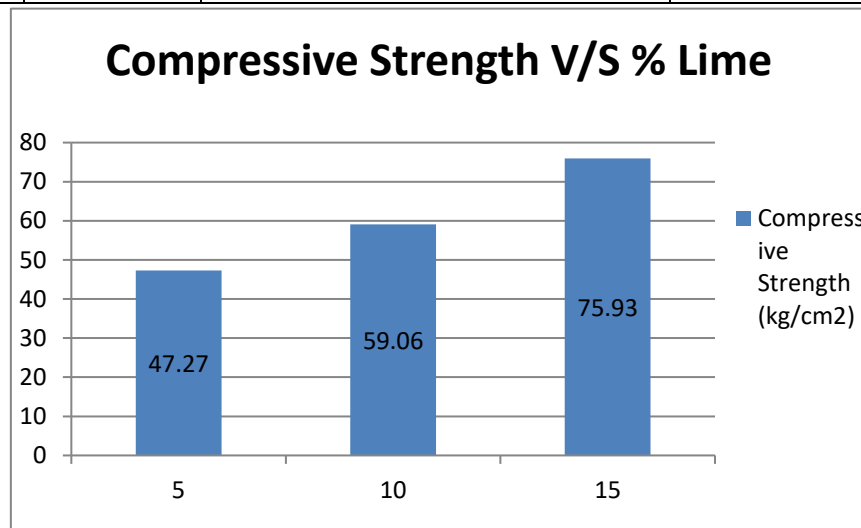
**Table 5.13** Compressive strength of Brick Specimen (Mix-IX)

Specimen No.	% of Lime	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	15	13000	76.02
2	15	13100	76.61
3	15	12850	75.15

Average compressive strength of these specimen after testing = 75.93 kg/cm<sup>2</sup>.

**Table 5.14** Combine table for compressive strength of Brick

Specimen No.	% of Lime	Load taken by the specimen brick (kg)	Compressive Strength (kg/cm <sup>2</sup> )
1	5	8083.98	47.27
2	10	10099.26	59.06
3	15	12984.03	75.93



**Figure 5.4** Compressive strength v/s Lime

### 5.3 Water absorption of the bricks-

Procedure- Dry the specimen in a ventilated oven at a temperature of 105 o C to 110 o C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (W<sub>1</sub>). Specimen warm to touch shall not be used for the purpose.

Immerse completely dried specimen in clean water at a temperature of 27 + or – 2 o C for 24 hours. Remove the specimen and wipe out any surplus water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (W<sub>2</sub>) [IS: 3495 (Part 1 and 2)-1992].

**Percentage water absorption** = [(W<sub>2</sub>-W<sub>1</sub>)/W<sub>1</sub>] X 100

= [(Final weight – Initial weight)/ Initial weight] X 100

**Table 5.15** Percentage of water absorption in clay brick

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2650	3225	21.70
2	2700	3290	21.85
3	2680	3275	22.20

Average water absorption of these specimen after testing = 21.92 %

So for water absorption test we take the specimen those were prepared with 5 %, 10 %, 15 % of each materials i. e.

**Mix I** = 5 % Fly ash + 95 % clay or 5 % Cement + 95 % clay or 5 % Lime + 95 % clay.

**Mix II** = 10 % Fly ash + 90 % clay or 10 % Cement + 90 % clay or 10 % Lime + 90 % clay.

**Mix III** = 15 % Fly ash + 85 % clay or 15 % Cement + 85 % clay or 15 % Lime + 85 % clay.

**Table 5.16** Percentage of water absorption in Fly ash mix-I

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2600	3190	22.69
2	2625	3210	22.28
3	2640	3230	22.35

Average water absorption of these specimen after testing = 22.44 %

**Table 5.17** Percentage of water absorption in Fly ash mix-II

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2570	3160	22.95
2	2610	3210	22.98
3	2600	3220	23.85

Average water absorption of these specimen after testing = 23.26 %

### 5.3 Water absorption of the bricks

**Procedure-** Dry the specimen in a ventilated oven at a temperature of 105 °C to 110 °C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (W<sub>1</sub>). Specimen warm to touch shall not be used for the purpose.

Immerse completely dried specimen in clean water at a temperature of 27 + or – 2 °C for 24 hours. Remove the specimen and wipe out any surplus water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (W<sub>2</sub>) [IS: 3495 (Part 1 and 2)-1992].

**Percentage water absorption** =  $[(W_2 - W_1) / W_1] \times 100$

=  $[(\text{Final weight} - \text{Initial weight}) / \text{Initial weight}] \times 100$

**Table 5.15** Percentage of water absorption in clay brick

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2650	3225	21.70
2	2700	3290	21.85
3	2680	3275	22.20

Average water absorption of these specimen after testing = 21.92 %

So for water absorption test we take the specimen those were prepared with 5 %, 10 %, 15 % of each materials i. e.

**Mix I** = 5 % Fly ash + 95 % clay or 5 % Cement + 95 % clay or 5 % Lime + 95 % clay.

**Mix II** = 10 % Fly ash + 90 % clay or 10 % Cement + 90 % clay or 10 % Lime + 90 % clay.

**Mix III** = 15 % Fly ash + 85 % clay or 15 % Cement + 85 % clay or 15 % Lime + 85 % clay.

**Table 5.16** Percentage of water absorption in Fly ash mix-I

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2600	3190	22.69
2	2625	3210	22.28
3	2640	3230	22.35

Average water absorption of these specimen after testing = 22.44 %

**Table 5.17** Percentage of water absorption in Fly ash mix-II

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2570	3160	22.95
2	2610	3210	22.98
3	2600	3220	23.85

Average water absorption of these specimen after testing = 23.26 %

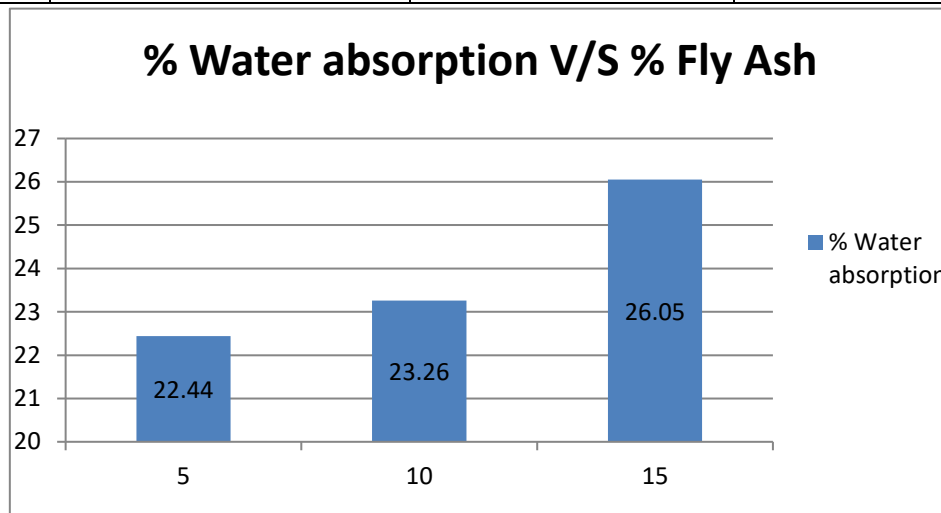
**Table 5.18** Percentage of water absorption in Fly ash mix-III

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2510	3140	25.10
2	2540	3180	25.20
3	2550	3260	27.84

Average water absorption of these specimen after testing = 26.05 %

**Table 5.19** Combine table for percentage water absorption of Fly ash mixes

S. No.	Fly ash mix	% Fly ash	% Water absorption
1	Mix I	5	22.44
2	Mix II	10	23.26
3	Mix III	15	26.05



**Figure 5.5** Percentage water absorption v/s % Fly ash

**Table 5.20** Percentage of water absorption in Cement mix-I

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2810	3370	19.93
2	2880	3400	18.05
3	2950	3570	21.02

Average water absorption of these specimen after testing = 19.67 %

**Table 5.21** Percentage of water absorption in Cement mix-II

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2850	3390	18.95
2	2910	3470	19.24
3	3010	3550	17.95

Average water absorption of these specimen after testing = 18.71 %

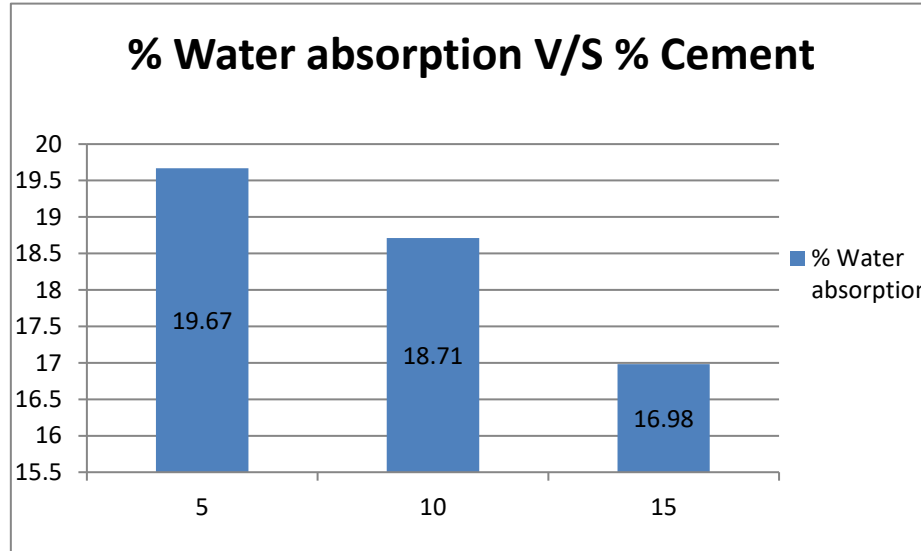
**Table 5.22** Percentage of water absorption in Cement mix-III

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	3100	3620	16.77
2	3120	3650	16.99
3	3200	3750	17.19

Average water absorption of these specimen after testing = 16.98 %

**Table 5.23** Combine table for percentage water absorption of Cement mixes

S. No.	Cement mix	% Cement	% Water absorption
1	Mix I	5	19.67
2	Mix II	10	18.71
3	Mix III	15	16.98



**Figure 5.6** Percentage water absorption v/s % Cement

**Table 5.24** Percentage of water absorption in Lime mix-I

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2800	3300	17.86
2	2810	3350	19.22
3	2850	3360	17.90

Average water absorption of these specimen after testing = 18.33 %

**Table 5.25** Percentage of water absorption in Lime mix-II

S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2750	3250	18.18
2	2780	3260	17.27
3	2820	3330	18.09

Average water absorption of these specimen after testing = 17.85 %

**Table 5.26** Percentage of water absorption in Lime mix-III

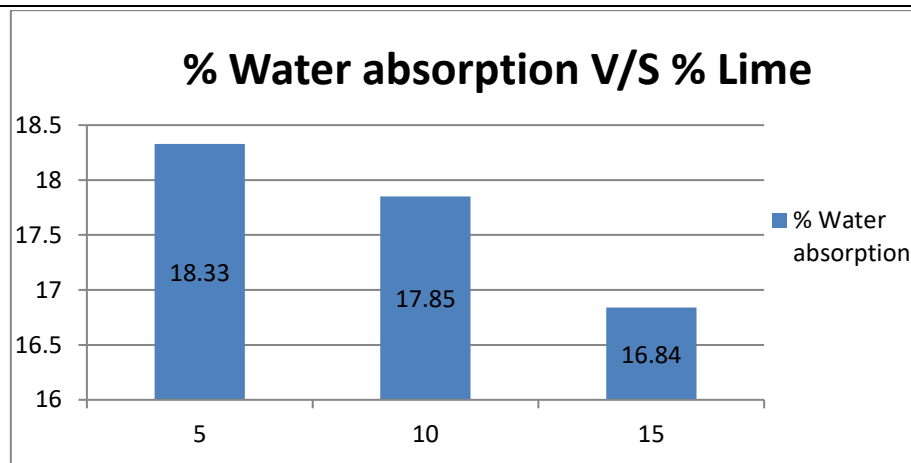
S. No.	W <sub>1</sub>	W <sub>2</sub>	% Water absorption
1	2900	3390	16.90
2	2950	3450	16.95
3	3000	3500	16.66

Average water absorption of these specimen after testing = 16.84 %

**Table 5.27** Combine table for percentage water absorption of Lime mixes

S. No.	Lime mix	% Lime	% Water absorption
1	Mix I	5	18.33
2	Mix II	10	17.85
3	Mix III	15	16.84





**Figure 5.7** Percentage water absorption v/s % Lime

## 6. CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

### 6.1 Summary

The purpose of this thesis was to evaluate the performance of sample specimens containing varying percentages of fly ash, cement, and lime with clay. The mixes were made in increasing percentages, such as 5%, 10%, and 15%. We can employ those resources in regions where these materials are abundant. The acceptability of the material used in building is determined by its compressive strength and structural requirements. In general, the compressive strength of these specimens increases with increasing percentages of cement and lime while decreasing with increasing percentages of fly ash.

### 6.2 Conclusions

Based on our observations of the prepared specimen, we came to the following conclusion:

- 1- By using 15% lime in brick manufacture, we can raise the compressive strength of bricks by 60-65%.
- 2- By using 15% cement in brick manufacture, we can raise the compressive strength of bricks by 120 - 125%.
- 3- We determined that adding fly ash to the mix affects the compressive strength of the brick.
- 4- We determined 17 percent water absorption when we added 15% cement to the mix.
- 5- We determined 16.84 percent water absorption when we added 15% lime to the solution.
- 6- We determined 26 percent water absorption when we added 15% fly ash to the mix.
- 7- While cement and lime bricks can be used as a substitute for conventional burnt clay bricks in general building construction, they should be avoided in the case of isolated weight bearing columns, piers and other strongly loaded structures.

### 6.3 Suggestions for future work

These are some ideas for future research in the topic of brick.

- 1- The effect of varying the proportions of lime, fly ash, and cement on the qualities of bricks should be explored.
- 2- The influence of fibre and rubber on brick characteristics should be researched.
- 3- Examine the impact of sawdust, stonedust, and rice husk ash on the properties of bricks.
- 4- Look into the influence of admixtures on brick properties.

## 7. REFERENCES

- [1] ASTM (1985). "ASTM standard test method for unconfined compressive strength of soil." ASTM D2166, Philadelphia.
- [2] Alaa. A. Shakir, Sivakumar Naganathan, Kamal Nasharuddin Bin Mustapha, 2013 "Development Of Bricks From Waste Material: A Review Paper" Australian Journal of Basic and Applied Sciences, 7(8): 812-818, 2013 ISSN 1991-8178.
- [3] Dhir, R.K. (2005): "Emerging trends in fly ash utilization: World Scenario", Proc. Of International Conference on fly ash utilization, pp: 0 1.1-1.10.
- [4] Fibre Reinforced Fly Ash Based Lime Bricks", International Journal of the IS: 12894-2002, Pulverized Fuel Ash-Lime Bricks—Specification, Bureau of Indian Standards, New Delhi.
- [5] IS: 3495 (Part 1 and 2)-1992, Methods of tests of Burnt Clay Building Bricks— Specification, Bureau of Indian Standards, New Delhi.

- 
- [6] IS: 6932-1973, Methods of tests for building lime—Specification, Bureau of Indian Standards, New Delhi.
- [7] J. N. Akhtar, J. Alam and M. N. Akhtar (2010), “An Experimental Study on Kumar Virender, (May 2004) , Compaction and Permeability Study of Pond Ash Amended with Locally Available Soil and Hardening Agent, <http://www.ieindia.org/publish/cv/0504/may04cv5.pdf>.
- [8] Kalaimani Ramakrishnan, Vigneshkumar Chellappa and Subha Chandrasekarabharathi, 2023 “Manufacturing of Low-Cost Bricks Using Waste Materials” 10th MATBUD’2023 Scientific-Technical Conference “Building Materials Engineering and Innovative Sustainable Materials”, Cracow, Poland, 19–21 April 2023.
- [9] Lee W. E., Souza G.P., McConville C. J., Tarvornpanich T. & Yqbal Y. (2008) Mullite formation in clays and clay-derived vitreous ceramics. *Journal of the European ceramic Society* 28/2, 465-471.
- [10] Matrai J. (1977) A POROTON teglak gyartastechnologiajarol es muszaki jellemzoirol. 19/6, 246-252.
- [11] Mebrahtom Teklehaimanot, Haregeweyni Hailay, and Tamrat Tesfaye, 2021, “Manufacturing of Ecofriendly Bricks Using Microdust Cotton Waste” *Hindawi Journal of Engineering* Volume 2021, Article ID 8815965, 10 pages <https://doi.org/10.1155/2021/8815965>.
- [12] Mindess, S., Young, J. F., and Darwin, D. (2004). “Aggregates and Response of Concrete to Stress” *Concrete*, 2nd Ed., Pearson Education, Inc. Upper Saddle River, NJ., Chap. 7, 121, and Chap. 13, 318.
- [13] Mishra Manoj Kumar, (December 2006) Geotechnical Characterization of Fly Ash Composites for Backfilling Mine Voids, <http://dSPACE.nitrkl.ac.in/dSPACE/bitstream/2080/379/1/mkmishra-geo-2006.pdf>.
- [14] N. S. Pandian and S. Balasubramanian, Leaching studies on ASTM type F fly ashes by an accelerated process method, *J. Testing Evaluation*, ASTM, 28, 44–51 (2000).
- [15] Palagyi G. (1976) A tegla multjabol Epitoanyag, 27/7, 269-274.
- [16] Rasool, M.A.; Hameed, A.; Qureshi, M.U.; Ibrahim, Y.E.; Qazi, A.U.; Sumair, A. Experimental study on strength and endurance performance of burnt clay bricks incorporating marble waste. *J. Asian Archit. Build. Eng.* 2022, 22, 240–255.
- [17] R. J. McLaren and A. M. Digioia, The typical engineering properties of fly ash, *Proc. Conf. on Geotechnical Practice for Waste Disposal*, ASCE, New York, pp. 683–697 (1987).
- [18] Sahu, K.C. (1991): “Coal and fly ash problem”, *Proc. Intl. Conf. on Environmental impact of coal utilization from raw materials to waste resources* (K.C. Sahu, ed.), Indian Institute of Technology, Bombay, pp: 11-12.
- [19] Tabin Rushad, Abhishek Kumar, Duggal S. K., Mehta P. K. *INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING* Volume 1, No 4, 2011.
- [20] Ukwatta, A.; Mohajerani, A.; Eshtiaghi, N.; Setunge, S. Variation in Physical and Mechanical Properties of Fired-clay Bricks Incorporating ETP Biosolids. *J. Clean. Prod.* 2015, 119, 76–85.
- [21] Value Addition to Industrial Waste, *Mining Engineer’s Journal-Annual Report* (2005-2006), pp. 19-22.