



Performance and durability of innovative sustainable materials in construction applications

Kokate Pravin Pandurang^{1*}, Dr. Ruchi Chandrakar²

¹ Research Scholar, Kalinga University, Raipur, Chhattisgarh, India

² Supervisor, Department of Civil Engineering, Kalinga University, Raipur, Chhattisgarh, India

Abstract

The industrial region of Pithampur in Indore (M.P.) was the source of all the components used in the samples. With a 1.36% increase in compressive strength, a 6% increase in split tensile strength, and a 5.1% increase in flexural strength, composite high-performance concrete using 50% manufactured sand is more cost-effective and environmentally friendly than conventional high strength concrete. Composite high-performance concrete that has silica fume and iron filing added to it has a compressive strength that is 4.9% higher than conventional high-strength concrete, a split tensile strength that is 7.8% higher, and a flexural strength that is 10.1% higher. Research indicates that the compressive strength, split tensile strength, and flexural strength may be enhanced by 2.73 percent, 15.7 percent, and 10.5 percent, respectively, when iron filing and silica fume are combined in a composite form.

Keywords: Flexural strength, composite high-performance, compressive strength, tensile strength

Introduction

In response to pressing environmental issues and the need to build resilient infrastructure for the benefit of future generations, sustainable development has become a dominant paradigm in today's-built environment. The use of modern materials is fundamental to this paradigm change since they improve structural performance while reducing the negative effects on the environment caused by building activities. A more robust and environmentally friendly constructed environment may be shaped by the use of modern materials, which are discussed in this article as they pertain to sustainable building.

Recognizing the building industry's significant impacts on environmental deterioration is the foundation of sustainable construction practices. The energy consumption, emissions of greenhouse gases, and trash produced by conventional building methods are all high because of the resource-intensive procedures used in these methods. As a result, sustainable building aims to lessen these effects via the use of eco-friendly procedures and cutting-edge materials.

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Literature Review

Martinez (2024) [10] The construction sector is seeing a surge in innovation when it comes to sustainable materials, driven by the growing importance of sustainability. New materials with improved durability and less environmental effect are discussed in this article. These include bioplastics, self-healing concrete, and recycled composites. By looking at current developments in the market, the article explores the possibility of certain materials being widely used, taking into account their benefits and existing constraints. The results provide light on the materials that will propel sustainable building practices in the future.

Kumar (2024) [9] This research delves into the challenges that the construction sector has when trying to incorporate sustainable building techniques. It identifies a lack of information and cost perspectives as the primary obstacles. This study delves at the material's use in concrete, the pros and cons of mixing it with other environmental factors, and the use of recovered solid waste in geopolymer composites for sustainable construction. The research investigations provide a comprehensive review of sustainable building materials and technologies, paving the path for further study and application in this area.

Patel (2021) [8] The many benefits of using sustainable practices in building construction have made them a top focus in recent years. Sustainable building construction is of utmost significance in the construction sector due to the worldwide trend towards sustainability. A great deal of environmental degradation is emanating from the massive urbanisation processes. There will be less pollution and better management of environmental concerns if buildings are constructed using sustainable materials. The article delves into the topic of recycled design goods and how they are used in the building sector. Projects to build affordable, environmentally friendly homes utilising materials that are readily accessible in the area are highly sought for. It protects the energy sector, the economy, and the natural environment. Therefore, the study takes into account novel goods that may meet the baseline standards for environmentally friendly building practices. The major objective of this study is to evaluate the feasibility of using recycled construction materials as opposed to traditional building materials via a comparative evaluation.

Khan (2023) [7] Innovative design, sophisticated materials, and sustainability concerns have all played a role in the rise of contemporary structures, which in turn have shaped the landscape of architectural accomplishments. An ever-increasing worry in the infrastructure sector is the impact on global warming caused by the manufacture, transportation, and consumption of construction materials. Therefore, it is crucial to actively seek for green materials that may reduce environmental consequences and help create a more

sustainable world. This study offers a concise overview of sustainable building materials, detailing their uses, pros and cons, carbon footprints, mechanical property improvements, and more. The materials covered include hempcrete, adobe, sheep wool, timber, cork, natural fibre, basalt fibre, engineered cementitious composite, and metals like stainless steel, titanium alloy, and smart shape memory alloy (Nitinol). Composites made of wood and bamboo are also detailed in terms of their fire resistance. The report concludes with suggestions for future building material selection based on the studied research.

Madiraju (2024) [6] Sustainable building methods that use eco-friendly materials are briefly discussed in this research. Reducing emissions of greenhouse gases from the production of building materials is an increasingly pressing environmental concern, and this issue requires immediate attention. The characteristics, uses, and environmental advantages of fifty eco-friendly materials are detailed in this research. With an emphasis on these materials' revolutionary potential, this article provides a concise, practical guidance for construction professionals, engineers, and architects to help them make educated decisions without sacrificing performance. By highlighting the importance of structural efficiency and environmental responsibility, this piece helps to change the way the building industry thinks about the future.

Research Methodology

The main objective of this research project is to examine and compare the characteristics of traditional high strength concrete with composite high-performance concrete. In order to achieve this goal, information is gathered on the M-75 grade concrete mix design, specimen preparation, and material specifications. All the data that has been gathered will be used to conduct experiments

Specifications of material used

Chemical admixtures, such as high range water reduction admixtures, fly ash, slag, sand, gravel, and cement are some of the ingredients that must be carefully chosen and measured out in order to produce high-performance concrete (HPC). Superior in strength and durability to standard

concrete is high-performance concrete. Therefore, the ingredients in high-performance concrete and those in conventional cement concrete are quite similar. But there are a lot of ways it's different from conventional concrete. It's quite strong, has a smooth fracture surface, isn't very porous, has discontinuous pores, etc. This is caused by a combination of factors, including a low water to cementitious material ratio, chemical admixtures, and cementitious materials. Between the time of installation or completion and two or three days after processing, the essential curing phase for HPC lasts. The following are common ingredients in high-performance concrete:

Cementitious Materials

Silica fume and iron filings are the cementitious components used in high concentrations or in conjunction with other cementitious materials.

Silica Fumes

Silica fume is a byproduct of the silicon and silicon alloys manufacturing process. Silica fume comes in a few different forms; the most common one right now is the densified one. In industrialised countries, it is already readily available and can be mixed with cement with ease. High strength concrete, which does not need silica fume for production, has a compressive strength of up to 98 MPa. However, silica fume is required above that strength. Silica fume makes it easier to make HPC with strengths ranging from 63 to 98 MPa.

Industrial by-products are the source of the ultrafine silica fume that is employed in accordance with IS:15388-2003. This fume is a greyish black powder with particles smaller than 1µm. There are 2.22 times the specific gravity and 430 kg/m³ of bulk density.

Iron Filings

Workshops in the vicinity of Pithampur, Indore, provide the iron filing needed in compliance with IS:1612-2003. There is a 1.5% water absorption rate, a 3.95 specific gravity, and a 2.23 fineness modulus for the iron filings that were used in this study. In Figure 1, we can see the utilisation of iron filings and silica fumes.



Photograph 1 Iron filing and Silica fumes

Data Analysis

Workability of fresh concrete

Workability

To determine the slump value, one must measure the height of the slumped concrete sample from the bottom of the spherical tamping bar to its highest point. Table 1 displays the results of the slump test for concrete with or without waste from demolition work, and Table 2 displays the results for concrete with or without waste from granite slurry.

Table 1: Workability of Concrete (Slump Result) with Replacement of Granite Slurry Waste (GSW) at w/c ratio 0.4

S. No.	Specimen Number	% Replacement of Granite Slurry Waste (GSW)	Slump Value (mm)
1.	(Conventional Concrete)	0	65
2.	S8	20	30

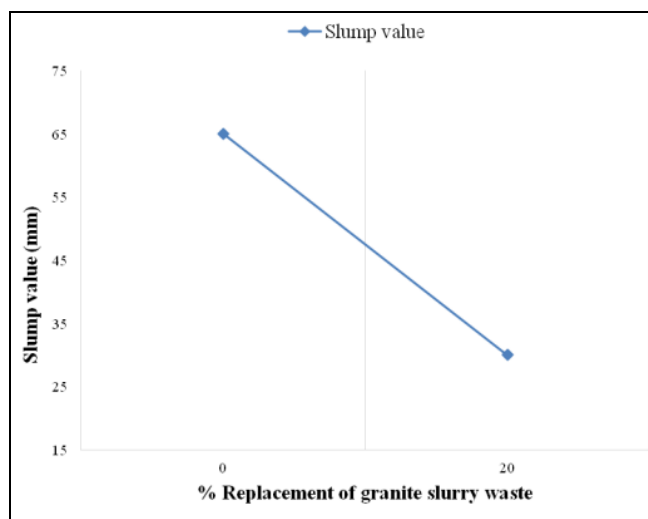


Fig 1: Graphical representation of workability of concrete at varied % replacement level of GSW

Compressive Strength Test

Standard curing time was used to evaluate compressive strength at 7, 28, and 90 days. For a water-to-cement ratio of 0.3, Table 3 displays the findings showing the variance in

compressive strength of concrete with different ranges of granite slurry waste (GSW). Compressive strength graphically fluctuates with a w/c ratio of 0.3, as seen in Figure 2. The compressive strength of concrete formed from demolition construction waste (DCW) with a water-to-cement ratio of 0.3 is shown in Table 4. The graphical fluctuation of compressive strength for a w/c ratio of 0.3 is also shown in Fig. 3. The compressive strength of concrete that was made with a w/c ratio of 0.3 and included a mix of demolition construction debris and granite slurry as partial cement and fine aggregate replacements is shown in Table 5. A graphical variation of compressive strength for a 0.4 w/c ratio is also shown in Fig. 4.

Table 3 shows that for a weight-to-cement ratio of 0.3, the maximum compressive strength is 41.2 MPa, 48.7 MPa, and 50.1 MPa, respectively, when 7.5% granite slurry waste is used as partial cement replacement. The curing intervals range from 7 days to 90 days. The compressive strength of concrete may be increased by as much as 7.5% when some of the cement is substituted with waste from granite slurry, as shown in Figure 3. Figure 3 shows that the compressive strength of concrete begins to decrease after a 7.5% partial cement replacement at a water-to-cement ratio of 0.4. For a water-to-cement ratio of 0.3, the maximum compressive strengths were measured at 38.2 MPa, 47.6 MPa, and 49.3 MPa, respectively, when 15% of the fine aggregates were substituted with demolition building debris. The curing intervals ranged from 7 days to 90 days. This information is shown in Table 4. Figure 4 shows that the compressive strength of concrete might be enhanced by as much as 15% when fine particles were partially substituted with demolition building trash. As shown in Figure 4, the compressive strength of concrete begins to decrease after a 15% partial replacement of fine particles at a water-to-cement ratio of 0.4. There is a noticeable decline in compressive strength due to the rising percentage of demolition building trash.

Granite slurry and demolition building debris are great sources of tiny particles, which increase the strength of concrete by reducing the area for free water and ensuring proper packing (microstructure). However, the strength of the concrete is diminished when an excessive amount of demolition construction debris and granite slurry is used to replace some of the cement and fine aggregates.

Table 2: Results of Compressive Strength Test for 0.4 W/C Ratio of Series-I

Series	Specimen number	% Replacement of granite slurry waste	Compressive Strength (MPa) - 7 Days	Compressive Strength (MPa) - 28 Days	Compressive Strength (MPa) - 90 Days
Series I	CC	0	28.3	37.6	41.3
	S1	2.5	34.7	42.5	44.6
	S2	5	38.3	44.3	46.8
	S3	7.5	41.2	48.7	50.1
	S4	10	34.4	42.9	45.9
	S5	12.5	30.8	40.3	42.3
	S6	15	27.8	36.4	39.1
	S7	17.5	23.8	31.9	36.2
	S8	20	19.6	29.3	32.8

Table 3: Results of Compressive Strength Test for 0.4 W/C Ratio of Series-II

Series	Specimen number	% Replacement of Demolition construction waste	Compressive Strength (MPa) - 7 Days	Compressive Strength (MPa) - 28 Days	Compressive Strength (MPa) - 90 Days
Series II	CC	0	28.3	37.6	41.3
	P1	5	29.6	42.3	45.8
	P2	10	31.1	44.7	48.4
	P3	15	38.2	47.6	49.3

P4	20	31.7	45.3	47.3
P5	25	28.5	40.7	43.7
P6	30	26.7	38.2	41.6
P7	35	23.9	34.2	37.5
P8	40	21.8	31.3	33.7

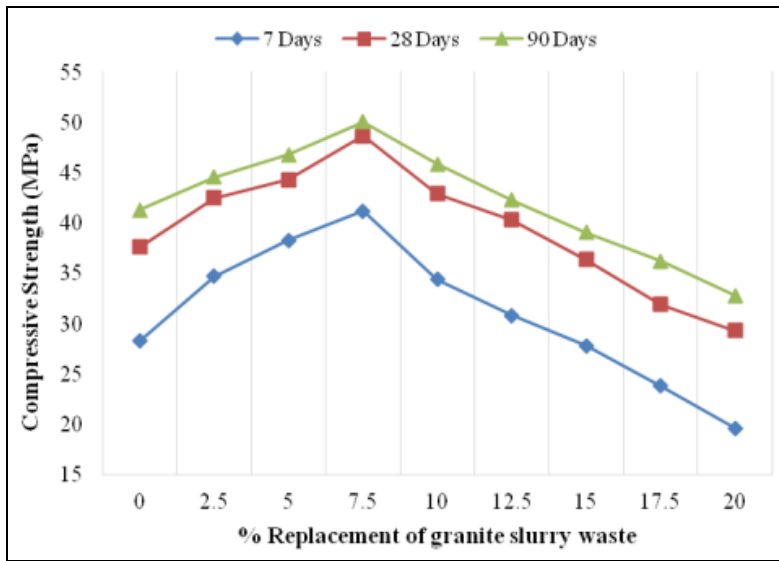


Fig 2: Graphical Fluctuation in Compressive Strength of Concrete Using Granite Slurry Waste for Series-I

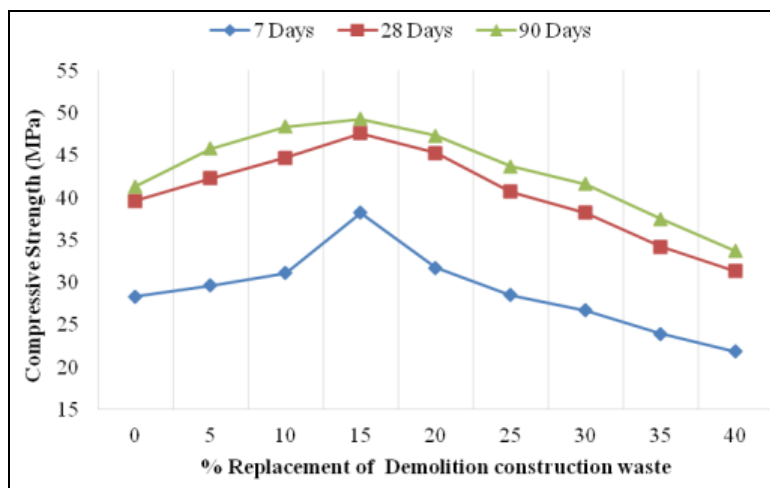


Fig 3: Graphical Fluctuation in Compressive Strength of Concrete Using Demolition Construction Waste for Series- II

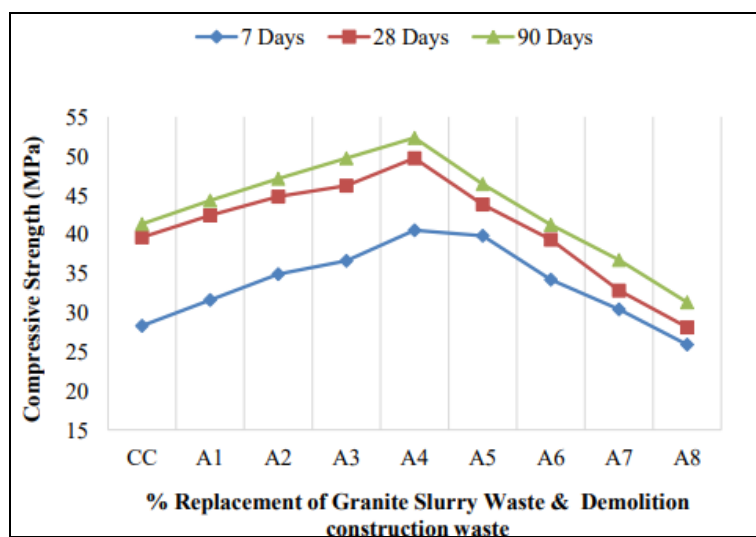


Fig 4: Graphical Fluctuation in Compressive Strength of Concrete Using Granite Slurry Waste and Demolition Construction Waste for Series-III

Table 4: Results of Compressive Strength Test for 0.4 W/C Ratio of Series-III

Series	Specimen Number	% Granite Slurry Waste	% Replacement of Demolition Construction Waste	Compressive Strength (MPa) - 7 Days	Compressive Strength (MPa) - 28 Days	Compressive Strength (MPa) - 90 Days
Series-III	CC	0	0	28.3	37.6	41.3
	A1	2.5	5	31.6	42.4	44.3
	A2	5	10	34.9	44.8	47.1
	A3	7.5	15	36.6	46.2	49.7

When testing concrete, compressive strength is vital, and with high strength concrete, it is very crucial. The compressive strength is determined by casting six 150 mm x 150 mm x 150 mm cubes of M-75 concrete for each trial mix. After 7 days of curing, three samples are tested, and after 28 days, the following three samples are tested.

We perform compressive strength tests on cubes after 7 and 28 days. A compression testing machine with a 2000-capacity is used to conduct compressive strength tests in accordance with IS 516-1959. The item was tested for compressive strength in photograph 2.



Photograph 2 Testing of specimen (compressive strength test)



Photograph 3 Testing of specimen (split tensile strength test)

Effect of Combination All Together

Table 5 and picture 4.11 show the cumulative effects of all components, comparing the 7- and 28-day compression strengths of traditional high-strength concrete with composite high-performance concrete.

Table 5: Effect of Combination all Together (compressive strength test)

Concrete	7 days (N/mm ²)	28 days (N/mm ²)
Conventional concrete	49.28	82.31
Combined effect	51.13	83.56

Split Tensile Strength Test

Testing for split tensile strength is carried out in accordance with IS 5816:2018. Cast cylindrical specimens with a diameter of 100 mm and a length of 300 mm are used for the split tensile strength test. The average value was derived after casting and testing three cylinders in each mixture. A computerized compression machine with a 2000 KN capacity is used to perform the split tension test. The specimen was tested for split tensile strength (see photograph 3).

Effect of M-sand

Figure 5 and Table 6 show the results of the 7-day split tensile strength testing that included synthetic sand. The results of the 28-day split tensile strength testing with manufactured sand are shown in Table 7 and Figure 6.

Table 6: Effect of M-sand at 7 days (split tensile strength test)

M-sand	7 days (N/mm ²)
25% M-sand	2.8
50% M-sand	2.9
75% M-sand	3.1

Table 7: Effect of M-sand at 28 days (split tensile strength test)

M-sand	7 days (N/mm ²)
25% M-sand	5.2
50% M-sand	5.4
75% M-sand	5.5

Effect of Silica Fumes

The effects of silica fumes on 7-day split tensile strength tests are shown in table 8 and figure 8. The effects of silica fumes on split tensile strength tests after 28 days are shown in Table 9 and Figure 9.

Table 8: Effect of Silica Fumes at 7 days (split tensile strength test)

Silica Fumes	7 days (N/mm ²)
2.5% SF	2.83
5% SF	2.93
7.5% SF	3.34
10% SF	3.22

Table 9: Effect of Silica Fumes at 28 days (split tensile strength test)

Silica Fumes	28 days N/mm ²
2.5% SF	5.24
5% SF	5.37
7.5% SF	5.52
10% SF	5.43

Conclusions

The study compares composite high-performance concrete to conventional high-strength concrete and finds that the addition of silica fume and iron filing improves the compressive strength by 3.9% and 3.06%, split tensile strength by 7.8% and 3.3%, and flexural strength by 9.8% and 6.7%, respectively. In addition to its flexural strength, compressive strength, and elastic modulus after it has hardened. Modified fibrous concrete has also been subjected to the acid attack, carbonation, and abrasion tests, which measure durability. In order to demonstrate that fibrous

concrete was produced with quality control in mind, an ultrasonic pulse velocity (UPV) test was also performed.

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