Dynamic Behaviour of Reinforced Concrete (RC) Beam
Made of Self Compacting Concrete (SCC)
by Using
Pulverized Fuel Ash (PFA) and Rice Husk Ash (RHA)
As an Additive

by

Mazila Binti Mohamad

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JANUARY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

**Dynamic Behaviour of Reinforced Concrete (RC) Beam
Made of Self Compacting Concrete (SCC)
by Using
Pulverized Fuel Ash (PFA) and Rice Husk Ash (RHA)
As an Additive**

by

Mazila Binti Mohamad

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(AP Dr Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2008

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.

MAZILA BINTI MOHAMAD

ABSTRACT

This report basically discusses about the research on the chosen topic, which is "Dynamic Behaviour of Reinforced Concrete (RC) Beam Made of Self-Compacting Concrete (SCC) by using Pulverized Fuel Ash (PFA) and Rice Husk Ash (RHA) as an additive". The objective of the project is to find the optimum mix design for SCC RC Beam with the usage of PFA and RHA. This research also study about the effect of PFA and RHA as filler in SCC. The challenge in this project is to find the most favorable mix design between PFA and RHA that will resulted in high strength concrete with high workability rate. Lab testing had been done for the designed mix for fresh properties of concrete as well as the hardened concrete. The fresh concrete was tested for its workability, viscosity and resistance to segregation. Once the RC beam has hardened it was tested for dynamic test.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 BACKGROUND STUDIES

Self-Compacting Concrete (SCC), also known as Self-consolidating concrete or High Performance concrete was developed in Japan during the late 1980s. The development of SCC started when the need for more durable concrete arises, and since durability of concrete directly connected to the adequate compaction after placing the concrete, a concrete that can move into every corner of the formwork by its own weight is the ideal solution.

Like the name suggest, SCC is a highly flowable, non-segregating concrete that can spread into place, fill the formwork and encapsulate the reinforcement without any mechanical equipment to help the compaction. Three key fresh properties of SCC are:

- **Filling ability** – the ability of the concrete to flow freely under its own weight, both horizontally and vertically upwards if necessary, and to completely fill formwork of any dimension and shape without leaving voids. Some people consider that rate of flow is a distinct fourth property, but this approach was not adopted here.
- **Passing ability** – the ability of concrete to flow freely in and around dense reinforcement without blocking.
- **Resistance to segregation** – during placement and while flowing, the concrete should retain its homogeneity. There should be no separation of aggregate from paste or water from solids, and no tendency for coarse aggregate to sink downwards through the fresh concrete mass under gravity.

The main reasons for the employment of self-compacting concrete can be summarized as follows:

1. to shorten construction period
2. to assure compaction in the structure, especially in confined zones where vibrating compaction is difficult
3. to eliminate noise due to vibration, effective especially at concrete products plants

A high-strength concrete is considered as such if it is 50 MPa and above. HSC is very effective in multi-storey buildings as it reduces the cross-sectional area of the structural elements. It is also effective in pavements because of less abrasion and longer durability.

Various researches has been done to produce concrete which have the characteristics of high flowability and workability during its fresh (plastic) state, but very strong and durable once it has hardened. The hardened concrete is dense, homogeneous and has the similar engineering properties and durability as traditional vibrated concrete. Self-compacting concrete is more sensitive than normal concrete to variation in the physical properties of its constituents and especially to changes in aggregate moisture content, grading and shape, so more frequent production checks are necessary.

1.2 PROBLEM STATEMENT

One of the disadvantages of SCC is its cost, associated with the use of chemical admixtures and use of high volume of Portland cement. One alternative to reduce the cost of SCC is the use of mineral additives such as Pulverized Fuel Ash (PFA) and Rice Hush Ash (RHA) which are fine material added into concrete. As the mineral additive replaces part of the Portland cement, the cost of SCC could be reduced especially if the mineral additive is an industrial by-product or waste. It is also known that PFA and

RHA are generally increases the workability, durability and long term properties of concrete. Therefore, the use of these types of mineral additive in SCC will make it feasible, not only to decrease the cost of SCC but also to increase its long term performance. To make sure these minerals additive have a good result in high strength concrete, the dynamic test will conduct after concrete has harden.

1.3 OBJECTIVE & SCOPE OF STUDY

The objectives of this research were:

- To determine the optimum mix design and the rheological properties of Self-Compacting Concrete (SCC) by using Pulverized Fuel Ash (PFA) and Rice Hush Ash (RHA) as filler.
- To investigate and compare the effect of filler between PFA and RHA in SCC.
- To determine dynamic behaviour of Reinforced Concrete (RC) beam made of SCC.

The scope of work for the rheological properties shall be conducted for fresh concrete, and the test conducted will investigate its flowability and workability. Once the concrete hardened, it shall be tested for dynamic test.

The mix design is generally based on the approach outlined below:

- Determine the proportion of cement and the dose of admixture to give the required robustness
- Test the properties of the SCC in the fresh and hardened state
- Analyses the dynamic test result to choose the best mix design for high strength concrete.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Concrete in its simplest explanation is a composite construction material made from the combination of aggregates and cementations binder. The composition of concrete is determined initially during mixing and finally during placing of fresh concrete. The type of structure being built as well as the method of construction determined how the concrete is placed and therefore also the composition of the concrete mix. The composition of concrete is made of cement, water, aggregates, admixtures, and additives.

Various types of concrete have been developed for specialist application and the most common ones are regular concrete, self-compacting concrete, shotcrete and asphalt concrete. Self-compacting concrete (SCC) are characterized by their extreme fluidity, behaving more like a thick fluid that is self leveling, as opposed to conventional concrete that needs consolidating which are normally vibration or packing.

2.2 SELF COMPACTING CONCRETE (SCC)

Okamura (2003) stated that the method for achieving self-compactibility involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregates and mortar when the concrete flows through the confined zone of reinforcement bars. The following methods are employed to achieve self-compactability:

1. limited aggregate content
2. low water-powder ratio
3. use of superplasticizer.

According to Ping Kun Chang (2003), to achieve high strength and workability while reducing creep and shrinkage and low durability, it is suggested to use water-reducing agent, superplasticizers and pozzolanic materials in the mix designs. The chemical reactivity of superplasticizers lasts only for 60 min. While pozzolanic materials, such as fly ash, blast-furnace slag or rice husk ash, are used, there is a risk of insufficient early strength of concrete. Therefore, how to minimize or eliminate the adverse effects of the materials used in the mixture design to increase durability is the main focus of the research.

Pozzolanic materials are crucial to HPC as far as flowability is concerned. In addition to lowering the heat of hydration, the use of fly ash and slag can improve the workability, plasticity, water tightness, resistance to sulfate and seawater attack. The mixture design of HPC emphasizes the amount of binder used. A higher content of pozzolanic materials implies that less cement is needed. Controlling the water content and the water-to-solid (W/S) ratio is an indirect approach to stabilizing the volume, thus ensuring greater durability achieved in the mixture proportion of concrete.

2.3 MIX PROPORTIONING OF SELF COMPACTING CONCRETE (SCC)

The flowability of a concrete mix is a complex interaction between the inter-particle friction in the aggregate phase, and the fluidity of the paste phase. The water-to-powder ratio and admixtures control the fluidity of the paste phase. If the aggregate particles have too much friction due to poor grading or shape, the paste will have to be very fluid to compensate and achieve the desired concrete flowability. If the paste is too fluid, segregation will result. The general approach is to select the most consistent and best-graded and shaped aggregate economically possible, and to use high paste fractions to increase space between the aggregate particles. The rheology is controlled by adjusting the water-to-powder ratio and using appropriate admixtures specifically designed for SCC production.

The nominal maximum size of the coarse aggregate must be chosen with respect to obtaining the desired passing ability and stability of the plastic concrete. When the use of a coarse aggregate larger than 12.5 mm (1/2 in.) is required, it will generally be beneficial to blend two or more different aggregate sizes to obtain an optimum gradation. Typical nominal maximum size of aggregate used in SCC is 19 mm (3/4 in.), although aggregates as large as 25 mm (1 in.) have been used. Aggregates with a nominal maximum size larger than 25 mm (1 in.) are not recommended for use in SCC Technical Bulletin [4].

Particle shape of the coarse aggregate can have a significant impact on the performance of an SCC mix. A rounded coarse aggregate will impart greater filling ability to a mixture when compared to a crushed stone of similar size. All other parameters being equal, a higher volume of well-rounded natural aggregate could be used in a concrete mix than of an angular crushed aggregate having the same gradation. SCC mixtures require special attention to the total gradation of the combined aggregates, and not just the separate coarse and fine aggregates. Size, gradation and surface texture will influence the volume of coarse aggregate that will permit acceptable passing and filling ability of the plastic SCC Technical Bulletin [4]. Highly gap graded aggregate mixtures should be avoided as the SCC mix will have a tendency to bleed and/or segregate, and will increase the overall paste fraction requirement of the concrete.

Frequently smaller size-range aggregates are used in SCC applications with very congested steel reinforcing, or challenging concrete placing conditions. An initial proportion of approximately 50% sand and 50% coarse aggregate Technical Bulletin [4], by either weight or bulk volume would be a good starting point for the first trial batch.

Once the plastic properties of the trial batched are assessed, the sand-aggregate ratio may be adjusted.

Powder includes Portland cement, supplementary cementitious materials and inert fillers passing a 150 μm (No. 100) sieve. When designing an SCC mixture, the compressive strength requirements may not be the decisive factor when selecting the amount of cementitious material. Inert fillers, obtained by grinding calcareous or siliceous aggregates, can be used to achieve better packing density. The fine fraction of these fillers will increase the specific surface of the blend, while the coarser fractions can help to bridge the gap between sand and Portland cement. The replacement of a portion of cement with finely ground limestone filler has been shown to improve filling ability and stability, without affecting the one day compressive strength of the concrete mixture. Such a concrete can, however, exhibit up to 10% lower 28 day compressive strength versus similar concretes without filler. The fineness and volume of the powder, in conjunction with the fine aggregate, help form a mortar matrix that supports the coarse aggregate. Characteristically, powder content for initial trial mixes should be in the 295–365 kg/m3 (650–800 lbs/yd3) range. When performing trial batches it may be prudent to start with higher powder contents, and then optimize the mix for improved economy.

To increase the slump flow of an SCC mixture, it may be necessary to not only use more water, but also to increase the powder content of the mix to prevent segregation. Generally, as the desired slump flow increases (for increased filling ability), the powder content required to achieve adequate passing ability and stability may also need to be increased. In the case of HRWR specifically designed for SCC, this adjustment requirement may be lessened. The use of an increased amount of HRWR may also be used to provide an increased slump flow.

The volume of paste and mortar in SCC will generally be greater than in conventional concrete. The volume of mortar and its ability to carry the coarse aggregate in conjunction with the fluidity of the paste provide the overall filling ability, passing ability and stability of SCC mixtures. When adjusting trial mixes for slump flow, consideration should be given to changing the volume of mortar and paste, as well as making admixture and water adjustments.

2.4 RICE HUSK ASH (RHA)

Rice-husk ash (RHA) is a very tine pozzolanic material and its particle size and specific surface depend upon the burning conditions under which it is produced. In general, the average particle size ranges from 5 to 10 urn, and the specific surface area ranges from 20 to 50 m^2/g. A previous investigation indicated that the rice-husk ash used in this study is highly pozzolanic, and can be used as a supplementary cementing material to produce highperformance concrete. The concrete incorporating 10% of the RHA as a cement replacement had somewhat higher compressive strength and higher resistance to chloride-ion penetration compared with the control portland cement concrete of the same water-to-cementitious materials ratio.

2.5 PULVERIZED FUEL ASH (PFA)

Pulverized Fuel Ash (PFA) also known as bottom ash and fly ash are by-products of the combustion of pulverized coal in power plants. However, bottom ash is formed from the melting fly ash because the temperature in the kiln is higher than the melting point of fly ash. In Thailand, the Mae Moh power plant produces bottom ash approximately 1,500 t per day or 20% of the total ashes ~fly ash and bottom ash!. Little bottom ash has been studied, for example, as fine aggregate in concrete ~Ghafoori and Bucholc 1996; Ghafoori and Bucholc 1997 or as fine aggregate in asphaltic concrete ~Churchill and Amirkhanian 1999. However, a good result was obtained when bottom ash was used as a fine aggregate in roller-compacted concrete ~Ghafoori and Cai 1998. Bottom ash has a large particle size and a high porous surface, resulting in higher water requirement and lower compressive strength. Therefore, most of it is disposed in landfills causing environmental and other problems.

2.6 SUPER PLASTICIZER (HIGH RANGE WATER REDUCER)

Super plasticizer is chemical admixtures that can be added to concrete mixtures to improve workability. Strength of concrete is inversely proportional to the amount of water added or water-cement (w/c) ratio. In order to produce stronger concrete, less water added, which makes the concrete mixture very much unworkable and difficult to mix, necessitating the use of plasticizers and super plasticizers.

Superplasticizers are also often used when pozzolanic ash is added to concrete improve strength. This method of mix proportioning is especially popular when producing high strength concrete and fiber reinforced concrete.

Adding 2% superplasticizer per unit weight of cement is usually sufficient. However, note that most commercially available superplasticizers come dissolved in water, so the extra water added has to be accounted for in mix proportioning. Adding an excessive amount of superplasticizers will result in excessive segregation of concrete and is not advisable. Some studies also show that too much superplasticizer will result in a retarding effect.

Superplasticizer is commonly manufactured from lignosulfonates, a by-product from the paper industry. Superplasticizer have generally been manufactured from sulfonated naphthalene formaldehyde or sulfonated melamine formaldehyde, although new generation products based on polycarboxylic ethers are now available. Traditional superplasticizers disperse the flocculated cement particles through a mechanism of electrostatic repulsion. In normal plasticizers, the active substances are adsorbed on to the cement particles, giving them a negative charge, which leads to repulsion between particles. Napthalene and melamine superplasticizers are organic polymers. The long molecules wrap themselves around the cement particles, giving them a highly negative charge so that the repel each other.

Polycarboxylate Ethers (PCE), the new generation of superplasticizers is not only chemically different to the older sulfonated melamine and naphthalene based products but their action mechanism is also different, giving cement dipersion is more powerful in its effect and gives improved workability retention to the cementationous mix. Furthermore, the chemical structure of PCE allows for a greater degree of chemical modification than the older generation products, offering range of performance that can be tailored to meet specific needs.

2.7 AGGREGATE

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories; fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch (9.5-mm) sieve. Coarse aggregates are any particles greater than 0.19 inch (4.75 mm), but generally range between 3/8 and 1.5 inches (9.5 mm to 37.5 mm) in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Recycled concrete is a viable source of aggregate and has been satisfactorily used in granular sub bases, soil-cement, and in new concrete. Aggregate processing consists of crushing, screening, and washing the aggregate to obtain proper cleanliness and gradation. If necessary, a benefaction process such as jigging or heavy media separation can be used to upgrade the quality. Once processed, the aggregates are handled and stored in a way that minimizes segregation and degradation and prevents contamination. Aggregates strongly influence concrete's freshly mixed and hardened properties, mixture proportions, and economy. Consequently, selection of aggregates is an important process. Although some variation in aggregate properties is expected, characteristics that are considered when selecting aggregate include; grading, durability, particle shape and surface texture, abrasion and skid resistance, unit weights and voids, absorption and surface moisture.

Grading refers to the determination of the particle-size distribution for aggregate. Grading limits and maximum aggregate size are specified because grading and size affect the amount of aggregate used as well as cement and water requirements, workability and durability of concrete. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength. When gap-graded aggregate are specified, certain particle sizes of aggregate are omitted from the size continuum. Gap-graded aggregate are used to obtain uniform textures in exposed aggregate concrete. Close control of mix proportions is necessary to avoid segregation.

Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Generally, flat and elongated particles are avoided or are limited to about 15 percent by weight of the total aggregate. Unit-weight measures the volume that graded aggregate and the voids between them will occupy in concrete. The void content between particles affects the amount of cement paste required for the mix. Angular aggregate increases the void content. Larger sizes of well-graded aggregate and improved grading decrease the void content. Absorption and surface moisture of aggregate are measured when selecting aggregate because the internal structure of aggregate is made up of solid material and voids that may or may not contain water. The amount of water in the concrete mixture must be adjusted to include the moisture conditions of the aggregate. Abrasion and skid resistance of an aggregate are essential when the aggregate is to be used in concrete constantly subject to abrasion as in heavy-duty floors or pavements. Different minerals in the aggregate wear and polish at different rates. Harder aggregate can be selected in highly abrasive conditions to minimize wear.

Flakey is the term applied to aggregate or chippings that are flat and thin with respect to their length or width. Aggregate particles are said to be flakey when their thickness is less than 0.6 of their mean size. The flakiness index is found by expressing the weight of the flakey aggregate as a percentage of the aggregate tested. This is done by grading the size fractions, obtained from a normal grading aggregate, in special sieves for testing flakiness. These sieves have elongated rather than square apertures and will allow aggregate particles to pass that have a dimension less than the normal specified size, i.e. 0.6 of the normal size. This grading process is normally performed by hand because flakey chippings tend to 'lie' on the sieve surface rather than fall through the aperture. There are a number of material and aggregate specifications that have a maximum amount of flakey material allowed, e.g. surface dressing chippings. Flakey aggregate has less strength than cubical aggregate, and does not create the dense matrix that well graded cubicle aggregate is able to do, and it will provide less texture when used in surface dressing.

Well graded means that within a material that is well graded there is a good distribution of all the aggregate sizes from largest to smallest, coarse aggregate to ''dust''. With a well graded material all the different size aggregate particles will position themselves within the total matrix in such a way to produce a tightly knit layer of maximum possible density, when compacted correctly. A well graded material is better able to carry and spread load imposed on it than a poorly graded material. A well graded material will possess good stability, with good distribution of load or stress spreading out uniformly through the material to the road pavement layer below. A poorly graded material is one where the size / particle distribution of the supplied material is out of balance with the intended specification /design of the received product. There may be too high a percentage of fines or coarse within the material, and maximum density by proper compaction will not be achievable. Segregation is separation of particular aggregate sizes, usually the larger sizes, is much more likely to occur in a poorly graded material.

Segregation leaves laid areas with too many fines, or areas that are ''open'' due to patches of coarse material.

2.8 DYNAMIC BEHAVIOUR OF REINFORCED HIGH STRENGTH CONCRETE BEAMS

The stress–strain diagram (as illustrated in figure 1) of a square specimen with 57 MPa of concrete strength which was subjected to repeated uniaxial compression as reported by Muguruma et al. (1983). In figure 1, the stress–strain curve of the same specimen tested under monotonically increasing compressive loading is plotted. From the limited experimental investigation (Bing et al. 1994) it can be concluded that the stress–strain curve of HSC under cyclic loading practically coincides with the curve resulting from monotonic application of the loading. Similar results for normal strength concrete were reported by Karsan and Jirsa (1969). Other parameters that ought to be accounted for include the degradation of stiffness and strength, the increase in concrete plastic strain ε_{pl}, as well as the effect of confinement provided by transverse reinforcement.

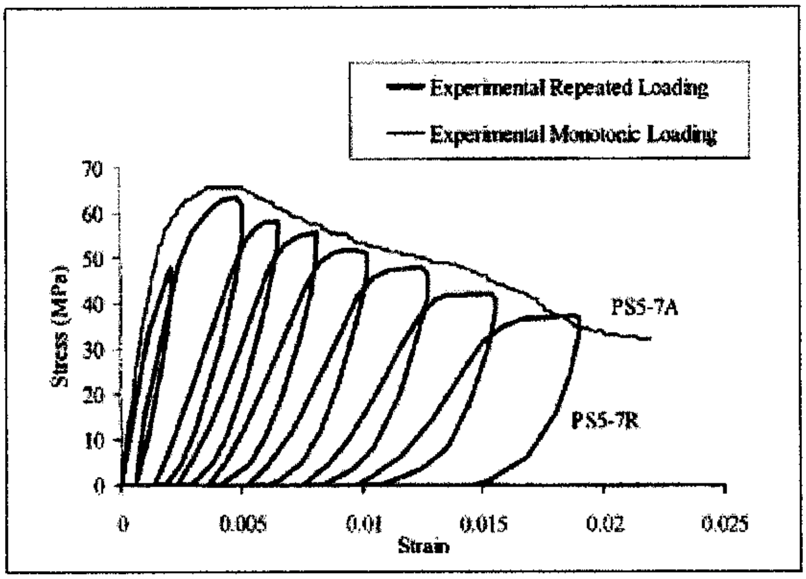


Figure 1: Stress–strain diagram for HSC specimen subjected to repeated uniaxial compression

As summarized by Aoyama and Noguchi (1979), a number of models have been developed to predict the response of concrete under cyclic loading. All these analytical models together with the more recent ones by Yankelevsky and Reinhardt (1987), Mander et al. (1988), Otter and Naaman (1989), and Martinez-Rueda and Elnashai (1997) were neither developed for HSC nor verified against experimental data for high-strength members. In Figure 2, the stress–strain diagrams of five well-known models for the cyclic behavior of concrete are illustrated.

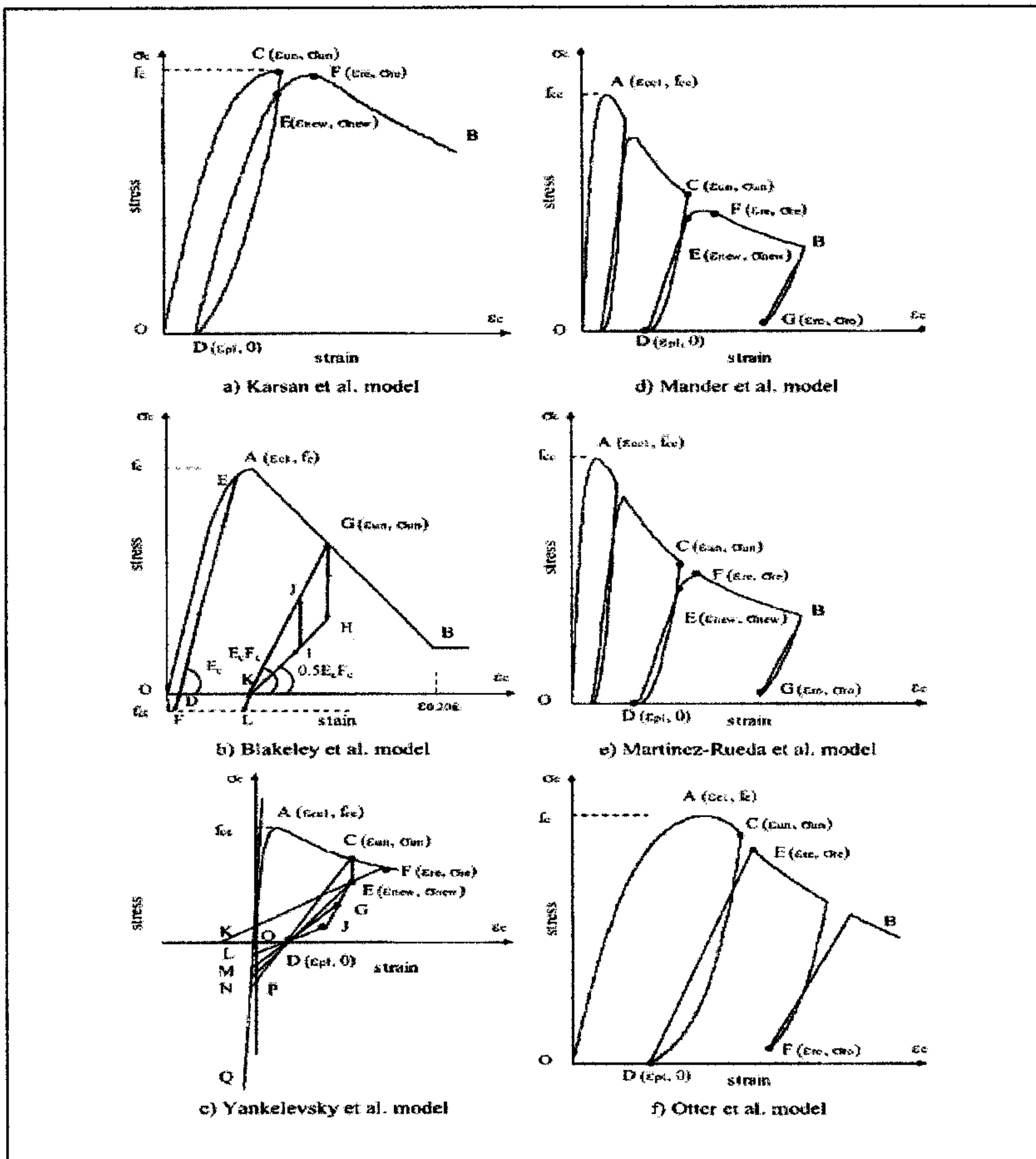


Figure 2: Analytical stress–strain curves for cyclic behavior of concrete

3.0 METHODOLOGY

3.1 PROJECT IDENTIFICATION

The methodology that has been followed through finishing this project is as shown below:

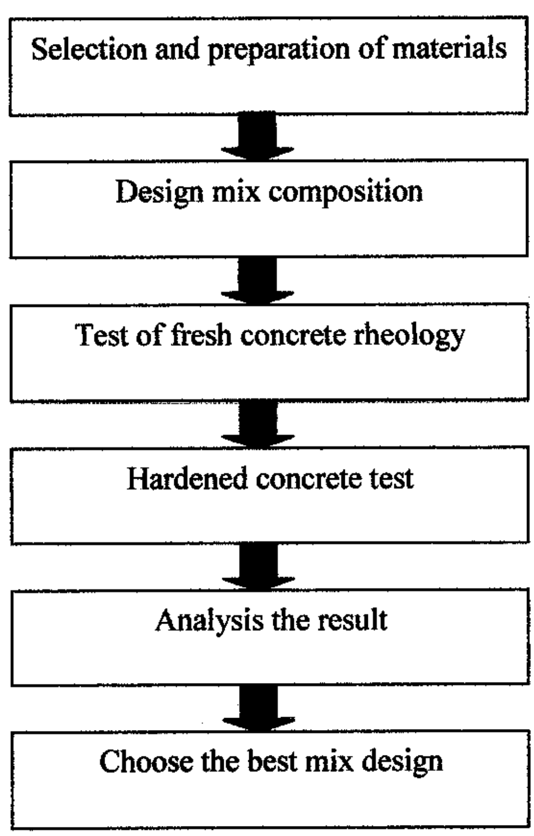


Figure 3: Flow chart of activities

3.2 MATERIAL PREPARATION

Before doing the mixing, preparation of the aggregates is very important and it must be done days before the mix to avoid error during the mix.

3.2.1 Portland Cement

Cement is a powder, which by hydraulic reaction (i.e. with water) forms a solid, cohesive mass. Ordinary Portland Cement (OPC), which is the standard, grey cement used for most purposes. Ordinary Portland cement sets by hydraulic (i.e. water) reaction. It is a complex mixture of components, probably the most important of which are dicalcium and tricalcium silicates (C2S and C3S to cement chemists). Besides that it also contains tricalcium silicate and tetracalcium aluminoferrite. The water/cement ratio is of paramount importance to the final set strength of the concrete, and the cement/aggregate ratio and aggregate size distribution are also important.

3.2.2 Pulverized Fuel Ash (PFA)

Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Instead of volcanoes, today's fly ash comes primarily from coal-fired electricity generating power plants. These power plants grind coal to powder fineness before it is burned. Fly ash - the mineral residue produced by burning coal - is captured from the power plant's exhaust gases and collected for use. Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron.

3.2.3 Aggregate preparation

Preparation of the aggregates took 2 days as we need to sieve the aggregates, soak it in the water and let it dry for one day at the room temperature. Sieve analysis need to be conducted to ensure that all sizes of the aggregates are being graded well. This is because we need to do the mix based on the different weight of the aggregates according to the sizes. The aggregates sizes that we sieve vary from less than 3.35mm to more than 20mm. The sieve sizes that we use are 20mm, 14mm, 10mm, 5mm and 3.35mm. The grading will be from 3.35mm-5mm, 5mm-10mm, 10mm-14mm and 14mm-20mm. The retained aggregate at each sieve will be separated according to the grade and aggregate that retained on the last pan will be considered as fine aggregates because the size is less than 3.35mm. After conducting sieve analysis, the aggregates need to be soaked in the water for 24 hours. The purpose is to remove dirt at the surface of the aggregates that might disturb the strength or proportion of the concrete and as well ensured that the aggregates are fully saturated. Then the aggregates must be dried for one day at room temperature. The purpose is to obtain the saturated surface dry aggregates. This is to ensure that the aggregates will not absorb water during the mix. If the aggregates are too dry, they can absorb the water content during the mix and this will lead to lack of water in the mix and will disturb the flowability of the concrete. Water content is the most important aspect to be taken into consideration during the mix. Lack or too much of water content will fail the self compacting concrete.

3.2.4 Preparation of RHA

RHA will be burn and grind before used as additive in the mixing (Figure 4). RHA burned so that we can get the ash of it which is free from activated carbon. It will be grind so that we can get the finer RHA. The final process before use the RHA in the mixing is sieving the grinded RHA until it pass through 180μm pan size. Final product of that rice husk ash will be in size than smaller than 180 μm.

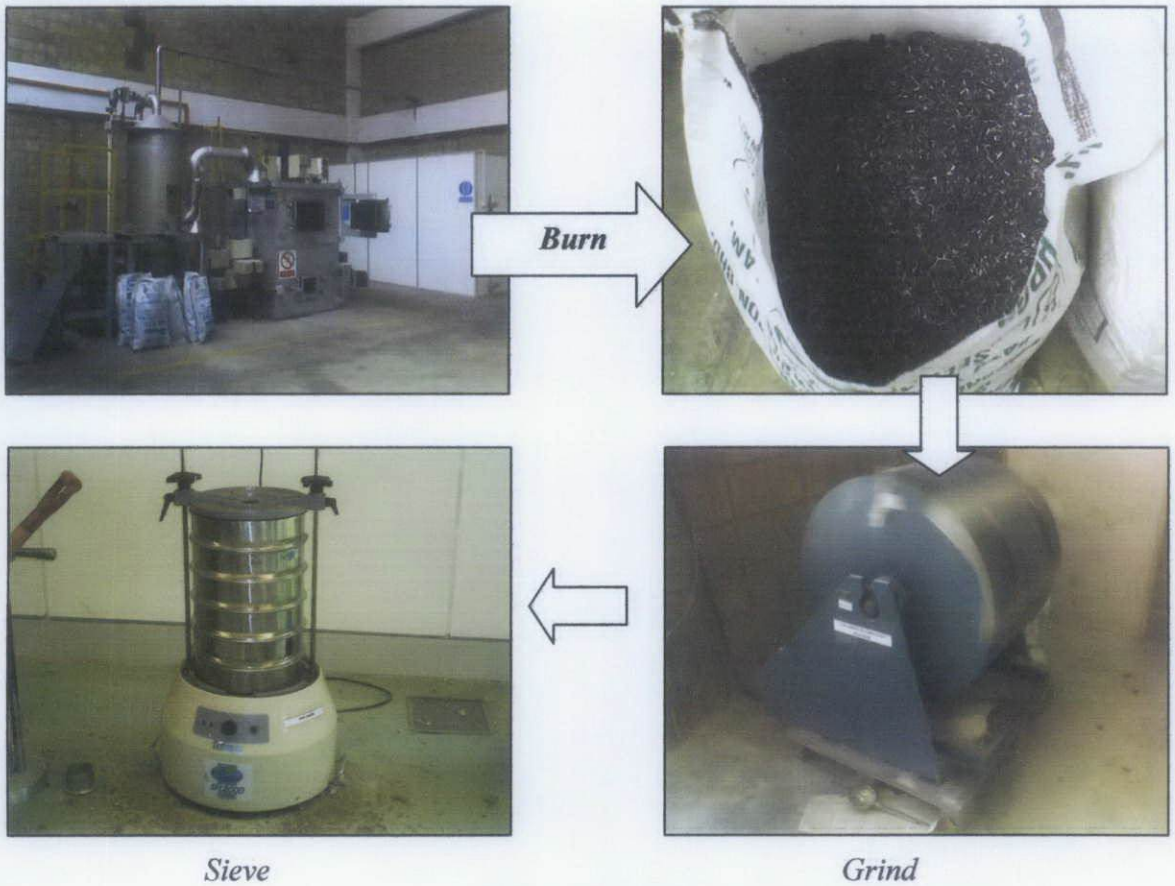


Figure 4: Process to obtain Rice Husk Ash

3.3 MIX DESIGN PROPORTION

In order to complete this project, lab work must be conducted to experiment the best proportion of the mix to obtain the self compacting state of the concrete. The mix must be ensured that it contains the admixtures and super plasticizer that could make the concrete flow able but yet maintain the strength. The mix proportion is very important because it leads to the high performance of the self compacting concrete characteristics. The mix designs were based on compressive strengths at 28 days that carried out from Mr. Agus, PhD Student.

Table 1: Compressive Strength at 28 Days

Specimens	Compressive strength (Mpa)
PFA 1	83.09
PFA 2	71.86
PFA 3	80.29
RHA 1	62.50
RHA 2	59.60
RHA 3	58.70

The design data is presented in the following table:

Table 2: Amount of materials

Mix No.	OPC (kg/m^3)	PFA (kg/m3)	RHA (kg/m3)	CA (20-8) [kg/m3]	CA (8-4) [kg/m3]	FA (4-0) [kg/m3]	water (kg/m3)	SP (%)
1	475.00	25	-	310	615	850	125	3
2	450.00	50	-	310	615	850	125	3
3	425.00	75	-	310	615	850	125	3
4	554.17	-	29.17	282	560	800	175	3
5	525.00	-	58.33	282	560	800	175	3
6	495.83	-	87.50	282	560	800	175	3

Table 3: Mixes for different cement and filler proportion

Mix No.	OPC (kg)	PFA (kg)	RHA (kg)	CA (20-8) [kg]	CA (8-4) [kg]	FA (4-0) [kg]	water (kg)	SP (kg)
1	54.15	2.85	-	35.34	70.11	96.9	14.25	1.71
2	51.30	5.70	-	35.34	70.11	96.9	14.25	1.71
3	48.45	8.55	-	35.34	70.11	96.9	14.25	1.71
4	63.18	-	3.33	32.15	63.84	91.2	19.95	2.00
5	59.85	-	6.65	32.15	63.84	91.2	19.95	2.00
6	56.52	-	9.98	32.15	63.84	91.2	19.95	2.00

3.4 CONCRETE MIXING

All concrete should be mix thoroughly until it is uniform. The sequence of concrete mix is very important and it must be followed accordingly. The procedure of concrete mix incorporating with HRWR is shown below:

1. Pour all coarse and fine aggregates into the mixer and mix for 25 seconds to ensure uniform distribution between both materials.
2. Pour half of the water and mix for 1 minute.
3. Leave the mixes for 8 minutes to let both coarse and fine aggregates to absorb water.
4. Pour all Portland cement and additive (PFA / RHA) into the mixer and mix for 1 minute.
5. Pour another half of the water and add HRWR and mix for 3 minutes.
6. Finally perform hand mixing until the mix is in uniform stage.

3.5 CONCRETE CASTING

Fresh concrete will then cast into beam formwork. The purpose is to produce sample of the concrete and perform several tests on the concrete. The size of formwork is 1.9m x 0.27m x 0.14m

3.6 CONCRETE CURING

After removal of mould on the second day, the wet clothes must be placed on top of beam until the day of testing. This is like as curing process. Usually, for small concrete we put it in the water for curing process, but for the large beam, we just put the wet clothes. The purpose of curing is to avoid shrinkage cracking due to temperature fluctuation and also to gain the maximum strength of the concrete.

3.7 FRESH CONCRETE TEST

For determining the self-compatibility properties slump flow, v-funnel and L-Box test were performed and measured. All fresh test measurement was duplicated and average of measurement was taken. In order to reduce the effect of workability loss on variability of test results, the fresh-state properties of mixtures were determined in a period of 30min after mixing.

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

3.7.1 Slump Flow Test

The slump flow test used to assess the horizontal free flow of SCC in the absence of obstructions. It gave no indication of the ability of the SCC to pass between reinforcement without blocking, but some indication of resistance to segregation. The equipments included a truncated cone with the internal dimension of 200 mm diameter at the base, 100 mm diameter at the top and a height of 300 mm with a base plate of a stiff non-absorbing material. The truncated cone was filled with SCC without tamping, followed by raising the cone vertically to allow the SCC flowing out freely. The final diameters of the SCC in two perpendicular directions were measured as workability of the SCC and the average slump flow value was calculated. Diameter should be between 650 and 750 mm.

3.7.2 V-Funnel Test

The deformability through restricted areas can be evaluated using V-Funnel Test. In this test, the funnel will be filled completely with concrete and at the bottom outlet would then be opened, allowing the concrete to flow out. The time of flow recorded. Flow time can be associated with a low deformability due to high paste viscosity, high inter particle friction or blockage of flow. Flow time should be below then 10 seconds to be considered as a good flowability Self Compacting concrete.

3.7.3 L-Box Test

L-box test is using for detecting concrete with higher possibility of segregation between coarse aggregate and mortar also for assessing the placeability of SCC. In this method, a closed vertical chamber is filled with the concrete to be tested so that a hydrostatic pressure head is produced. After a slide is opened the concrete has to level out through horizontal (L-box) flow obstacles. The difference in levels determines the tendency to blocking.

3.8 HARDENED CONCRETE TEST

Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics if its history is unknown. For new concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures. To check the dynamic behavior of RC beams, concrete beam specimens are cast to test for dynamic test.

3.8.1 Dynamic Test

The reinforced concrete beams prepared for this project were 1,900 mm long, having a cross section of 140 X 270 mm and were simply supported over a 1,850 mm span. Two 12 mm bars were selected as flexural reinforcement, and two more were placed in the compression region for fabrication easement. Ten 9 mm stirrups were placed in the beam as shear reinforcement at spacing of 200 mm evenly along the span. A clear cover of 30 mm was provided on all sides. The grade of the steel was 400 MPa.

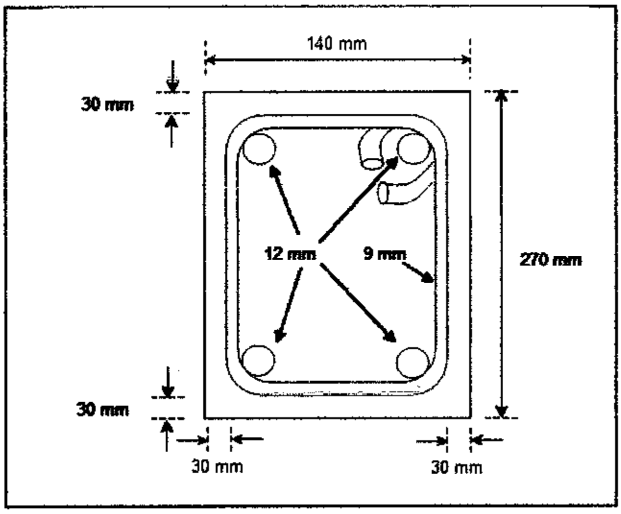


Figure 5: Beam Cross Section

The tests were carried out using a 270 kN capacity hydraulic actuator. The actuator was operated under load control for the fatigue loading. The load was applied at the fourth-point bending of the beam within the 1,850 mm supported span. All contact points along the beam were supported with rollers to ensure that the load was applied evenly during testing. Strain gauges were located on the bottom of concrete surface.

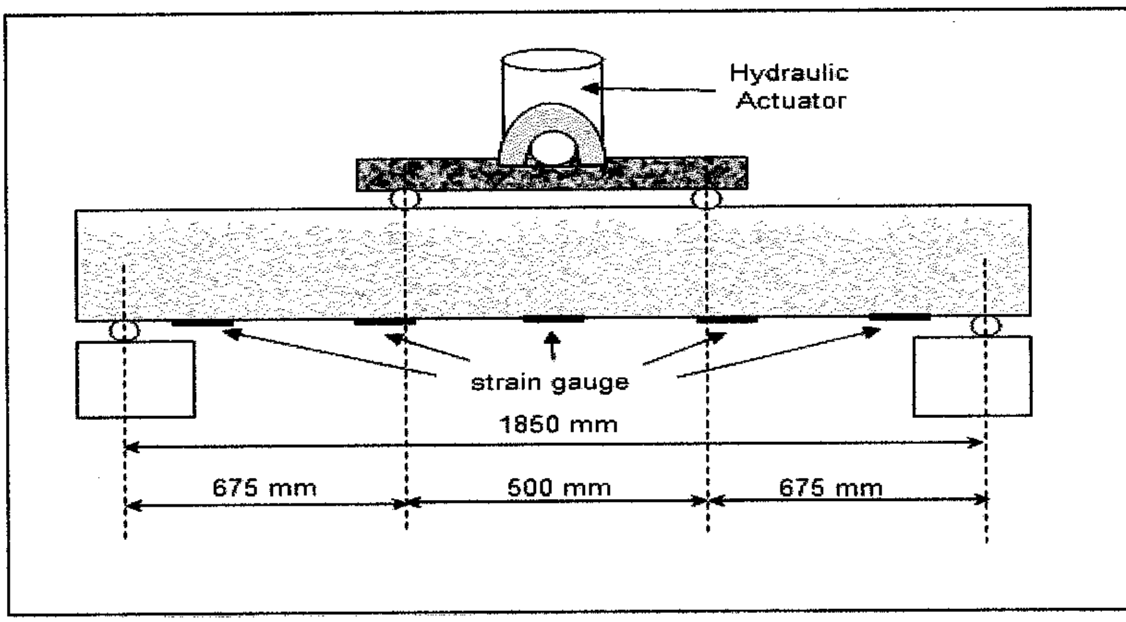


Figure 6: Dynamic Test Setup

4.0 HEALTH SAFETY ENVIRONMENT

Mixing and pouring Self Compacting Concrete (SCC) in small volume is a relatively safe endeavor. However, there are a few potential hazards that are noise, dust, vibration, and so on. The equipment that uses electric in wet condition also has risk. To avoid all hazardous from happening, proper protection for eyes, skin and lungs are required as below:

- **Safety Glass**

Safety glass is worn to protect eyes. The best safety glasses are the wraparound style with polycarbonate lenses.

- **Face Mask**

A fitted charcoal-filter mask is worn when handling dry ingredients. A paper mask is better than nothing but offer minimal protection.

- **Hearing Protection**

Hearing protection is used during noisy activities. So it is good to protect the ears. The best hearing protector is that can fit over the ears and the second best are ear plugs.

- **Glove**

A heavy-duty rubber gloves or surgical glove (latex or non latex) is worn to protect hand.

Table 4: Health and Safety Apply During Final Year Project

NO	ITEMS	DESCRIBTION OF ITEM	EFFECT OF MATERIAL		WORKER EXPOSURE				SAFETY
			HUMANS	ENVIRONMENT	NOISE	DUST	ODOUR	HEAT	
1	Cutter	Cut the steel	√	X	√	X	X	√	Use goggles, glove, face mask & ear muff
2	Incinerator Machine	Burn the Rice Hush	√	X	X	√	X	√	Use goggle & glove
3	Abrasion LA	Grind the Rice Hush	√	X	√	√	√	X	Use goggles, glove, face mask & ear muff
4	Sieve Shaker	Sieve the Rice Hush Ash	√	X	√	√	√	X	Use goggles, glove, face mask & ear muff
5	Cement Mixer	Mix the concrete	√	X	√	√	√	X	Use goggles, glove, face mask & ear muff
6	Dynamic Machine	Do dynamic test to beams	√	X	√	X	X	X	Use ear muff
7	Portland Cement	Material for mixing concrete	√	X	X	√	√	X	Use goggles, glove, face mask & ear muff
8	Pulverized Fuel Ash	Material for mixing concrete	√	X	X	√	√	X	Use goggles, glove, face mask & ear muff
9	Rice Hush Ash	Material for mixing concrete	√	X	X	√	√	X	Use goggles, glove, face mask & ear muff
10	Super Plasticizer	Material for mixing concrete	√	X	X	X	√	X	Use face mask & glove

5.0 RESULTS AND DISCUSSION

5.1 EXPERIMENTAL RESULTS FROM FRESH CONCRETE TEST

Based on result on 3 mixes PFA and 3 mixes RHA that had been done for fresh concrete test, the conclusions were:

- All mixes is considered Self Compacting Concrete (SCC) except for PFA 1 because the flow time is less than 10 seconds in V-funnel test. For this study, PFA 1 is not considered as SCC.
- For L-box test, the difference in levels determines the tendency to blocking. From the result, the PFA 1 has high difference in levels. This characteristic is same with normal concrete. So PFA 1 has less passing ability through reinforcement.
- For slump flow test, the diameter of concrete should be between 650 and 750 mm and 500 mm diameter should be reached within 3 - 6 seconds. Based on result, the PFA 1 and PFA 3 do not meet the requirement test. So, PFA 1 and PFA 3 are not so workability compare to the other mixes.
- PFA 2 is too fast to reach 500mm diameter which is 1 minutes. So this mix is so fluidity. It is because the aggregates have content water and do not dry properly. The concrete were hardened quickly during pouring in the formwork. The result after the beam harden, the beam look like marble because contain a lot of water.

To determine the optimum mix design (based on rheological properties of SCC), the result from the dynamic test must take into consideration.

Table 5: Result for the fresh concrete test

Date	Mix	Rheologi					
		V funnel	L box		T500	Slump flow	
		second	h1 (cm)	h2 (cm)	second	x (mm)	y (mm)
30-Aug-07	1	10.8	1	22	-	500	300
10-Sept-07	2	2.5	9	11	1	750	760
26-Sept-07	3	6.82	8	11	7.58	560	540
12- Dec-07	4	6.53	9	8	3.19	780	730
14-Dec-07	5	6.87	9	10	4.56	760	720
17-Dec-07	6	8.75	10.6	11.5	5.66	670	600

5.2 EXPERIMENTAL RESULTS FROM DYNAMIC TESTS

Six beams were tested under cycling load at the same load capacity. Three were using PFA and three were using RHA as filler. The maximum load was chosen based on a percentage of the maximum load to failure. The minimum load depended on the frequency of the loading and was selected to ensure stability of the test setup. For practical purposes, the maximum number of cycles applied to a single specimen was 6 x 10^4 cycles.

During the dynamic test, the testing of RHA 2 was failed due to the failure of the equipment. The beam support slightly moved during the test and resulted in damaging of the beam. This testing cannot be repeated because of the limited time to construct the new beam of RHA 2. So, only five beams were used to obtain the objective of this study.

5.2.1 Cracks Mechanisms

For cycling load tests (dynamic test), the mode of failure was fatigue of the concrete. Flexural cracks were initiated after the first cycle and propagated as the number of applied cycles increased. Also, in the same manner, the shear cracks were started.

The crack growth during the fatigue tests began with microcracking within the beam, which progressed to form larger surface cracks and grew into diagonal cracks. At this time, the diagonal cracks grew at 45^0. The failure cracks of the beams are shown in the figures below under cycling load tests:

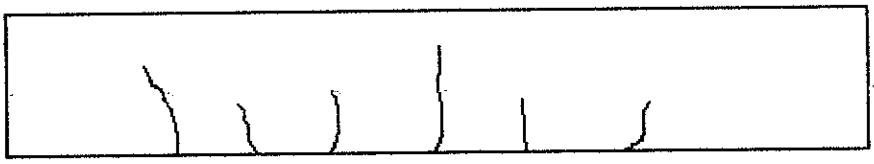


Figure 7: Load versus Deflection under Dynamic Test for PFA 1

(not considered as SCC)

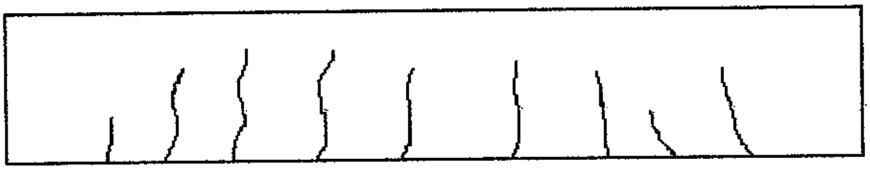


Figure 8: Load versus Deflection under Dynamic Test for PFA 2

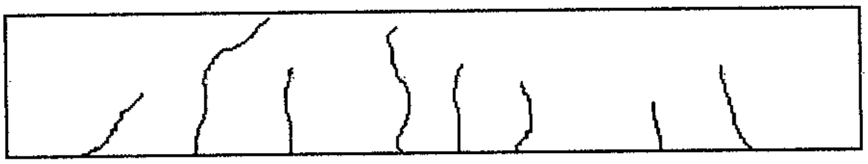


Figure 9: Load versus Deflection under Dynamic Test for PFA 3

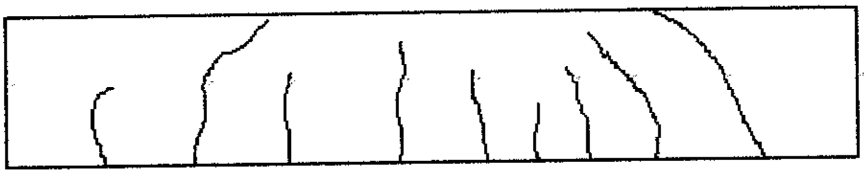


Figure 10: Load versus Deflection under Dynamic Test for RHA 1

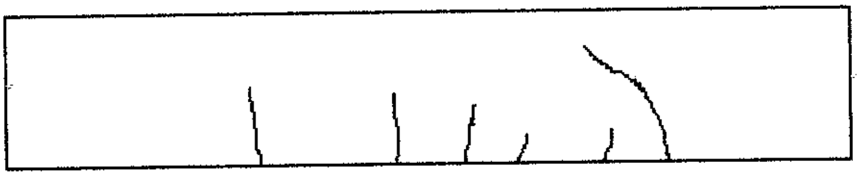


Figure 11: Load versus Deflection under Dynamic Test for RHA 2(Failed)

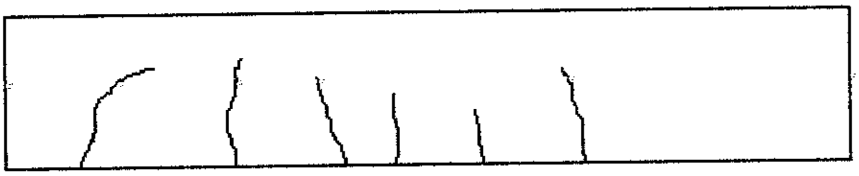


Figure 12: Load versus Deflection under Dynamic Test for RHA 3

From the cracks that were occurred during dynamic test, the conclusions that had been done were:

- PFA 2 performance was very good comparing to PFA 3. It was because the crack for PFA 2 was not occurring until compression part (top part). A good beam is a beam that can avoid crack to occur at compression part.
- RHA 3 performance was very good comparing to RHA 1 because less number of cracks occurred and no crack occurred at compression part.

5.2.2 Deflection Measurements

The changes of the mid span deflections with the increase of time for all beams tested under fatigue loading are given below:

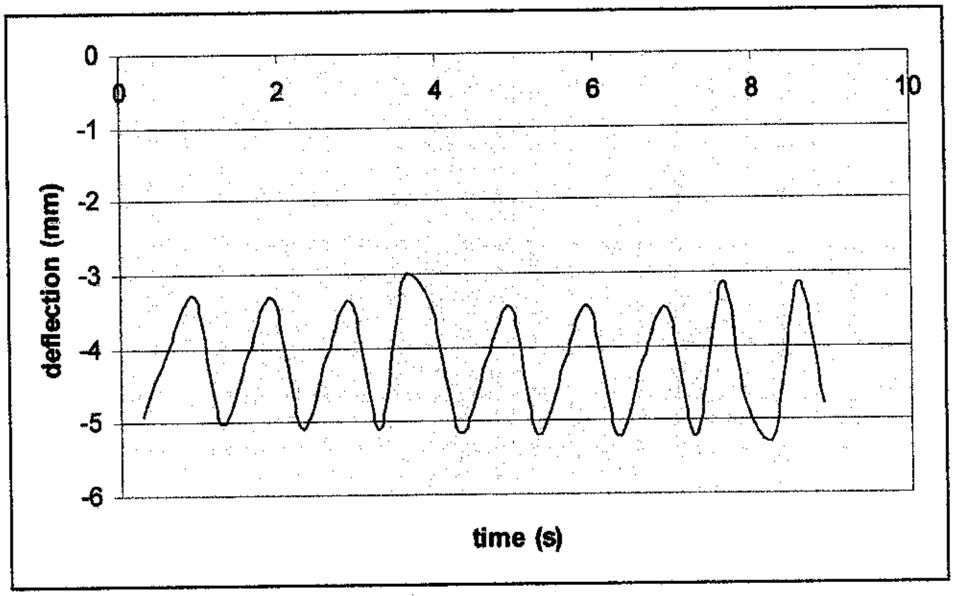


Figure 13: Deflection versus Time under Dynamic Test for PFA 1
(Not considered as SCC)

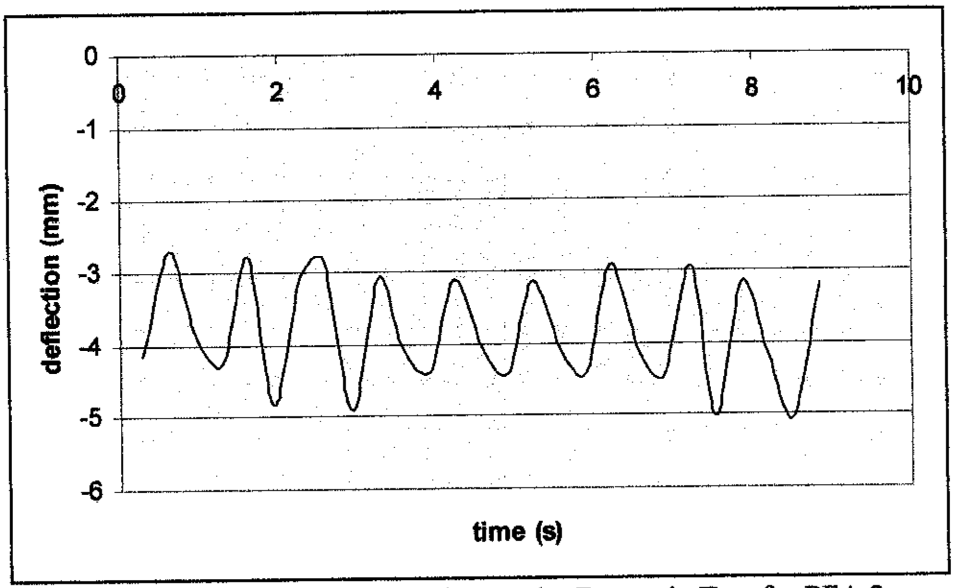


Figure 14: Deflection versus Time under Dynamic Test for PFA 2

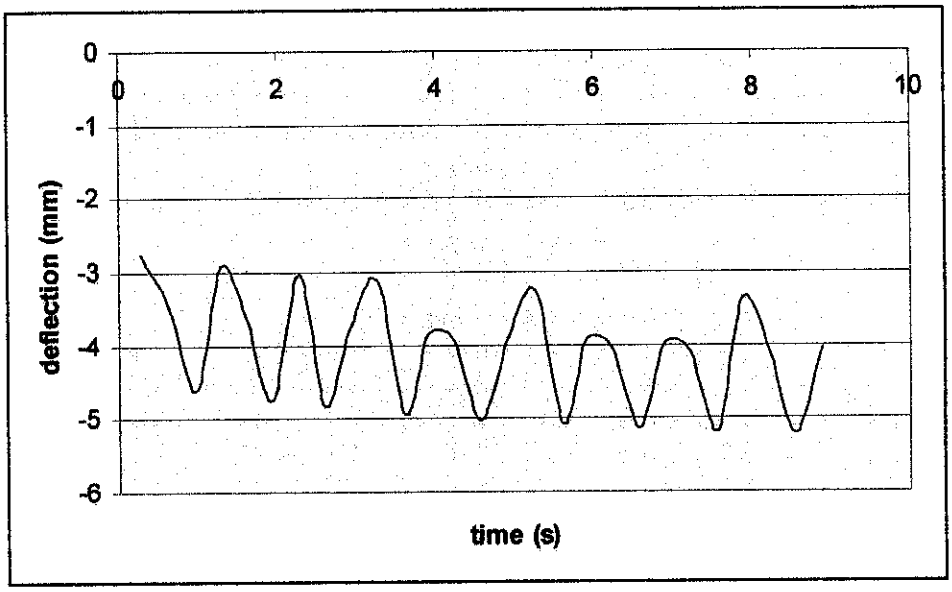


Figure 15: Deflection versus Time under Dynamic Test for PFA 3

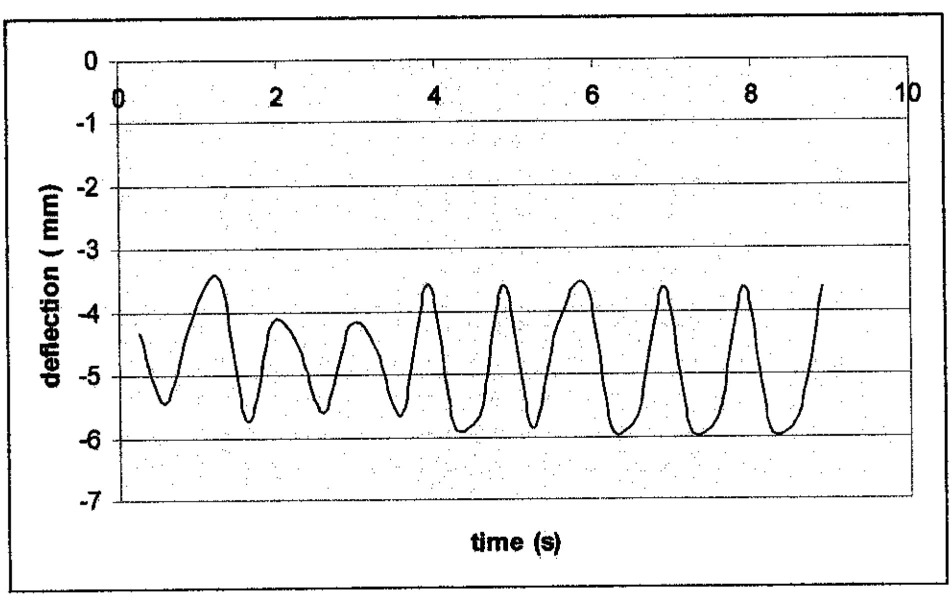


Figure 16: Deflection versus Time under Dynamic Test for RHA 1

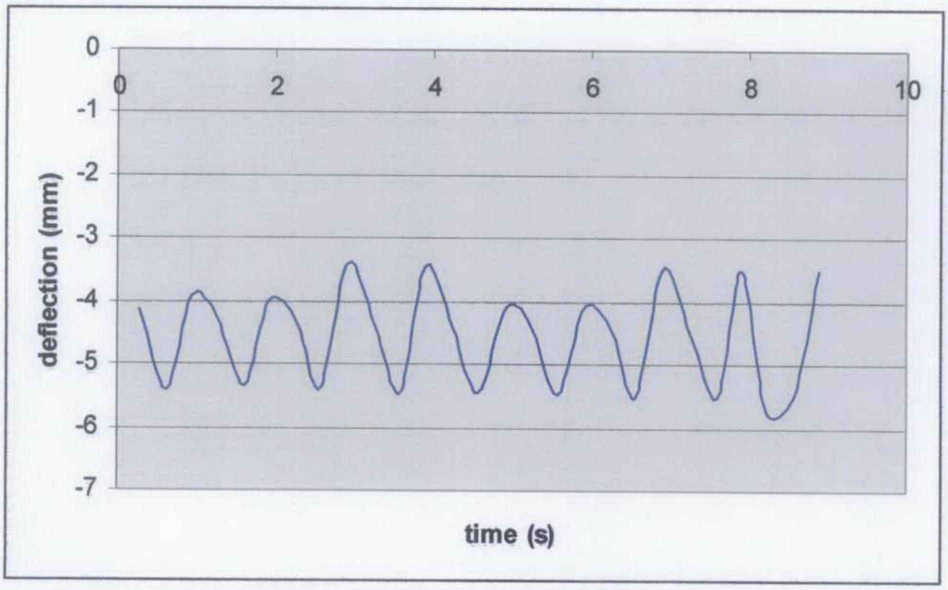


Figure 17: Deflection versus Time under Dynamic Test for RHA 3

The load-deflection diagram of beams, tested under cycling load is plotted. The deflection increases as the number of applied cycles (time) increases. Series of load-deflection curves, conducted at all stages during the dynamic load history, for specimens under cycling load is shown below:

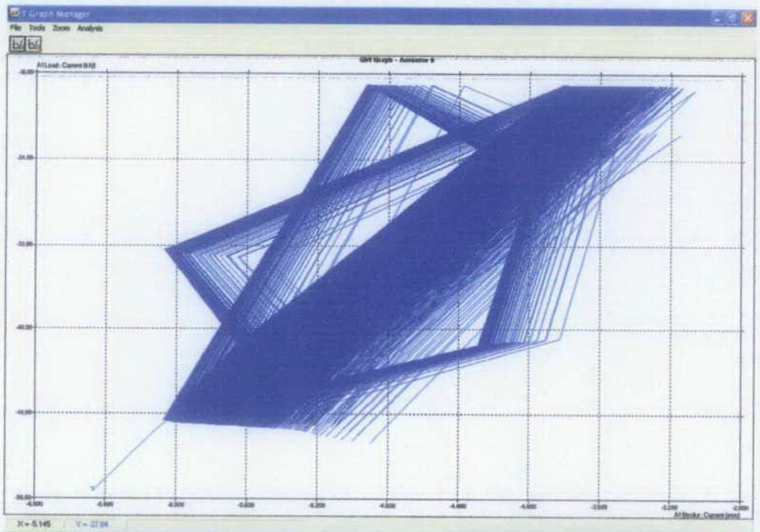


Figure 18: Load versus Deflection under Dynamic Test for PFA 1

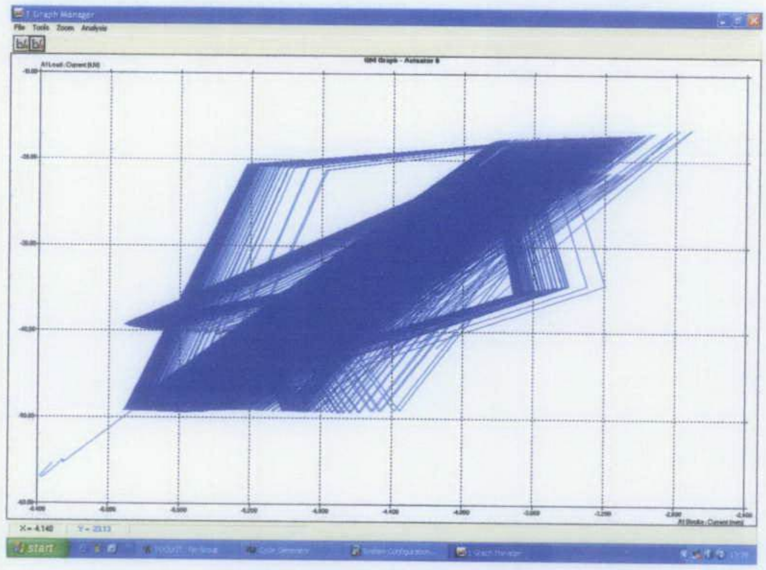


Figure 19: Load versus Deflection under Dynamic Test for PFA 2

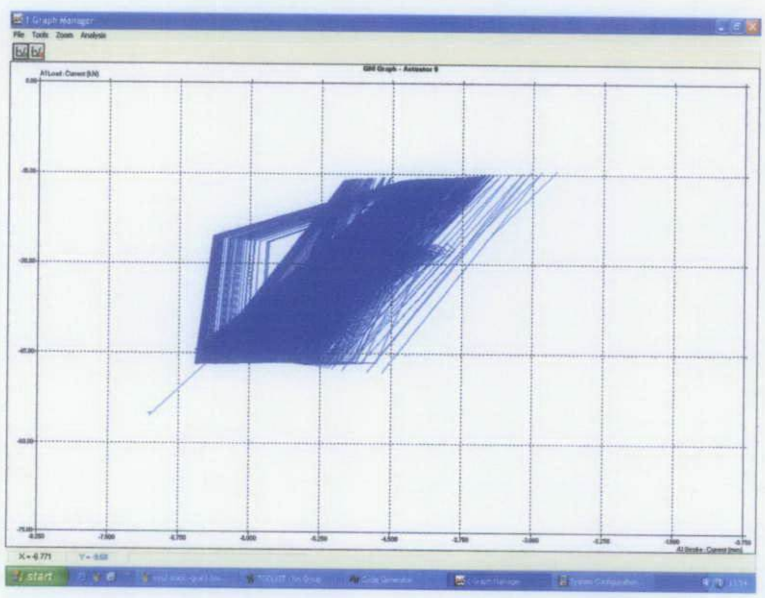


Figure 20: Load versus Deflection under Dynamic Test for PFA 3

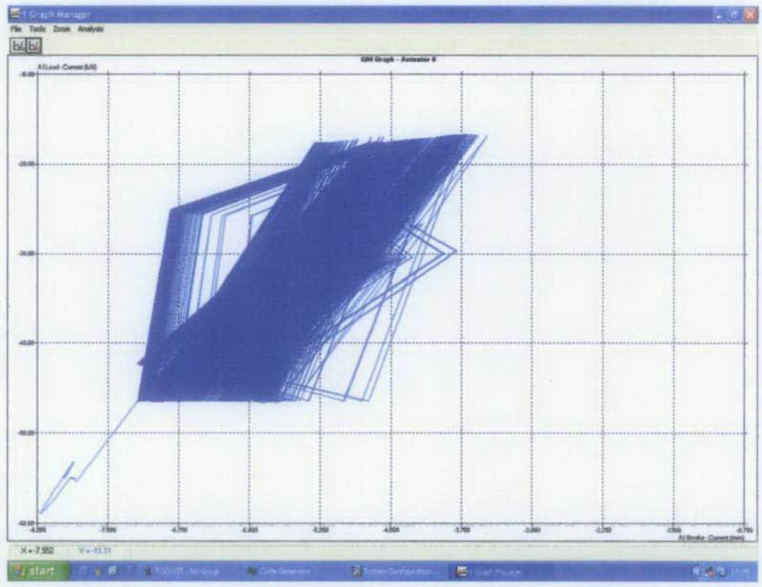


Figure 21: Load versus Deflection under Dynamic Test for RHA 1

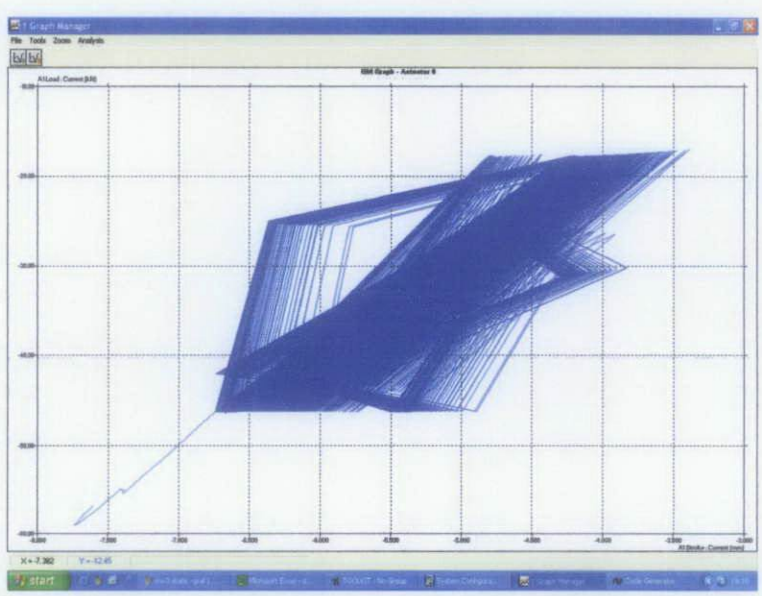


Figure 22: Load versus Deflection under Dynamic Test for RHA 3

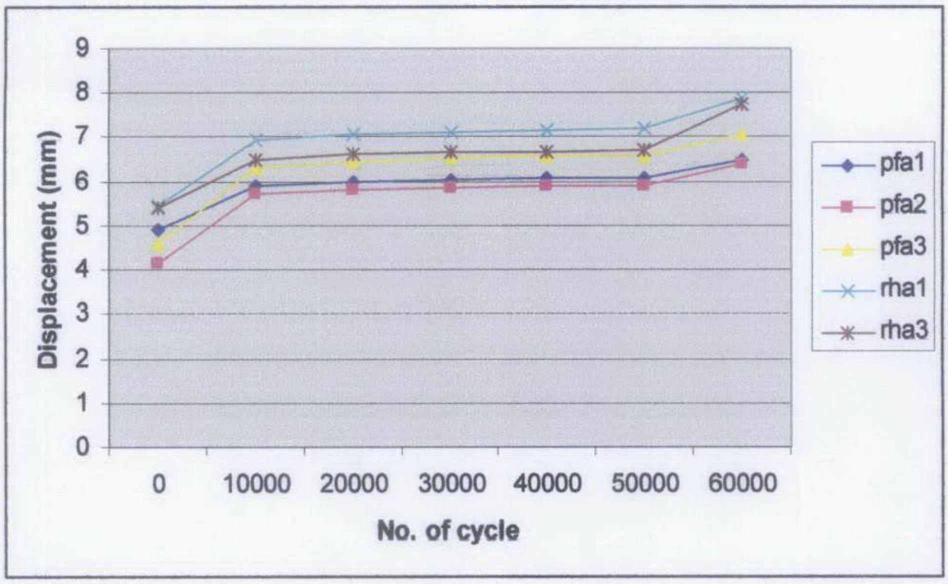


Figure 23: Deflection versus No. of Cycles under Dynamic Test for Beams

Figure 23 shows the deflection-cycles curves for PFA 1, PFA 2, PFA 3, RHA1, and RHA 3 under dynamic test. From the figure, it can be seen that the deflection of PFA 2 is better in deflection performance compare to others beams. By that, it can be concluded that the self compacting concrete beam using mix design in PFA 2 is the best beam compare to others in term of deflection measurement.

5.2.3 Strain Measurements

Five strain gauges were placed at the bottom of each beam. The setups of strain gauges are illustrated below:

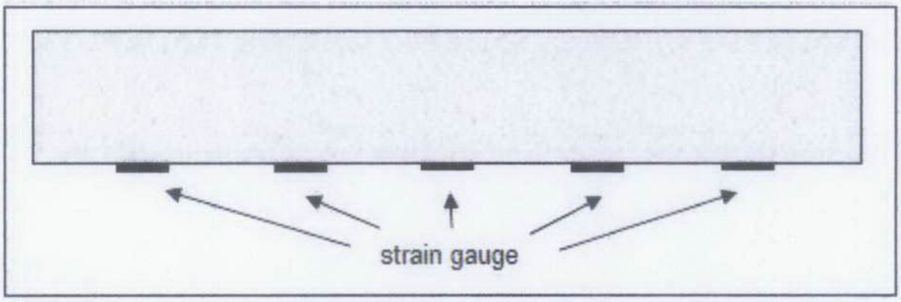


Figure 24: Strain Gauge Setup for Dynamic Test

The recorded strains on the concrete for the beams are presented below:

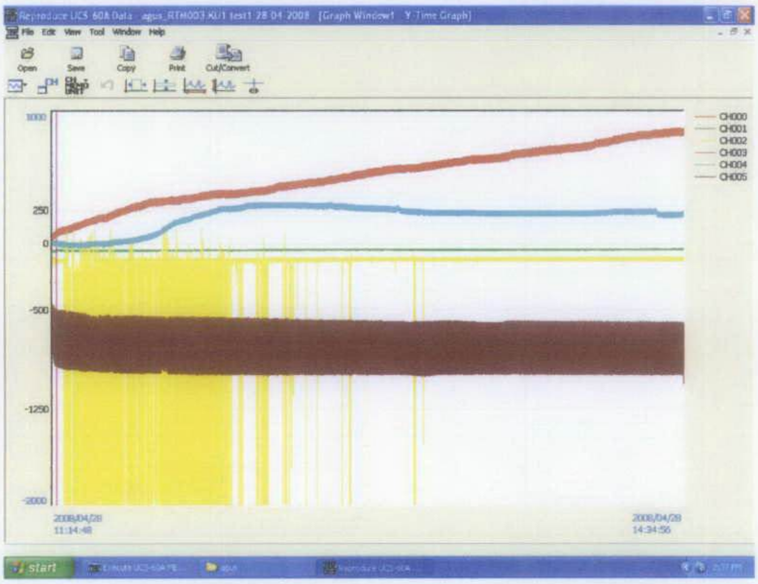


Figure 25: Strain Measurement under Dynamic Test for PFA 1

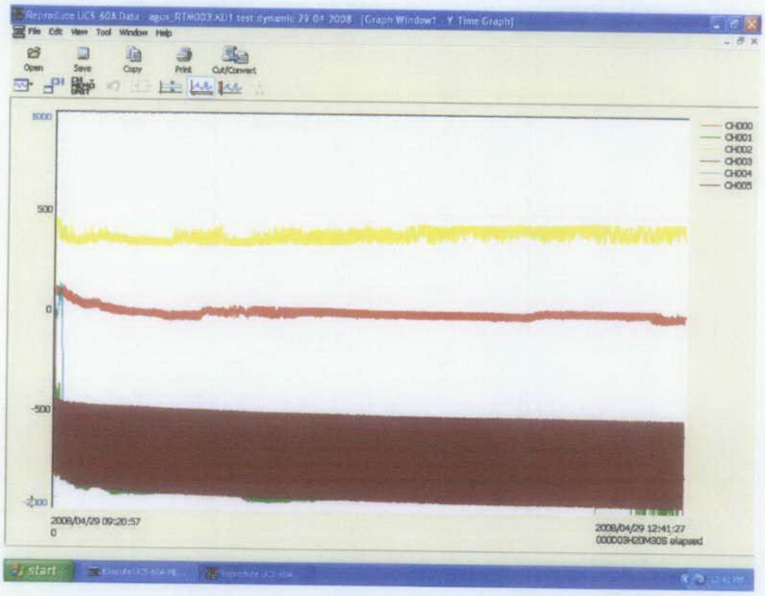


Figure 26: Strain Measurement under Dynamic Test for PFA 2

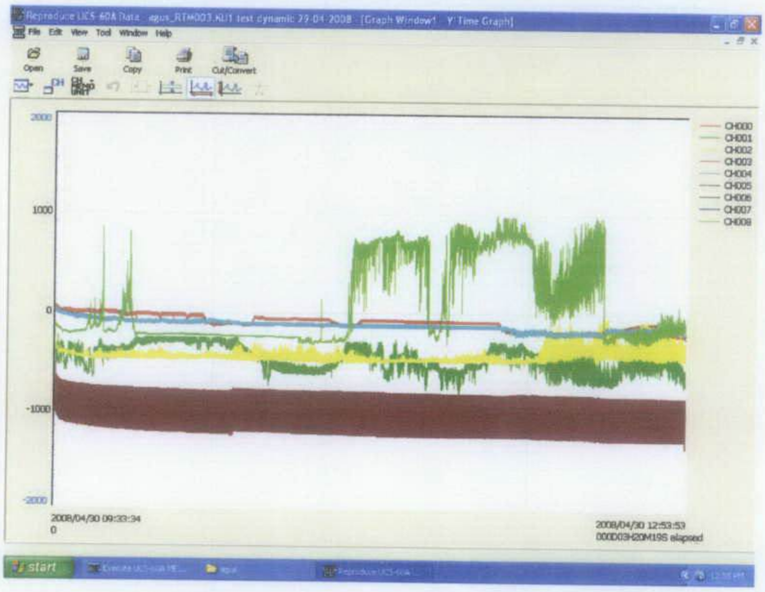


Figure 27: Strain Measurement under Dynamic Test for PFA 3

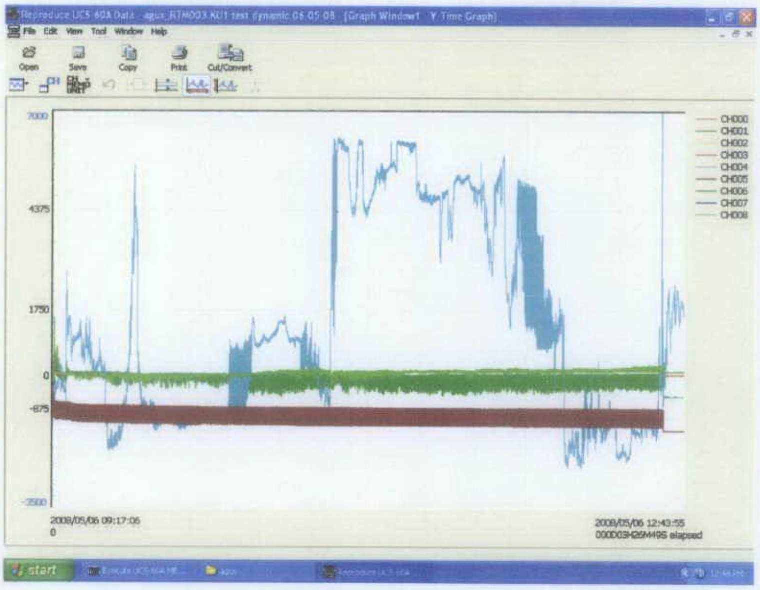


Figure 28: Strain Measurement under Dynamic Test for RHA 1

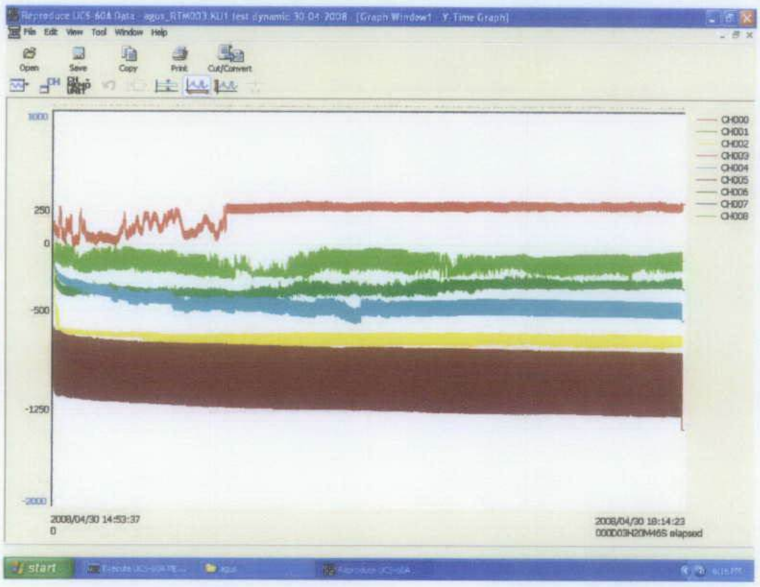


Figure 29: Strain Measurement under Dynamic Test for RHA 3

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Conclusions are based on an experimental study conducted on five 140 x 270 x 1,900 mm reinforced concrete beams. Three beams were self compacting concrete beam using pulverized fly ash (PFA) as cement replacement and two using rice husk ash. All beams were tested under dynamic loading conditions. All objectives of this study are achieved:

1. The optimum mix design and rheological properties of self compacting concrete by using pulverized fly ash and rice husk ash are PFA2 and RHA3. The consideration that have been taken to determine the optimum mix design are result from fresh concrete test, cracks mechanism and deflection measurement.
2. The filler using PFA is better in deflection performance compare to RHA. It can be seen in deflection performance that PFA beams have lower deflection than RHA beams.
3. The displacement of SCC beam from PFA and RHA are around 4-8 mm. It is within the range of dynamic behaviour of SCC.

6.2 RECOMMENDATION

1. The technicians that responsible to take care the dynamic machine must take appropriate training about how to repair and maintain the dynamic machine. Whenever the dynamic machine needs to be repaired, the technicians must ask the supplier to repair the machine. This will take a couple of month for supplier to come and repair the machine because they are very busy with their work. Furthermore, the distance between them and the university are also far away.

2. The support of dynamic machine must be change to the fix support. One of the beams failed because the support is not fixed. So the beams tendency to move during the dynamic test is increased and this can cause the broken of the beam.

3. The project must be done at least 2 beams for 1 mix for back up and to get more accurate data regarding the performance of the beams.

4. This project work should be continued by comparing the normal beams and SCC in terms of cost and strength to choose the best beams to be implemented for industrial purposes.

7.0 REFERENCES

1. ACI Committee 215 (1974). "Consideration for design of concrete structures subjected to fatigue loading." *ACI J.,* 71(3), 97-121.

2. Batchelor, B., Hewitt, B. E., and Csagoly, P. (1978). "An investigation of the fatigue strength of deck slabs of composite steel/concrete bridges." *Transp. Res. Rec., 664,* Transportation Research Board, Washington, D.C., 153-161.

3. Brouwers, H.J.H. and H.J. Radix, 2005, *"Self-compacting Concrete: Theoretical and Experimental Studies"*, Department of Civil Engineering, Faculty Engineering Technology, University of Twente Concrete Research Committee, "Self-Compacting Concrete in Shikoku

4. Hajime Okamura and Masahiro Ouchi, 2003, "Self Compacting Concrete" *Journal of Advance Concrete Technology*, Vol 1 , 5-15 Island" 2000 to 2002.

5. Mallet, O. (1991). *Fatigue of reinforced concrete,* HMSO, London.

6. Nan Su, Kung Chung Hsu, and His-Wen Chai, 2001, " A Simple Mix Design Method for Self-Compacting Concrete", *Cement and Concrete Research* **31 (2001):** 1799 – 1807

7. Okada, K., Okamura, H., and Sonoda, K. (1978). "Fatigue failure mechanism of reinforced concrete bridge deck slabs." *Transp. Res. Rec. No. 664,* Transportation Research Board, Washington, D.C., 136-144.

8. Ping-Kun Chan, 2003, " An approach to optimizing mix design for properties of high-performance concrete", *Cement and Concrete Research* **34 (2004):** 623 – 629

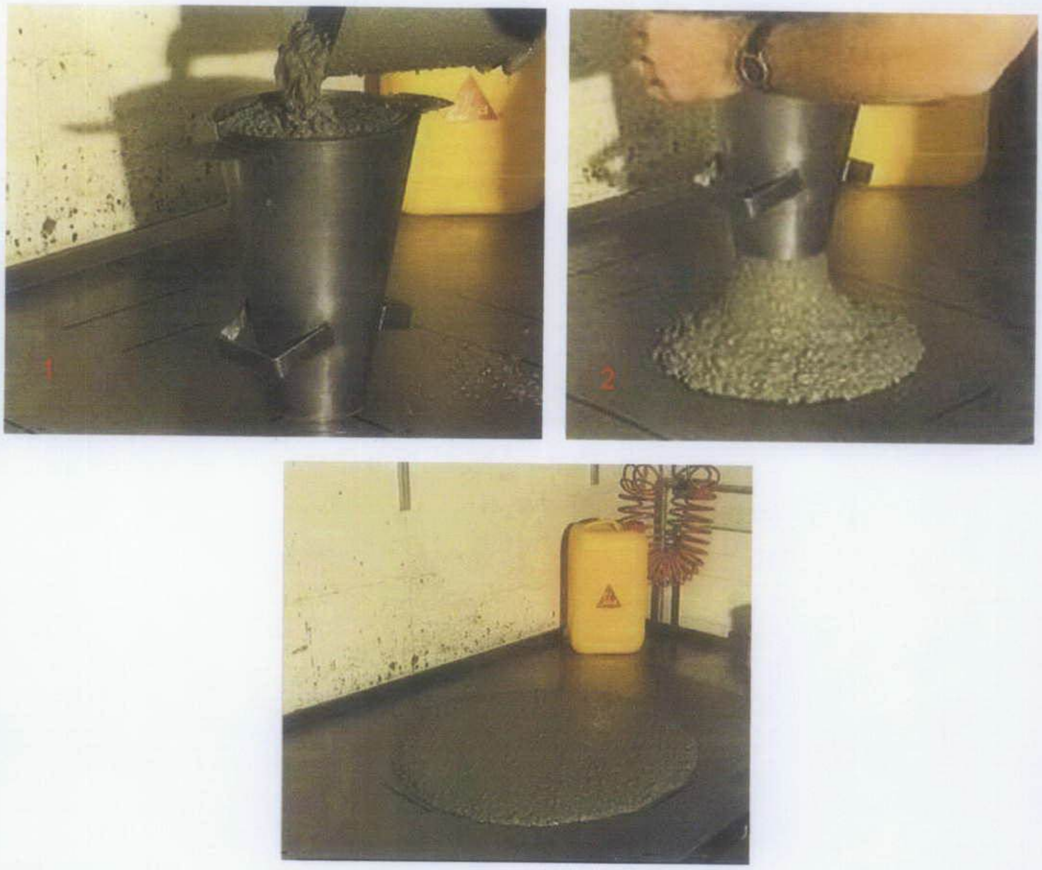
9. Shikoku Island Concrete Research Association: Report by Self-Compacting

10. Sonoda, K., and Horikawa, T. (1982). "Fatigue strength of reinforced concrete slabs under moving loads." *Proc., IABSE Colloquium, Fatigue of Steel and Concrete Struct.,* International Association for Bridge and Structural Engineering, Zurich.

11. Vema, J. R., and Stelson, T. E. (1962). "Failure of small reinforced concrete beams under repeated loads." *ACI J.,* 59(9), 1489.

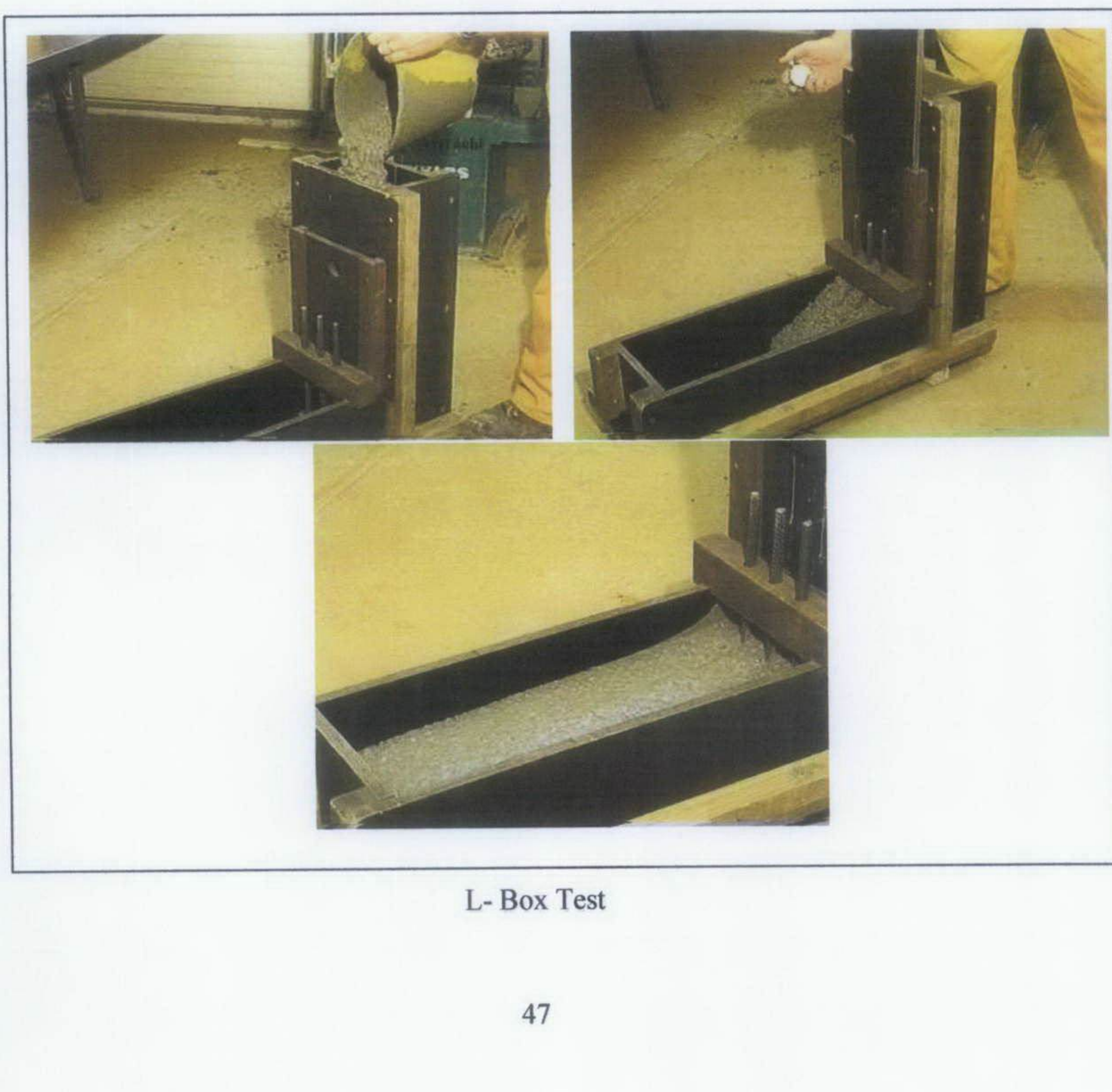
12. Y. Xie, B. Liu, J. Yin, and S. Zhou, 2001, "Optimum mix parameters of high-strength self-compacting concrete with ultrapulverised fly-ash", *Cement and Concrete Research* **32 (2002):** 477 – 480

8.0 APPENDICES

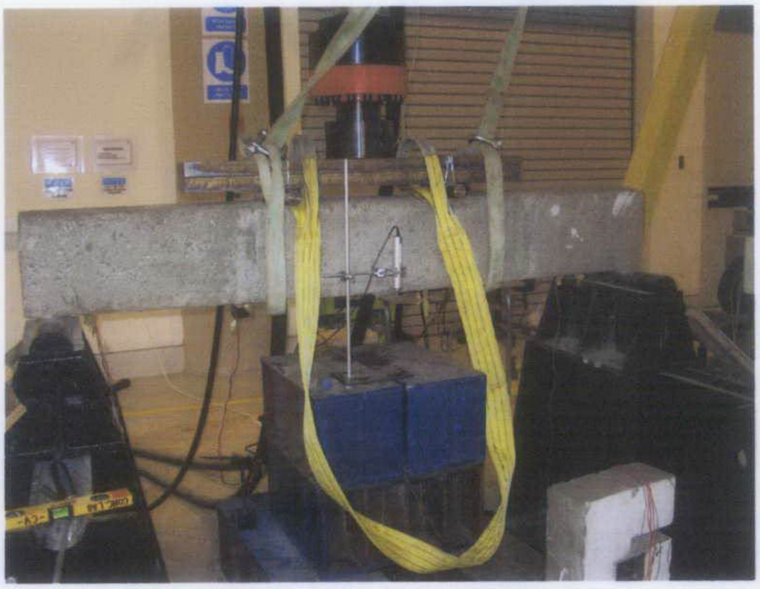


Slump flow Test

V-Funnel Test



L- Box Test



Beam was set up for dynamic test

Crack occur at PFA1

Crack occur at PFA 2 beam

Crack occur at PFA3 beam

Crack occur at RHA 1

Failure for RHA 2 beam caused of movement of support

Crack occur at RHA 3