Strength comparison of concrete: coarse aggregate replaced by jhama brick ballast and fine aggregate replaced by surkhi

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Abstract

Concrete is a very common material used in construction, but the high cost and reducing availability of traditional aggregates require sustainable substitutes. This research assesses the application of Surkhi (Jhama Brick dust) as fine aggregate and Jhama Brick (JB) ballast as coarse aggregate in M20 grade concrete. Four blends were tried: (i) Cement + Sand + Stone (control), (ii) Cement + Sand + JB Ballast, (iii) Cement + Surkhi + Stone, and (iv) Cement + Surkhi + JB Ballast. The compressive strength was tested at 3, 7, and 28 days. It was observed that the greatest 28-day strength (17.77 N/mm²) occurred for sand-JB ballast mix, which was superior to the control mix (13.95 N/mm²). The mixes with Surkhi had much lower strength, with the minimum being 5.76 N/mm² for Surkhi + JB Ballast. While none of the mixes attained the desired M20 concrete strength of ≈20 N/mm², the addition of JB ballast improved strength over the usual stone aggregate, revealing its possibility as a budget-friendly and eco-friendly substitute for non-structural and temporary usage.

Keywords: Compressive Strength, Jhama Brick (JB), Surkhi

1. Introduction

Concrete is the most common construction material because of its versatility, strength, and nature to be molded into different shapes. Concrete in the classical sense consists of cement, fine aggregate (sand), coarse aggregate (stone), and water. Its usage ranges from building construction to road construction, bridges, and dams. However, increasing cost and availability of conventional aggregates have made researchers look toward locally available and sustainable alternatives [1].

The use of recycled aggregates in concrete has been the focus of considerable research worldwide. Early investigations revealed that the incorporation of recycled aggregates could negatively influence the mechanical properties of concrete, particularly compressive strength, due to the weaker interfacial transition zones [2]. Nevertheless, subsequent studies demonstrated that with appropriate mix design adjustments, it is possible to achieve acceptable performance levels.

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For example, [3] reported that recycled aggregate concrete (RAC) could meet structural requirements when carefully proportioned, while [4] highlighted that even unconventional recycled sources, such as asphalt pavement, can be successfully integrated into concrete mixtures without severely compromising strength. Growing awareness of sustainability has further advanced the adoption of recycled aggregates.[5] emphasized that the use of construction and demolition waste aligns with sustainable construction principles, reducing environmental impacts associated with natural aggregate extraction. Structural reliability has also been confirmed in comparative studies. A researcher [6] showed that RAC can still meet Eurocode 2 design predictions, suggesting that the material has sufficient mechanical performance for structural applications when carefully engineered. Few researchers investigated the influence of marble dust on gypsum-stabilized clay. They reported notable improvements in UCS and CBR values, showing marble dust as a viable stabilizing agent [7-8].

Durability has been another major focus of research. Few research examined the effects of fine recycled aggregates on concrete and concluded that while durability may be reduced compared to natural aggregate concrete, performance remains within acceptable ranges under certain exposure conditions [9]. Earlier works by [10] also highlighted that recycled concretes often exhibit different stress–strain behavior, while microstructural studies by [11] confirmed that recycled aggregates affect the interfacial transition zone, influencing both durability and strength. Life Cycle Assessment quantifies the environmental impacts. Similarly, [13] observed strength reductions depending on the replacement ratio and processing methods used for recycled aggregates. Their findings highlighted enhanced UCS, CBR, and swelling resistance, suggesting practical benefits for soil stabilization.

To address these performance concerns, admixtures have been explored as a potential solution. [12] investigated the use of superplasticizers in RAC and reported significant improvements in workability and strength. Likewise, [13] showed that superplasticizers enhanced the durability of recycled aggregate concretes, making them more comparable to conventional mixes. With the combined use of chemical admixtures and optimized design strategies, recycled aggregates can be used effectively in structural concrete while supporting sustainability goals.

2. Material

2.1 Cement

Cement is an indispensable material in the construction world. Cement plays the role of binding agent among all other constituent materials in the concrete and holds aggregate and other components together providing structural integrity. When cement comes in contact with water, the hydration of cement proceeds both inward and outward of the cement molecule and the resultant microstructure of hydrated cement influences the different physical properties of concrete. Here in this study ordinary Portland cement has been used as the binding material for all the four combinations of materials while forming the concrete mix. Table 1 shows the physical properties of cement.

2.2 Sand

Sand is a fundamental construction material widely used due to its availability, affordability and versatility, which is also known as fine aggregate. It is the aggregate most of which passes through a 4.75mm IS sieve. It plays a critical role in creating strong and durable structures when combined with other materials like cement and aggregates.

2.3 Stone

Stone as coarse aggregates are a vital component in concrete contributing to its performance. It provides the bulk, strength and stability for concrete mixtures as it serves the major portion in the concrete mix which makes it a critical ingredient. Stones with rough surface texture offer better bonding with cement paste.

2.4 Surkhi

Surkhi is a very ancient building material. Surkhi is a finely powdered material made from burnt clay or broken bricks that's used as a substitute for sand in mortar and concrete. In many parts of India, the use of lime and surkhi is a common practice because of its environment friendly nature.

2.5 JB Ballast

Brick Ballast is a type of coarse aggregate made by breaking overburnt, rejected or broken bricks. Brick ballast is a cost-effective alternative. Figure 1 & 2 shows the Jhama brick and brick industry photographs.

2.6 Water

Water is that critical ingredient in concrete without which mixture is not possible. When water comes in contact with cement, the hydration process initiates which is basically an exothermic reaction in nature giving rise to the cement fluid. This cement fluid binds all other inert constituent materials together in the concrete.

Fig.1. Jhama Brick

Fig. 2. Brick Industry

Table 1. Test performed on materials

SL no	Materials	Test Parameter	IS Unit of Measurement	Result	Required As Per Is Code	Range (Is)	Remark
1	cement	Consistency test of cement	%	32%	IS 4031	22-30%	Slightly higher
2		Specific gravity of cement	g/cc	3.12	IS 2720	3.1-3.16gm/cc	Within the range
3		Compressive strength of cement	N/mm^3	14.99MPA	IS 2250	15MPa-30MPa	Within the range
4	brick	Water absorption of brick	%	5.25%	IS 1077:1992	12-20%	Less
5		Compressive strength of brick	N/mm^3	$4.99N/mm^2$	IS 3495	≥ 7.5	Less
6	sand	Fineness modulus of sand	%	1.485	IS 383: 1970	2.2-3.2	Not within the range
7		Surface moisture test of sand	%	7.53%	IS 383: 1970	20%	Less
8		Specific gravity of sand	No dimension	2.81	IS 383: 1971	2.70-2.80	Within the range
9		bulking of sand	%	15.5	IS 2386-3	4-25%	Within the range
10	stone	Impact test of stone	%	19.25%	IS 1121	-	-
11		Water absorption test of stone	%	5gm	IS 1124	-	-

3 Methodology

The first task of this study was to collect the materials. Cement, sand (as fine aggregate), stone (as coarse aggregate), and JB were obtained from locally available sources. Surkhi and brick ballast were prepared from the JB. Various tests were performed on the cement, sand, stone, and brick to ensure that the relevant parameters met the limits recommended in the IS codes. The cement was tested for standard consistency, specific gravity, and compressive strength; the sand for fineness modulus, surface moisture, specific gravity, and bulking; and the stone for impact value, water absorption, sieve analysis (grain size distribution), and flakiness and elongation indices. After confirming these properties, concrete cube samples were prepared and cured. M20 grade concrete with the recommended mix ratio of 1:1.5:3 was used. Experimental photographs are shown in Figures 3 and 4, and Figure 5 illustrates the methodology of the present work.

Fig. 3. Preparation of sample (fine aggregate replaced by surkhi)

Four different combinations have been examined in the study –
Cement + Sand as fine aggregate + Stone as coarse aggregate
Cement + Sand as fine aggregate + JB Ballast as coarse aggregate
Cement + Surkhi as fine aggregate + Stone as coarse aggregate
Cement + Surkhi as fine aggregate + JB Ballast as coarse aggregate

Fig. 4. Compressive Strength testing on Universal Testing Machine

Stepwise procedure:
Step 1: Collection of materials (cement, sand, stone, Jhama Brick)
Step 2: Preparation of surkhi and brick ballast
Step 3: Test Performed in different materials
Step 4: Molding of concrete cubes
Step 5: Curing of concrete cubes
Step 6: Determination of compressive strength of concrete cubes
Step 7: Determination of different trends in strength gain in concrete cubes

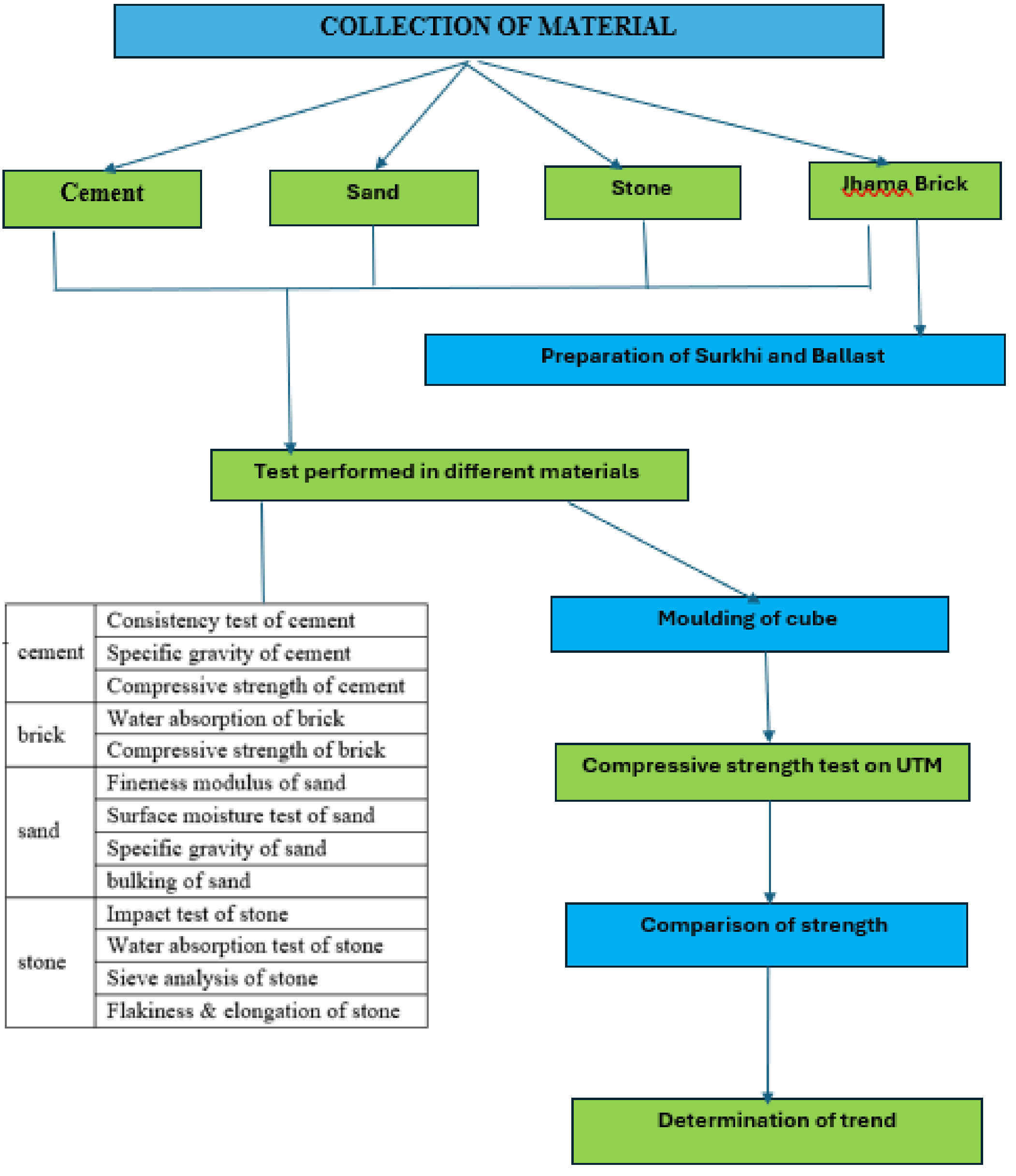

Fig. 5. Flow chart for working methodology

4 Results and Discussion

In this study an attempt has been made to use different derived forms of JB to develop concrete like composite material which is useful for different structures. Use of waste material is cost effective and leads to a sustainable development of society. In this study compressive strengths of 3 days, 7 days and 28 days of four different combinations such as

“Cement + Sand + Stone”, “Cement + Sand + JB Ballast”, “Cement +Surkhi + Stone”, “Cement +Surkhi +JB Ballast” have been analyzed.

The compressive strengths at 3, 7, and 28 days for the "Cement + Sand + Stone" combination were 6.57, 10.80, and 13.95 N/mm², respectively (Figure 6). For "Cement + Sand + JB Ballast," the corresponding values were 8.17, 9.46, and 17.77 N/mm²; for "Cement + Surkhi + Stone," 4.08, 4.84, and 8.13 N/mm²; and for "Cement + Surkhi + JB Ballast," 4.06, 5.15, and 5.76 N/mm².
Analysis of these results shows that the highest early-age (3-day) strength was obtained for the "Cement + Sand + JB Ballast" combination, and the lowest for "Cement + Surkhi + Stone." The conventional mix, "Cement + Sand + Stone," gave a slightly lower early strength than the maximum and a higher value than "Cement + Surkhi + JB Ballast."

The maximum value of 7 days compressive strength has been observed in the traditional concrete i.e. “Cement + Sand + Stone” and the least is obtained in the combination “Cement + Surkhi + Stone” while “Cement + Sand + JB Ballast” has slightly lesser value of compressive strength than that of the traditional concrete and a little improved result than “Cement + Surkhi + JB ballast”.

The maximum final strength has been observed in the combination of “Cement + Sand + JB Ballast” and the least is in the combination “Cement + Surkhi + JB ballast” while traditional concrete has slightly lesser value than of the maximum and “Cement + Surkhi + Stone” got a little better result than that of the least value of final strength.

It has been observed that the strength of concrete in none of the cases reaches its targeted mean strength value, but the strength obtained is also in a range that the modified concrete can be useful for many temporary structures in areas where the aggregates are not easily available. Out of all the combination, cement, sand as fine aggregate and JB ballast as coarse aggregate is the preferred combination from this point of view for the final strength gain criteria.

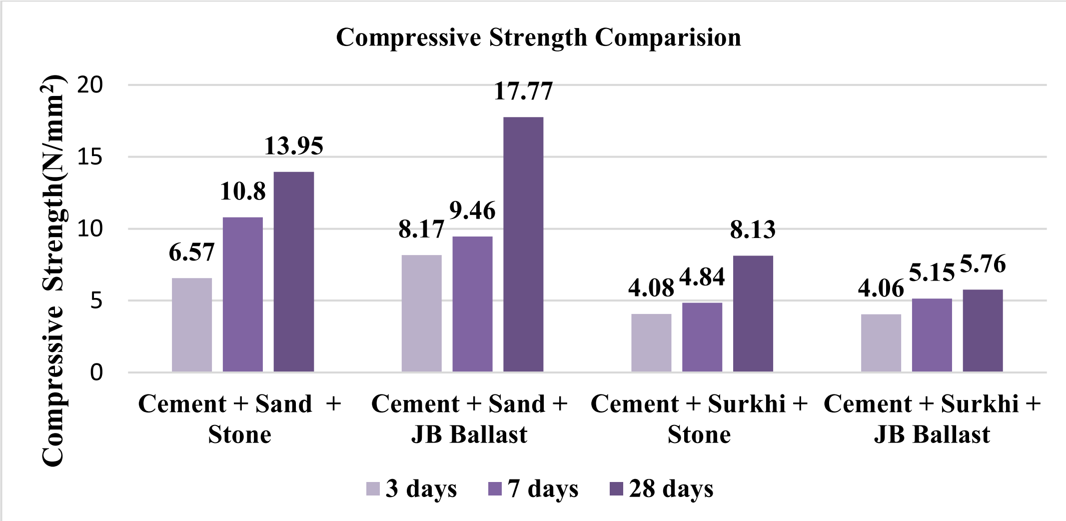

Fig. 6. Compressive Strength comparison for different combinations

5 Conclusion

From the findings, the following conclusions were drawn:

- M1 (Cement + Sand + Stone) achieved a 28-day strength of 13.95 N/mm², lower than the desired strength for M20 concrete but higher than Surkhi-based mixes.
- M2 (Cement + Sand + JB Ballast) had the highest compressive strength at every curing age. Its 28-day strength was 17.77 N/mm², higher than that of the control mix M1 (13.95 N/mm²).
- M3 (Cement + Surkhi + Stone) exhibited fair development of strength, with 8.13 N/mm² at 28 days.
- M4 (Cement + Surkhi + JB Ballast) had the least strength of 5.76 N/mm² after 28 days and hence is not fit for structural usage.

The trend here is that JB ballast is a better material than stone as a coarse aggregate, while substituting sand with Surkhi drastically decreases strength.

In general, M2 (Cement + Sand + JB Ballast) had the best performance of all the mixes and holds promise to serve as a sustainable and cost-effective substitute for traditional stone aggregate.

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