# STRENGTH APPRAISAL OF ARTIFICIAL SAND AS FINE AGGREGATE IN SFRC

Mahendra R. Chitlange[1] and Prakash S. Pajgade[2]
[1]Department of Applied Mechanics, Government Polytechnic, Aurangabad. Maharashtra, India
[2]Department of Civil Engineering, Prof. Ram Meghe Institute of Technology and Research, Badnera, Amravati, India
E-Mail: mrchitlange1@rediffmail.com

**ABSTRACT**

The huge quantity of concrete is consumed by the construction industry all over the world, probably second largest after water. In India, the conventional concrete is produced by using natural sand from riverbeds as fine aggregate. Dwindling sand resources poses the environmental problem and hence government restrictions on sand quarrying resulted in scarcity and significant increase in its cost. This paper presents the study of steel fiber reinforced concrete with artificial sand as fine aggregate. Three matrices with compressive strength 20, 30 and 40 MPa were designed and reinforced with crimpled steel fibers at dosage rate of volume fraction 0, 0.5, 1.0, 1.5 and 2.0 percent. The specimens were prepared, cured and tested for compressive strength, flexural strength and split tensile strength. The strength of steel fiber reinforced natural sand concrete (SFRNSC) and steel fiber reinforced artificial sand concrete (SFRASC) have been compared with the test data from the present study. The promotional use of artificial sand will conserve the natural resources for the sustainable development of the concrete in construction industry.

**Keywords:** artificial sand, steel fibres, SFRNSC, SFRASC, compressive strength, flexural strength, split tensile strength.

## 1. INTRODUCTION

There is scarcity of natural sand due to heavy demand in growing construction activities which forces to find the suitable substitute. The cheapest and the easiest way of getting substitute for natural sand is by crushing natural stone to get artificial sand of desired size and grade which would be free from all impurities. For the purpose of experimentation concrete mixes are designed for M20, M30 and M40 grades by 100% replacement of natural sand to artificial sand. The artificial sand concrete is reinforced with crimpled steel fibers at the dosage rate of volume fraction 0%, 0.5%, 1.0%, 1.5% and 2.0% and its mechanical properties namely cube compressive strength, flexural strength and split tensile strength are presented in the paper.

## 2. REVIEW OF LITERATURE

It was found that the compressive, flexural, split tensile strength and durability studies of concrete made of quarry rock dust in varying proportions were higher than those of conventional concrete by using natural sand as fine aggregate. The workability of the concrete mixes decreased with an increase in percentage of stone dust. It indicates that water requirement is higher in such concrete to maintain desired workability [1-6]. It was tried experimentally to explore the use of crusher dust, stone chips and fly ash in self compacting concrete. Test results indicated that for SCC, sufficiently low water to powder ratio can be attained even with the use of crusher dust, leading to high compressive strength [7]. Since ancient times, fibres have been used to reinforce brittle materials. In modern times, a wide range of engineering materials incorporate fibres to enhance composite properties. The enhanced properties include tensile strength, compressive strength, elastic modulus, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics, and fire resistance [8-14]. In these studies various mechanical properties were studied and mathematical models were presented using natural sand as the fine aggregate. Considering the scarcity of natural sand, the feasibility of artificial sand as fine aggregate was proved and reported consistent higher results [15].

In the present experimental study the feasibility of artificial sand with crimpled steel fibres is studied. This study reports the experimental results of the strength properties of the steel fibre reinforced natural sand and artificial sand concrete, namely cube compressive strength with fibre volume dosage from 0% to 2.0%, flexural strength and split tensile strength with fibre volume dosage from 0% to 1.5%.

## 3. MATERIALS AND METHODS

### 3.1 Materials

#### 3.1.1 Cement

The blended type of cement with specific gravity 3.10 confirming to IS 1489 (Part 1) – 1991 was used [16]. The initial and final setting time was 164 minutes and 244 minutes respectively. The 7 days compressive strength was 43.2 N/mm$^2$.

#### 3.1.2 Fine aggregate

The natural sand with specific gravity 2.60 and fineness modulus 2.66 was used. The water absorption and bulk density was 1.85% and 1560 kg/m$^3$, respectively. The artificial sand obtained from local crusher with specific gravity 2.73 and fineness modulus 3.01 was used. The water absorption and bulk density was 2.55% and 1762 kg/m$^3$ respectively. The both sands are confirming to zone II of IS 383-1970 [17].

**3.1.3 Coarse aggregate**

Crushed natural rock stone aggregate of nominal size up to 25 mm (A1) and aggregate passing 12.5 mm (A2) were used. The aggregates A1 and A2 were proportioned by trial in the mixes. The specific gravity, water absorption and bulk density was found to be 2.96, 1.32% and 1620 kg/$m^3$ respectively.

**3.1.4 Steel fibers**

The crimpled steel fibres of equivalent diameter 1.35 mm and 40 mm long with aspect ratio of 30 were used in the natural sand and artificial sand concrete. The yield strength of the fiber was 550 MPa.

**3.1.5 Super plasticizer**

The lignosulphonate based 'Roff super plast - 320' confirming to ASTM C494-1977 with specific gravity 1.16 was used in the proportion of cement content for desired workability [18].

**3.2 Experimental program**

Concrete mixes were designed in accordance with IS 10262-1982 [19] and IS 456-2000 [20] by assuming good degree of quality control and moderate exposure conditions. The mixes are designed for M20, M30 and M40 concrete with 100% replacement of natural sand by artificial sand. The adopted mixes proportions by weight batching method are summarized in Table-1.

**Table-1.** Concrete mix proportions (kg/$m^3$).

| Material | M20 | M30 | M40 |
|---|---|---|---|
| Cement | 310 | 385 | 450 |
| Artificial sand | 612 | 590 | 556 |
| Coarse aggregate A1 | 520 | 504 | 480 |
| Coarse aggregate A2 | 780 | 755 | 720 |
| Water | 155 | 174 | 180 |
| Super plasticizer (Lit) | 3.1 | 3.85 | 4.5 |
| Water / Cement ratio | 0.50 | 0.45 | 0.40 |
| Cement/Aggregate ratio | 1:6.16 | 1:4.80 | 1:3.90 |

The exact amount of concrete ingredients were weighed and mixed thoroughly in laboratory concrete mixer till the consistent mix was achieved. The workability of fresh concrete was measured in terms of slump value and compaction factor. The physical properties of green concrete are given in Table-2.

**Table-2.** Density and workability of green plain concrete.

| S. No. | Mix | Water cement ratio | Wet density (kg/$m^3$) | Dry density (kg/$m^3$) | Workability of fresh concrete | | |
|---|---|---|---|---|---|---|---|
| | | | | | Slump (mm) | CF | VB (sec) |
| 1 | NS20 | 0.50 | 2624.45 | 2610.25 | 120 | 0.90 | 9.3 |
| 2 | AS20 | 0.50 | 2620.18 | 2607.12 | 90 | 0.90 | 10.2 |
| 3 | NS30 | 0.45 | 2615.89 | 2603.48 | 100 | 0.88 | 16.0 |
| 4 | AS30 | 0.45 | 2610.45 | 2598.32 | 75 | 0.87 | 18.50 |
| 5 | NS40 | 0.40 | 2598.34 | 2587.87 | 80 | 0.88 | 19.2 |
| 6 | AS40 | 0.40 | 2588.64 | 2577.64 | 55 | 0.87 | 22.4 |

The standard cubes of 150 mm size, cylinders of 150 mm diameter - 300 mm length and prism of 100x100x500 mm were cast in steel moulds and compacted on a vibrating Table. The specimens were cured in water for 28 days by immersion and tested immediately. The 51 cube specimens each of SFRNSC and SFRASC were tested for determining the compressive strength and 42 prisms specimens each of SFRNSC and SFRASC were tested for flexural strength according to IS 516-1959 [21]. The 42 cylinder specimens each of SFRNSC and SFRASC were tested for split tensile strength according to IS 5816-1999 [22].

In the concrete mixer, the natural sand concrete and artificial sand concrete were prepared with about 80% of the designed water quantity and then steel fibers were spread manually in the volume fraction of 0%, 0.5%, 1.0%, 1.5% and 2.0%. After two minutes mixing, the remaining quantity of water mixed with super plasticizer was spread and concrete was mixed to get the uniform color. The 5 standard cube specimens each without fibers and 3 test specimens each from all mixes of SFRNSC and SFRASC were casted and compacted on Table vibrator. In all 270 specimens were tested.

**4. RESULTS AND DISCUSSIONS**

The compressive, flexural and split tensile strengths of Steel Fiber Reinforced Artificial Sand Concrete (SFRASC) were higher than the conventional Steel Fiber Reinforced Natural Sand Concrete (SFRNSC). The test results of SFRNSC and SFRASC are reported in Tables 3 and 4 respectively.

The average increase in compressive strength of SFRNSC due to addition of steel fiber ($V_f$ = 1.5%) was found to be 3.81%, 3.66% and 2.63% for M20, M30 and M40 concrete respectively (Table-3). For the same steel fiber volume fraction in SFRASC, the increase in strength

VOL. 5, NO. 10, OCTOBER 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

was found to be 3.42%, 3.29% and 3.02% for M20, M30 and M40 concrete respectively (Table-4).

**Table-3.** 28 Days compressive strength of SFRNSC (N/mm$^2$).

| Fiber aspect ratio | Fiber volume fraction | Reinforcing index (RI=AR*Vf) | **28 Days compressive strength of SFRNSC** (N/mm$^2$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **M20** | | **M30** | | **M40** | |
| | | | **Stress** | **% Increase** | **Stress** | **% Increase** | **Stress** | **% Increase** |
| 0 | 0.0 | 0.000 | 37.04 | - | 41.85 | - | 47.84 | - |
| 30 | 0.5 | 0.150 | 37.48 | 1.19 | 42.23 | 0.91 | 48.16 | 0.67 |
| 30 | 1.0 | 0.300 | 37.90 | 2.32 | 42.65 | 1.91 | 48.62 | 1.63 |
| 30 | 1.5 | 0.450 | 38.45 | 3.81 | 43.38 | 3.66 | 49.10 | 2.63 |
| 30 | 2.0 | 0.600 | 38.20 | 3.13 | 43.18 | 3.18 | 48.95 | 2.32 |

**Table-4.** 28 Days compressive strength of SFRASC (N/mm$^2$).

| Fiber aspect ratio | Fiber volume fraction | Reinforcing index (RI=AR*Vf) | **28 Days compressive strength of SFRASC** (N/mm$^2$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **M20** | | **M30** | | **M40** | |
| | | | **Stress** | **% Increase** | **Stress** | **% Increase** | **Stress** | **% Increase** |
| 0 | 0.0 | 0.000 | 38.92 | - | 43.76 | - | 49.65 | - |
| 30 | 0.5 | 0.150 | 39.40 | 1.23 | 44.25 | 1.12 | 50.15 | 1.01 |
| 30 | 1.0 | 0.300 | 39.80 | 2.26 | 44.72 | 2.19 | 50.69 | 2.09 |
| 30 | 1.5 | 0.450 | 40.25 | 3.42 | 45.20 | 3.29 | 51.15 | 3.02 |
| 30 | 2.0 | 0.600 | 39.80 | 2.26 | 44.75 | 2.26 | 50.50 | 1.71 |

The increase in strength of SFRASC over the companion mix of SFRNSC is shown in Table-5.

**Table-5.** Comparative compressive strength of SFRNSC and SFRASC.

| Fiber aspect ratio | Fiber volume fraction | Reinforcing index (RI=AR*Vf) | **28 Days compressive strength of SFRNSC and SFRASC** (N/mm$^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **M20 SFRC** | | | **M30 SFRC** | | | **M40 SFRC** | | |
| | | | **NS** | **AS** | **% increase** | **NS** | AS | **% increase** | **NS** | **AS** | **% increase** |
| 0 | 0.0 | 0.00 | 37.04 | 38.92 | 5.08 | 41.85 | 43.76 | 4.56 | 47.84 | 49.65 | 3.78 |
| 30 | 0.5 | 0.15 | 37.48 | 39.40 | 5.12 | 42.23 | 44.25 | 4.78 | 48.16 | 50.15 | 4.13 |
| 30 | 1.0 | 0.30 | 38.45 | 40.25 | 4.68 | 43.38 | 45.20 | 4.20 | 49.10 | 51.15 | 4.18 |
| 30 | 1.5 | 0.45 | 38.20 | 39.80 | 4.19 | 43.18 | 44.75 | 3.64 | 48.95 | 50.50 | 3.17 |
| 30 | 2.0 | 0.60 | 38.30 | 40.54 | 5.85 | 43.15 | 45.51 | 5.47 | 49.24 | 51.55 | 4.69 |

At the steel fiber volume fraction of 2.0%, the average increase in strength of SFRNSC was found to be 3.13%, 3.18% and 2.32% and in SFRASC 2.26%, 2.26% and 1.71% for M20, M30 and M40 concrete respectively. The maximum value of standard deviation in the test results was found to be 1.27. There is reduction in the increase of the strength from Vf 1.5 % to 2.0%. It indicates that steel fiber volume fraction of 1.5% is the optimum, hence flexural and split tensile strengths were performed up to Vf of 1.5% (as observed in Figure-1).

VOL. 5, NO. 10, OCTOBER 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

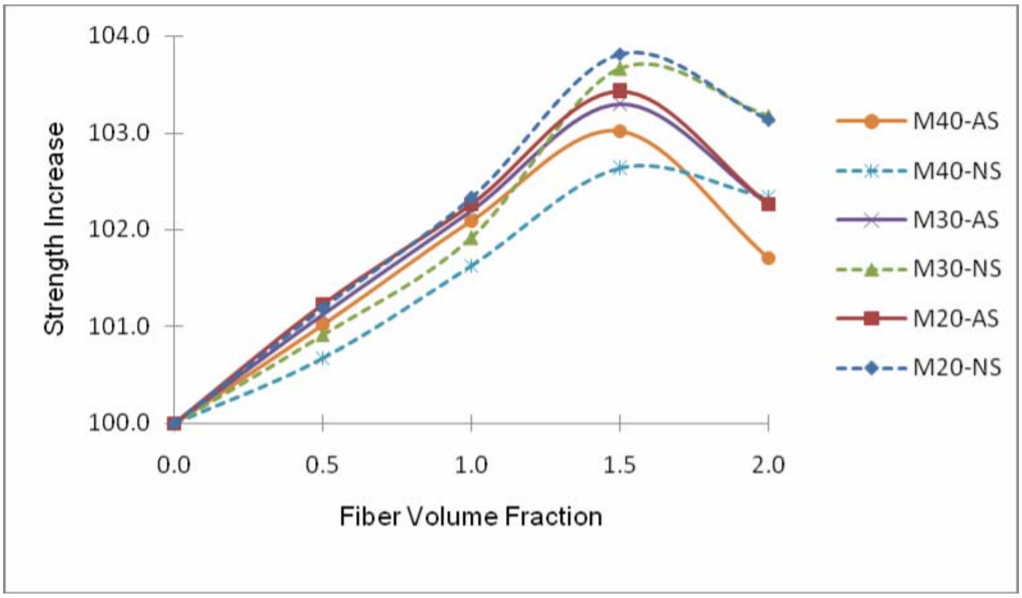


**Figure-1.** Increase in compressive strength with respect to fiber volume fraction.

The flexural strength of SFRASC also increased. At volume of steel fibers $V_f$ = 1.5%, the increase in strength was found to be 27.57%, 25.00% and 24.22% for M20, M30 and M40 SFRASC respectively. For SFRNSC, the increase in flexural strength was found to be 27.95%, 26.10% and 16.49% over the plain natural sand concrete. The increase in flexural strength of SFRASC over the companion mix of SFRNSC is shown in Table-6.

**Table-6.** Comparative flexural strength of SFRNSC and SFRASC.

| Fiber aspect ratio | Fiber volume fraction | Reinforcing index (RI=AR*Vf) | 28 Days flexural strength of SFRNSC and SFRASC (N/mm2) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M20 SFRC | | | M30 SFRC | | | M40 SFRC | | |
| | | | NS | AS | % increase | NS | AS | % increase | NS | AS | % increase |
| 0 | 0.0 | 0.00 | 4.83 | 5.55 | 14.91 | 5.25 | 6.00 | 14.29 | 5.70 | 6.40 | 12.28 |
| 30 | 0.5 | 0.15 | 5.28 | 6.12 | 15.91 | 5.70 | 6.50 | 14.04 | 6.11 | 6.90 | 12.93 |
| 30 | 1.0 | 0.30 | 5.74 | 6.60 | 14.98 | 6.21 | 7.00 | 12.72 | 6.64 | 7.45 | 12.20 |
| 30 | 1.5 | 0.45 | 6.18 | 7.08 | 14.56 | 6.62 | 7.50 | 13.29 | 7.12 | 7.95 | 11.66 |

The average increase in split tensile strength of SFRASC due to addition of steel fiber ($V_f$ = 1.5%) was found to be 21.84%, 20.43% and 21.21% for M20, M30 and M40 concrete respectively. For SFRNSC, the increase in split tensile strength was found to be 19.11%, 20.37% and 21.37% over the plain natural sand concrete. The increase in split tensile strength of SFRASC over the companion mix of SFRNSC is shown in Table-7.

**Table-7.** Comparative split tensile strength of SFRNSC and SFRASC.

| Fiber aspect ratio | Fiber volume fraction | Reinforcing index (RI=AR*Vf) | 28 Days split tensile strength of SFRNSC and SFRASC (N/mm2) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M20 SFRC | | | M30 SFRC | | | M40 SFRC | | |
| | | | NS | AS | % increase | NS | AS | % increase | NS | AS | % increase |
| 0 | 0.0 | 0.00 | 4.03 | 4.35 | 7.94 | 4.32 | 4.65 | 7.64 | 4.68 | 4.95 | 5.77 |
| 30 | 0.5 | 0.15 | 4.25 | 4.65 | 9.41 | 4.60 | 5.00 | 8.70 | 5.05 | 5.25 | 3.96 |
| 30 | 1.0 | 0.30 | 4.52 | 4.95 | 9.51 | 4.90 | 5.30 | 8.16 | 5.37 | 5.60 | 4.28 |
| 30 | 1.5 | 0.45 | 4.80 | 5.30 | 10.42 | 5.20 | 5.60 | 7.69 | 5.68 | 6.00 | 5.63 |

## 6. CONCLUSIONS

Based on the present study of SFRNSC and SFRASC, following conclusions are drawn:

- It is observed that there is consistent increase in the strength of plain concrete when natural sand is fully replaced by artificial sand. The sharp edges of the particles in artificial sand provide better bond with cement than the rounded particles of natural sand resulting in higher strength. The increase in compressive stress is marginal as compared to flexural and split tensile strength.
- Considering the workability and balling effect of the fibres, the optimum volume fraction of fibre is 1.5%. To get the design degree of workability, the use of super plasticizer was essential. The excessive bleeding of concrete is reduced by using artificial sand.
- The cost of artificial sand is in the range of 40% to 70% to that of natural sand and considering cost of screening, washing and wastage due to oversize particles of natural sand, the artificial sand concrete will be about 15% to 25% cheaper than that of natural sand concrete.
- The test results obtained from well planed and carefully performed experimental programme encourages the full replacement of natural sand by artificial sand considering the technical, environmental and commercial factors.

## REFERENCES

[1] Hudson B. P. 1997. Manufactured Sand for Concrete. The Indian Concrete Journal. 71(5): 237-240.

[2] Sahu A. K., Kumar Sunil and Sachin A. K. 2003. Crushed Stone Waste as Fine Aggregate for Concrete. The Indian Concrete Journal. 77(1): 845-847.

[3] Chitlange M. R., Dr. Pajgade P. S., Dr. Nagarnaik P. B. 2008. Artificial Sand as Fine Aggregate for Concrete. Civil Engineering and Construction Review. 21(12): 64-67.

[4] Kode V. R., Murty D. S. R., Swarna Kumar P. 2007. Appraisal of Crushed Stone Dust, as Fine Aggregate in Structural Concrete. Civil Engineering and Construction Review. 20(7): 52-58.

[5] Ahmed E. Ahmed and Ahemed A. El-Kourd. 1989. Properties of Concrete incorporating Natural and Crushed Stone very Fine Sand. ACI Material journal. 86(4): 417-424.

[6] Tahir Celik and Khaled Marar. 1996. Effects of Crushed Stone Dust on Some Properties of Concrete. Cement and concrete research. 26(7): 1121-1130.

[7] Pravin kumar, Kaushik S. K. 2005. SCC with Crusher Dust, Fly Ash and Micro Silica. The Indian Concrete Journal. 79(8): 32-37.

[8] ACI 544.1R-96, State of the Art Report on Fiber Reinforced Concrete.

[9] Banthia N. and Nanadkumar N. 2003. Crack Growth Resistance of Hybrid Reinforced Cement Composite. Journal of cement and concrete composites.

[10] Job Thomas and Ananth Ramaswamy. 2007. Mechanical Properties of Steel Fiber-Reinforced Concrete. Journal of Material in Civil Engineering, ASCE. 19(5): 385-392.

[11] Romauldi T.P. and Bastson C.B. 1963. Behaviour of Reinforced Cement Concrete Beam with Closely-Spaced Reinforcement. American Concrete Institute Journal. pp. 775-789.

[12] Tantary M. A., Upadhyay A. and Prasad J. 2007. Design Aid for Shear Strength of Steel Fibre Based Concrete. The Indian Concrete Journal. 81(1): 37-42.

[13] Prakash K. B., Ravi K., Nataraj K. C. 2006. Characteristic Properties of Hybrid Reinforced Concrete Produced with Fibres of Different Aspect Ratios. Civil Engineering and Construction Review. 19(12): 50-60.

[14] Natraja M. C., Dang N., Gupta A. P. 1998. Steel Fiber Reinforced Concrete under Compression. The Indian Concrete Journal. 72(7): 253-256.

[15] Chitlange M. R., Mrs. Bang R. S., Pajgade P. S. 2010. Appraisal of Artificial Sand Concrete. IE (I) Journal CV. Feb. 90: 10-12.

[16] Bureau of Indian Standards. 1991. Specification for Portland Pozzolana Cement Part I Fly Ash based, IS 1489 (P-1): New Delhi.

[17] Bureau of Indian Standards. 1970. Specification for coarse and fine aggregates from natural sources for concrete, IS 383: New Delhi.

[18] ASTM C494-1977. Standard specification for chemical admixtures for concrete.

[19] Bureau of Indian Standards. 1982. Recommended Guidelines for concrete mix Design, IS 10262: New Delhi.

[20] Bureau of Indian Standards. 2000. Code of Practice for Plain and Reinforced Concrete, IS 456: New Delhi.

[21] Bureau of Indian Standards. 1959. Method of test for strength of concrete IS 516: New Delhi.

[22] Bureau of Indian Standards. 1999. Method of test for splitting tensile strength of concrete, IS 5816: New Delhi.