CHAPTER 6

CONCLUSIONS

6.1 GENERAL

This research investigation was aimed at studying the possibility of using ceramic industrial waste as coarse aggregate and bottom ash as 50 percent replacement for river sand in concrete making. Tests were carried out to find out the mechanical and durability properties of concrete prepared using ceramic waste coarse aggregate and bottom ash-sand mix fine aggregate. Flexural behaviour of the RCC beam was also carried out to ascertain the compatibility of the material with steel for structural applications.

Following conclusions were drawn based on the experimental investigations.

6.2 CONCLUSIONS

i. Ceramic waste and bottom ash could be transformed into useful coarse aggregate and fine aggregate respectively for concrete making through proper processing.

ii. The specific gravity of bottom ash fine aggregate is 5.6 percent less than that of river sand.

iii. The bulk density of bottom ash fine aggregate is 12.40 percent less than that of river sand.

iv. Water absorption of bottom ash fine aggregate is 16.60 percent higher than that of river sand.

v. The specific gravity of ceramic waste coarse aggregate and that of crushed stone coarse aggregate is more or less same.

vi. The water absorption of ceramic waste coarse aggregate is 43.61 percent less than that of crushed stone coarse aggregate.

vii. The mechanical properties of ceramic waste coarse aggregate are well within the range of the values of concrete making aggregate.
viii. In sulphate soundness test after 30 cycles, the loss of weight of ceramic waste coarse aggregate is 32.70 percent less than that of crushed stone coarse aggregate.

ix. The slump values of CWBA aggregate concrete are lower than those of crushed stone coarse aggregate concrete at the respective water-cement ratio.

x. As far as the strengths are concerned, the basic trend in behaviour of CWBA aggregate concrete is not significantly different from those of crushed stone coarse aggregate concrete.

xi. There is no much difference in the rate of development of compressive strength of CWBA aggregate concrete when compared to crushed stone coarse aggregate concrete at 28 and 56 d.

xii. The basic trend in the relationship between compressive strength and w/c ratio of CWBA aggregate concrete is similar to that of crushed stone coarse aggregate concrete at 28 and 56 d.

xiii. As in the case of crushed stone coarse aggregate concrete, the strength of CWBA aggregate concrete increases with increase in cement-aggregate ratio.

xiv. As in the case of crushed stone coarse aggregate concrete, the compressive strength, split tensile strength, modulus of rupture and modulus of elasticity of CWBA aggregate concrete increases with decrease in w/c ratio.

xv. Compressive strength of CWBA aggregate concrete is 8 percent to 29 percent and 8 percent to 34 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.

xvi. Split tensile strength of CWBA aggregate concrete is 5 percent to 21 percent and 5 percent to 13 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.

xvii. CWBA aggregate concrete has lower tensile to compressive strength ratio when compared to crushed stone coarse aggregate concrete.
xviii. Modulus rupture of CWBA aggregate concrete is 5 percent to 13 percent and 6 percent to 17 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.

xix. The trend in the stress strain behaviour at compression is similar for both CWBA aggregate concrete and crushed stone coarse aggregate concrete with higher modulus of elasticity in CWBA aggregate concrete.

xx. Modulus of elasticity of CWBA aggregate concrete is 9 percent to 18 percent and 16 percent to 25 percent higher than those of crushed stone coarse aggregate concrete at 28 and 56 d respectively.

xxi. The strain at ultimate stress for CWBA aggregate concrete is higher than that of crushed stone coarse aggregate concrete. The area under the stress strain curve is more in CWBA aggregate concrete than crushed stone coarse aggregate concrete for the respective w/c ratio. This shows that the CWBA aggregate is more ductile than crushed stone coarse aggregate concrete.

xxii. The permeation characters viz. water absorption, volume of voids, sorptivity, and chloride diffusion charges of CWBA aggregate concrete and crushed stone coarse aggregate concrete reduce with reduction in w/c ratio.

xxiii. The percentages of water absorption, percentage of volume of voids, coefficient of sorptivity, and rapid chloride penetration charge are lower for CWBA aggregate concrete than those of crushed stone coarse aggregate concrete.

xxiv. CWBA aggregate concrete can be used in reinforced flexural members. The behaviour of reinforced CWBA aggregate concrete beam under gradually increased loading is following the most common load deflection trend associated with that of concrete containing crushed stone coarse aggregate.
6.3 SUGGESTION FOR FURTHER STUDY

From the experience of the experimental study, the following suggestions are made

i. Studies on the micro structure of CWBA aggregate concrete may be carried out to ascertain the effect of surface texture of ceramic waste coarse aggregate on mechanical properties of concrete.

ii. Effect of ingredients like bottom ash and silica fume may be studied in detail to enable easy prediction of tailor made mix ratios to meet certain performance goals.

iii. Study on the properties of CWBA mixed with different types of steel, glass and carbon fibres may be carried out to measure the enhancement of mechanical properties due to addition of fibers.

iv. Study on the effect of total replacement of sand by bottom ash as fine aggregate may be studied on the mechanical and durability properties of CWBA.

v. Long term studies may be carried out on the effect of temperature, creep and shrinkage on reinforced CWBA aggregate concrete.
APPENDIX A

CALCULATION OF ULTIMATE MOMENT FOR REINFORCED CERAMIC WASTE BOTTOM ASH AGGREGATE CONCRETE BEAM (RCWBA_{50})

The section of the beam and the stress block (parabolic) is presented in Fig.A.1.1

The properties of the beam are as follows:

- Compressive strength of concrete : 53.00MPa
- Yield strength of steel rod : 415MPa
- Mix ratio : 1:1.05:2.24
  (1 cement: 1.05 F.A.:2.24C.A.)
- Water cement ratio : 0.35
- Area of parabolic compression stress block : \( \frac{3}{4} \) of the area of enclosing rectangle
- No. of steel rods in tension zone : 2 bars, 12mm dia. RTS

The stress block in the compression zone is assumed to be parabolic, based on 38.1(c) of IS 456:2000. Steel is assumed to have reached yield point. The stress in steel is the
actual yield stress ($f_y$) instead of the reduced value ($0.87f_y$) adopted for design purposes. The depth of neutral axis, $x_u$ may be calculated using the relation,

$$f_y A_{st} = \frac{3}{4} f_{ck} b X_u$$

(A.1)

$$\frac{415 \times 2 \times \pi \times \frac{12^2}{4}}{3 \times 53.00 \times 150} = \frac{3}{4} \times 53.00 \times 150 \times x_u$$

(A.2)

$$X_u = \frac{4 \times 415 \times 2 \times \pi \times \frac{12^2}{4}}{3 \times 53.00 \times 150}$$

(A.3)

$$X_u = 15.73\text{mm}$$

(A.4)

The maximum depth of critical neutral axis may be found using the following relation:

$$X_{u,\text{MAX}} = 0.49 \times d$$

(A.5)

$$= 0.49 \times 225$$

$$= 108\text{mm}$$

Since $X_u \leq X_{u,\text{MAX}}$, the moment of resistance of the beam section may be found out using the provisions of IS 456:2000.

The lever arm ($X_i$) may be calculated using the relation,

$$X_i = (d - 0.416 X_u)$$

(A.6)

$$X_i = (225 - 0.416 \times 15.47)$$

(A.7)

$$X_i = 218.46\text{mm}$$

(A.8)

The ultimate moment may be found out using the relation,
\[ M_u = f_y A_{se} K_1 \]  
\[ M_u = 415 \times 2 \times \pi \times \frac{12^2}{4} \times 210.46 \]  
\[ M_u = 20496338.24 \text{ Nmm} \]  
\[ = 20.50 \text{ kNm} \]

Equation A.9 does not include the partial safety factor of 0.87 for reducing the yield strength of steel, since the beam under study is subjected to breaking.