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# Crushed rock sand — An economical and ecological alternative to natural sand to optimize concrete mix☆

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**Summary** The study investigates the use of crushed rock sand as viable alternative to Natural River sand that is being conventionally used as fine aggregate in cement concrete. Various mix designs were developed for different grades of concrete based on IS, ACI and British codes using Natural River sand and crushed rock sand. In each case, the cube compressive strength test, and beam flexure tests were conducted. The results of the study show that, the strength properties of concrete using crushed rock sand are nearly similar to the conventional concrete. The study has shown that crushed stone sand can be used as economic and readily available alternative to river sand and can therefore help to arrest the detrimental effects on the environment caused due to excessive mining of river sand.


## Introduction

Rapid growth in the infrastructure at the global level has made concrete the most widely and commonly used construction material throughout the world. This has created immense pressure on the concrete industry to produce large quantum of concrete to meet the growing demand of infrastructure development. The cost of concrete production primarily depends on the cost of its constituent raw materials namely, cement, aggregates (coarse and fine) and water. Among the constituent raw materials, the Natural River sand which forms around 35% of the concrete volume plays an important role in deciding the cost of concrete. Depleting sources of Natural River sand and strict environmental guidelines on mining has gradually shifted the attention of the concrete industry towards a suitable fine aggregate alternative that can replace the presently used Natural River sand. Crushed rock sand has surfaced as

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**Table 1** Slump results for sand blend study.

| Fine aggregate blend (%) | M25 slump (mm) | | | | M30 slump (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | OPC + PFA | | OPC | | OPC + PFA | | OPC | |
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| NS/CRS (70/30) | 200 | 140 | 200 | 135 | 200 | 145 | 200 | 135 |
| NS/CRS (50/50) | 200 | 135 | 200 | 130 | 200 | 135 | 200 | 130 |
| NS/CRS (30/70) | 180 | 125 | 180 | 120 | 180 | 125 | 180 | 120 |
| NS/CRS (0/100) | 180 | 115 | 180 | 110 | 180 | 120 | 180 | 110 |

a viable alternative to Natural River sand and is being now used commonly throughout the world as fine aggregate in concrete. It is manufactured by crushing the quarried stone to a size that will completely pass through 4.75 mm sieve.

Several studies have been conducted in the past to investigate the effect of partial replacement of Natural River sand with crushed rock sand. Celik and Marar (1996) concluded that partial replacement upto 30% leads to decrease in slump value. However, a significant improvement in the compressive, flexural strength and impact resistance was observed. A significant reduction in the cost of concrete without affecting the strength property was reported in the study conducted by Ilangovan (2000). Sahu et al. (2003) observed that concrete made using crushed rock sand attained the comparable compressive strength, tensile strength and modulus of rupture as the control concrete. Sahul Hameed and Sekar (2009) concluded that the compressive strength, split tensile strength and the durability properties of concrete made of quarry rock dust are nearly 14% more than the conventional concrete.

A survey of literature has shown that numerous studies have been conducted in the past to utilize crushed rock sand as fine aggregates in concrete. But, an in-depth study has not been performed to optimize the replacement level of crushed rock sand in concrete. The present study has attempted to study the effect of partial to full replacement of Natural River sand with crushed rock sand on the workability, compressive strength and flexural strength of concrete.

## Materials

The materials for the study comprised of cement, fly ash, fine aggregates, coarse aggregates, admixture and water. Ordinary Portland cement (OPC) 43-grade was used in most of concrete design mixes. In some design mixes pulverized fly ash (PFA) was used as a supplementary cementing material. The percentage of fly ash was limited to 35%. The fine aggregates included Natural River sand from River Banas, and crushed stone sand from Gunavata and Chandwaji region in the State of Rajasthan. The coarse aggregates selected for study comprised of 20 mm and 12.5 mm-sized aggregates. High range water reducer admixture were incorporated to reach the desired workability.

## Experimental program

The experimental program was divided into two parts. The first part was dedicated to examine the effect of fine aggregates type, grading and blend ratio on the fresh and hardened properties of concrete. The second part of the program focused on the optimization of the selected design mix.

The Natural River sand from Banas was mixed with crushed stone sand from Gunavata and Chandwaji and concrete design mixes corresponding to M25 and M30 grade of concrete were prepared. The samples were tested for slump, compressive strength and flexural strength. The effects on each of these properties were examined by changing the percentage replacement of Natural River sand (NS) with crushed rock sand (CRS). An optimization study was performed to study the effect on the properties of concrete when paste content was held constant and the fly ash was considered to be powder instead of aggregates. Other goals of optimization were to examine the effect of partial replacement of cement with fly ash.

## Results and discussion

### Workability study

The workability of concrete was measured in terms of the slump value. The values of initial and final slump (after 2 h) were measured in mm and are exhibited in Table 1. The results indicate that, the initial slump values for OPC and partial replacement of OPC with PFA design mixes are same even at higher percentages of blending. But, the final slump values after 2 h tend to be slightly higher in case when PFA is used as partial replacement for OPC thereby indicating that PFA has a positive influence on concrete slump.

### Admixture demand study

The admixture dosage was increased from 0 to 1% and the slump values were measured. The slump values for concrete manufactured using NS and 100% replacement with CRS were plotted (Fig. 1). The plots reveal that at low level of admixture dosage (upto 0.70%), the concrete manufactured using CRS as 100% fine aggregates has almost zero slump values. However, at higher dosage of admixture, the slump values of concrete manufactured using 100% NS and 100% CRS as fine aggregates become almost comparable.

### Compressive strength study

The compressive strength was tested for different specimens of concrete manufactured with different percentages of fine

**Table 2** Compressive strength values for different blending percentages.

| Fine aggregate blend (%) | M25 grade concrete | | M30 grade concrete | |
|---|---|---|---|---|
| | OPC | OPC + PFA | OPC | OPC + PFA |
| NS/CRS(100/0) | 35.33 MPa | 34.18 MPa | 38.83 MPa | 40.42 MPa |
| NS/CRS (70/30) | 37.82 MPa | 36.70 MPa | 42.34 MPa | 41.17 MPa |
| NS/CRS (50/50) | 35.27 MPa | 34.32 MPa | 39.21 MPa | 35.27 MPa |
| NS/CRS (30/70) | 29.37 MPa | 28.27 MPa | 35.00 MPa | 33.53 MPa |
| NS/CRS (0/100) | 26.67 MPa | 22.67 MPa | 31.08 MPa | 28.11 MPa |

**Table 3** Flexure strength of concrete with NS and CRS.

| Grade | Flexure strength (CRS) | | Flexure strength (NS) | |
|---|---|---|---|---|
| | 7 Days | 28 Days | 7 Days | 28 Days |
| M25 (OPC + PFA) | 2.93 MPa | 3.50 MPa | 3.09 MPa | 3.72 MPa |
| M30 (OPC + PFA) | 3.20 MPa | 3.80 MPa | 3.34 MPa | 3.98 MPa |

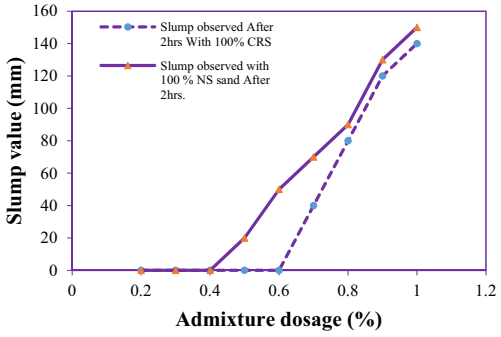


**Figure 1** Plot of slump value with varying admixture dosage.

aggregate blending. The results are tabulated in Table 2. The results show that the compressive strength is almost the same for concrete using OPC and OPC with partial replacement with PFA for all blending percentages. However, it is seen that as the blending percentage is increased beyond 50% the compressive strength tends to reduce. The incorporation of PFA in the mix is also seen to slightly reduce the compressive strength.

## Flexure strength study

Experimental studies for flexure strength were also carried out. Flexure strength is tabulated at Table 3.

## Conclusions

Following broad conclusions can be drawn from the study:

a. Expect that a higher blend ratio of crushed stone to natural sand will decrease workability. Even the best shaped manufactured sands are usually more poorly shaped than Silicious river sand. It is viable to use mix with high percentage of micro-fines in all concrete type. The workability is decreased, but it can be restored by increasing the paste content and including water reducing admixture, especially high range water reducing admixture (HRWRA).
b. Considerable reduction in compressive strength was noticeable at and beyond 50% CRS replacement. Therefore for mix with 70—100% CRS replacement it is desired to mix washed crushed rock sand along with proper screening at crushing stages so that one gets compressive strength higher than the designed strength.
c. The properties of concrete (Compressive and flexural strength) made with partial or full replacement with CRS are comparable to natural sand results.
d. The cost of concrete can be decreased by increasing the amount of crushed stone sand. The price can further be lowered by including the PFA in mix.
e. Besides being a cost effective alternative, use of CRS as fine aggregates in concrete helps in sustaining the ecological balance.

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