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# Effect of Manufacture sand on Strength Characteristics of Roller Compacted Concrete

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ABSRACT

The American Concrete Institute (ACI) 116R defines RCC as "Concrete compacted by roller compaction; concrete that in its unhardened state will support a roller while being compacted". RCC as a pavement material has been gaining acceptance over the past years. Common river sand has become more expensive due to excessive cost and depletion of the natural resource. In such a situation the M-sand can be an alternative material to river sand. Hence in the present study a control mix was established for RCC aiming for flexural strength of 5N/mm$^2$. The proportioning of the materials was done based on soil compaction concepts specified in ACI211-3R-19.This paper also presents the effect of manufacture sand (0% to 100% replacement with natural sand) on strength properties of RCC. Test results indicate that the increase in flexural strength levels at increasing levels of fine aggregate replacement by M-sand. The study also revealed that addition of M-sand reduces the cement and fine aggregate contents in RCC mixtures.



## 1.0 Introduction

Roller compacted concrete is a zero-slump concrete consisting of dense-graded aggregate and sand, cementations' materials, and water. Because it contains a relatively small amount of water, it cannot be placed by the same methods used for conventional (slump) concrete. Roller compacted concrete has the same basic ingredient as conventional concrete: cement, water, and aggregates. The basic difference is that roller compacted concrete is a much drier mix with practically zero slumps. It is drier, and looks and feels like damp gravel. It does not require any forms, dowels, reinforcing steel & finishing. Also, the method of compaction is different than the conventional compacted concrete and it is compacted by vibratory or pneumatic-tired rollers. The objective of mix design is to produce a roller compacted concrete that has sufficient paste volume to coat the aggregates in the mix and to fill in the voids between them. Any of the basic roller compacted concrete proportioning methods like those based on concrete consistency testing, the solid suspension model, the optimal paste volume method, and soil compaction testing may be used for mix design. Roller-Compacted Concrete uses aggregate sizes often found in conventional concrete. However, the blending of aggregates will be different than that done in case of conventional concrete. Crushed aggregates are preferable in roller compacted concrete mixes due to the sharp interlocking edges of the particles, which help to reduce segregation, provide higher strengths, and better aggregate interlock at joints and cracks. The use of roller compacted concrete for pavements at industrial facilities such as port and intermodal container terminals is particularly appropriate because of the ability to construct low-cost concrete pavements over large areas. Roller compacted concrete is also used in bulk material storage, general cargo storage, container terminals, road / rail transfer facilities, truck parks, tank roads and parking, sewage sludge stacking, composting slabs and pre-casting yards. Keeping the above points in view an experimental program has been planned to study the strength characteristics of RCC. The work is also extended to study the feasibility of incorporating manufacture sand as fine aggregate content in the mix proportion.

**2.0 Literature review**



Bakoshi et al.,(1) used bottom ash in amounts of 10 to 40% as replacement for fine aggregate.Test results indicate that the compressive strength and tensile strength of bottom ash concrete generally increases with the increase in replacement ratio of fine aggregate and curing age. Berg&Neal(2) used municipal solid waste bottom ash(MSWBA) as a potential aggregate for concrete masonry units(CMU).The test results indicate that MSWBA could be used as an aggregate in concrete to produce CMU that meets ASTM C90 standards when it is proceeded for maximum size and gradation and ferrous removal by magnetic separation. Ghafoori et al.,(3) carried out investigations on a series of laboratory-made roller compacted concretes(RCC) containing high-calcium dry bottom ash as a fine aggregate. Concrete specimens of six different proportions were prepared at their optimum moisture content and fabricated in accordance with ASTM C 1170 procedure. Specimens were tested for compression, splitting tension, drying shrinkage e and resistance to abrasion and rapid freezing and thawing. Based on the test results they concluded that good strength, stiffness, drying shrinkage etc can be obtained with compacted concretes containing bottom ash.

## 3.0 Experimental program

Before fixing the mix proportions of control mix for roller compacted concrete, different trail mixes were conducted using soil compaction method specified in ACI 211.3R-02 to obtain the flexural strength of 5 N/mm$^2$. In soil compaction method, the proportioning of aggregates is fixed according to the recommended RCC pavement combined aggregate grading limits (Table.A3.2: ACI 211.3R-18). Then, for the fixed or adjusted aggregate proportion, a number of concrete mixtures varying in their cement contents (i.e 13, 14, 15, 16%) are prepared using the procedure as for compaction of soils, using a compaction hammer with intermediate proctor energy. Water content to the mixes is then obtained by using a plot between dry density vs moisture content (%).Beam specimens of size 500x100x100mm were cast to find the flexural strength of different RCC mixes prepared. The author aims to fix the mix proportion of RCC having a minimum flexural strength of 5.0N/mm$^2$.For that a plot is drawn between % cement content and flexural strength of different RCC mixes,. From this graph, a cement content of 14.5% is obtained against flexural strength of 5N/mm$^2$, Fig.1. Then the mix proportion of control mix is calculated using 14.5% of cement. The mix composition of controlled RCC is presented in Table.1



Table:1

| % of Cement | Cement | Fine aggregate | Coarse aggregate | W/C ratio |
|---|---|---|---|---|
| 14.5 | 1 (305Kg/m$^3$) | 2.75 | 4.13 | 0.413 |

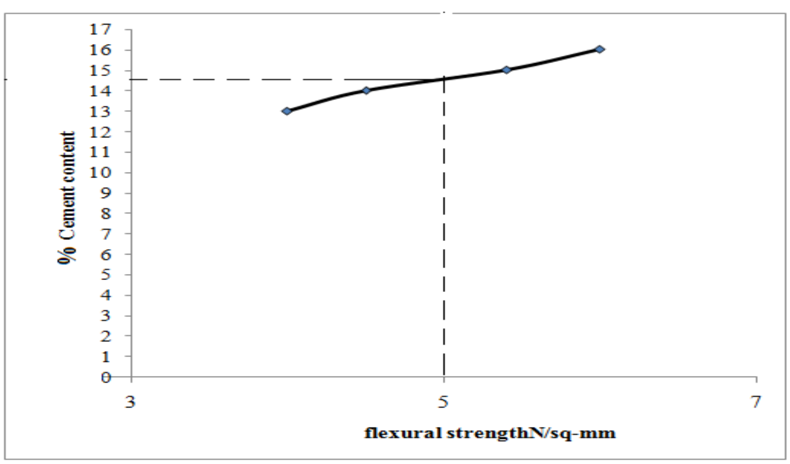


Fig.1.Plot between different % of cement contents (13, 14, 15 &16%) vs. flexural strengths

### 3.1Materials

**Cement**: Ordinary Portland (53 grade) cement was used. Specific gravity is 3.15

**Natural Sand**: Locally available river sand having bulk density 2680 kg/m$^3$ was used and the specific gravity is 2.68.

**Manufactured sand**: M- Sand was used as partial replacement of fine aggregate. It was collected from V.N.S ready mix plant, Vijayawada, India. The bulk density of manufactured sand was 2713 kg/m3, specific gravity was found to be 2.713.

The percentage of particles passing through various sieve were compared with natural sand and it was found to be similar. The results are presented in Table.2.

**Coarse Aggregate**: Crushed angular aggregate with maximum grain size of 20mm and downgraded was used and having bulk density 2870kg/m3. The specific gravity was found to be 2.87.

**Water:** Fresh potable water, which is free from acid and organic substance, was used for mixing the concrete.



**Table 2: Sieve analysis of River sand & M-Sand**

| Sieve size | River sand passing% | M-sand passing% |
|---|---|---|
| 4.75mm | 99.84 | 99.30 |
| 2.36mm | 99.25 | 82.70 |
| 1.18mm | 94.67 | 61.15 |
| 600µm | 69.13 | 45.90 |
| 300 µm | 5.40 | 19.85 |
| 150 µm | 0.73 | 11.40 |

### 3.2 Results and Discussions

The main objective of the present investigation was to develop mix proportion of RCC to obtain required flexural strength of 5.0N/mm$^2$.The work is also aimed to study the effect on strength characteristics of RCC by incorporating M-sand as an alternative material to the river sand. The 150mm concrete cubes were cast for compressive strength, 150x300mm cylinders for splitting tensile strength and 100x100x500mm beams for flexural strength. After casting, all the test specimens were finished with a steel trowel. Immediately after finishing, the specimens were covered with plastic sheets to minimize the moisture loss from them. All the test specimens were stored at temperature of about $24^0$C in the casting room. They were demoulded after 24hrs and were put into a water-curing tank.

**Table: 3 Mixture proportions**

| Mixture No | M1 | M2 | M3 | M4 | M5 |
|---|---|---|---|---|---|
| Cement Kg/$m^3$ | 305 | 305 | 305 | 305 | 305 |
| Sand Kg/$m^3$ | 839 | 630 | 420 | 210 | 0 |
| Coarse aggregate (20mm) kg/$m^3$ | 1260 | 1260 | 1260 | 1260 | 1260 |
| M-sand Kg/$m^3$ | 0 | 210 | 420 | 630 | 839 |
| w/c Ratio | 0.413 | 0.413 | 0.413 | 0.413 | 0.413 |
| Compaction Factor | 0.82 | 0.81 | 0.807 | 0.79 | 0.779 |
| Air content (%) | 2 | 2 | 2 | 2 | 2 |
| Fresh concrete density(Kg/$m^3$) | 2404 | 2405 | 2405 | 2405 | 2404 |



The 150mm concrete cubes were tested for compressive strength, 150x300mm cylinders for splitting tensile strength and 100x100x500mm beams for flexural strength. Tests were performed at 3,7 and 28days in accordance with the provisions of the Indian standard specifications IS:516-1959(4).compressive strength results are shown in Fig's 1 &2, Flexural strength results in Fig's 3.

### 3.2.1 Compressive strength

Compressive strength of concrete mixes made with and without M-sand was determined at 3, 7 and 28days of curing. The test results are given Table.6 and shown in Fig's 1&2, Fig.2 shows the variation of compressive strength with age for various % of M-sand. From the test results, it can be seen that the compressive strength of M-sand RCC mixes with 0,25,50,75 &100% fine aggregate replacement with M-sand were higher than the control mix (M-1) at all ages. It is evident from Table.4 and Fig.2 that compressive strength of all mixes continued to increase with the increase in age. However, maximum strength at all ages occurs with 50% fine aggregate replacement. Further increase in percentage of replacement, decreases the compressive strength. It is observed that there is consistent increase in the strength of concrete when partial replacement of natural sand by M-Sand. The sharp edges of the particles in M-Sand provide better bond with cement than rounded particles of natural sand resulting in higher strength up to optimum replacement. The optimum replacement of sand by M- Sand is 50%.The average increase in the compressive strength of roller compacted concrete with partial replacement of50% natural sand by M-Sand at the age of 3, 7& 28 days showed, 30%, 33.8% & 37.5% greater than controlled concrete respectively.

**Table: 4 Test Results**

| Designation Of Mix | % of sand | % of M-sand | Compressive strength N/mm$^2$ | | |
|---|---|---|---|---|---|
| | | | 3d | 7d | 28d |
| M1 | 100 | 0 | 21.6 | 24.44 | 35 |
| M2 | 75 | 25 | 24.89 | 26.22 | 37.5 |
| M3 | 50 | 50 | 28.11 | 32.7 | 48.14 |
| M4 | 25 | 75 | 24.89 | 30.22 | 43.17 |
| M5 | 0 | 100 | 18.67 | 22.22 | 33.74 |



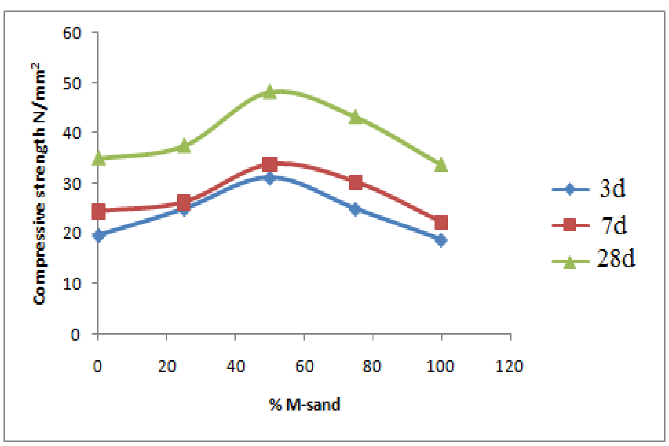


Fig.2. Compressive Strength of RCC at the age of 3, 7& 28 days with various proportions of M-Sand

### 3.2.2 Flexural strength of concrete

The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 3, 7 and 28 days. The beams were tested using Flexure Testing Machine (FTM) of capacity 100KN.

**Table: 5 Test Results**

| Designation of Mix | % of sand | % of M-sand | Flexural strength N/mm$^2$ | | |
|---|---|---|---|---|---|
| | | | 3d | 7d | 28d |
| M1 | 100 | 0 | 4 | 4.8 | 6.6 |
| M2 | 75 | 25 | 4.6 | 5.625 | 6.69 |
| M3 | 50 | 50 | 5.6 | 6.4 | 7.21 |
| M4 | 25 | 75 | 4.4 | 5.6 | 6.9 |
| M5 | 0 | 100 | 3.8 | 4.4 | 6.8 |

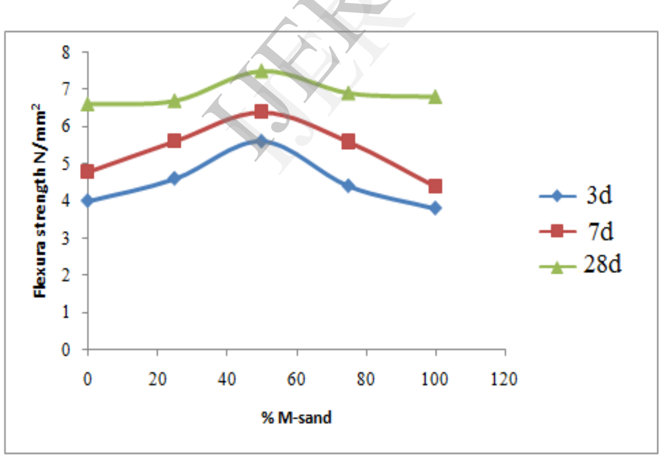




Fig.3.Flexural strength of roller compacted concrete at the age of 3, 7 &28days with various proportions of M-Sand

The flexural strength of the roller compacted concrete mixes increases with the increase in percentage of M-sand. The percentage, increase in strength was found to be 1.36%, 9.1%, 4.55% and 3.0% for partial replacement of natural sand by M-Sand with 25 %, 50%, 75% and 100% respectively for 28days strength. The test results flexure strength of RCC presented in Table.5 also shows that the partial replacement of 50% natural sand with M-sand is optimum.Fig.3

### 3.2.3 Splitting Tensile Strength

The splitting tensile strength of RCC mixtures made with and without M-sand was measured at the ages of 3, 7 and 28 days. The results are given in Table.6.From the Table.6; it is evident that the splitting tensile strength of all mixes continued to increase with the age and increase in % of M-sand. However maximum strength at all ages occurs at 50% fine aggregate replacement. The rate of increase in strength is more prominent after 28days.

**Table: 6 Test Results**

| Designation of Mix | % of sand | % of M-sand | Splitting tensile strength N/mm$^2$ | | |
|---|---|---|---|---|---|
| | | | 3d | 7d | 28d |
| M1 | 100 | 0 | 1.67 | 2. 4 | 2.47 |
| M2 | 75 | 25 | 1.7 | 2.65 | 3.18 |
| M3 | 50 | 50 | 2.26 | 2.83 | 3.53 |
| M4 | 25 | 75 | 1.95 | 1.98 | 2.47 |
| M5 | 0 | 100 | 1.56 | 1.78 | 2.02 |



### 4.0Conclusions

The following conclusions are drawn from this investigation

1. Compressive strength, splitting tensile strength and flexural strength of fine aggregate (sand)replaced M-sand RCC mixes were higher than the plain concrete(control mix) specimens at all the ages. The strength differential between the M-sand concrete specimens and plain concrete specimens became more distinct after 28 days.

2. From the experimental results it is observed that, M-Sand can be used as partial replacement for the natural sand, and the compressive and flexure strengths are increased as the percentage of M-Sand is increased up to optimum level. The optimum percentage of replacement of natural sand by M-sand is 50%.

3. The percentage of increase in the compressive strength is 37.5% and the flexure strength is 9.1% at the age of 28 days by replacing 50% of natural sand with M-Sand.

4. The dwindling sources of natural sand and its high cost could encourage the adoption of M-sand by 50% replacement of natural sand.

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