CHAPTER 1
INTRODUCTION

1.0 Self Compacting Concrete

The development of Self Compacting Concrete (SCC) by Professor Hajme Okamura in 1986 has made a remarkable impact on the construction industry by overcoming some of the problems associated with fresh concrete. The SCC in fresh form addresses many problems associated with the skill of workers, complexity of reinforcement, type and shape of structural section, pumpability, segregation resistance and, more particularly, compaction. The Self Compacting Concrete, which is rich in fines content, is proved to be more durable. Started in Japan, number of investigations were reported worldwide on the mix design of SCC and its micro-structure and durability aspects. However, the Bureau of Indian Standards (BIS) has not brought out a standard mix procedure although number of agencies and researchers carried out extensive investigations to establish rational mix design procedures and self compactibility testing methods. The composition of Self Compacting Concrete is similar to that of normal concrete, that is, cement, fine and coarse aggregates, water, mineral and chemical admixtures. The notable difference of SCC from normal concrete is that, the SCC has more fines content, high range water reducing agents (Super Plasticizers) and Viscosity Modifying Agents (VMA) which alter the rheological properties to some extent.
The advantages of SCC over normal concrete include increased productivity, more uniform and cohesive material with few or no honeycombs, improved strength and durability characteristics, good finish, adaptability in congested reinforced sections, reduction in the size of structural members and so on. The workplace environment is improved by SCC by eliminating noise pollution and creating safe environment to formwork due to elimination of compaction by vibration leading to pleasant work atmosphere.

Therefore the SCC is described by the Concrete Society and BRE (2005) as a quiet revolution in the construction industry. This has resulted in using SCC in a massive way in pre-cast products industries also in Europe and elsewhere. However, the increase in fines content and usage of admixtures make SCC more sensitive with reduced robustness when compared with normal concrete requiring more understanding and greater quality control.

Developed in Japan in 1986, major construction projects in Japan started using SCC in late 90s. As of today, in Japan, the percentage of SCC in annual production in Ready Mixed Concrete (RMC) and Pre-Cast Concrete is reported to be around 1.2 percent and 0.5 percent of concrete products respectively. The estimated SCC production per day in the construction industry in the United States of America is about 128,000 m$^3$ in the first three months of 2011. It is about 1 percent of annual RMC production. As years passed, the usage of SCC grew tremendously worldwide. However, India is not in
the forefront of using SCC, though a lot of research is going on in various aspects of the mechanical behaviour and structural applications of SCC. Although SCC has proved to be an efficient material, there is a need to conduct more research on the standardization of self compacting characteristics and its behaviour when used in different structural elements, paving way for the acceptance of its usage in all hazardous and inaccessible project zones for greater quality control.

1.1 Fibre Reinforced Self Compacting Concrete

Concrete technology has undergone revolutionary changes in the recent past with the availability of various grades of cements and mineral admixtures. Though there are notable improvements, some problems still remained. When compared to materials like steel, these problems can be regarded as drawbacks for this cementitious material. Concrete, which is a ‘quasi-fragile material’ has the drawback of very low tensile strength and its ductility is almost nil. The solution to these two problems to some extent is addition of fibres. This is found to increase the energy absorption apart from bridging the cracks retarding their propagation. Fibre Reinforced Concrete (FRC) has been prominent since 1960s and much investigation has been reported in this regard. Some important applications of FRC are bridge decks, pre-cast elements, pavements, industrial floors, some critical zones in RCC elements and shotcreting.
The development of FRC has covered the entire range of concrete types using different varieties of fibres in plain and RCC. Further development of latest generation ‘concretes’ in the recent past needs to update knowledge on the behaviour of such concrete with the addition of fibres to make them more efficient and effective. One such latest generation concrete is Self Compacting Concrete (SCC).

Incorporation of fibres enhances the benefits of this special concrete at fresh stage and in the hardened state. Keeping this in view, concrete technologists have concentrated on investigating the mechanical and durability aspects of SCC incorporating different types of fibres which are:

1. Steel fibres
2. Nylon fibres
3. Polypropylene fibres
4. Glass fibres
5. Carbon fibres
6. Asbestos fibres

Hybridization of different types of fibres in concrete is another concept which is proved to offer more attractive and enhanced properties to concrete. Hybrid fibre concept consists of using a combination of minimum two types of fibres which use the potential properties of fibres more efficiently. Many studies were reported by different researchers on the characteristics of conventional concrete with hybrid fibre reinforcement. In the present study, the effect of
Hybrid Fibre Reinforcement consisting of Glass and Steel Fibres in SCC is sought to be investigated. For this purpose, investigations were made to explore the behaviour of Steel Fibre Reinforced SCC (SFRSCC), Glass Fibre Reinforced SCC (GFRSCC) and Hybrid Fibre Reinforced SCC (HFRSCC) under axial compression in both unconfined and confined states. As the fibers used in the present investigations are of steel and glass, a brief description of these fibers is given below.

1.1.1 Anti-Crack High Dispersion(HD) Glass Fibres

These are designed chopped strand glass fibres prepared for uniform dispersion in the concrete to prevent cracking, and improve other characteristics of concrete. These fibres can be used in the conventional concrete mixes at low dosages of 0.6 kg/m³. The high aspect ratio of these fibres has an effect on the setting period while the large number of fibres gives a close distance between the fibres. Some important characteristics of these anti-crack HD glass fibres are rapid dispersion, easy and safe handling, facilitating homogeneous mix, control of cracks at fresh and hardened states, and enhancing durability.

1.1.2 Steel Fibers

Steel fibres are proved to be very effective in conventional and SCC concrete mixes for enhancing their properties. Steel fibres of different diameters, aspect ratios and shapes have been successfully
used. Slurry Infiltrated Fibre Concrete (SIFCON) is one type of special concrete with high performance characteristics. Studies on the incorporation of steel fibre in SCC, that is, Steel Fibre Reinforced SCC (SFRSCC) provided feasible and attractive solution to some problems posed by SCC.

1.1.3 Hybrid Fibre Reinforcement

It has been reported that hybridization of fibres further enhances the efficiency of fibre reinforced concrete. As individual studies on GFRSCC and SFRSCC have shown, both types of fibres enhance the efficiency of SCC in terms of mechanical properties and durability. A combination of glass and steel fibres are used in the present studies to investigate the behaviour of HFRSCC. The proportion of glass fibres to steel fibres is obtained from trial mixes to satisfy fresh and hardened properties.

1.2 Stress-Strain Behaviour

One way of determining many physical properties is to study Stress-Strain behaviour. One can predict how the material will behave when it is subjected to different working loads. This enables safe and efficient design of structural elements. The continued studies on the Stress-Strain behaviour of FRSCC and developing models, allow accurate prediction of their behaviour. Predicting the Stress-Strain behaviour of FRSCC in confined states accurately and improving the existing models or developing new models, reveal many factors that have an effect on the Stress-Strain behaviour. There are many
parameters whose effects have to be incorporated in the modeling which include material properties, fibres, confinement and age. The confinement of concrete is the prime requirement in critical zones such as beam-column joints when subjected to seismic loads as prescribed in IS:13920. The introduction of fibres in concrete helps in confining the concrete in such critical locations of beam-column joints for developing ductility resulting in reduction of use of confinement steel. Many models have been developed to predict the behaviour. However, little information is available on the effect of confinement using fibres in SCC and to explain the Stress-Strain behaviour of HFRSCC consisting of Glass and Steel Fibres in Confined and Unconfined States. Hence studies were carried out on the HFRSCC under axial compression in unconfined and confined states, and mathematical models were discussed based on those proposed by Saenz (1964) and Mansur et al (1997).

### 1.3. Wall Panels

According to Varghese (2003), the length of a vertical load bearing member which is more than four times its thickness, is called a wall. The walls in buildings, apart from their structural function, enclose the building and protect the inmates from environment, divide the total building space into various functional requirements and help in providing security. These walls support different floors or roof slabs and resist lateral loads caused by winds, earthquakes and other eventualities. Based on the type of materials of construction, the walls are classified as follows:
1. Brick Masonry walls
2. Stone Masonry Wall
3. Concrete Walls
4. Reinforced Concrete Walls
5. Reinforced Masonry Walls
6. Prestressed Concrete Walls
7. Fibre Reinforced Concrete Walls

Earlier, the concrete walls were mostly designed for environmental protection setting aside their capability as structural members. However, with the passage of time, Reinforced Cement Concrete (RCC) walls have gained in importance as load-carrying members in the light of investigations carried out and various other codes incorporating allowable design stresses. At present, the RCC walls are used as,

1. Integral components in the structural system, and
2. Shear walls resisting lateral and seismic loads.

As the use of SCC has gained popularity, it has become indispensable for its use in walls in multi-storeyed structures. Its increased use in structural systems and increased acceptance of tilt up pre-cast structures seem to be the reasons for this importance. At present, many codes of practices have given design equations which are intended for designing load bearing walls supported at bottom and top. When these walls become slender they undergo buckling, a phenomenon not considered in the designs of conventional concrete
members. Further, no studies have been reported on the behaviour of SCC wall panels when subjected to axial compression and buckling. Hence the present work has been taken up to study the structural behaviour of SCC wall panels with minimum eccentricity. Investigations were carried out to find out the critical loads for Plain SCC and Fibre Reinforced SCC. The fibres used in the present research are Glass Fibres, Steel Fibres and Hybrid Fibres obtained by mixing glass and steel fibres in suitable proportion for maintaining the fresh properties of SCC mix. Using the properties obtained from the studies on fresh and hardened states, the SCC and FRSCC wall panels were cast and tested under compression for critical loads. These experimental results were compared with the loads obtained by carrying out suitable structural analysis procedures. The detailed procedures are explained in the chapters that follows.

Specifically, this thesis is divided into Eight Chapters. While the current Chapter deals with introduction of Fibre Reinforced Self-Compacting Concrete (FRSCC), the next Chapter defines the scope and objectives of present investigations on FRSCC. The 3rd Chapter traces the scholarly work already done in this area and identifies the theme to be covered in this study not explored so far. In the following Chapter, experimental investigations on different kinds of FRSCC are taken up. In the 5th Chapter, the results of the experiments covered in the earlier Chapter are presented. In the next Chapter, the results of the experiments conducted on FRSCC are discussed. In the
penultimate Chapter, the structural application of FRSCC as wall panel and the related results are dealt with. In the final Chapter, all the findings of the foregoing Chapters are summed up.

Before concluding this dissertation, it is reiterated that FRSCC developed with hybrid fibre can be used as structural wall panel member for future application.