CHAPTER 6

CONCLUSION

6.1 General

In this research the properties of low-calcium fly ash-based geopolymer concrete such as physical, mechanical and chemical property of geopolymer concrete block were studied. The performance of the geopolymer hollow block with respect to the mechanical properties and the behavior of geopolymer brick masonry prism of varying height were also studied.

6.2 Summary

Fly ash-based geopolymer concrete in this study has utilised the low-calcium (ASTM Class F) dry fly ash as the source material. The alkaline liquid comprised a combination of sodium silicate solution and sodium hydroxide solids in pellets form dissolved in water. Coarse and fine aggregates used in the local concrete industry were used. The coarse aggregates were crushed granite-type aggregates comprising 20 mm, 14 mm and 7 mm and the fine aggregate was fine sand. The mixture proportions used in this study were developed based on previous study on fly ash-based geopolymer concrete (Hardjito and Rangan, 2005). Molarity of sodium hydroxide (NaOH) solution was chosen in the range of 8M to 14M. Ratio of activator solution-to-fly ash by mass was fixed to be 0.40. Curing at elevated temperatures was done in two different ways, i.e. curing at room temperature and in the laboratory oven at 60°C. Ratio of sodium silicate solution-to-sodium hydroxide solution by mass is 2.5.

Test specimens were made in the laboratory using the equipments normally used for Portland cement concrete such as steel moulds and vibrating
table. The fly ash and the aggregates were first mixed together in a mixing pan for about 5 minutes manually. After the dry mix is made the prepared alkaline solution is thoroughly mixed with the dry mix for another 5 minutes to make fresh geopolymer concrete. Fresh concrete was placed in the mould. The specimens were compacted with three-layer placing and tamping using a rod. This was followed by an additional vibration of 10 seconds using a vibrating table. Specimens such as cubes, cylinders and beams were cast and tested. After casting the concrete mix was allowed to settle down in the moulds for 30 minutes. Different batches were adopted for 7 days, 14 days and 28 days of testing.

After casting, the specimens were cured under two curing conditions such as curing at room temperature (30°C) and in the laboratory oven at 60°C. For heat-curing, dry (oven) curing was used.

The prism tests were conducted with clay brick and geopolymer brick assemblages with different size and concentration of alkaline solution. Clay brick and geopolymer brick were manufactured in the industry to study the behaviour of unreinforced geopolymer brick masonry prism. Clay Brick Prism (CBP) and Geopolymer Brick Prism GBP (M1) and GBP (M2) of brick size 225 x 105 x 70 mm were cast using 10M and 12M NaOH concentration with prism dimension of 609 x 220 x 609 mm (h/t = 2.77) and 609 x 220 x 914 mm (h/t = 4.3).

Test procedures used in this study were based on available or modified procedures normally used for Portland cement concrete either from the available standards such as the Indian Standard or ASTM or from the previously published works in the areas within this study.
Laboratory tests were conducted to find the characteristic mechanical properties such as compressive strength, Split tensile strength and flexural strength for GPC solid block and GPC hollow block for 7, 14 and 28 days of testing and for curing at room temperature and elevated temperature. Cube specimens of size 150 x 150 x 150 mm for measuring compressive strength, cylinder specimens of 100 mm diameter by 150 mm height for indirect splitting tensile strength and prism specimens of 100 x100 x 500 mm for flexural strength were cast in the study. Hollow concrete block of size 100 x 100 x 250 mm with 45 x 75 x 125 mm hollow were also cast for measuring the compressive strength.

In order to study the water absorption and the resistance of fly ash based geopolymer concrete to sulphuric acid GPC cube specimen of 150 x 150 x 150 mm cured at 30°C and 60°C were tested. The test specimens were immersed in a 3% sulphuric acid for a period of exposure of 28 days. The sulphate resistance was evaluated based on the change in weight and change in compressive strength, split tensile strength and pH value of specimen after sulphate exposure.

Brick masonry prisms were tested to obtain stress–strain curves for typical masonry used in the Indian construction industry as per IS 1905 (1987). Clay bricks and geopolymer brick were used in constructing masonry prisms. Behaviour of unreinforced geopolymer masonry prism is compared with clay brick masonry prism. Modulus of elasticity was calculated from stress-strain curves by measuring the slope of a secant between ordinates. Calculation was also done to predict the modulus of elasticity using regression equation. The predicted value obtained from linear regression analysis is tested for chi square test.
6.3 Specific Conclusion

The following conclusions are drawn based on the experimental work reported in this research.

6.3.1 Mechanical Property of Geopolymer Solid and Hollow Block

- Compressive strength and split tensile strength increases with increase in concentration of NaOH from 8M to 14M. Increase in compressive strength was also observed with increase in curing time for GPC solid and hollow block.

- Maximum compressive strength achieved for GPC solid block for curing at 60°C was 37.12 MPa. For GPC hollow block the maximum value of compressive strength is 22.14 MPa. The maximum value of split tensile strength for GPC solid and hollow block cured at 60°C was 4.12 MPa and 3.56 MPa respectively.

6.3.2 Water Absorption of Geopolymer Concrete

- Water absorption decreases with increase in concentration and curing time. The percentage of water absorption was found to decrease with increase in concentration of NaOH from GP1 to GP4.

- The percentage of water absorption varied in the range from 2% to 4.33% and 1.33% to 3.42% for specimen cured at room temperature and at 60°C. The percentage of water absorption is found to be less in specimens cured at elevated temperature than specimen cured at room temperature.
6.3.3 Acid Resistance of Geopolymer Concrete to Sulphuric Acid

- Geopolymer concrete has a very good resistance in acid medium in terms of weight loss. The weight loss on exposure to sulphuric acid in GPC for specimen cured at room temperature and at 60°C was about 0.53% to 2.01% and 0.2% to 1.02% after 28 days curing respectively.

- The reduction in compressive strength observed for GPC specimens for specimen cured at 30°C and 60°C were 7%, 14%, 22% and 6%, 12%, 20% for 7, 14 and 28 days of exposure.

- The residual tensile strength for specimen after immersion in 3% sulphuric acid for curing at 30°C and 60°C was found to vary between 1.81 MPa to 3.36 MPa and 2.45 MPa to 3.99 MPa.

- Solution recorded considerable increase in pH value which can be attributed to migration of alkalis from specimen to solution.

6.3.4 Behaviour of Unreinforced Geopolymer Brick Masonry Prism

- The successful production of GPC brick with the existing concrete production facilities in plant indicates that conventional concrete tools and equipment can be utilized. Geopolymer concrete has excellent compressive strength and is a best fit for structural applications.

- The stress strain behavior of GPC brick when compared to clay brick prism was found to be better and the analytical values obtained using regression analysis and chi square test is substantially conservative when compared to the test values.
GPC utilises the industrial waste for producing the binding material in concrete and it can be considered as eco-friendly material.

6.4 Limitation of Study

1. In this present work, geopolymer unreinforced masonry prism has been tested for the study of its behavior. The experiment can be extended further to study the behavior of reinforced geopolymer masonry structure. Also a comparative study can be performed for reinforced GPC masonry with different loading conditions.

2. The bond between geopolymer concrete and steel reinforcements needs to be studied for the practical use of this material.

6.5 Future Scope of Research

Practical recommendations on the use of geopolymer concrete technology in practical applications such as precast concrete products and waste encapsulation need to be developed in Indian context.

Only qualitative information is available the mechanical strength which can be used to decide about any particular combination of geopolymer mixes to achieve the desired level of strength.

Several studies have shown that fiber addition is an effective method to improve the mechanical characteristics of brittle material such as concrete by providing crack arresting mechanism. Future study has to focus on the effect of fiber addition on the postcrack performance of geopolymer concrete. It is also necessary to study the effect of steel and glass fibers in geopolymer concrete.
The mechanical characteristics of geopolymer concrete specimens at elevated temperature (600–800°C) need to be assessed for checking its potential applications as heat resisting construction material.