CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is the most commonly used construction material. Customarily, concrete is produced by using the Ordinary Portland Cement as the binder. However, the manufacturing of the Portland Cement is an energy intensive process and releases a very large amount of green house gas to atmosphere. Production of one ton of Portland cement requires about 2.8 tons of raw materials, including fuel and other materials and hence it is well known that cement production depletes significant amount of natural resources. As a result of de-carbonation of lime, manufacturing of one ton of cement generates about one ton of carbon dioxide. Nowadays, there is a big concern about the development of alternative materials to Portland cement. Therefore, there are efforts to develop the other form of cementitious materials for producing concrete.

1.2 CEMENT REPLACEMENT MATERIALS

In order to address the above said issues, several materials were proposed to replace the function of cement in concrete. Waste materials that contain silica and alumina were applied to replace some portion of cement in concrete. Fly ash, Rice husk ash, silica fume and ground granulated blast furnace slag are some of the examples of cement replacement materials that are commonly used. The binder product resulted from pozzolanic reaction
that occurred between cement replacement materials and hydration paste has significantly improved conventional concrete properties. However, these materials can only replace up to certain percentages of portion of cement in concrete.

In the year 2002, high volume fly ash concrete has been developed by Malhotra that utilized fly ash to replace cement up to 60% without reducing concrete performance. Percentage replacement of cement above 60% would not provide any improvement to the concrete performance, therefore new binder material that could fully replace cement portion in concrete is necessary to create superior and more environmentally friendly concrete.

In 1978, a new material was introduced by Davidovits, which can be used as an alternative binder to cement. This material was named as geopolymer for its reaction between alkaline liquid and geological based source material. Followed by this, in the year 2002, Hardjito and Rangan carried out research on fly ash based geopolymer concrete and studied the engineering properties by applying steam curing in order to accelerate the polymerization process in this geopolymer concrete.

1.3 GEOPOLYMER TECHNOLOGY

The term geopolymer was coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules. These geopolymers rely on thermally activated natural materials (e.g., kaolinite clay) or industrial byproducts (e.g., fly ash or slag) to provide a source of silicon (Si) and alumina (Al), which is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and networks to create the hardened binder. Such systems are often referred to as alkali-activated cements or inorganic polymer cements.
Geopolymer is an inorganic polymer similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline. The polymerization process involves substantially a fast chemical reaction under alkaline condition on Si-Al minerals that result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The geopolymerisation reaction is exothermic and takes place under atmospheric pressure at temperatures below 100°C.

The exact mechanism by which geopolymer setting and hardening occurs is not yet fully understood. However, the most proposed mechanisms for the geopolymerization includes the following four stages that proceed in parallel and thus, it is impossible to be distinguished: (i) Dissolution of Si and Al from the solid aluminosilicate materials in the strongly alkaline aqueous solution, (ii) Formation of oligomers species (geopolymers precursors) consisting of polymeric bonds of Si-O-Si and/or Si-O-Al type, (iii) Poly-condensation of the oligomers to form a three-dimensional aluminosilicate framework and (iv) Bonding of the unreacted solid particles and filler materials into the geopolymeric framework and hardening of the whole system into a final solid polymeric structure.

1.4 FLY ASH BASED GEOPOLYMER CONCRETE

Fly Ash is a main solid waste generated from the coal combustion in the power stations. Waste created by a typical 500-megawatt coal plant includes more than 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber each year. Presently, as per the Indian Ministry of Environment and Forest figures, only 20% to 30% of fly ash is used in manufacturing cements, construction, concrete, block and tiles and some disposed off in landfills and embankments. More than 75% of this waste is unutilized leading to several environmental problems of the air, soils and surface and ground-water pollution. Therefore proper disposal and utilization
of these ashes are required to preserve the ecosystem from severely or permanently damaged by the uncontrolled coal plant waste disposal.

Fly ash, which is rich in silica and alumina, has full potential to use as one of the source material for geopolymer binder. The utilization of fly ash in the development of geopolymeric materials for construction purposes has been and continues to be subject of many research studies. Recent works on the geopolymerisation of fly ash, reported production of geopolymeric materials with high mechanical strength, low density, less water absorption, negligible shrinkage and significant fire and chemical resistance.

Significant research works on fly ash based geopolymer concrete manufactured from fly ash in combination with sodium silicate and sodium hydroxide solution has been carried out by several researchers and they have reported higher strength and better durability of geopolymer concrete than Portland cement concrete.

1.5 RESEARCH SIGNIFICANCE

Current applications of geopolymer concrete are affected by its curing method. The requirement of elevated temperature in its maturing period is supplied with electric equipment that could generate hot steam or heat. This method would prevent the geopolymer concrete to be applied in a cast in situ concrete work. Therefore this research is focused on the utilization of ambient temperature to cure the geopolymer concrete.

Although a lot of research has been directed towards geopolymer concrete on the various mechanical properties such as compressive strength, tensile strength and flexural strength, relatively less work has been performed on fibre reinforced geopolymer concrete to examine the effects of addition of fibres on the structural performance. The ductility improvement of
geopolymer concrete is a crucial factor in concrete science and hence the objective of this research is to provide data and to gain insight into the behaviour of fibre reinforced geopolymer concrete composites.

From the literatures, it was also found that, the engineering characteristics of geopolymer concrete such as static elastic modulus, compressive strength, tensile strength, flexural strength, water absorption, sorptivity, permeability, shrinkage, creep, acid resistance etc, have been investigated in detail. However, the impact resistance of this geopolymer concrete was not studied so far. Hence an attempt has been made to study the performance effectiveness of plain and fibre reinforced geopolymer concrete under impact load.

In addition to that, the information on the flexural behavior of fibre added geopolymer reinforced concrete beams is not found in the past literatures. And yet this information is vital for the use of fibre reinforced geopolymer concrete for structural applications. Therefore, extensive experimental and analytical investigations were carried out, to study the flexural behavior of plain and fibre added geopolymer composite reinforced concrete beams.

1.6 PROBLEM DEFINITION

So far, the main thrust of research involving geopolymer concrete has been aimed at characterizing the mechanical properties of geopolymer concrete. The results of such research have wide applicability, particularly with regard to precast industry. However, research on the utilization of geopolymer concrete for cast-in situ has not been carried out so far. Also limited research works have been performed on the fibre reinforced geopolymer concrete. Despite the engineering characteristics of the geopolymer concrete, its performance under impact loading and flexural
behavior of fibre added geopolymer composite reinforced concrete beams is not still well known. Hence the scope of the present study encompasses the following objectives:

- To arrive at mix ratios for making fly ash based geopolymer concrete.
- To assess the strength characteristics of geopolymer concrete prepared by using two different sources of fly ash.
- To provide a solution for utilizing geopolymer concrete in cast-in-situ construction by developing geopolymer concrete composites.
- To compare the strength characteristics of Geopolymer Concrete (GPC) and Geopolymer Concrete Composites (GPCC).
- To evaluate the strength characteristics of steel fibre reinforced geopolymer concrete composites for different volume fractions of steel fibres.
- To study the mechanical properties of polypropylene fibre reinforced geopolymer concrete composites for different fibre volume fractions.
- To evaluate the engineering characteristics of glass fibre reinforced geopolymer concrete composites for different volume fractions of fibres.
- To assess the performance of plain and fibre reinforced geopolymer concrete composite under impact loading.
To investigate experimentally, the flexural behavior of fibre added geopolymer composite reinforced concrete beams.

To study analytically, the response of geopolymer composite reinforced concrete beams under flexure using finite element software ANSYS and to compare with the experimental results.

1.7 RESEARCH METHODOLOGY

Figure 1.1 Phases of research
1.8 ORGANIZATION OF THE THESIS

Eight chapters follow this introductory chapter. The literature available within the perusal of the objectives of the present study is broadly reviewed in chapter 2. It summarizes the existing literatures on the geopolymer concrete, fibre reinforced concrete and the experimental and analytical investigations on the flexural behaviour of reinforced concrete beams with and without fibres. Chapter 3 describes in detail, the experimental program undertaken to assess the mechanical properties of geopolymer concrete prepared by using two different sources of fly ash for various concentration of alkaline solution and different types of curing. Chapter 4 describes in detail how the limitations of geopolymer concrete is rectified by evolution of Geopolymer Concrete Composite and the comparison between the strength characteristics of Geopolymer concrete (GPC) and Geopolymer Concrete Composites (GPCC). Chapters 5, 6 and 7 describe in detail, the experimental investigations carried out to study the mechanical properties of Steel Fibre Reinforced Geopolymer Concrete Composites (SFRGPCC), Polypropylene fibre reinforced Geopolymer Concrete Composites (PFRGPCC) and Glass Fibre Reinforced Geopolymer Concrete Composites (GFRGPCC) respectively, which include a description of the specimens and the manner in which they were cast, instrumented and tested. In Chapter 8, the experimental study on flexural behavior of geopolymer composite reinforced concrete (R.C) beams with and without fibres is presented and the effect of various fibres on the improvement of flexural strength and toughness is discussed. The analysis of fibre added geopolymer composite reinforced concrete (R.C) beams with flexural and shear reinforcement using finite element software ANSYS is also presented. The beams were analyzed up to failure and the response of the beams computed at different stages of loading using ANSYS were compared with the experimental results. Chapter 9 covers the important conclusions drawn from the present study and also offers suggestions for future research in the light of findings of the present study.