CHAPTER 1

INTRODUCTION

1.1 GENERAL

Cement-based materials such as concrete have long been used for the civil engineering infrastructural facilities. However, the deterioration of such facilities all over the world has led to the realization that cement-based materials must be improved in terms of their strength and durability characteristics. The use of silica fume as a mineral admixture is a convenient way of improving the engineering properties of cement-based materials. The increased use of mineral admixtures as cement replacement materials (CRM) in concrete could reduce the greenhouse gas emissions into the environment. To increase the fracture resistance of cementitious materials, fibers are frequently added, thus forming a composite material. The most promising materials used in today’s construction industry are the concrete fiber composites (shortcrete and Steel fiber reinforced concrete). Steel fiber reinforced concrete (SFRC) is increasingly used day by day as a structural material due to the enhanced mechanical properties. Balaguru and Shah (1992) and ACI Committee 544 (ACI 544.4R-1989) have reported that the addition of steel fibers in concrete matrix improves mechanical properties of concrete such as flexural strength, tensile strength, compressive strength, toughness and energy absorption capacity at post-peak load. Steel fiber reinforced concrete has gained acceptance for a variety of applications, namely, industrial floors, bridge decks, pavement and overlays, hydraulic and marine structures, precast elements, tunnel linings, nuclear vessels, repair and
rehabilitation works, blast resistance and penetration resistance structures (Balaguru and Shah 1992; ACI 544.1R-1996).

Steel fibers have distinct advantages over other types of fibers due to their high-elastic modulus and a strong bond with the surrounding cementitious matrix. Steel fibers when added to concrete mix, get randomly distributed and act as crack arresters. Debonding and pulling out of fibers require more energy, thereby the toughness and resistance to dynamic and cyclic loads increases considerably (ACI 544.1R-1996). ACI Committee 544 (ACI 544.3R-1993) states that the flexural strength of fiber reinforced concrete is normally specified for pavement applications while compressive strength is normally specified for structural applications. In certain applications, toughness parameters may also be specified. The improved toughness in compression imparted by fibers is useful in preventing sudden and explosive failure under static loading and in absorption of energy under dynamic loading (ACI 544.4R-1989). Therefore, any attempt made in improving the energy absorption capacity by enhancing the post-fracture stress-transfer capacity of the steel fiber reinforced concrete will therefore be effective in improving the resistance to impact and blast load. Constructed facilities of the world have been deteriorating due to the effect of the natural environment, excessive use beyond the actual design, aging of the materials and general obsolescence. Steel fiber reinforced concrete composites are almost ideal materials not only for already proven purposes, but also for rehabilitation, retrofit, and renovation of the world’s deteriorating structures.

Mineral admixtures, generally used in concrete, are condensed silica fume (SF), fly ash (FA), ground granulated blast furnace slag (GGBS), rice husk ash (RHA) and metakaolin (MK). The characteristics of the above materials are such that they can be effective either for confining concrete pores and/or for improving concrete properties with further cementitious
products. The admixture which has proved to be effective is silica fume. The use of silica fume - a highly pozzolanic material, as a supplementary cementing material (SCM) in concrete, increases the C-S-H gel formation that is mainly responsible for the enhancement of strength and durability by confinement of pore structure in the transition zone, thereby increasing the impermeability of concrete (Aïtcin 1998). High-strength and low permeability are logical developments of presence of silica fume and superplasticizer in concrete (Neville 2000).

Chemical admixtures have become one of the essential components of concrete in recent years. The most commonly used chemical admixtures are the superplasticizers, which have the ability to enhance the workability of concrete considerably. Superplasticizers (SP) are used to lower the water-binder (w/b) ratio of the mix and to produce high-strength and durable concrete with adequate slump, in combination with SCM. With the advent of SP it was possible to drastically lower the water-cement ratio (w/c) of concrete. This technology breakthrough has resulted in the development of high-performance concrete (HPC).

1.2 NEED FOR THE PRESENT STUDY

The use of high-strength concrete (HSC) in construction industry has steadily increased over the past years, which has led to the design of smaller sections. Reduction in mass is also important for the economical design of earthquake resistant structures (ACI 363-1992; Chin and Mansur 1997; Swamy 1987). The brittle response of HSC/ HPC has apparently set some limitations on its widespread use, due to sudden and catastrophic failure, particularly, in structures which are subjected to earthquake, blast, or impact loads. The brittle nature of HSC/ HPC can be overcome by the addition of discrete fibers of shorter length and smaller diameter in the
concrete matrix. In the case of HSC, the increase in concrete strength reduces its ductility. This inverse relation between strength and ductility is a serious drawback on the widespread use of HSC/ HPC for various civil engineering applications. However, a compromise between these two characteristics of concrete in general can be obtained by adding discrete steel fibers of smaller diameters (Wafa and Ashour1992; Ezheldin and Balaguru 1992). The ductility of HSC, in terms of the post-peak compressive stress-strain behavior, can be improved by the addition of steel fibers (Naaman and Homrich 1985; Mansur et al. 1999). Although a number of researchers have investigated the effect of inclusion of discrete steel fibers on the mechanical properties and stress-strain behavior of concrete, research on the use of fibers, especially that of steel fibers in HPC, is particularly lacking.

Various researchers have developed empirical expressions/mathematical models for the estimation of strengths of high-strength fiber reinforced concrete (HSFRC), only for the particular water-cementitious materials (w/cm) ratio and specimen parameters. The models developed by various researchers so far have their own limitations in practice, and therefore could not be applied for all types of specimen parameters and a wide range of w/cm ratios. Further, performance of composite materials of HPSFRC under dynamic load (repeated impact), which has a wide range of practical significance, has been investigated rarely. Information available on the durability aspects of HPSFRC with and without SCM is also lacking. To the researcher’s knowledge, literature available is rather scarce on the behavior of steel fiber reinforced concrete (SFRC) composite elements. Therefore, there is an urgent need to focus on the mechanical properties, mathematical modeling of strength, durability characteristics, and structural behavior of high-performance steel fiber reinforced concrete (HPSFRC).
1.3 OBJECTIVES AND SCOPE OF THE PRESENT STUDY

Based on the gaps identified in the area of HPC and SFRC, the present research is set to study on high-performance steel fiber reinforced concrete (HPSFRC).

The objectives of the present research work are:

- To study the static mechanical properties of high-performance steel fiber reinforced concrete (HPSFRC);
- To study the dynamic (impact) mechanical properties of HPSFRC;
- To study the durability characteristics of HPSFRC under chosen conditions, and
- To study the behavior of HPSFRC plate elements under combined in-plane compressive and uniform transverse loads.

The scope of the present investigation was taken up to study experimentally the mechanical and durability properties of HPSFRC with silica fume replacement, using crimped steel fibers and to develop mathematical models for the prediction of 28-day compressive and tensile strengths and to verify the models for validation. The structural behavior of HPSFRC element is complex and therefore, the study is also focused on the test on the behavior of SFRC elements subjected to in-plane and transverse loads, and to develop an analytical model for predicting the out-of-plane central deflection.

1.4 ORGANIZATION OF THE THESIS

Discussions in this chapter (Chapter 1) show the necessity and importance of the investigations on the mechanical properties, modeling of
compressive and tensile strengths, and durability characteristics of HPSFRC, and the behavior of HPSFRC plate elements. Chapter 2 deals with the review of literature for this research work. Chapter 3 describes the experimental investigations of this research work. Chapter 4 presents the results and discussion on static and dynamic mechanical properties of HPSFRC, and the development of statistical models involving non-dimensional parameters for the prediction of compressive and tensile strengths. The durability properties studied are also discussed in this chapter. Chapter 5 discusses the behaviour of HPSFRC plate elements subjected to in-plane and transverse loads. The conclusions drawn from this study and suggestions for further research are presented in Chapter 6.