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CHAPTER 1
INTRODUCTION

1.1 General

Concrete is the most widely used construction material in India and other countries also. It is difficult to point out another material of construction which is as versatile as concrete. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required. It is so closely associated with every construction activity that it touches every human being in his day to day living. Cement concrete is one of the seemingly simple but actually complex materials. Many of its complex behaviors are yet to be identified to employ this material advantageously and economically. The behavior of concrete with respect to long-term drying shrinkage, creep, fatigue, morphology of gel structure, bond, fracture mechanism and polymer modified concrete, fibrous concrete are some of the areas of active research in order to have a deeper behavior of these materials. In India the annual consumption of cement is in the order of 22 million tons. Concrete is a site-made material unlike other materials of construction and as such can vary to a very great extent in its quality, properties and performance owing to the use of natural materials except cement. From materials of varying properties, to make concrete of stipulated qualities, an intimate knowledge of the interaction of various ingredients that go into the making of concrete is required to be known, both in the fresh and hardened conditions. This knowledge is necessary for concrete technologists as well as for site engineers.

The useful physical properties and low cost make cement based materials most widely used in civil engineering constructions. However these materials have a number
of drawbacks. They are brittle, have a low failure strain, and are weak in tension. To overcome these problems, both polymer modification and fibre reinforcement have been used successfully in practice. In this work the combined use of polymers and fibres was studied experimentally. However it is necessary first to describe briefly the separate effect of polymers and fibres in concrete. Concrete is a strong and tough material. When it is reinforced with steel, resists the cyclones, earthquakes, blasts and it is fire resistant also. When compared to many Engineering materials like steel, rubber, concrete requires less energy input for its manufacture. Currently, a large number of mineral admixtures which are waste products of other industries are being beneficially used in making quality concrete. Some of the mineral admixtures are given below.

### 1.2 Mineral Admixtures

The Indian standards IS 456-2000 permits the use of mineral admixtures for modifying the properties of concrete. The use of Industrial waste products such as fly ash which has both pozzolanic and cementations properties lead to cost and energy savings. The following minerals can be added to concrete either as admixture or as a part of cement.

#### 1.2.1 Metakaolin

Metakaolin is obtained by calcination of pure or refined clay at temperatures of 650° C- 850° C and by grinding it subsequently to achieve a fineness of 700-900 m²/kg. It is a highly reactive pozzolana. Highly reactive Metakaolin is made by water processing to remove unreactive impurities to make 100% reactive pozzolana, such a product white or cream in color purified and thermally activated is called High Reactive Metakaolin (HRM). Some other Mineral admixtures are given below.
1.2.2. Fly ash:

Fly ash is finely divided residual material obtained from the combustion of powdered coal in electric generating plant (ASTMC 618) and transported by the flue gases and collected by electrostatic precipitator, in U.K. Fly ash consists of inorganic matter present in the coal that has been fused during coal combustion. Fly ash particles those are collected in electrostatic precipitators are usually of silt size (0.074-0.005mm).

1.2.3. Silica fume:

Silica fume is another artificial pozzolanic mineral admixture. It also referred to as micro silica or condensed silica fume. The silica fume is obtained by reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloys. When quartz is subjected to $2000^\circ$ C, reduction takes place and SiO vapos get in to fuels. In the course of exit, the oxidation takes place and the product is condensed in low temperature zones. When the silica is condensed it attains non-crystalline state with ultra-fine particle size. The super fine particle is collected through the filters. After it cools and condensed, it is collected in bags.

1.2.4. Rice husk Ash:

Rice husk Ash is obtained by burning the rice husk in a controlled manner without causing environmental pollution. It has a high SiO$_2$ content when it properly burnt and it can be used as a concrete mineral admixture. In India reinforced concrete has been used extensively for the construction of houses buildings, roads, bridges and dams. The advantages of concrete are well known to Engineers and Architects
1.3. Polymers:

The continuous research by the concrete technologists to improve the properties of concrete has resulted in finding the new type of concrete known as polymer concrete. The porosity is due to the air voids or water voids or due to the inherent porosity of gel structure itself on account of the porosity the strength of concrete is naturally reduced. It is conceived by many research workers that reduction of porosity results in increase of strength of concrete. The polymer used in this investigation is Natural Rubber Latex. More details about polymer concrete are presented in Chapter-2.

1.4 High Performance Concrete:

It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability resistance to frost, thermal cracking adequately. The term high-performance concrete (HPC) is used to refer to concrete of required performance for the majority of concrete applications. The performance requirement of concrete cannot be the same for different applications. Hence the specific definition of HPC required for each industrial application is likely to vary. The strategic Highway Research program (SHRP) has defined HPC for highway application on the following strength, durability and w/c ratio criteria.

Examples of characteristics of HPC that may be considered critical in an application requiring performance enhancement are, ease of placement and compaction without segregation, early-age strength, long-term mechanical properties, permeability, density, heat of hydration, toughness, volume stability and long life in severe environments, i.e. durability. Concretes possessing many of these characteristics often achieve higher strength. Therefore HPC is often of high strength, but high strength
concrete may not necessarily be of high performance. HPC usually contains additional ingredients such as mineral and chemical admixtures as compared to conventional concrete. In this investigation Metakaolin based Natural rubber latex modified fibre reinforced high performance concrete (NRLMFRHPC) properties have been studied.

1.5 About Natural Rubber latex modified fibre reinforced high performance concrete:

The Natural Rubber Latex Modified Fibre Reinforced High Performance Concrete (NRLMFRHPC) is a special type of concrete developed in this study to provide several benefits in the construction of concrete structures to achieve the higher strength with conventional ingredients, normal mixing and curing practices. In the other words the NRLMFRHPC is a concrete that gives excellent performance in the structure in which it will be placed, in the environment to which it will be exposed and with the loads to which it will be subjected during its design life.

For the past few decades, active research has taken place in polymer modified concrete, polymer concrete and polymer impregnated concrete. Currently the same is used as popular construction materials because of comparative high performance, multi functionality and sustainability compared to conventional cement concrete. Concrete polymer composites are environment conscious sand confirm to concerns of saving of natural resources, the longevity of infrastructures and the environmental protection. Adding Natural Rubber latex in the fresh concrete mix makes polymer modification of concrete. The polymer Natural Rubber latex is stabilized by surfactants and each polymer has its own film forming properties within the applicable temperature range and the chemical conditions during hardening and curing. The Natural Rubber latex modified
Fibre Reinforced High performance Concrete is achieved by incorporating the natural latex polymer and fibres into HPC.

1.6. Need of the present research:

The latex modified concretes have gained considerable attention in the field of construction although latex as a protectant has a long history of usage dating back to the 1800s. The use of latex increased many folds in 1980s. Inclusion of polymeric substances into hydraulic cement concrete has made a tremendous impact towards improving its performance properties. However, polymers to be included into concrete should neither cause damage to its mechanical capacities nor to its durability characteristics. Natural Rubber Latex (NRL) as a dispersion of poly-isoprene is naturally polymerized by brasiliensis tree. Most of its properties are therefore determined during the process of natural polymerization rather than controlled as normally is the case with emulsion polymerization. In its fresh state, NRL comprises 30–40% rubber particles suspended.

Though many studies have reported the usage of polymers including Natural Rubber Latex to modify the strength and workability characteristics of ordinary concrete, vary little is reported about its usage in HPC and fibre reinforced HPC. HPC is different from ordinary concrete as it contains additional raw materials such as mineral and chemical admixtures. Hence, the compatibility of Natural Rubber Latex with these mineral and chemical admixtures needs to be investigated. The effect of NRL on strength, workability and durability characteristics of fibre reinforced HPC need special attention. Also development of empirical models to connect the various strength and workability parameters of natural rubber latex modified fibre reinforced HPC is essential for its better applications. Further, traditionally in the mix design of concrete, only
workability and compressive strength are considered. However as HPC is more focused on performance parameters, factors other than compressive strength such as tensile or flexural strength, permeability etc., are also to be considered in the mix design. Hence there is also need to develop mix design charts for NRLMFRHPC considering all such parameters. Hence, the present study properties to conduct detailed research on strength, workability and durability characteristics of Natural rubber latex modified fibre reinforced High-Performance-Concrete.

1.7 Objectives of the present work:

The present investigation aims at conducting a feasibility study of producing NRLMFRHPC with locally available raw materials and indigenously produced mineral admixture (Metakaolin) and Natural Rubber latex as a polymer. The workability characteristics of NRLMFRHPC in fresh state are to be studied. Also, the behavior of NRLMFRHPC in basic loading modes namely compression, tension and flexure are to be evaluated.

In the present investigation a systematic study of effect of Rubber Latex and steel fibres on the workability, compressive strength, tensile strength and flexural strength of NRLFRHPC will be evaluated through experimentation in laboratory. Cubes, cylinders and beams will be cast and tested for obtaining properties like compressive strength, tensile strength, flexural strength, and durability studies will also be conducted. Accordingly, the specific objectives of the present work are listed below.

- To conduct a feasibility study of producing NRLMFRHPC with the available raw materials, mineral admixture Metakaolin, polymer “Natural Rubber Latex” and steel fibres using conventional curing methods.
• To conduct the experiments on NRLMFRHPC with different types of mixes and to evaluate the cube compressive strength split tensile strength of cylinders and flexural Strength of beams.

• To conduct compaction factor and Vee-bee time tests to evaluate the workability of NRLMFRHPC.

• To conduct the compressive strength, split tensile strength and flexural strength tests on various NRLMFRHPC mixes and compare the results with reference M20 concrete mix.

• To analyze the results and evaluate the effect of steel fibres and the effect of natural rubber latex on strength and workability of HPC.

• To conduct Chloride Ion Permeability Tests on different mixes of NRLMFRHPC as a measure of durability.

• To analyze the result of Chloride Ion Permeability test and evaluate the effect of NRL polymer on permeability of HPC.

• To develop regression models using statistical analysis for various parameters of NRLMFRHPC,

• To develop suitable mix design charts combining strength and durability parameters.

• To suggest a suitable mix design procedure for NRLMFRHPC mixes.

Thus, a detailed experimental program will be carried out on various NRLMFRHPC mixes produced with the available raw materials, mineral admixture Metakaolin and Natural rubber latex polymer. Properties like workability, compressive,
split tensile and Flexural strengths will be obtained. The results will be analyzed and useful conclusions will be drawn. It is hoped that this research leads to the continuous development of NRLMFRHPC for various applications in India.

1.8 Organization of the thesis:

The investigations carried out to achieve the specific objectives are presented in the following manner.

Chapter 2 deals with the literature review and its various ingredients. Special attention has been given on the review of mineral admixtures, fibres and polymers and their effects on the properties of Polymer concretes.

In Chapter 3, the physical properties of the materials used in the investigation have been presented. The details of tests conducted on basic raw materials like cement, fine aggregate, coarse aggregate, water and properties of mineral admixtures Metakaolin, Steel fibres and Natural rubber latex used in the present investigation are presented. The experiments have been conducted as per the specifications of relevant I.S codes.

Chapter 4 explains the details of the experimentation conducted on various Metakaolin based NRLMFRHPC mixes to evaluate their workability, compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams. The results of workability of NRLMFRHPC mixes are also tabulated. The effect of Steel fibres and the effect of Rubber latex are studied and the corresponding graphs are presented in this chapter.

The 5th Chapter deals with the Chloride permeability studies on NRLMFRHPC mixes with various proportions. The test conducted for durability is Rapid Chloride Ion
Permeability Test (RCPT). Based on the charge passed the durability of NRLMFRHPC mixes have been evaluated and the corresponding graphs have been reported in this chapter.

Chapter 6 deals with the development of regression models and mix design charts. A trial procedure for design of NRLMFRHPC mixes combining strength and durability parameters is also presented in this Chapter.

Chapter 7 reports the conclusions and suggestions for future investigation.

A comprehensive bibliographical list is provided at the end of the thesis keeping in view of future investigators working in the concern field.