CHAPTER 1

INTRODUCTION

1.1 General

Human safety in case of fire is one of the major considerations in the design of buildings. It is extremely necessary to have a complete knowledge about the behavior of all construction materials before using them in the structural elements. Concrete is a non-homogeneous material consisting of hardened cement paste and aggregates. With an increase in temperature, cracking is initiated due to thermal incompatibilities between the aggregates and the hardened cement paste. Developments in 1990’s have seen a marked increase in the number of structures involving the first time heating of concrete. These include nuclear reactor pressure vessels, storage tanks for hot crude oil and hot water, coal gasification and liquefaction vessels, pavements subjected to jet engine blast, and in area’s exposed to fire. The extensive use of concrete as a structural material in all the above mentioned structures and public utility buildings, multistorey buildings, exposed to the elements of terrorism necessitated the need to study the behavior of concrete at high temperature and its durability for the required needs.\(^{53,66}\)

The study of thermal properties of concrete is an important aspect while dealing with durability of concrete structure exposed to elevated temperature. Damage to the structure depends on the intensity, duration of exposure and also on the combustibility of the materials used in construction. The degree of damage to the structure ranges from slight damage and deflection to a complete collapse of the members and structures as seen in case of world trade centre towers. The main role of concrete in a fire is to protect any embedded steel for as long as possible against rise in temperature. Concrete is in itself incombustible and its temperature coefficient is practically the same as that of steel, thus giving it an advantage over materials like structural clay tile, which expands much more rapidly than steel, and hence tends to fail by reason of the destruction of the bond caused by unequal expansion. The rate of heat conductivity of concrete is very low, partly to its porosity and consequent air content, and partly to the dehydration of the water of chemical combination. This later action increases the porosity, and hence the conductivity of the concrete which leads to dehydration. One of the main reasons why Portland cement concrete is so widely used in building construction is that it can help satisfy the need for public safety in face of the hazards of fire better than most of its competitors. Concrete is incombustible and a reasonable insulator against the transmission of heat. These qualities
An experimental investigation on the behaviour of steel fibre reinforced ternary blended concrete subjected to sustained elevated temperature.
permanent. Exposure to sustained temperatures of 650°C to 820°C makes the concrete friable, porous and after cooling usually can be taken apart with fingers.\(^{(21)}\)

The desirable properties for aggregates in case of fire are low thermal conductivity that delays temperature rise, a thermal expansion as close to that of a paste as possible in order to minimize development of thermal stresses and a high specific heat to absorb heat. It is found that the greatest decrease in thermal conductivity occurs with those rock types that show the greatest decrease in thermal expansions. Higher thermal expansion stresses cause more micro cracking of crystals and loosening of grains resulting in increased rock porosity and hence decreased thermal conductivity.\(^{(14)}, (64)\)

The pozzolanic material such as silica fume (SF), ground granulated blast furnace slag (GGBFS), fly ash (FA), rice husk ash (RHA) and metakaolin (MK) have shown to improve the microstructure of cement paste by densifying the cement paste matrix and improving interfacial zone. The hydrates, such as calcium silicate hydrate (CSH) phases produced as a result of consumption of free lime Ca(OH)\(_2\) by the above pozzolanas, are deposited within the pore system and around the grains of the concrete constituents. This leads to the formation of a denser concrete microstructure. Therefore the effect of pozzolanas on the microstructure and phase composition of concrete is important for fire-resistance studies.\(^{(43)}\)

Addition of steel fibres helps to resist the pore pressure created and arrests the cracks and expansion, thus increasing the tensile strength. The addition of polypropylene fibres minimizes fire induced spalling in the concrete members. One of the most accepted theory is that by melting at a relatively low temperature of 170°C polypropylene fibres create 'channels' for the generated steam pressure (within the concrete) to escape, thus preventing the small 'explosions' that cause spalling. The amount of polypropylene fibres needed to mitigate spalling is about 0.1-0.15% (by volume). This technique is highly effective for concrete used in tunnel linings as tunnels are susceptible to fires with very high heating rates. However, this technique can equally be applicable to HSC members in buildings and hence should be used. Alternatively steel fibres can also be used to enhance fire resistance of concrete members. The addition of steel fibres enhances the tensile strength of concrete and reduces spalling. Also, hybrid (mixture of polypropylene and steel) fibres have been shown to be effective in minimizing spalling and thus enhancing the fire resistance of concrete structures.\(^{(36)}\)

As the fall in strength begins at a temperature of 250°C to 300°C the concrete takes on a pink or red colouration which deepens up to a temperature of 600°C and then
changes to grey and finally buff. The extent of the damage suffered by concrete in a fire may often be judged by noting the depth to which the pink colouration has penetrated and any concrete which has passed the pink stage should be cut out and replaced. (12),(21) The major reasons of failure behaviour of concrete at elevated temperatures are:
thermal stresses induced by thermal gradients, decomposition of calcium hydroxide in the cement paste, loss of free (evaporable) water from the concrete, loss of chemically combined / bound (non evaporable) water from the hydrated cement paste, calcinations or phase transformation of aggregates
As discussed above, the concrete is severely affected by the temperature, and thus in this research programme the mechanical and near surface characteristics are studied.

1.2 Objective of the proposed work
The main objective of the present research is to study the behaviour of ternary blended steel fibre reinforced concrete when subjected to sustained elevated temperatures for 3 hours. The temperatures considered for the study are 200°C, 400°C, 600°C, 800°C and 1000°C. The ternary blend combinations that are used in the research work are (FA + SF), (FA + GGBFS), (FA + MK). In each combination 30% of cement was replaced by each of the ternary blends. To achieve the above objective following experimental programmes are planned.
1. To find the optimum percentage of steel fibre to be used with respect to workability and strength parameters.
2. To find the optimum mix proportion of various ternary blends with respect to workability and strength characteristics of steel fibre reinforced ternary blended concrete.
3. To study the behaviour of various steel fibre reinforced ternary blended concrete with optimum percentage of steel fibres when subjected to sustained elevated temperatures like 200°C, 400°C, 600°C, 800°C and 1000°C.
4. To find the near surface characteristics such as water absorption and soroptivity for steel fibre reinforced ternary blended concrete when subjected to sustained elevated temperatures.
5. To develop a mathematical model for the strength characteristics for steel fibre reinforced ternary blended concrete when subjected to different sustained elevated temperatures.
1.3 Scope of work

This study helps to know the behavior of specialized concrete at sustained elevated temperatures which can be used in industrial chimneys, cooling towers, gasification and liquification tanks and vessels which are subjected to high temperature in the field of metallurgical, chemical, power, glass and cement industries. These specialized concretes would also be used extensively to meet the demand towards the new thrust of atomic power generation to resist the effects of artificially induced high temperatures such as might be encountered near furnaces or in atomic reactors, in pavements subjected to jet engine blast, and in areas exposed to fire. Also more importantly this study will also help to make structures and buildings more durable and sustaining in case of accidental fires or against acts of terrorism and war.

1.4 Organization of the thesis.

Chapter 1 deals with small introduction about the behaviour of concrete at elevated temperature, objective of the work and scope of work.

Chapter 2 deals with detailed literature review on temperature effect on concrete, fibre reinforced concrete, different pozzolanas and the need of ternary blended concrete and literature reviews of individual authors.

Chapter 3 deals with the objective of the present study.

Chapter 4 deals with description of the materials used in the experimentation and also brief explanation about the procedure of the experimentations.

Chapter 5 deals with the study of characteristics properties of steel fibre reinforced concrete with varying percentage of fibres, and hence to arrive at optimum percentage of steel fibre to be used.

Chapter 6 deals with the study of workability and strength characteristics of steel fibre reinforced ternary blended concrete.

Chapter 7 deals with the study of behaviour of steel fibre reinforced ternary blended concrete subjected to different sustained elevated temperatures and hence to find the best mix proportion from all the different ternary blended mixes which can sustain high temperature.

Chapter 8 describes the development of mathematical model for the strength characteristics for steel fibre reinforced ternary blended concrete when subjected to different sustained elevated temperatures.

Chapter 9 deals with major findings and conclusions.

Chapter 10 deals with the scope of further studies, research, references, Published work.