Chapter 1

Introduction

1.1 RESEARCH BACKGROUND

1.1.1 CONCRETE

Concrete is an extraordinary and key structural material in the human history. It is well known that with the development of human civilization, concrete will continue to be a dominant construction material in the future. High Performance Concrete (HPC) is a concrete mixture, which possess high durability and high strength when compared to normal concrete. Any concrete which satisfies some criteria suggested to overcome limitations of conventional concretes may be called High Performance Concrete. Mix design of high performance concrete is different from that of normal concrete because water-binder ratio is very low and it may contain mineral admixtures which change the properties of fresh and hardened concrete Aitcin (1998). It may include concrete, which provides either substantially improved resistance to environmental influences or substantially increased structural capacity while maintaining adequate durability. It may also include concrete, which significantly reduces construction time to permit rapid opening or reopening of roads to traffic, without compromising long-term serviceability. Therefore, it is not possible to provide a unique definition of high performance concrete without considering the performance requirements of the intended use of the concrete. The requirements involve enhancements of characteristics such as placement and compaction without segregation, long-term mechanical properties, and early age strength or service life in severe environments. The applications of such concretes are growing with the passage of time due to their excellent performance, low influence on energy utilisation and environment friendliness Mehta (2003). American Concrete Institute defines High Performance Concrete as “A concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices”. Developments of modern concrete industry causes many environmental problems such as pollution, waste dumping, emission of dangerous gases, depletion of natural resources etc. Cement production accounts for about 5% of total global CO$_2$ emissions. On the other side of the spectrum, in order to decrease the rate of climate
change, a global resolution to an 8% reduction in greenhouse gas emissions was set in
the Kyoto Protocol in 1997. Developed countries were much knowledgeable for its
need and a climate change tax was introduced by them. In this connection, UK
Government also introduced same kind of tax on 1st April 2001, in order to achieve
its target of a 12.5% reduction in greenhouse gas emissions which is the government’s
domestic goal of 20% reduction in CO₂ emissions by 2010. Therefore, it is evident
that, in order to keep its position as a presiding material in the future, the model of
concrete industry needs to be move towards “sustainability”. Traditionally, High
Performance Concrete (HPC) may be regarded as synonymous with High Strength
Concrete (HSC). It is because of low water-to-cement ratio, which is needed to attain
high strength, also generally improves other properties. However, it is now recognized
that with the addition of mineral admixtures HPC can be achieved by further lowering
water-to-binder ratio, but without its certain adverse effects on the properties of the
material. Hence, it is important to understand how concrete performance is linked to
its microstructure and composition. In fact, performance can be related to any
properties of concrete. It can mean excellent workability in fresh concrete, or low heat
of hydration in case of mass concrete, or very quick setting and hardening of concrete
in case of spray concrete which is used to very low imperviousness of storage vessels
or repair roads and airfields. However, from structural point of view, one understands
usually that high strength, high ductility and high durability, which are regarded as the
most favorable factors of being a construction material, are the key attributes to HPC.
Decennium ago, HSC was only tested in laboratory without real applications because
there were still many uncertainties on the structural behavior of HSC at that time. Up
to the present, HPC has been widely used in tall building and bridge construction.
The use of HPC in concrete structures has increased in recent years Aitcin et al
(2004). An increasing interest in the use of HPC in construction industry has made it
necessary to explore all its properties Mehta and Monterio (2006). With this
background, a comprehensive experimental investigation was carried out to consider
the effects admixtures and fibres on the properties HPC.

1.1.2 HIGH PERFORMANCE CONCRETE

High performance concrete is a concrete mixture, which possess high
durability and high strength when compared to normal concrete. Any concrete which
satisfies certain criteria proposed to overwhelmed limitations of conventional
concretes may be called High Performance Concrete. HPC is the latest development in concrete. It has become popular these days and is being used in many prestigious projects such as Nuclear power projects, flyovers, multistoried buildings, bridges etc. Since 1990s, HPC has become very popular in construction works. At present, the use of HPC has spread throughout the world. In 1993, the American Concrete Institute (ACI) published a broad definition for HPC and is defined as “A concrete which meets special performance and uniformity requirements that cannot always be achieved by using only the conventional materials and mixing, placing and curing practices”. The Strategic Highway Research Programme (SHRP) has defined HPC for highway application on the following strength, durability, and w/c ratio criteria.

- It should satisfy one of the following strength criteria:
  - 4 hour strength ≥17.5 MPa
  - 24 hour strength ≥35.0 MPa
  - 28 days strength ≥ 70.0 MPa
- It should have a durability factor greater than 80% after 300 cycles of freezing and thawing.
- It should have a water-cement ratio of 0.35 or less.

The addition of mineral admixtures in concrete has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture has brought pressures to reduce cement consumption by the use of supplementary cementitious materials. Mineral admixtures such as fly ash, rice husk ash, metakaolin, silica fume etc, are more commonly used in the development of HPC mixes. They help in obtaining both higher performance and economy. These materials increase the long term performance of the HPC through reduced permeability resulting in improved durability. Addition of such materials has indicated the improvements in the strength and durability properties of HPC. High reactive metakaolin, which is a relatively newer material in the concrete industry, is effective in increasing the compressive strength and reducing the sulphate attack.
1.1.3 RESEARCH SIGNIFICANCE

As stated in introduction, one of the main objectives of this research was to produce a concrete from a systematic investigation so as to contribute to the development of performance based specifications for HPC in terms of strength and durability. In addition to strength, durability was considered to be essential to measure durability characteristics of HPC containing both fibres and admixtures. The criteria for assessing the quality and behaviour of hardened HPC are dependent on their intended purposes. For instance, a HPC designed for a marine exposure condition needs to be assessed differently sulphate exposure and sea water attack condition. This means that a general research on HPC with the goal of the data contributing to the development of performance based specifications should not be confined to mechanical property. This long-term performance based specifications like durability mechanism and microstructural investigation will be beneficial for developing countries like India.

1.1.4 STUDY CONTRIBUTION

This study helps in identifying the influence of Alccofine 1203, Ground Granulated Blast furnace Slag (GGBS), Metakaolin on strength characteristics of HPC. The use of alternative material of Portland cement leads to reduction of emission gases and impact on production capacity of cement plant. This study also provides a strategy to reduce the waste disposal and its related gains. This research work will help to produce an economical concrete with modified properties.

1.1.5 RESEARCH OBJECTIVES

- To determine the mechanical and durability characteristics of HPC by incorporating mineral admixtures like Metakaolin, Alccofine 1203, and Ground Granulated Blast furnace Slag and fibres like flat crimped steel fibres and polypropylene fibres.
- To identify the optimum percentage of admixtures and fibres in order to accelerate the properties of HPC mix for M80 grade concrete.
- Exploring the use of optimum percentage of admixtures and fibres to enhance the properties of HPC
• To study the chemical composition of M80 grade HPC using X-Ray Diffraction (XRD) analysis.

• Analysing the concrete microstructure of M80 grade HPC along with identification of different phases of concrete and its quantitative assessment using Scanning Electron Microscopy (SEM) analysis.

1.1.6 SCOPE OF WORK

To accomplish the defined objectives for this research work the following scope of work was defined:

• Identifying and collecting the samples of materials that are suitable for the concrete mix

• Materials used in the study were Alccofine 1203, Metakaolin and GGBS and fibres used were Strongcrete, Nokrack and Flat crimped steel fibres. Percentage of fibres adopted for these works very from 0.1 to 1% volume of concrete.

• Detailed laboratory investigations for determination of mechanical properties of HPC like compressive strength, flexural strength, split tensile strength test and slump test were performed with different proportions and combinations of admixtures and fibres.

• Detailed laboratory investigations for determination of durability characteristics of HPC like water absorption, sulphate attack test, sea water test, sorptivity test and water permeability test.

• To asses and analyze the laboratory results of mechanical properties and durability properties obtained at 7, 28, 56, 90 and 365days.

• Detailed chemical and microstructural investigations like XRD and SEM analysis were performed.

1.1.7 OUTLINE OF THESIS

Chapter 1. Introduction

Chapter one briefly presents the importance of high performance concrete in supporting construction industry and the use of mineral admixtures in concrete to enhance concrete’s strength and durability. In addition the aim, objectives and the scope of the research are also presented.
Chapter 2. Literature review

Chapter two presents the information from the existing literature to understand the role of mineral admixtures and fibres in improving properties of concrete, the information about selected materials to produce high performance concrete.

Chapter 3. Materials and methodology

This chapter presents description about materials and test methods which were used to produce high performance concrete. In addition, the method of testing concrete properties and concrete durability were also presented.

Chapter 4. Experimental program

Chapter four presents the information about the mix proportions and description of specimen sizes used for the study.

Chapter 5. Results and Discussion

This chapter explores the optimum amount of mineral admixtures and fibres to produce a desired strength of concrete, the feasibility of using mineral admixtures to produce high performance concrete in combination with fibres. In addition, the discussion on the experimental results on strength development of high performance concrete. The durability tests comprises water absorption test, sorptivity test, sulphate resistance test, sea water test and water permeability test. In addition, the discussion on the microstructure analysis and chemical composition of hardened concrete was done based on XRD and SEM investigations.

Chapter 6. Conclusions

The last chapter covers the finding of the research in regard to the use mineral admixtures and fibres to develop a HPC. In addition, it also presents some scope of future work.