CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is being used in the construction industry since long times. Its production is the most significant among all man-made materials with a global production of about 8.8 billion tons per year [1]. However, the use of cement as a binder in a concrete mixture is often criticized by circles concerned with environmental conservation. With the increased use of cement in concrete, there have been environmental concerns both in terms of damage caused by the extraction of raw materials and emission of carbon dioxide (CO_2) during cement manufacture. It is reported that to manufacture one ton of Portland cement, 1.6 tons of raw materials and about 6.5 million BTUs of energy is needed, consequently about one ton of CO_2 is released to the atmosphere [2, 3]. It is claimed that world's yearly cement production of 2 billion tons emits about 1.65 billion tons of CO_2, or about 7% of the total greenhouse gas emissions into the atmosphere [1, 4]. Due to the manufacture of Portland cement, it is estimated that by the year 2020, the CO_2 emissions will rise by about 50% from the current levels [3]. In view of such fact, concrete industry worldwide is under pressure to find the alternative binding materials, so the utilization of cement could be minimized.

Enormous efforts have been made throughout the world to reduce the use of Portland cement in concrete. These include the utilization of supplementary cementitious materials and the development of alternative binders to ordinary cement [5]. An effort made in this regard is the development of geopolymer concrete. The geopolymer concrete is an innovative and alternative binding material that does not include Portland cement. Instead, utilizes waste materials that are rich in silica and alumina such as fly ash to produce the binder required to manufacture the concrete.

Up to date research on geopolymer concrete has demonstrated that this new binder material is likely to have enormous potential as an alternative to ordinary Portland cement (OPC) concrete. In recent years, geopolymeric materials have become the focus of increasing interest and have received considerable attention because such materials show environmental benefits due to the reduction in the consumption of natural resources and the decrease in the net production of CO_2. Unlike to OPC, geopolymeric materials are environmentally friendly and need only moderate amount of energy to produce because high temperature calcining is not required. The development of geopolymer technology could contribute to reduce CO_2 emissions by about 80% compared to that of OPC with no economic sacrifices, while at the same time converting a potentially hazardous industrial by-product to a value-added construction material [6].

Prior to the introduction of fly ash, metakaolin was used as a source material in the production of geopolymer concrete, however, since last decade much research has been done using fly ash as the source material of goepolymer concrete [6]. Fly ash, that is rich in silica and alumina, has full potential to be used as one of the source materials for geopolymer concrete. The abundant availability of fly ash worldwide creates opportunity to utilise this by-product material, as a substitute for OPC to manufacture concrete. Utilization of fly ash in the manufacture of geopolymer concrete is an important strategy and appears to be technically feasible in the cement industry. The replacement of cement with fly ash reduces the dependence of the construction industry on cement production. This in turn not only reduces the greenhouse gas emissions and solves the environmental and ecological problems but also significantly minimizes the waste disposal of industrial by-products and conserves the natural resources.

In fact, all concretes almost rely essentially on being fully compacted. Adequate compaction of fresh concrete is essential to achieve good consolidation, uniform properties, strong bond with reinforcement and improved interface between the aggregate and hardened paste [7]. Conventional concrete tends to present a problem with regard to adequate compaction in thin sections or areas of congested reinforcement. Despite of good mix design, inadequate compaction of concrete results in large volume of entrapped air voids, affecting ultimate performance of structures.

Placement of fresh concrete requires skilled operatives to ensure adequate compaction to attain full strength and durability of the hardened concrete. As concrete is produced and placed at construction sites, under situations far from ideal, conventional vibrating concrete in such situations may cause risk to the labour and there are always doubts about the strength and durability of concrete placed in such locations. One of the solutions to overcome these difficulties is the employment of self-compacting concrete (SCC) [8].

SCC is a type of concrete that can flow into places and around obstructions by its own weight to fill the formwork completely and self-compact without any segregation and blocking [9]. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. SCC which was developed first in Japan in the late 1980s in response to the lack of skilled labour and the need for improved durability offers several advantages in technical, economic, and environmental terms over conventional concrete. These include an improved quality of concrete, reduced construction time, easier placement in congested reinforcements, uniform and complete consolidation, increased bond strength, reduced noise levels due to absence of vibration, lower overall costs, and safe working environment [10-12].

Inspired by geopolymer technology and keeping in view the increasing trend to SCC, an attempt has been made to develop an innovative type of concrete that would achieve the combined advantages of the two types of concrete. Self-compacting geopolymer concrete (SCGC) is relatively a new concept and can be regarded as revolutionary development in the field of concrete technology. It is a novel material that involves innovation in the production and casting of concrete. It is a type of concrete that might not require vibration for placing it and could be produced by complete elimination of OPC. Replacing Portland cement with abundantly available by-product material such as fly ash and placing the concrete without external vibration may prove to be the most effective way of resource conservation, environmental protection and time & labour saving. The development of environmental friendly SCGC with acceptable fresh and hardened properties (as illustrated in this study), is extremely helpful for the sustainable development and would provide many benefits to the construction industry.

1.2 Problem Statement

Concrete is probably one of the most widely used construction materials in the world largely due to the availability of its constituent materials, its ease for preparing and fabricating in all sorts of conceivable shapes, its low relative cost, and its minimal maintenance requirements. Massive production of concrete and the associated substantial manufacture of cement have, however, been observed to have a very negative impact. One of the biggest issues of growing concern at the moment faced by concrete industries is the impact of cement production on the environment. Cement, an essential constituent of concrete that typically makes up about 12% of the entire concrete mix, is not an environmentally friendly material. The production of cement not only depletes significant amount of natural resources but also liberates a considerable amount of CO_2 and other greenhouse gases into the atmosphere as a result of decarbonation of limestone and the combustion of fossil fuels. In addition, Portland cement is among the most energy intensive construction materials, after steel and aluminium [1]. To address these problems, the geopolymer technology introduced by Davidovits [6] seems to be a feasible solution.

Until now, a number of studies have been done on the performance of geopolymer concrete, which shows several advantages. Despite of all positive remarks on geopolymer concrete, there exist some concerns about geopolymer concrete that need to be addressed. In a fresh state, geopolymer concrete because of cohesive nature quickly becomes very stiff and reduces the workability of concrete. Placement of fresh concrete in inaccessible or heavily reinforced sections requires high workability. The lack of sufficient workability in such cases makes concrete not to fill the form properly and weakens the bond between the concrete and reinforcement, consequently lowers the ultimate performance of concrete. Literature review indicated that so far no work has been conducted on SCGC. This research is therefore projected from conventional vibrated geopolymer concrete to self-compacting geopolymer concrete to address the compaction problems. By making geopolymeric concrete to be self-compactable, the combined advantages of the two types of concrete, which include reduction of CO_2 emission to the atmosphere, prevention of raw material depletion and easy placement in hard to reach areas within the formwork, can be achieved.

1.3 Aims and Objectives of the Research

This research study dealt with the manufacture of fly ash-based SCGC. The primary aim of this research study was to explore the possibility of producing SCGC made with locally available constituent materials by examining its basic physical and mechanical properties. The specific objectives of this research study were as follows:

1. To develop a suitable mix proportion for fly ash-based geopolymer concrete that would fulfill the self-compactability criteria and could achieve 28-days compressive strength of 40 MPa.

2. To establish the effect of salient synthesis parameters on fresh properties and compressive strength of SCGC.

3. To determine the physical and mechanical properties of SCGC and compare with that of conventional OPC concrete.

1.4 Scope of the Research

To achieve the stated objectives, this study was carried out in two phases. In the first phase, a suitable mix proportion for fly ash-based SCGC that could fulfil self-compactability criteria and could have 28 days compressive strength of 40 MPa was developed. For this, a total of seventeen mixtures using constant fly ash content of 400 kg/m^3 were formulated by varying the mix parameters such as amount of extra water, curing time, curing temperature, dosage of superplasticizer and concentration of sodium hydroxide. The amounts of extra water were utilized as 10%, 12%, 15% and 20%, sodium hydroxide concentrations as 8M, 10M, 12M & 14M, and superplasticizer dosages as 3%, 4%, 5%, 6% & 7% by mass of fly ash. The specimens were cured in the oven at temperatures of 60, 70, 80 and 90°C for 24, 48, 72 and 96 hrs. The key workability characteristics such as filling ability, passing ability and resistance to segregation of fresh SCGC were assessed through slump flow, V-Funnel, L-Box, and J-Ring test methods, following the European guidelines EFNARC for SCC. During this phase, the effects of various mix parameters (such as extra water, curing time, curing temperature, superplasticizer and concentration of sodium hydroxide) on the fresh properties as well as on the compressive strength of SCGC were also investigated. In the second phase of the study, the various physical and mechanical properties of SCGC were determined. These properties included density, water absorption, compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, Poisson’s ratio, and creep and drying shrinkage. Concrete specimens such as 100x100x100 mm cubes, 100x200 mm and 100x150 mm cylinders, 100x100x500 mm and 76x76x285 mm prisms were prepared and tested for this purpose. These properties were then compared against OPC control mixture which was designed based on selected SCGC mix. Analytical models available for conventional cement concrete were also used to compare the experimental results. A schematic diagram of experimental work is outlined in Figure 1.1.

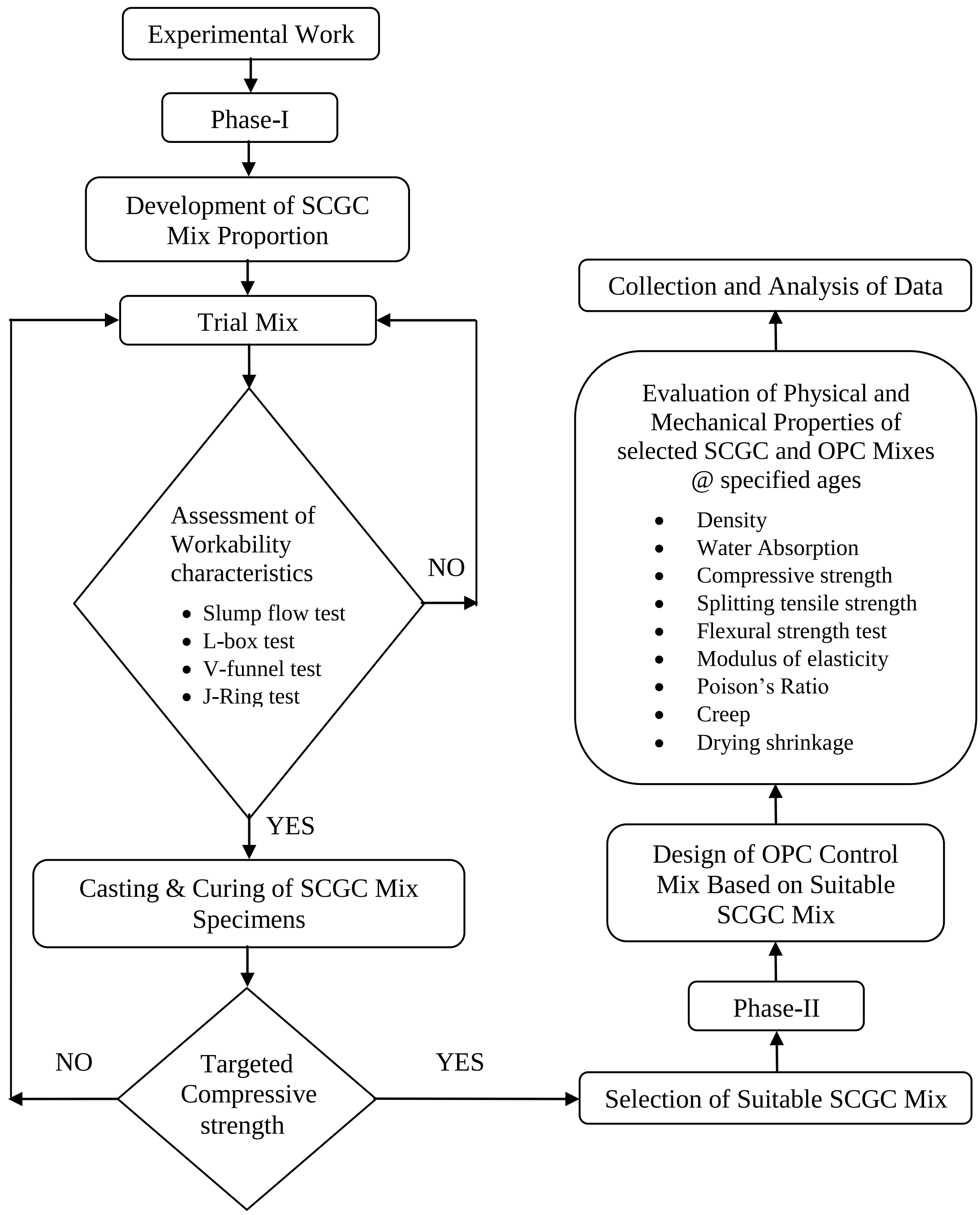

Figure 1.1 Schematic Diagram of Experimental Work

1.5 Disposition of Thesis

The thesis consists of five chapters. It is arranged as follows:

Chapter 1 states background of study, problem statement, aims & objectives and scope of the study.

Chapter 2 describes a review of available and related literature on geopolymer concrete and self-compacting concrete with focus held on the mechanical properties of two types of concrete. The testing methods to evaluate the fresh properties of SCC, the geopolymerization mechanism, and the existing knowledge on constituent materials used to produce geopolymer concrete are also reviewed.

Chapter 3 describes the research methodology including the materials used, design of mix proportions, mixing, casting and curing of test specimens. The equipments and procedures used to evaluate the fresh and hardened properties of SCGC are also explained in this chapter.

Chapter 4 presents and discusses the experimental results and the analysis of the results. The correlations of existing analytical models with the test results and the accuracy of models to predict the behaviour of SCGC is also discussed in this chapter.

Chapter 5 presents the conclusions drawn from the investigation of this study and offers recommendations for future work.

A list of References and Appendices containing the details of experimental data are given at the end of the thesis.