

## **Strength and Workability Assessment of Recycled Brick Powder-modified Concrete: Toward Sustainable Construction Materials**

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### **Abstract**

*Concrete is widely used for the construction of most buildings, bridges, and other structures throughout the world. The entire construction sector is currently looking for a suitable and usable unused product that would significantly reduce the consumption of fine aggregate and finally lower the cost of production. Pozzolanic materials like crushed brick powder can be used as a substitute for fine aggregate in mortar. In this study, crushed brick powder was used in proportion with fine aggregate, i.e., sand. Sand was replaced by crushed brick powder by percentage weight of sand up to 30% in 5% intervals. The compressive strength with 0% crushed brick powder was found to be 2661 psi, but as the percentage of crushed brick powder increased, the compressive strength also increased. The maximum compressive strength of 3597 psi was observed when 10% crushed brick powder was used. The compressive strength starts to decline after 10% of crushed brick powder.*

**Keywords:** *Sustainable concrete; Pozzolanic materials; Sand replacement; Brick waste recycling; Compressive strength; Brick powder.*

### **Introduction**

Sand is a crucial component of concrete, the most popular and extensively used building material in the world. Typically, the sand comes from river beds and pits, which can cause ecological imbalance and other environmental problems, such as

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erosion and the deterioration of aquatic habitats. Crushed brick powder, a byproduct of crushed, burnt clay bricks, may be a preferable option for concrete production in order to allay these worries. Crushed brick powder in place of the sand can reduce the excessive use of natural sand resources and make use of locally accessible resources and waste products from the brick industry and construction sites, both of which support sustainable building methods. The problem of air pollution from unused brick powder can also be reduced. Nonetheless, the problem of pollution from the brick industry will persist, which may be a distinct area of research. The purpose of this research is to create environmentally friendly concrete by substituting crushed brick powder for some portion of the sand in the concrete mix. The strategy of substituting crushed brick powder for sand not only contributes to the preservation of natural sand resources but also provides a sustainable solution to the issue of construction waste disposal on building sites and in the brick sector, where waste typically pollutes the air, land, and water.

This study's main goal is to address the issues of sand scarcity while advancing sustainability and lessening the negative effects on the environment. Because crushed brick powder recycles leftover brick materials, it can be utilized as a partial substitute for sand and promote environmental sustainability. It was explored by the six different replacement levels of sand with crushed brick powder (0%, 5%, 10%, 15%, 20% and 30%). This study compared the effects of crushed brick powder replacement on both nominal and design mixes, unlike previous studies, for M20 grade concrete. The compressive strength of concrete was measured as a basis for investigating the optimum content of crushed brick powder that could be replaced with sand in concrete. Tests of the concrete mixes' workability and compressive strength showed that a 10% replacement level optimally increased the concrete's strength and workability. This study offers insightful information about the potential use of crushed brick powder in place of sand, highlighting the significance of appropriate material proportion to maximize crushed brick powder content while preserving performance. The addition of admixtures, which will be the subject of future research, could improve the overall performance of the concrete. Numerous studies have demonstrated that partially replacing natural sand with crushed brick powder or recycled fine aggregates can significantly enhance concrete's compressive strength and durability while addressing environmental concerns.

Compressive strength was raised by adding recycled fine aggregate (RFA), notably brick powder, to concrete grades M10, M20, and M25; however, workability and density decreased as RFA content rose [5]. It was observed that the highest

compressive strength and enhanced workability were obtained with a mixture of 10% brick dust and 20% ceramic waste [1]. Further research supports these findings. It was reviewed several studies that brick dust and other recycled materials have shown an increase in compressive and tensile strength; however, workability and flexural strength were found to be somewhat reduced [6].

It was examined M20 concrete and discovered that a 40% crushed brick powder substitution provided the maximum compressive strength, making it a practical and sustainable substitute [3]. Other studies reinforce the benefits of using crushed brick powder and brick aggregates. It was reported that superior compressive strength and performance were demonstrated by high-strength concrete that was 100% crushed brick powder substituted [2].

### **Statement of Problem:**

In addition to the large output of brick powder and demolition waste brick, the development in the building industry results in a significant consumption of natural fine aggregate. Sand must be partially replaced in the building sector, as the high demand for fine aggregate must be met by extracting it from natural resources, which disrupts the ecological balance. Crushed brick powder can be the best substitute for sand if it meets the technical requirements for fine aggregate and is readily available locally. Since waste from brick kilns takes up a lot of space to dispose of, it can be turned into a powder and used in place of fine aggregate in concrete. While crushing bricks for making brick chips, a significant amount of crushed brick powder is produced.

### **Objectives of the Study**

1. To determine the optimal percentage of crushed brick powder that can be used.
2. To compare the performance of recycled brick powder-modified concrete with that of conventional concrete.

### **Materials and Methodology**

#### **A. Material**

Concrete is a material composed of aggregate bonded together with cement and sand. It is most often utilized in the building industry and is the second most used material in the world after water. The following materials are commonly found in concrete:

- **Cement:** Cement is the main component of the concrete mix, which acts as a binder and provides the strength to the concrete. For this study, Seven Ring cement (OPC) was used.

- **Fine Aggregate:** Sand from the Local River was used as a filler in the concrete mix. It was clean and free from any types of dust, clay, and chemicals. From the report of sieve analysis, Fineness Modulus (FM) was found 1.65.
- **Coarse Aggregate:** The primary ingredient that gives concrete its volume, alongside strength, is coarse aggregate. Therefore, sufficient care was used when selecting the appropriate coarse aggregate to ensure the greatest outcomes. The employed coarse aggregate (brick chips) was clean, dry, and irregularly shaped. It had the necessary qualities of good aggregates, such as impact and abrasion strength.
- **Water:** The proper ratio of cement to water had to be maintained for concrete to have sufficient strength. Pure, uncontaminated water free of silt, salts, and organic matter was used for this study. Water is required to prevent moisture loss during curing as well as to initiate the cement's hydration during mixing. It was mixed and cured in potable water.
- **Crushed Brick Powder (Surkhi):** Surkhi is the crushed powder of a burnt clay brick. It was sieved through #4 (Sieve opening 4.75mm) sieve. From the report of sieve analysis, Fineness Modulus (FM) was found 3.35. Chemical composition of surkhi are shown below:

**Table 1: Chemical Composition of Surkhi [4]**

S.L	Chemical Constituents	Percentages
1.	Alumina	20% to 30%
2.	Silica	50% to 60%
3.	Lime	5%
4.	Oxide of iron	5% to 6%
5.	Magnesia	2% to 3%

## B. Methodology

In order to ensure that the surkhi are clean and devoid of organic material, they are first gathered from locations such as recycling facilities and building sites. The appropriate particle size is then attained by passing surkhi through a #4 (Sieve opening 4.75 mm) sieve, and the material that has been sieved is kept in a dry container with a label. Then, in accordance with normal procedures to guarantee correct design, concrete mixes are made using different percentages of brick powder (5%, 10%, 15%, 20%, and 30%) in place of sand.

Slump tests are used to assess the workability of concrete, and the water content is chosen to get the required consistency. After being mixed, cured, and cast into cubes, the best mixtures are tested for compressive strength. These tests provide crucial information on the efficacy of brick powder as a sustainable sand substitute by applying increasing loads to assess the strength of the concrete. Table 1 shows the different slump values of the different concrete specimens of this research.

**Table 2: Slump height of different concrete specimens.**

Serial number	Slump height(mm)
A1, A2, A3	76
B1, B2, B3	78
C1, C2, C3	75
D1, D2, D3	75
E1, E2, E3	74
F1, F2, F3	74

**C. Mix Design:**

In order to attain desired qualities like strength and durability, mix design entails figuring out the ideal ratios of cement, water, aggregates, and admixtures. It guarantees that concrete successfully and economically satisfies structural requirements. We have used different percentages of surkhi in place of sand in the design mix (i.e. 0%, 5%, 10%, 15%, 20%, and 30%). To get the intended effects, the mix must be properly designed. Table 2 below displays the approximate amounts of each concrete ingredient for three cubes.

**Table 3: Mix design of concrete using varying percentage of crushed brick powder.**

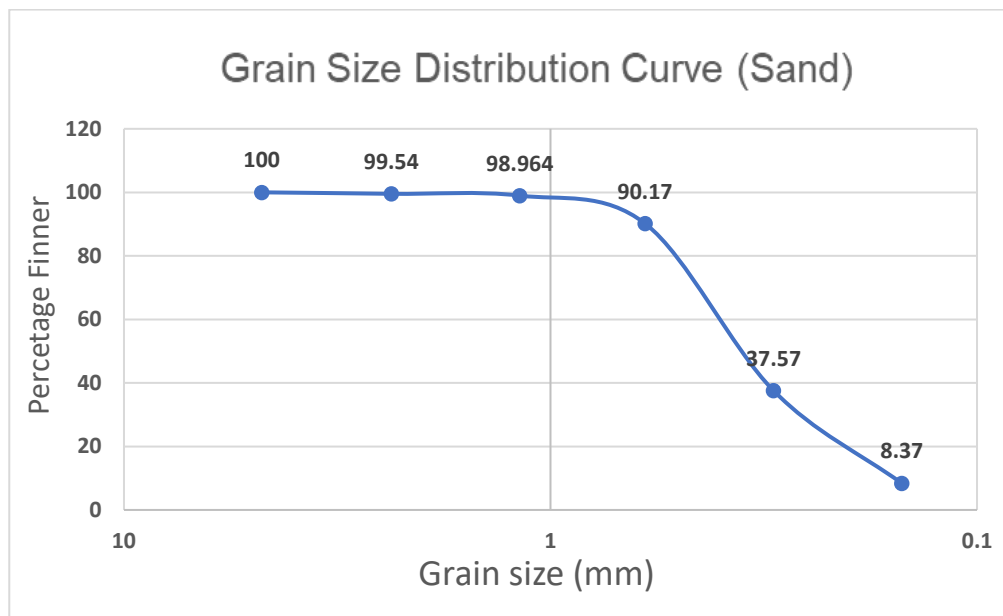
% of Surkhi	CA (gm)	Fine Aggregates		Cement (gm)
		Sand (gm)	Surkhi (gm)	
0	7200	3600	0	2400
5	7200	3420	180	2400
10	7200	3240	360	2400
15	7200	3060	540	2400
20	7200	2880	720	2400
30	7200	2520	1080	2400

The various amounts of surkhi used in place of sand highlight the nominal mix proportions for M20 concrete displayed in Table 1. For each of six cubes, there are

2400 gm of cement and 7200 gm of coarse aggregate. The fine aggregate (sand) steadily drops from 3600 gm to 2520 gm as the substitution of surkhi increases from 0% to 30%. The corresponding amounts of surkhi range from 0 to 1080 grams.

### Result and Discussion

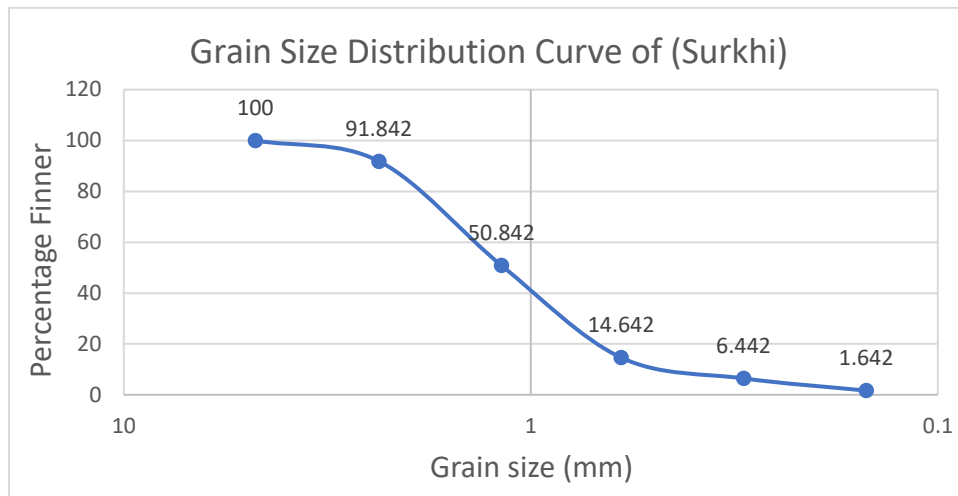
In this research, the mechanical strength was measured throughout the specified number of days using test cubes. Cubes were assessed for this experiment after 28 days for all samples. This study's main goal was to assess the concrete's compressive strength after some surkhi was added in place of sand. After 28 days, concrete cubes that had been cast with varying amounts of surkhi in place of sand were tested for compressive strength. The findings demonstrated the influence of surkhi on the mechanical characteristics of the concrete by comparing the surkhi-modified concrete with the regular concrete. The findings from these tests are crucial for determining the viability of surkhi as a sustainable alternative in concrete production.



**Figure 1:** Grain Size Distribution Curve for Local Sand.

The steep slope means the sand is poorly graded (Uniform), meaning the particle sizes are relatively similar. Nearly 100% of the particles are smaller than 10mm.

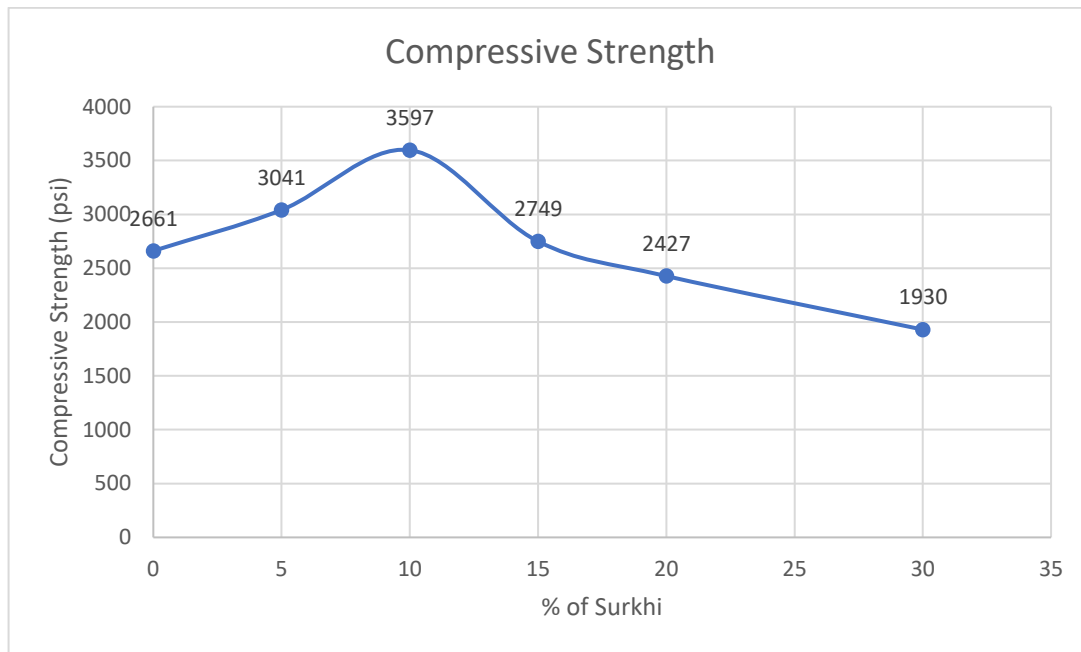
A very large percentage of the particles are very small. Over 90% of the particles are smaller than 1mm, and about 85% are smaller than 0.1mm. The curve is smooth and spread over a wide range of grain sizes, meaning it is well-graded, meaning it has a good mix of different particle sizes.



**Figure 2:** Grain Size Distribution Curve for Crushed Brick Powder.

**Table 4: Compressive strength of concrete using varying % of Crushed Brick Powder.**

SN	Surkhi	Area (cm <sup>2</sup> )	Max Load (kg)	Compressive strength (kg/cm <sup>2</sup> )	Av. Strength (kg/cm <sup>2</sup> )	Compressive Strength (psi)
1	0%	81.07	15000	185.03	187.08	2661
		81.07	15500	191.19		
		81.07	15000	185.03		
2	5%	81.07	17500	215.86	213.81	3041
		81.07	17000	209.70		
		81.07	17500	215.86		
3	10%	81.07	20500	252.87	252.87	3597
		81.07	20500	252.87		
		81.07	20500	252.87		
4	15%	81.07	16000	197.36	193.25	2749
		81.07	16000	197.36		
		81.07	15000	185.03		
5	20%	81.07	14000	172.69	170.64	2427
		81.07	13500	166.53		
		81.07	14000	172.69		
6	30%	81.07	11000	135.69	135.69	1930
		81.07	11000	135.69		
		81.07	11000	135.69		



**Figure 3:** Compressive strength with respect to % of Crushed Brick Powder.

The experimental results provide valuable insights into the effect of incorporating crushed brick powder i.e. surkhi as a partial replacement of sand in concrete mixes for M20 grade concrete, analyzed over 28-day curing periods. It has been found that, the addition of different percentage of Surkhi positively impacts the compressive strength of concrete up to 10%. The compressive strength with 0% surkhi was found to be 2661psi, but as the percentage of surkhi increased, the compressive strength also increased. The maximum compressive strength 3597psi was observed when 10% surkhi was used. The compressive strength starts to decline after 10% of surkhi as shown in Table 3.

According to these findings, surkhi can potentially replace some of the sand in concrete up to a specific point (10% in this study), after which the concrete's compressive strength is reduced. The excessive replacement of sand, which results in inadequate bonding and diminished structural integrity, is probably the cause of this decrease. High Surkhi percentages reduce the material's structural integrity and render it less appropriate for structural applications, while low surkhi percentages increase strength and can make concrete production more sustainable. These findings suggest that although Surkhi can be a useful partial substitute for sand, concrete's mechanical qualities are reduced when the replacement threshold is exceeded by 10%.

## Conclusion

This study shows how crushed brick powder, i.e., surkhi, could be used in concrete to partially replace sand. According to the experimental research, there are mechanical advantages of adding surkhi to M20 grade concrete. Compressive strength increases when surkhi replaces 10% of the sand. The nominal mix of concrete with 10% surkhi showed a significant improvement in compressive strength, reaching 3597 psi after 28 days. These improvements are probably the result of well-graded Surkhi and its tiny particle size, which efficiently fills in gaps and raises the density and strength of the concrete. This demonstrates that surkhi is a dependable substitute for sand in the manufacturing of sustainable concrete. However, compressive strength significantly decreased when the percentage of surkhi was increased above 10%. For example, concrete with 30% surkhi experienced a reduction in strength to 1930 psi, indicating that excessive surkhi compromises the concrete's structural integrity. There is a limit how much sand can be substituted without sacrificing structural integrity, as this decline is ascribed to a fall in cementitious content and weaker bonding within the concrete matrix.

In summary, adding 10% crushed brick powder in place of sand improves strength, but going above this limit degrades the material's mechanical qualities. Crushed brick powder can therefore efficiently increase concrete strength and promote sustainability, but its content must be properly balanced to preserve concrete's longevity and structural integrity.

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