CHAPTER 1
INTRODUCTION

1.1 HIGH PERFORMANCE CONCRETE (HPC)

1.1.1 General

High performance concrete (HPC) is a new type that offers high compressive strength. Though it has been primarily used in high strength applications, in the very near future it will be mostly specified and used for its high durability. The American Concrete Institute (ACI) defines HPC as a concrete having special combination of performance and uniformity requirements that cannot be attained by conventional methods like normal mixing, placing and curing practices. The name HPC represents mixtures that possess the following three properties: high workability, high strength, and high durability (Mehta & Aitcin 1990). According to ACI, the durability under severe environmental condition is an optional requirement and not a mandatory one.

Hence HPC has few benchmark properties. It is classified based on its strength being equal or more than 60 MPa, and the water/binder value of 0.40 (Aitcin 1998). This value is close to full hydration of Portland cement (Powers 1968).

HPC could also be made using the conventional technology, provided the materials should be carefully selected and controlled (Freedman 1971, Perenchio 1973, Blick & Petersoen 1974). HPC has good segregation
resistance and high durability. This is achieved by using higher quality ultra fine material (Aitcin 1998).

1.1.2 Origin of High Performance Concrete

- A long practical and commercial experienced with High performance concrete in various business during more than 25 years.
- The role of Hans Henrik Bache researcher during his whole professional career as a pioneer development of High performance concrete in future and our history.
- The first interesting results obtained by the scandinavans in usual concrete, the very impressive discoveries of Bache and co-workers Denmark and significant research effort in the early 1980.

1.1.3 Principles of High Performance Concrete

- One of the most important principles is to uses of the least amount of cement in HPC.
- Uses of preserving natural resources, since the cement is the most expensive and energy consuming ingredients compare with the other constituents of the concrete.
- Economic reasons of saving the cost of materials and energy.
- Application of presetting pressure for better compaction.
- Long durability consideration.
- Addition of coir fibers to achieve ductility.

1.1.4 Properties of High Performance Concrete

- High strength and high modulus of elasticity
- High durability and long life in severe environments
- The durability properties are those of an impermeable material. There is almost no penetration of chlorides and sulphates and high resistance to sulphate attack.
- Low permeability and diffusion
- Compaction without segregation
- It has capacity to deform and support flexural and tensile loads, even after initial cracking.

1.1.5 Applications of High Performance Concrete

High strength and superior durability characteristics of High Performance Concrete have already been utilized in many structural applications in various countries. Some of the applications of High Performance Concrete are:

- Bridges – Joigny (France), Greatbelt (Denmark), Akkegawa (Japan), Willows (Canada)
- High rise buildings-Water tower plaza (US), Nova Scotia (Canada)
- Tunnels-La Bauma and Villejust (France), Manche (UK)

1.2 NATURAL STEATITE AND ITS USES

1.2.1 General

Steatite is a type of metamorphic rock, largely composed of talc ore, rich in magnesium. It is composed of hydrated magnesium silicate: \( \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH}_2) \). Steatite is the softest known mineral and listed as 1 on the Mohs hardness scale. It is already used in paint industry, particularly in marine paints and protective coatings. This is used in ceramics due to its high resistivity, very low dielectric loss factor and good mechanical strength. Addition of steatite powder increases the viscosity and mechanical properties of feed stock. The thermal properties of steatite is also good (Karatas et al...
Massive steatite cut into panels is used for switchboards, acid proof tabletops in laboratory, laundry and kitchen sinks, in tubs and tanks, as well as for lining alkali tanks in paper industry. Due to its high melting point (1630°C) (Ministry of mines 2011), steatite can be used in refractory and fire places. It is also quite useful in sculpturing. When fabricated by a combined method of high energy ball milling, cold pressing and sintering, improves thermal properties of ceramics (Hasan et al 2011, Rohan et al 2004). Cement mortars prepared with steatite particles have been investigated for restoration of sculptures and other craftworks. It was observed that highest compressive strength (43 MPa) and lowest apparent porosity (0.19%) were achieved when steatite particles are coarser (ranging from 1.41 mm to 0.42 mm), and 40% of polymeric phase is employed (Cota et al 2012). A special cement-based mortar containing additions of fine powder waste from mineral extraction of steatite has been developed in Brazil, as a composite material for restoration of steatite elements (Túlio et al 2011). The steatite is mostly used in electrotechnics. Stabilization of protoenstatite in steatite body is achievable by the development of small crystals (Witold et al 2004). Improper selection of parameters lead to undesired problems such as separation of the powder-binder mixture and formation of collapses and cracks on the structure of the molded parts. The optimum molding parameters of the feed stocks for the zig-zag shaped mold are determined to be at an injection pressure of 80 to 140 MPa at barrel temperature of 190 to 230°C (Erguney 2011). When a property of powder injection molded steatites is investigated, sintered at 1300°C for 4 hours, a theoretical density of 98% - 99% is achieved. Three point bending and tensile test was performed on the samples sintered at 1200°C to 1300°C. The maximum three point bending and tensile strength values are found to be 154MPa and 47MPa respectively (Urtekin & Tuc 2012). Indian steatite, mined in Rajasthan and Andhra Pradesh, is comparable with the best quality available in other countries. The Steatite mined in India, with more than 92%
brightness, less than 1% Fe₂O₃ and less than 1.5% CaCO₃ is preferred for exports (Ministry of mines 2011). Indian steatite is considered to be the second best in the world next to ‘Italian steatite’. The UFNSP used in this experiment develops M-S-H gel; hence the comparative study of C-S-H and M-S-H is vital. On account of the basic structural difference between the two gel types, M-S-H and C-S-H are essentially immiscible (Brew & Glasser 2005). Magnesium hydroxide (Mg (OH)₂ aka brucite) is a good starting point for the development of low pH cements. pH value of excess brucite in equilibrium with water is calculated to be around pH 10.5 (Tingting & Vande parre 2011). Hence in principle, cement based on the hydration of MgO powder, calcined at low temperature to ensure fast hydration, should yield the desirable pH. According to Tingting & Vande parre (2011) high MgO contents do not affect the pH, where as high silica fume content results in a pH closer to 9.5. Both MgO and Silica fume composition have potential applications for the encapsulation of wastes containing heavy metals (Tingting & Vande parre 2011). All the above studies in this section lead to the motivation of using magnesium rich steatite powder as replacement to cement in HPC.

1.2.2 Ultra Fine Natural Steatite Powder (UFNSP) Used in this Study

Natural steatite known as soap stone is bought in form of panels and was ground to powder by using high quality crushers and super fine grinders. Ultra Fine Mineral Pvt. Ltd facilitated the grinding process. This powder is ground to very fine particles and the particle size is maintained to as low as 5 microns; this is to maintain the fineness of UFNSP to be lesser than that of cement. This UFNSP is used as natural admixture in this study. The properties of UFNSP were discussed in Chapter 4.
1.2.3 Ancient Applications of Steatite

- The 21st-century BCE statue of Iddi-Ilum of Mari is made of soapstone. Soapstone is used for inlaid designs, sculpture, coasters, and kitchen counter tops and sinks. The Inuit often use Steatite for traditional carvings. Some Native American tribes and bands make bowls, cooking slabs, and other objects from soapstone; historically, this was particularly common during the Late Archaic archaeological period.

- Steatite is sometimes used for construction of fireplace surrounds, cladding on metal woodstoves, and as the preferred material for wood burning masonry heaters because it can absorb, store and evenly radiate heat due to its high density and magnesite (MgCO₃) content. It is also used for counter tops and bathroom tiling because of the ease of working the material and its property as the "quiet stone." A weathered or aged appearance will occur naturally over time as the patina is enhanced. Applying mineral oil simply darkens the appearance of the stone; it does not protect it in any way.

- Tepe Yahya, an ancient trading city in southeastern Iran, was a centre for the production and distribution of soapstone in the 5th –3rd millennia BC. It was also used in Minoan Crete. At the Palace of Knossos, archaeological recovery has included a magnificent libation table made of steatite. The Yoruba of West Nigeria utilized soapstone for several statues most notably at Esie where archaeologists have uncovered hundreds of male and female statues, about half of life size. The Yoruba of Ife also produced a miniature soapstone obelisk with metal studs called superstitiously "the staff of Oranmiyan"
• The outer layers of the Christ the Redeemer sculpture are made of Steatite. Rio de Janeiro

1.2.4 Modern Applications of Steatite

• Soapstone has been used in India for centuries as a medium for carving. Mining to meet world-wide demand for soapstone is threatening the habitat of India's tigers.

• In Brazil, especially in Minas Gerais, due to the abundance of Steatite mines in that Brazilian state, local artisans still craft objects from that material, including pots and pans, wine glasses, statues, jewel boxes, coasters, vases. These handicrafts are commonly sold in street markets found in cities across the state. Some of the oldest towns, notably Congonhas, Tiradentes and Ouro Preto, still have some of their streets paved with soapstone from colonial times.

• Currently, soapstone is most commonly used for architectural applications, such as counter tops and interior surfacing. There is currently only one active North American soapstone mine. That mine is found in Central Virginia and is operated by the Alberene Soapstone Company. All other architectural soapstone is mined in Brazil, India and Finland and imported into the United States. Welders and fabricators use soapstone as a marker due to its resistance to heat; it remains visible when heat is applied. It has also been used for many years by seamstresses, carpenters, and other craftsmen as a marking tool because its marks are visible and not permanent.

• Steatite can be used to create molds for casting objects from soft metals, such as pewter or silver. The soft stone is easily carved
and is not degraded by heating. The slick surface of soapstone allows the finished object to be easily removed.

- Steatite can be put in a freezer and later used in place of ice cubes to chill alcoholic beverages without diluting. These are called whiskey stones.
- Steatite ceramics are low-cost biaxial porcelains of nominal composition (MgO)₃(SiO₂)₄. By mass, steatite is approximately 67% silica and 33% magnesia, and may contain minor quantities of other oxides such as CaO or Al₂O₃. Steatite is used primarily for its dielectric and thermal insulating properties in applications such as tile, substrates, washers, bushings, beads and pigments.

### 1.3 ORGANISATION OF THESIS

The body of this thesis comprises seven chapters, after which specific data and calculations for mix design have been included within an appendix. The seven chapters of the thesis, together with their brief description, are presented below.

Chapter 1 the introduction presents a brief description of the whole thesis, that is general introduction about high performance concrete and steatite. It also discusses about the application of both.

Chapter 2 literature reviews of previous research related to the subject of the current investigations in more detail. The subjects discussed within this chapter include, studies on high performance concrete, studies on magnesium based cement and concrete technology and studies on steatite. References on the relevant literatures are separately set at the end of chapter 7.

Chapter 3 describes aim and scope of investigation and different stages of works involved in this research.
Chapter 4 material investigation contains a discussion on the physical and chemical properties of materials used in this research and mix proportions calculated for HPC.

Chapter 5 experimental investigation and mix proportions describes the finding of mixtures for UFNSP admixed HPC, studying the durability response of HPC cubes, ascertaining the flexural behavior of reinforced HPC concrete beams.

Chapter 6 results and discussion presents the description, analyses and discussion of the data obtained from the experimental work.

Chapter 7 conclusions and scope for future work summarizes the outcome of the investigation and presents recommendations that may be carried out in order to enhance the current findings.