CHAPTER 1

INTRODUCTION

1.1 GENERAL

Cement concrete is a mixture of cement mortar, coarse aggregate and water. Concrete has been the second largest material consumed in the world next to water and hence, it is important to understand the properties of concrete with different admixtures in order to ensure a safe and durable structure. Concrete produced from the mixture of cement, fine aggregate, coarse aggregate, water and discontinuous discrete fibres is called Fibre Reinforced Concrete. Polyolefin Macro-Monofilament Fibre Reinforced High Performance Concrete (PMMFRHPC) has randomly distributed polyolefin macro-monofilament (PMM) fibres, cement mortar with admixtures, coarse aggregate and water. PMM Fibre Reinforced High Performance Concrete, in the present investigation, is produced by the addition of two cost-effective mineral admixtures, viz., fly ash and metakaolin, along with the addition of Polyolefin Macro-Monofilament Fibres.

Concrete is relatively brittle and its tensile strength is about one tenth of its compressive strength. Concrete is, therefore, reinforced with steel reinforcing bars in structural members. For wider applications, it is becoming increasingly popular to reinforce the concrete with small and randomly distributed artificial or natural fibres in order to minimize shrinkage cracks and to improve ductility and tensile strength. Recently, the concretes are produced replacing cement partially by mineral and pozzolanic admixtures to
enhance the performance of concrete. High Performance Concrete (HPC) has improved properties and serviceability than normal concrete. Conventional and special materials are used to make these specially designed concretes to meet a combination of performance requirements. High performance concrete (HPC) has been defined as concrete that possesses high workability, high strength and high durability and ACI (American Concrete Institute) has defined HPC as a concrete in which certain characteristics are developed for a particular application and environment. HPC is a concrete made with appropriate materials combined according to a selected mix design, mixed properly, transported, placed, consolidated and cured. Consequently, it gives excellent performance, when it is placed in the exposed environment, with the loads subjected to its design life. In addition, HPC is influenced by many factors, including specified performance properties, locally available materials, local experience, personal preferences and cost.

The primary application of HPC has been for structures requiring long service lives, such as oil drilling platform, long span bridges and parking structures. HPC still requires good construction practices and curing, to deliver intended performance for which they are designed. The disadvantage of high performance concrete is its brittleness and explosive failure. The lack of ductility in HPC leads to failure of structures suddenly without developing an appropriate collapse mechanism. Mixing fibres into the concrete matrix can increase the ductility and fracture toughness compared to plain concrete. FRHPC is gaining popularity as modern structural material with high potential. Studies on FRHPC have shown to exhibit behaviour similar to that of well confined concrete.

1.2 ADVANTAGES OF USING FIBRES IN CONCRETE

Fibres of various shapes and sizes produced from various materials like steel, plastic, glass, and natural materials are being used. However, for
most of structural and non-structural purposes, steel fibre and polypropylene fibre have been the choice compared to other fibres.

The Advantages of using fibres in concrete can be listed as follows:

- Reduction of shrinkage cracks.
- Reduction in rebound loss of the mortar by nearly 30 percent.
- Increase in tensile strength of concrete for enhanced durability.
- Savings of cement, up to three percent.
- Increase in labour productivity by over five percent.
- Enhancement of the compression behaviour of concrete, primarily by increasing its strain capacity.

Both steel and polymeric fibres are often used in construction projects in order to achieve the dual benefits of the products, i.e., the structural improvements provided by steel fibre and the plastic shrinkage improvements provided by polymeric fibres. In this investigation, PMM Fibres are used to reinforce the concrete in its hardened state, thereby improving the strength and durability. The PMM fibres have a sufficient high modulus of elasticity and tensile strength to assume excess strain across a crack and hold it tightly.

1.3 POLYOLEFIN MACRO-MONOFILAMENT FIBRES

Polyolefin Fibre is a man-made artificial fibre, made from a synthetic linear polymer obtained by polymerising an unsaturated hydrocarbon [e.g. ethylene (\(\text{CH}_2\text{-CH}_2\)) or propylene (\(\text{CH}_3 = \text{CH} - \text{CH}_3\))] to give a linear saturated hydrocarbon. There are two polyolefin polymers used to make synthetic fibres, namely polypropylene and polyethylene. The International Bureau for the Standardisation of Manmade Fibres defines polyolefin fibres
as, "fibre composed of linear macromolecules of unsubstituted saturated aliphatic hydrocarbons". Polyolefin fibres are made by melt spinning. Usually polymer granules are fed to an extruder which melts the polymer, which following the same is pumped through a spinneret. The filaments are cooled in an air stream before being wound on a package or collected in cans as a tow.

Polyolefin fibres are those fibres produced from polymers formed by chain growth polymerization of olefins (alkenes) and those that contain greater than 85% polymerized ethylene, propylene, or other olefin units. Polyolefin fibres have specific gravity less than one, the fibres are unaffected by solvents at room temperature and are swollen by aromatic and chlorinated hydrocarbons, only at elevated temperatures. Polyolefin fibres are lustrous white translucent fibres with good draping qualities and a characteristic slightly waxy hand. They have excellent abrasion resistance and exhibit fair wrinkle resistance.

There are two types of fibres in the market, namely micro type and macro type fibres and both serve different purposes. Micro type fibres are typically polypropylene, cellulose or nylon monofilament or fibrillated fibres with diameters less than 0.22 mm, length ranging from 12.7 mm to 19 mm, with addition rates between 0.30 kg/m$^3$ - 0.88 kg/m$^3$ in concrete and specifically designed to control/reduce plastic shrinkage cracks that occur within the first 24 hours after placing concrete. Macro type fibres are typically monofilament with a diameter between 0.3 mm - 1.3 mm, lengths ranging from 38 mm - 64 mm and made with polyolefin. The typical synthetic macro fibre addition rates vary between 1.8 kg/m$^3$ to 7.0 kg/m$^3$, and the primary benefit of Macro type fibres is post-crack control and/or to meet temperature/shrinkage. In other words, it can substitute for steel required to crack control in slabs on ground, precast and composite deck applications.
Polyolefin Macro-Monofilament Fibres have the potential to improve the post-cracking properties of hardened concrete. Their use as an alternative to nominal bar or fabric reinforcement is a relatively recent development. Micro Synthetic fibres control plastic shrinkage cracking which usually occurs in the very early stages of concrete drying. Macro fibres reinforce the concrete in its hardened state, thereby improving the strength and durability

1.4 NEED FOR THE PRESENT INVESTIGATION

The inherent deficiencies of normal concrete that is being extensively used so far calls for modification of concrete properties by incorporating fibres and by replacing cement with mineral admixtures, and thereby to study the scope for improved behaviour of such concrete with respect to strength properties and durability aspects. The available literature indicates that considerable scope exists in the study of the influence of Polyolefin Macro-Monofilament Fibres in concrete, primarily with respect to the following:

- Evaluation of the combined performance of hardened properties and early age crack resisting properties of High Performance Concrete (HPC) incorporating low volume fraction of fibres.
- Investigation on durability of high performance concrete incorporating PMM fibres.
- Flexural behaviour of beams and behaviour of beam-columns made using PMM fibres.

The present study focuses on comprehensive characterization of the mechanical properties such as compressive strength, splitting tensile strength and modulus of rupture. In addition, the durability of concrete as attained
through test on permeability of concrete, drying shrinkage properties and corrosion resistance of HPC mix incorporating PMM fibres are dealt with.

### 1.5 RESEARCH OBJECTIVES

The primary objective of this investigation is to evaluate the performance enhancement of Polyolefin Macro-Monofilament Fibre Reinforced High Performance Concrete, with respect to the strength and durability of hardened concrete, and to study the behaviour of beams and beam-columns made incorporating PMM fibres. In order to achieve this, the following specific aims are outlined:

1. To optimise the use of mineral admixtures such as fly ash and metakaolin and chemical admixture (superplasticizer) for the development of High Performance Concrete.

2. To understand the influence of Polyolefin Macro-Monofilament Fibres on the High Performance Concrete and to optimize its dosage.

3. To study the Mechanical properties such as compressive, split tensile and flexural strengths and durability investigation of PMMFRHPC.

4. To develop mathematical models for getting the strength properties and durability in terms of the parameters which influence them.

5. To study the flexural behaviour of PMMFRHPC beams subjected to two symmetrical concentrated loads and to compare the beams with high performance reinforced concrete beams without fibres.
6. To study the behaviour of PMMFRHPC beam-columns and to compare the results with high performance reinforced concrete beam-columns without fibres.

7. To compare the experimental results of PMMFRHPC beams and beam-columns with those obtained by Finite Element Analysis using ‘ANSYS’ software.

1.6 SCOPE OF THE THESIS

This research was initiated with M60 grade Concrete, designed using two cost effective mineral admixtures fly ash and metakaolin and with the addition of chemical admixture, superplasticiser. The PMMFRHPC mixes were produced by incorporating Polyolefin Macro-Monofilament Fibres at dosages of 0.1, 0.2 and 0.3 percentage by volume fraction of concrete. Furthermore, a statistical regression analysis has been performed to get information on the influence of important parameters.

Experimental study was made to substantiate the suitability of PMMFRHPC mixes for applications of structural elements, beam and beam-columns in monotonic and cyclic loading

1.7 METHODOLOGY OF RESEARCH

A flowchart depicting the methodology of the research is presented in Figure 1.1. Methodology involves three Phases:

**Phase-I**: Studies on existing literature and development of PMMFRHPC

**Phase-II**: Test on the properties of PMMFRHPC in the fresh and hardened states

**Phase-III**: Investigations on the strength and behaviour of beams and beam-columns made of PMMFRHPC
Figure 1.1 Methodology of Research
The purpose of the research is the study of suitability of available materials, preparation of PMMFRHPC mix and testing the various properties of fresh and hardened concrete, followed by the establishment of an empirical relationship between the hardened concrete properties and in terms of the parameters which influence them, and in addition, the examination of behaviour of PMMFRHPC structural elements, such as flexural beams and beam-columns. Based on the results of the overall experimental investigation and modelling of PMMFRHPC within the research programme, the conclusions, contributions and recommendations of PMMFRHPC concrete are furnished.

1.8 ORGANISATION OF THE THESIS

The entire content of the thesis has been organised in seven chapters:

The first chapter presents a general introduction in support of the need for this investigation. An outline of the objectives, scope of the research, short overview of the present research and brief discussion on methodology of the research are all given in the first chapter.

The second chapter deals with a critical review of available literature on the development of high performance concrete and fibre reinforced concrete.

The third chapter gives the various tests conducted on the consistent materials of PMMFRHPC developed in this investigation, the properties of the concrete in the fresh and hardened states and the mathematical modelling developed to predict the mechanical properties.
The fourth chapter describes the eight different types of tests conducted to determine the durability of PMMFRHPC adopted in this investigation and the mathematical models developed for durability studies.

The fifth chapter furnishes the research programme on PMMFRHPC beams. Details of casting and curing of ten beams and the experimental setup used to test these beams are given here. In addition, it gives the observations made during the experimentation process and the behaviour of the beams. Prediction of the ultimate load carrying capacity of the beams and comparisons of theoretical results with experimental values are given. The load-deflection curves obtained by Finite Element Analysis are compared with those obtained experimentally and the details are given in this chapter.

The sixth chapter provides a detailed outline of the research programme on PMMFRHPC beam-columns, design aspects of beam-columns subjected to axial compression and two symmetrical concentrated lateral loads, and gives the details of the specimens cast for experimentation purpose. The experimental setup and the interpretation made from the test results of ten beam-columns of PMMFRHPC are also furnished. Finite Element Analysis of these beam-columns using ANSYS package has been presented and discussed. The experimental values are compared with the results of Finite Element analysis.

The seventh chapter provides a summary of the research findings and conclusions arrived at, based on the research work related to the strength and durability of polyolefin macro-monofilament fibre reinforced high performance concrete and the strength and behaviour of ten beams and ten beam-columns made of this concrete. Some suggestions are given for further research work in this area.