# Experimental Assessment of Mechanical and Durability Properties of Fly Ash Bricks with Varying Cement Content

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## ABSTRACT

Among the many building materials needed for various construction projects, brick is an essential one. There aren't many viable alternatives to traditional bricks at the moment because of the high demand for building materials. One of the substitutes is fly ash brick. Fly ash, granite dust, sand, cement, and other ingredients are mixed to make these construction materials. Moreover, the mixture is supplemented with water in an equal volume. The mechanical and durability qualities of fly ash bricks are experimentally evaluated in this study by comparing bricks with 0%, 3%, and 5% cement to typical clay bricks. Tests for efflorescence, compressive strength, and water absorption were all part of the performance evaluation. For bricks containing 5% cement, the testing findings showed a compressive strength of 147.5 kg/cm², a 56.6% improvement over regular bricks, and this strength rose dramatically with increasing cement concentration. Fly ash bricks with 5% cement showed a gradual drop in water absorption from 11.01% in traditional bricks to 6.76% in these same bricks, suggesting reduced porosity and higher density. Surface deposits decreased from modest to moderate in conventional bricks to less than 7% in fly ash bricks containing 5% cement, and efflorescence was also significantly reduced with cement addition. As a sustainable, high-performance substitute for traditional clay bricks in contemporary building, the created fly ash bricks show great promise.

***Keywords:*** *Fly Ash Bricks, Cement, Compressive Strength, Water Absorption, Efflorescence.*

## I. INTRODUCTION

A combination of fly ash, sand, lime, and gypsum cement makes up fly ash bricks. Identical to the usual burnt clay bricks, these may be utilised widely in all building constructional tasks. In comparison to traditional clay bricks, fly ash bricks are both stronger and lighter. Utilising fly ash as the primary raw material in brick production will not only provide ample opportunities for its appropriate and beneficial disposal, but will also significantly aid in the control of environmental pollution in areas surrounding thermal power plants, where it is currently piling up as waste and causing significant pollution problems.

There is a great deal of air pollution caused by the production of commercial brick. The technology utilised for manufacturing. Protect the environment using fly ash bricks. It differs from traditional bricks in that it does not require a fire operation during manufacture. There is enough coal, one of the conventional fossil fuels, to provide most of the country's energy needs. For this reason, India's power industry is and will be a significant user of coal for the foreseeable future. Coal combustion in thermal power plants results in steam, which powers turbines that generate electricity, but it also generates numerous by-products, such as fly ash and other similar materials. Fly ash comes from 80 thermal power plants in India that burn millions of tonnes of coal per year. The annual fly ash generation in India is about 100 million tonnes. As a result, every year, 30–40 million tonnes of fly ash go underutilised. There could be further ecological disruption caused by the necessity for thousands of hectares of storage land for this disposal. Actually, this garbage is just dumped on the nearby lands as a watery slurry. In addition to degrading the quality of the environment, this method of disposal turns arable land into garbage. According to the UNDP's Human Development Report, every year, erosion claims between 83 and 163 million hectares of land in India, cutting into agricultural output worth $2.4 billion, or 4 to 6.3% of the total. The relevance of employing fly ash as a construction material has therefore reached unprecedented levels. Several research have been conducted out across the world to make an attempt to employ fly ash in numerous civil engineering projects by virtue of its good characteristics as an element of concrete.

Instead of using manual moulds, which can lead to frequent changes in brick size and possibly poor exterior quality, various semi-automatic and automatic machines can be used to prepare Fly Ash bricks using pre-attached moulds. The employment of machines in the production of ash bricks has reduced the need for human work, resulting in a lower cost per brick that families from all economic backgrounds may afford.

Every year, the nation goes through almost 340 billion tonnes of clay, uses up 180 billion tonnes of bricks, and renders around 5,000 acres of topsoil land infertile for an extended length of time. In light of the high demand for homes, the government is quite worried about soil erosion due to the manufacture of large numbers of bricks.

Fly ash brick has a wide range of uses due to its long lifespan and exceptional engineering properties, which make it ideal for a variety of infrastructure projects, including but not limited to: constructing pavements, dams, tanks, underwater works, canal lining, irrigation work and more. Across the country, thermal power facilities have massive amounts of fly ash on hand. A more efficient way to fulfil the demand for bricks and save transportation costs would be to set up small plants close to thermal power stations.

**Uses of Fly Ash**

Thermal power plants produce fly ash, a finely split by-product, when they burn pulverised coal. There are mostly mineral substances found in it, including silica ($SiO_2$), alumina ($Al_2O_3$), iron oxide ($Fe_2O_3$), and calcium oxide (CaO), with smaller amounts of magnesium and potassium. The cementitious chemicals formed when lime and fly ash react in the presence of water enhance the strength and durability of the material. Its physicochemical properties are comparable to those of Portland cement and volcanic ash, which makes it an excellent material for a wide range of agricultural, environmental, and technical uses. By finding practical uses for fly ash, we can lessen the negative impact of trash disposal on the environment, save valuable resources, and advance sustainable development. What follows is a discussion of a few of fly ash's most important uses.

- **Fly Ash in Brick Manufacturing:** Fly ash bricks, made from fly ash, are rising in popularity as an alternative to traditional burnt clay bricks in building projects. In comparison to conventional clay bricks, fly ash bricks have many advantages, including a higher compressive strength, more precise dimensions, less water absorption, better thermal insulation, and resistance to efflorescence. Traditional brick production results in a great deal of greenhouse gas emissions; however, these bricks are made without kiln burning, which means that no rich topsoil is used in their creation. Fly ash isn't only used to make bricks; it may also be made into paver blocks, interlocking blocks, hollow blocks, and unglazed tiles for walkways and pavements. Sustainable building practices and a significant decrease in pollution can result from the broad use of masonry materials made from fly ash. Their widespread use can be further encouraged by government incentives, increased public knowledge, and rules that are supportive of them.
- **Fly Ash in Cement and Concrete Manufacturing:** The manufacturing of cement and concrete makes considerable use of fly ash as an additional cementitious ingredient. It improves concrete's strength and longevity when combined with lime and water; this is because it goes through pozzolanic reactions that create more calcium silicate hydrate (C-S-H) gel. The heat of hydration, workability, bleeding/segregation, permeability, and long-term compressive strength can all be improved by partially replacing some of the Portland cement with fly ash. Fly ash concrete is more resistant to chemical degradation, including sulphate assault, chloride penetration, alkali-silica reaction, and others. Using fly ash in place of some cement makes concrete production more eco-friendly and cuts down on building expenses by minimising the carbon dioxide emissions linked with cement manufacture.

- **Fly Ash in Paints and Distemper:** The chemical stability, tiny particle size, and smooth texture of fly ash make it an ideal filler material for use in paints, wall putty, and distemper. Distemper made from fly ash has the same adhesion, durability, and surface quality as products made from traditional white cement. Adding fly ash to the mix lowers manufacturing costs significantly without sacrificing performance. The economic feasibility and environmental benefits of fly ash-based coatings have been shown in several construction projects. Another way that industrial waste materials are being put to good use is by being used in protective and ornamental coatings with fly ash.
- **Fly Ash in Agriculture and Soil Improvement:** The several important plant nutrients included in fly ash make it a useful fertiliser and soil amendment. These include calcium, magnesium, potassium, iron, zinc, molybdenum, sulphur, and selenium. To promote healthy crop growth, fly ash improves soil texture, promotes soil aeration, and boosts water retention capacity when applied in the right amounts. By enhancing the physicochemical qualities of deteriorated or acidic soils, it can also aid in their reclamation. Fly ash, when applied to crops in a regulated manner, can boost yields, especially when mixed with organic manure or traditional fertilisers. Soil features and environmental regulations should inform its application restrictions to avoid the buildup of unwanted trace elements.

## II. REVIEW OF LITERATURE

Rashid, Fahad. (2024). As part of efforts to reduce construction waste, bricks made from fly ash and other industrial byproducts are gaining popularity. The objective of this study is to evaluate the compressive strength, water absorption, flexural (rupture) strength, density, and efflorescence of fly ash bricks in comparison to the more traditional burnt clay bricks used in Pakistan. Experimental results showed that fly ash bricks exhibited lower water absorption, higher compressive and rupture strengths, and less overall degradation than conventional clay bricks. Despite the low efflorescence levels seen in fly ash bricks, there could be room for improvement in specific uses. We calculated the percentage difference between clay bricks and fly ash to see which one is better for masonry construction in Pakistan. This study's results expand our understanding of fly ash bricks' potential as a sustainable substitute for conventional construction materials.

Manjur, Kazi et al., (2024). Sustainable solutions are becoming more important in the construction industry as the demand for building materials continues to climb worldwide as a result of growing environmental concerns. A by-product of coal combustion in thermal power plants, fly ash has the potential to be used in brick manufacture, which presents a fantastic opportunity for sustainable building. The purpose of this research is to investigate the possible material and environmental effects of bricks made from fly ash and other waste materials, such rice husk (RH) and expanded polystyrene (EPS). Instead of using clay bricks, which remove topsoil and add to pollution, you may use fly ash bricks, which are better for the environment. Mixing materials like sand, fly ash, EPS, rice husk, and cement produces specimen material for the testing phase. Classical clay bricks undergo a battery of mechanical tests, including compressive and flexural strengths as well as initial absorption rate and water absorption tests. The compressive strength of bricks manufactured with varying proportions of fly ash, sand, and cement ranges from 1.70 MPa to 13.5 MPa, in contrast to the 7.70 MPa strength of ordinary clay. All specimens tested showed flexural strengths between 10% and 20% of their compressive strength, which is a normal range. This study offers comprehensive frameworks for evaluating the potential of fly ash bricks to address waste management and sustainable construction challenges.

Kumar, Mahesh et al., (2023). A green construction material, fly ash brick is composed of rice husk, cement, bottom ash, and fly ash. Instead of using clay or lime, the production technique utilises fly ash, which is a waste product of coal-fired power stations. An essential feature to seek out in fly ash brick is its longevity. Utilising fly ash in manufacturing processes helps to decrease the use of virgin resources and the amount of waste generated by power plants. Compared to traditional clay bricks, fly ash bricks have less of an environmental impact. There are a number of performance-related benefits to using fly ash brick. These bricks outlast ordinary clay ones because to their increased compressive strength and decreased water absorption rate. Additional advantages include good insulation and minimal heat transmission. Compared to traditional clay bricks, fly ash bricks are more cost-effective and need less energy during production. When compared to conventional clay bricks, fly ash bricks have a less carbon footprint, making them the more eco-friendly choice. Among their numerous advantages, they are long-lasting, sturdy, and weatherproof. A building can also benefit from their excellent insulating properties, which keep it cool in the summer and warm in the winter. Another practical alternative to more expensive clay bricks is fly ash bricks, which are far more affordable. Also, because they utilise less energy during manufacture, they are less expensive to create. Using a battery of tests, including compressive strength and water absorption, this study contrasts and compares conventional break brick with fly ash brick. Using the Taguchi method of parameter design, this study reports the findings of an experimental investigation into the fly ash brick mix proportions. The L9 orthogonal array, with its four factors and three levels per factor, was used for the test design.

Jayaprakash, Harshini et al., (2019). Flyash is a major player among emerging construction materials. Fly ash is one of the several waste materials used by brick manufacturers. Flyash reduces the cement content while simultaneously mitigating a variety of concerns. Making the globe a more environmentally friendly place is, basically, what it is. Flyash brick offers several advantages, however due to inadequate hydration, it has low strength at first. This study experimentally examined several fly ash brick compositions to identify the appropriate mix ratio. The sample bricks were made using a mix of ingredients that included flyash, eco-sand, cement, and other additives. Because of these additions, the material hydrated quickly and had good early compressive strength. There were a total of 28 testing days, spread out among 3, 5, 7, and 28. Findings indicated that a mix of fly ash, ecosand, cement, and silica fume produced the strongest results.

Hasan, Monjurul et al., (2015). Coal fly ash is a hazardous byproduct of thermal power stations that burn coal, and its improper disposal has become an environmental concern. On the other hand, a lot of topsoil is lost during the typical clay brick making process, which uses a lot of clay. Focusing on the method employed in Bangladesh, this research investigates the possibility of using fly ash instead of clay to make bricks. Using fly ash in clay at concentrations ranging from 0% to 50% by volume, the effects on brick properties were studied. The bricks were made in the field alongside the regular bricks, and during testing, they were identified by their unique numbers. Fly ash brick shows no indications of physical distortion after being burnt in the kiln. As the proportion of fly ash in brick increases, its compressive strength decreases. Laboratory results showed that 20% fly ash produced the maximum compressive strength of 19.6 MPa. Bricks made with fly ash absorb more water when the amount of fly ash is higher. The specific gravity and abrasion value of coarse aggregate produced from fly ash bricks were also measured; the results indicated that the optimal percentage of fly ash for producing high-quality bricks with current technology was 20%.

Ashish, Deepankar & Kumar, Ravi. (2015). One factor propelling India's economic growth is the building sector, which in turn is driven by the country's massive infrastructural needs. The main construction materials are brick and cement. The traditional material for making bricks is clay. Clay is the primary component of produceable soil. To tackle this issue, we are making bricks using non-traditional resources, including fly ash. This material outshines clay bricks in every way: longevity, efficiency, and affordability. An additional advantage of this process is the recycling of industrial waste into building materials of excellent quality. For this study, we are making four different types of non-traditional (fly ash) bricks with different cement percentages: 0%, 2%, 4%, and 6%. After that, throughout the brickmaking process, properties including efflorescence, water absorption, and compressive strength were evaluated. Regular bricks were used as a comparison for the results.

Makaka, Golden. (2014). For quality and long-term sustainability, we must find alternative methods of producing bricks and rethinking home design. For bricks made in open kilns with locally produced materials to pass inspection by the South African Bureau of Standards, they must include certain additives, such as fly ash. The effects of fly ash on clay brick properties are detailed in this study, which should help improve buildings' thermal efficiency. Before shaping the bricks, the quantities of clay and fly ash were adjusted. A passive solar dwelling was constructed using fly ash bricks. Hydrophilicity and thermal conductivity both decrease with increasing fly ash concentrations. The compressive strength was shown to increase as the amount of fly ash increased. In a volume ratio of 50% fly ash to 50% clay, the finest bricks exhibited the lowest thermal conductivity, highest compressive strength, and lowest water absorption. The bricks were determined to be uniform in size because of their minimal burning shrinkage. These features were shown to have a significant impact on the home's thermal efficiency. The average interior temperatures were found to vary by 11˚C.

## III. MATERIAL AND METHODS

This research looks into fly ash bricks with several percentages of cement, including none, three percent, and five percent. Following their production, the bricks underwent a battery of tests to determine their properties, including compressive strength, water absorption, and efflorescence, which were then compared to those of traditional bricks.

### Materials Used

Materials used are cement, fly ash, gypsum, sand and lime.

### Experimental Setup

This research focuses on creating fly ash bricks with varying compositions.

A mixture of fly ash (55%), lime (20%), sand (20%), gypsum (5%), and cement (0%).

The ingredients are fly ash (52%), lime (20%), sand (20%), gypsum (5%), and cement (3%).

Composition: 50% fly ash, 20% lime, 20% sand, 5% gypsum, 5% cement.

Both the fly ash and ordinary bricks underwent testing according to the protocols outlined in IS 3495-1973 and IS 12894-1990, respectively, for the following tests:

### Compressive Strength Test

A compressive testing equipment with a 100-ton capacity that reads to the nearest half-ton was used to evaluate the red and fly ash bricks. A constant and consistent force was exerted. The compressive strength of six different types of bricks was measured. Compressive strength on average was determined.

### Water Absorption Test

After drying, the bricks made of red and fly ash were given a weight. After soaking for 24 hours, they were weighed once more. Following the protocol outlined in IS 3495 (Part-II) 1976, the bricks underwent testing (36).

### Efflorescence Test

From the samples of red and fly ash bricks, 5 of each colour were chosen at random. Then, with each brick submerged to a depth of 2.5 cm or more, they were set on edge in a dish of distilled water. Everything was set up in a well-ventilated room and left there until the water in the dish drained. After the water had been absorbed and the bricks looked dry, the same amount of distilled water was added to the dish and let to evaporate as previously. The efflorescence of the brick was checked at the conclusion of this time.

## IV. RESULTS AND DISCUSSION

### Compressive Strength Test

**Table 1: Compressive Strength of Different Brick Specimens**

| Type of Specimen | Mean Load at Failure (kN) | Average Compressive Strength (kg/cm²) | % Increase in Average Compressive Strength |
|---|---|---|---|
| Conventional brick | 210.4 | 94.2 | – |
| Fly ash brick (0% cement) | 265.8 | 119.0 | 26.3% |
| Fly ash brick (3% cement) | 298.6 | 133.7 | 41.9% |
| Fly ash brick (5% cement) | 329.4 | 147.5 | 56.6% |

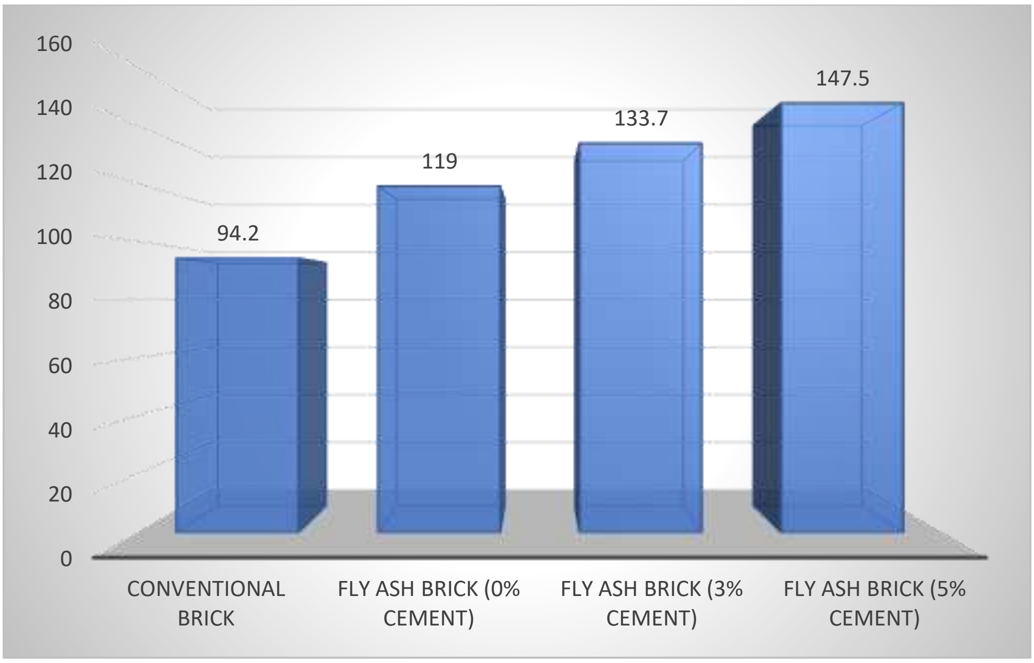


**Figure 1: Compressive Strength**

The average compressive strength of the traditional brick, as shown in Table 1 and Figure 1, was 94.2 kg/cm². This served as the basis for comparison. The compressive strength of the cement-free fly ash brick was 119.0 kg/cm², which is a 26.3% increase over the standard brick. With an additional 3% cement, the compressive strength reached 133.7 kg/cm², a 41.9% improvement. In comparison to the standard brick, the fly ash brick with 5% cement demonstrated a 56.6% gain in compressive strength, reaching 147.5 kg/cm².

### Water Absorption Test

**Table 2: Water Absorption Test Results**

| Type of Specimen | Mean Dry Weight (kg) | Mean Wet Weight (kg) | Average Water Absorption (%) | % Decrease in Water Absorption |
|---|---|---|---|---|
| Conventional brick | 3.18 | 3.53 | 11.01 | – |
| Fly ash brick (0% cement) | 2.68 | 2.91 | 8.58 | 22.1% |
| Fly ash brick (3% cement) | 2.74 | 2.94 | 7.30 | 33.7% |
| Fly ash brick (5% cement) | 2.81 | 3.00 | 6.76 | 38.6% |

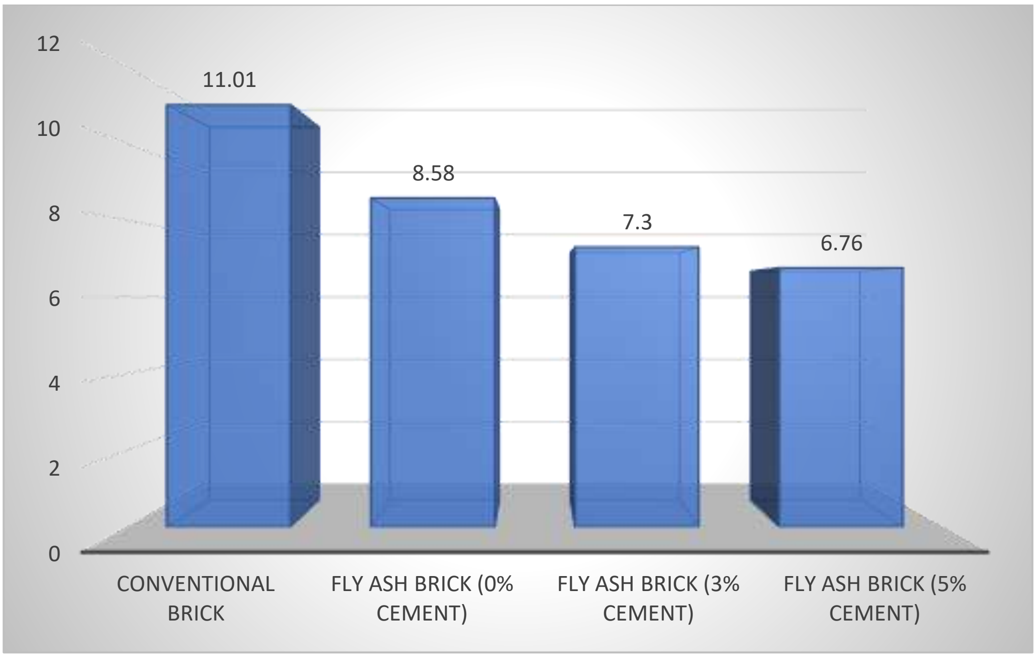


**Figure 2: Water Absorption Test Graph in Percentage**

The typical brick had the greatest average water absorption rate of 11.01%, suggesting relatively larger porosity, as shown in Table 2 and Figure 2. Water absorption was 8.58 percent lower in the cement-free fly ash brick, a reduction of 22.1 percent relative to the regular brick. Average water absorption was further decreased to 7.30%, or 33.7%, with the addition of 3% cement. With a water absorption value of 6.76 percent, the fly ash brick mixed with 5 percent cement outperformed the standard brick by 38.6 percent.

**Efflorescence Test**

**Table 3: Efflorescence Test**

| Conventional Brick | Slight to Moderate |
|---|---|
| Fly ash brick (0%) | The grey deposit are less than 10% |
| Fly ash brick (3%) | The grey deposit are less than 8% |
| Fly ash brick (5%) | The grey deposit are less than 7% |

The specifics of the efflorescence test are shown in Table 3. By comparing the efflorescence test results of conventional brick, fly ash brick without cement, fly ash brick with 3% cement, and fly ash brick with 5% cement, we find that the amount of grey or white deposits on the surface of fly ash brick without cement is less than 10%, on the surface of fly ash brick with 3% cement is less than 8%, and on the surface of fly ash brick with 5% cement is less than 7%.

## V. CONCLUSION

The country's fly ash utilisation has stayed below 10% for the previous 5 years, and getting to the end objective of 100% utilisation would take a while. In India, NTPC stations account for around 22 million tonnes of the almost 70 million tonnes of ash generated annually. From a use perspective, we need to take the required steps on both the government and non-government levels to put this massive amount of ash to good use. Based on the results of this research, fly ash bricks are a viable and environmentally friendly substitute for traditional clay bricks in contemporary building projects. According to the results of the experimental assessment, fly ash bricks with cement added have improved mechanical and durability properties, such as increased compressive strength, decreased water absorption, and decreased efflorescence. The bricks' overall quality, service life, and structural dependability are all improved by these upgrades.

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