Properties of Self Compacting Concrete (SCC) Containing Different Pozzolanic Materials

By

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CERTIFICATION OF APPROVAL

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Approved by,

(Assoc. Prof. Dr. Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMMAD ZULFAHEEM BIN SUHAIMI

ABSTRACT

Self Compacting Concrete (SCC) is a high performance concrete which can consolidate by its own weight without mechanical vibrations into every part of the formwork while maintaining its homogeneity. The objectives of this project are to determine the optimum dosage of superplasticizer to satisfy the rheological requirements of SCC according to the standard practices in fresh state and to determine the optimum replacement of Pulverized Fly Ash (PFA) and Silica Fume (SF) as substitute of cement on the basis of hardened concrete properties which are compressive strength and porosity. This study shows the optimum dosage of Superplasicizer (SP) to satisfy rheological requirements of SCC and optimum replacement of PFA and SF as substitute of cement. Two main groups of SCC which are SCC without pozzolan and SCC with pozzolan have been investigated. SCC mix without pozzolan has been used to determine the mix which has optimum amount of Superplasticizer (SP) which later will be used as main SCC mix to test the optimum amount of pozzolan for SCC mix with pozzolan. From this study, it has been found that the optimum amount of Superplasticizer to be used in Self Compacting Concrete (SCC) is 2.5%, the optimum amount of Pulverized Fly Ash (PFA) as cement replacement material in Self Compacting Concrete (SCC) is 5% and optimum amount of Silica Fume (SF) as cement replacement material in Self Compacting Concrete (SCC) is 5%.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS AND NOMENCLATURES

SCC: Self Compacting Concrete

CVC: Conventional Vibrated Concrete

SF: Silica Fume

PFA: Pulverized Fly Ash

HRWR: High Range Water Reducer

OPC: Ordinary Portland Cement

C-S-H: Calcium Silica Hydrates

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Self-compacting concrete (SCC) is one of the most outstanding advances in concrete technology during the last decade. Due to its specific properties, SCC may contribute to a significant improvement of the quality of concrete structures and open up new fields for the application of concrete (Holschemacher & Klug, 2002). As the name suggest, this type of concrete does not need vibration and compaction process during the pouring process due to its composition and behaviour. SCC is compacting itself by its own weight without bleeding or segregation and flow freely in every part of the mould thus filling the formwork completely without any vibration means. SCC is a better choice compare to Conventional Vibrated Concrete (CVC) in certain aspects such as reduction in construction time, reduction in manpower for placing and compacting, lesser equipment requirements. SCC has ability to fill complex forms and members with congested reinforcement and eliminate of rubbing and patching as ordinary concrete required to fill defects in poorly consolidated surface (Hurd, 2002).

SCC was first introduced in early 1980's in Japan because of concerns about concrete durability. Researchers also discovered that poor compaction of concrete was a major factor in the declining quality of construction works (Hurd, 2002). However, the development of SCC today is not just because of avoiding vibration process but more towards the growing concern of difficulties of ensuring high quality of complex concrete structures due to indigent compaction of in- situ concrete. This problem eventually endangers the structures in the future. Hence, SCC is believed as one of the solutions to this problem which eliminate vibration process by workers. The use of unskilled workers is also contributes in development if SCC. Thus, by using SCC which is able to compact itself, it can fill the formwork and produce perfect compaction of the concrete

The fresh SCC must be able to flow into and fill all the spaces within the formwork including narrow openings under its own weight. While maintaining this flow, it also must resist segregation. Obeying all these demands, result in mix proportions that differ from CVC (Hurd, 2002).

1.2 Problem Statement

Concrete is used widely in construction field. Currently, the strength of concrete has been achieved of very high level such as 100 MPa and above in order to cater the design need. Usually, high strength concrete possess low water content and low workability which eventually will affect quality of hardened concrete. Thus, the existence of SCC offers solution to this problem. However, SCC still needs further research in Malaysia in order to answer following:

1. No standard guidelines to design the mix of SCC in Malaysia. There are countries in Europe and several countries in Asia which already has their own guidelines. One of the reasons why Malaysia cannot follow their guidelines is because our weather condition is different with country who already has established SCC mix design.

Through this study, standard has been provided for use of SCC in Malaysia in order to help the development of SCC in Malaysia so that, in the future SCC is being used widely around Malaysia.

1.3 Objectives

This study is undertaken to achieve the following objectives:

1. To determine the optimum dosage of superplasticizer to satisfy the rheological requirements of SCC according to the standard practices in fresh state
2. To determine the optimum replacement of PFA and SF as substitute of cement based on hardened concrete properties which are compressive strength and porosity.

1.4 Scope of Study

The scope of this study is to find the optimum dosage of SP to satisfy rheological requirements of SCC and optimum replacement of PFA and SF as substitute of cement based on hardened concrete properties. In this study, two main groups of SCC mixes are examined namely:

- Group 1: SCC mixes without pozzolanic materials
- Group 2: SCC mixes with pozzolanic materials

  Sub- group 2:

- Group 2.1: SCC mixes with PFA as cement replacement materials.
- Group 2.2: SCC mixes with SF as cement replacement materials.

Group 1 will be studied in order to determine the best SCC mix produced with optimum amount of superplasticizer. Then, the selected mixes will be used for Group 2 in order to find the best mix associate with pozzolanic materials.

All preparations of the mixtures and materials have been conducted in UTP concrete laboratory. To carry out the investigations, tests on Group 1 has been carried out first to determine the best mix which possess optimum amount of superplasticizer and satisfy SCC rheological properties. Then, the best mix of group 1 has been used for Group 2. Finally, both groups have undergone hardened concrete tests which are compressive test and porosity test in order to find out the strength obtained for each of the SCC mix.

1.5 Relevancy of the Project

The development effort of SCC and application of SCC has been widely done by numerous countries in Europe such as Sweden and United Kingdom as well as in Asia which is Japan (Goodier, 2003). Thus, Malaysia which currently has no standard mix design for SCC, has to put effort to develop SCC technology in Malaysia so that in the future SCC applications maybe widely studied in Malaysia.

1.6 Feasibility of The Project

This project has been completed within 4 months according to the project planning and schedule. According to initial planning, all SCC mix works has been finished within 6 weeks and the rest of the weeks before evaluation day are kept for testing properties of the hardened concrete as shown in gannt chart.

This project is feasible as the basis has already been studied in Concrete Technology subject. Other than that, the tests and method of implementing this study are not too complicated and concept of SCC is easily understandable to implement and perform the study in short period of time.

CHAPTER 2

LITERATURE REVIEW

Concrete is material that is widely used for construction of building, pavement and foundation mainly consists of gravel and sand which is bonded together due to hydration process of cement and water. Currently as technology advances, concrete also has been developed in order to produce the best concrete as possible. There are many types of concrete such as regular concrete, shotcrete, stamped concrete and also self compacting concrete.

2.1 Self Compacting Concrete (SCC)

Self Compacting Concrete (SCC) is concrete that possesses high ability to flow into all spaces within formwork and narrow openings by its own weight to produce a void free mass and able to compact itself with very little or no mechanical vibration. This concrete was first developed in Japan in 1988 in order to produce durable concrete structures by improving construction works quality (Goodier, 2003). As its name implies, the concrete can consolidate and compact itself by its own weight without or less mechanical vibration. Compaction is a process to release entrapped air within fresh concrete in order to produce a dense concrete which plays important role in determining the ultimate strength of concrete. Initially, SCC was developed as response to reduction in numbers of skilled workers in Japan (Goodier, 2003) Problem always occur in Conventionally Vibrated Concrete (CVC) casting process, where it is compacted by using mechanical vibrator. The compaction process is done by skilled workers. However, gradual reduction of skilled workers has contributed significantly towards reduction of construction work quality (Goodier, 2003). Later, SCC is spread all over the world due to its benefits. SCC not only solves skilled workers shortage but also offers many other benefits such as reduced cost of placement due to elimination of compaction works, shortened time taken for construction and also reduce noise during casting (Holschemacher & Klug, 2002).

In general, basic components of SCC composition are quite similar with CVC. CVC aggregate are generally suitable for SCC but may different in terms of their grading. Portland cement and other fine aggregates such as fly ash and ground granulated blast furnace slag may be needed in larger proportion than in CVC in order to achieve desired cohesion (Hurd, 2002). Other than that, special admixture also needed by SCC to control its flow characteristics, workability retention and viscosity or cohesion of the mix (Hurd, 2002). Okamura and Ozawa have employed these three following methods for SCC in order to ensure SCC will achieve Self Compacting ability (Okamura & Ozawa, 1995):

1. Limited aggregate content
2. Low water- powder ratio
3. Use of superplasticizer

Thus, SCC will have high deformability of paste and also resistance to segregation in its fresh states in order to achieve self compacting ability.

The mix design of SCC should be performed in order to obtain required flowability, segregation resistance, self- compacting ability with excellent deformability and other desired properties suitable with the local condition. It needs to take into account characteristics of local material that is going to be used for SCC, desired application, required performance, and expected environmental conditions at the time of concrete placement (Co.-Conn, 2005). The behaviour of chemical admixtures has also been considered under Malaysian environmental conditions. SCC is less tolerant of production variability compare to CVC and therefore to produce desired SCC plants are necessary where the equipment, operation and materials are suitably controlled (Co.-Conn, 2005).

2.1.1 Behaviour of Fresh SCC Mixes

SCC in plastic state has different properties compare to CVC due to its components composition. SCC in fresh state is in a form of a liquid particle suspension. Thus, following behaviour must be possessed by SCC in order to enable it to self compacting itself efficiently.

- Flowing Ability
- Passing Ability

- Segregation Resistance

Flowing Ability- The ability to completely fill all areas and corners of the formwork into which it is placed (Goodier, 2003). This ability also referred as Filling ability and 'fluidity'. This ability is achieved by SCC when it flows under its own weight at unconfined condition (Safiuddin, West, & Soudki, 2009). This ability is depends on the aggregate content, W/B ratio, binder content and also high range water reducer (HRWR) dosage of concrete (Safiuddin, West, & Soudki, 2009). A good flowing ability also can be achieved by limiting the coarse aggregate content and increasing the amount of cementing materials while adding proper dosage of HRWR (Safiuddin, West, & Soudki, 2009). There are several tests that can be used to measure Flowing Ability such as Slump Flow Test, J-Ring Test, V-funnel test and also L-Box Test. However, the simplest and most widely used method to test Flowing Ability is Slump Flow Test.

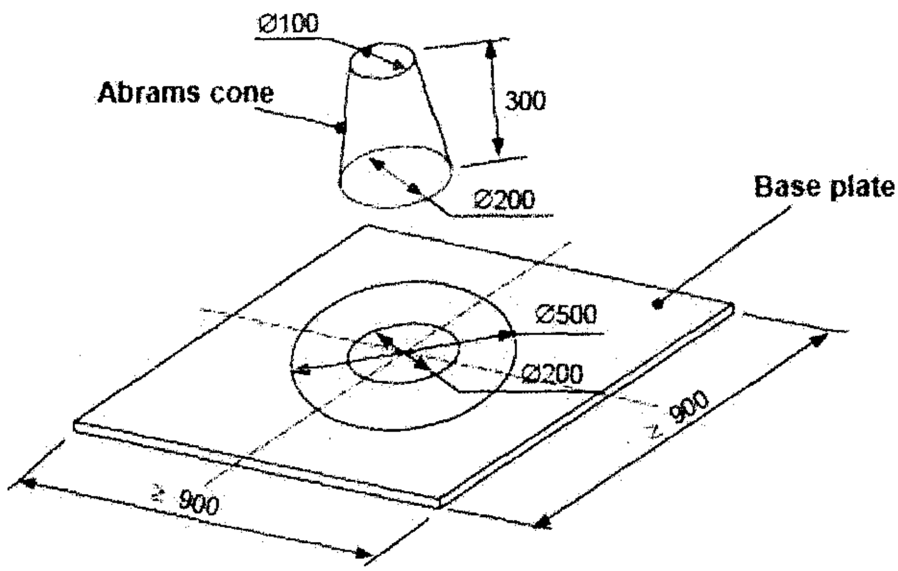


Figure 2.1: Slump Flow Test

Passing Ability- the ability to pass through congested reinforcement without separation of the constituents or blocking (Goodier, 2003). By having a good passing ability, SCC will easily flows, placed and consolidated by itself through heavily reinforcing bars without any aggregate blockage (Safiuddin, West, & Soudki, 2009). A good passing ability can be achieved by increasing the filling ability of fresh SCC and by controlling and limiting the segregation of the coarse aggregates of the SCC

(Safiuddin, West, & Soudki, 2009). This ability also can be measured by several tests such as L- Box Test and J- Ring Test.

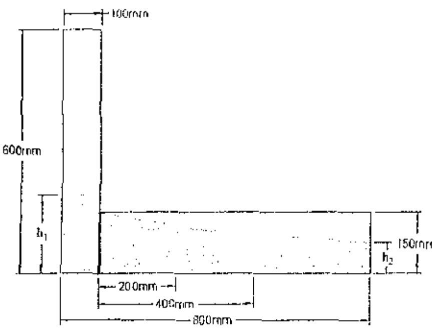


Figure 2.2: L- Box Test

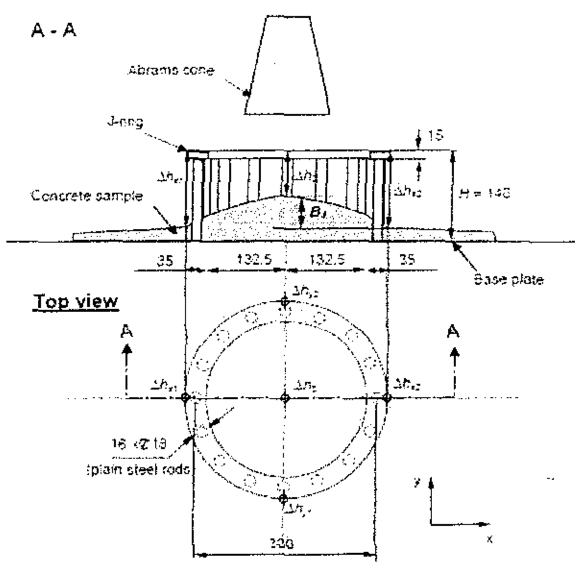


Figure 2.3: J- Ring Test

Segregation Resistance- the ability to retain the coarse components of the mix in suspension in order to maintain a homogeneous material (Goodier, 2003). If SCC does not possess this ability, the hardened properties of the material and also its durability will be highly affected. By preparing a proper mixture composition of SCC, a good segregation resistance can be obtained. An increased amount of cementing materials, a small nominal maximum size of aggregate, a limited content of well- graded coarse aggregates and a low W/B ratio should be used to achieve good segregation resistance (Safiuddin, West, & Soudki, 2009). There are several tests used for evaluating segregation resistance which are Wet Sieving Stability and Penetration Test for Segregation.

2.1.2 Cost versus Benefit

In reality, SCC is slightly expensive per cubic yard than CVC 6 inch slump concrete. However, the in place cost of SCC will decrease due to several factors as stated below (Hurd, 2002).

The casting and compaction of fresh concrete undeniably is one of the important processes in construction. This process often demand mentally and physically prepared workers because they have to face unpleasant and inconvenience environment of work such as less rest during concrete casting and also works for hours. Thus, there will be changes in workforce and often the workers involved are not well trained and their work is affected by mental and physical stress. Eventually their work will become slow and increase construction time. By using SCC, the time taken for construction will be much lesser than CVC (Hurd, 2002) since there is no mechanical vibration needed and the concrete placed itself (Okamura, Ozawa, & Ouchi, 2000) within the formwork quickly. Other than that, labour cost will be reduced due to fewer labours needed for SCC compare to CVC which need higher amount of workers for casting and compacting the CVC.

Figure 2.4: Placing of SCC

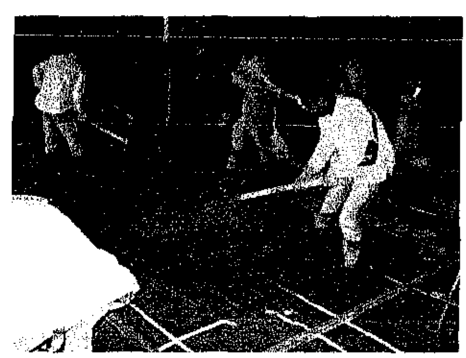


Figure 2.5: Placing of CVC

Source: www.encyclopedia.com

In CVC, mechanical vibrator is needed in order to compact the concrete. This will lead to increasing cost in order to obtain the vibrator. Other than that, by using CVC which needs vibrator, it will produce noise which will contribute to noise pollution. This attribute will give disadvantage to construction site which is very near to residential areas or any social areas because it will produce noise pollution. Opposite with SCC, which not require any mechanical vibrator hence it will reduce equipment cost in terms of obtaining the vibrator not produce any noise which likely will be one of the source of noise pollution (Hurd, 2002). In other word, SCC is suitable to use at any place because of its human friendly characteristic in terms of noise that it produce.

Other than that, CVC as we all known which includes mechanical vibration is operated by worker and exposed to human error which eventually will affect the concrete structure strength. Honeycomb is one of the examples that may occur due to human error which possibly due to inadequate vibration. Hence, later during hardened state of concrete the concrete will not achieved its desired strength and need to be rectified. With SCC which self consolidated and can flow freely through congested space, there is no need to be worry about uneven compaction problem or another defects that may cause from inadequate compaction (Okamura, Ozawa, & Ouchi, 2000). Thus, any additional works and cost needed in order to repair the defects can be eliminated (Hurd, 2002).

2.2 Superplasticizer

Superplasticizer is linear polymers containing sulfonic acid groups attached to the polymer backbone at regular intervals (Verbeck, 1968). It is a type of High Range Water Reducer (HRWR). Main purposes of superplasticizer combination with concrete are (FHWA, 2011):

1. To produce a flowing concrete with high slump range. Thus, the concrete can be used in placement where heavy reinforcement involve and also can be placed in mould or formwork where adequate consolidation cannot be readily achieved by vibration.

2. To produce high strength concrete with lower permeability by reducing water requirements of concrete without affecting the concrete workability.

The mentioned purposes above are greatly help SCC to achieve self compacting ability.

2.3 Pozzolanas

Pozzolanas are materials contain reactive silica and/ or alumina (Practical Action, 2007). Pozzolanas on their own without mixing with other materials have no binding property. However, it will set and harden like cement if it mix with lime in the presence of water (Practical Action, 2007). There are 2 major advantages of pozzolanas in addition with lime or Ordinary Portland Cement (OPC) based products (Practical Action, 2007):

1. Properties of cement improved for example improve workability, improve water retention and reduced bleeding, improve sulphate resistance and low heat of hydration.

2. Overall cost significantly reduced. Assuming pozzolanas does not to be transported too far and usually cost of pozzolanas are low and below lime or OPC.

There are 2 major groups of pozzolanas (Practical Action, 2007):

1. Natural Pozzolanas: For example, volcanic ash and diatomite.

2. Artificial pozzolanas: For example, Calcined Clays and Pulverized Fly Ash (PFA).

2.4 Pulverized Fly Ash (PFA)

Pulverized Fly Ash (PFA) is by-product from coal fired power station electricity generation (United Kingdom Quality Ash Association, 2006,). PFA is probably the greatest pozzolana used globally today (Practical Action, 2007). PFA is already in a fine powdered form thus there is no further processing for PFA to be used as pozzolana. Due to no further processing, its availability in bulk and its low cost thus make it ideal for blending at cement factories and for large construction projects (Practical Action, 2007). Other than that, PFA's reactivity is relatively low compare to other pozzolanas thus it is less used in combination with lime.

2.5 Silica Fume (SF)

Silica Fume (SF) is by product of the manufature of silicon metal and ferro-silicon alloys. It can be functioning as highly efficient pozzolan (Dunster, 2009). SF reacts chemically with Calcium Hydroxide produced by hydration of Ordinary Portland Cement (OPC) to form Calcium Silicate Hydrates (C-S-H) which function to bind concrete together (Dunster, 2009). Usage of SF can give specific benefits towards construction, design and performance of materials contain SF (Dunster, 2009):

1. Increase cohesiveness of fresh concrete which will result in easiness in improved handling characteristics.
2. Curing can be started earlier since there is no need to wait for bleed water to dissipate.
3. High early strength.
4. Lower permeability and improved durability.
5. Greater resistance to abrasion and impact than CVC of same strength grade.
6. Can be used as an ingredients in high performance concretes containing micro- fibres to combat explosive spalling during exposure to fire.
7. Has environmental benefits due to reduction of cement contents and improved service life.
8. Easily achieved 60 N/mm2 compressive strength and also has higher flexural strength and modulus of elasticity than CVC which has identical compressive strength.

CHAPTER 3

METHODOLOGY

3.1 Project Work

In general, sequences of my project are as shown in figure below.

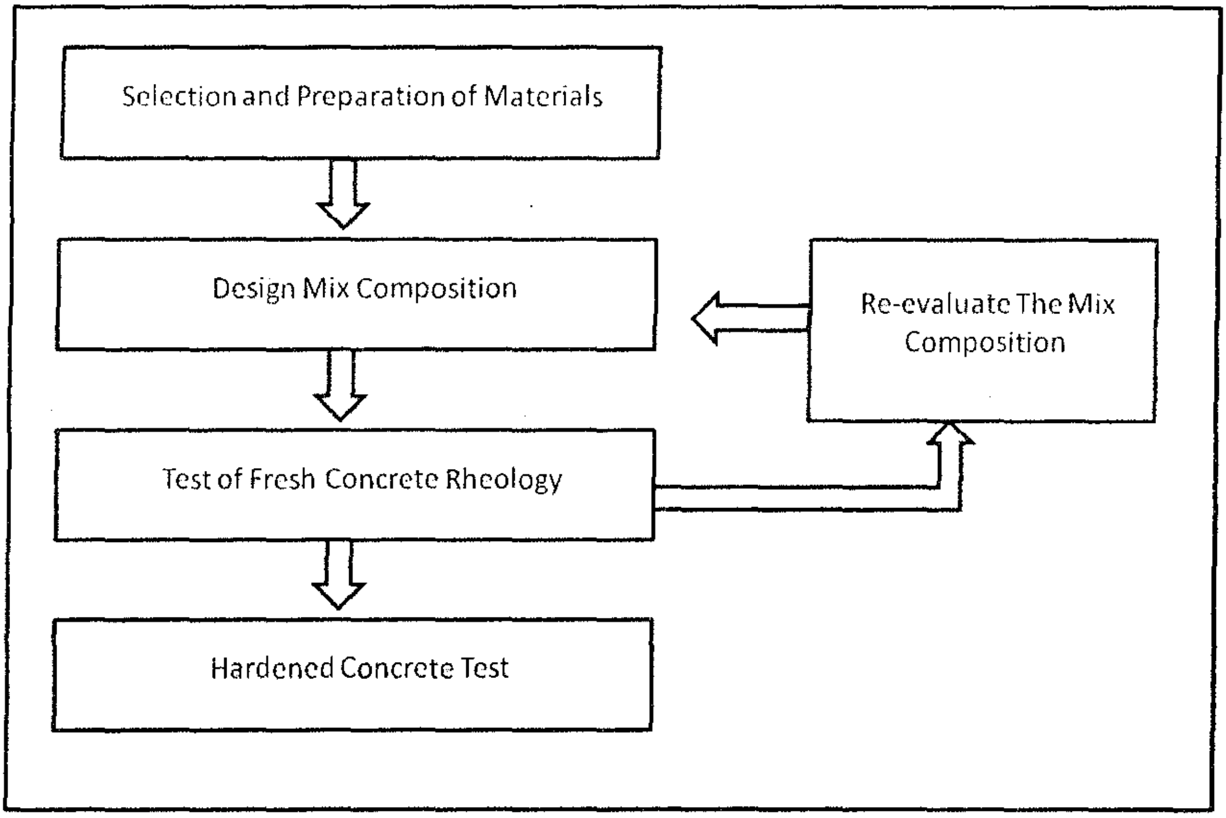


Figure 3.1: Project Process Flow

3.1.1 Selection and Preparation of Materials

In order to do our test, we have to select and prepare the materials needed. The materials that we need to select and prepare are:

- Ordinary Portland Cement (OPC)
- Coarse aggregate (5 mm- 10 mm)

  Crushed granite
- Coarse Aggregate (10 mm- 14 mm)

  Crushed Granite

- Fine Aggregate (local river sand)

  Mining Sand
- Water
- Superplasticizer (Sika Viscocrete- 25 MP)

3.1.2 Design Mix Composition

One of the objectives of this study is to determine the optimum superplasticizer amount to be used in SCC according to the standard practices in fresh state. Another objective is to find the optimum amount of PFA and SF as substitute of cement based on hardened concrete properties which are compressive strength and porosity. Thus, there are 3 stages:

- First stage (Group 1) : Determine the best mix which has optimum amount of superplasticizer from trial mixes.
- Second stage (Group 2.1) : Determine optimum amount of PFA as cement replacement material in the best mix obtained in first stage.
- Third stage (Group 2.2) : Determine optimum amount of SF as cement replacement material in the trial mixes obtained in first stage.

In the first stage which is to determine the best mix which has optimum amount of superplasticizer. All SCC mixes compositions are shown in *Table 1* below.

Mix. No	OPC	Coarse Aggregate		Fine Aggregate	Water	Superplasticizer (S/P)		W/C
		(5-10mm)	(10-14mm)			S/P %	S/P Weight	
BM1	450	700	200	1030	200	2%	9	0.44
A1	450	470	250	1000	200	2%	9	0.44
AS1	450	470	250	1000	200	2.50%	11.25	0.44
AS2	450	470	250	1000	200	3%	13.5	0.44
AS3	450	470	250	1000	200	3.50%	15.75	0.44

*** All units except S/P% and W/C are in kg/m³**

Table 1: Mix Design for Trial Mixes

In table above, BM1 is the initial mix and base mix. BM denotes Base Mix, mix with initial A denotes mix which differ in aggregate amount with BM1 and mixes with initial AS are mixes which differ in aggregates and superplasticizer amount with BM1. Initially, BM1 did not satisfy the rheological properties of SCC thus, A1 is the modification of BM1 to find its compliance with SCC rheological properties. Once, we found the aggregate composition has been found complies with SCC, modification in superplasticizer amount is achieved to obtain the optimum amount of superplasticizer in compliance with SCC rheological properties.

For second stage which is to determine optimum amount of PFA as cement replacement material (Group 2.1), the composition mixes are as shown in *Table 2* below:

Mix. No	**OPC**	**Coarse Aggregate**		**Fine Aggregate**	**Water**	**Superplasticizer (S/P)**		**W/C**	**PFA**	
		(5-10mm)	**(10-14mm)**			**S/P %**	**S/P Weight**		**PFA %**	**PFA Weight**
PFA 3	427.5	470	250	1000	200	2.50%	11.25	0.44	5%	22.5
PFA 1	405	470	250	1000	200	2.50%	11.25	0.44	10%	45
PFA 2	382.5	470	250	1000	200	2.5%	11.25	0.44	15%	67.5

*** All units except S/P%, PFA% and W/C are in kg/m³**

Table 2: Mix Design for PFA Mixes (Group 2.1)

For third stage which is to determine optimum amount of SF as cement replacement material (Group 2.2), the composition mixes are as shown in *Table 3* below:

Mix. No	OPC	Coarse Aggregate (5-10mm)	Coarse Aggregate (10-14mm)	Fine Aggregate	Water	Superplasticizer (S/P) S/P %	Superplasticizer (S/P) S/P Weight	W/C	Silica Fume (SF) SF %	Silica Fume (SF) SF Weight
SF 1	438.75	470	250	1000	200	2.50%	11.25	0.44	2.50%	11.25
SF 2	427.5	470	250	1000	200	2.50%	11.25	0.44	5.00%	22.5
SF 3	416.25	470	250	1000	200	2.50%	11.25	0.44	7.50%	33.75

***All units except S/P%, PFA% and W/C are in kg/m³**

Table 3: Mix Design for SF Mixes (Group 2.2)

3.1.3 Test of Fresh Concrete Rheology

After each composition has been mixed based on their design mix, the concrete will be tested at its fresh state to ensure its compliance with SCC properties. Tests that will be used are Slump Flow Test, V- Funnel Test and L- Box Test.

3.1.4 Re- evaluate The Mix Composition

This step is only applicable for first stage (Group 1) which is to find optimum superplasticizer. After rheological tests have been done, the results will be analyzed to ensure its compliance with SCC rheological properties. After that, the next mix that will be design is designed based on the previous mix result in order to ensure the betterment of its rheological tests result compare to the previous mix. This stage is continuously will be done till the best mix with optimum amount of superplasticizer is obtained.

3.1.5 Hardened Concrete Tests

Each mix will have hardened concrete tests which are compressive test and porosity test. These tests are done to ensure the produced SCC achieves the required strength. The tests will be done at 3 days, 7 days, 28 days and 56 days after concrete cubes of the particular mix have been casted.

3.2 Tools and Equipment

Tools and equipment that are used during this project are as follow:

1. Concrete Mixing Machine
2. Slump Flow Test Equipment
3. V- Funnel Test Equipment
4. L- Box Test Equipment
5. Compressive Test Machine
6. Vacuum Dessicator.

3.2.1 Concrete Mixing Machine

This machine is used to mix the composition of both SCC mix groups which are SCC mixes without pozzolan and SCC mixes with pozzolan. This concrete mixer rotates at 1460 rpm.

After all materials to be used have been prepared and selected, the materials will be mixed in concrete mixer. Currently, the progress is still in searching the optimum superplasticizer for SCC mix which is for group 1 (as explained earlier in introduction). The mixing procedure is as follow:

3.2.1.1 Mixing Procedure for Group 1

1. Coarse aggregate (5 mm- 10 mm), coarse aggregate (10 mm- 14 mm) and fine aggregate are poured in concrete mixer.

2. OPC is poured into concrete mixer

3. 80% of required water content is poured into concrete mixer.

4. Those materials poured in step 1 to step 3 are being mixed for 3 minutes.

5. 20% of remaining water is mixed with superplasticizer. The mixture is poured into concrete mixer.

6. The mixing process is continued for another 2 minutes.

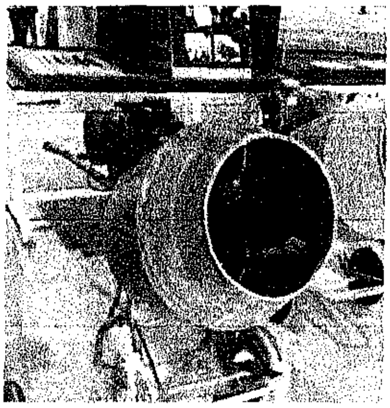


Figure 3.2: Concrete Mixer

3.2.2 Slump Flow Test Equipment

Slump Flow Test Equipment is used to measure filling ability or flowing ability of rheological properties of both groups of SCC.

3.2.2.1 Test Procedure of Slump Flow Test

1. Abram's Cone is –placed in the centre of the slump flow board in normal orientation (large opening down).
2. Abram's Cone is filled completely with SCC without rodding or other consolidation technique.
3. The cone is raised in 3 ±1 seconds to a suitable height which enough to allow the fluid SCC to flow out freely onto the slump flow board.
4. The diameter of the SCC is measured at 2 different point which both point is perpendicular to each other.

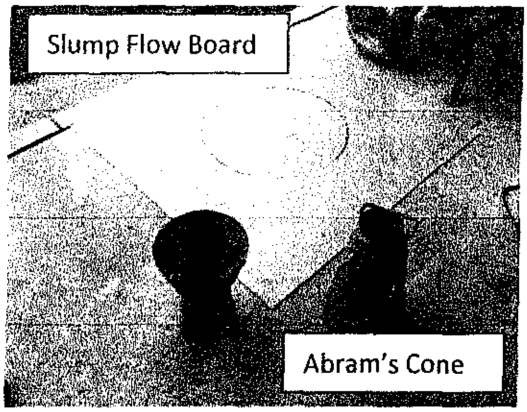


Figure 3.3: Slump Flow Equipment

3.2.3 V- Funnel Test Equipment

V- Funnel Test equipment is used to measure filling ability or flowing ability of rheological properties of both group of SCC.

3.2.3.1 Test Procedure of V- Funnel Test

1. The V-Funnel is placed on a flat ground.
2. The interior of the V- Funnel is cleaned to ensure there is no obstacle for SCC to flow during testing period.
3. The V- Funnel gate is closed and a bucket is placed under the gate to collect the tested concrete after flowing out from V- Funnel
4. The funnel is filled completely with SCC
5. The gate is opened to allow SCC flowing out from the funnel
6. Time taken at the moment when gate is opened till all SCC flowing out completely is recorded.

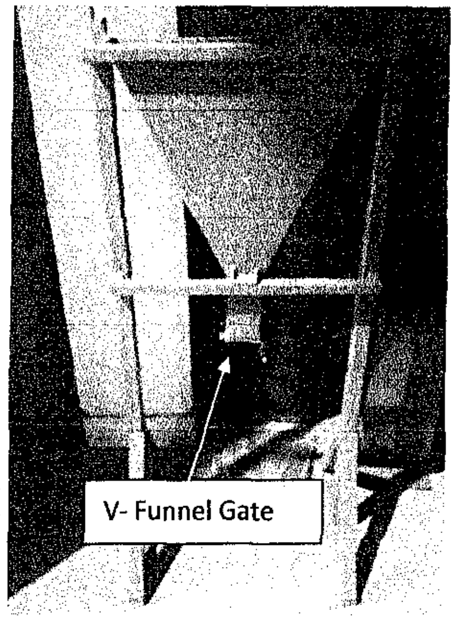


Figure 3.4: V- Funnel

3.2.4 L- Box Test Machine

This equipment is used to measure passing ability of rheological properties of both group of SCC.

3.2.4.1 Test Procedure of L- Box Test

1. With the gate of the L- Box is closed and the reinforced bar is in its designed place, the SCC is filled completely in the vertical space of the L- Box.
2. The gate is lifted after SCC has completely filled the vertical space.
3. The concrete height at H_2 and H_1 is taken.
4. Visual inspection around the rebar is done to indicate its passing ability.
5. Visual inspection on the SCC at horizontal space is done to detect occurrence of bleeding.

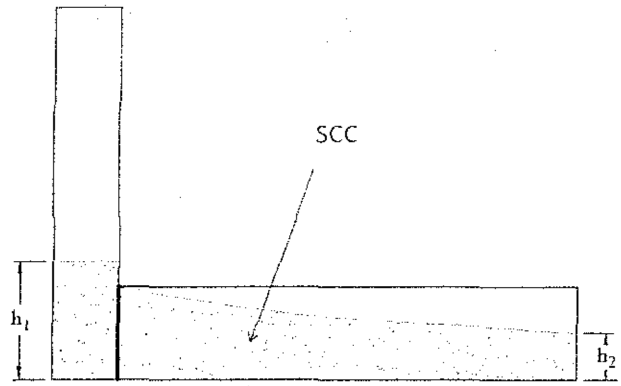


Figure 3.5 Cross Section of L- Box

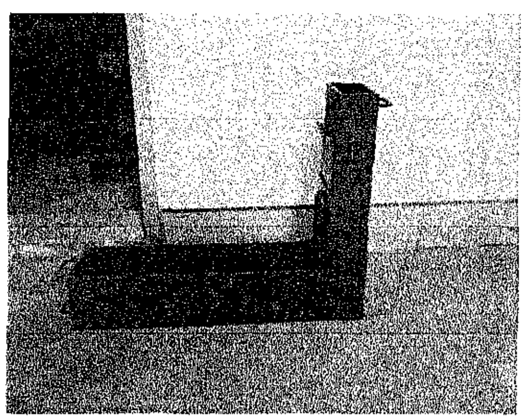


Figure 3.6: L- Box

3.2.5 Compressive Test Machine

Compressive Test Machine will be used to evaluate the strength of concrete in hardened state. The specimen strength will be evaluated on day 3, 7, 28 and 56 after casting.

3.2.6 Vacuum Dessicator

Vacuum dessicator is used to evaluate the specimen porosity.

3.3 Gannt Chart

This particular project needs to be completed within the given time frame. In order to ensure this project completion, a gannt chart has been constructed. In the gannt chart, all planning has been included and managed into certain time frame. In the end of the given time frame, all activities and tasks regarding this project is expected to be completed. Refer to appendix A for gannt chart.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Fresh Concrete Results

4.1.1 Trial Mix Design Result: Group 1

Mix No.	Slump Flow Test (mm)	V- Funnel Test (s)	L- Box Test (mm) Blocking Ratio H_2/H_1
BM1	425 mm	402 s	0
A1	620 mm	9.19 s	0.52
AS1	710 mm	6.19 s	0.29
AS2	620 mm	35 s	0.55
AS3	575 mm	35 s	0.55

Table 4: Trial Mixes Design Rheological Test Result (Group 1)

Shown above is rheological test result for trial mixes for Group 1. Judging based on criteria that we have set as below:

- Acceptable slump flow range : 600 mm- 760 mm
- Acceptable blocking ratio (L-Box Test) : 0.8- 0.9
- Acceptable V- Funnel Test range : 6 s- 11 s

Thus, the best SCC trial mix in Group 1 which have optimum amount of superplasticizer is mix no AS1 which has 2.5 % amount of superplasticizer. Although its blocking ratio from L- Box test still not satisfy the requirement, it still can be considered as the best mix since it has the best result from the other two tests.

4.1.2 SCC with Addition of Pozzolanas: Group 2

Mix No.	Slump Flow Test (mm)	V- Funnel Test (s)	L- Box Test (mm) Blocking Ratio H_2/H_1
PFA3	620	120	0.44
PFA1	580	84	0
PFA2	500	240	0
SF1	550	120	0
SF2	325	180	0
SF3	350	180	0

Table 5: SCC with PFA (Group 2.1) and SF (Group 2.2) as Cement Replacement Material Rheological Test Result

In Group 2, the criteria for choosing the optimum PFA and SF in order to form SCC still following the criteria for Group 1 as shown before. For SCC with addition of PFA, the best mix which possess the nearest SCC characteristic is PFA3 which contains 5% PFA. Although it does not pass L- Box and V- Funnel Test, it still has the nearest characteristics to be SCC compare to the other two mixes which is PFA2 and PFA3 which both mixes do not pass all test to be considered as SCC.

As for SCC with addition of SF, the best mix which possess the nearest SCC characteristic is SF1 which contains 2.5% SF. Although it has failed all tests, it still has the nearest characteristic to be SCC based on the result. Its Slump Flow result has the nearest value to criteria which is 550 mm and the result for V- Funnel also has the nearest value to criteria compare to other mixes which is 120 s.

4.2 Hardened Concrete Test Result

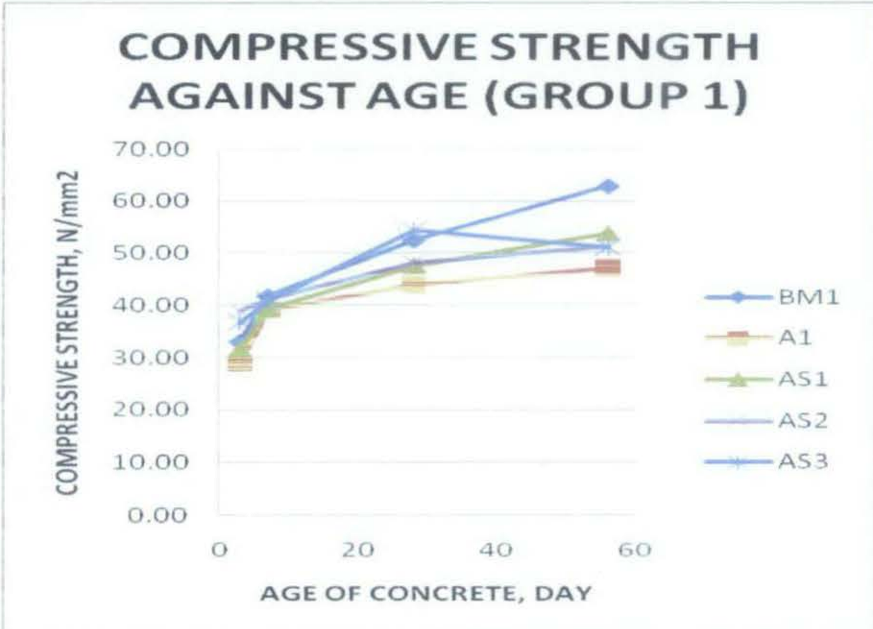
4.2.1 Compessive Strength Test

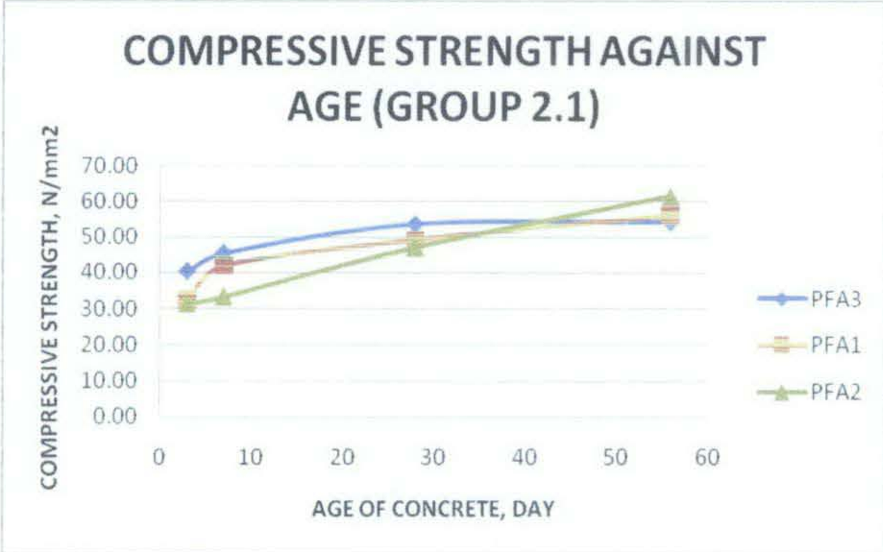
Shown below are result of compressive test for both groups and also the relationship between compressive strength obtained at day 3, day 7 and day 28 for trial mixes (Group 1), SCC with PFA (Group 2) and also SCC with SF (Group 2).

Mix Name	Day			
	3 Day	7 Day	28 Day	56 Day
BM1	32.97	41.71	52.44	62.88
A1	29.06	39.07	43.91	47.06
AS1	31.49	39.26	47.49	53.71
AS2	38.82	41.13	48.15	51.30
AS3	36.68	40.89	54.38	50.99
PFA3	40.22	45.40	53.60	54.20
PFA1	32.32	41.84	49.21	56.01
PFA2	31.28	33.23	47.03	61.44
SF1	32.32	46.99	50.16	56.52
SF2	36.98	41.26	54.30	62.40
SF3	34.40	41.84	52.75	57.67

*All values are in MPa.

Table 6: Compressive Test Result of SCC mixes for Group 1 and Group 2





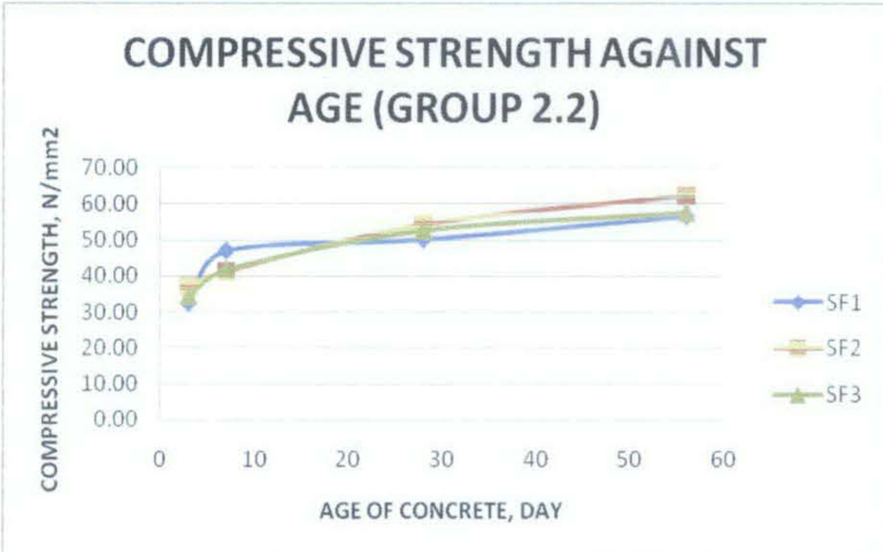


Table 7: Relationship between Compressive Strength and SCC Mixes

As illustrated in the *Table 6*, it may conclude that all samples has successfully achieved desired strength which is ±40 MPa at day 28. Furthermore, based on relationship between compressive strength and SCC mixes for trial mixes (Group 1), it may suggest that their strength between each mixes are relatively equal and not much difference. Thus, mix AS1 still reliable to be considered as best mix with optimum amount of superplasticizer because of its acceptable compressive strength.

For mixes of SCC with addition of PFA (Group 2.1), it may also conclude that the more addition of PFA, causes lesser in compressive strength but it only applicable for age under 28 days. Then, for more than 28 days which is in this study we test it at day 56, the more addition of PFA, causes higher in compressive strength. This is because with increasing PFA content, lower lower early strength is achieved and this is shown by the PFA 3 result under 28 days. This phenomenon happen due to presence of fly ash which retards the reaction of alite within portland cement at early stages (Taylor, 1997). However in the middle stages, the reaction accelerated at this is shown by the result of the compressive strength at day 56 where PFA 2 has the highest value of compressive strength. Although PFA 3 does not have highest compressive strength at day 56, we still consider it as mix which contain optimum PFA due to its fresh properties. Moreover, its compressive strength already pass our target which is 40±5 MPa.

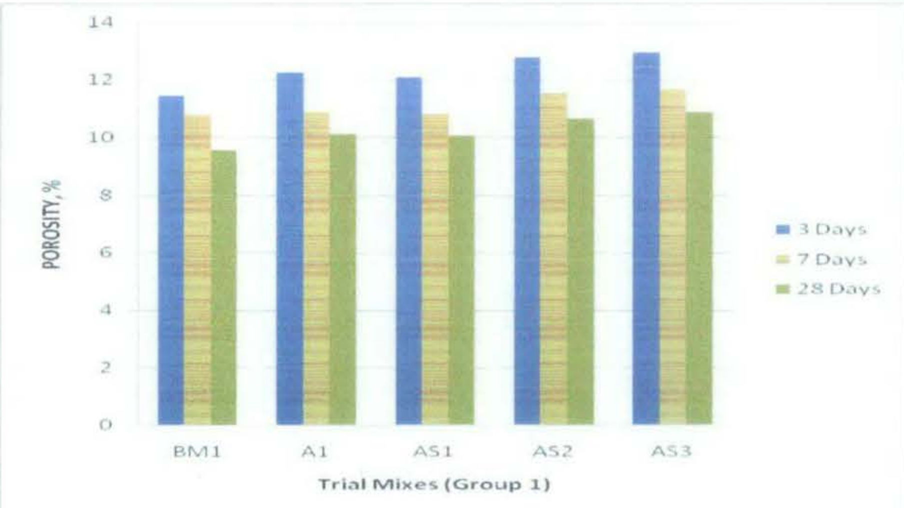
As for SCC with addition of SF (Group 2.2), we can see that SF 1 has developed faster than other samples at early age. This can be seen by its graph gradient. This is why at day 3, it has the highest compressive strength compare to other samples. However, after about 10 days, its reaction rate become slower and other samples which are sample SF 2 and SF 3 has faster reaction rate. This explains why at day 56, sample SF 2 has the highest compressive strength. Regardless of its late day strength, SF 1 already pass our compressive strength target which is 40±5 MPa. Thus, based on its fresh properties SF 1 is the mix which contain optimum SF.

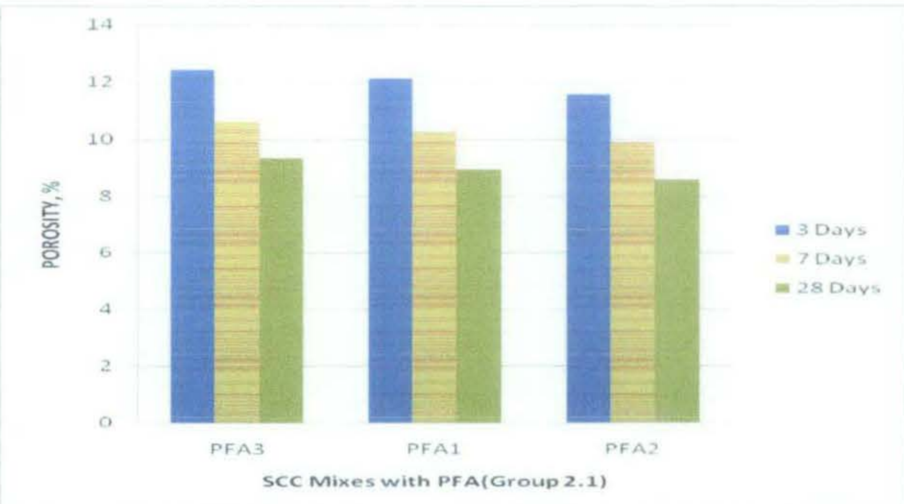
4.2.2 Porosity Test Result

Shown below are the result of Porosity Test obtained at day 3, day 7 and day 28 for Trial mixes (Group 1), SCC with PFA (Group 2) and SCC with SF (Group 2).

	Porosity %		
	3 Days	7 Days	28 Days
BM1	11.46	10.78	9.56
A1	12.26	10.9	10.12
AS1	12.1	10.8	10.05
AS2	12.79	11.53	10.64
AS3	12.94	11.68	10.87
PFA3	12.43	10.62	9.33
PFA1	12.11	10.25	8.94
PFA2	11.57	9.89	8.6
SF1	12.28	10.52	9.11
SF2	11.97	10.12	8.86
SF3	11.45	9.66	8.43

Table 8: Porosity Test Result of SCC Mixes of Group 1 and Group 2





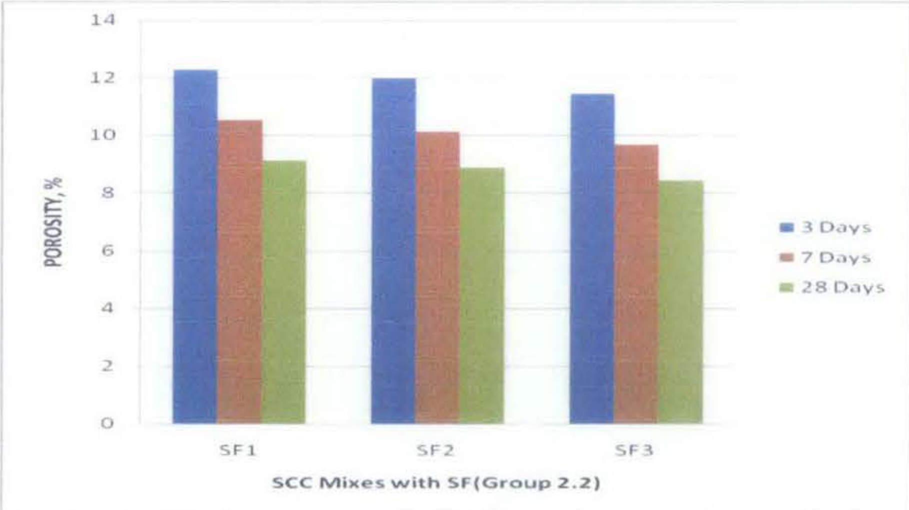


Table 9: Relationship between Porosity and SCC Mixes

As explained earlier in the literature, addition of superplasticizer will increase strength and reduce porosity. However, in Group 1 the increase addition of superplasticizer does not have effect in lowering the porosity value although all mixes have equal water cement ratio value. Thus, it may be because of unconstant value of coarse aggregates between each mix in Group 1 that affect the result. Nevertheless, it is noted that porosity for all mixes did decrease within time. Thus it indicates a good sign and performance in the long run. In this group, AS 1 is still regarded as mix which has the optimu amount of superplasticizer. Although it does not have the lowest porosity value, it still have considerable porosity value and believed that its porosity value will keep on decreasing.

For Group 2.1 which is SCC mixes with PFA, we can see that the more PFA we add, the lesser the porosity value. This is because PFA is finer materials than cement thus enabling the particle to fill in more space or void in between cement and aggregates. This has lead to refinement in pore structure. In this group, although PFA 3 does not have the lowest porosity value, it still can be considered as the best mix in group 2.1 which has optimum value of PFA based on its result at fresh properties. Moreover, the value of its porosity still in acceptable level considering it has lower porosity value compare to AS 1 at day 28.

For Group 2.2 which is SCC mixes with SF, we can see that the more SF we add, the lesser the porosity value. This is because SF is finer materials than cement thus enabling the particle to fill in more space or void in between cement and aggregates. This has lead to refinement in pore structure. In this group, although SF 1 does not have the lowest porosity value, it still can be considered as the best mix in group 2.2 which has optimum value of SF based on its result at fresh properties. Moreover, the value of its porosity still in acceptable level considering it has lower porosity value compare to AS 1 at day 28.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The development of SCC nowadays is very important for future improvement of technology. In this project, there were two objectives of SCC development which are to determine the optimum dosage of superplasticizer to satisfy the rheological requirements of SCC according to the standard practices in fresh state and to determine the optimum replacement of PFA and SF as substitute of cement based on hardened concrete properties which are compressive strength and porosity.

Currently, the first objective which is to determine the optimum dosage of superplasticizer to satisfy the rheological requirements of SCC according to the standard practices in fresh state has successfully achieved. The optimum amount of superplasticizer to be used with our SCC design mix composition is 2.5%. However, in the future in order to see the clear effect of superplasticizer upon concrete such as its workability during its fresh state, it is recommended that the only amount that is varied and manipulated is the superplasticizer. In this study, there are more than one material that is manipulated such as superplasticizer and coarse aggregate; hence we unable to see clearly the effect of superplasticizer upon concrete.

The second objective has also successfully achieved. The optimum amount of PFA is 5% and optimum amount of SF is 2.5%. Although all mixes in Group 2 do not pass all three tests in order to be qualified as SCC, the trial to find another SCC mix cannot be done due to time constraint and to meet the second objective which is only to find optimum amount of PFA and SF based on optimum amount of superplasticizer that have been got earlier in Group 1 from AS1. Thus, for future improvement and future development, the other AS1 composition such as volume of sand or aggregates has to be manipulated and changed in order to ensure that the mix will possess characteristics of SCC. Hence, when the amount of superplasticizer has been obtained from the acceptable SCC mix, then the following mix which volume of PFA and SF are manipulated, the judgement of the optimum amount of those pozzolanas in an acceptable SCC mix contained optimum amount of superplasticizer can be done.

Other than that, from porosity test, we can conclude that the increase and addition of PFA and SF will lower the value of porosity. This is very important as the porosity value indicates the strength of the concrete. The higher the porosity, the more void or spaces exist within the concrete thus, will result in weaker concrete. Moreover, by adding PFA and SF it will increase the concrete strength in the long term as we can see the difference in compressive strength between AS 1 and Group 2 at day 56. Thus, in the future research, it is highly recommended that the duration of compressive strength test can be extend till 90 days in order to see clearly the development of strength of sample added with PFA and SF.

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APPENDICES

GANNT CHART

NO	WEEK / DETAIL	FYP 1														FYP 2													
		WEEK																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Selection of Project Topic	■	■																										
2	Preliminary Research Work		■	■	■	■																							
3	Submission of Extended Proposal Defence						●																						
4	Proposal Defence								■	■																			
5	Preparing &Testing SCC Mixes										■	■	■	■	■	■	■	■	■										
6	Submission of Interim Draft Report													●															
7	Submission of Interim Report														●														
8	Preparing &Testing SCC mixes with pozzolan											■	■	■	■	■	■	■	■	■									
9	Data and Result Analysis																				■	■	■	■	■				
10	Submission of Progress Report																						●						

11	Submission of Draft Report																								●				
12	Submission of Dissertation(Soft Bound)																									●			
13	Submission of Technical Paper																									●			
14	Oral Presentation																										●		
15	Submission of Dissertation (Hard Bound)																											●	

Legend:

☐ (white box)	FYP 1
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■ (dark box)	TIME PLANNING
●	SUGGESTED MILESTONE BY COORDINATOR