Comparative study on mechanical properties of waste rein-forced mud-bricks

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Abstract- **This study addresses the experimental work carried out on the production of waste reinforced mud brick incorporating waste materials such as fly ash (FA), rice husk (RH), sugarcane bagasse (SCB), and eggshell (ES) as substitutes for traditional burnt clay bricks. Fly ash was collected at the RTPS thermal power plant in Raichur, rice husk was collected at the Savitri Group rice mill in Raichur, eggshell was collected from local mess and hotels, and sugarcane bagasse was collected at the local juice shop in Bagalkote. Waste materials were prepared as per the requirements. Sugarcane bagasse and eggshells were dried in the sun light for 8 hours to remove the moisture content and then grounded into smaller pieces with the use of a mixer grinder. Wooden mould of dimensions 230mm x 100mm x 70mm was used to produce the waste-reinforced mud bricks by adding different proportions (ranging from 5% to 35%) of waste materials to the total weight of the bricks. Waste reinforced mudbricks were dried in the sun light for 48 hours. Strength and durability of the bricks were enhanced by burning using the sugarcane bagasse, wood and coal. The mechanical properties such as compressive strength, water absorption tests were performed according to ASTM Standard methods (ASTM C67).**

***Index Terms*— Waste Reinforced; Mud- Bricks; Mechanical properties; compressive strength; water absorption.**

I. INTRODUCTION

Housing – a basic need of mankind, in its construction and de-pendency, holds a very significant role of an 'Bricks'. Out of many types of bricks one stands for popularity for reasons such as cheapness of materials, nearness of sources of supply and raw materials, and the facility with which they can be handled by labor during construction and mortar, and labor available a special reference to manpower. It has also been global history that burnt clay bricks generally have dominated construction the most [4]. Even the simplest material like bricks is of great im-portance in the construction process due to properties such as cheapness, endurance, and light nature. However, the depend-ency of brick on clay the raw material used in the production has reached up to 340 billion tons annually making variations in natural resource more worrying [1-3]. Fly ash is the sub product of coal combustion which is produced in the power plants, and based on the chemical analysis it is heterogeneous material, which may consist of mullite which is an aluminium-silicon oxide and iron oxides like hematite and magnetite [15]Worldwide manufacturing and using of burnt clay bricks remain as common practice in many parts of the world. Accord-ing to the report, china leads in the production of bricks with a whopping 180 billion tons per annum and is followed by India. However, over reliance of natural resources especially clay has raised a very big and sensitive environmental issue [5-8]. The problem of an escalating rate of using resources in the order of fly ash, rice husk, sugarcane bagasse, and eggshell, together with the rate of waste generation, is an environmental issue of concern. Solving this problem is critical to obtaining ecological-ly friendly results that can also be profitable and provide solu-tions for the future[9].

The current study is aimed at utilization of waste materials to produce waste reinforced mud bricks towards the following objectives,

- To prepare bricks by adding different proportions of waste materials.
- To evaluate the mechanical properties of waste reinforced bricks.

II. MATERIALS AND METHODOLOGY

II.I. Materials

The waste materials, such as fly ash, rice husk, eggshell, and sugarcane bagasse, were collected according to their availability. Fly ash was collected at the RTPS thermal power plant in Raichur, rice husk was collected at the Savitri Group rice mill in Raichur, eggshell was collected from local mess and hotels, and sugarcane bagasse was collected at the local juice shop in Bagalkote. Redmud and clay were collected from brick production plant in Bagalkote.

Figure. 1. Fly ash(FA)

Figure. 2. Rice husk(RH)

Figure. 3. Egg shell(ES)

Figure. 4. Sugarcane bagasse(SCB)

II.II. Methodology

In order to meet the objectives of the project work a detailed experimental procedure and methodology in the form of flow chart is shown in Figure. 5.

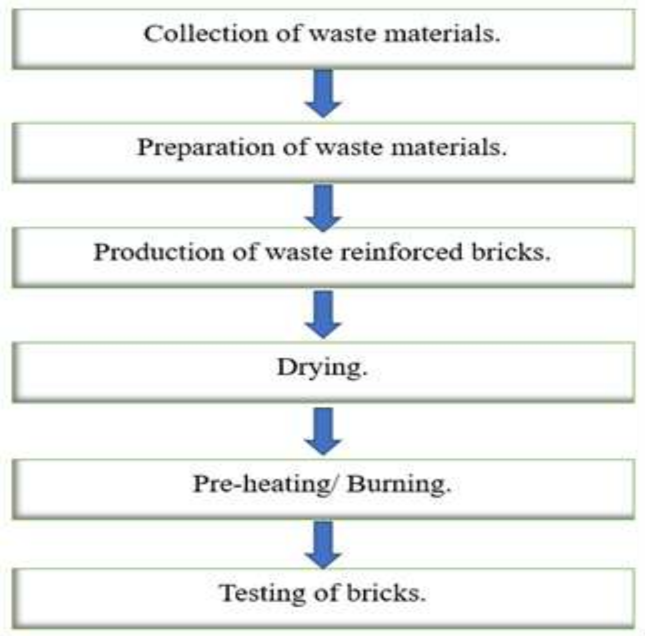


Figure. 5. Flow chart to meet the objectives of the project work

A detailed description of the above methodology throughout the entire project work is presented below.

II.III. Collection of waste materials

The waste materials, such as fly ash, rice husk, eggshell, and sugarcane bagasse, were collected according to their availability. Fly ash was collected at the RTPS thermal power plant in Rai-chur, rice husk was collected at the Savitri Group rice mill in Raichur, eggshell was collected from local mess and hotels, and sugarcane bagasse was collected at the local juice shop in Bagalkote.

II.IV. Preparation of waste materials

Waste materials were cleaned and sorted to remove contaminants or unwanted elements from them. Sugar cane bagasse was dried in sunlight for 8 hours as shown in Figure.6 and grounded into smaller pieces with the help of a mixer grinder. Similarly the eggshell was dried in the sun light for 8 hours and grounded into a smaller size, rice husk is grounded into fine powder using mixer grinder as shown in Figure.7.

Figure. 6. Grinding of Sugar cane bagasse

Figure.7. Grounding of rice husk into fine powder

II.V. Production of waste reinforced bricks with different proportions of waste materials

Table. 1. shows the different waste materials proportions for WRMBs

S.NO	WRM Bricks	Proportions In % By the total Weight of the brick.	Total Weight in gm
1.	WRMB 1	FA-35%, RH-35%, RM-15%, C-15%	2000 gm
2.	WRMB 2	FA-30%, RH-16%, RM-26.6%, C-26.6%	3000 gm
3.	WRMB 3	FA-25%, SCB-5%, RM-35%, C-35%	2000 gm
4.	WRMB 4	ES-25%, SCB-5%, RM-35%, C-35%	2000 gm
5.	WRMB 5	FA-15%, RH-15%, RM-35%, C-35%	2000 gm
6.	WRMB 6	FA-15%, RH-5%, RM-40%, C-40%	2000 gm
7.	WRMB 7	FA-10%, SCB-5%, ES-5%, RM-40% C-40%	2000 gm
8.	WRMB 8	FA-5%, RH-5%, SCB-5%, ES-5% RM-40%, C-40%	2000 gm

Figure.8. WRMB 1

Figure.9. WRMB 2

Figure.10. WRMB 3

Figure.11. WRMB 4

Figure.12. WRMB 5

Figure.13. WRMB 6

Figure.14. WRMB 7

Figure.15. WRMB 8

II.VI. Drying

Waste reinforced mud bricks were left for drying in the sun light for 48 hours as shown in Figure.16 after the brick mixture has been shaped using a mould.

Figure.16. Drying of Waste reinforced mud bricks

II.VII. Pre-heating/ Burning

Waste reinforced mud bricks are burned on direct fire as shown in Figure.17 for enhancing the strength and durability of bricks. The sugar cane bagasse, wood and coal were used as a fuel to burn the waste-reinforced mud bricks.

Figure.17. Burning of waste reinforced mud bricks

II.VIII. Testing of bricks

Waste reinforced mud bricks were tested for water absorption and compressive strength test according to the procedure de-scribed in in the following section after they have been heated or burnt.

III. EXPERIMENTAL WORK

III.I. Compressive strength test

Using a hydraulic compression testing apparatus, a compressive strength test is performed to assess the comparative perfor-mance of waste-reinforced bricks. The ASTM standards (ASTM C67 for the compression test)[17-18] methods were followed in order to determine the compression strength for different pro-portions of waste material bricks. The outcomes are discussed below. Figure.18 shows the compression strength test performed on waste reinforced mud brick.

Figure.18. Hydraulic compression testing machine used for compression test.

ASTM(C67) Procedure for Compression Test

- Place the specimen with flat face horizontal and facing upwards between plates of the testing machine.
- Apply load axially at a uniform rate till failure occurs and note maximum load at failure.
- The load at failure is maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

III.II. Water absorption test

Water absorption test on bricks is conducted to determine durability property of bricks such as quality and behavior of bricks in weathering. A brick with water absorption of less than 7% provides better resistance to damage by freezing. The degree of compactness of bricks can be obtained by water absorption test, as water is absorbed by pores in bricks. The water absorption by bricks increases with increase in pores. So, the bricks, which have water absorption less than 3 percent can be called as vitrified.

This test provides the percentage of water absorption of bricks and procedure of the same is discussed below Figure.19 shows the water absorption test performed on waste reinforced mud brick.


Figure.19 Water absorption test performed on waste reinforced mud brick.

IV. RESULTS AND DISCUSSIONS

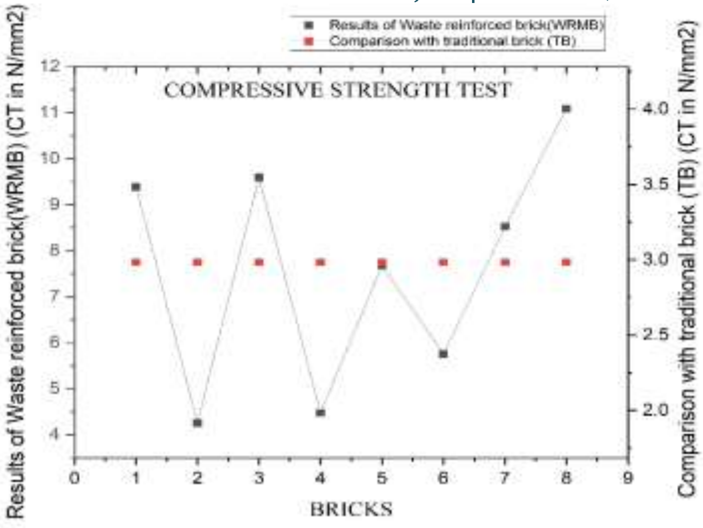
IV.I. Compressive Strength Test Results

The results of compressive strength test of waste reinforced bricks with different proportions of waste materials compared with the traditional bricks is shown in the table 2.

Table.2. Results of compressive strength test

S.NO	WRMB	Results of compression test of Waste reinforced brick(WRMB) CT in N/mm^2	Comparison with traditional brick (TB) CT in N/mm^2
1.	WRMB 1	9.380	2.984
2.	WRMB 2	4.263	2.984
3.	WRMB 3	9.593	2.984
4.	WRMB 4	4.476	2.984
5.	WRMB 5	7.674	2.984
6.	WRMB 6	5.756	2.984
7.	WRMB 7	8.5275	2.984
8.	WRMB 8	**11.085**	2.984

Traditional Brick (TB): Uniform strength of 2.984 N/mm².
Waste-Reinforced Bricks (WRMB):
Highest Strength: WRMB 8 (11.085 N/mm²), ~271% stronger than TB.
Lowest Strength: WRMB 2 (4.263 N/mm²), still ~43% stronger than TB.
Key Observation:
Most WRMB samples (for example, Waste-Reinforced Bricks 1, 3, 5, 6, 8) have much higher compressive strength than traditional bricks. This suggests that waste materials like fly ash (FA), sugarcane bagasse (SCB), and eggshell (ES) improve structural integrity.



The Figure.20 shows the graph of compressive strength test of waste reinforced bricks with different proportions of waste materials compared with traditional brick.

VI.II. Water Absorption Test Results

The results of water absorption test of waste reinforced bricks with different proportions of waste materials compared with traditional bricks is shown in the table 3.

Table.3. Results of Water Absorption Test test

S.NO	WRMB	Results of water absorption test of Waste reinforced brick(WRMB) WAT in %	Comparison with traditional brick (TB) WAT in %
1.	WRMB 1	21.96	18.42
2.	WRMB 2	16.88	18.42
3.	WRMB 3	16.43	18.42
4.	WRMB 4	45.5	18.42
5.	WRMB 5	43.20	18.42
6.	WRMB 6	21.61	18.42
7.	WRMB 7	**5.85**	18.42
8.	WRMB 8	36.85	18.42

Traditional Brick (TB): Fixed absorption rate of 18.42%.
Waste-Reinforced Bricks (WRMB):
Best Performance: WRMB 7 (5.85% absorption), about 68% lower than TB.
Worst Performance: WRMB 4 (45.5%) and WRMB 5 (43.2%) absorbed more than twice as much water as TB.
Moderate Performers: WRMB 1, 2, 3, 6 (16.43–21.96%), close to TB.
Key Observation:
WRMB 7's low absorption (5.85%) shows that the right mix of waste materials (FA-10%, SCB-5%, ES-5%, etc.) improves water resistance.

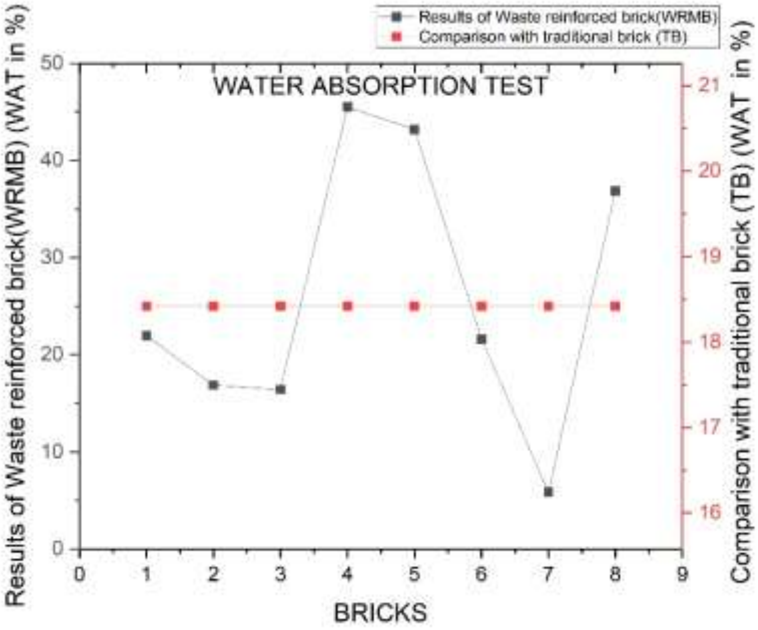


Figure.21 shows the graph of water absorption test of waste reinforced brick compared with traditional brick.

We established that waste material bricks are significantly stronger and less absorbent than traditional bricks in compressive strength and water absorption tests. We compared the performance in our experimental study with the findings of the Kalaimani Ramakrishnan et al [3] study. The highest compressive strength achieved waste-reinforced mud brick (WRMB 8) was 11.085 N/mm², a significantly higher value than their traditional brick of only 2.984 N/mm². The best performing waste-reinforced brick by Kalaimani Ramakrishnan et al [3] experiment (Trial 3) achieved 11.063 N/mm², and their traditional class brick average was 7.71 N/mm². For water absorption, the best mix in our experimental study (WRMB 7) had a low value of 5.85% compared to their traditional brick of 18.42%. On the contrary all their waste bricks had a water absorption less than 6%, with the best (Trial 1) recording 5.15%, and their traditional brick average 10.93%. Taken together these results show that industrial and agro-wastes improve compressive strength, and equally notable, reduce water absorbency of bricks, thereby creating stronger bricks. And because of this, waste bricks can be considered to be superior to traditional clay bricks.

V. COST ESTIMATION

The cost of the waste materials per kg weight, including the shipping cost, was estimated in rupees (INR). The weight of the waste materials used in one brick is multiplied by the unit cost of the waste materials to calculate the total material cost. The total cost of brick production was estimated, as shown in Table 4-5.

Table 4: Cost for production of waste reinforced mud bricks. (WRMB 1-4)

	Unit Cost (in INR)	WRMB 1		WRMB 2		WRMB 3		WRMB 4	
		Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)
Fly ash	0.15/Kg	0.7	0.105	0.9	0.135	0.5	0.075	-	-
Sugar cane bagasse	0.4/Kg	-	-	-	-	0.1	0.04	0.1	0.04
Rice husk	2.2/Kg	0.7	1.54	0.5	1.1	0.7	1.54	-	-
Egg shell	10/Kg	-	-	-	-	-	-	0.5	5
Red mud	2.40/Kg	0.3	0.72	0.8	1.92	0.7	1.68	0.7	1.428
Clay	5/Kg	0.3	1.5	0.8	4	0.7	3.5	0.7	3.5
Total cost	-	-	3.865	-	7.155	-	6.795	-	9.968

Table 5: Cost for production of waste reinforced mud bricks. (WRMB 5-8)

	Unit Cost (in INR)	WRMB 5		WRMB 6		WRMB 7		WRMB 8	
		Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)	Weight (kg)	Cost (INR)
Fly ash	0.15/Kg	0.3	0.45	0.3	0.045	0.2	0.03	0.1	0.015
Sugar cane bagasse	0.4/Kg	-	-	-	-	0.1	0.04	0.1	0.04
Rice husk	2.2/Kg	0.3	0.66	0.1	0.22	-	-	0.1	0.22
Egg shell	10/Kg	-	-	-	-	0.1	1	0.1	1
Red mud	2.40/Kg	0.7	1.68	0.8	1.92	0.8	1.92	0.8	1.92
Clay	5/Kg	0.7	3.5	0.8	4	0.8	4	0.8	4
Total cost	-	-	6.29	-	6.185	-	6.99	-	7.195

VI. Conclusion

The comparative analysis of mechanical properties of waste reinforced mud-bricks has revealed the possible application of waste materials in the process of traditional mud-brick production. Thus, the objectives of the project included the investigation of the possibility of improving the mechanical characteristics of mud-bricks by adding different types of wastes. During the experimental phase, we methodically studied the consequences of waste reinforcement with regard to essential mechanical characteristics such as compressive strength and Water absorption. The incorporation of waste materials including fly ash, rice husk, sugarcane bagasse and egg shell exhibited good results in regard to addition of strength and durability to the mud-bricks. It satisfies the ecological problems that result from improper disposal or waste in addition to being a creativity in architectural and construction materials. The results highlighted in the subsequent tests it was found that there are significant enhancements in the mechanical characteristics of waste reinforced mud-bricks.

• The period to which waste reinforced mud brick(WRMB) resistant was found to be more than the traditional brick (TB) in respect to the compressive strength.

• The value of Water absorptions of the waste reinforced mud-brick has been minimized with proportions of FA-10%, SCB-5%, ES-5%, RM-40%, C-40% and is minimum in relation to other WRMB as well as the traditional brick (TB).

The study further reveals waste material ability to strongly influence the making of mud-bricks could add strength and innovation to building components, thus proposing better and sustainable building material than those available in the market. Therefore, the findings of this comparative study on the mechanical properties of waste reinforced mud-bricks contribute to the advancement in the utilization of local abundant construction materials that are environmentally sustainable. The findings of this study show that is possible to use waste-reinforced mud-bricks in constructions thus advocating for the use of environmentally friendly materials in constructions.

VII. **Scope for future work**

The future works on "Comparative study on mechanical properties of waste reinforced mud-bricks" could include waste material optimization.

- Mechanical properties of waste reinforced bricks can be studied by varying the waste material proportions.
- Different waste materials other than those used in this study can also be used for the production of bricks, and the mechanical properties can be studied.
- Different combinations of waste materials can be used for the production of waste-reinforced bricks.
- Comparison of waste-reinforced bricks with traditional cement bricks can also be carried out.

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