IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 6, May 2025 Impact Factor: 7.67

Experimental Analysis on Bella Stone Powder with Partial Replacement of Cement in Concrete

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Abstract: *This study examines the impact of partially replacing cement with Bella Stone Powder on the mechanical properties of M30-grade concrete. The main objective is to assess changes in compressive strength and split tensile strength with varying Bella Stone Powder content. Cement was replaced by Bella Stone Powder at levels of 0%, 5%, 10%, 15%, 20%, and 25% by weight. Concrete cubes and cylinders were cast and tested at 7 and 28 days to evaluate mechanical performance. Results indicated that a 10% cement replacement with Bella Stone Powder produced the highest compressive and split tensile strengths, marginally surpassing the control mix. Beyond this level, strength began to decrease, likely due to the dilution of cementitious material and reduced bonding efficiency. The study concludes that Bella Stone Powder can be effectively utilized as a partial cement replacement up to 10%, enhancing mechanical properties and supporting sustainable construction practices*

Keywords: Concrete, Cement Replacement, Bella Stone Powder, Sustainable concrete, Compressive Strength, Split Tensile Strength

I. INTRODUCTION

Concrete is one of the most widely used construction materials globally, valued for its high compressive strength, durability, and versatility. However, its primary binding component—cement—is also a significant contributor to global carbon dioxide (CO_2) emissions, accounting for approximately 5–8% of the total annual CO_2 emissions worldwide. This environmental concern has led to increasing interest in sustainable alternatives and supplementary materials in concrete production.

Among these alternatives, industrial by-products and stone waste materials have gained significant attention. Stone cutting and processing industries produce large volumes of fine dust or powder as a by-product, which is often disposed of in landfills, contributing to environmental degradation.

Studies have shown that stone powder exhibits pozzolanic properties and can be utilized in concrete to partially replace cement, offering environmental and economic benefits.

Bella Stone Powder (BSP), a by-product generated during the cutting and polishing of decorative stone such as marble and granite, shares characteristics similar to other industrial stone dusts previously studied. Its mineralogical composition, fineness, and reactivity make it a promising candidate for partial replacement of cement in concrete. Previous investigations into materials such as ceramic powder, crushed stone dust, and brick powder have demonstrated improvements in the mechanical properties of concrete—such as compressive, split tensile, and flexural strength—at varying replacement levels, In another study, ceramic dust powder yielded optimum results at 7.5% replacement, while higher amounts led to diminishing strength returns.

In terms of environmental sustainability, using crushed rock dust at 20% cement replacement contributed to acceptable strength and better durability while reducing the carbon footprint of concrete production.

This research aims to experimentally evaluate the feasibility of using Bella Stone Powder as a partial substitute for Ordinary Portland Cement (OPC) in concrete. The study investigates the impact of different replacement levels on the compressive strength and workability of concrete mixes. By contributing to the existing body of knowledge on sustainable construction practices, this research seeks to promote the beneficial reuse of industrial waste, reduce cement consumption, and foster environmentally friendly construction technologies.

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Therefore, there is a critical need to find sustainable alternatives that can partially replace cement in concrete without compromising its performance.

II. MATERIALS

Bella Stone Powder (BSP)

Bella stone powder is a finely crushed stone material often used in construction and landscaping. (used 90 microns passed powder). As a byproduct of stone quarrying or crushing, it is composed of very small particles that can serve multiple purposes in various applications, particularly in concrete production.

Figure 1 Bella Stone Powder Waste Material

Table 1 Chemical Properties of Bella Stone Powder and Cement

Bella Stone Powder			Cement		
Sr. No	**Chemical Constituent**	**Percent (%)**	**Sr. No**	**Chemical Constituent**	**Range (%)**
1	SiO_2	90.00	1	SiO_2	17-25
2	CaO	3.22	2	CaO	60-70
3	AL_2O_3	4.86	3	AL_2O_3	3-8
4	MgO	0.84	4	MgO	1-3
5	Fe_2O_3	1.02	5	Fe_2O_3	0.1-4
6	Others	0.06	6	Others	1-3

Table 2 Physical Properties of Experimental Material

Sr. No.	Test	Coarse Aggregate	Fine Aggregate	Bella Stone Dust
1	Specific Gravity	2.80	2.68	2.72
2	Water Absorption	0.45 %	1.24 %	2.1 %
3	Fineness Modulus	-	2.69	2.13
4	Sieve Analysis	-	Zone - II	-

Cement

Cement is used to work according to IS: 12269 – 2013 Ordinary Portland Cement (OPC) - 53 Grade

Coarse Aggregate

Coarse aggregate is used according to IS: 383 – 2016 Specification for Coarse and Fine Aggregate from Natural Sources for Concrete, which fraction is from 20 mm to 4.75 mm.

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Fine Aggregate

Fine aggregate is used to work according to IS: 383–2016 Specification for Coarse and Fine Aggregate from Natural Sources for Concrete which fraction is from4.75mm to 150µ

Water

Normal Potable water is used in the concrete mix.

III. EXPERIMENTAL METHODOLOGY

Based on Trial mix results, the M30 Grade Concrete Mix was designed as per IS: 10262 - 2009. The Design Mix is definedas below.

In this experimental work, Cubes of 150 × 150 × 150 mm and Cylinders of 150 mm Diameter and 300 mm length were casted and Tested for Compressive Strength and Split Tensile Strength after 7 and 28 Days of water curing. The Cement was replaced with Bella Stone Powder at 0%,5%, 10% 15% 20% and 25% in Concrete mix.

Table 3 M-30 Concrete Mix Design

Material	Weight in kg/m^3
Cement	412
Water	194
Coarse Aggregate 20 mm (60 %) 10 mm (40 %)	**1212** 726 486
Fine Aggregate	662
W/C ratio	0.42
Target Mean Strength	38.25 N/mm^2

Table 4 Design Mix Proportion for Various M30 Grade Concrete

Sr. No	Concrete Type	Bella Stone Powder Replacement with Cement
1	B0	Normal Concrete
2	B1	5% Replacement
3	B2	10% Replacement
4	B3	15% Replacement
5	B4	20% Replacement
6	B5	25% Repalcement

IV. EXPERIMENTAL RESULTS

Slump Test

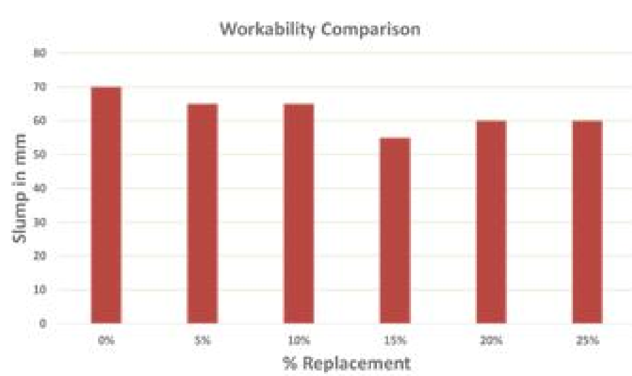

Figure 2 Workability Test Result

DOI: 10.48175/IJARSCT-26778

ISSN 2581-9429 IJARSCT

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Figure 3 Slump Measuring

These results suggest that increasing the percentage of Bella Stone Dust beyond 10% tends to reduce the workability of the mix, likely due to the finer particle size and higher surface area, which increases water demand.

Compressive Strength Test

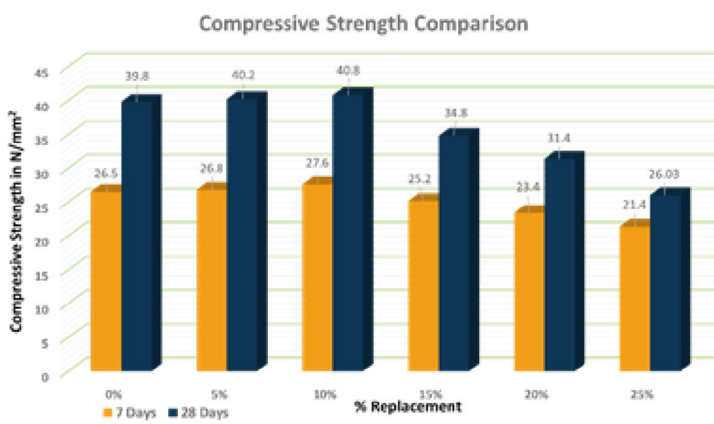

Figure 4 Compressive Strength at 7 days and 28 days

Figure 5 Testing of Cube

Compressive Effect on Early Strength (7 Days)

From 0% to 10% replacement, the compressive strength increased by approximately 4.15% (from 26.5 to 27.6 N/mm²).

Beyond 10%, the strength started to decline significantly:

At 15% replacement, it dropped to 25.2 N/mm² (−8.7% from the peak).

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At 25%, it declined to 21.4 N/mm² (−22.5% from the peak).

Compressive Effect on Later Strength (28 Days)

The strength increased from 39.8 N/mm² (0% replacement) to 40.8 N/mm² at 10% (+2.5%).
After 10%: At 15% replacement, the strength decreased to 34.8 N/mm² (−14.7% from the peak).
At 25% replacement, it further declined to 26.03 N/mm² (−36.2% from the peak).

Split Tensile Strength Test

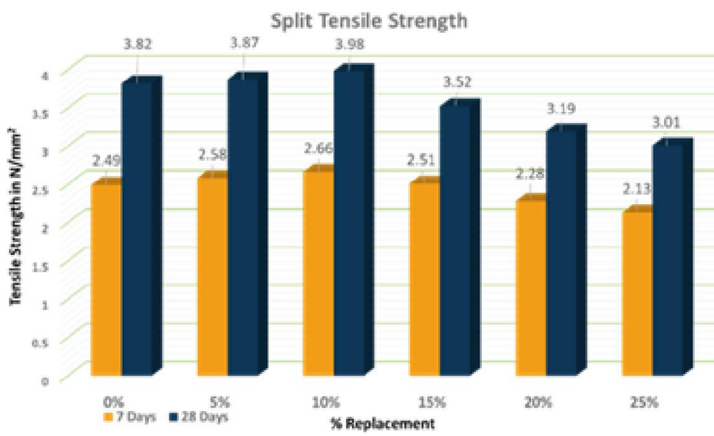

Figure 6 Split Tensile Strength at 7 days and 28 days

Figure 7 Testing of the Cylinder

Tensile Effect on Early Age Strength (7 Days)

Strength increased from 2.49 N/mm² (0%) to 2.66 N/mm² (10%), showing a 6.83% improvement.
Beyond 10%, the strength declined: At 15%: 2.51 N/mm² (−5.64% from peak). At 25%: 2.13 N/mm² (−19.92% from peak).

Tensile Effect on Later Age Strength (28 Days)

Strength increased from 3.82 N/mm² (0%) to 3.98 N/mm² (10%), a 4.19% increase.
Beyond 10%, strength dropped progressively: At 15%: 3.52 N/mm² (−11.56% from peak). At 25%: 3.01 N/mm² (−24.37% from peak).

V. Conclusion

The slump value decreased as the percentage of fine aggregate replaced with Bella Stone powder increased.
From 70 mm (0%) to 65 mm (10%), workability remained within acceptable range.
Beyond 10%, slump reduced to 55 mm at 15%, indicating reduced workability.
Optimal strength was achieved at 10% replacement of cement with Bella Stone Powder.

At 10% replacement: 7-day strength increased to 27.6 N/mm² from 26.5 N/mm² at 0% (≈ +4.15%).
28-day strength peaked at 40.8 N/mm², higher than the control mix (39.8 N/mm²).
Beyond 10% replacement, compressive strength declined significantly: At 25%, it dropped to 21.4 N/mm² (7 days) and 26.03 N/mm² (28 days), indicating a 36.2% reduction in long-term strength compared to the peak value.
The highest split tensile strength was also observed at 10% replacement of cement:7 days: 2.66 N/mm² (+6.8% increase from control), 28 days: 3.98 N/mm² (+4.2% increase from control).
Strength reduced after 10%, with the lowest values at 25% replacement: 2.13 N/mm² (7 days), 3.01 N/mm² (28 days), showing a 24.4% reduction from peak tensile strength.
Higher replacement levels (above 10%) led to reductions in mechanical performance and workability, thus not recommended for structural applications without further modification.

ACKNOWLEDGMENT

Thanks to the Department of Civil Engineering, Darshan University, Rajkot, for providing a suitable laboratory toperform the required tests, guidance under Prof. Chetan Solanki, Head of the department Prof. Dipak Jivani.

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