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# Performance of RCC column with silica sand and dolomite aggregate as replacement for natural sand

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**ABSTRACT**:

The increasing shortage of natural river sand and the growing demand for sustainable construction materials have led to the use of alternative fine aggregates in concrete. This study looks at the performance of RCC columns and concrete samples where natural sand is partially and fully replaced with silica sand and dolomite sand, while also exploring Concrete-Filled Steel Tubes (CFST) as a reinforcement option. The experimental work included tests on fresh and hardened concrete, such as slump tests, compressive strength, split tensile strength, pull-out bond strength, and axial compression tests on CFST and conventionally reinforced columns. The mix used was M30 grade concrete designed according to IS 10262:2009. The test results show that partially replacing natural sand significantly improves mechanical properties. Silica sand at 25% replacement and dolomite sand at 35% replacement produced the highest compressive and tensile strength because of better particle packing and fewer voids. Full replacement with either material resulted in a drop-in strength. Bond strength, measured by the pull-out test, also increased at optimal replacement levels, with silica sand (25%) showing the best bond stress. Axial compression tests on columns indicated that CFST columns surpassed conventional reinforced columns, demonstrating a greater load-carrying capacity, increased ductility, and improved resistance after failure.

**Keywords:** Silica Sand, Dolomite Aggregate, RCC Column, CFST, Compressive Strength, Split Tensile Strength, Bond Strength, Axial Compression.

## 1. INTRODUCTION:

Concrete is one of the most popular construction materials because of its strength, durability, and versatility. However, the rising demand for infrastructure development has resulted in the over-extraction of natural river sand, which has raised environmental issues and created shortages. This has triggered the search for alternative fine aggregates that can support construction while promoting sustainable construction practices.

Silica sand and dolomite sand have proved to be promising alternatives due to their desirable physical and chemical properties. Silica sand offers hardness, durability, and increased particle packing, whereas dolomite aggregate helps in increased density, strength, and chemical resistance in concrete. Besides optimizing material, structural efficiency can be achieved by using Concrete-Filled Steel Tubes (CFST), which offer the compressive strength of concrete and the confinement and tensile strength of steel, thereby increasing the load-carrying capacity and ductility of the structure.

The performance of the reinforced concrete specimens and columns with partial and full replacement of natural sand using silica sand and dolomite sand, along with CFST applications, is analyzed in this research. The experimental work involves testing the hardened concrete properties and behavior.

## 2. MATERIAL AND PROPERTIES

### 2.1 General

Following are the materials used in this study silica sand, Dolomite aggregate, Cement OPC 43 grade conforming to IS 8112-1989, Coarse aggregate, Fine aggregate – Natural sand (IS383-1970), Concrete Filled Steel Tubes (CFST).

### 2.2 Silica Sand

Silica sand is fine powder which can replace up to a different percentage of conventional sand usage in concrete. Its micro-filling effect improves the particle packing of the concrete and hence improve moisture resistivity of concrete.

**Table 2.1 Properties of Silica Sand**

| Properties | Results |
|---|---|
| Specific gravity | 2.61 |
| Fineness modulus | 2.70 |

### 2.3 Dolomite Sand

Dolomite sand is a mineral aggregate that is obtained from dolomite rock and quarry by-products, which is used as a partial substitute for the conventional fine aggregate in concrete. The chemical composition and particle properties of dolomite sand are stable, and this improves the density and particle packing.

**Table 2.2 Properties of Dolomite Sand**

| Properties | Results |
|---|---|
| Specific gravity | 2.71 |
| Fineness modulus | 4.46 |

### 2.4 Fine Aggregate

Fine aggregate used for this study is natural river sand (IS383-1970). Fine aggregate is used to achieve uniformity in the mixture and also helps the cement paste to hold the coarse aggregate particle in suspension.

**Table 2.3 Properties of Fine Aggregate**

| Properties | Results |
|---|---|
| Specific gravity | 2.56 |
| Fineness modulus | 2.73 |

### 2.5 Coarse Aggregate

Coarse aggregate of size 20mm is used for this study. Coarse aggregate controls shrinkage of Concrete and provides volume stability to the concrete.

**Table 2.4 Properties of Coarse Aggregate**

| Properties | Results |
|---|---|
| Specific gravity | 2.79 |
| Fineness modulus | 2.32 |

### 2.6 Cement

Cement is a binding material that holds together with the other ingredients of concrete. Ordinary Portland cement of grade 43 is used.

### 2.7 Concrete Filled Steel Tubes

Concrete Filled Steel Tubes (CFST) are structural members where a hollow steel tube is filled with concrete, combining steel's tensile strength with concrete's compressive strength. This composite system offers superior strength, high ductility, better fire resistance, and faster construction by eliminating the need for formwork. The steel tube acts as permanent formwork and confines the concrete core, which prevents the steel from local buckling.

### 2.8 Design of Concrete mix

In the present investigation, M30 mix is designed based on IS 10262:2009. The water cement ratio adopted is 0.375 and the mix ratio adopted is 1: 1.546: 3.01.

## 3. METHODOLOGY

### 3.1 Test on Fresh concrete

#### 3.1.1 Slump Cone Test

The slump cone test assessed the workability and consistency of the fresh concrete mix. A standard slump cone measuring 300 mm in height, 200 mm in bottom diameter, and 100 mm in top diameter was used. Before the test, the inner surface of the mould was cleaned and lightly oiled to prevent the concrete from sticking. The mould was placed on a smooth, horizontal, non-absorbent base plate and held firmly in place. Freshly mixed concrete was added to the mould in three roughly equal layers. Each layer was compacted with 25 uniform blows using a tamping rod that was 16 mm in diameter and 600 mm long, ensuring the rod slightly penetrated the layer below. After compacting the top layer, excess concrete was levelled off with a trowel. The mould was then lifted straight up without any sideways or twisting motion. The slump value was measured as the vertical difference between the height of the mould and the highest point of the settled concrete. This measured slump value indicates workability the concrete mix.

**Fig 1 Slump Cone Test**

### 3.2 Tests on Hardened Concrete

#### 3.2.1 Compressive Strength Test

The 3-cube specimen of each variation was removed from the curing tank after the specified curing period for 7 days and 28 days. and any excess surface water was wiped off before testing. The bearing surfaces of the testing machine were cleaned to ensure proper contact and accuracy. The specimen was then placed in the machine so that the load would be applied to the opposite faces of the cube as cast, and it was carefully aligned at the centre of the base plate. The movable head was gently rotated by hand until it just touched the top surface of the specimen, ensuring uniform contact. The load was applied gradually, without shock, and continuously at a rate of about 140 kg/cm² per minute in accordance with Bureau of Indian Standards recommendations until the specimen failed. The maximum load at failure was recorded, and any unusual characteristics observed in the mode of failure were noted for further evaluation.

Compressive strength= Load at failure / face cross sectional area

**Fig 2 Compressive Strength Test**

#### 3.2.2 Split Tensile Strength Test

The 3-cylinder specimen of each variation was removed from the curing tank after 7 days and 28 days, or at the desired age for estimating tensile strength, and the surface water was wiped off. Diametrical lines were drawn on both ends of the specimen to ensure proper axial alignment, and its weight and dimensions were recorded. The compression testing machine was then set to the required range. A plywood strip was placed on the lower platen, and the specimen was positioned on it, ensuring that the marked lines were vertical and centred on the plate. Another plywood strip was placed above the specimen, and the upper platen was lowered until it just made contact. The load was applied continuously and without shock at a rate of 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min as per Bureau of Indian Standards IS 5816:1999), and the load at which the specimen failed (P) was finally recorded.

$$T=2*P/ \pi*L*D$$

Where:
T=splitting tensile strength, MPa
P=maximum applied load indicated by the testing machine
D-diameter of the specimen, mm
L-length of the specimen, mm

**Fig 3.2 Split Tensile Strength Test**

#### 3.2.3 Pull out Test:

The 3 cured cylindrical specimen of each specimen after 7 days and 28 days are removed and was placed in the pull-out test fixture so that the concrete or mortar cylinder was fully supported while the embedded bar remained free for gripping. The specimen was carefully aligned to ensure that the bar was centred and that the load would be applied axially without causing bending. The exposed end of the bar was then secured in the jaws of the Universal Testing Machine (UTM), a small seating load was applied, and the machine was set to operate in displacement control at a constant rate, typically between 1–5 mm/min. The load and displacement readings were zeroed before starting the test. Loading was initiated, allowing the machine to pull the bar upward until failure occurred, while load and slip were recorded continuously. The test was stopped when the bar was completely pulled out or when a sharp drop in load indicated bond failure. Finally, the maximum load was noted, the bond stress was calculated using the bond area (π × bar diameter × embedment length), and the mode of failure—adhesive, cohesive, or splitting—was observed and recorded.

Bond surface area, $A = \pi * L * D$

d= diameter of the bar (mm)
L= embedment length inside the cylinder (mm)

Bond Stress (Bond Strength) $= F_{max}/A$

**Fig 3.3 Pull Out Test**

### 3.2.4 Axial Compression Strength Test

The axial compression test on reinforced concrete column specimens measuring 150 mm × 150 mm in cross-section and 600 mm in height and also Concrete filled steel tubes of 100 mm x 100 mm Cross Section and 2 mm thickness, 2 numbers of each variations are used to determine their ultimate load-carrying capacity under concentric loading. Each column was reinforced with four longitudinal bars of 12 mm diameter and lateral ties of 6 mm diameter spaced at 125 mm centre-to-centre, using Fe 500 grade high-strength steel for both longitudinal and transverse reinforcement. After 28 days of water curing, removed the specimens from the tank, wiped off excess moisture, and checked the top and bottom faces to ensure they were level and perpendicular to the longitudinal axis so that uniform load transfer could be achieved; minor surface irregularities were corrected where necessary. Then placed each specimen vertically in the Universal Testing Machine, carefully aligning it to ensure axial loading. A small seating load was applied to establish proper contact between the specimen and the platens, after which applied the compressive load gradually and continuously without shock at a uniform rate until failure occurred. The load at failure is recorded and examined the mode of failure, including concrete crushing, yielding or buckling of reinforcement, and the effectiveness of lateral ties in confining the concrete core, to evaluate the structural performance of the columns under axial compression.

Compressive stress $F_c = F_{max}/A$

$F_{max}$= Max load at failure

A=cross sectional area ($mm^2$)

Axial strain = $\Delta L / L_o$

$\Delta L$=change in length (mm)
$L_o$=original length (mm)

**Fig 3.4 Axial Compression Test**

## 4. RESULTS AND DISCUSSIONS

### 4.1 Compressive Strength Test

Both silica sand and dolomite aggregate demonstrated an improvement in compressive strength when used as partial replacements for natural sand, indicating their potential suitability as alternative fine aggregate materials in concrete production. In the case of silica sand, a 25% partial replacement level produced higher compressive strength compared to full replacement, suggesting that moderate substitution enhances the micro-filling effect and improves matrix densification without adversely affecting particle gradation. Similarly, dolomite aggregate achieved its optimum performance at 35% partial replacement, where the compressive strength was highest compared to complete replacement, highlighting the importance of controlled incorporation for maintaining structural stability of the mix. At their respective optimum replacement levels (25% and 35%), silica sand exhibited comparatively superior strength performance than dolomite aggregate, indicating more effective particle interaction and bonding within the cement matrix. The overall strength enhancement observed in both cases can be attributed to improved particle packing, reduced porosity, and increased density of the concrete mix, which facilitate better stress distribution and load transfer. However, full replacement of natural sand with either silica sand or dolomite aggregate resulted in a reduction in compressive strength, likely due to increased void content, non-uniform grading, and weaker interfacial bonding between aggregate particles and cement paste

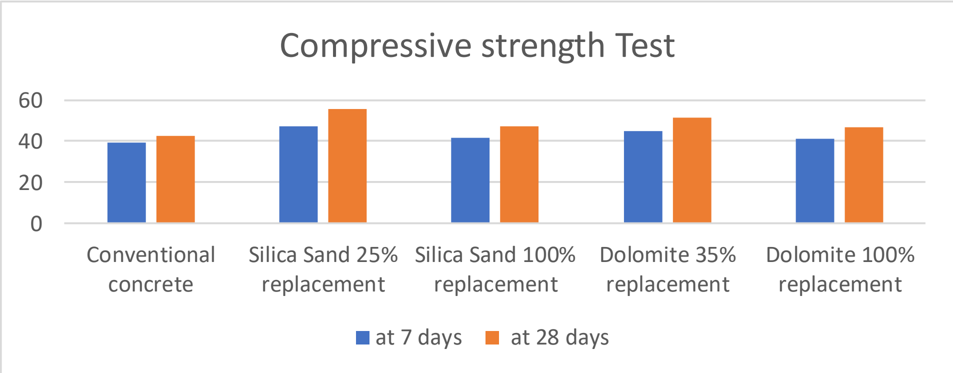



**Table 4.1 Average compressive strength of cubes**

| Type of Specimen | 7 Days Avg CompressiveStrength (MPa) | 28 Days Avg Compressive Strength (MPa) |
|---|---|---|
| Conventional Concrete | 39.38 | 42.36 |
| Silica sand 25% replacement | 47.36 | 55.4 |
| Silica sand full replacement | 41.44 | 47.25 |
| Dolomite sand 35% replacement | 44.96 | 51.53 |
| Dolomite sand full replacement | 40.96 | 46.59 |

**Bar chart 4.1 Avg Compressive strength of cubes**

### 4.2 Split Tensile Strength Test

The tensile strength results indicate that the highest tensile strength was obtained at 100% silica sand replacement; however, a 25% replacement level exhibited a notable improvement in split tensile strength compared to full replacement, suggesting that partial substitution promotes more favourable particle gradation and interfacial bonding within the cementitious matrix. Similarly, dolomite aggregate at a 35% replacement level produced enhanced split tensile strength relative to complete replacement, demonstrating the effectiveness of optimized incorporation in improving resistance to tensile cracking. Overall, mixes containing silica sand replacements exhibited higher split tensile strength than conventional concrete, confirming its positive contribution to tensile performance. This enhancement can be attributed to the filler effect of silica sand, which reduces internal voids, improves particle packing density, and increases matrix compactness, thereby facilitating improved stress transfer and delaying crack initiation and propagation under tensile loading.

**Table 4.2 Avg Split Tensile Strength at 28 Days**

| Name of specimen type | Avg split Tensile strength |
|---|---|
| Conventional concrete | 2.88 |
| Silica Sand 25% replacement | 2.98 |
| Silica Sand 100% replacement | 2.83 |
| Dolomite 35% replacement | 2.65 |
| Dolomite 100% replacement | 2.55 |

**Bar chart 4.2 Avg Split Tensile Strength at 28 Days**

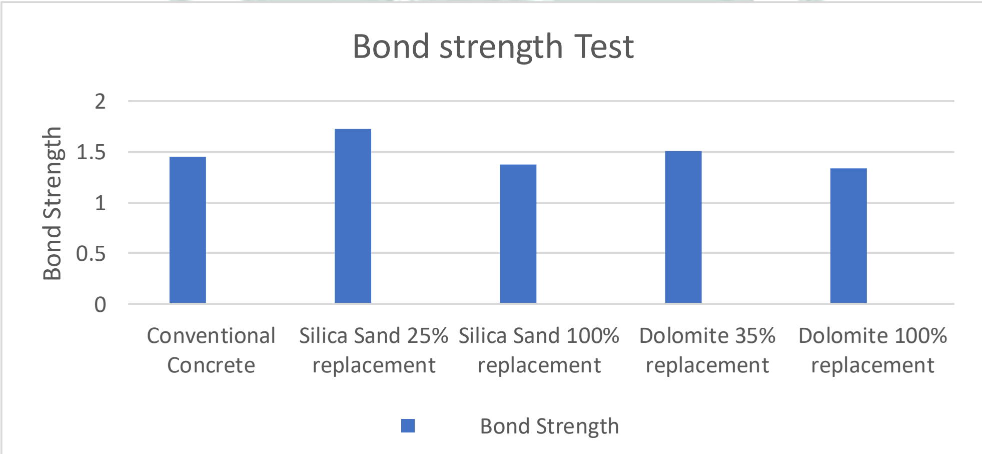
### 4.3 Pull Out Test

The bond strength results indicate that the maximum bond stress was achieved at a 25% silica sand replacement level, demonstrating its effectiveness in enhancing the interfacial interaction between reinforcement and the surrounding concrete matrix. At this level, silica sand exhibited significantly higher bond strength compared to full replacement, suggesting that partial substitution promotes improved particle packing and matrix integrity without adversely affecting the bond interface. Similarly, dolomite aggregate at a 35% replacement level resulted in improved bond strength relative to complete replacement, highlighting the importance of optimized replacement proportions for maintaining adequate mechanical interlocking and adhesion. Conversely, full replacement of natural sand with either silica sand or dolomite aggregate led to a reduction in bond strength, which may be attributed to increased void content, less favourable gradation, and weaker paste–aggregate interaction affecting stress transfer at the interface. The comparatively superior performance of silica sand can be associated with its fine filler characteristics, which reduce internal voids, enhance density, and contribute to improved confinement and contact between reinforcement and the concrete matrix, thereby increasing bond resistance.

**Fig 4.3 Pull Out Test Results at 28 days**

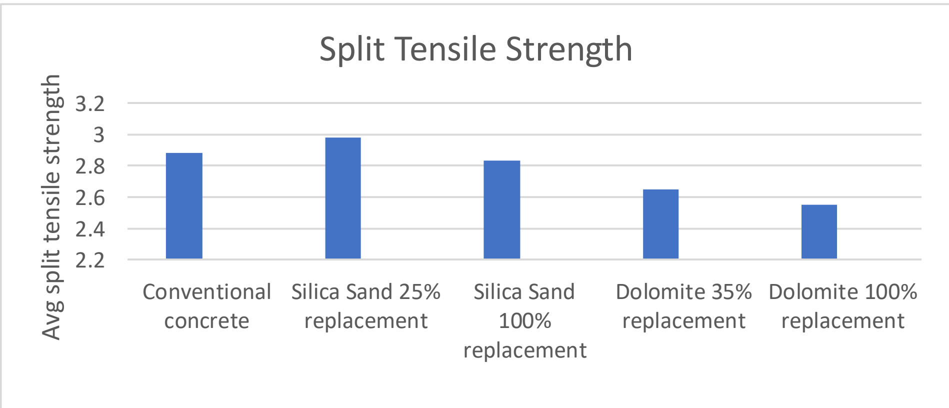
| Name of the type of specimen | Bond Strength |
|---|---|
| Conventional Concrete | **1.449** |
| Silica Sand 25% replacement | **1.72** |
| Silica Sand 100% replacement | **1.375** |
| Dolomite 35% replacement | **1.51** |
| Dolomite 100% replacement | **1.34** |

**Bar Chart 4.3 Pull out Test Results at 28 days**




### 4.4 Axial Compression Strength Test

The experimental results indicate that CFST columns exhibited significantly higher axial compression strength compared to conventionally reinforced concrete columns, demonstrating the beneficial composite interaction between the steel tube and the infilled concrete core. The CFST specimens sustained greater axial loads while exhibiting comparatively higher deformation capacity, indicating enhanced ductility and energy absorption characteristics relative to normal reinforced columns. Furthermore,




even after the initiation of concrete crushing, the CFST columns continued to sustain additional load due to the confinement effect provided by the steel tube and the redistribution of stresses within the composite section. This post-peak load-carrying ability highlights the superior structural resilience and safety performance of CFST columns compared to conventional reinforced concrete columns under axial compression.

**Fig 4.4 Average Axial Compression Strength Test at 28 days**

| Name of Type of Specimen | Peak Load (Reinforcement) | Peak load (CFST) |
|---|---|---|
| Conventional Concrete | 615 | 673 |
| Silica Sand 25% replacement | 693 | 789 |
| Silica Sand 100% replacement | 660 | 715 |
| Dolomite 35 % replacement | 678 | 722 |
| Dolomite 100 % replacement | 668 | 694 |

## CONCLUSIONS

- All mixes containing silica sand and dolomite sand showed good workability. The improved workability is due to the fine and uniform particle size of silica and dolomite aggregates.
- Silica Sand and Dolomite aggregate at optimum replacement (i.e. 25%,35%) improved the compressive strength than the normal concrete and full replacement
- Full replacements of both silica sand and dolomite resulted in decreased compressive strength because of increased voids and reduced aggregate interlocking.
- Maximum tensile strength was observed at 25% silica sand replacement. Dolomite at 35% replacement also improved tensile strength compared to the normal concrete and full replacement. Full replacement for both materials reduced tensile strength due to poor particle packing.
- Silica sand (25%) achieved the highest bond strength. Dolomite at 35% also improved bond performance. Full replacements lowered bond strength due to weak interfacial bonding between concrete and steel.
- CFST columns exhibited significantly higher axial load capacity compared to normal reinforced columns. Even after concrete cracking, CFST columns continued to carry load, ensuring better ductility, safety, and post-failure resistance.
- CFST reduced sudden failures.
- Both silica sand and dolomite sand are viable substitutes for natural river sand, reducing environmental impact and promoting sustainable construction. Dolomite, being locally available and cost-effective, provides an economical alternative.

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