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# Innovative Sustainable Materials: Integration of Fly Ash and Mycelium for Enhancing Compressed Stablized Earth Bricks

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**Abstract:- Home-building construction has involved the earth as a material for centuries. From mud bricks which are practically simple and sun dried to stronger clay fired up kiln-made bricks, it builds up to highly compressed stabilized earth bricks today, well regarded as the energy efficient, cost-effective, and environmental-friendly bricks contributing towards sustainable development. This study takes a look at mycelium, a kind of fungus that has an obsessed binding function. Mycelium nourishes by sawdust, straw, and grain substrates, degrading cellulose into chitin, which is a reasonably high-strength compound. These materials are expected to grow or assemble themselves, repair themselves, adapt to seasons, utilize natural forces, and live in harmony with the environment; be conducive to biodiversity and natural balance, economically feasible, and require less labor; carbon-free; and waste-free and return to nature whenever the material is no longer needed. These materials aim at sustainable and balanced human development.**

***Keywords**:- Clay Bricks, CSEB, Carbon Free Construction, Mycelium-Based Composite Materials, Fly Ash*

## I. INTRODUCTION

Centuries ago, forests were everywhere and were the main supplier of materials for building houses. They supplied the wood and other materials that were needed to construct a house or a building. Previously, the forest was an important part of our life and economic development. Due to the fast-growing population and their needs, earth as a building material has gained renewed interest in recent times. Earth has been a construction material since the emergence of human civilization. Recently, a new earthen construction method was developed. It is called Compressed Stabilized Earth Blocks. Compressed Stabilized Earth Blocks have been researched at Central Building Research Institute, Roorkee, India. Most of the time, such blocks are manufactured using lime. CSEBs are particularly good for making strong walls. This modern development includes traditional techniques like sun-dried bricks and rammed earth, offering a sustainable and efficient building solution.

Compressed Stabilized Earth Brick, called Pressed Earth Brick, are blocks for building. They are made by squeezing damp earth with high pressure. It consists of materials such as dry soil, non-expanding clay, small stones, and Portland cement to make it. CSEBs are environmentally friendly compared to clay bricks, which are widely used in houses nowadays. It is the manufacturing procedure that sets CSEB bricks apart from normal burnt bricks. The CSEB brick requires compaction, either static, dynamic, or Vibro-static, as well as the amount of the applied stabilizer for the improvement of strength. Compression force, curing, proportion of stabilizer, and soil condition affect the quality of the blocks immensely. More than two dozen brick types, covering a range of brands, will be covered by this study. Each type will be tested against compressive strength, water absorption, density, and thermal conductivity. The environmental impact and sustainability of each of the production processes involved will also be compared. The aim is to gain knowledge of the strengths and weaknesses of each type of brick, which will lead to making informed decisions in construction projects oriented toward durability, cost-efficiency, workability, and environmental responsibility.

With the increasing problems in the environment caused by people, there is a need to take care of our environment in a sustainable way. In this regard, one such material is Compressed Stabilized Earth Bricks are an energy-efficient, low-cost, and environmentally friendly building material. The main ingredient in CSEBs is soil, which is inexpensive and abundant. These bricks are used in over thirty countries. They're relatively easy to produce and can replace concrete in many applications. CSEBs have been tested for their strength and are suitable as load-bearing materials in buildings. They are made from a mixture of three primary components: cement, soil, and sand. These are mixed with water in definite proportions. The present research deals with the use of fly ash as a stabilizer in CSEB. This is very relevant, as a huge quantity of fly ash is produced annually in Nepal from various industries. This increases the generation of waste from different industries; and the waste must be reused to avoid pollution that may arise if disposed of unwisely. Compressed Stabilized Earth Blocks (CSEB) offer a good solution to these problems.

CSEB are made from a mix of soil, a little cement or lime as a stabilizer, and water. This mixture is then compressed into blocks, creating solid and durable blocks that are environmentally friendly. Unlike normal bricks that are fired, CSEB are not burned, greatly reducing carbon emissions. Also, materials for CSEB can often be sourced locally, reducing transportation costs and boosting local economies. By the end of this study, we want to show that CSEB can be a good choice instead of traditional building materials. It provides a sustainable solution that satisfies both money and environmental needs.The Native knowledge and conventional wisdom about earthquake-resistant technology in Nepal; the significance of methodical research in this field to identify what society has already accepted; and the necessity of incorporating some of those techniques and strategies into our current efforts to increase seismic safety, particularly in rural areas where traditional building materials like stone, timber, brick, mud, and bamboo are still widely used In order to improve the earthquake resilience often 22 million people who live in Nepal, their paper attempts to conduct a preliminary investigation into the traditional knowledge and expertise of earthquake-resistant technologies in the Nepal Himalayas. (Amod Mani DIXIT et.al (2004)).

CSEBs offer better thermal insulation properties compared to burnt clay bricks because of their composition and lower density. This makes them more energy-efficient in terms of heating and cooling buildings.(Ghavami et al. (1999)).

In this studies, three different concrete mixes with different the combination of natural material content namely 0%, 25%, 50%. Three samples specimen will be prepared for each concrete mixes. The parameters will be tested are compressive strength, tensile strength. This paper analyzed an investigation on the behavior of concrete specimens produce from coconut shell aggregate. A total of 36 specimens with varying percentage of replacement were casted and tested. The attempt is made to prove in all respect the serviceability and durability, experimental study is satisfying and can be implemented in rural areas by considering all technical aspect.(S.A. Kakade (2015)).

## II. METHODOLOGY

### *A. Materials*

Bricks are a building material used to construct walls, pavements, and other architectural elements. Compressed Stabilized Earth Brick is a mixture of red soil that has passed the liquid limit test and plastic limit test, cement (43-grade OPC), fly ash, sand, and clean water in an appropriate proportion. No additional admixture and chemical are used in this mixture.

### *B. Methods*

To achieve the objectives of the study a distinct methodology is a must. For the same purpose, the methodology for this study has been summarized below.

- Soil Preparation: Bring only soil samples from the selected sites if it matches the characteristics required. Collect samples from different depths and locations to get a mix that is representative. Pass the collected soil through sieves or screens to remove large particles, stones, and debris. This ensures uniformity in the particle size and workability of the mix.
- Stabilizer Preparation: Obtain Ordinary Portland Cement (OPC) from a reliable source. Ensure it is fresh and meets quality standards. Store it in a dry, moisture-free environment. Collect fly ash from industrial sources, ensuring it is fine and free of contaminants.
- Sample Testing: The primary goal of soil testing is to assess its behavior concerning compressibility, strength, and permeability, which are crucial for engineering applications such as Compressed Stabilized Earth Blocks (CSEBs).
  - ✓ Liquid Limit: This is the water content at which a groove, made in a soil sample using a standard tool, will close over a distance of 13 mm when subjected to 25 blows in a standard liquid limit device, such as the Casagrande apparatus. It represents the transition point between a liquid and a plastic state, providing crucial information about the soil's workability and its suitability for molding into stable blocks.
  - ✓ Plastic Limit: This is the water content at which soil transitions from a plastic to a semi-solid state. At this point, the soil will start to crumble and break apart when it is roll into a thread with a diameter of approximately 3 mm.
- Production of solid CSEBS: For each CSEB mix, the specific proportions of red soil, sand, Ordinary Portland Cement (OPC), Fly ash were measured using a weighing scale and mixed thoroughly with a shovel to ensure a homogenous mixture. Approximately 15% of water relative to the total weight of the mixture was added to achieve the desired consistency. The prepared mix was then filled into a (225 × 110 × 85) mm mold and compressed using a mortar interlocking press. Measure and mix materials (OPC, Fly ash, sand, red soil, and water) according to the ratios 1:6(OPC, and sand,) and 1:3:7(OPC, sand and clay) using a weighing scale. Substitute OPC with 0%, 10%, 20%, and 30%, of Fly ash. Mix thoroughly to ensure uniform distribution of materials. Water is added to facilitate workability and binding of the mixture.
- Curing and compressive strength check: The blocks that are produced for low-cost housing are for exterior application, so they must be well protected during manufacturing and curing to ensure that they last and perform well. The blocks were stored under a secured environment for all the curing operations. The blocks were subjected to at least two sessions of spraying in a day using the spray bucket to ensure the hydration reactions. The blocks were cured for a period of 28 days. The water absorption and compressive strength tests are carried out to find the best ratios of blocks and whether the block with RHA is the best or not.

- Water absorption capacity is the amount of water that a CEB block is able to absorb, in kilograms, during complete submerged in water for 24 hrs, expressed as a percentage of the dry weight of the block. The water absorption rate for these blocks was determined according to the British standard BS EN 772-21:2011.

✓ Water absorption capacity/rate (BS, EN 772-21:2011):
Water absorption rate (WS) = Ms- Md *100
Ms is mass of sample soaked and Md Mass of sample when dried.

✓ Mean water absorption rate: BS, EN 772-1:2011+A1:2015):

✓ Mean of water absorption= WS1+WS2+WS3+....WSn /Number of sample

Fig 1: Weighing of Material

Fig 2: Dry Mixing of Material

- Compressive Strength of Compressed Earth Block: Compressive strength is a basic mechanical property measurement necessary for testing the quality of experimental CSEBs as a masonry unit in compression. Inadequate strength of the masonry unit (CSEBs) will lead to failure of the structural masonry wall. The failure of the unit can lead to cracks and weakness, which can cause the ingress of water or moisture into the structure, reducing the interior comfort level. Cracking in masonry is one of the major problems contributing to abandonment of a structure or, in extreme cases, collapses the structure. The blocks were then tested according to the British Standard for fired clay bricks– BS EN 772-1:2011+A1:2015) for each block shape and mix ratio under each of the curing options.

✓ *Cross Section Area of the Block*
Area (A) = length*breadth

✓ *Compressive Strength of the Blocks (Fc) (BS, EN 772-1:2011+A1:2015)*
Compressive strength (MPa) = P/A
Where P = force at point of failure

✓ *Mean Compressive Strength Of The Blocks*
Mean compressive strength= C1 + C2 + C3 + Cn/ Number of compressive strength

Fig 3: Filling the Mould with Wet Mixture

Fig 4: CSEB

Fig 5: CSEB with Fly Ash

Figures 1,2,3,4 and 5 shows details of the compressed stabilized earth blocks making process

## III. RESULT AND DISCUSSION

### *A. Atterbegr's Limit Test*

The Atterberg limit test is a laboratory process of determining the critical water content of fine-grained soils at which they undergo a change of state from liquid to plastic and from plastic to solid. It helps assess the soil for behavior in terms of plasticity and is used for soil classification and prediction of soil behavior with change in moisture.

- Plastic Limit Test: It is the moisture content at which a fine-grained soil can no longer be remolded without cracking. In this test, a soil-water paste changes from a semi solid to a plastic state.

Table 1: Plastic Limit Test for Soil Sample Taken

| PLASTTIC LIMIT TEST | | | |
|---|---|---|---|
| **Container Number** | **A** | **B** | **C** |
| Wt. of container, gm (W) | 8 | 8 | 9 |
| Wt. of wet soil +Container ,gm (W1) | 16 | 19 | 21 |
| Wt. of dry soil +Container ,gm (W2) | 14 | 15 | 17 |
| Wt. of water ,gm (W1-W2) | 2 | 4 | 4 |
| Wt. of dry soil ,gm (W2-W) | 6 | 7 | 8 |
| Water Content (W%) [(W1-W2)/(W2-W) | 33.33 | 57.14 | 50 |
| Average W% | 46.82 | | |

Table 2: Liquid Limit Test for Soil Sample Taken

| LIQUID LIMIT TEST | | | |
|---|---|---|---|
| **Container Number** | **A** | **B** | **C** |
| Wt. of container, gm (W) | 7 | 7 | 8 |
| Wt. of wet soil +Container ,gm (W1) | 26 | 28 | 26 |
| No. of blow | 19 | 24 | 14 |
| Wt. of dry soil +Container ,gm (W2) | 20 | 21 | 21 |
| Wt. of water ,gm (W1-W2) | 6 | 7 | 5 |
| Wt. of dry soil ,gm (W2-W) | 13 | 14 | 13 |
| Water Content (W%) [(W1-W2)/(W2-W) | 46.15 | 50 | 38.4 |

Graph between water content (%) and no. of blows (N) in order to determine liquid limit of soil. The moisture content corresponding to 25 no. of blows is plotted. Hence, the moisture content corresponding to 25 no. of blows obtained was 56.9% from the graph plotted of the soil sample taken.

### *B. Plasticity Index Determination*

The plasticity index is the difference between the liquid limit and the plastic limit (PI = LL-PL).

Here, PI= 54.25-46.82=7.42

Hence, the plasticity index obtained is 9.4. Soil description based on plascity index is given below:

Table 3: Ip Vs Plasticity of Soil

| **Value of plasticity Index(Ip)** | **Plasticity** |
|---|---|
| <7 | Low plastic |
| 7<IP<17 | Medium plastic |
| >17 | High plastic |

### *C. Water Absorption*

- ➢ *Water Content of Different Concrete CSEB Brick:*

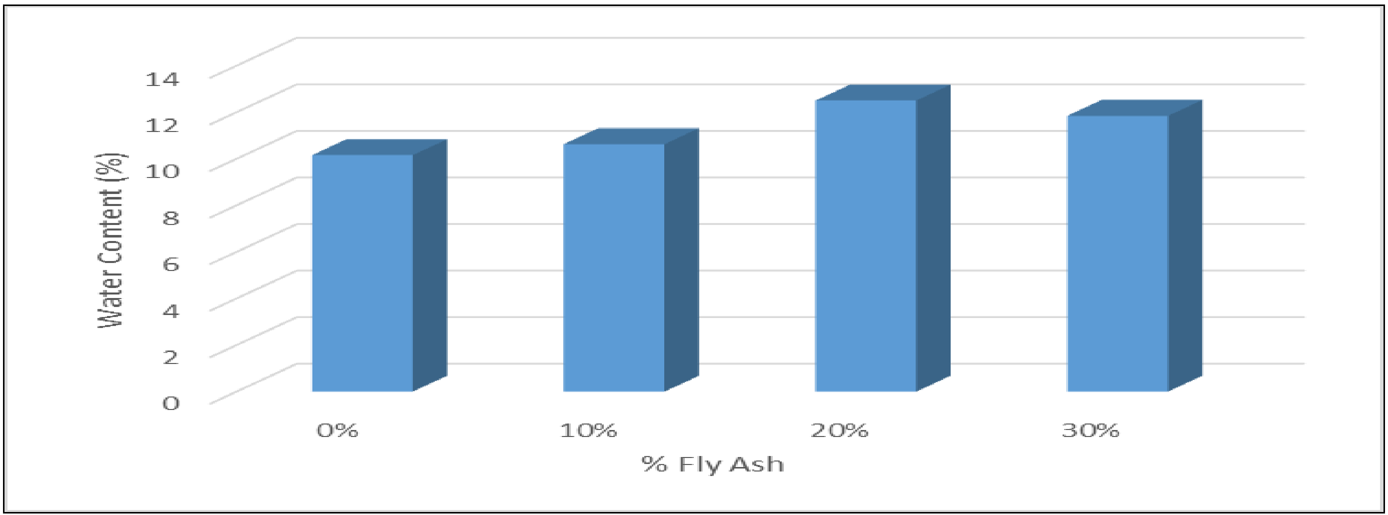


Fig 6: Average Water Absorption Against Samples as Per Set Ratios

➢ *Water Content of Different clay CSEB Brick:*

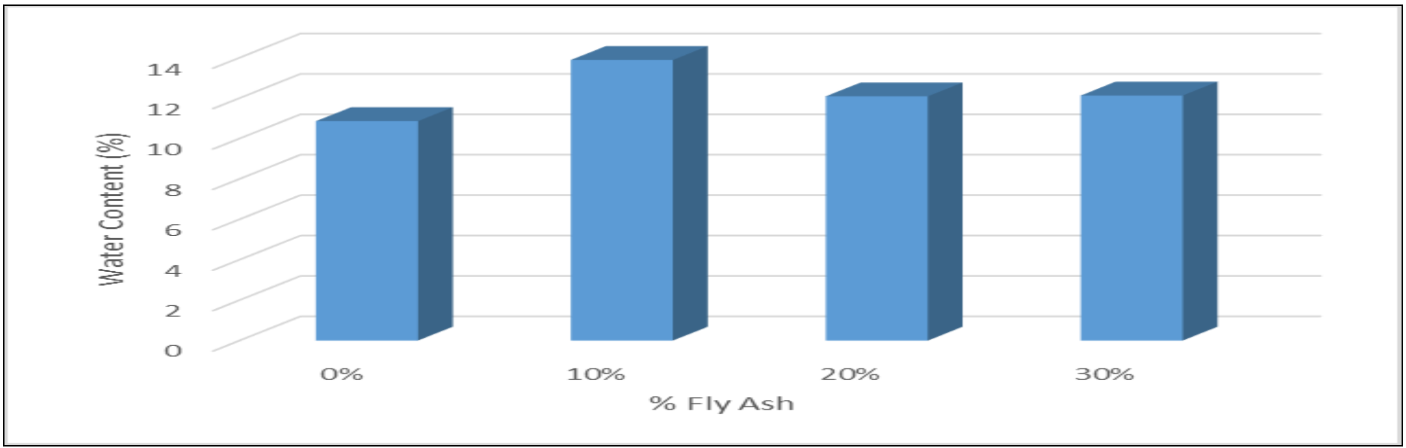


Fig 7: Average Water Absorption against Samples as Per Set Ratios

The minimum water absorption capacity is for clay cseb brick with 0% replacement of cement and the maximum water absorption capacity is for clay cseb brick with 10% replacement of cement by fly ash. Concrete CSEB brick with 0% replacement of cement has the minimum water absorption capacity whereas concrete cseb brick with 20% replacement of cement by fly ash has maximum water absorption capacity.

*D. Compressive Strength Test*

➢ *Average Compressive Strength of Concrete Brick*

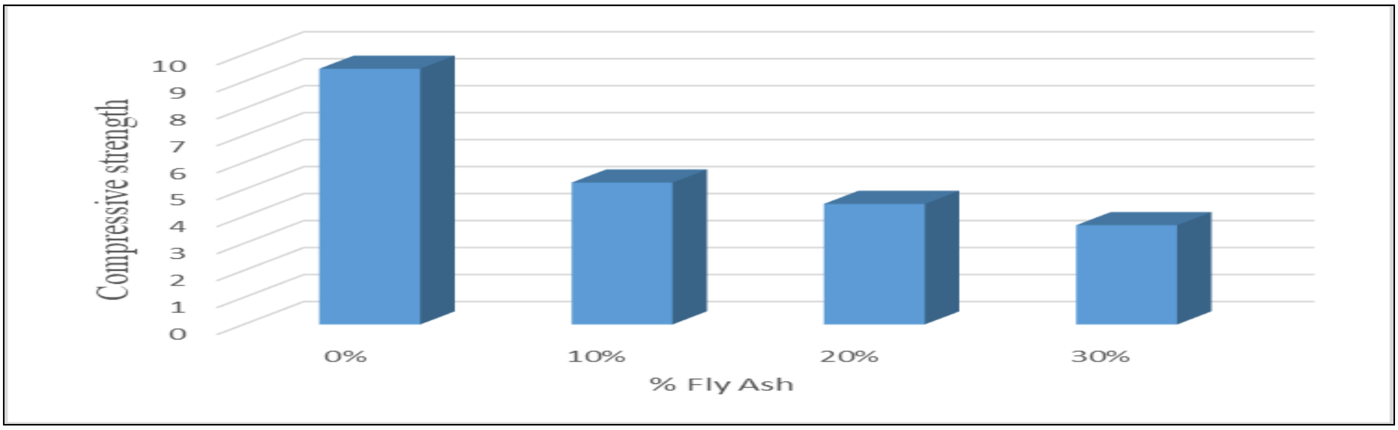


Fig 8: Average Compressive Strength (N/mm^2) against Samples as Per Set Ratios

➢ *Average Compressive Strength of Clay Brick*

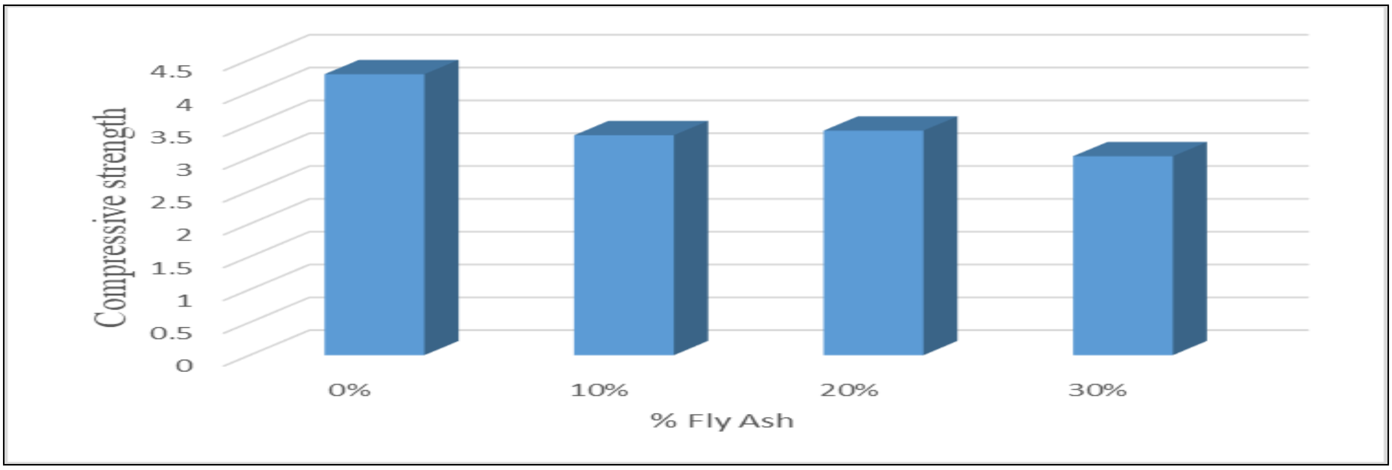


Fig 9: Average Compressive Strength (N/mm^2) against Samples as Per Set Ratios

The minimum compressive strength for clay CSEB brick is with 30% replacement of cement, while the maximum compressive strength for clay cseb brick is with 0% replacement of cement by fly ash. The minimum compressive strength for concrete CSEB brick is with 30% replacement of cement, while the maximum compressive strength for concrete cseb brick is with 0% replacement of cement by fly ash.

*E. Weight Test*

➢ *Average Dry Weight of Various Concrete Brick*

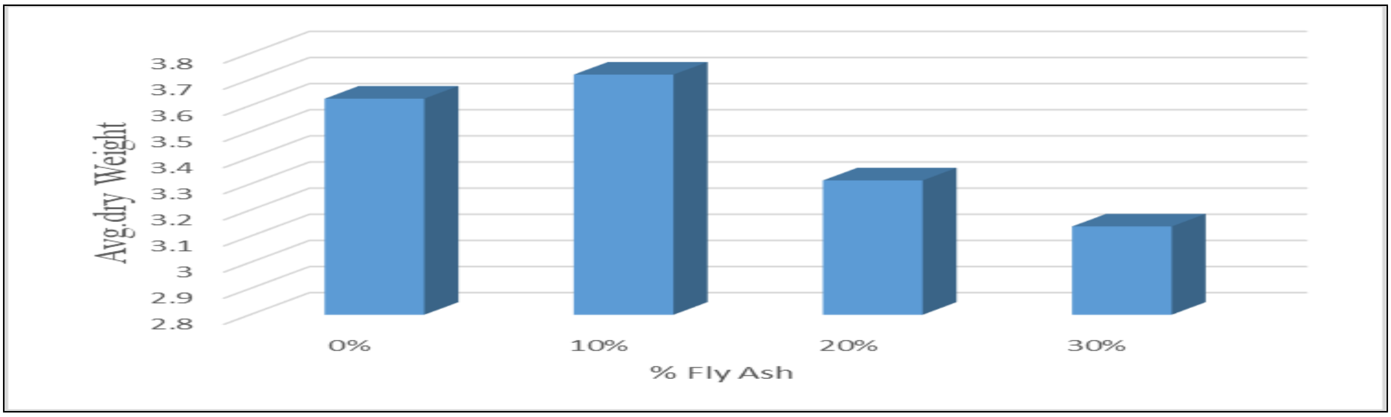


Fig 10: Average Dry Weight against Samples as Per Set Ratios

➢ *Average Dry Weight of Various Clay Brick*

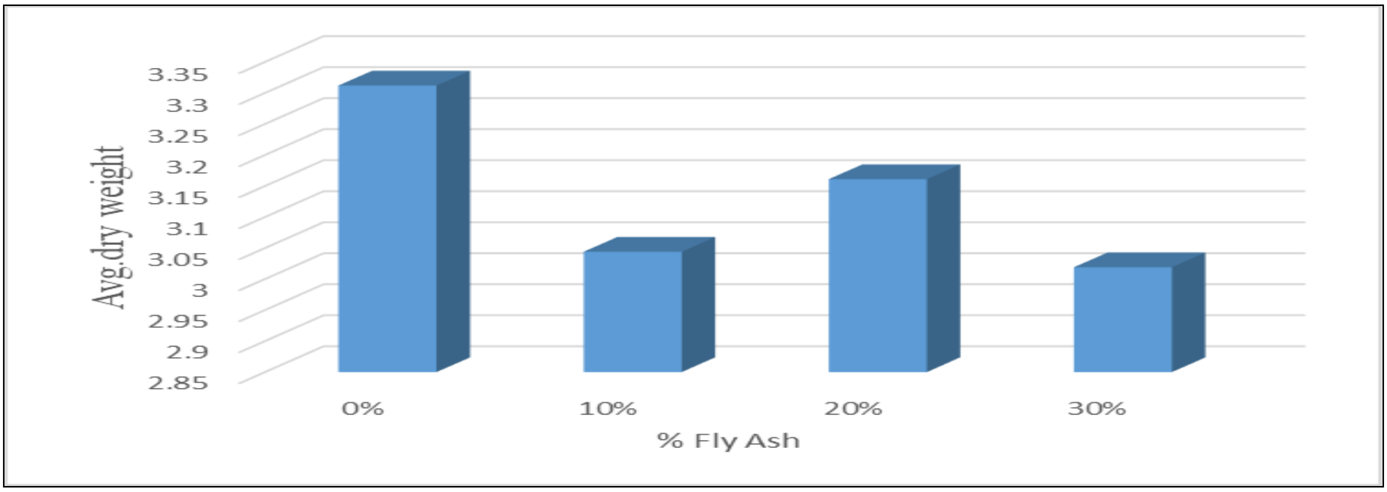


Fig 11: Average Dry Weight against Samples as Per Set Ratios

➢ *Average Wet Weight of Various Concrete Brick*

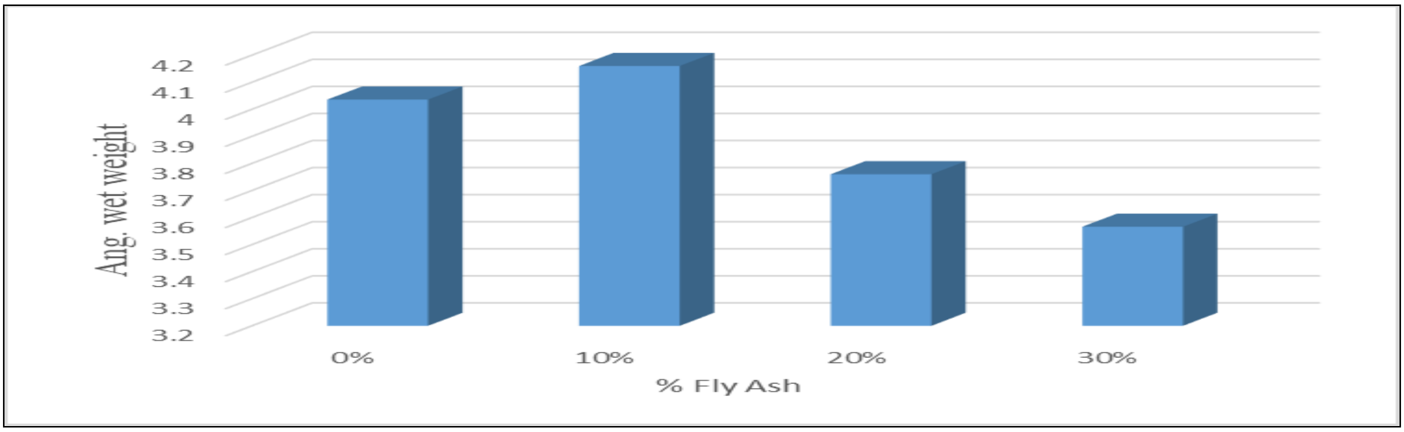


Fig 12: Average Wet Weight Against Samples as Per Set Ratios

➢ *Average Wet Weight of Various Clay Brick*

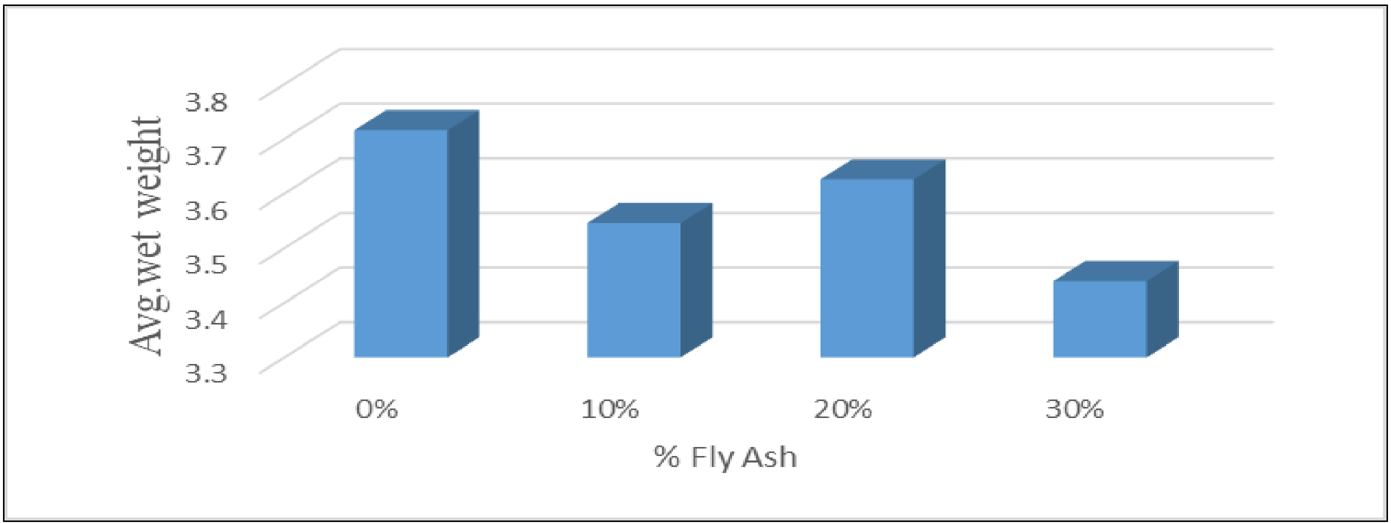


Fig 13: Average Wet Weight against Samples as Per Set Ratios

In dry condition, clay cseb brick has the minimum dry weight at 30% replacement of cement and clay cseb brick with 0% replacement of cement by fly ash has maximum dry weight. The dry weight for the concrete CSEB is minimum when the cement replacement is 30%, whereas it is maximum at a 10% replacement of cement by fly ash. The wet weight for the clay CSEB brick is minimum when the replacement of cement is 30%, whereas the wet weight for the clay cseb brick is maximum for 0% replacement of cement by fly ash. Concrete CSEB brick has minimum wet weight for 30% replacement of cement, whereas the maximum wet weight is for 0% replacement of cement by fly ash.

## IV. CONCLUSION

This paper focused on the properties and internal mechanism of CSEBs with partial cement replacement by fly ash. It was concluded from the experimental results that the properties of water absorption, compressive strength, and dry and wet weights of clay and concrete CSEB bricks without fly ash replacement were higher than those of bricks with 30% replacement of fly ash. In some cases, it was found that moderate replacement levels, such as 10% or 20%, had positive influences on water absorption and dry weight, hence showing the range of optimal utilization of fly ash. The addition of fly ash increased the sustainability of CSEBs, besides providing a cost-effective alternative for building materials, especially in less economically developed regions. Overall, the findings confirm that fly ash can effectively replace a portion of cement in CSEBs while optimizing their characteristics for temporary constructions and contributing to environmental sustainability through waste utilization.

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**BIOGRAPHIES**

**Er. Ajay Yadav,** a University topper and Dean's List honoree, is a dedicated researcher and author of multiple engineering textbooks. Recently, he received a fully funded scholarship through ICCR to pursue an M.Tech in Geotechnical Engineering at **IIT Roorkee(QS ranking-369)**. He was also honored with the prestigious **Geo-Tech Award** during his undergraduate studies. He has published more than 15 research papers and his research areas are sustainable construction materials, Machine learning, Structural analysis, and Geo tech.

**Ashish Chapagain**, a Civil Engineering graduate from Oxford College of Engineering and Management, affiliated with Pokhara University, has always strived for excellence. Recognized on the Dean's List and as the top performer of his 2019 batch, his academic achievements are a testament to his unwavering dedication and passion for the engineering field.

**Milan BK**, a civil engineering student from Oxford College of Engineering and Management, Pokhara University, is passionate about structural systems and sustainable development. He is driven to create innovative solutions for modern engineering challenges.

**Prabin Bhattarai**, a civil engineering student, is passionate about designing and developing resilient infrastructure. He is dedicated to advancing the field through innovative and sustainable solutions.

**Subhangam Singh Adhikari,** a civil engineering students from Oxford College of Engineering and Management, specializes in the design and development of resilient infrastructure. He is dedicated to advancing the field of civil engineering through innovative and sustainable design solutions.