EXPERIMENTAL ANALYSIS OF CLAY BRICKS WITH PARTIAL REPLACEMENT OF CLAY WITH STONE DUST POWDER

Dr. TABITHA SUBBARAO GEDDAM [1], JAMI AJAYKUMAR[2], BALIVIDA MANOJ[3], CHELLUBOINA ASHISH KRISHNA PRASAD[4], SIMHADRI ASWINI[5]

[1] Associate Professor, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College, Andhra Pradesh, India
[2, 3, 4, 5] Student, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College, Andhra Pradesh, India

ABSTRACT

In response to the growing need for sustainable construction materials, this study investigates the potential of incorporating stone dust powder as a partial replacement for clay in oven-dried brick production. The research aims to comprehensively assess the influence of varying proportions of stone dust on the physical, mechanical, and durability properties of bricks. Through a systematic experimental approach, soil and stone dust samples are collected, prepared, and subjected to a battery of tests following established ASTM and IS standards. These tests include grain size analysis, specific gravity determination, Atterberg limits determination, free swell index measurement, compression testing, water absorption assessment, and efflorescence testing.

The findings of this study shed light on several important aspects of brick production with stone dust incorporation. Analysis of soil characteristics identifies it as sandy silt with gravel and sand constituents, laying the groundwork for subsequent experimentation. The sieve analysis reveals the particle size distribution of both soil and stone dust, informing their suitability for brick manufacturing. Specific gravity measurements offer insights into the density and compactness of the materials, crucial factors affecting brick structural integrity.

Evaluation of Atterberg limits provides crucial data on the plasticity and moisture susceptibility of the soil and stone dust mixtures, guiding material selection and proportioning. Free swell index testing elucidates the volume change behavior of the mixtures when exposed to water, offering valuable information for predicting brick performance in various environmental conditions. Compression testing assesses the load-bearing capacity and structural integrity of the bricks, revealing the influence of stone dust incorporation on compressive strength.

Challenges encountered during water absorption and efflorescence testing underscore the importance of further investigation into manufacturing processes to address potential weaknesses in brick composition or production methods. Despite these challenges, the study contributes significantly to the body of knowledge surrounding sustainable construction materials by exploring alternative raw materials and manufacturing techniques. The insights gained from this research have the potential to inform brick manufacturing practices, offering opportunities for enhancing structural performance, durability, and environmental sustainability in the construction industry.

1. INTRODUCTION

The origins of brickmaking can be traced back to ancient civilizations like Mesopotamia, where the first sun-dried bricks were produced around 4000 BCE. Over time, civilizations like the Egyptians and Romans refined brickmaking techniques, introducing fired bricks for enhanced strength and durability. The medieval period witnessed the resurgence of brick usage, particularly in Europe, with distinctive architectural styles emerging.

With the advent of the Industrial Revolution, brick production underwent significant mechanization, marking a transition from traditional handcrafted methods to more efficient manufacturing processes. In the 20th century, modern construction materials began to emerge, challenging the longstanding dominance of traditional clay bricks.

1.1 Objectives of the Study

Evaluate Raw Materials**:**

Investigate and characterize the properties of the raw materials, including the clay and stone dust powder, to understand their individual characteristics and potential synergies in brick production.
Optimize Mixing Proportions**:**

Determine the most effective mixing proportions of clay and stone dust powder to achieve desirable physical and mechanical properties in the resulting bricks. This involves a meticulous exploration of various ratios to identify the optimal combination.
Assess Physical Properties of Bricks**:**

Conduct thorough testing to evaluate the physical properties of the experimental bricks, including but not limited to density, porosity, and thermal conductivity. This step aims to provide insights into the structural integrity and insulation capabilities of the new composite material.
Analyze Mechanical Properties**:**

Investigate the mechanical properties of the bricks, such as compressive strength, tensile strength, and flexural strength. Understanding how the introduction of stone dust powder influences these properties is crucial for assessing the suitability of the material for construction purposes.
Perform Microstructural Analysis**:**

Employ microscopy and other analytical tools to study the microstructure of the experimental bricks. This step aims to reveal any changes or enhancements in the internal composition that may impact the overall performance of the material.
Examine Environmental Impact**:**

Evaluate the environmental implications of using stone dust powder as a partial replacement for clay in brick production. This includes assessing the sustainability aspects, such as reduced resource consumption and lower environmental footprint.

1.2 Scope of the Work

Materials Exploration: A detailed examination of the properties of raw materials, specifically clay and stone dust powder, to understand their characteristics and compatibility in brick production.
Mixing Proportions Optimization: An investigation into various mixing ratios to identify the optimal combination of clay and stone dust powder for enhanced physical and mechanical properties. Comprehensive Testing: Rigorous evaluation of the physical and mechanical properties of the experimental bricks, including density, porosity, compressive strength, tensile strength, flexural strength, and microstructural analysis.
Environmental Impact Assessment: Examination of the environmental implications associated with the use of stone dust powder in brick production, with a focus on sustainability and reduced environmental footprint.

2. MATERIALS & METHODOLOGY

In our search for sustainable and innovative building materials, this chapter takes a close look at the materials chosen for our experiment. Understanding the raw materials, which are clay and stone dust powder, is crucial before we examine their properties, mixing ratios, and the overall experimental design.

Fig-1: Reddish Clay

The clay used in our experiment comes from Local Store. It's a naturally occurring material formed over time from tiny rock and mineral pieces, which is why it's been used in construction for so long. The specific location where the clay is found affects the types of minerals it contains, and these minerals determine how the clay behaves.

Fig -2: Stone dust

2.1 Mixing Procedures

1. Batch Mixing**:** The clay and stone dust powder are combined in batch mixing, with each experimental group representing a specific formulation. The mixing process is optimized to achieve a homogeneous blend of the materials.
2. Water Content Management: The addition of water is carefully controlled during mixing to achieve the required plasticity for moulding while avoiding excess moisture that may compromise the final brick quality

2.2 Brick Moulding

1. Mold Design**:** Specific moulds are designed to produce bricks of standard dimensions, ensuring consistency across all experimental groups.
2. Compaction and Shaping: The mixed materials are compacted within the moulds to achieve the desired brick shape and density.

2.3 Drying Conditions

1. Oven dry: The moulded bricks are subjected to controlled firing parameters in a Oven. The firing temperature, duration, and cooling conditions are optimized to achieve the desired burnability and strength development.

2. Environmental Monitoring: The Drying environment is closely monitored to minimize variations and ensure consistent firing conditions for all experimental groups

3. TESTS CONDUCTED

- **Determination of Moisture Content in Soil (IS 2720: Part 2)**

  Moisture content: Calculate the moisture content (w) as a percentage using the following formula:

$$w = [(M2 - M3) / (M2 - M1)] * 100\%$$

where:

- w = Moisture content (%)
- M1 = Weight of empty moisture can (g)
- M2 = Weight of can with wet soil (g)
- M3 = Weight of can with dry soil (g)

- **Determination of Grain Size Distribution in Soils (IS 2720 Part 4)**
- Express the weight of each fraction retained on each sieve and withdrawn from the sedimentation cylinder as a percentage of the total dry weight of the sample.
- Plot the grain size distribution curve by plotting the percentage passing on the y-axis versus the particle size on the x-axis (logarithmic scale).
- From the curve, determine the various parameters such as percentage fines, coefficients of uniformity and curvature, etc.
- **Determining Atterberg Limits (Liquid Limit & Plastic Limit) IS 2720: Part 5**

  Plot the number of drops on the y-axis and the corresponding moisture content on the x-axis. Draw a straight line through the data points and extend it to intersect the Liquid Limit line on the y-axis (around 25 drops). The moisture content at this point is your Liquid Limit.

  Plot the moisture content on the y-axis and the corresponding number of rolls needed for crumbling on the x-axis. Draw the best-fit curve through the data points. The moisture content at the intersection of the curve and the Plastic Limit line on the y-axis is your Plastic Limit.
- **Determination of Water Absorption of Bricks as per IS 3495 (Part 2): 1992**

  Calculate the water absorption by weight for each brick using the following formula:

$$\text{Water Absorption (\%)} = [(M_2 - M_1)/M_1] * 100$$

  where
  - M_1 is the dry weight of the brick.
  - M_2 is the wet weight of the brick after immersion.
- **Determining the compressive strength of bricks as per IS 3495 (Part 2): 1992**

  Use the following formula to calculate the compressive strength (MPa):

$$\text{Compressive Strength (MPa)} = \text{Maximum Load (N)} / \text{Average Cross-sectional Area (mm}^2)$$

$$\sigma = P / A$$

- **Determination of Efflorescence Test as per IS 3495(Part 3): 1992**

After the second evaporation cycle, remove the bricks from the dish and wipe them gently with a damp cloth to remove any loose deposits.

Examine the brick surfaces carefully under good lighting for any remaining efflorescence.

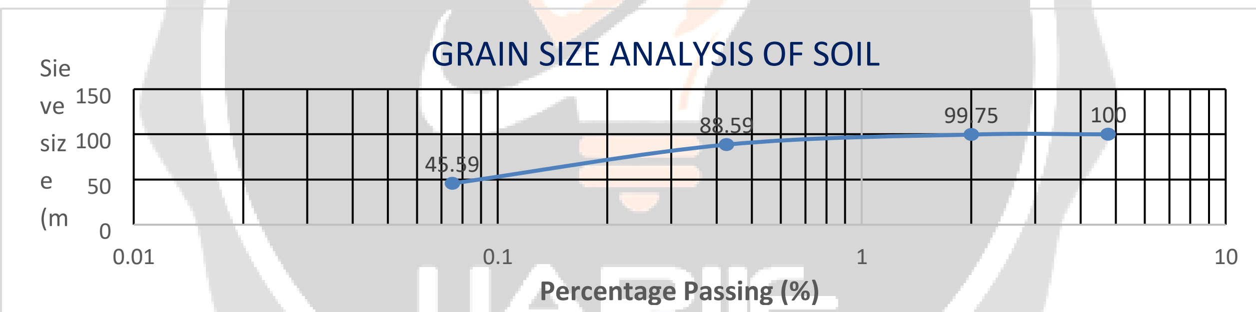
Report the degree of efflorescence observed for each brick based on the following categories:

- Nil: No perceptible deposit of efflorescence.
- Slight: Not more than 10% of the exposed area covered with a thin deposit of salts.
- Moderate: Heavier deposit than "Slight," covering up to 50% of the exposed area but unaccompanied by powdering or flaking of the surface.
- Heavy: Heavy deposit of salts covering more than 50% of the exposed area but unaccompanied by powdering or flaking of the surface.
- Very Heavy: Heavy deposit of salts covering more than 50% of the exposed area with powdering or flaking of the surface.

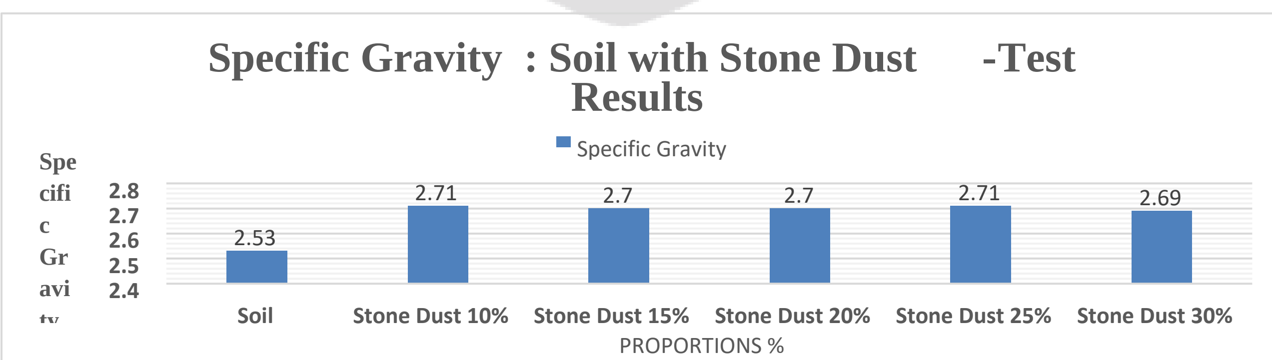
4.RESULTS

4.1 Grain Size Test:

GRAIN SIZE ANALYSIS OF SOIL (IS : 2720 - PART - 4)				
Total Sample Taken (W1):	300 gm			
Sieve size (mm)	Weight Retained in (gm)-W2	Cumulative Weight Retained in (gm)-W3	Cumulative percentage retained (%)-W3/W1X100	Percentage passing (%)
4.75	0	0	0	100
2	0.75	0.75	0.25	99.75
0.425	33.48	34.23	11.41	88.59
0.075	128.99	163.22	54.41	45.59
GRAVEL (%)			0	
SAND (%)			54.41	
CLAY & SILT (%)			45.59	

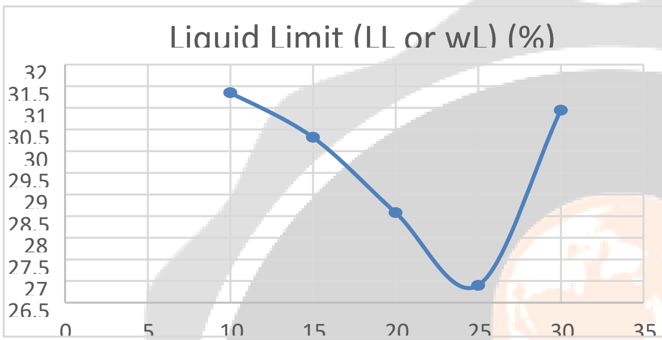


4.2 Specific Gravity Test:



4.3 Atterberg Limits Test:

Soil with stone dust		10%	15%	20%	25%	30%
Liquid Limit (LL or w_L) (%)	:	31.35	30.32	28.58	26.90	30.95
Plastic Limit (PL or w_P) (%)	:	11.7	13.4	13.1	13.5	14.6
Plasticity Index (PI) (%)	:	**20**	**17**	**15**	**13**	**16.35**



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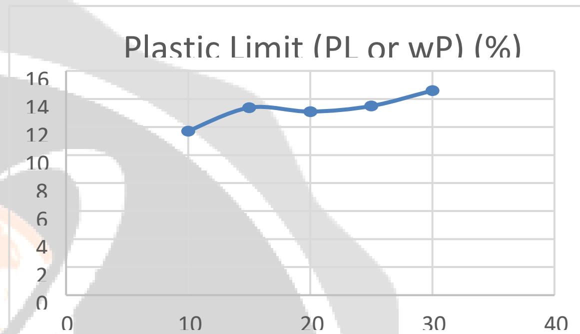

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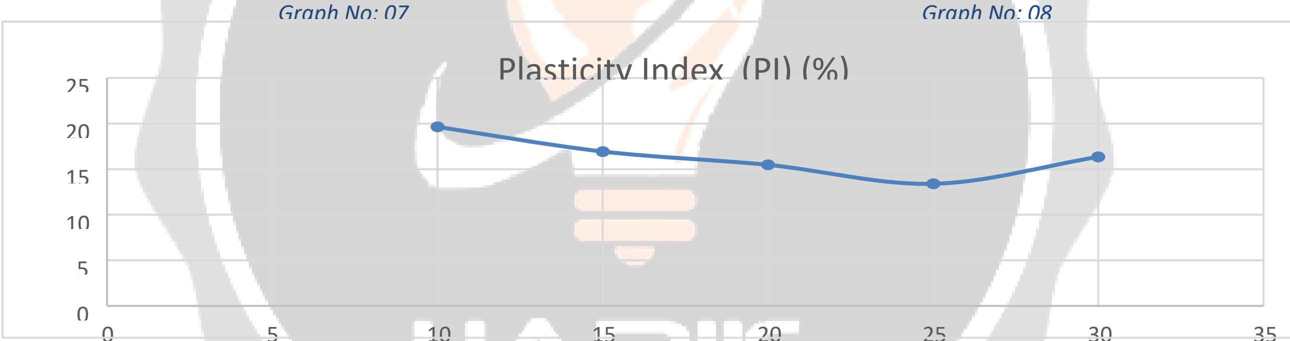
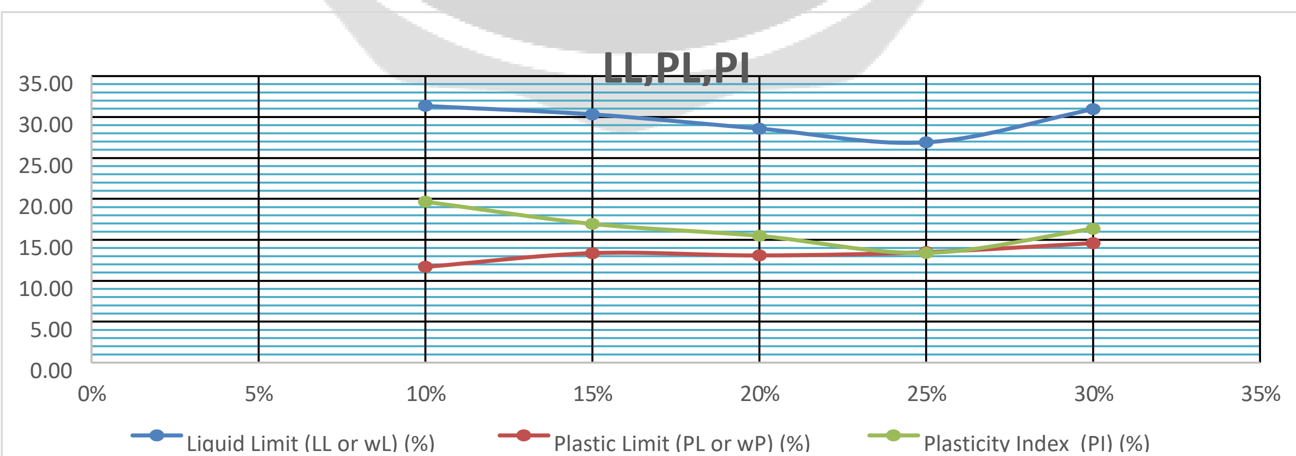
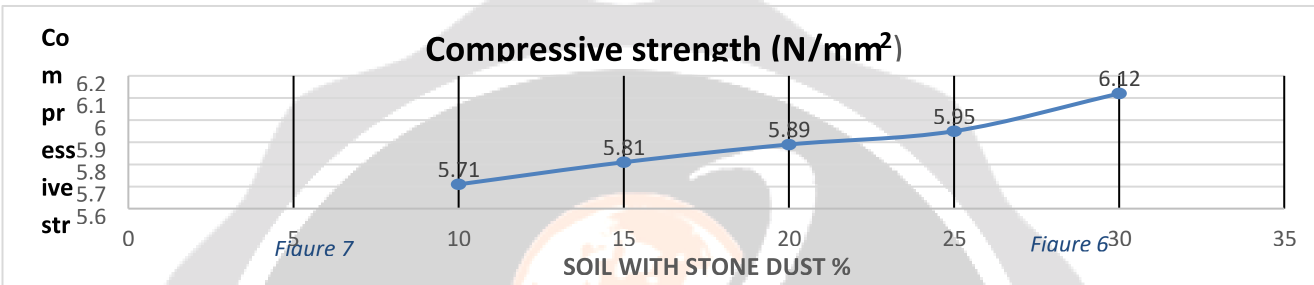
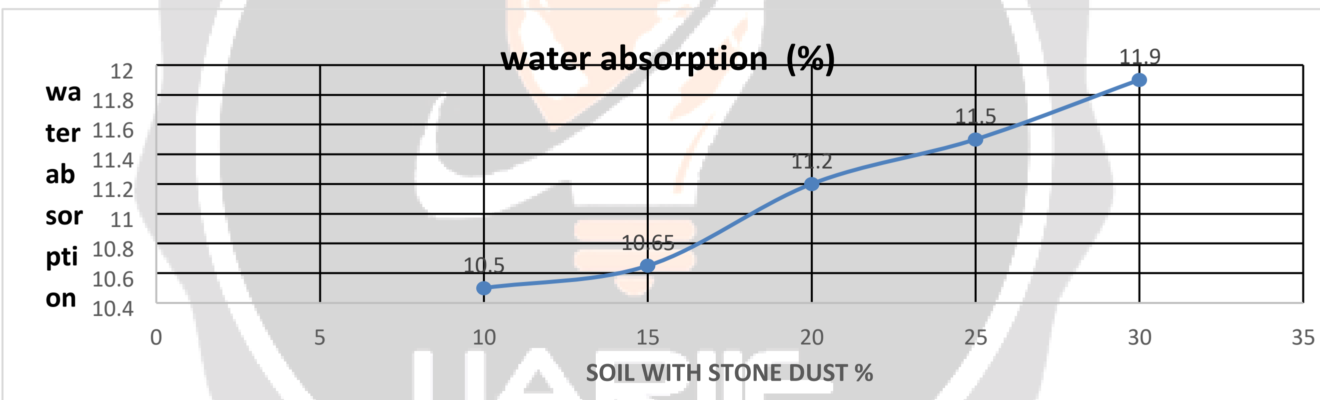
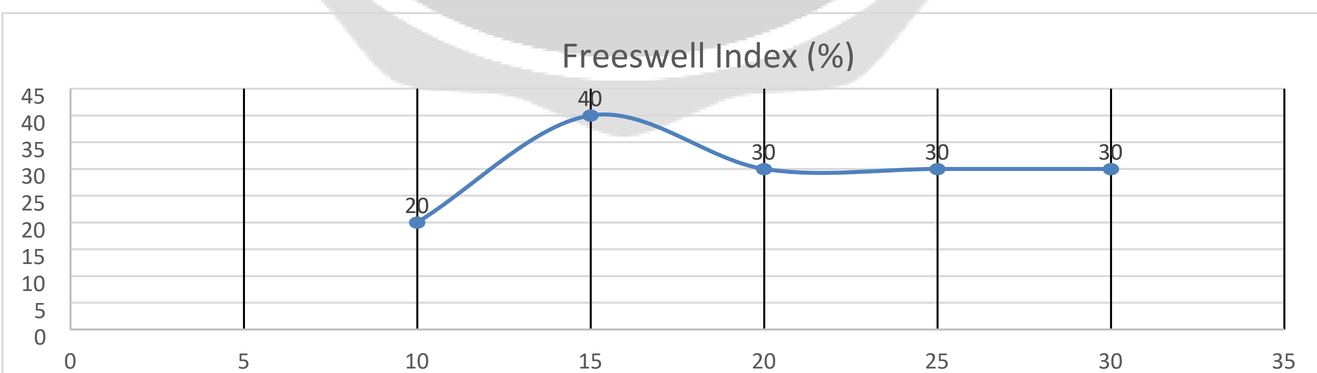




S. NO	1	2	3	4	5
STONE DUST (%)	10	15	20	25	30
Compressive Strength (N/mm^2)	5.71	5.81	5.89	5.95	6.12
water absorption (%)	10.5	10.65	11.2	11.5	11.9
Freeswell Index (%)	20	40	30	30	30
Efflorescence	MODERATE.				







5. CONCLUSIONS

In conclusion, the experimental results suggest that stone dust can be effectively used to augment the compressive strength of soil bricks. The gradual increase in strength with higher proportions of stone dust indicates its potential as a partial replacement material in brick manufacturing. However, it is essential to consider the economic and environmental implications of sourcing and processing stone dust, as well as the long-term performance of the bricks under various conditions. Future studies could focus on optimizing the stone dust content for maximum strength, durability, and sustainability. The results indicate that increasing the proportion of stone dust in the soil-brick mixture improves the compressive strength, with the highest strength observed at 30% stone dust. However, this enhancement in strength comes with a trade-off in higher water absorption rates and changes in soil plasticity characteristics. The Free swell Index suggests variability in expansion upon wetting, which stabilizes after 20% stone dust addition. The Liquid Limit and Plastic Limit show a decrease and then an increase, indicating a complex relationship between stone dust content and soil workability. Overall, the addition of stone dust up to 30% appears to improve the structural integrity of the bricks while affecting their water interaction and plasticity properties.

6. REFERENCES

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