CHAPTER 7

CONCLUSIONS

7.1 GENERAL

The present investigation was to find the effectiveness of industrial waste materials such as Granite powder and Bottom ash as partial replacement for M-sand in concrete. Experimental study was carried out to find the parameter such as strength, durability, micro structure behaviour and structural behaviour of RC beam. The test results and discussions were made in the previous chapters.

Based on the results of the experimental investigations, the following conclusions were arrived and described in various headings as below.

a. Effect of Granite powder on fresh property, hardened properties and durability properties of concrete.

b. Effect of Bottom ash on fresh property, hardened properties and durability properties of concrete.

c. Effect of combined mix of Granite powder and Bottom ash on fresh property, hardened properties and durability properties of concrete.

d. Effect of combined mix of Granite powder and Bottom ash on microstructural properties of concrete.

e. Effect of ideal mix of Granite powder and Bottom ash on structural behaviour of concrete.
7.1.1 Effect of Granite Powder on Fresh Property, Hardened Properties and Durability Properties of Concrete

- The slump value of concrete mixture was decreased when M sand was replaced with Granite powder compared to control concrete mix. The slump was maintained as constant value of 80 mm by increasing the dosage of superplastizers to get the medium workability for pumped concrete.

- The compressive strength, Split tensile strength, Flexural strength and Modulus of elasticity of concrete for the replacement of 10% Granite powder (GP10) was more than the control mix (GP 0) at all the ages. The strength for the remaining mix proportions was reduced slightly compared to control mix due to the presence of fine particles.

- The saturated water absorption of the mixes from GP10 to GP50 was around 1.2 percent. The saturated water absorption of concrete mixes with M-sand replacement by GP was slightly higher compared to that of concrete mix without replacement material due to the voids effect of GP.

- The porosity for the mixes GP10 to GP50 was around 1.9 percent. The value of porosity of concrete mixes with M-sand replacement by GP was increased compared to that of concrete mix without GP.

- The chloride ion penetration was also low for the mix GP10 and GP20. For the mixes GP30 to GP50, the ion penetration was moderate. Therefore, all the concrete mixes with GP replacement was durable against chloride attack.
In Acid and Chloride resistance test, the percentage loss in weight and compressive strength for the mix GP10 was reduced when compared to the control mix GP0. For increase in replacement percentage of GP, the percentage loss in weight and compressive strength was increased marginally.

Hence based on the above conclusions, the replacement of granite powder in M-sand up to 10% was appropriate to produce HSC / HPC.

7.1.2 Effect of Bottom Ash on Fresh Property, Hardened Properties and Durability Properties of Concrete

- The slump value of concrete mixture was decreased when M sand was replaced with bottom ash due to the presence of more voids. The slump was maintained as constant value of 80 mm to get the medium workability for pumped concrete by increasing the percentage dosage of superplasticizers.

- The bottom ash concrete reaches strength at a very slower rate in initial period and attains strength at faster rate beyond 28 days. The compressive strength of bottom ash concrete mix BA 10 at 90 days of curing age exceeded by 17.46% of their 28 days compressive strength as compared to an improvement of 10.91% over 28 days compressive strength by the control concrete mix (BA0). For the other mixes also the percentage increment in strength of concrete at 90 days curing compared to 28 days curing was than the control concrete.

- The split tensile strength of BA10 concrete was decreased by 10% when compared to control mix due to the presence of
hollow particles. For the other concrete mixes, the decrease in percentage was slightly more.

- The flexural strength of BA 10 concrete was nearly same as that of BA 0 concrete.

- The modulus of elasticity of BA concrete was reduced marginally when the percentage replacement increased.

Hence based on the above results, the replacement of bottom ash in M-sand up to 10% was suitable to produce HSC / HPC concrete.

7.1.3 Effect of Combined Mix of Granite Powder and Bottom Ash on Fresh Property, Hardened Properties and Durability Properties of Concrete

- The initial slump value of concrete mixture was decreased when M sand was replaced with 20 %, 30% and 40% combined replacement of granite powder and bottom ash, due to the presence of more voids. The slump was maintained as constant value of 80 mm to get the medium workability for pumped concrete by varying the percentage dosage of superplasticizers.

- The partial 20% replacement of M-sand by Granite powder and Bottom ash (GP10+BA10) satisfies the compressive strength and split tensile strength at 28 days while compared with control mix.

- The partial 20% and 40% replacement of fine aggregate by GP and BA meets the target mean strength of M60 concrete at 56 days curing.
The value of Flexural strength and Modulus of elasticity at 28 days of mix GP10+BA10 was very close to control concrete. For the other mixes, the strength variation was in range of 0.5% - 3% and 4.5% - 8.7% respectively, due to increases in the pore size and delay in formation of hydrated products. The mechanical properties were satisfied at the age of 56 days.

Water absorption and porosity of concrete mixes with M-sand replacement by Granite powder and Bottom ash were almost equal to the control mix. The water absorption and porosity of 20% replacement (GP10 +BA10) was low compared other replacement mixes due to less voids.

The chloride ion penetration for the mixes GP10+BA10 and GP20+BA10 were low. For the other mixes with 30% and 40% replacement of M-sand, the ion penetration was moderate.

The loss in weight and compressive strength of concrete mixes with M-sand replacement by GP and BA were increased for all the replacement when compared to control mix due to slight increase in pores in concrete. The loss in weight and compressive strength of concrete mix GP10+BA10 was less compared to all other mixes.

Hence from the above conclusions, the concrete mix GP10 +BA10 (20% replacement) was more appropriate to produce HSC / HPC mix from the strength and durability point of view.
7.1.4  Effect of Granite Powder and Bottom Ash on Microstructural Properties of Concrete

7.1.4.1  Dry Granite powder and bottom ash

The SEM image of Granite powder confirmed that the maximum percentages of particles are angular in shape.

The SEM image confirmed that the Bottom ash particles are with more percentage of spherical shape and also the presence of number of hollow layer in one spherical particle.

The presence of important minerals like silica, alumina, and oxides were detected in Granite powder and Bottom ash using EDS.

XRD analysis results of Granite powder and Bottom ash confirmed that the important and major component present in it is silica in crystalline form.

7.1.4.2  Control concrete (GP0+BA0)

The SEM image of Control concrete GP0+BA0 reveals very minimum voids and also the structure signifies rough nature.

The important elements such as oxygen (63.7%), Calcium (13.77%), Silicon (2.02%) and Aluminium (1.19%) present in control concrete were detected using EDS.
7.1.4.3 Concrete with waste (GP10+BA10)

The SEM image of concrete with waste GP10+BA10 exposes more percentage of voids compared to control concrete and also the structure implies smooth nature.

The important elements such as oxygen (64.2%), Calcium (10.03%), Silicon (6.44%) and Aluminium (2.34%) present in concrete with waste were detected using EDS.

Based on the above results, it was concluded that the partial replacement of M-sand by waste such as Granite powder and Bottom ash influences the change of microstructural properties in control concrete. Even though, the presences of voids were increased marginally in concrete mix GP10+BA10, there was an increase in the percentage of minerals like Oxygen, Silicon and Aluminium of 0.5%, 4.24% and 1.15% respectively, compared to control mix (GP0+BA0). The percentage increase of minerals in the concrete mix (GP10+BA10) will produce excess amount of C-S-H gel compared to control mix concrete, which have a tendency to improve the strength properties of concrete.

7.1.5 Effect of Ideal Mix of Granite Powder and Bottom Ash (GP10+BA10) on Structural Behaviour of Concrete

7.1.5.1 Monotonic loading

- The ultimate load carrying capacity of RCW beam (GP10+BA10) was 10% less that of control RC beam.

- The stiffness, ductility factor and energy absorption of RCW beam (GP10+BA10) was 4%, 6.8% and 8.2% less than that of control RC beam.

Based on the above test results it was concluded that the behaviour all the parameters of both the beams were similar and there was slight
decrease in strength parameters due to increase in fine pore particle. Since the deviation of results of RCW beam for all the parameters was less than 10% when compared to RC beam, the usage of the industrial waste materials in concrete as partial replacement for M-sand was increased and also safe disposal of waste materials.

7.1.5.2 Cyclic loading

- The ultimate load carrying capacity of RCW beam was slightly (10%) less than that of RC beam.
- The cumulative ductility factor value and cumulative energy absorption of RCW beam was 0.9 times that of RC beam.
- The stiffness of RCW beam was slightly lower than that of RC beam (1% - 7%) in different load cycles.

In general the use of industrial waste materials in concrete causes marginal decrease in strength parameters. Hence from the environmental point of view it was safe to use the waste materials as partial replacement in concrete for its proper disposal and also for effective use of important minerals in waste materials.

7.2 SUGGESTION FOR FUTURE WORK

- The waste materials can be used in the manufacturing of building and pavement blocks
- The strength, durability and structural behaviour of mix with waste can be enhanced by using fibers in mix.
- To exhibit the possibilities of waste materials in self-cure concrete and self-compacting concrete.
REFERENCES


8. ASTM C 1202, Rapid Chloride Permeability Test.


Journal of Civil Engineering (Building and Housing) vol. 10, no. 3, pp. 335-346.


27. IS 10262 2009, Concrete Mix Proportioning - Guidelines, Bureau of Indian Standards, New Delhi.


33. IS 516 1959 (Reaffirmed 1999) Methods of Test for Strength of Concrete, Bureau of Indian Standards, New Delhi.

34. IS 5816 1970, Splitting Tensile Strength of Concrete, Bureau of Indian Standards, New Delhi.


46. Malkit Singh & Rafat Siddique 2014, ‘Strength properties and micro-structural properties of concrete containing coal bottom ash as partial


