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CHAPTER 1
INTRODUCTION

1.1 Background of the study

1.1.1 Self Compacting Concrete (SCC)

Concrete is about second largest material utilized by human being as food and water are the main consumption. The production of concrete can be obtain by mixing some contents using standard ration and they are cement, fine aggregate, coarse aggregate as well as water. As those mixture added together, it will become a form and become hard like a stone which is called as concrete.

Concrete are more economical compare to the steel as it gives higher compressive strength and don't have corrosive characteristic. As it is locally available materials, it is generally used in all the construction work nowadays.

In order for the concrete to have good strength and durability, the compaction are needed. The compaction basically can be done by using the vibration method and it requires sufficient skilled workers. However, the quality of the construction started to reduce inversely proportional to the reduction of the skilled workers. Okamura who realized the situation proposed the solution which required less amount of workers used which is the concrete can be compacted without being compacted manually [1].

The self compacting concrete or self consolidating concrete [5] was first discovered by Okamura in 1986 after the Japan had a major problem regarding to the durability of concrete structure in the early 1983. The normal concrete basically need to be compacted by using vibrator which required skilled labour worker. Two types of vibrator that are common used on building construction are immersion vibrators and surface vibrators which have their own specific application [3]. In comparison with self-compacting concrete (SCC), it is an innovative concrete which not requires vibration for compacting process. This worldwide man-made material has the ability to flow on its own and can achieve full compaction by itself even in the presence of congested reinforcement [2].

1.2 Problem Statement

1.2.1 Ductility of Self Compacting Concrete

There is ductility problem of self compacting concrete due to high powder content in the concrete.

1.2.2 Shrinkage

In order to produce SCC, the mixture ratio of the cement or powder is the highest compare to other concrete (normal concrete and Roller Compacted Concrete) while the ratio of the gravel is the lowest. The high volume of cement added will cause the concrete to shrink.

1.2.3 Standard Guideline

The self compacting concrete is a new material utilized in the construction industry as t man-made material was completed in 1988. The fundamental study of the mixture have been carried out by numerous researchers until now. Thus, there is no standard guideline to design the self-compacting concrete.

1.3 Objective and Scope of Study

1.3.1 Objective

The objective of this project is mainly to study the performance of the fibre self-compacting concrete incorporated with cement replacement materials. The sub objectives of the project are listed as following :

1. To enhance the ductility of self compacting concrete by adding steel fiber.
2. To design the mixture of the SCC with different type of material ; cement, water as well as chemical additive which is super plasticizer.
3. To study the effect of fiber and SCC mixture with different percentage.

1.3.2 Scope of Study

This project essentially focuses on the performance of steel fibers with the concrete. The concrete basically will be added with some cement replacement material (CRM) like fly ash, microwave incinerated rice husk ash (MIRHA), and silica fume. The performance of steel fibers into concrete is evaluated under some fresh test and hardened test of the concrete. For fresh concrete, the performance of steel fibers can be examined for the test for slump flow, T50 and V - funnel while for the hardened concrete, the steel fibers performance is assessed in terms of compressive strength, tensile strength as well as the flexural test. The outcome to be achieved is by finding out the optimum percentage of steel fibers need to be added into concrete. This correlation may help in understanding the best percentage of fibers added in concrete which is suitable to be used in construction industry.

1.4 Relevancy of Project

Since a lot of concrete used in the construction work, it is important to find out the better improvement for the quality of the concrete for cost saving and future use. Nowadays, numerous type of high rise and mix building have been constructed because the land cost is expensive. In fact, high rise building is more risky and need better concrete for the durability of the building. SCC has special characteristic which is high in ductility, thus the durability of the concrete is also high. Another important aspect is that this material will help to save the construction cost as SCC doesn't need any labour workers for compaction. Besides, it reduces noise levels at construction site, thus, environmental pollution can be prevented.

1.5 Feasibility of Project

The project will be done in two semesters that includes three area of study which are research, development of application and also beta-testing and improvement of the full prototype. The project will involve some experimental works in order to check the good mixture of fibre and SCC. Further testing will be carried out for the better outcome. Based on the description above, it is very clear that this project will be feasible to be carried out within the time frame.

CHAPTER 2
LITERATURE RIVIEW

2.1 Definition

From the report *Self-Consolidating Concrete* by Frances Yang, SCC itself is standing for Self-Consolidating Concrete, or Self-Compacting Concrete and sometimes is called as High-Workability Concrete, Self-Leveling Concrete, or Flowing Concrete. Those terms above are used to specify this highly workable concrete only requires little to no vibration for compaction [5]. It is an innovative concrete that can be compacted into every corner of the formwork by means of its self-weight only does not requires vibration for placing and compaction [2],[4]. It is in want of a standard definition, but may be nominally considered a concrete mix of exceptional deformability during casting, which still meets resistance to segregation and bleeding. The normal consolidated concrete which experience inadequate vibration in heavily congested areas basically will led to surface shrinkage and inadequate bond with the rebar. SCC has low and can be used to make "super-flat" floors without post-pour leveling [5].

SCC has characteristic which is highly flowable in nature due to very careful mix proportioning, usually coarse aggregate is replacing with fines and cement, and adding some chemical additives like super plasticizer. It depends on the sensitive balance between creating more deformability while ensuring good stability, as well as maintaining low risk of blockage [5].

2.2 Development of SCC

It had becoming a major issue regarding to the problem of the durability of concrete structures in Japan early 1983 as the skilled worker started to decrease gradually in the industry. In order to create the durable concrete structure, sufficient amount of labour were required for compaction activity. The only solution to achieve high durable concrete structures was not rely to the quality of construction but to have self-compacting concrete, which can be compacted into every side of a formwork, merely by means of its own weight and vibrating compaction automatically by itself [1]

The SCC idea was proposed into scientific world in Japan in 1986 by Professor Hajime Okamura from Tokyo University [2]. K. Ozawa developed the first prototype in 1988 as a response to the growing problems associated with concrete durability and the high demand for skilled workers [1][2]. SCC become well known throughout the world and it has been the subject of multitudinous investigations so that it can be adapted into the production of modern concrete. Meanwhile, the numerous production of additives have been developed as well as sophisticated plasticizers and stabilizers tailor-made for the precast. In comparison with other high-performance concretes, these concretes have their own special characteristics and differ from other normal concretes and can be only by systematic optimization both of the individual constituents and of the composition [2].

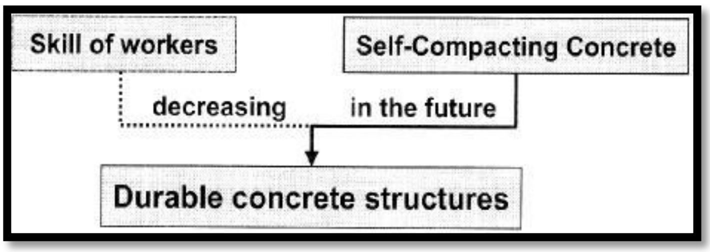


Fig. 2.1: Necessity of Self-Compacting Concrete [1][7]

2.3 Mechanism for achieving self-compactibility

In the making of SCC, it involves considering with a lot of factors that affect deformability and segregation. These factors include water to cement ratio and the several properties of the aggregate: volume, size, distribution, and spacing, void content, ratio between fine and coarse, surface properties, and density. The chemical admixtures like HRWRA, VMA and SCM are other factor need to be highlighted [5],[8]. For overall, Okamura and Ozawa have proposed those formula to achieve self-compactability [2] :

a) Limited aggregate content
b) Low water-powder ration
c) Use of super plasticizer

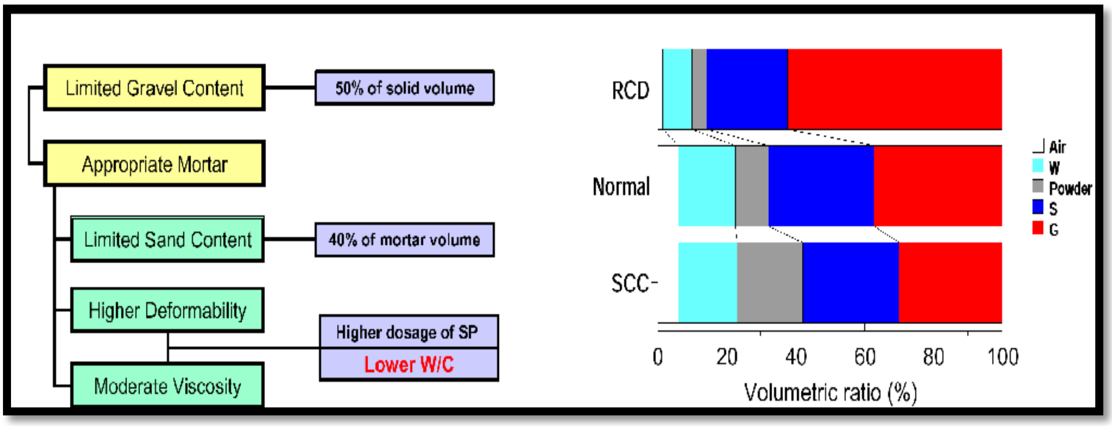


Fig. 2.2 - Methods for achieving self-compactability[1].

In order to make sure the satisfactory achievement of SCC during its wet phase and for its successful categorization, there are three key aspects of workability which need to be carefully controlled *(Ouchi et al 2003)* [10]:

1. Filling ability which mean the ability of the concrete to flow, maintaining homogeneity while undergoing the deformation necessary to fill the formwork completely, encasing the reinforcement and achieving consolidation through its own weight without vibration.
2. Resistance to segregation which mean the ability of the particle suspension to maintain a cohesive state throughout the mixing, transportation and casting processes.
3. Passing facility which mean the ability to pass through closely spaced reinforcement or enter narrow sections in formwork, and to flow around other obstacles without blocking.

2.4 Advantages of SCC

SCC has many advantages such as the followings:

1. From the contractors point of view, SCC has the ability to fill complex forms with limited accessibility, rapid pumping of concrete and improve aesthetics of flatwork for less effort, thus improving the efficiency of the building site as well as shorten the construction period. Besides, the labor operations' cost can be saved [1],[2],[5]

2. There are no poker vibration which gives huge advantages for them to have good quality working environment [2]
3. As there is no vibration omitted from casting operations, the workers experience a less strenuous work because noise and vibration exposure are eliminated especially at concrete products plan [1][2]
4. SCC is believed to increase the durability relatively to vibrated concrete (this is due to the lack of damage to the internal structure, which is normally associated with vibration)

2.5 Ductility of Concrete

Ductility is the strain ability of the materials can take before rupturing. It is the ability of a section to deform beyond its yield point without a significant strength loss A material with high ductility will be able to be drawn into long, thin wires without breaking. A material with low ductility is instead brittle, and though it may be strong, once it deforms enough, it will simply rupture. Ductility can be expressed in terms of displacement, rotation, or curvature ratios. [20]

2.5.1 Importance of Ductility

There are several importance of ductility for concrete :

1. Chances of Sudden failure are minimized due to ductility.
2. Ductility prevent progressive collapse and disproportionate collapses [21].
3. It is also generally accepted that the more ductile a structural form is, the more robust it is [21].
4. Ductility is very important in case of earthquake. It saves from catastrophe and minimize loss of human life in the event of tremor [21].

2.5.2 *Factors Affecting Ductility*

1. The higher tension steel area causes a less ductile behaviour for the section [22].
2. Increase in the steel yield strength also causes a less ductile behaviour for the section [22].
3. Increase in concrete strength causes lessen in ductility [22].
4. The compression reinforcement carries part of the compression force that would be carried by the concrete in a singly reinforced beam, the required depth of the neutral axis is decreased and the section reaches a much higher curvature (higher ductility) before the concrete reaches its maximum useable strain [22].

Use fibres in normal or high strength concrete to increase ductility is also one of the solution. Such concrete is known as Ductile Concrete

2.5.3 *Ductile Concrete Comparison*

Properties/ Material present	**Ductile Concrete**	**Ordinary Concrete**
Cement	Yes	Yes
Fine aggregate	Yes	Yes
Coarse aggregate	May/May not be	Yes
Water/cement ratio	Low	Relatively high
Fibers	Yes	No
Superplastocizer	Yes	May/May not be
Mineral Admixture	Yes	May/May not be
Compressive Strength	High	Normal
Tensile Strength	High	Low

Fig. 2.1: Ductile Concrete Comparison

2.6 Fibers

Low tensile strength of concrete is due to the propagation of single internal crack. If the crack restrained locally by extending into other matrix adjacent to it, the initiation of crack is retarded and higher tensile strength of concrete is achieved [23]. This restrained can be achieved by adding small length fibres to concrete. In addition to increase the tensile strength, addition of fibres enhance fatigue resistance [24], energy absorption, toughness, ductility and durability [25].

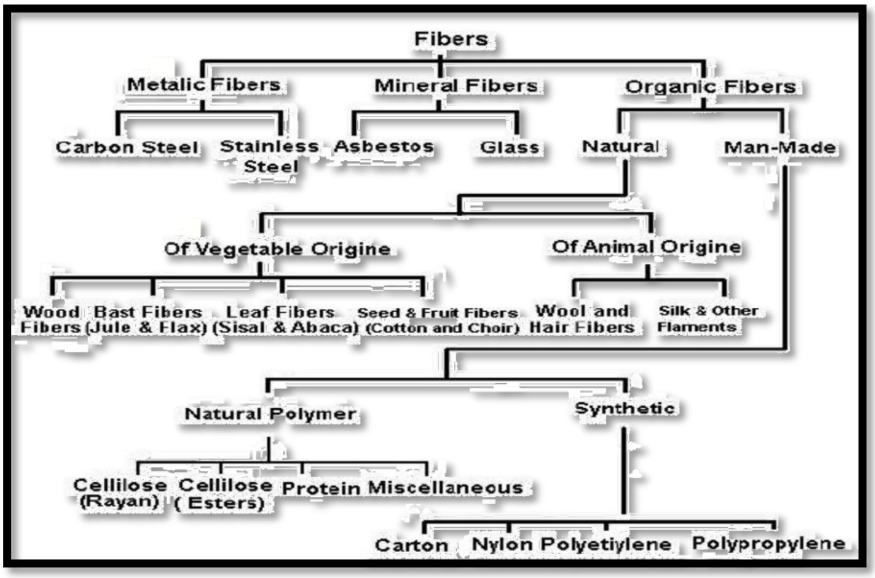


Fig. 2.3: Fibre Classifications (James Patrick Maina Mwangi, 1985)

Behaviour under flexural and direct tension depends upon the fibre type and fibre contents in concrete. For structural applications, deflection hardening or pseudo strain-hardening or both is enviable [26].

2.6.1 Properties of Fiber

1. Fibres are primarily used for their ability to provide post-cracking resistance to the concrete [21].
2. The addition of fibres to concrete in low-to-moderate dosages (1.5% by volume) does not greatly affect compression strength and elastic modulus. Improvements in post-peak behavior, however, have been observed, characterized by an increased compression strain capacity and toughness [21].

3. In tension, the ability of fibres to enhance concrete post-cracking behavior primarily depends on fiber strength, fiber stiffness, and bond with the surrounding concrete matrix [21].
4. Fibres are designed to pullout through the concrete matrix . Thus, the behavior of ductile concrete is highly dependent on the ability of the fibres to maintain good bond with the concrete as they are pulled out [21].
5. Steel fibres of about 5% in volume, increase the cracking resistance, splitting tensile strength and direct tensile strength up to 2.5 times the strength of unreinforced concrete and 10 to 15 times increase the ductility of the member [27].

2.7 Fibre Reinforcement Self-Compacting Concrete

For some researches done, fibers are mixed together with concrete to enhance its tension and compression performance, as well as perseverance and durability of the concrete. Furthermore, fiber reinforced concrete (FRC) has also been proclaimed to give contribution in increased shear and bending resistance in structural members, and to lead to improvement in the bond of reinforcing bars under monotonic and cyclic loading. These advantages enticed researchers to consider and evaluate fiber reinforced concrete for seismic applications as early as in the 1970's. High-performance fiber reinforced cement composites are a class of fiber reinforced concrete characterized by a tensile stress-strain response that exhibits strain-hardening behavior in tension accompanied by multiple cracking up to relatively high composite strains. Typical tensile stressstrain curves for mortar, FRC and HPFRCC are shown in Figure 2.1 *(Namman et al 1996)*. While conventional FRCs exhibit tensile softening response after first cracking, HPFRCCs exhibits a strain-hardening behavior. Researches conducted by Naaman et al *(1996)* illustrate that the unique strain-hardening property of HPFRCCs can be achieved through technological developments involving the matrix, the fiber, the fibermatrix interface and the composite production process. The maximum stress attained by the composite after its first cracking stress is defined as the post-cracking strength, *upc*, with $u_{pc} \geq u_{cc}$, as shown in Figure 2.1.

One the other hand, when conventional FRC is subjected to direct tension, it essentially exhibits a linear behavior until the first cracking stress, u_{cc}, is reached.

For larger elongations, there is a steady reduction in resistance which follows a descending branch up to complete separation as shown in Figure 2.1.

2.7.1 Previous research

Though adding fibers will extend the range of applications of SCC, a reduction in workability due to fiber addition may become a handicap in practice. Besides the fibers, there are also many parameters which affect the flowability of fresh SCC [15]. Indeed, the type, diameter, aspect ratio, and volume fraction of fibers come in addition to the maximum aggregate size, coarse aggregate content, fine aggregate content to play an important role in flowability of SCC with fibers.[10],[15]

An earlier study by Swamy and Mangat (1974) reported that the relative fiber-to-coarse aggregate volume and the fiber "balling up" phenomenon limit the maximum content of steel fibers. Edington et al (1978) observed a relationship between the size of coarse aggregate and the fiber volume fraction. Narayanan and Kareem-Palanjian (1982) found that the "optimum fiber content" (without balling) increased linearly with an increase in the percentage of sand to total aggregates. Johnston (1996) remarked that the distribution of fibers and coarse aggregates was mainly determined by their relative sizes. While considering the effectiveness in the hardened state, Vandewalle (1993) recommended choosing fibers longer than the maximum aggregate size. Gru¨newald (2006) also suggested that the fiber length be 2 to 4 times that of the maximum coarse aggregate size, a recommendation similar to that generally suggested by ACI committee 544.

2.7.2 Experimental Studies on Mixture Design with Steel Fibers

The mixture of steel fibers and SCC has been reviewed by many researchers, which highlights on the development, manufacture and supply of chemicals and cementitious products for the construction industry, has been continuously developing the achievement of mixture SCC and fibers. It is not very easy with for coarse aggregates and fibers to produce good flowable concrete at the same time, so fiber volume fractions were almost low in most previous studies. For the sake of this study, prior research are divided into two category which the first category having a fiber content less than 1.5 % by volume, while the second category having a fiber volume fraction equal to or exceeding 1.5 % [10].

2.8 Chemical admixture

The two principle chemical admixtures :

a) Super-plasticizer (synthetic high-range water reduces)
b) Viscosity Modifying Admixtures (VMA)

2.8.1 Super plasticizer

Superplasticizers causes a significant increase in flowability with little effect on viscosity. This can be explained through the experiment where the addition of 0.3 to 1.5 percent (by weight of cement) conventional superplasticizer to a concrete mix with 50-70 mm slump increases slump to 200-250 mm [5]. This means, it exhibited enormous increases in slumps at the recommended dosage [16].

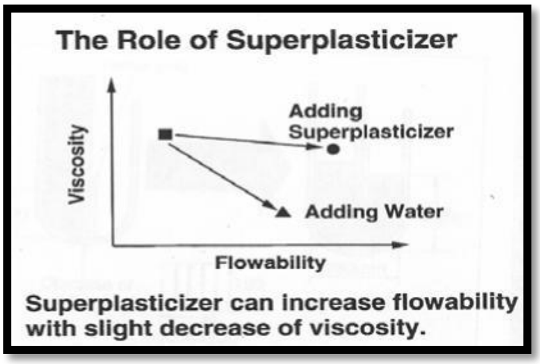


Fig. 2.4: Effects of superplasticizer. (Okamura) [5]

The new generation of superplasticizers is based on polycarboxylated ethers, which act as powerful cement dispersants that require less mix water to provide dramatic increase in flow [5]. At the recommended dosage rates the compressive strengths of test cylinders cast from superplasticized concretes were equal to or greater than the strengths of cylinders cast from the control mix even though no at-tempt was made in these tests to reduce the water-cement ratio. This was true for cylinders compacted by vibration as well as those not compacted by vibration [16].
The requirements for superplasticizer in self-compacting concrete are summarized below :

a) High dispersing effect for low water/powder (cement) ratio: less than approx. 100% by volume
b) Maintenance of the dispersing effect for at least two hours after mixing
c) Less sensitivity to temperature changes

2.9 Cement Replacement Material

Since the discovery of concrete, it keeps evolving from a simple mixture to an advanced concrete technology. Originally, the concrete mixing comprise cement, sand, aggregates and water but nowadays the concrete integrates with chemical admixtures, cement replacement materials and others.

Cement replacement materials also called as supplementary cementitious materials. They are special types of naturally occurring materials or industrial waste products that can be used in concrete mixes to partially replace some of the portland cement. The cement replacement materials can be added in percentage which the amount is depending on the type of CRM used as they have their own desired properties and effect on concrete. It is a material that, when used in conjunction with Portland cement, contributes to the properties of the concrete through hydraulic or pozzolanic activity, or both. Surprisingly, concrete with cement replacement materials can actually give higher in term of strength and also high in durability compare to the concrete which ordinary Portland cement [18].

They are two types of cement replacement materials :

1) Natural (ASTM C 618 Class N)
    i) Produced from natural mineral deposits (e.g. volcanic ash)
    ii) May require heat treatment (e.g. metakaolin)
2) Processed / Manufacture
    i) Silica fume (ASTM C 1240)
    ii) Slag (ASTM C 989)
    iii) Fly Ash (ASTM C 618)
    iv) Rice Husk Ash

Below are the advantages of utilizing cement replacement materials on concrete [19]:

1) Generally enhance the workability and finishing of fresh concrete
2) Reduce bleeding and segregation of fresh concrete
3) Lower the heat of hydration beneficial in mass pours
4) Improve the pumpability of fresh concrete
5) Generally improve the long term strength gain
6) Reduce permeability and absorption (especially silica fume)
7) Reduce alkali-aggregate reactivity

Tables below showing the chemical and physical characteristics of CRM :

Selected Properties of Typical Fly Ash, Slag, Silica Fume, Calcined Clay, Calcined Shale, and Metakaolin							
	Class F fly ash	**Class C fly ash**	**GGBFS**	**Silica fume**	**Calcined clay**	**Calcined shale**	**Meta-kaolin**
Loss on ignition, %	2.8	0.5	1	3	1.5	3	0.7
Blaine fineness, m^2/kg	420	420	400	**20,000**	990	730	**19,000**
Relative density	2.38	2.65	2.94	2.4	2.5	2.63	2.5

Table 2.2 : Physical characteristics of CRM

Chemical Analysis of Typical Fly Ash, Slag, Silica Fume, Calcined Clay, Calcined Shale, and Metakaolin							
	Class F fly ash	**Class C fly ash**	**GGBFS**	**Silica fume**	**Calcined clay**	**Calcined shale**	**Meta-kaolin**
SiO_2, %	**52**	**35**	**35**	**90**	**58**	**50**	**53**
Al_2O_3, %	**23**	**18**	**12**	**0.4**	**29**	**20**	**43**
Fe_2O_3, %	**11**	**6**	**1**	**0.4**	**4**	**8**	**0.5**
CaO, %	**5**	**21**	**40**	**1.6**	**1**	**8**	**0.1**
SO_3, %	**0.8**	**4.1**	**9**	**0.4**	**0.5**	**0.4**	**0.1**
Na_2O, %	**1**	**5.8**	**0.3**	**0.5**	**0.2**	**—**	**0.05**
K_2O, %	**2**	**0.7**	**0.4**	**2.2**	**2**	**—**	**0.4**
Total Na eq. alk, %	**2.2**	**6.3**	**0.6**	**1.9**	**1.5**	**—**	**0.3**

Table 2.3 : Chemical characteristic of CRM

2.9.1 Fly ash

Fly ash is a finely divided residue (a powder resembling cement) that results from the combustion of pulverized coal in electric power generating plants. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called fly ash. It is a waste by-product material that must be disposed of or recycled.

Figure 2.5 : Fly Ash

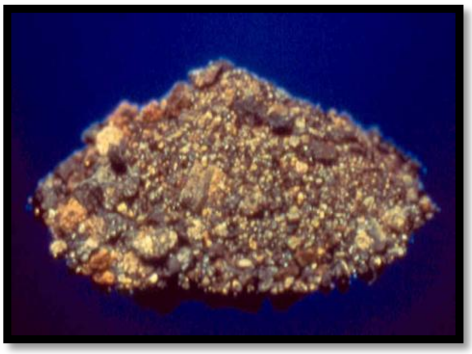


Figure 2.6: Bottom Ash

Figure 2.7 : Bulk Fly Ash

Fugure 2.8 : Boiler Slag

2.9.2 Silica Fume

Silica fume is also referred as microsilica or condensed silica fume. It is produced in electric arc furnaces as a by-product of the production of silicon metals and ferrosilicon alloys which is ultra-fine non-crystalline mineral composition consist of amorphous glassy spheres of silicon dioxide. Silica fume has very small particle size and large surface area and high content of silica dioxide (SiO_2) make it highly reactive pozzolan.

In order to reduce the cement content or as an additive material which can increase the performance of concrete, silica fume is used as a supplementary cementitious materials. Because of the cost is expensive, it is used in small amounts which is between 5% and 10% by mass of the total cementing material. It also has a spherical shape like fly ash but has extremely small particle size which is 100 times smaller than the average cement particle.

The benefit seen from adding Silica Fume are the result of changes to the microstructure of the concrete due to:

1. Physical Contribution

- Adding Silica Fume brings millions of very small particles to concrete mixture.
- Just like fine aggregates fills in the spaces between coarse aggregate particles, Silica Fume fills in the spaces between cement grains.
- This phenomenon is frequently referred to as particle packing or micro-filling .

2. Chemical Contribution

- It is a very high amorphous silicon dioxide content because of that silica fume is a very reactive Pozzolanic material in concrete.
- As the Portland Cement in concrete begins to react chemically it releases Calcium hydroxide.
- The Silica Fume reacts with this Calcium hydroxide to form additional binder material called Calcium Silicate hydrate (C-S-H), which is very similar to the Calcium hydrate formed from the Portland cement .

2.9.3 Micro waved Incinerated Rice Husk Ash (MIRHA)

The present day construction industry is under tremendous compulsion of producing not only strong, but also durable construction materials to cater to the increasing demands, devastating forces, and fast polluting environment. Considerable efforts are being taken worldwide to utilize local natural waste and by product materials to improve the performance of construction materials.

Blending of rice husk ash in cement has become a common practice. Owing to its technological and economical advantages, it has gained its importance. Rice is a primary source of food and nourishment for billions of people especially in the Asian region

About 600 million tons of rice paddy is produced each year throughout the world which generate about 120 million tons of rice husk. Every ton of rice paddy produces about 0.20 tons of husk and on combustion every ton of husk produces about 0.18 to 0.20 tons of ash. Most of the husk produced from the processing of rice is either burnt or dumped as a waste.

When rice husk is burnt in Microwave incinerator, rice husk ash is produced with high reactive silica. At UTP a dedicated microwave incinerator was developed to produce ultrafine rice husk ash (MIRHA) that showed high reactivity in the performance enhancement of concrete. MIRHA has great potential to be a cement replacer MIRHA is capable of producing high strength, high performance and very high durable concrete

Figure 2.9 :MIRHA

2.10 Experimental Work

2.10.1 Slump Test

The slump test is carried out to estimate flowabilility of the concrete. This test is the easiest and most familiar approach to figure out the deformability of SCC [10]. To carry out this test, a standard slump cone is used. The SCC will be poured in the cone it will automatically flow by itself without any compaction effort [5]. In general, the recommended slump flow by researcher should be larger than 600mm [10]. Other researchers state the flow must be in the range from 500mm to 700mm. The flow more than 700mm could lead to segregation of the mix [5].

Figure 2.10: Slump-flow test [2]

2.10.2 V-Funnel Test

V-funnel test for mortar or paste is conducted to find out the characteristic of materials used in self-compacting concrete ; powder material, sand as well as superplasticizer. The indices for deformability and viscosity are Tin and *Rm* [1].

Tin = $(d_1 d_2 - d_o^2)/d_0^2$,

d_r d_2: measured flow diameter; d_o: flow cone diameter

Rm = 1014

t (sec): measured time (sec) for mortar to flow through the funnel

A larger Tin indicates higher deformability and a smaller *Rm* indicates higher viscosity. Characterizing methods for materials were proposed using the Tin and *Rm* indices [

CHAPTER 3
METHODOLOGY

3.1 Methodology

This project will be conducted according to this methodology to meet the objective. In order to achieve the main objective of this project, the goals for the three sub objectives highlighted in the earlier part need to be accomplished. In order to find the performance of fibre self-compacting concrete, detailed review as well as brief research about the topic is focused on the selected papers which concentrate on the design mixture itself. The issues relevancy between the selected papers and our project's objective need to be taken into account to ensure the credibility of this project.

For the other sub objective which is to outline the study of mixture and strength of concrete, literature reviews as well as brief research about the topic are carried out on several resources such as books, journals and also internet.

3.2 Flow Chart

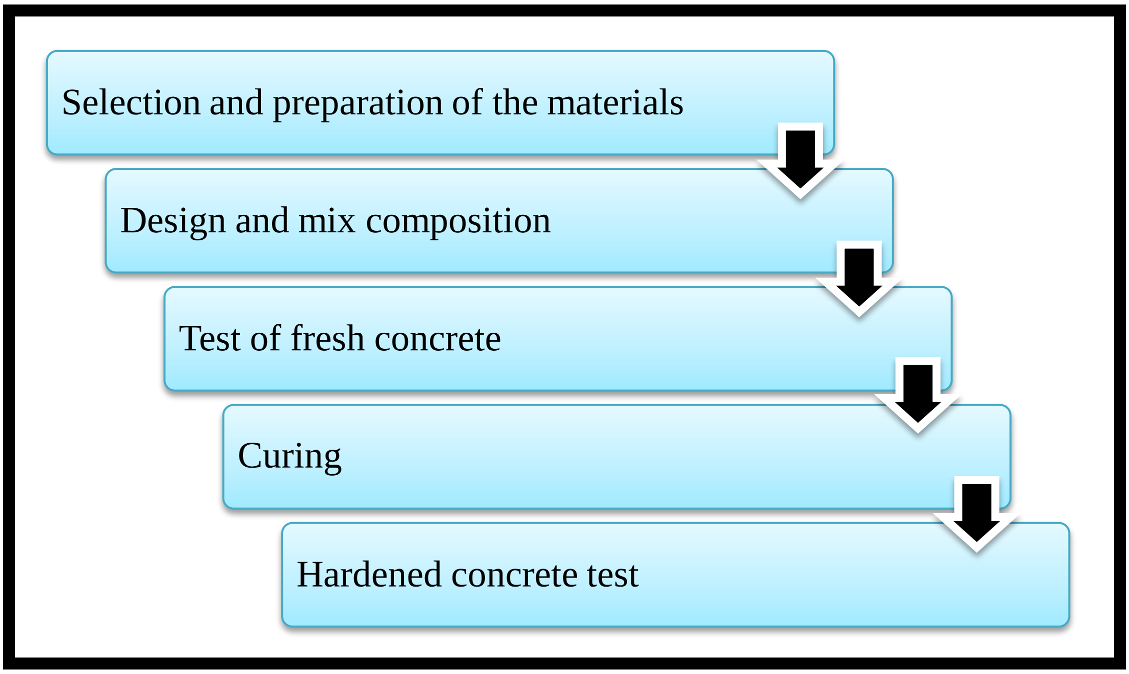


Figure 3.1 : Project flow

Mix design often use volume as a key parameter because of the importance of the need to over fill the voids between the aggregate particles. The mix composition is chosen to satisfy all performance criteria for the concrete in both the fresh and hardened states.

Curing is important for all concrete but especially so for the top-surface of elements made with SCC. These can dry quickly because of the increased quantity of paste, the low water/fines ratio and the lack of bleed water at the surface. Initial curing should therefore commence as soon as practicable after placing and finishing in order to minimize the risk of surface crusting and shrinkage cracks caused by early age moisture evaporation.

3.3 MATERIALS PREPARATION

3.3.1 Aggregates

The materials used in this study were locally available. Crushed limestone with a maximum nominal size of 20mm was used as the course aggregate, and local river sand was used as the fine aggregate in the concrete mixture. The grading of the aggregates is presented in *Table 3.1*.

BS Sieve Size (mm)	Passing (%)	
	Coarse Aggregate	Fine Aggregate
10.00	31.3	-
5.00	3.0	95.9
3.35	2.1	92.3
2.36	1.8	86.6
2.00	-	83.6
1.18	-	69.2
0.60	-	48
0.30	-	24.8
0.21	-	14.4
0.15	-	7.7
Pan	0	0

Table 3.1 : Grading of the coarse and fine aggregate

3.3.2 Cement

ASTM, Type I, ordinary Portland cement (OPC) was used in this project. It was supplied by Tasek Corporation Berhad.

3.3.3 *Cement replacement material (CRM)*

3.3.3.1 *Fly ash*

ASTM C618 defines two type of fly ash which are Class C as well as Class F. For this experiment, only Class F is used as this class has the pozzolanic characteristic which when combined with calcium hydroxide, it exhibits cementitious properties. The physical properties and chemical compositions are provided in *Table 3.2* and *Table 3.3* as well.

Physical properties	Fly ash
Shape	Mainly solid sphere with some hollow cenospheres
Particle size (μm)	5 - 20
Surface area (m^2/kg)	300 - 500
Relative density (specific gravity)	1.9 - 2.8
Colour ranges	From off-white to light gray

Table 3.2 : Physical properties of fly ash

Chemical composition	Portland cement	Fly ash
Silica	21.95%	2.30
Alumina	5.1%	3.7
Lime	63.8%	0.5%
Iron	2.4%	0.2%
Sulphur	2.4%	0.7%
Magnesia	2.7%	9.2%
Alkalines	0.5%	trace
LOI	.2	22.3%
Specific Gravity	3.15	52.8%

Table 3.3 : Chemical properties of OPC and fly ash

3.3.3.2 *Silica fume*

The silica fume in this study is provided by Elkem Sdn Bhd. The physical properties and chemical compositions are provided in *Table 3.4* and *Table 3.5* as well.

Physical properties	Silica Fume
Shape	Spherical in shape
Particle size (µm)	0.1 - 0.3
Surface area (m^2/kg)	15 000 - 25 000
Bulk density (kg/m2)	2.2 - 2.5
Relative density (specific gravity)	130 - 430
Colour ranges	Colours varies from light to dark gray depending mainly on the carbon content

Table 3.4 : Physical properties of silica fume

Chemical composition	Portland cement	Silica Fume
Silica Dioxide(SiO_2)	21%	85 - 97
Calcium Oxide(CaO)	62%	< 1
SiO_2 content	-	Dependent upon alloy

Table 3.5 : Chemical composition analysis of OPC and silica fume

3.3.3.3 Micro - waved Incinerated Rise Husk Ash (MIRHA)

MIRHA is the production of the controlled temperature rice husk. The rice husk is burnt in Micro wave incinerator and rice husk ash is produced with high reactive silica which give high reactivity in the performance enhancement the concrete. The MIRHA used in this study was produced at Universiti Teknologi Petronas (UTP). Below is the table showing the chemical properties of MIRHA.

Chemical composition	Portland cement	MIRHA
Sulfur dioxide (SO_2)	20.3	86.1
Calcium oxide (CaO)	62	1.03
Magnesium Oxide (MgO)	2.8	0.84
Aluminum Oxide (Al_2O_3)	4.2	0.17
Potassium Oxide (K_2O)	0.9	4.65

Table 3.6 : Chemical properties of materials used

3.3.4 Steel fiber

There are many type of steel fibers used in market nowadays like straight type, hooked-end, paddled-type, deformed, crimpled as well as irregular type . For this study, only straight type is used. Below are the characteristics of the straight type steel fiber.

Type of fiber	Code	L(mm)	D(mm)	L/D
Steel - Straight type	WSF0220	20	0.2	100

Table 3.7 : Steel fiber properties

Figure 3.2 : Steel fiber - straight type

3.3.5 Super plasticizer

In this study, the type of super plasticizer used is Sica VicoConcrete - 25MP provided by Sica Kimia. Sica VicaConcrete - 25MP is a third generation super plasticizer for concrete and mortar. It meets the requirement for high range water reducing super plasticizer according to EN 934 - 2.

3.4 Mix Design Proportion

The objective was to find the optimum percentage of steel fibers added into the concrete that shall produce very workable and at the same time very durable concrete. Accordingly, four groups which each of them containing six mixes using different mix proportion of steel fibers plus different type of cement replacement materials (CRM) used were performed. Throughout the project, 24 trial mixes were carried out. The proportions of concrete mixtures are summarized in *table* below.

NO	OPC	FLY ASH		FINE AGG	COARSE AGG	WATER			SP		FIBER	
		%	W		10-5 mm	W/B	W/C	W	%	W	%	W
C_1S_0	420	30	180	900	750	0.32	0.36	192	2	12	0	0
C_1S_1	420	30	180	900	750	0.32	0.36	192	2	12	0.5	3
C_1S_2	420	30	180	900	750	0.32	0.36	192	2	12	1.0	6
C_1S_3	420	30	`180	900	750	0.32	0.36	192	2	12	1.5	9
C_1S_4	420	30	180	900	750	0.32	0.36	192	2	12	2.0	12
C_1S_5	420	30	180	900	750	0.32	0.36	192	2	12	2.5	15

Table 3.8 : Mix design for 70% + 30% Fly Ash

NO	OPC	SILICA FUME		FINE AGG	COARSE AGG	WATER			SP		FIBER	
		%	W		10-5 Mm	W/B	W/C	W	%	W	%	W
C_6S_0	570	5	30	900	750	0.32	0.337	192	2	12	0	0
C_6S_1	570	5	30	900	750	0.32	0.337	192	2	12	0.5	3
C_6S_2	570	5	30	900	750	0.32	0.337	192	2	12	1.0	6
C_6S_3	570	5	30	900	750	0.32	0.337	192	2	12	1.5	9
C_6S_4	570	5	30	900	750	0.32	0.337	192	2	12	2.0	12
C_6S_5	570	5	30	900	750	0.32	0.337	192	2	12	2.5	15

Table 3.9 : Mix design for 95% OPC + 5% Silica Fume

NO	OPC	SILICA FUME		FINE AGG	COARSE AGG	WATER			SP		FIBER	
		%	W		10-5 Mm	W/B	W/C	W	%	W	%	W
C7S0	540	10	60	900	750	0.333	0.370	200	2	12	0	0
C7S1	540	10	60	900	750	0.333	0.370	200	2	12	0.5	3
C7S2	540	10	60	900	750	0.333	0.370	200	2	12	1.0	6
C7S3	540	10	60	900	750	0.333	0.370	200	2	12	1.5	9
C7S4	540	10	60	900	750	0.333	0.370	200	2	12	2.0	12
C7S5	540	10	60	900	750	0.333	0.370	200	2	12	2.5	15

Table 3.10 : Mix design for 90% OPC + 10% Silica Fume

NO	OPC	FLY ASH		MIRHA		FINE AGG	COARSE AGG	WATER			SP		FIBER	
		%	W	%	W		10-5 mm	W/B	W/C	W	%	W	%	W
C8S0	330	30	180	15	90	900	750	0.32	0.582	192	2	12	0	0
C8S1	330	30	180	15	90	900	750	0.32	0.582	192	2	12	0.5	3
C8S2	330	30	180	15	90	900	750	0.32	0.582	192	2	12	1.0	6
C8S3	330	30	180	15	90	900	750	0.32	0.582	192	2	12	1.5	9
C8S4	330	30	180	15	90	900	750	0.32	0.582	192	2	12	2.0	12
C8S5	330	30	180	15	90	900	750	0.32	0.582	192	2	12	2.5	15

Table 3.11 : Mix design for 55% OPC + 30% Fly Ash + 15% MIRHA

SCC mix design varies from the conventional concrete in many ways. The first is that it has high volume of paste, which means that the cement and water in the SCC mix design is higher than conventional concrete. However, the paste ratio should not be too excessive to avoid heat of hydration. This is where the cement replacement materials are recommended to lower the heat of hydration.

Next, SCC mix design needs high volume of fine particles (< 80 micrometer) to ensure good workability and reduce risk of segregation or bleeding. Optimum dosage of superplastiser which in this experiment is about two percent from the weight of total mix is essential to obtain good fluidity. However, a dosage near saturation amount can lead to concrete segregation. To enhance the flowability, SCC requires low volume of coarse aggregate (5-10mm), as this can reduce the chances of a coarse aggregate being stuck at reinforcement bars.

The mix proportions of water cement ratio (W/C) are differ for all of the groups as cement replacement material will affect the workability. The silica fume is 100 times smaller than Ordinary Portland Cement (OPC) thus has higher surface area. It will absorb some amount of water added together, so need to add more water compare to other. It same goes to the MIRHA but in other way, it requires some particular time to release back the water. For the group C3 has the highest amount of the water added as the amount of the silica fume is five percent higher than the group C2, so higher amount of water is needed.

The superplasticzer was incorporated in all mixes. In order to keep constant water/binder ratio, superplasticizer had been used in different dosages in M-series and T-series. The content of SP was adjusted slightly for each mix to find the most efficient dispersion of the cementitious particles. Once the optimum superplasticizer is determined, the dosage of that superplasticizer is used for PFA-series; in this case, a dosage of 7% is used.

3.5 Project Activities

These are the details task done throughout the project.

1. Experimental work :
   a) Experiment on $100m^3$ of cube concrete to check the compression stress at 3, 7 and 28 days.
   b) Experiment on 150 x 200 mm cylinder concrete to check the tensile strength at 28 days
   c) Experiment on 100:100:500 of beam concrete to check the flexural strength at 28 days.
2. For the fresh concrete, the tests that will be conducted are slump flow test, slump T_{50} as well as V-funnel test.

3.6 Mixing and Casting

The concrete mixes were prepared using a pan mixer. The interior of the drum was initially washed with water to prevent absorption. The mixing time is referred from the previous researcher named Modhere, 2009.

Procedure for concrete mixing :

1. The coarse and fine aggregate were mixed first and wait for one minute.
2. The mix followed by the cement and the cement replacement materials and wait for one minute and half.
3. Then, half the water will be added on the mix for one minute and a half. The rest of the water will be added together with the super plasticizer.
4. The mix was left for six minutes to let the water to be absorbed by the aggregates.
5. In the middle of the six minutes, the steel fiber are added.

Note that, steel Fibers must be uniformly distributed and randomly oriented throughout concrete to improve its structural and microstructure properties. Proper mixing method is vital to ensure the homogeneity of the fiber distribution.

Figure 3.3 : Pan mixer

After the mixing was completed, tests were conducted on fresh concrete to determine the rheological properties. The tests conducted were slump flow test, slump T50 and v-funnel test. Segregation and bleeding was visually inspected during the slump flow test. Nine mould of 100-mm cubic specimens, one mould of 100mm x 100mm x 500mm beam and 100mm diameter x 200mm height of column were prepared for each mix proportion. No compaction was applied in any of the mixtures. After 1-day, the specimens were demoulded, and stored in curing tank.

Figure 3.4: Curing tank

3.7 Fresh Concrete Test

For determining the self-compactibility properties slump flow, slump T50 and v-funnel tests were performed and measured. Slump flow test is tested by the flow diameter of the concrete, while slump T50 is tested by testing the flow of concrete by 500mm in second (time) and last but not least is the V - Funnel test which is tested by testing the flow of the concrete in second (time). All fresh test measurements were duplicated and average of measurement was given. In order to reduce the effect of workability loss on variability of test results, the fresh-state properties of mixtures were determined right after mixing.

All the tests for fresh concrete tests are in accordance with *The European Guidelines for Self Compacting Concrete (2005)*, which reference standards is European Standard.

3.7.1 Slump flow test (ASTM 1611)

Slump flow test is proposed for testing filing ability (flowability) and deformability. Slump flow test judges the capability of concrete to deform under its own weight against the friction of the surface with no external restraint present. No compaction energy must be applied during the test so that the SCC flows only under the influence of gravity. It is based on the slump test described in EN 12350-2. The result is an indication of the filling ability of self-compacting concrete.

Apparatus :

1. Abram's cone - standard Abram's con as defined in ASTM C143/C143M
2. Slump flow board - a non-absorbent rigid plate. A circle 500mm in diameter should be marked at the center in order to measure the T_{50} value

The procedure for slump flow test :

In general, the slump flow test for self compacting concrete is about the same as the conventional concrete.

1. Prepare the slump flow board and the Abram's cone
2. The Abram's cone is placed at the center of the board either at normal orientation or inverted.

3. Pour the fresh concrete into a Abram's cone.
4. Then withdraw the cone vertically upwards in one movement, without interfering with the flow of concrete.
5. Without disturbing the base plate or the concrete, the largest diameter of the flow spread of the concrete to the nearest 10mm.
6. Then the diameter of the flow spread at right angles to it is measured, and the mean of the reading is the slump flow.

The concrete spread is also checked for segregation. If segregation is observed, then the test is considered unsatisfactory.

Figure 3.5: Abram's cone

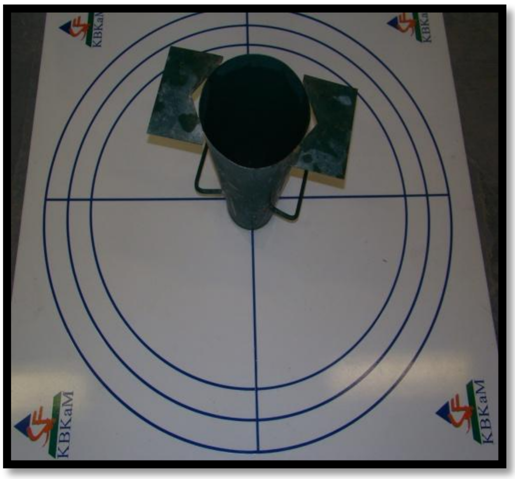


Figure 3.6 : Slump flow board with the 500mm marked in diameter

3.7.2 Slump T_{50} test

This test is to measure the rate which SCC flows which is the time for the fresh concrete to reach 500mm in diameter. The slump T_{50} is measured before the slump flow test result is taken. It provides a relative measure of SCC's plastic viscosity. The lower the time taken (in second) which is higher in T_{50} value, the better the result.

Apparatus :

1. Same as slump flow test apparatus
2. Stop watch

Procedure :

T50 is determined during the slump flow measurement.

1. Prepare the slump flow board and the Abram's cone
2. The Abram's cone is placed at the center of the board either at normal orientation or inverted.
3. Pour the fresh concrete into a Abram's cone.
4. Lift the Abram's cone (start the stop watch as soon as the Abram's cone is lifted)
5. When the fresh concrete reached 500mm in diameter, indicated by a circle marked on the slump flow board, the stopwatch is stopped.
6. Take the reading at the stopwatch.

Figure 3.7: Slump flow and slump T_{50} test

3.7.3 V-funnel

V-funnel test is proposed for testing viscosity and deformability of concrete. The viscosity of a suspension is dependent mainly on the water/solids ratio and the overall grading curve. This means that a SCC with higher water content flows faster out of the funnel and has a lower viscosity than SCC with lower water content.

Apparatus :

1. V shaped funnel
2. Stopwatch

Procedure :

1. The test is carried out by filling a V shaped funnel with fresh concrete
2. The time taken for the concrete to flow out of the funnel is measured
3. The time is recorded as the V-funnel flow time.

Figure 3.8 : V shaped funnel

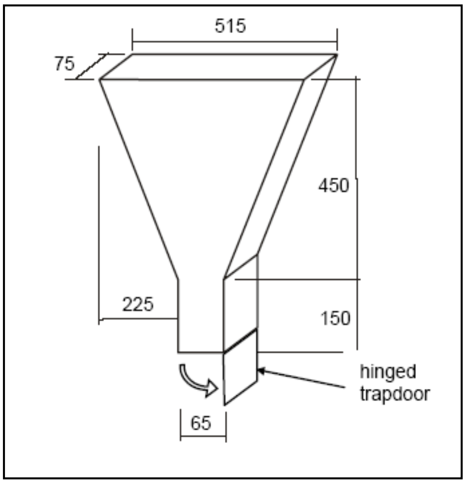


Figure 3.9 : V-funnel dimension

Figure 3.10 : V-funnel test

3.8 Hardened Concrete Test

3.8.1 Compressive strength test

To determine the compressing strength of the concrete, based on the BS 1881 : Part 116: 1983. In BS 5328, the compressive strength is expressed as ‘grade’, which is the minimum characteristic cube strength. The industry still uses the old standard when dealing with concrete types. In the new BS EN 206-1 and BS8500, the characteristic compressive strength is expressed as a strength class.

Apparatus : Compression Testing Machine (it complies with the requirement of BS 1610)

Procedure for compressive strength test :

1. Remove the specimen from the curing tank and wipe the surface water and grit off the specimen.
2. Put the specimen under the sunlight to let them dry (the moisture on the specimen can affect the result of the test)
3. Weight each of the specimen to the nearest kg.
4. Clean the top and lower platens of the testing machine. Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the .
5. Check the reading at the monitor. Change it to suitable type of test (for this test is compressive test) and suitable specimen (cube 100mm x 100mm x 100mm)
6. The load is applied and increased continuously at nominal rate within the range 0.2 N/mm^2 to 0.4 N/mm^2 until no greater load can be sustained. The maximum load applied to the cube is recorded.
7. The type of failure and appearance of cracks is noted.
8. The compressive strength of each cube is calculated by dividing the maximum load by the cross sectional area.

Figure 3.11 : Compression machine (ADR 1500)

3.8.2 Tensile and flexural strength test

The tensile strength test is the test on the column with the size of 100mm in diameter x 200mm height while flexural test is the test on the beam with the size of 100mm x 100mm x 500mm. Both procedure is about the same as compressive strength. The different is, we need to change the mode at the monitor of the type of test and the size of sample.

Figure 3.12 : Tensile strength test

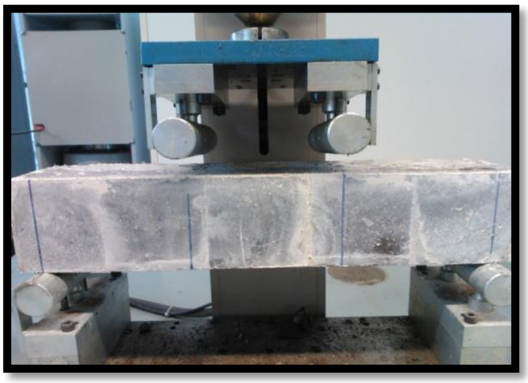


Figure 3.13 : Flexural strength test

3.9 Project Timeline

Several targets have been set for the FYP 2. Table below shows the project activities and key milestones for FYP 2.

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Materials preparation	■	■													
2.	Concrete mixing and casting			■	■	■	■	■								
3.	Test for fresh concrete (slump flow, slump T50 and V-funnel)			■	■	■	■	■								
4.	Test for compressive strength, tensile strength and flexural test				■	■	■	■	■	■	■	■				
5.	Progress report submission								■							
6.	Discussion and analysis on result					■	■	■				■	■			
7.	Submission of dissertation (soft bound) And technical paper													■	■	
8.	Final of project dissertation (hard bound)															■

Table 3.12 Project Activities

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Submission of Progress Report								●							
2.	Pre - EDX											●				
3.	Submission of Draft Report												●			
4.	Submission of Dissertation (soft bound)													●		
5.	Submission of Technical Paper													●		
6.	Oral Presentation														●	
7.	Submission of Project Dissertation (Hard Bound)															●

Table 3.13: Key Milestone

CHAPTER 4
RESULT & DISCUSSION

4.0 RESULT & DISCUSSION

In this study, there are four groups all together. Every single group represent the type of cement replacement materials added into the concrete. Each group consist of six sample which every single of the sample represent the percentage of the steel fibers added in the mixture.

Group :

Group C_1 : 70% OPC + 30% Fly Ash
Group C_2 : 95% OPC + 5% Silica Fume
Group C_3 : 90% OPC + 10% Silica Fume
Group C_4 : 55% OPC + 30% Fly Ash + 15% MIRHA

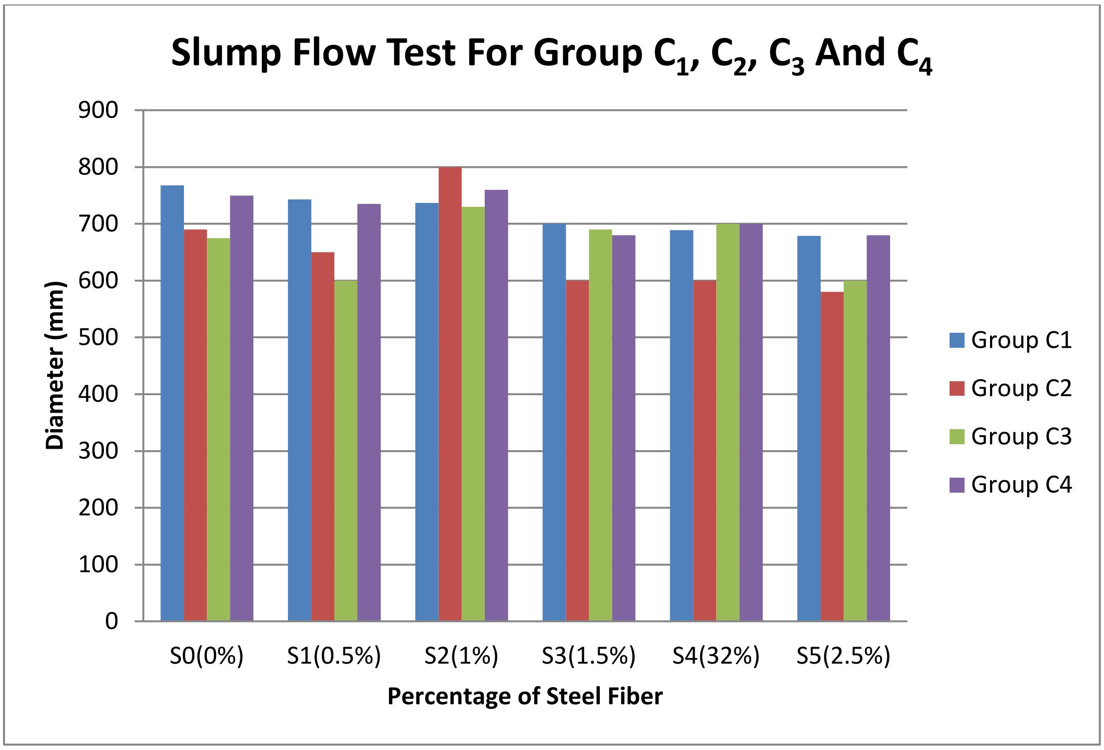
Mix sample :

C_xS_0 : 0% steel fiber
C_xS_1 : 0.5% steel fiber
C_xS_2 : 1.0% steel fiber
C_xS_3 : 1.5% steel fiber
C_xS_4 : 2.0% steel fiber
C_xS_5 : 2.5% steel fiber

4.1 FRESH CONCRETE TEST RESULTS

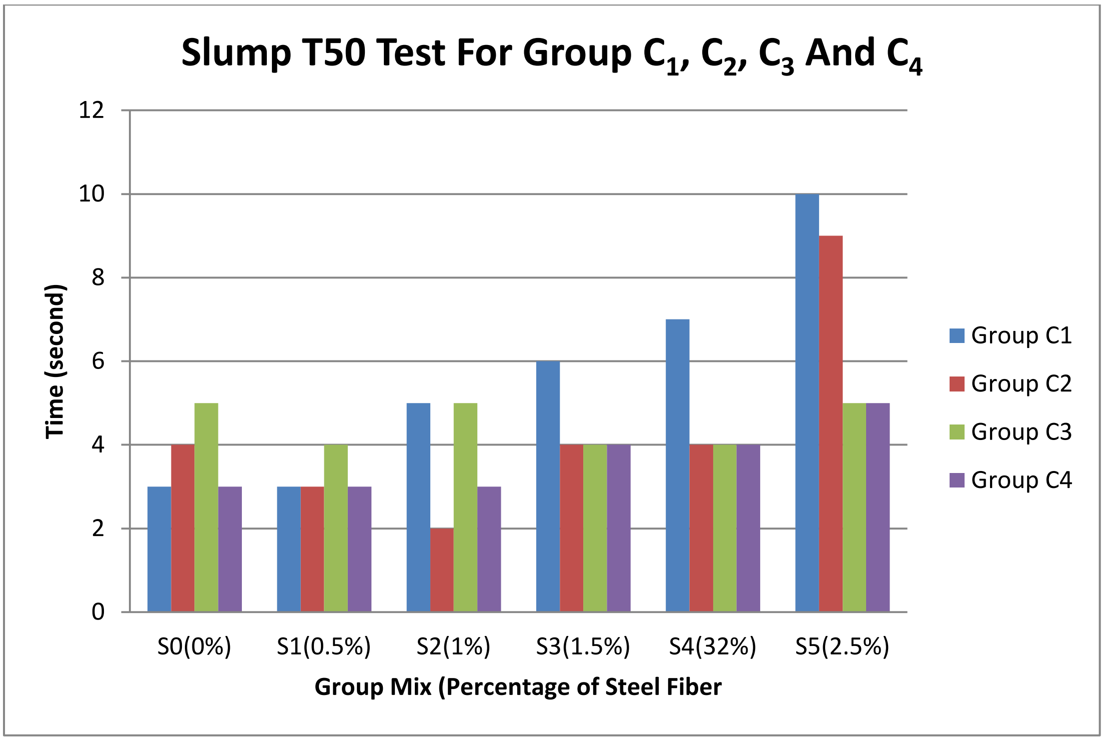
Mix	0%	0.50%	1%	1.50%	2%	2.50%
Slump Flow Test (Group C1)	768	743	737	700	689	679
Slump Flow Test (Group C2)	690	650	800	600	600	580
Slump Flow Test (Group C3)	675	600	730	690	700	600
Slump Flow Test (Group C4)	750	735	760	680	700	680
Slump T50 Test (Group C1)	3	3	5	6	7	10
Slump T50 Test (Group C2)	4	3	2	4	4	9
Slump T50 Test (Group C3)	5	4	5	4	4	5
Slump T50 Test (Group C4)	3	3	3	4	4	5
V - Funnel Test (Group C1)	7	8	8	12	13	15
V - Funnel Test (Group C2)	7	7	6	11	35	80
V - Funnel Test (Group C3)	7	7	6	6	8	11
V - Funnel Test (Group C4)	6	7	6	20	26	32

Table 4.1 : Fresh concrete test reult



Graph 4.1 : Slump flow test comparison among all the group

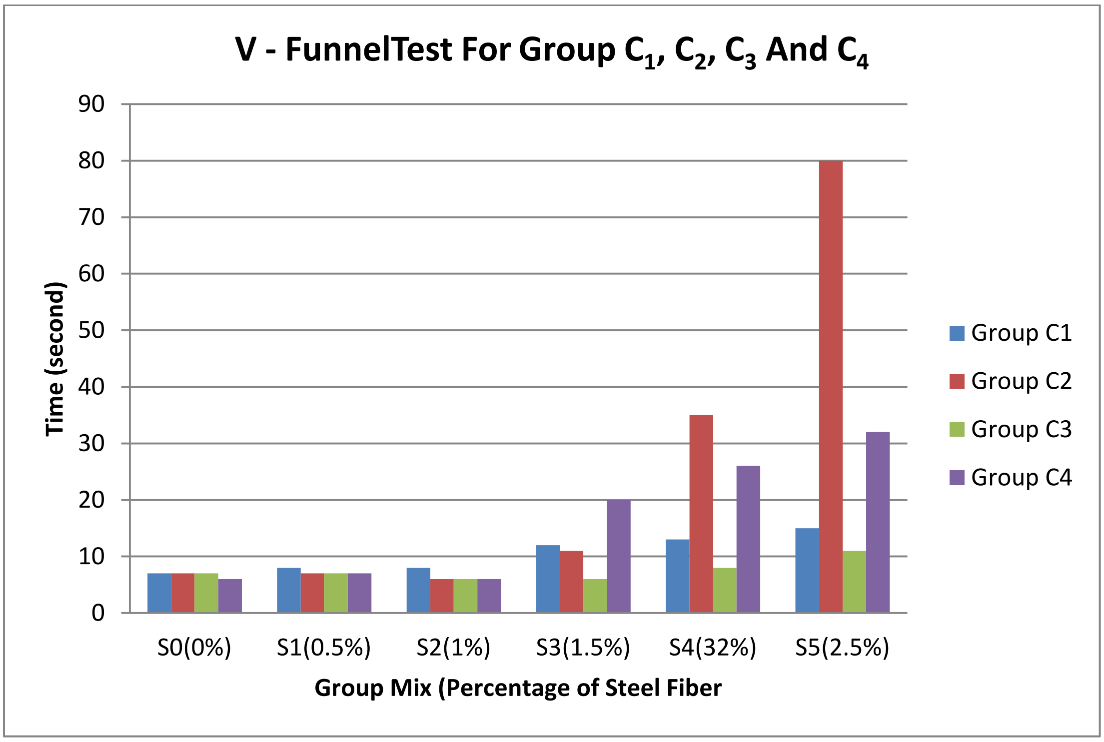
For the slump flow test, the highest result showing the good sample which mean that particular sample has high flowability which in term of fresh concrete it is good. For the group C_1, it shows that the sample with no additional steel fibers give the highest result which is 768mm in diameter. The result for this group also showing that as the percentage addition of steel fiber increase, the result is eventually decrease. It means that the addition of steel fiber in the concrete will affect the behaviour of the fresh concrete. Group C_2 also showing the same result but there is sudden increase of result at the percentage of 1.0% which the result is increasing from 650mm to 800mm and the decrease back to 600mm at the percentage of 1.5%. The result then started to decrease eventually from the percentage of 1.5% to 2.5%. For the group C_3 and C_4, the result is almost the same as the group C_2 which the result at the sample S2 give the highest result. But the different between the group C3 and C4 with group C2 is that the sample S4 give high result compare to sample S3 but still lower than sample S2.



Graph 4.2 : Slump T_{50} test comparison among all the group

Slump T_{50} time is a test to assess the flowablity and the flow rate of SS in the absence of obstruction as per stated on the slump test test described in EN 1235-2. It is a time to measure the fresh concrete speed flow and hence the viscosity. In order for the fresh concrete to be characterized as SCC, the slump T_{50} should passing the time range of 2 - 5 second.

Group one shows a good result for the sample of S0, S1 and S2 but as the percentage of fiber addition increase, the value T50 time from S3 to S5 start to decrease. Group C_2 also give a good result from S0 to S4. It shows that addition fiber of 1% is very good for this fresh test as the time is about 2s while the result for S5 for this group is fail because it is out of the time range which is 9s which given the same result as the sample S5 group C_1. Group C3 and C4 are satisfying the SCC requirement for the T50 test as the result are in the range of 2 - 5 second.



Graph 4.3 : V - funnel test comparison among all the group

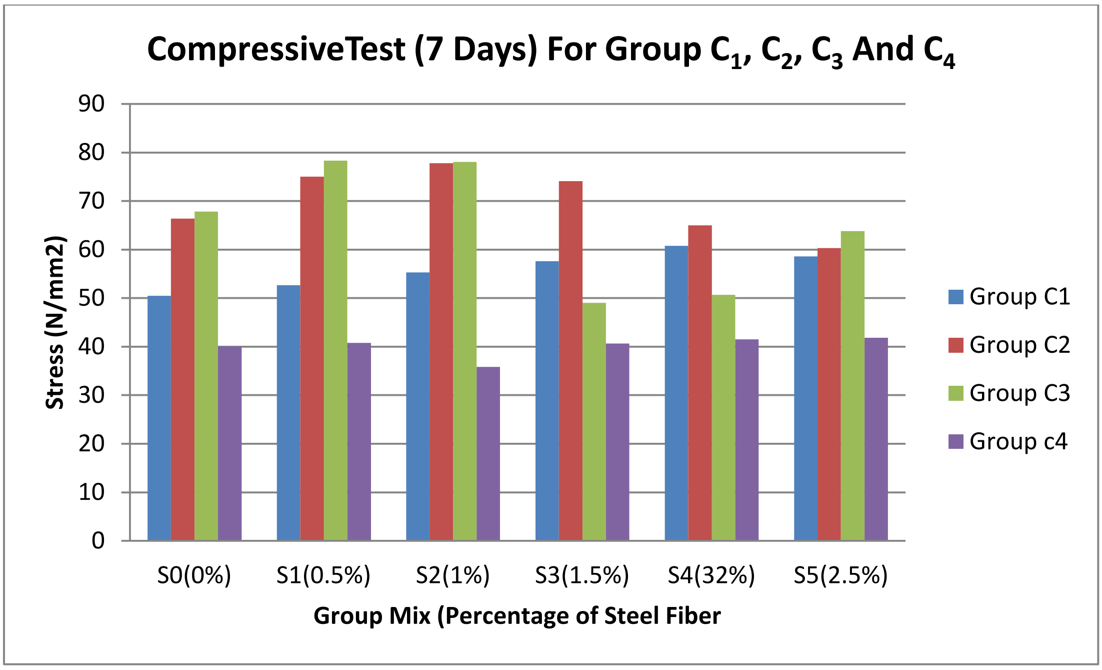
The recommended value for V-funnel test for mix to be characterized as self compacting concrete should be on the range of 6 - 12 second. For the group $C_{1,}$ the result showing that on sample S0 - S3 satisfy the time within the range. Sample S4 and S5 give the result of 13s and 15s respectively thus is not good enough to be recommended as self compacting concrete. Group C_2 result also same as the group C_1 as all the samples satisfy the time range except for the sample S4 and S5 and furthermore the time for sample S5 is high out of the range which is 80s. The result showing that addition of 2.5% into concrete with the mix of silica fume is not very good. Whereby for the group C_3 the result is different compare to the last two groups. All the samples are showing the good results which inside the time range for the requirement of SCC. The result also showing that sample S2 and S3 give the best result which is 6s while group C_4 results stated that the first three sample satisfy the time range while the last three are not.

4.2 HARDENED CONCRETE TEST RESULTS

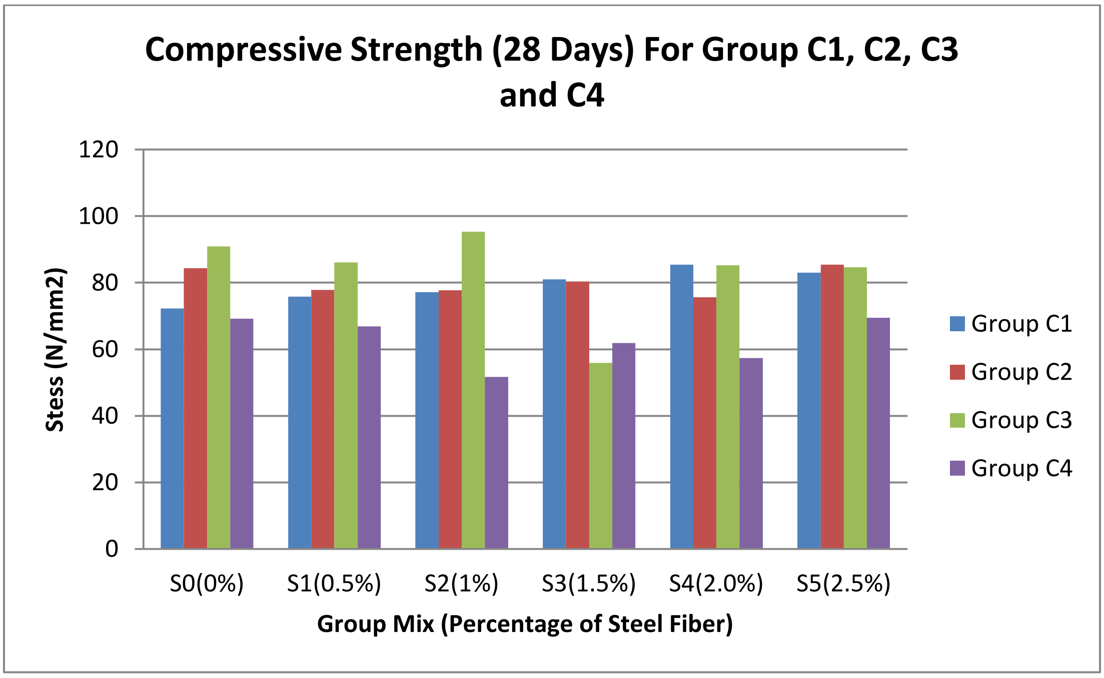
4.2.1 Compressive strength

Mix	0%	0.50%	1%	1.50%	2%	2.50%
Group C1 (7 Days)	50.51	52.63	55.31	57.59	60.74	58.69
Group C2 (7 Days)	66.36	75	77.78	74.05	65	60.28
Group C3 (7 Days)	67.8	78.33	78.05	49.04	50.69	63.8
Group C4 (7 Days)	40.08	40.75	35.81	40.63	41.53	41.81
Group C1 (28 Days)	72.24	75.78	77.15	81.02	85.39	83
Group C2 (28 Days)	84.42	77.88	77.78	80.37	75.67	85.41
Group C3 (28 Days)	90.93	86.08	95.32	55.94	85.21	84.65
Group C4 (28 Days)	69.18	66.86	51.66	61.87	57.34	69.43
Group C1 (56 Days)	81.29	85.4	87.1	90.91	93.26	92.3
Group C2 (56 Days)	90.01	90	92.19	99.18	93	98.01
Group C3 (56 Days)	97.69	96	98.49	85.06	97.1	100.69
Group C4 (56 Days)	90.81	82.15	75.66	82.91	70.73	86.87

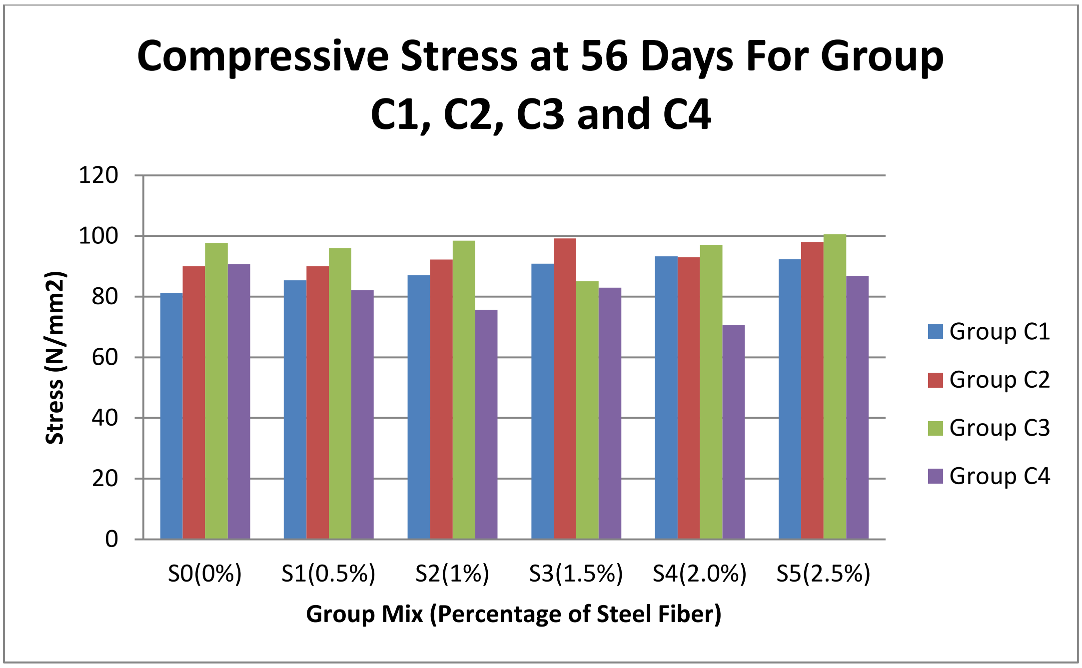
Table 4.2 : Compressive stress for 7 days, 28 days and 56 days



Graph 4.4 : Compressive test (7 days) comparison among all the group



Graph 4.5: Compressive test (28 days) comparison among all the group



Graph 4.6: Compressive test 56 days) comparison among all the group

Discussion for compressive test result 7 days

For the normal concrete:

- Density : *2240 - 2400 kg/m³ (140 - 150 lb/ft³)*
- Compressive strength : *20 - 40 MPa (3000 - 6000 psi)*

The density result showing that all the samples for all the groups have a good result as all of them are in the range of 2240 - 2400 kg/m^3 and some of the exceed 2400 kg/m^3

Result for group C_1 showing that the increase the percentage of steel fiber addition into concrete, the higher the compressive strength but the strength at addition of 2.5% is decrease.

Result for group C_2 showing that the addition of steel fibers by 1.0% gibe highest strength compare to other sample. The pattern of the chart showing that the compressive strength start to increase for 0% of steel fiber until the addition of 1.0% the it start to decrease eventually. Sample S5 shows the lowest result.

Result for group C_3 showing that addition of steel fibers by 0.5% give highest strength which is 78.33N/mm^2 follow by addition of 1.0% which the result is about the same which is 78.05N/mm^2. While the addition by 1.5% give lowest compressive strength.

For group C_4, the graph showing that the result of addition steel fibers by 2.5% give highest strength which is 41.81N/mm^2 compare to others while addition by 1.0% give the lowest compressive strength which is 35.81N/mm^2

Discussion for compressive test result 28 days

Compare with compressive test at 7 days, compressive test at 28 days give higher result. For overall result, group C3 give the highest result compare to others in fiber addition of 1%. Addition MIRHA into concrete do not give good result compare to others. However, its result showing that all of them (addition of steel fiber) are above 40Mpa which still good. It can be concluded that for the compressive strength at 28 days, the optimum fiber addition is 1%.

Discussion for compressive test result 56 days

It is generally known that by increasing the curing time by 56 days can increase the result for compressive strength. Basically the result increase by 10Mpa to 25Mpa from the result of 28days. Moreover, with later ages of test results used, the result showing that by increasing the time for curing will increase the strength and thus improves the durability of concrete in terms of heat generation in hydration and other aspects.

Group 1 showing that the strength is increasing by increasing addition of fiber addition but other groups result are uneven. All of the group except for group C4 give high result which in the range of 80Mpa to 100Mpa. For overall result, the highest strength is at addition of 1.5% of steel fiber by group C2.

Figure 4.1 : Cube with no fiber addition

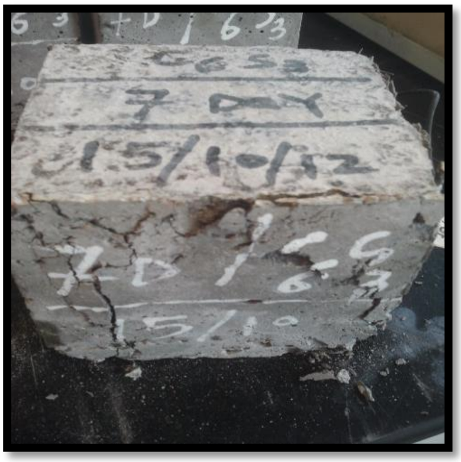
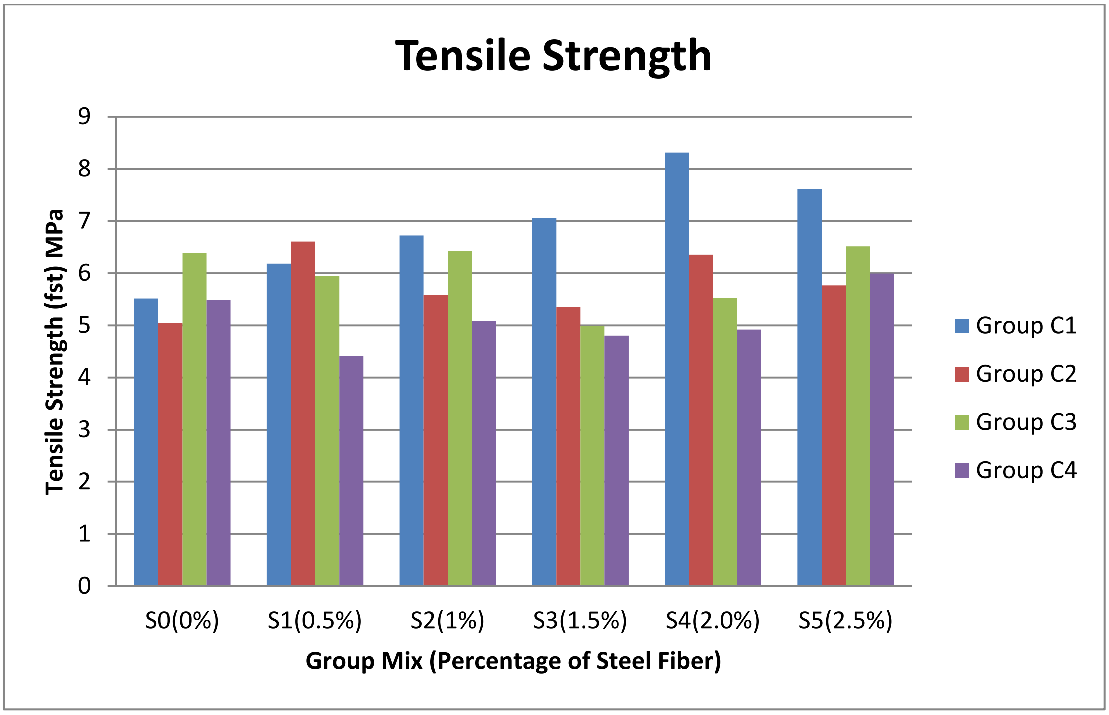


Figure 4.2 : Cube with fiber addition

4.2.2 Tensile strength

Steel fiber dosage (%)	Group C1	Group C2	Group C3	Group C4
0	5.51	5.043	6.386	5.488
0.5	6.18	6.604	5.942	4.412
1	6.72	5.58	6.429	5.086
1.5	7.053	5.347	4.993	4.801
2	8.312	6.352	5.519	4.918
2.5	7.618	5.766	6.515	5.989

Table 4.3 : Tensile strength test result



Graph 4.35: Tensile strength comparison among all the group

For the normal concrete, standard tensile strength is about *2 - 5 MPa (300 - 700 psi).* Compare with the graph above, it shows that SCC with fiber addition increase the tensile strength. Some of the results are in the range of 2 - 5 Mpa but most of them are more than that. For this test, group C1 which is 70%OPC + 30% Fly Ash gives highest result which is 8.312Mpa. It shows that the optimum fiber addition is about 2%.

The result showing that, it may be noted that the maximum value attained was 8.312Mpa which the tensile strength increase 66.24% by addition of 2% steel fiber. Thus ductility of concrete increase as steel fiber is added. The pictures below showing the result of self compacting concrete with fiber addition and no fiber addition. With no fiber addition, the result of the concrete is totally crash while with fiber addition only cracks appears on the column. It can be noted that the column can stand more tension, thus high ductility.

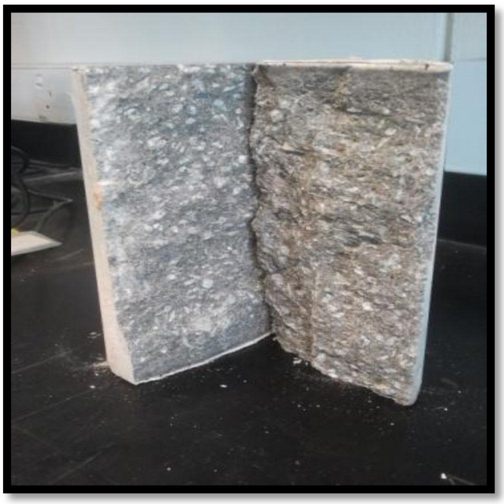


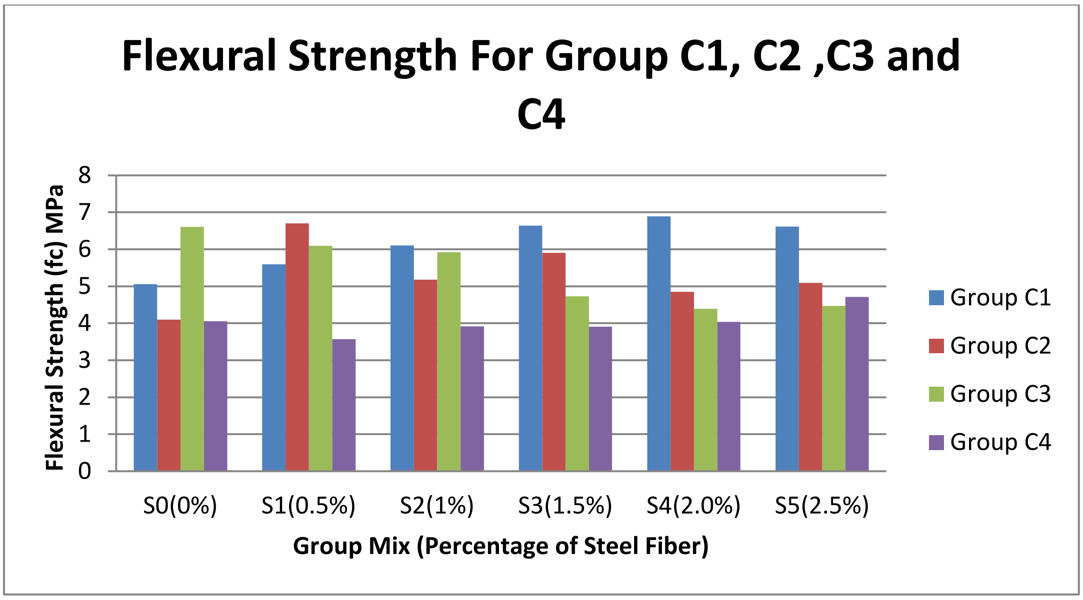
Figure 4.3 : Cube with no fiber addition

Figure 4.4 : Cube with fiber addition

4.2.3 Flexural strength

Steel fiber dosage (%)	Group C1	Group C2	Group C3	Group C4
0	5.057	4.095	6.608	4.057
0.5	5.592	6.698	6.092	3.575
1	6.106	5.182	5.921	3.918
1.5	6.637	5.902	4.732	3.906
2	6.89	4.852	4.389	4.037
2.5	6.612	5.093	4.471	4.715

Table 4.3 : TFlexural strength test result



Graph 4.40: Flexural strength comparison among all the group

For flexural test, normal concrete is about *3 - 5 MPa (400 - 700 psi)* which about the same as tensile strength.

Basically, group C4 gives the lowest result but still in the range of 3 - 5 Mpa. Group with highest result is group C1 with the fiber addition is about 2% which is same as tensile test result. The maximum strength is 6.89Mpa which increasing by 37.8% from normal concrete flexural strength. Its showing that adding of steel fiber will increase the ductility of concrete.

The pictures below showing the result of beam with fiber addition and no fiber addition. With no fiber addition, the result of the concrete is totally crash while with fiber addition, the beam bend without breaking into two pieces and only cracks appears on the column. It can be noted that the beam has high in flexural strength, thus high ductility.

Figure 4.1 : beam with no fiber addition

Figure 4.2 : beam with fiber addition

CHAPTER 5
CONCLUSION & RECOMMENDATION

5.1 Conclusion

Improving the performance of SCC is of great importance for modern construction material. The objectives of this project are to determine the optimum percentage addition of steel fiber to SCC and also to investigate the effect of cement replacement material in SCC. In this study, steel fibers had been added in order to improve the performance of concrete. A total of 24 successful mixes had been achieved for this project. All the 24 mixes had been tested for fresh concrete and for hardened concrete test, the test which already been conducted is compressive strength for 7 days, 28 days and 56 days, tensile strength as well as flexural strength. Based on the results presented in this paper, the following conclusion can be drawn.

1. Increase of steel fibers in the SCC affect the workability of the concrete. In the fresh concrete test which including all three test, slump flow, slump T50 and V-funnel, it shows that as the percentage addition of steel fiber into SCC increase the result will decrease. It shows that increase in steel fiber addition will affect the flowability of SCC. The optimum steel fiber addition is about 1% from the weight of the mix.
2. The compressive strength of SCC not giving much different between normal concrete. From this test also, it shows that as the steel fiber increase, the compressive strength will decrease.
3. Higher strength in both tensile and flexural strength showing that adding of steel fiber will increase the ductility of self compacting concrete. The concrete has higher strength to stand tension flexural stress.
4. It indicates that for a successful SCC mix, the most important parameter is the amount of free water in the mix. Every cement replacement materials have different properties which could affect the workability of SCC if the amount of water is not enough. Adequate water to cement ratio should be observed, as well as the saturation level of the aggregates.
5. Incorporation of CRM in SCC give different result for each of the group. Concrete with the mixture of silica fume give high compressive strength while the addition of MIRHA give lower compressive strength. It shows that

addition of silica fume give high early age strength while addition of MIRHA give lower early age strength.

5.2 Recommendation

The following is the recommendations in dealing with SCC, which are proposed for future researches.

1. The research shall tests for steel fiber incorporated concrete up until 90-days to get more accurate and higher result, since in this project, 7-days concrete shows lower strength but still higher compare to the normal concrete. The 90-days concrete will have the potential to obtain higher result.
2. To study the effect of CRM on SCC at constant water to cement ratio, a wider range of SP dosage is needed.
3. During the mixing of SCC, tests of moisture content should be carried out more frequently, since SCC is more sensitive than normal concrete to variations. Aggregate moisture should be kept constant for all mixes.
4. Further study for 90days and 120 days compressive strength can be done for determining better strength.

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