

CHAPTER 9

CONCLUSIONS

9.1 GENERAL

The report on this thesis includes the following studies:

- (a) Characterization of manufactured sand
- (b) Effect of manufactured sand on fresh and hardened properties of concrete
- (c) Effect of manufactured sand on durability properties of concrete
- (d) Effect of manufactured sand on micro structural properties of concrete
- (e) Effect of manufactured sand on structural behaviour of concrete

9.2 CHARACTERIZATION OF MANUFACTURED SAND

The primary objective is to evaluate the effect of physical and chemical characteristics of various proportions of manufactured sand in concrete. The following conclusions are made from the above experimental investigations:

- The presence of alumina content in the manufactured sand sets rapidly, when it reacts with the cement. Thus it reduces the workability of the concrete.

- Blending of manufactured sand with natural sand reduces the amount of microfines, which improves the workability, strength, durability and structural properties of the concrete.

9.3 EFFECT OF MANUFACTURED SAND ON FRESH AND HARDENED PROPERTIES OF CONCRETE

The fresh and hardened properties of concrete with manufactured sand varying from 0 to 100% as ten increments have been studied and the following conclusions are drawn.

- The slump value is decreased by about 60% for 100% replacement of manufactured sand, while in the case of blending of manufactured sand with natural sand, the slump value is decreased by about 23 to 38% when compared to the natural sand.
- The strength achievements are increased up to the replacement level of 70% manufactured sand. Beyond that proportion, there is no improvement in the strength achievement due to the large amount of fine particles in it.
- The strength achievements are higher at early period, for higher grade concrete due to the high cement content and less water content.
- The compressive strength, splitting tensile strength and flexural strength of the concrete with 70% of manufactured sand are increased by about 20%, 15% and 20% respectively when compared to the natural sand.

- When compared to the 28 days strength, the strength is increased by about 12 to 20% for 1 year.
- The modulus of elasticity of the concrete with 70% manufactured sand is 8% higher than the concrete with natural sand.
- The Poisson's ratio is increased by about 7% while using the 70% manufactured sand.
- The relationships between the compressive strength with splitting tensile strength, flexural strength and modulus of elasticity are higher than the standards of IS specifications.

So, it was confirmed that, even though the strength properties are increased for 100% manufactured sand, blending of 70% manufactured sand with 30% natural sand gives better results.

9.4 EFFECT OF MANUFACTURED SAND ON DURABILITY PROPERTIES OF CONCRETE

The durability properties of the concrete were studied for 100% manufactured sand and the optimum replacement of 70% manufactured sand and then those properties were compared with 100% natural sand. From the experimental investigations the following conclusions are arrived.

- The percentage expansion due to alkali aggregate reaction is reduced by 4% and 17% for 100% manufactured sand and 70% manufactured sand respectively.

- The drying shrinkage strain is 3% and 10% less for 100% and 70% manufactured sand respectively, when compared to the natural sand.
- The abrasion resistance is increased by about 5% and 15% for 100% manufactured sand and 70% manufactured sand respectively.
- The impact resistance energy is increased by about 5%, 10% and 15% at 7 days, 28 days and 56 days respectively for 100% manufactured sand and it is increased by about 8%, 15% and 20% at 7, 28 and 56 days respectively for 70% manufactured sand.
- The chloride ion penetrability is less due to less absorption capacity.
- The corrosion effect is also reduced while using the manufactured sand and also the corrosion is minimum for higher grade concrete due to less water absorption.
- The concrete with manufactured sand has a high resistance to acid attack.
- Water permeability, water absorption and sorptivity are reduced by about 20% for 70% replacement level of manufactured sand, but the reduction of these durability properties are not significant for 100% replacement level of manufactured sand.

So it was confirmed that the concrete specimens with 70% manufactured sand is more impermeable than normal conventional concrete and it shows better durability properties.

9.5 EFFECT OF MANUFACTURED SAND ON THE MICRO STRUCTURAL PROPERTIES OF CONCRETE

The micro structural properties of concrete with natural sand and manufactured sand were investigated by conducting the SEM coupled with Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) analysis. The following conclusions were made from the above analysis.

- SEM images confirmed that the natural sand particles are round or spherical in shape and the manufactured sand particles are elongated and angular in shape.
- EDS detects the presence of minerals like silica, calcium, alumina and oxides both in natural sand and manufactured sand.
- XRD analysis confirmed that the major component present in it is silica content, which is in crystalline form.

9.6 EFFECT OF MANUFACTURED SAND ON STRUCTURAL BEHAVIOUR OF CONCRETE

The structural behaviours like load carrying capacity, ductility, energy absorption capacity, toughness index and stiffness of reinforced concrete beams with natural sand and manufactured sand are experimentally investigated and compared with the analytical model using finite element analysis software (ANSYS). The following are the conclusions arrived at from the above studies.

- The initial crack is delayed for R.C beams with 70% manufactured sand when compared to the natural sand.

- The load carrying capacity is 15 to 20% higher for 70% manufactured sand when compared to the natural sand.
- The ductility is improved by about 8% and 19% for 100% manufactured sand and 70% manufactured sand respectively when compared to the natural sand.
- Energy absorption capacity is increased by about 6% and 34% for 100% and 70% manufactured sand respectively.
- The toughness indices are marginally increased for 100% manufactured sand and 15% increased for 70% manufactured sand when compared to the natural sand.
- When compared to concrete with natural sand, the stiffness degradation is increased for manufactured sand due to its flakiness.
- The developed analytical model performs same as that of experimental performance. Hence it can be used for further investigations without destruction of beams to study the structural behaviour of any grade of R.C beams.

Based on the test results, the concrete with manufactured sand behaves like conventional concrete. The replacement level of 70% manufactured sand improves the structural behaviour of concrete. The improvements thus achieved in strength, stiffness, energy absorption capacity and ductility indicate that the manufactured sand appears to be an appropriate material for the construction of buildings and other structures.

9.7 GENERAL CONCLUSIONS

From the above conclusions, it was generally concluded that the manufactured sand can be utilized as fine aggregate in concrete, which

reduces the environmental impact, scarcity of natural sand and cost of construction. Even though the manufactured sand is already used in the market, there is a need to develop a new code for testing the manufactured sand. Based on these experimental investigations, a new code can be developed for studying the effects of manufactured sand in concrete.

The results of this thesis work will be helpful to:

- Construction industry to focus on manufactured sand in order to produce comparable, even better quality of concrete.
- Environmental organizations seeking to understand interactions of minerals with the environment.
- Private, government organizations and construction firms that use the data for construction purposes in order to minimize the use of scarce resources of natural river sand.
- Educational institutions, which use the information for academic and research purposes.

9.8 SUGGESTIONS FOR FUTURE WORK

The future research can be on the following fields and researches can make efforts:

- To create a codal provision for exclusively for the properties of manufactured sand utilization in concrete.
- To utilize the manufactured sand in HSC and HPC.
- To explore the possibilities of the manufactured sand on self compacting concrete.