CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

A systematic experimental study has been conducted to understand the behaviour of geopolymer concrete subjected to elevated temperatures.

The influence of parameters like aggregate content, fine aggregate to total aggregate ratio, ratio of alkali to fly ash, ratio of sodium silicate to sodium hydroxide, molarity of sodium hydroxide, curing temperature and curing time on mechanical properties of geopolymer concrete has been investigated.

A basic study on the interface shear strength of geopolymer concrete has been carried out.

The mechanical properties of specimens have been studied after they were subjected to elevated temperatures (200 °C, 400 °C, 600 °C, 800 °C) and cooled under air cooling and water cooling methods. Residual mechanical properties like compressive strength, tensile strength split tensile strength, flexural strength and modulus of elasticity of geopolymer concrete have been discussed.

Flexural behaviour like deflection, ductility, moment-curvature and cracking behaviour of geopolymer concrete beams after exposure to elevated temperatures have been studied.

7.2 CONCLUSIONS

The following important conclusions could be derived based on the present investigation carried out.

1. Based on the present study, it is observed that a geopolymer concrete with total aggregate content of 70% by volume, ratio of fine aggregate to total aggregate of 0.35, NaOH molarity 10, \( \frac{\text{Na}_2\text{SiO}_3}{\text{NaOH}} \) ratio of 2.5 and alkali to fly ash ratio of 0.55 gives maximum compressive strength.
2. The curing temperature of 100 °C yields maximum compressive strength for the geopolymer concrete.

3. An early strength development in geopolymer concrete could be achieved by the proper selection of curing temperature and the period of curing. With 24 hours of curing at 100 °C, 96.4% of the 28th day cube compressive strength could be achieved in 7 days in the present study.

4. The interface shear strength of both unreinforced and reinforced geopolymer specimens is influenced by the aggregate content. The interface shear strength reduces rapidly when the total aggregate content becomes less than 65%, whereas the enhancement in interface shear strength is not significant for aggregate content above 65%.

5. The interface shear strength of geopolymer concrete is lower to that of OPC concrete. Compared to OPC concrete, a reduction in the interface shear strength by 33% and 29% was observed for unreinforced and reinforced geopolymer specimens respectively.

6. The interface shear strength of geopolymer concrete can be approximately estimated as 50% of the value obtained based on the available equations for the calculation of interface shear strength of ordinary portland cement concrete (method used in ACI).

7. Fly ash based geopolymer concrete undergoes a high rate of strength loss (compressive strength, tensile strength and modulus of elasticity) during its early heating period (up to 200 °C) compared to OPC concrete.

8. At a temperature exposure beyond 600 °C, the unreacted crystalline materials in geopolymer concrete get transformed into amorphous state and undergo polymerization. As a result, there is no further strength loss (compressive strength, tensile strength and modulus of elasticity) in geopolymer concrete, whereas, OPC concrete continues to lose its strength properties at a faster rate beyond a temperature exposure of 600 °C.

9. Effect of thermal shock due to water cooling on geopolymer and OPC concrete after exposure to elevated temperatures is more or less similar. In the present
study, both geopolymer and OPC concrete had a maximum strength loss of 10% due to water cooling.

10. New equations have been proposed to predict the residual strengths (cube compressive strength, split tensile strength and modulus of elasticity) of geopolymer concrete after exposure to elevated temperatures (upto 800 °C). These equations could be used for material modelling until better refined equations are available.

11. Compared to OPC concrete, geopolymer concrete shows better resistance against surface cracking when exposed to elevated temperatures. In the present study, while OPC concrete started developing cracks at 400 °C, geopolymer concrete did not show any visible cracks up to 600 °C and developed only minor cracks at an exposure temperature of 800 °C.

12. Geopolymer concrete beams develop crack at an early load stages if they are exposed to elevated temperatures.

13. Even though the material strength of the geopolymer concrete does not decrease beyond 600 °C, the flexural strength of corresponding beam reduces rapidly after 600 °C temperature exposure, primarily due to the rapid loss of the strength of steel.

14. With increase in temperature, the curvature at yield point of geopolymer concrete beam increases and thereby the ductility reduces. In the present study compared to the ductility at ambient temperature, the ductility of geopolymer concrete beams reduces by 63.8% at 800 °C temperature exposure.

15. Appropriate equations have been proposed to predict the service load crack width of geopolymer concrete beam exposed to elevated temperatures. These equations could be used to limit the service load on geopolymer concrete beams exposed to elevated temperatures (up to 800 °C) for a predefined crack width (between 0.1mm and 0.3 mm) or vice versa.

16. The moment-curvature relationship of geopolymer concrete beams at ambient temperature is similar to that of RCC beams and this could be predicted using strain compatibility approach.
17. Once exposed to an elevated temperature, the strain compatibility approach underestimates the curvature of geopolymer concrete beams between the first cracking and yielding point.

7.3 SCOPE FOR FUTURE STUDIES

1. Fly ash from different sources in India has different chemical and physical properties and this affects the strength and other properties of geopolymer concrete. A study on the influence of source of fly ash on properties of geopolymer concrete will help in arriving at a better mixture design procedure of geopolymer concrete.

2. Further study on geopolymer concrete beams after exposure to elevated temperature can refine the proposed prediction equations based on the present study.

3. The shear behaviour of geopolymer concrete beam after exposure to elevated temperatures can be studied.

4. Study on interface shear strength of geopolymer concrete with different quantities of reinforcement and after exposure to elevated temperature can be conducted for developing better equations to predict the interface shear strength of geopolymer concrete after exposure to elevated temperatures.

5. Study on thermal properties of geopolymer paste, mortar and concrete are other areas to be explored.

6. Fire test on geopolymer concrete beams and other structural elements can be conducted for better understanding of fire endurance of geopolymer concrete structural members.