The Effect of Different Proportions of Aggregates in Self-Compacting Concrete

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CERTIFICATION OF APPROVAL

The Effect of Different Proportions of Aggregates in Self-Compacting Concrete

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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 original work contained herein have not been undertaken or done by unspecified sources or persons.

NOOR FUZZIHA BT ABD HALIN

ABSTRACT

The purpose of conducting this study was to obtain Self Compacting Concrete with different proportions of aggregate. The project was an experimental basis and requires research to familiarize with Self Compacting Concrete. The project requirement was to consider aggregates as important aspect. Material preparation was very critical as the aggregates need to undergo the sieve analysis, soaking in the water for 24 hours and let it dry for another 24 hours at room temperature to ensure the aggregates were saturated surface dry. Admixture (VMA) and superplasticizer (HRWR) were to be added in SCC to ensure stability and flowability of the SCC. The results was obtained and the all the trial mixes could be considered as SCC from the results of Slump Flow Test and V-Funnel Test. For the Segregation Index (SI), the results show improvement from trial mix 1 (0.5 CA/FA) until trial mix 4 (0.8 CA/FA). For the Compressive Strength Test only trial mix 4 (0.8 CA/FA) achieved the requirement of at least 28 MPa at 28 days. The reason was due to different type of superplasticizer used. The superplasticizer need to be changed until the desired strength of concrete could be achieved. From the results, it can be concluded that SCC could be obtained using only admixtures and superplasticizer as the agent to increase stability and flowability. The ratio of coarse aggregate to fine aggregate that achieved the best SCC was 0.8. The most important thing was, the right superplasticizer need to be used in order to achieve desired strength in Self Compacting Concrete.

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First and foremost, Alhamdullillah and with all the supports that I get, I finally come to the end of my final year project. I had learned so much and discovered a lot through this period of 2 semesters. I had not only learn new things but able to improve myself, develop my confident at a higher level and to be more independent person.

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1. INTRODUCTION

1.1 Background of Study

Self-compacting concrete (SCC) is defined as flow able concrete without segregation and without the addition of energy. The concrete could easily flows through the reinforcement without the occurrence of segregation. It was developed in Japan in 1988, and European development began in Sweden in the 1990s in order to reach durable concrete structures. SCC requires accurately graded aggregate and high powder contents to enhance cohesiveness. This is usually achieved by the addition of ground blast furnace slag, pulverised fuel ash or inert materials such as limestone.

Self-compacting concrete is defined so that no additional inner or outer vibration is necessary for the compaction. This will lead to less human energy and will require only few workers to pour the concrete inside the formwork. Cost of hiring the workers can be reduced by using the SCC. SCC is compacting itself alone due to its self-weight while flowing in the formwork. In structural members with high percentage of reinforcement it fills also completely all voids and gaps.

Self-compacting concrete consists of the same components as conventionally vibrated normal concrete, which are cement, aggregates, water, additives and admixtures. However, the high amount of super plasticizer for reduction of the liquid limit and for better workability, the high powder content as lubricant for the coarse aggregates have to be taken into account. In principle, the properties of the fresh and hardened SCC, which depend on the mix design, should not be different from Normal Concrete (NC).

1.2 Problem Statement

Improved existing Self Compacting Concrete (SCC) with different proportion of aggregate that helps in:

- reducing noise-level in the plants and construction sites
- eliminating problems associated with vibration
- decreasing the number of labor involved
- faster construction
- improving quality and durability

In the mixing of the concrete at the lab, High Range Water Reducer (HRWR) and Viscosity Modifying Admixture (VMA) will be used as the powder type agent and viscosity agent to increase the workability and ability to flow of the concrete between small spaces of the reinforcement bars inside the formwork. Without a viscosity-modifying admixture, the mixture would tend to segregate.

In order to differentiate the sizes of aggregates to be used, sieve analysis must be conducted. The percentage of aggregates to be mixed is very important as it will contribute to large aspect of workability of SCC. To ensure that the percentage of the sizes of aggregates used is correct, trial mixes with different ratio of course aggregates to fine aggregates must be conducted

1.3 Objective

To obtain the self compacting concrete that has different aggregate proportions with high workability and ability to flow without segregation to occur between the rebar.

1.4 Scope of Work

Experimental basis project that require observation and hand on experience during the mixing work. Research must be done to familiarize with the SCC.

2. LITERATURE REVIEW

2.1 Self-Compacting Concrete (SCC)

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction Masahiro [1].

Self-compacting concrete (SCC) is able to flow without segregation and without the addition of energy. It was developed in Japan in 1988, and European development began in Sweden in the 1990s. SCC flows alone under its dead weight up to leveling, airs out and consolidates itself thereby without any entry of additional compaction energy and without a nameable segregation. SCC owns over three key characteristics which are Filling Ability (Ability of to fill a formwork completely under its own weight), Passing Ability (Ability to overcome obstacles under its own weight without hindrance), obstacles are reinforcement and small openings, Segregation resistance (Homogeneous composition of concrete during and after the process of transport and placing). These characteristics were made possible by the development of highly effective water reducing agents (superpalsticizers), those usually based on polycarboxylate ethers R.Cioffi et al [2]. The mixture composition of SCC deviates from conventional concrete. The powder contents of SCC are normally lying (in some cases even considerably) above those of conventional concrete.

SCC requires accurately graded aggregate and high powder contents to enhance cohesiveness. This is usually achieved by the addition of ground blast furnace slag, pulverised fuel ash or inert materials such as limestone. Relatively little skill is required for pouring, and the properties are generally similar or superior to those of the equivalent conventional concrete.

By adjusting the aggregate content and using a combination of chemical and mineral admixtures, self-compacting concrete mixes behave in a manner not normally observed in standard concrete. These admixtures, typically consisting of high-range water-reducing (HRWR, or superplasticizing) and viscosity-modifying admixtures, meet the requirements of ASTM C494.

Filler materials are often used for replacing some of the aggregates and modifying the viscosity. High doses of HRWR produce a mix with high fluidity and allow for a reduced water-powder ratio (for the purposes of SCC, powder can be described as particles smaller than 0.01 inch, including some fine aggregate, cement, fly ash, limestone powder, blast furnace slag, and silica fume).

The basic ingredients used in SCC mixes are practically the same as those used in the conventional HPC vibrated concrete, except they are mixed in different proportions and the addition of special admixtures to meet the project specifications for SCC. The hardened properties are expected to be similar to those obtainable with HPC concrete. Laboratory and field tests have demonstrated that the SCC hardened properties are indeed similar to those of HPC.

The SCC mixes are designed and tested to meet the demands of the projects. For example, the mix for mass concrete is designed for pumping and depositing at a fairly high rate. SCC was used in the construction of the anchorages of the Akashi-Kaikyo Suspension Bridge [Masahiro et al [3]]. The SCC was mixed at a batch plant at the job site and pumped through a piping system to the location of the anchorages 200 m away. The SCC was dropped from a height of as much as 5 m without aggregate segregation. For mass concrete, the maximum size of coarse aggregates may be as large as 50 mm. The SCC construction reduced the construction time for the anchorages from 2.5 years to 2 years. Similarly, SCC mixes can be designed and placed successfully for concrete members with normal and congested reinforcement. The coarse aggregate size for reinforced concrete generally varies from 10 mm to 20 mm.

SCC offers many advantages for the pre-cast, pre-stressed concrete industry and for cast-in-place construction which are low noise-level in the plants and construction sites, eliminated problems associated with vibration, less labor involved, faster construction, improved quality and durability and higher strength [Masahiro et al [3]].

Self-compacting concrete can greatly improve construction systems previously based on conventional concrete requiring vibrating compaction. This sort of compaction, which can easily cause segregation, has been a kind of obstacles to the rationalization of construction work. Once this obstacle has been eliminated, concrete construction can be rationalized and a new construction system, including formwork, reinforcement, support and structural design can be developed [Ozawa [4]].

2.2 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 (½ 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 (¾ 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 [5].

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 [5]. 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 [5], 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/m^3 (650–800 lbs/yd^3) 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.

Viscosity modifying admixtures (VMA) are beneficial for adjusting the viscosity, and may be used to improve the stability of SCC mixtures.

2.3 Function of High Range Water Reducer (HRWR) and Viscosity Modifying Agent (VMA) in Self Compacting Concrete (SCC)

By adjusting the aggregate content and using a combination of chemical and mineral admixtures, self-compacting concrete mixes behave in a manner not normally observed in standard concrete. These admixtures, typically consisting of high-range water-reducing (HRWR, or superplasticizing) and viscosity-modifying admixtures, meet the requirements of ASTM C494.

Viscosity modifying admixtures (VMA) are also used for some SCC mixes to control segregation, such as when there is a gap-graded aggregate mix. VMAs are inert admixtures, not influencing setting characteristics or reacting with other admixtures.

Viscosity modifying admixtures (VMA) are beneficial for adjusting the viscosity, and may be used to improve the stability of SCC mixtures [Technical Bulletin [5]]. VMAs can also be advantageous when using lower powder contents, as well as when using gap graded, angular, flat and/or elongated aggregates. In some cases, high range water reducing admixtures specifically designed for SCC (such as ADVA® 380 or ADVA Cast 555) will play a dual role in SCC mixtures by providing both fluidity and improved mixture stability. The use of a VMA in conjunction with a HRWR may also increase the water tolerance of a mixture.

Without a viscosity-modifying admixture, the mixture would tend to segregate. However, the viscosity-modifying admixture enhances the viscosity of the mixture, which reduces aggregate segregation, settlement, and bleeding. The resulting mix, when properly designed, is considered to be self-compacting or self-placing. High doses of HRWR produce a mix with high fluidity and allow for a reduced water-powder ratio [Frank Dehn [6]].

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. In the design of SCC, high-range water reducing (HRWR) admixtures are essential to achieve required flowability and high concrete strength (minimized water-cementitious material [w/cm] ratio) [Bulent Erkmen [7]].

In essence, for a concrete mix to be considered self-compacting, it should exhibit certain characteristics. The mix should flow easily and completely fill spaces between reinforcement and forms by virtue of its own weight - thus reducing dependence on vibration techniques. And the mix should also have good stability and resist separation such as aggregate settlement or bleeding.

2.4 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 Tarun [8].

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.

3. METHODOLOGY/PROJECT WORK

3.1 Project Work

3.1.1 Literature Review

Literature review is a research that is conducted to familiarize with the project. Literature review is a research based on the journals, publications and also reference books in the library. We could get the idea to conduct our project from the knowledge that we gained in the literature review.

3.1.2 Discussion

Weekly meeting with the supervisor is conducted to ensure that the project is going on the right path. The meeting will lead to a better understanding besides researching. Knowledge could be exchange at the meeting

3.1.3 Experiment and mix 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 flowable but yet maintain the strength. The mix proportion is very important because it leads to the high performance of the self compacting concrete characteristics.

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 (C_2S and C_3S 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 Aggregate preparation

Preparation of the aggregates take 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, (Figure 1, Appendix 1,2).

Sieve Analysis

Aggregate were well graded

Soaking in the water for 24 hours

Rinse the aggregate before letting it dry at room temperature for another 24 hours

Figure 1: Aggregate Preparation

3.2.3 HRWR and VMA

Adva, which is HRWR (Figure 2) that supplied by the manufacturer, will be used in this study. It is brownish in colour and visually observed as a viscous liquid. For the VMA (Figure 3), it is a form of gel-like material that behaves like normal gum. It will increase the friction between particles and reduce the tendency of segregation to occur.

Figure 2: HRWR

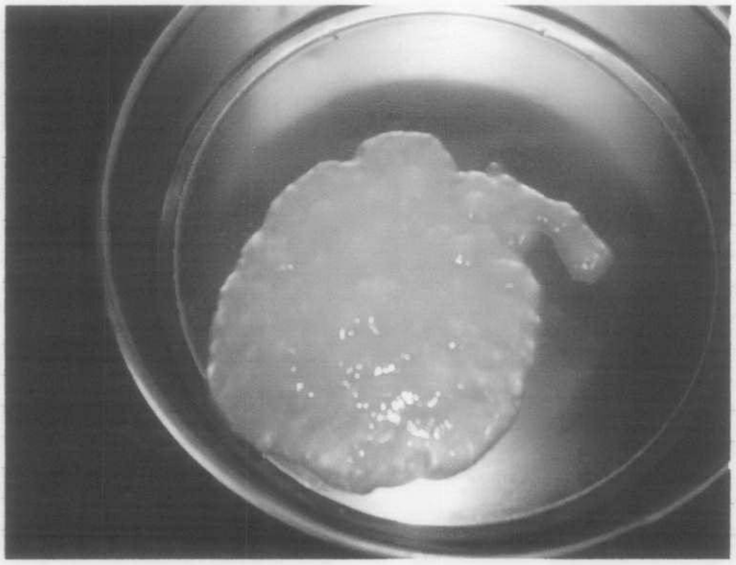


Figure 3: VMA

3.3 Concrete Mixing

All concrete should be mix thoroughly until it is uniform (Appendix 3). The sequence of concrete mix is very important and it must be followed accordingly. The procedure of concrete mix incorporating with HRWR and VMA 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 into the mixer and mix for 1 minute.
5. Pour another half of the water and add HRWR and mix for 3 minutes.
6. Add VMA in the mix and mix for 2 minutes.
7. Finally perform hand mixing until the mix is in uniform stage.

3.4. Concrete Casting

Fresh concrete was then poured into cylinder of 100mm diameter and 200 mm height. The purpose is to cure the concrete and perform several tests on the concrete (Figure 4).

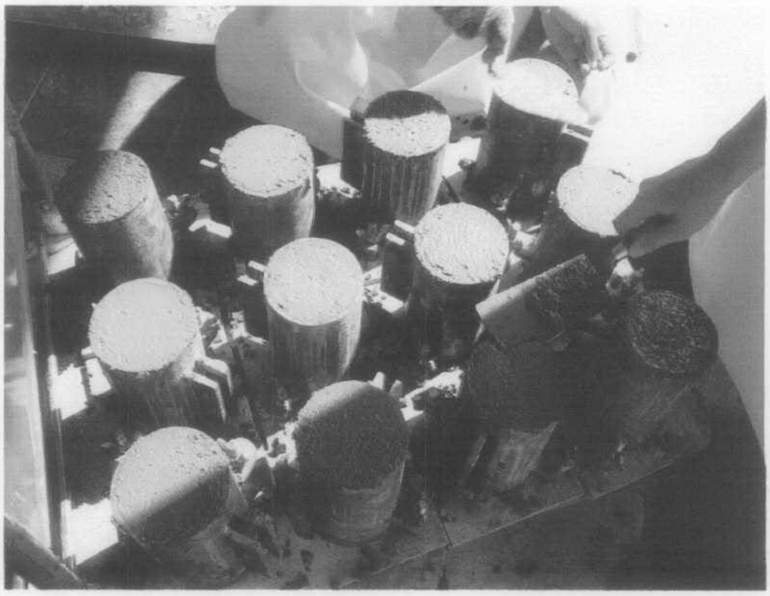


Figure 4: Concrete casting

3.5 Concrete curing

After removal of mould on the second day, the cylinder must be placed inside the curing tank until the day of testing. The purpose of curing is to avoid shrinkage cracking due to temperature fluctuation and also to gain the maximum strength of the concrete (Figure 5).

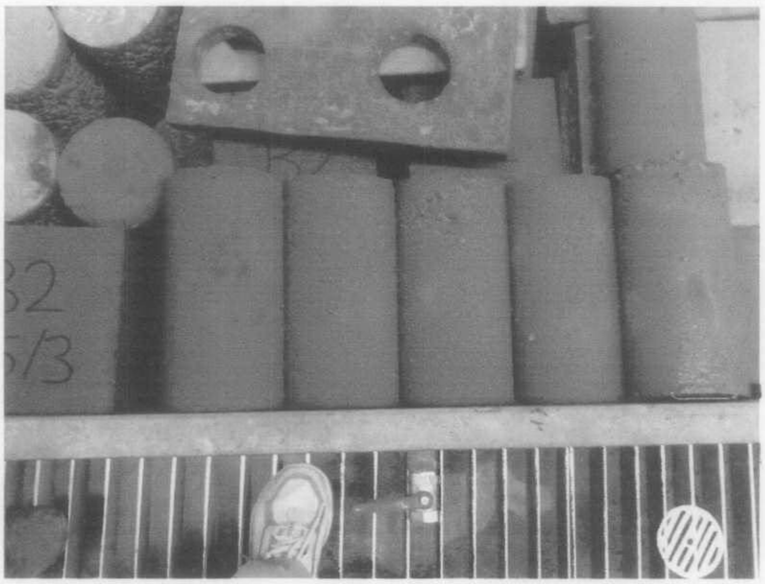


Figure 5: Concrete Curing

3.6 Fresh Concrete Test

After mixing process, several tests need to be conducted to measure the flowability, segregation and compressive strength of the self compacting concrete.

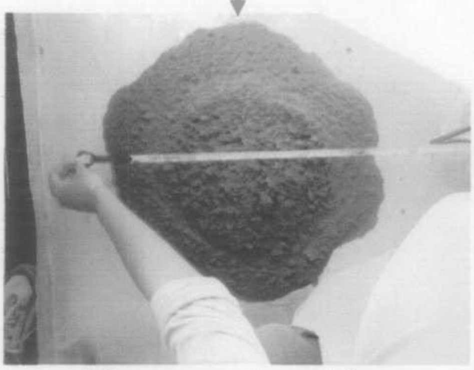
3.6.1 Slump Flow Test

The slump flow test (Figure 6) was 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.

The truncated cone for slump flow test

Concrete was being filled inside the cone

The cone was being lifted



Measurement was taken

Figure 6: Process of Slump Flow Test

3.6.2 V-Funnel Test

The deformability through restricted areas can be evaluated using V-Funnel Test (Figure 7). In this test, the funnel was filled completely with concrete and at the bottom outlet would then be opened, allowing the concrete to flow out. The time of flow was 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 Self Compacting concrete.

Concrete was being filled in the funnel

Concrete was falling free out of the funnel

Figure 7: V-Funnel Test Process

3.6.3 Segregation Test

The segregation test method, which was developed by Fujiwara was used. The method include pouring fresh concrete over a 5 mm mesh and measuring the mass of the mortar passing through the screen after 5 minutes. The segregation index (SI) was taken as the ratio of the mortar passing to that contained in the original concrete sample.

3.6.4 Compressive Strength Test

Comparative performance of hardened concrete was investigated by measuring the development of compressive strength with curing age of 3, 7, 28 and 60 days. The compressive strength was taken as the maximum compressive load it could carry per unit area.

3.7 Calculation and Mix Proportioning

Before mixing, calculations need to be done for the mix proportion. The mix proportions were done by referring to the literature review and also by discussion with supervisor. Below is the example of doing the mix proportioning:

In the mix concrete, it contains several materials which were course aggregate, fine aggregate, water and cement. Since this was the mix for self compacting concrete, superplastisizer (HRWR) and also admixture (VMA) were also needed to ensure workability and to avoid segregation of the concrete. Calculation for mix proportioning was done by calculating $1m^3$ of concrete. After mix proportioning, the amount will be reduce to $0.025\ m^3$ to do the concrete casting.

We assume that the air in the concrete was 1.5% of $1m^3$ of concrete.

$1m^3 = 1000$ liter

So it is important to make sure that the proportion does not exceed or lack from 1000 liter.

Nomenclature:

Course aggregate (CA)

Fine aggregate (FA)

Water content (WC)

Cement (C)

Air

Superplastisizer (HRWR)

Admixture (VMA)

To do the mix proportioning, the ratio for the element to cement must be obtained.

WC/C = 0.4, VMA/C = 0.08.

CA/FA=1, so CA = FA

From reading, HRWR = 10 liter and Air = 1.5 % of concrete mix = 15 liter.

Proposed cement content = 400 kg/ m^3

= 400/ 3.15 (specific gravity of cement)

= 126.98 liter

CA + FA + WC + C + Air + HRWR + VMA = 1000 liter

CA + CA + 0.4 (126.98) + 126.98 + 15 + 10 + 0.08 (126.98) = 1000 liter

2CA + 50.79 + 126.98 + 15 +10 + 10.16 = 1000 liter

2 CA + 212.93 = 1000 liter

2CA = 787.07 liter

CA = 393.54 liter = FA

In kg/m^3 for each material:

Below are the assumptions of the specific gravity for each material. The assumptions are either from supplier or from the literature review.

Specific gravity for aggregates = 2.65

Specific gravity for cement = 3.15

Specific gravity for water = 1

Specific gravity for HRWR = 1

Specific gravity for VMA = 1

CA = 393.54 x 2.65

= 1042.88 kg/m^3

FA = 393.54 x 2.65

= 1042.88 kg/m^3

WC = 50.79 x 1

= 50.79 kg/m^3

$C = 126.98 \times 3.15$ but $W/C = 0.4$, so $WC/C = 160\ kg/m^3$
$= 400\ kg/m^3$

$Air = 15\ kg/m^3$

$HRWR = 10\ kg/m^3$

$VMA = 10.16\ kg/m^3$

The design mix in the lab is for 0.025 m^3. So every value needs to be multiply by 0.025.

Mix proportion for 0.025 m^3

Table 1: Mix proportion for 0.025 m^3 of first trial mix

Material	kg
CA	26.07
FA	26.07
WC	4.00
C	10.00
Air	0.375
HRWR	0.25
VMA	0.254

Since the study is on different proportioning of aggregates in the SCC, the experiment must be done with the varying proportion of coarse and fine aggregates. The tables below shows the mix proportioning with different amount of aggregates used and the ratio between fine and coarse aggregates.

Table 2: Different proportion of aggregates content

Coarse Aggregates (CA) kg/m^3	Fine Aggregates (FA) kg/m^3	CA/FA	WC/C	HRWR (liter/ m^3)	VMA (liter/ m^3)
695	1391	0.5	0.4	10	10
782	1304	0.6	0.4	10	10
859	1227	0.7	0.4	10	10
927	1159	0.8	0.4	10	10
988	1098	0.9	0.4	10	10
1043	1043	1	0.4	10	10

Design mix for 0.025 m^3

Table 3: Trial mixes for different aggregate proportion of 0.025 m^3

CA g/m^3	CA for 0.025 m^3 (kg)	FA kg/m^3	FA for 0.025 m^3 (kg)	Water content for 0.025 m^3 (kg)	Cement content for 0.025 m^3 (kg)	HRWR (liter/ m^3)	HRWR for 0.025 m^3	VMA (liter/ m^3)	VMA for 0.025 m^3
95	17.375	1391	34.775	4	10	10	0.25	10	0.25
'82	19.55	1304	32.6	4	10	10	0.25	10	0.25
59	21.475	1227	30.675	4	10	10	0.25	10	0.25
27	23.175	1159	28.975	4	10	10	0.25	10	0.25
88	24.7	1098	27.45	4	10	10	0.25	10	0.25
043	26.075	1043	26.075	4	10	10	0.25	10	0.25

4.0 RESULTS AND DISCUSSION

4.1 Results

In the study, several concrete mixes were conducted to obtain the optimum self compacting concrete. At first, the mixes are supposed to be conducted according to the planned proportion. Due to some problems arises; the mixes done are only up to the 4th mix. The mix is being done starting from the lowest coarse aggregate to fine aggregate ratio because in self compacting concrete, the amount of fines must be higher compare to the amount of coarse aggregates. The mixes and the results are as follows:

Table 4: Preliminary Mix

	CA (kg/m^3)	FA (kg/m^3)	W/C	W (kg/m^3)	C (kg/m^3)	HRWR (l/m^3)	VMA (l/m^3)
1st	1044	1044	0.4	162	412	10	2
2nd	1043	1043	0.4	160	400	10	10

The purpose of conducting the preliminary mixes was to obtain the better performances of self compacting concrete with different amount of VMA.

Table 5: Trial Mix

	CA (kg/m^3)	FA (kg/m^3)	CA/FA	W/C	W (kg/m^3)	C (kg/m^3)	HRWR (l/m^3)	VMA (l/m^3)
1st	695	1391	0.5	0.4	160	400	10	10
2nd	782	1304	0.6	0.4	160	400	10	10
3rd	859	1227	0.7	0.25	100	400	10	10
4th	927	1159	0.8	0.25	100	400	10	10

For the trial mixes, five mixes were conducted but only 4 results could be recorded. The reason is because the 3rd mix of CA/FA 0.7 was done twice due to the problem arises after concrete are remove from the mould. The concrete of the first mix of the 3rd mix crumbled during the process of curing. Due to that, mix of the same proportion need to be conducted again to record the results of compressive strength test.

The mixes should be according to the proportion of the planned mixes. During the mix, some problems arise and the proportion needs to be changed. As for the 3rd (0.7 CA/FA) and the 4th (0.8 CA/FA) mix, the water cement ratio need to be changed due to the high segregation index. When the water content is high, the concrete have higher tendency to segregate. So the water cement ratio was being reduced from 0.4 to 0.25. Since the aggregates had already soaked in the water, they are already saturated and the amount of water needed was less. When water cement ratio was reduced, the segregation index was lower.

Table 6: Results

	Slump Test (mm)			V-Funnel Test (s)	Segregation Index (SI)	Compressive Strength Test (MPa)		
Mixes	x-dir	y-dir	avg			3d	7d	28d
Pre lim-1	550	600	575	16.9	-	-	-	1.824
Pre lim-2	700	650	675	11.2	-	-	-	1.942
1st	500	550	525	9.6	0.091	1.084	1.481	1.854
2nd	550	500	525	9.1	0.090	0.934	1.422	1.591
3rd	550	570	560	7.2	0.006	0.623	0.714	0.822
4th	500	600	550	-	0.004	3.214	8.221	34.42

4.2 Discussion

From the results, it was shown that the result of preliminary mix 2 was better compare to the result of the preliminary mix 1. This shows that the trial mixes will follow the amount of VMA used in preliminary mix 2. The slump test and V-Funnel test also shows that preliminary mix 2 was better compare to preliminary mix 1. For the mix to be considered SCC, the value of slump test must be more than 500mm and the V-Funnel test must be less than 10 seconds.

For the 1^{st} until the 4^{th} mix, the results of the slump test results show that the mixes can be considered as Self Compacting Concrete. This is because all the results are more than 500 mm flow in diameter. Below is the picture of good and bad slump flow (Figure 8, 9).

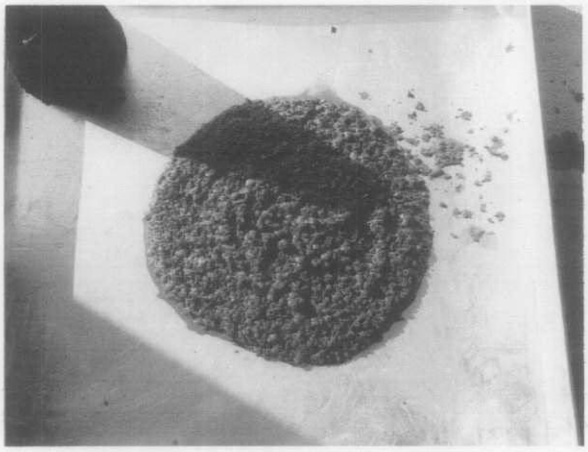
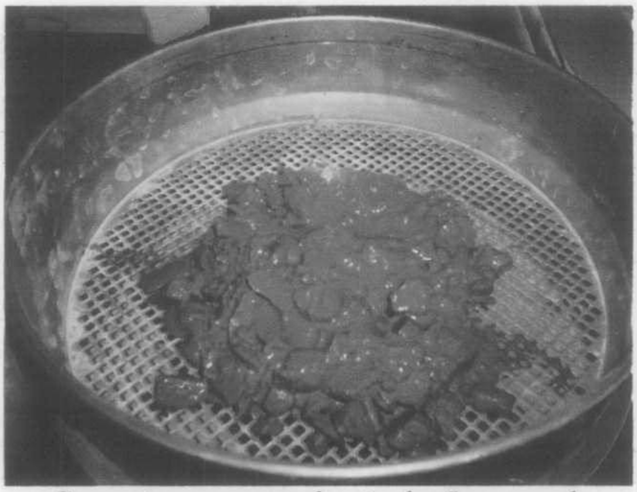


Figure 8: Slump flow without segregation

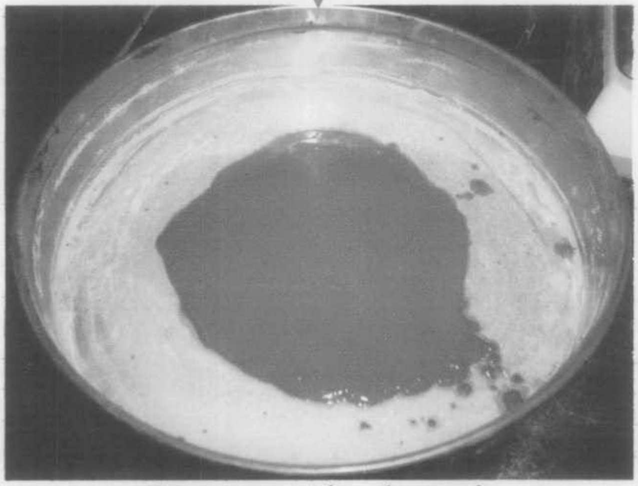
Figure 9: Slump flow with segregation

For V-Funnel test, the result was improving from mix 1 to mix 3. They were all complying to the requirement of SCC which the value must be less than 10 seconds. The V-Funnel test is a test to observe the flowability of the SCC. If the time is less for the concrete to flow out of the funnel, it means that the concrete has enough capability to flow under its own weight.

For the segregation index, the lesser the value, the better the concrete is. If the value of SI is small, it means that the concrete mix has fewer tendencies to segregate. The results also show an improvement from mix no 1 (0.5 CA/FA) to mix no 4 (0.8 CA/FA). Below is the picture of high SI and low SI (Figure 10, 11).

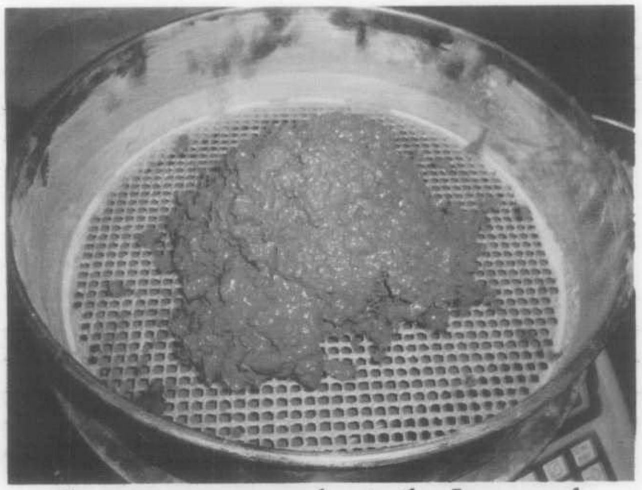


Concrete was poured onto the 5mm mesh

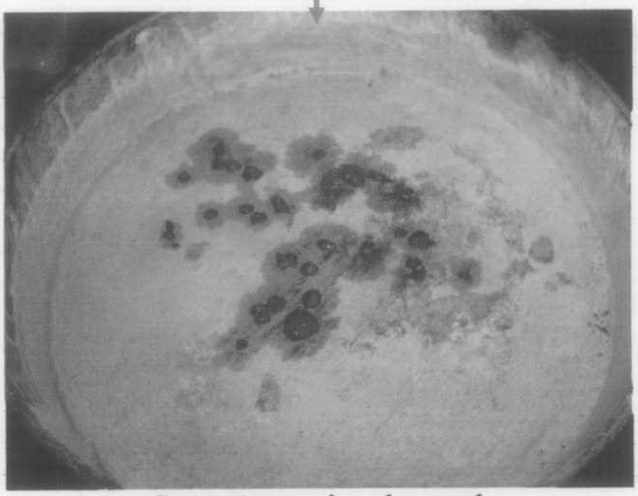


Concrete passing the mesh

Figure 10: High Segregation Index (SI)



Concrete was poured onto the 5mm mesh



Concrete passing the mesh

Figure 11: Low Segregation Index (SI)

For the Compressive Strength Test, it was found difficult to achieve the strength of equal to the Normal Concrete which is 28 MPa at 28 days. From all the results, it could be seen that the strength of the concrete was too low. To overcome the problem, some calculation is being done for example to calculate the amount of cement paste needed to cover all the surfaces of the aggregates (Appendix 4). The calculation shows that the cement paste was enough to cover the surface of the aggregate and there was nothing wrong with the mix proportion. Even though the water cement ratio had been reduced at mix 3 (0.7CA/FA), the problem has not yet being overcome. So assumption has been done that the problem might be because of the superplastisezer used. The main reason of the problem arises for the superplastisezer used might be due to the reaction occurred during the mix. The VMA used might be not compatible in chemical properties with the HRWR (vismex 114, Appendix 5) as they might be repelling with each other during the process of mixing. Due to this the concrete desired strength might not be achieved until the appropriate HRWR is being used.

The purposed of the HRWR is to increase the slump flow test, reduce the water-cement ratio as well as maintaining the strength of the concrete. So at mix no 3, we change the type of HRWR (plastocrete R-6, Appendix 6) used and the result was not good. We need to do the mix twice as the concrete cannot hardened after being cast in the mould for 24 hours. The new HRWR might be retarding the process of hardening of the concrete. When the concrete was put in the water for curing process, they crumble after few hours. Due to that, same mix was done again but this time the concrete is leave to be hardened for 3 days. The samples did not crumble but it still cannot achieve the desired strength.

As for the last mix, again the HRWR type is changed (sika viscocerete 3430, Appendix 7). For this mix, the concrete seem to be hardened a lot faster compared to previous mix. Due to that, V-Funnel test result could not be recorded as the concrete had already hardened during conducting the test. The concrete cannot flow through the open funnel. The best result of compressive strength test was achieved as the result exceeds the minimum requirement of 28 MPa at 28 days. The strength was 34.42 MPa at 28 days. Below is the picture of sample mixes (Figure 12).

Figure 12: The sample of mixes (from left: 4th mix, 3rd mix, 2nd mix, 1st mix)

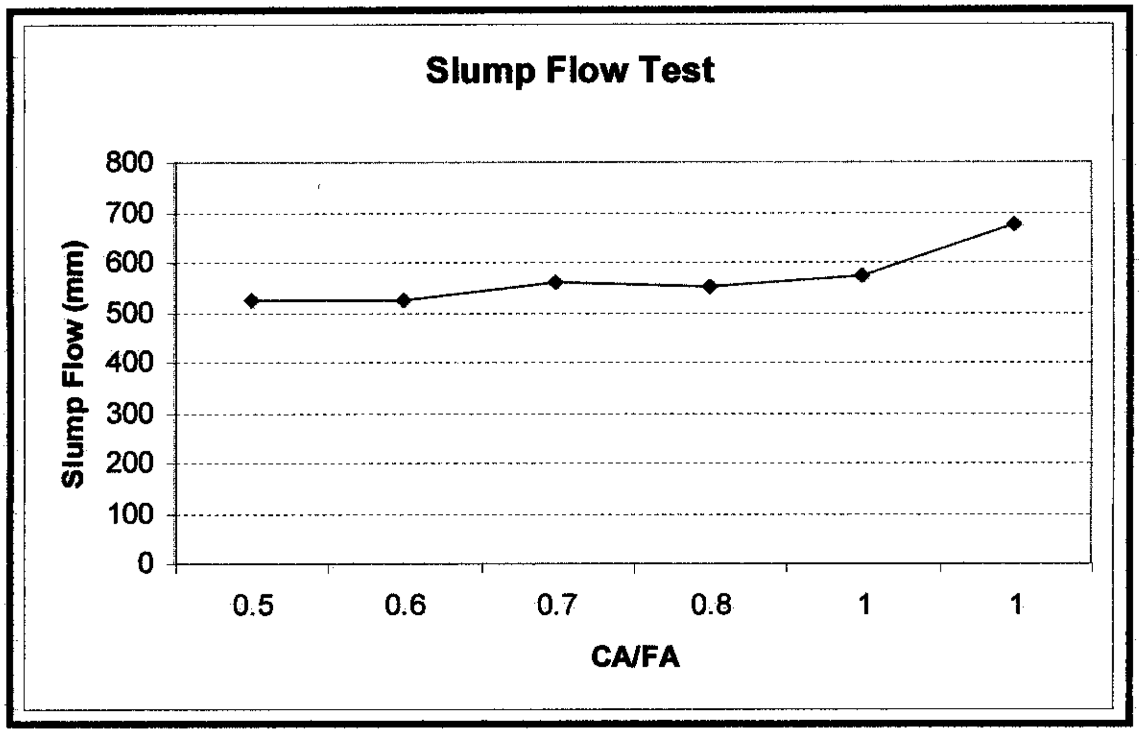


Figure 13: Slump Flow Test Evaluation

From the graph (Figure 13), it can be said that the mixes are all can be considered as Self Compacting Concrete. The readings show the results are all above 500 mm in diameter of flow. From the 0.5 CA/FA until 0.8 CA/FA, the result of slump flow test show increasing result.

Even though pre-lim 1 and pre-lim 2 of CA/FA 1, shows good result in slump flow test, the segregation are observed to be occurred. The water content is too high that it leads to the segregation between the aggregates and the cement paste.

The 0.8 CA/FA mix shows the best result as the slump flow is 550 mm which was the maximum flow among the 4 mixes without segregation to be observed.

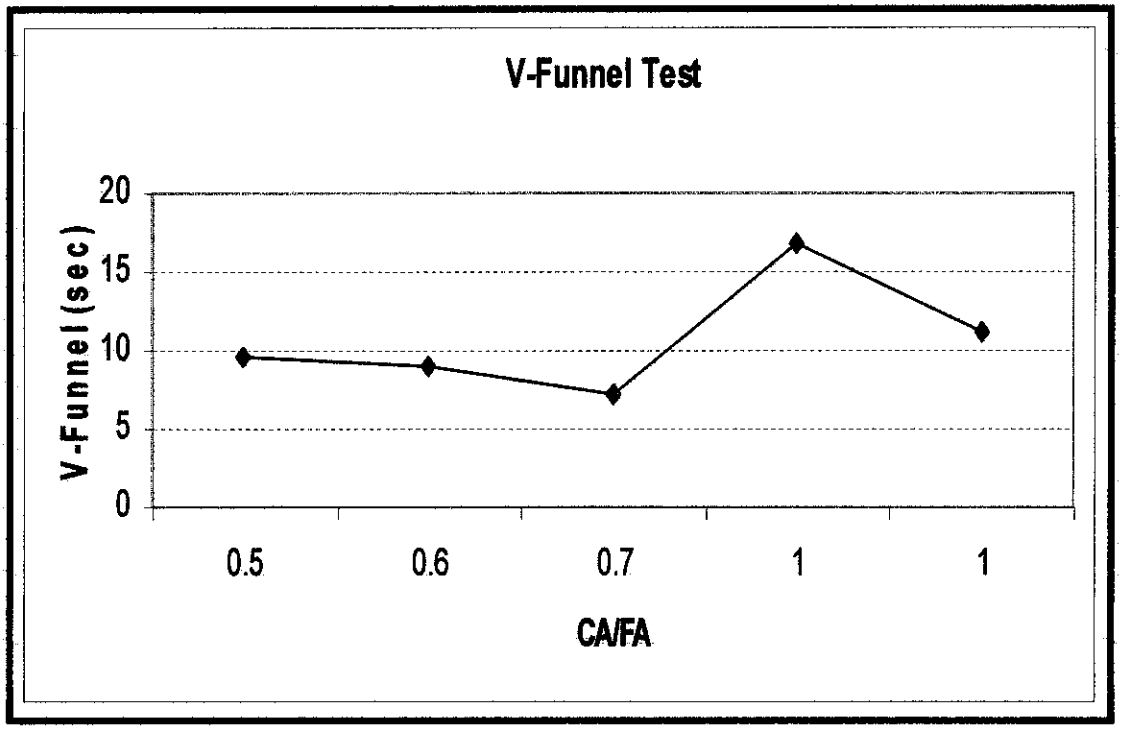


Figure 14: V-Funnel Test Evaluation

From the graph (Figure 14), it is clearly shown that the time is decreasing as the number CA/FA is increased. When the time for the concrete to flow out of the funnel is lesser, the better flowability the SCC is.

The preliminary mix (CA/FA 1) does not fulfill the requirement of SCC as they did not achieve the time of less than 10 seconds for the concrete to flow out of the funnel.

For the 0.7 CA/FA mix, the time taken for the concrete to flow out of the funnel is 7.2 seconds which was the best time recorded. It shows that the concrete was able to flow under its own weight.

For the 0.8 CA/FA mix, V-Funnel test could not be conducted due to the rapid hardening of the concrete.

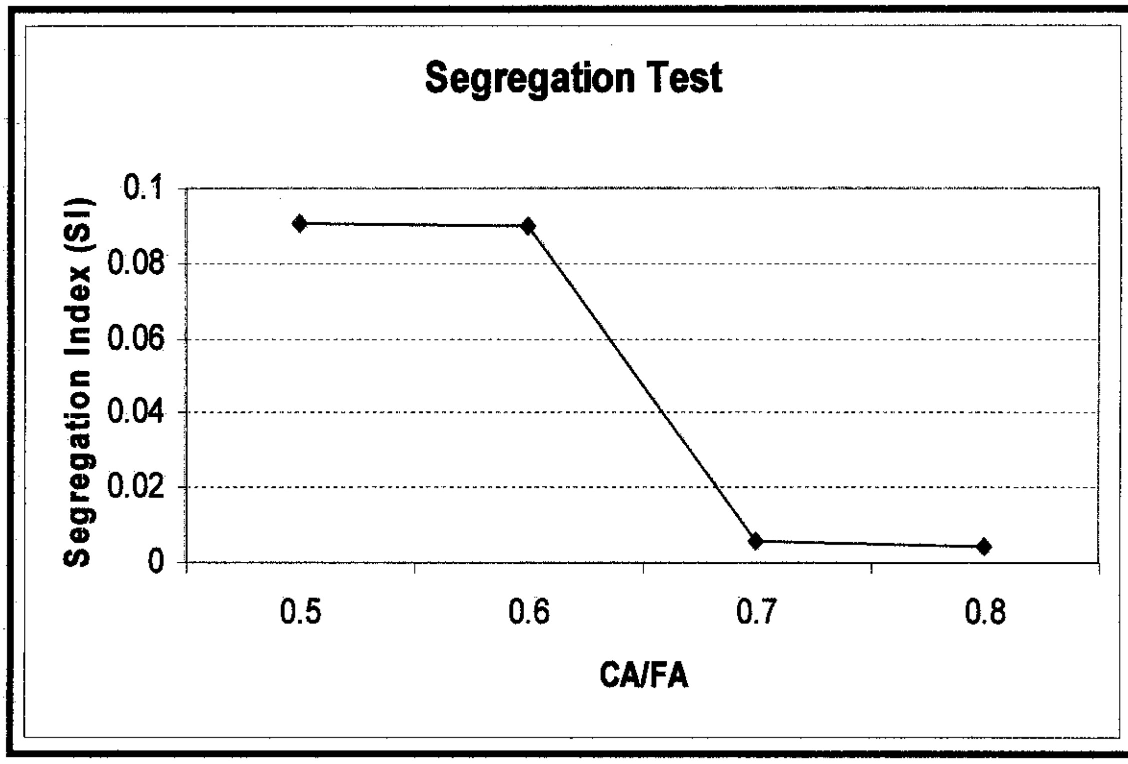


Figure 15: Segregation Index (SI) Evaluation

As plotted on the graph (Figure 15), it can be seen that the graph is declining from CA/FA 0.5 to CA/FA 0.8. Segregation index (SI) is the process of determining the concrete tendency to segregate. When the concrete was being placed on the 5mm mesh, the passing flow of the concrete will show whether the concrete has high segregation or not.

For mix of CA/FA 0.5 and CA/FA 0.6, since the water cement ratio was too high and not yet being modified, the Segregation Index was high.

For mix of CA/FA 0.7, the Segregation Index had started to reduce due to the lesser amount of water in the concrete. The water cement ratio had been reduced because the previous mixes did not show good results in the Segregation Index.

For mix of CA/FA 0.8, the best Segregation Index result had been achieved. The value of the passing over retained mass of the concrete was 0.004 and it shows that the concrete has the lessen amount of tendency to be segregated.

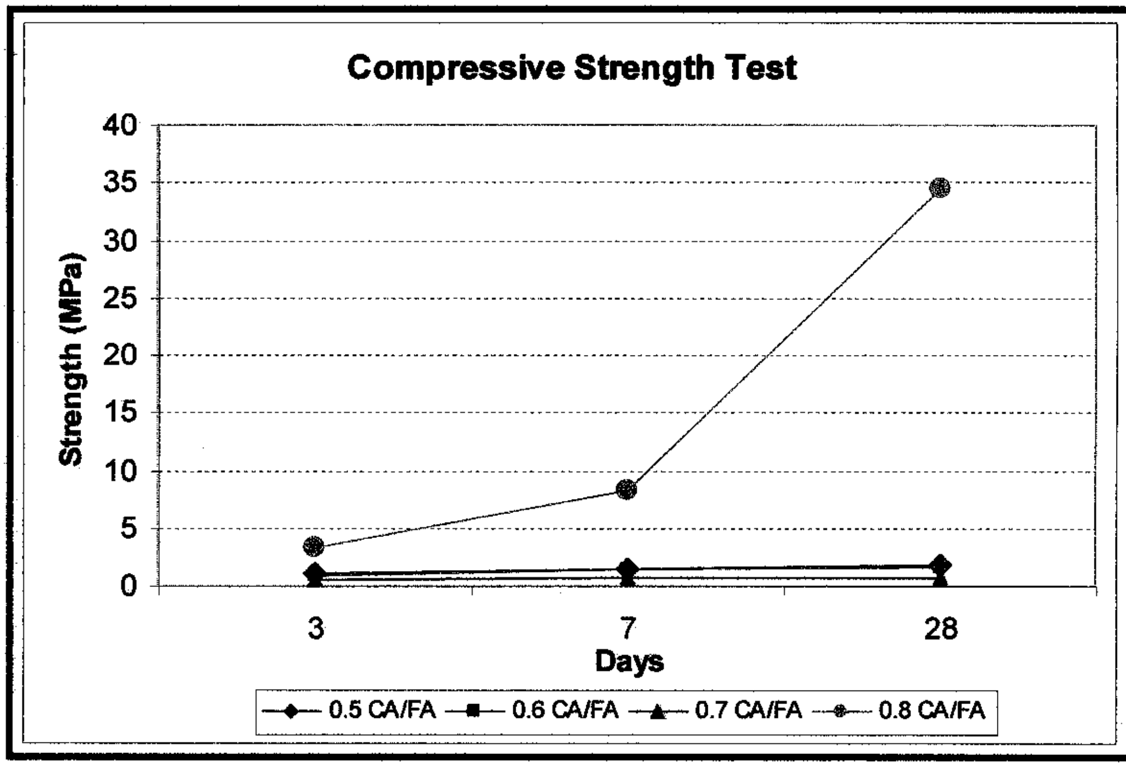


Figure 16: Compressive Strength Test Evaluation

From the graph (Figure 16), it shows clearly that only the CA/FA 0.8 mix shows the strength of the concrete to be the highest and achieved the requirement of at least to achieve the normal concrete strength of 28 MPa at 28 days. The strength of the 0.8 CA/FA mix increased gradually from 3^{rd} days to 28^{th} days. At day 3, the strength was 3.214 MPa and at 28 days, it already achieved the strength of 34.42 MPa.

For mix of CA/FA 0.5, 0.6 and 0.7, some problem arises and the desired strength cannot be achieved. The reason might be due to the high water cement ratio for mix of 0.5 and 0.6 CA/FA. Besides, the HRWR type also might lead to the low strength of the concrete for mix 0.5, 0.6 and 0.7 CA/FA. After changing the HRWR type to sika viscocrete 3430 at CA/FA 0.8 mix, then only the desired strength was achieved.

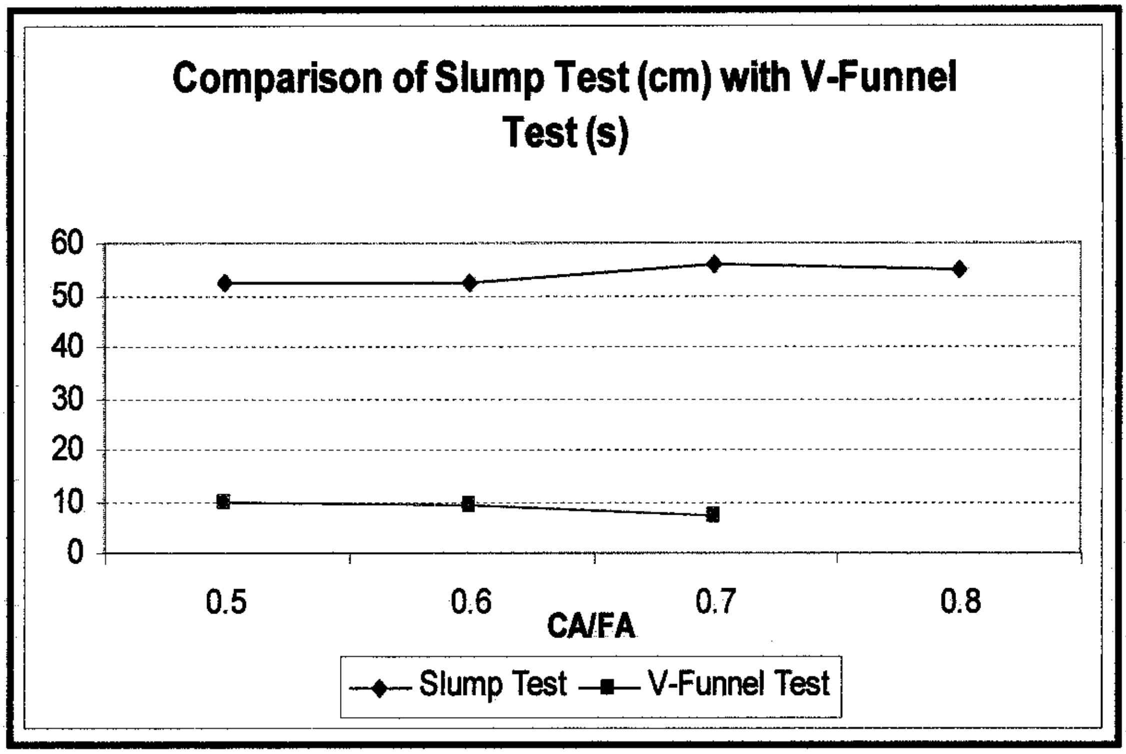


Figure 17: Comparison of result between Slump Test and V-Funnel Test

From the comparison of the results (Figure 17), it shown that when the Slump Flow Test increased, the time taken for the V-Funnel Test will decrease.

For 0.5 CA/FA, when the slump test result is 525 mm, the time taken for V-Funnel test was 9.6 seconds. When CA/FA was 0.6, the slump flow maintained at 525 mm but the time taken for concrete to empty the funnel was 9.1 seconds.

For 0.7 CA/FA mix, it show the best comparison as the slump test increased to 560 mm and the V-Funnel time was just 7.2 seconds which was the time achieved compared to all the mixes.

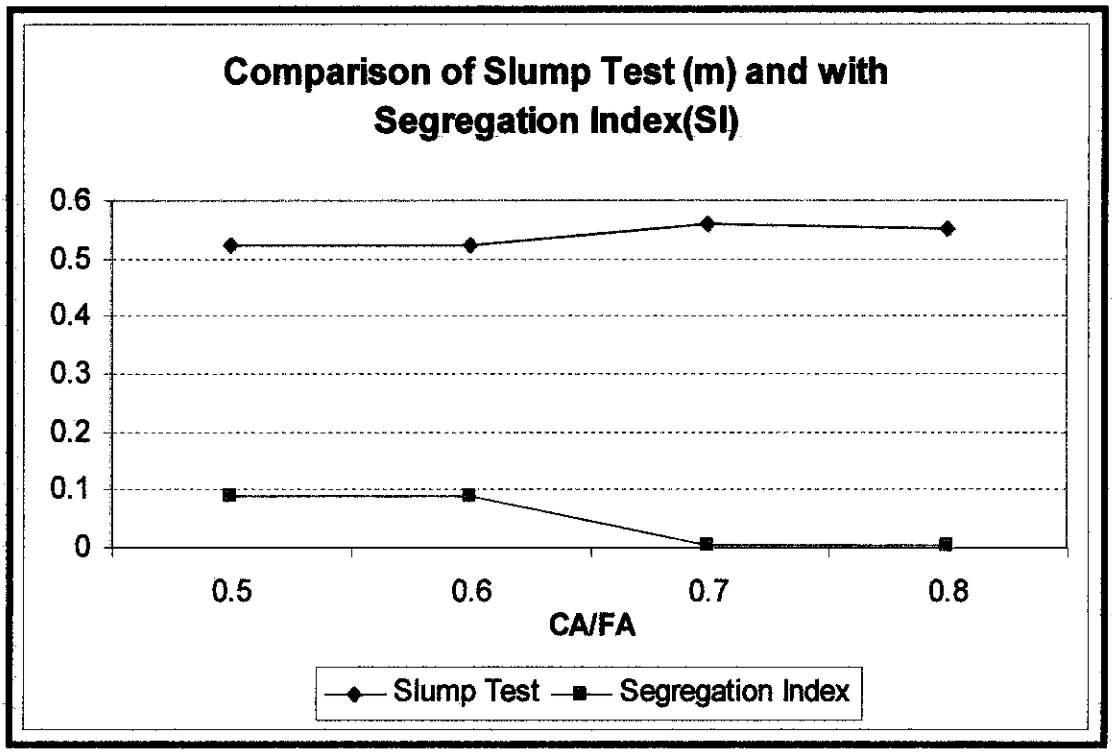


Figure 18: Comparison of result between Slump Test and Segregation Index (SI)

The comparison graph (Figure 18) shows that the pattern of when the slump flow test result was better, the segregation index result will be lesser in value.

For 0.5 and 0.6 CA/FA mix, the segregation index result was high due to the high water cement ratio which was 0.4. When segregation index was high, the slump flow test was low.

For 0.7 and 0.8 CA/FA mix, the water cement ratio had been modified to 0.25 to reduce the segregation index. When the segregation index was reduced, the result for slump flow test was increased.

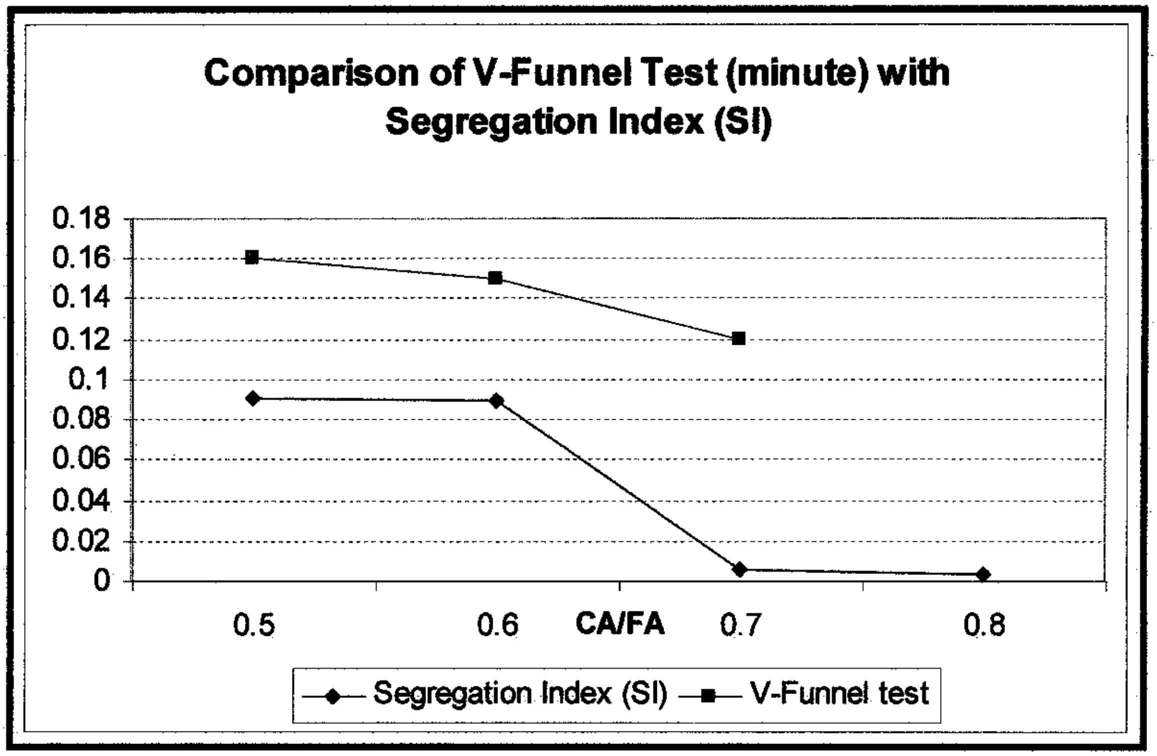


Figure 19: Comparison of result between V-Funnel Test and Segregation Index (SI)

From the comparison of result (Figure 19), it could be concluded that when the time taken for concrete to flow out of the funnel was reduced, the segregation index was also lower.

For every mix (0.5, 0.6 and 0.7 CA/FA), when the V-Funnel test result was low, the Segregation index was low.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From all the trial mixes, it can be concluded that the Self Compacting Concrete could be achieved using HRWR and VMA as the superplasticizer and admixture in the concrete. The optimum SCC was achieved in the last mix with the additional of VMA and HRWR (sika viscocrete 3430) in the mix. The coarse aggregate to fine aggregate ratio was 0.8 and it achieved the best result for slump flow test, Segregation as well as Compressive Strength Test.

5.2 Recommendation

To achieve optimum self compacting concrete, VMA and HRWR (sika viscocrete 3430 and plastocrete R-6) could be added together in the mix. The purpose is to obtain the high strength concrete with slower hardening process. The mixes could be conducted with the same water cement ratio to ensure better comparison between aggregate proportions in the mix.

6.0 REFERENCES

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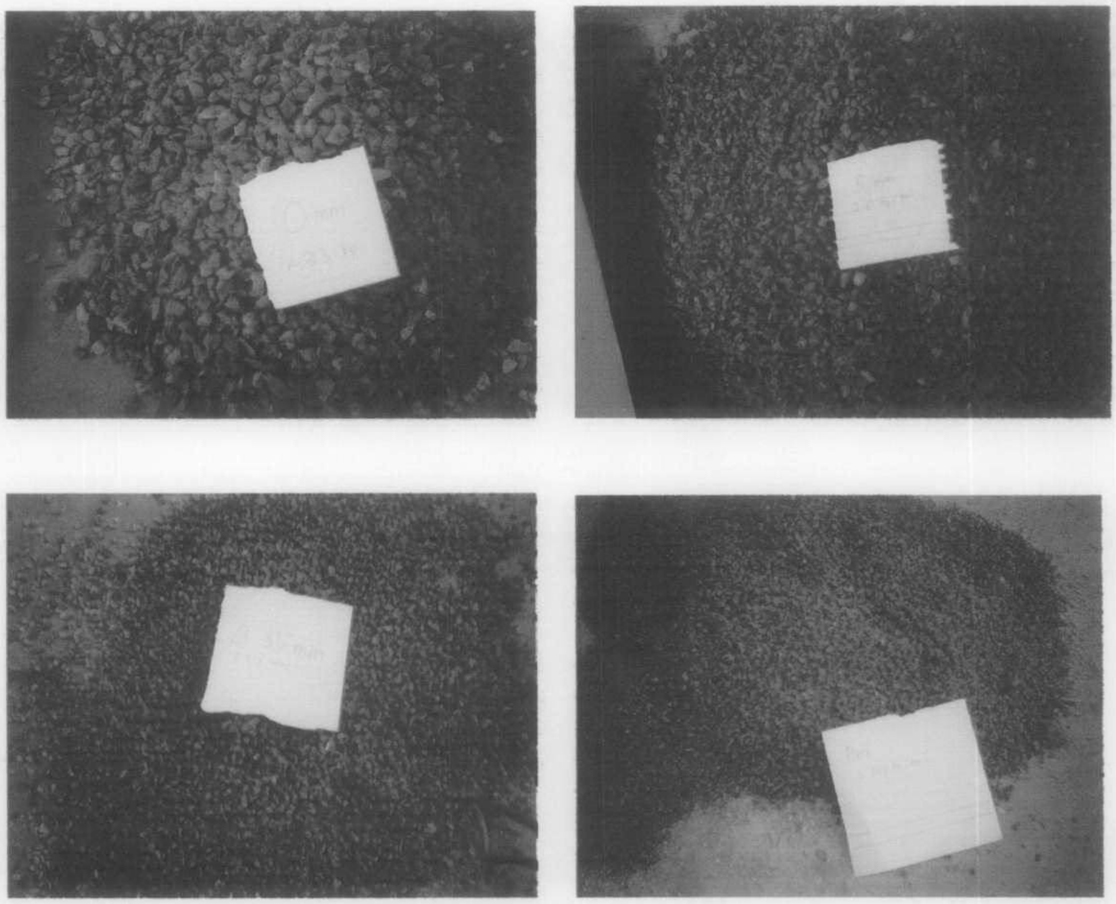
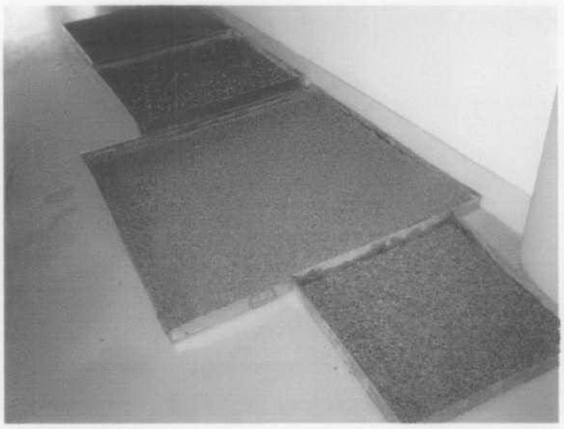
7.0 APPENDICES



Appendix 1: Aggregates grading size after sieve analysis



Appendix 2: Let dry at room temperature for one day

Appendix 3: Concrete is being mix inside the concrete mixer

Appendix 4:

From mix 1 (0.5 CA/FA)

Coarse aggregate (kg/m3) = 695 ⟶ 3.35mm - 5mm = 69.5
5mm – 10 mm = 312.75
10mm – 14 mm = 312.75

Fine aggregates (kg/m3) = 1391

<u>Surface area of 3.35 mm – 5mm (avg = 4.2mm)</u>

Surface area = (π d2 /4)
= 13.85 mm2

<u>Surface area of 5 mm – 10mm (avg = 7.5mm)</u>

Surface area = (π d2 /4)
= 44.2 mm2

<u>Surface area of 10 mm – 14mm (avg = 12mm)</u>

Surface area = (π d2 /4)
= 113 mm2

Volume,V of aggregates

3.35 mm – 5mm (avg = 4.2mm)

V= 4/3 πr3

= 38.8mm3

= 3.88 x 10 ^-8 m3

5 mm – 10mm (avg = 7.5mm)

V= 4/3 πr3

= 220.9mm3

= 2.209 x 10 ^-7 m3

10 mm – 14mm (avg = 12mm)

V= 4/3 πr3

= 904.8mm3

= 9.048 x 10 ^-7 m3

Calculation for cement paste

Specific gravity of aggregates = 2650

Specific gravity, ∂ = W/ nV

3.35 mm – 5mm

2650 = 1.7375/ n (3.88 x 10^-8)

n = 16895

Area to be covered = n x surface area

= 0.234 m2

5 mm – 10mm

2650 = 7.82/ n (2.209 x 10^-7)

n = 13358

Area to be covered = n x surface area

= 0.59 m2

10 mm – 14mm

2650 = 7.82/ n (9.048 x 10^-7)

n = 3261

Area to be covered = n x surface area

= 0.368 m2

For fine aggregates = 0mm- 3.35mm (avg = 1.65mm)

FA = 34.775 kg

Surface area = (π d2 /4)

= 2.2 mm2

Volume of aggregates

V= 4/3 πr3

= 19.86 mm3

= 1.986 x 10 ^-8 m3

Specific gravity,∂ = W/ nV

2650 = 34.775/ n (1.986 x 10^-8)

n = 660757

Area to be covered = n x surface area

= 1.453 x 10 ^-3 m2

$\sum$area to be covered by cement paste = (0.234 + 0.59 +0.368 +01.45 x 10 ^-3) m2

= 1.193 m2

Volume of cement paste needed for 0.025 m3 = 2.386 x 10^ -3 m3

For 1m3: volume = 0.1 m3

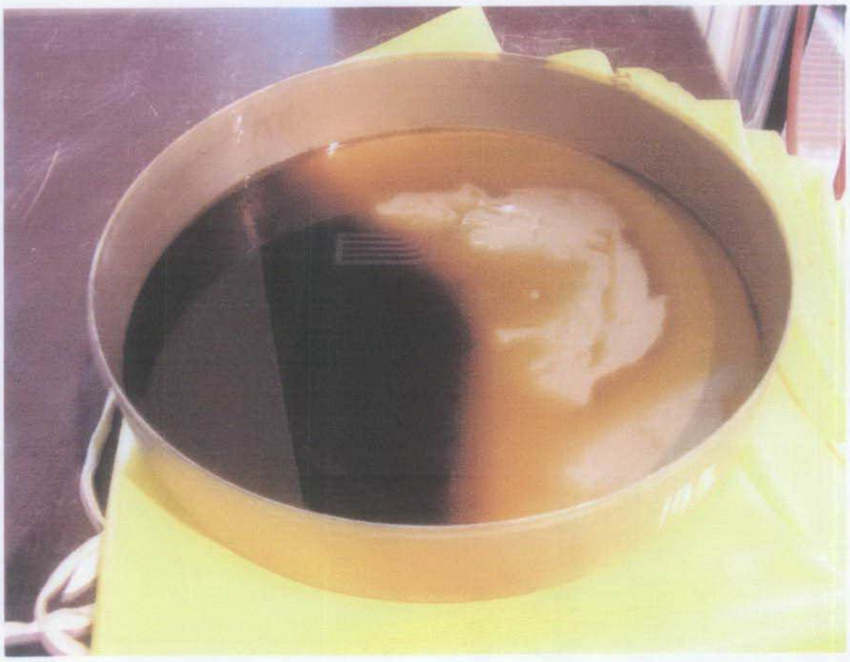
Cement paste = 0.4c + c/3.15 = 0.1 m3

c = 0.139 m3

From assumption 1000 L = 1m3 = 1000 kg

So cement needed = at least 139 kg < 400 kg.

Appendix 5



Appendix 6