High Tensile Strength Concrete

by

Mohd Iqbal Farid Bin Monsarif

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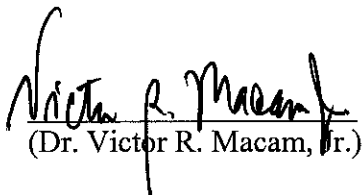31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

High Tensile Strength Concrete

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A project dissertation submitted to the
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Approved by,

(Dr. Victor R. Macam, Jr.)

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TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

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

MOHD IQBAL FARID BIN MONSARIF

ABSTRACT

This report basically discusses the research done and basic understanding of the chosen topic, which is High Tensile Strength Concrete. The objective of this project is to produce a concrete that can resist high tensile stress since concrete is known very weak in tensile. The factor affecting tensile strength and the suitable test to determine the concrete tensile strength are discussed in this report. All methods in conducting the project are explained consist of the project plan, lab works and calculation needed. Tests such as split tensile test, flexural test and compression test to study the effect of different size of aggregate towards the tensile strength of concrete are explained. All result obtain from the tests are discussed mainly regarding the effect of different aggregate size towards concrete strength and at the same time how Silane Coupling Agent (SCA) behave as water repellent to the aggregates. The conclusion and recommendation section summarized all works that have been done through out the semester and recommend suitable solution that might increase the strength of concrete in tension for further action in the next semester.

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CHAPTER 1

INTRODUCTION

1.1   Background Studies

Concrete is a construction material that consists of cement, aggregate, water and admixtures. Concrete solidifies and hardens after mixing and placement due to a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a stone-like material.

Concrete is widely used worldwide because of its many advantages. Concrete is economical, durable and relatively low maintenance requirement. It also has the ability to be cast into any desired shape. It is the most frequent material used in construction.

The ultimate strength of concrete is influenced by the water-cement ratio *(w/c)*, the design constituents, and the mixing, placement and curing methods employed. All things being equal, concrete with a lower water-cement ratio makes a stronger concrete than a higher ratio. A low w/c ratio and fully compacted concrete that means low porosity resulting a quality hardened concrete with good strength in both compression and tension.

1.2 Problem Statement

Concrete is well known of its high compressive strength, but it is extremely weak in tension. Concrete has relatively low tensile strength compared to other building material. It has low ductility, low strength-to-weight ratio and cracking problems. Normally, tensile strength of concrete is only 5-10% of its compressive strength.

Concrete is a heterogeneous material consisting of three major components: bulk cement paste, aggregates and interfacial transition zone (ITZ). The aggregates are the main volume of the concrete and the bulk cement paste are the one which bond all the aggregates together and form a hardened stone-like concrete. In addition, the ITZ is a layer between the aggregates and the cement paste where failure due to crack always happen in this zone.

1.3 Objective & Scope of Study

The objectives of the project are:
   i.   To determine the effect of Interfacial Transition Zone (ITZ) to the tensile strength of concrete.
   ii. To determine suitable chemical admixture to increase the bond in ITZ.

The scopes of study for this project are:
   i.   Study the effect of different aggregate size towards ITZ.
   ii. Study the effect of chemical admixture to ITZ.

CHAPTER 2

LITERATURE REVIEW

2.1   What is Concrete?

Concrete is defined as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate; in hydraulic-cement concrete, the binder s formed from a mixture of hydraulic cement and water. From the definition itself, concrete is mainly consist of three main elements: cement, water and aggregates.

Cement can be described as a material with adhesive and cohesive properties when which make it capable of bonding mineral fragment into a compact whole. Hydraulic cement is cement that sets and hardens by chemical interaction with water. Portland cement is the important hydraulic cement. It is produced by pulverizing Portland cement clinker, consisting essentially of hydraulic calcium silicates, usually by intergrinding with small amounts of one or more forms of calcium sulfate in order to control reaction rates (A.M Neville, 2002).

Table 2.1: Main Compounds of Portland Cement.

Name of compound	Oxide composition	Abbreviation
Tricalcium silicate	3 CaO.SiO2	C3S
Dicalcium silicate	2CaO.SiO2	C2S
Tricalcium aluminate	3CaO.Al2O3	C3A
Tetracalcium aluminoferrite	4CaO. Al2O3.Fe2O3	C4AF

Hydration of cement is the reactions by virtue of which Portland cement becomes a bonding agent take place in a water-cement paste. In other words, in the presence of water, the silicates and aluminates listed in Table 2.1 form products of hydration which in time produce a firm and hard mass – the hydrated cement paste. The two calcium silicates are the main cementitious compound in cement. The rate of hydration decreases continuously, so that even after a long time there remains an appreciable amount of unhydrated cement. That is why concrete need to be cured at least for another 28 days after it casted so that it can reach 100 percent of it designed strength.

Aggregate is defined as granular material such as sand, gravel, crushed stone or iron blast furnace slag used with a cementing medium to form hydraulic cement concrete or mortar. Typically hydraulic-cement concrete has volume fractions of aggregate that range approximately from 0.7 to 0.8. The remaining volume is occupied initially by a matrix of fresh cement paste consisting of water, cement and admixtures that also enclosed air voids. When the aggregates occupy most of the volume, they are relatively are inert and intended to be stable. It is the cement paste matrix that undergoes the remarkable transformation from nearly fluid paste to rock-hard solid, transform plastic concrete into an apparent monolith, and controls many important engineering properties of hardened concrete (Klieger, Lamond, 1994).

In manufacturing good quality concrete, two size group of aggregates are used which are the fine aggregates that not larger than 5mm in diameter and coarse aggregates that at least 5mm in diameter. Many properties of the aggregates depend entirely on the properties of the parent rock, e.g. chemical and mineral composition but there are some properties possessed by the aggregate but absent in the parent rock: particle shape and size, surface texture and absorption. All these properties may have a considerable influence on the quality of the concrete either fresh or in the hardened state (A.M Neville, 2002).

2.2   Strength of Concrete

Strength of concrete commonly considered its most valuable property, although. In many practical cases, other characteristics such as durability and permeability may in fact more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste. Moreover the strength of concrete is almost invariably a vital element of structural design and is specified for compliance purposes (A. M Neville, 2002).

The strength of concrete originates from the strength of the hardening cement paste which in turn originates from the hydration products. The major portion of the hydration products is in the form of a rigid gel, the cement gel (Popovics, 1998).

In engineering practice, the strength of concrete at a given age and cured in water at a prescribed temperature is assumed to depend primarily on two factors only: the water/cement ratio and the degree of compaction. When concrete is fully compacted, its strength is taken to be inversely proportional to the water/cement ratio. This relation is established by Duff Abrams in 1919.
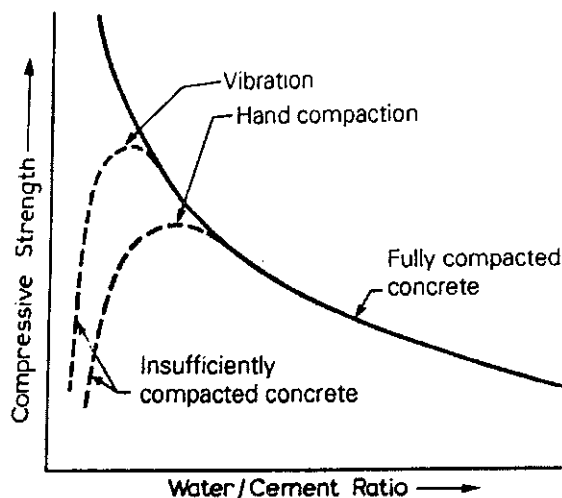

Figure 2.1: The relation between strength and water/cement ratio of concrete.

The other factor that gives effect to the concrete strength is the property of the coarse aggregates. Gilkey in 1961 stated that for given cement and acceptable aggregates, the strength that may be developed by a workable, properly placed mixture of cement, aggregate and water is influenced by: ratio of cement to mixing water, ratio of cement to aggregate, property of aggregate particles and maximum size of the aggregate. The stress at which the cracks develop under compression load are depend largely on the properties of the coarse aggregate: smooth gravel leads to cracking at lower stresses than rough and angular crushed rock, probably because mechanical bond is influenced by the surface properties and to a certain degree by the shape of the coarse aggregate (Jones and Kaplan, 1957).

The influence of shape and surface texture of coarse aggregate to the strength of concrete is qualitatively the same as on the flexural strength. Kaplan in 1959 observed that the flexural strength of concrete is generally lower then the flexural strength of corresponding mortar. Mortar would thus seem to set the upper limit to the flexural strength of concrete and the presence of the coarse aggregate generally reduces this strength. On the other hand, the compressive strength of concrete is higher than that of mortar which according to Kaplan, indicates that the mechanical interlocking of the coarse aggregate contributes to the strength of concrete in compression. At this stage, noted that the coarse aggregate particles act as crack arresters so that under an increasing load, another crack is likely to open. Therefore, failure is gradual and even in tension, there are descending part of the stress-strain curve.

As stated above, the compressive strength of concrete is one of the most important technical properties. In most structural applications, concrete is employed primarily to resist compressive stresses. For some reason, the compressive strength is generally used as measure of the overall quality of the concrete. In addition to its practical significance, the tensile strength of concrete has a fundamental role in the fracture mechanism of hardened concrete. It is an accepted view that fracture in concrete occurs through cracking. This means that concrete fracture is essentially a tensile failure regardless of whether the fracture is caused by compression, freezing or by other factors. Therefore

the mechanical properties of a hardened concrete are control to a great extent by the fact that its tensile strength is about one-tenth of the compressive strength. Tensile stresses usually caused by tensile or flexural loads, temperature changes, shrinkage and moisture changes (Popovics, 1998).

Oluokun relate the compression and the tensile strength of a concrete using the equation of where f_t and f_c are the tensile strength compressive strength respectively with unit of MPa or N/mm^2.

$$f_t = 0.2 \, (f_c)^{0.7}$$

2.3   Interfacial Transition Zone (ITZ)

It is now commonplace to consider concrete as a material consisting of three phases: the hardened cement paste (hcp), the aggregate and the interfacial transition zone (ITZ) between the hcp and the aggregate particles. Clearly, the strength of concrete must depend upon the intrinsic strength of the hcp and upon the strength of the bond between the hcp and the aggregate. Unfortunately, it has so far not been possible to determine, in a meaningful way, the bond strength between the various phases in the concrete and consequently it has not been possible to quantify the effect of the properties of the ITZ on the properties of concrete (Buyukozturk and Wecharatana, 1995).

It is generally assumed that the ITZ is the "weak link" in normal strength concrete. A fracture path through concrete will pass through several interfacial regions, running parallel to the interface in some places and across it in others. Study of the fracture surface in the Scanning Electron Microscope (SEM) allows the microstructure of these regions to be examined. This technique is very useful for qualitative characterization but because the crack path favors weaker regions of the microstructure, fracture surfaces are unrepresentative of the concrete as a whole (Maso, 1996).

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2.4   Silane Coupling Agent (SCA)

Silane coupling agent (SCA) is silicon-based chemicals that contain two types of reactivity – inorganic and organic – in the same molecule. A typical general structure is

$$(RO)_3SiCH_2CH_2CH_2-X$$
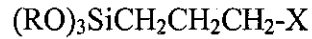
where RO is a hydrolysable group, such as amino, methacryloxy, epoxy, etc. A SCA will act at an interface between an inorganic substrate such as glass, metal or mineral and an organic material such as an organic polymer, coating or adhesive to bond two dissimilar materials.

Ma in 1999 has coated the surface of marble specimens with styrene-butadiene resin emulsion, or KH-550, KH-560, KH-570 SCA solutions separately, before applying cement mortar. Splitting tensile test result showed that the modified interfacial layers were 27%, 57%, 69% and 84% higher than that control specimens respectively. SCA can noticeably improve the microstructures of cement hydrates in the ITZ. The modifying mechanism of the ITZ using SCA is worth further investigation (Xiong,2004).

Moreover, silane also has the ability to make the surface of the aggregate become water repellent when it applied on the aggregate surface. It is assumed that one of the factors that weakened the ITZ is the pore that left by the water attached at the aggregates surface when hydration process occurs. Theoretically, if the water at the aggregate surface can be removed by making the aggregate hydrophobic, possibility for pores to occur can be reduced. In order to do that, silane has the potential to make it possible.

2.5   Tensile Strength Test

Currently there are no standardized test procedures for determining directly the tensile strength of concrete. This is due to the difficulty involved in inducing pure axial tension within a specimen without introducing localized stress zone. However, knowledge of the tensile capacity of concrete is necessary in that it is the tensile strength of concrete that will determine its resistance to cracking. Therefore several test procedures have been developed to indicate indirectly the tensile capacity of concrete (Klieger, Lamond, 1994). These include three standard test procedures: ASTM Test Method for Flexural Strength of Concrete (Using simple beam with third point loading), ASTM Test Method for Flexural Strength of Concrete (Using simple beam with center-point loading) and ASTM Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens (Kett, 1999)

CHAPTER 3

METHODOLOGY AND PROJECT WORK

3.1   Project Plan

In order to achieve the objectives of this project, several methodology need to be done so that the project will run smoothly. The crucial methodology at the early stage of this project is the literature review where it provides information in order to give basic ideas in understanding the project.

The literature review is then followed by the laboratory works which consist of experiment and calculation. For the first semester, the laboratory works are more toward preliminary study and act as the foundation of the project. The result will be used in the second semester for the project to proceed.

3.2   Literature Review

The methodology that would be done through the final year project is literature review and also the experiment. Literature review is done through articles, journals, books and websites to collect related information of the project such as the properties of concrete, factor affecting concrete strength, test procedure and other related theories.

3.3   Experiment and Calculation

Based on prior literature review and related theory, experimental works is done in the laboratory in order to prove the theory and collect more information. The experimental works are:

3.3.1   Concrete mix using aggregate size of 20mm, 14mm and 10mm.

This experimental work was done in order to prove that smaller size aggregate will give higher tensile strength than the bigger size aggregate as stated by Kaplan in 1959 and at the same time find out the aggregate size that give highest tensile strength. In order to perform the experiment, the aggregate need to be sieved to segregate the 20mm, 14mm and 10mm aggregate size.

Design mix for every mixing are calculated based on BS 1881 and the target strength is 40 N/mm^2 at 28 days. The concrete mixing procedure adopted in this project is the normal procedure as conducted in the building construction. The procedures of the concrete mixing are as follow:

1. Pour all coarse and fine aggregate into the mixer and mix for 1 minute.
2. Pour half of the water and mix for 1 minute.
3. Leave the mix for 8 minutes.
4. Pour in the cement and mix for 1 minute.
5. Pour another half of water and add for 1 minute.
6. Perform hand mixing until the mixture is well mixed.

Table 3.1: Mix proportion for concrete mixing using aggregate size of 10mm.

	Kg/m3	Kg/total volume of 0.034m^3
Water	235	7.99
Cement	425	14.45
Fine Aggregates	735	25
Coarse Aggregates	975	33.15
Total	2370	80.59

Table 3.2: Mix proportion for concrete mixing using aggregate size of 14mm.

	Kg/m3	Kg/total volume of 0.034m^3
Water	220	7.48
Cement	400	13.6
Fine Aggregates	690	23.5
Coarse Aggregates	1080	36.72
Total	2390	81.3

Table 3.3: Mix proportion for concrete mixing using aggregate size of 20mm.

	Kg/m3	Kg/total volume of 0.034m^3
Water	205	6.97
Cement	375	12.75
Fine Aggregates	625	21.25
Coarse Aggregates	1210	41.14
Total	2415	82.11

3.3.2 Mortar mix using aggregate size of 5mm

The design mix for this experiment is based on the ratio of 2:1 where two part of aggregate with one part of cement and water to cement ration of 0.35. Thirty (30) samples are casted for five (5) days of testing.

3.3.3 Concrete mix using Silane Coupling Agent (SCA) treated aggregate with size of 20mm, 14mm and 10mm.

This experiment was done to prove the early hypothesis that by making the aggregate water repellent will remove the water from the aggregate surface and reduce the potential of void to occur. By doing that, the tensile strength of the concrete might be increased. The procedures of the concrete mixing were the same as normal concrete mixing. The only different was the aggregate being coated by SCA before mixing. Design mix for every mixing was calculated based on BS 1881 and the target strength is 30 N/mm^2 at 28 days.

3.3.4 Hardened concrete/mortar tests

For the concrete mix to check the aggregate size effect, twelve (12) cubes of 10cm x 10cm x 10cm and three (3) 10cm x 10cm x 50cm prisms of concrete sample casted for every aggregate size:

Table 3.4: Test planned for every mix

Days	Test
3	3 cubes for split test
7	3 cubes for split test
28	3 cubes for split test 3 cubes for compression test 3 prisms for flexural test

For the test to check the effect of SCA towards the strength of concrete, 18 cylindrical samples were cast or three days of test which were on the 2nd, 7th and 28th day. Three samples for split tensile test and another three samples for compression test for each test day.

For the mortar test, thirty (30) cylindrical samples of 5.5cm diameter x 10cm length were casted. The tests for the mortar are done on the 1st, 3rd, 7th, 14th and 28th days after the day of casting. Three (3) samples are used for compression test and other 3 samples are used for split tensile test for each day.

- **Split Tensile Test (BS 1881: Part 117 – 1983)**

   The objective of this test is to measure the tensile strength of the concrete.
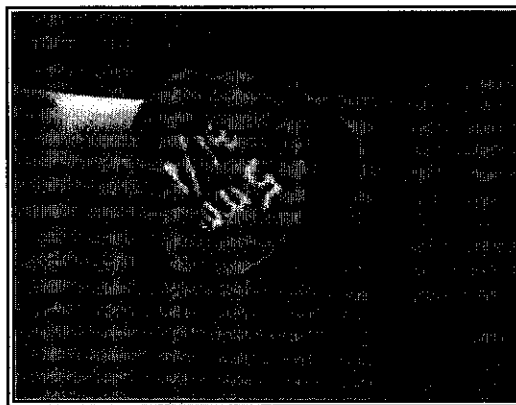

Figure 3.1: Mortar split tensile test

- **Flexural Test**

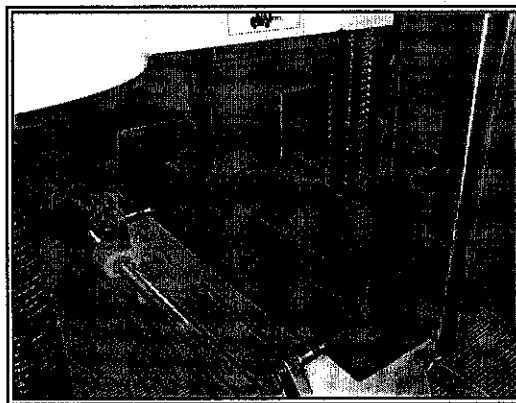   The objective of this test is to measure the flexural strength of the concrete.

Figure 3.2: Flexural test using Universal Testing Machine (UTM)

3.3.5 Scanning Electron Microscope (SEM)

The Scanning Electron Microscope (SEM) is a type of electron microscope capable of producing high resolution images of a sample surface. Due to the manner in which the image is created, SEM images have a characteristic three-dimensional appearance and are useful for judging the surface structure of the sample. Relating to the project, SEM is used to study the bond between the aggregate and the cement paste of the concrete. This zone is known as the Interfacial Transition Zone (ITZ), a thin shell with a thickness of 10 to 50 μm.

3.4 Tools and Materials

- Personal computer
- Concrete mixer
- Cube compression machine
- Sieving machine
- Concrete mould

3.5 Hazard Analysis

Hazard is anything that can cause harm to life, health, property and environment. Most hazards are dormant or potential, with only a theoretical risk of harm, however, once a hazard becomes active, it can create an emergency situation.

Hazard might come in several modes such as physical hazard which consist of noise, vibration, poor lighting, heat, dust, fire and explosion. Hazard can also come in the mode of chemical and can severely affect the nervous system, breathing and contamination if exposed to it. In the other hand, infectious, bacteria and viruses are the example of biological hazards.

Working in concrete lab might expose a person with lots of hazard. Here are some hazards that might occur during this project and the prevention method:

3.5.1   Hazard checklist

Physical hazard could be caused by any unsafe act or unsafe condition. For example:

- Noise from sieving machine.
- Electrical appliances
- Falling / slip
- Back pain due to heavy lifting
- Concrete debris get into eyes during testing

An article dated February 21, 2008 by OSHA said that those who work with Portland cement are at risk of developing skin problems. Wet Portland cement can damage the skin because it is caustic, abrasive, and absorbs moisture. It also contains trace amounts of hexavalent chromium, a toxin harmful to the skin. Furthermore, cement particle also harmful if it gets into eyes and being inhaled. Dealing with concrete, a person must never take this for granted.

Other chemical hazards that possible to happen during this project are:

- Silane: combustible, cause irritation to eyes and skin

3.5.2 Prevention method

Some of the incidents happened in the lab can be prevented if basic safety regulations and attitude were taken seriously. This can be done by wiping out the unsafe condition and avoiding the unsafe acts:

- Wear Personal Protection Equipment (PPE): gloves, goggle, boots.
- Avoid horseplay
- Do not eat/drink in the lab
- Use proper lifting method
- Avoid using any defective equipment and report it to the lab technician.
- Proper housekeeping
- Study the lab procedure

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Experimental-based Study Result

4.1.1 Effect of aggregate size of 20mm, 14mm and 10mm in concrete.

The first test was implemented to find out the effect of different aggregate size to the tensile strength is the split tensile test which is done on the 3rd, 7th and 28th day. The concrete were designed as Grade 40 which can sustain compressive stress up to 40 N/mm^2. The results obtained from the tests were then plotted in a graph. The graph obtain is as follows:
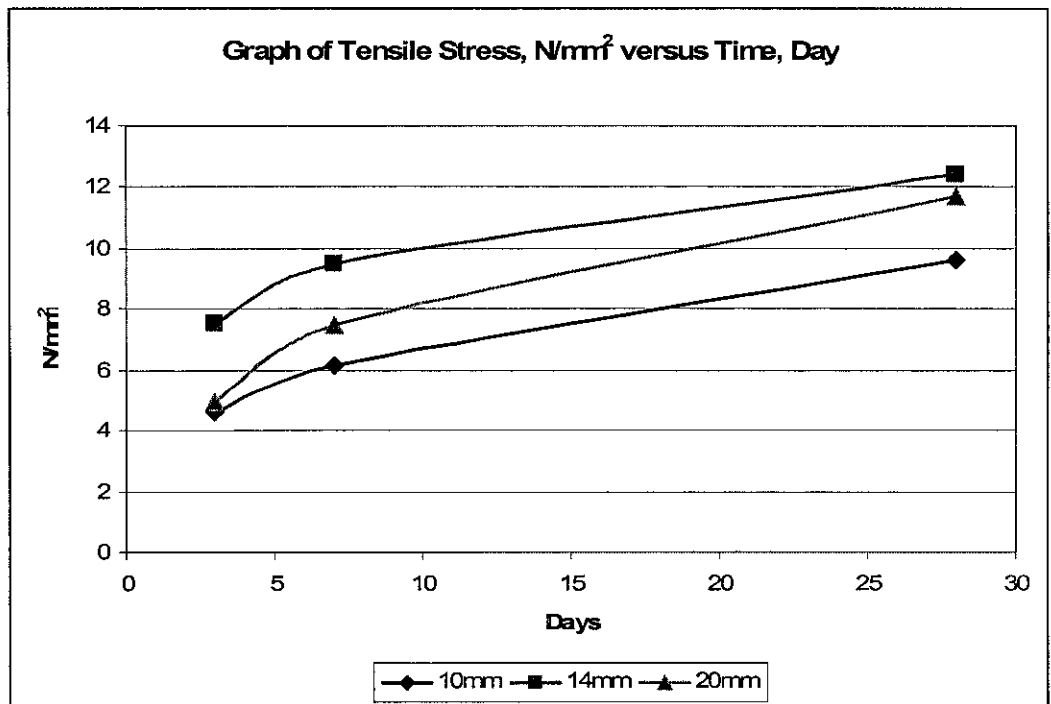

Figure 4.1: Tensile strength due to different aggregate size.

From the graph above, it is shown that different size of aggregate used in concrete mixing give different values of tensile strength. As at 28 days, the concrete with 10mm aggregates size give stress of 9.59 N/mm^2, 12.41 N/mm^2 for the 14mm aggregate and 11.67 N/mm^2 for the 20mm aggregate. In comparison, the 14mm aggregate gives highest tensile strength to the concrete compared to the 10mm and 14mm aggregates.

Kaplan in 1959 stated that smaller size aggregate gives higher tensile strength than the bigger size aggregate. As shown in the graph, the 14mm and 20mm aggregate sizes concrete follow the trend where the tensile strength of 14mm aggregate concrete is higher than the 20mm aggregate concrete. This result is supported by the flexural test done on the prism sample of the mixes on the 28days. The results are as follows:
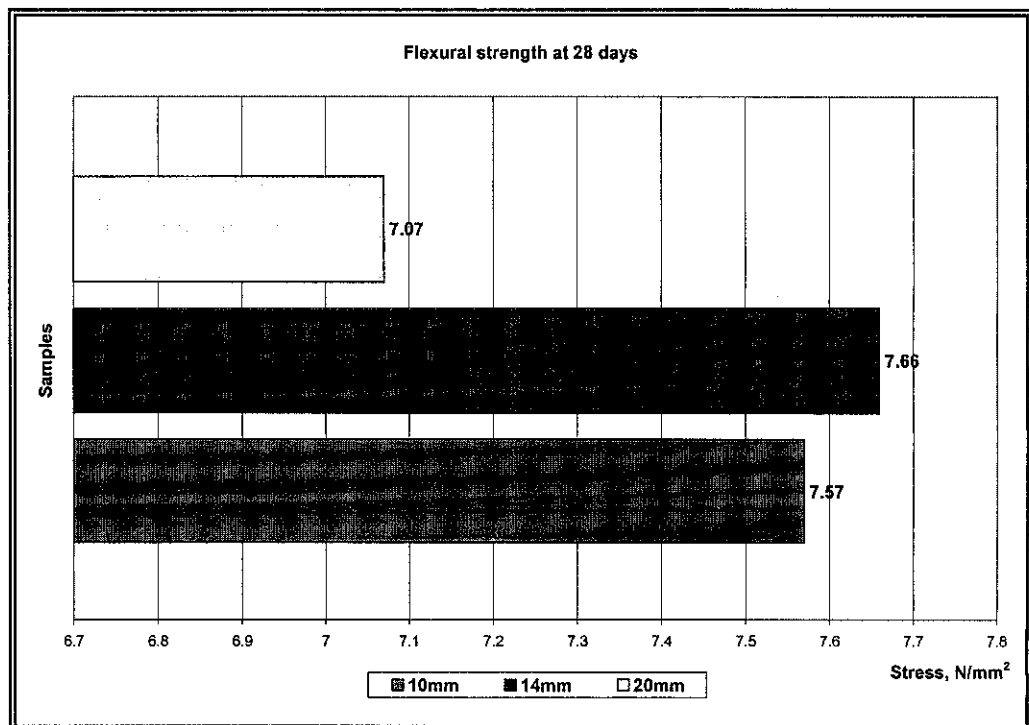

Figure 4.2: Effect of different aggregate sizes to flexural strength

As far as the surface area is concern, the 10mm aggregate which has greater surface area compare to the 20mm aggregate gives higher value of flexural strength on the test done at 28 days. Greater surface area means more contact between the aggregates and the cement paste which will result in stronger bonding. However, from the result we can see that the 14mm aggregate give higher value to concrete flexural strength compare to the 10mm aggregate. This might because the 14mm aggregate has the ability to stop the crack when it occur due to it larger size.

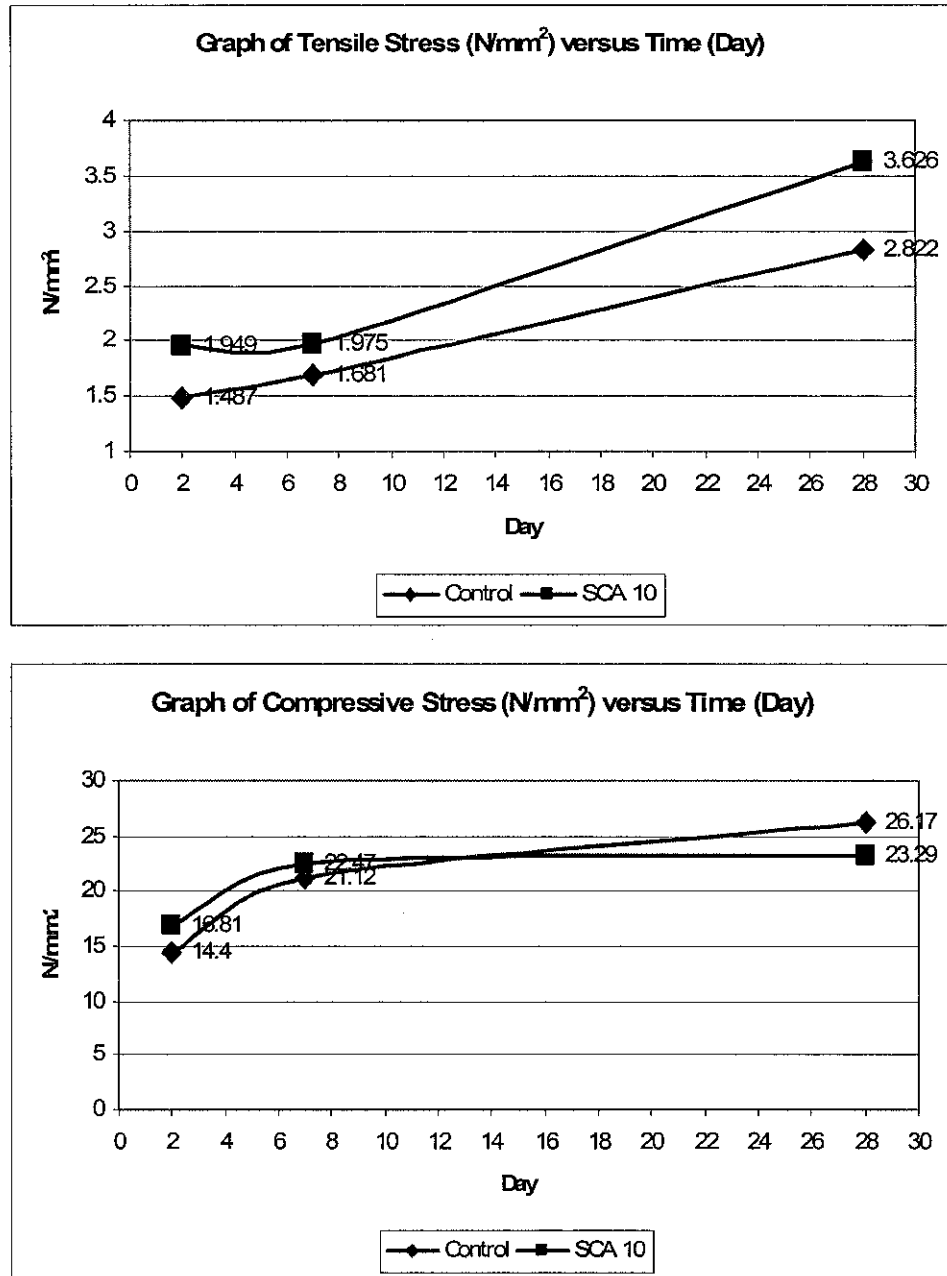## 4.1.2 Effect of SCA treated aggregate in concrete.

Figure 4.3: Effect of 10mm SCA coated aggregate to concrete strength

From Figure 4.3, the concrete with 10mm SCA coated aggregates size give tensile stress of 3.626 N/mm^2 at 28 days and 23.29N/mm^2 for the compressive stress. In comparison, the SCA increased the tensile stress by 28.5% and 11% decrements in compressive stress compare to the control mix.
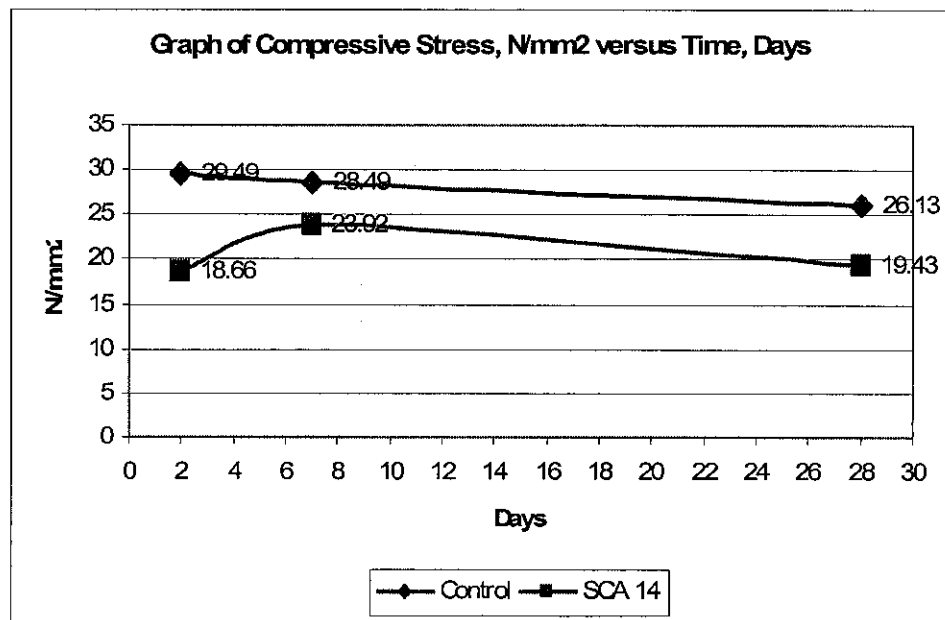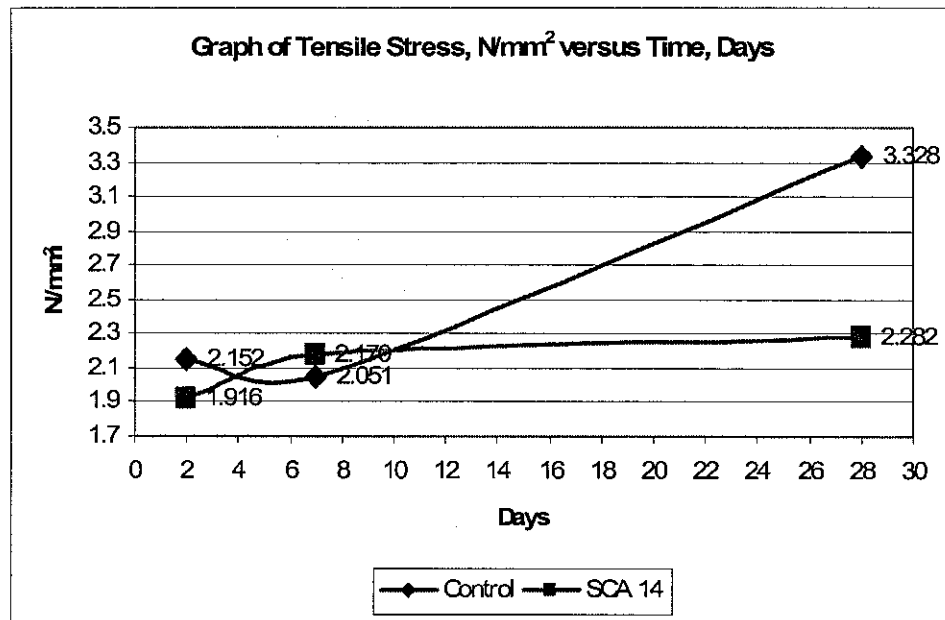
Figure 4.4: Effect of 14mm SCA coated aggregate to concrete strength

From Figure 4.4, the concrete with 14mm SCA coated aggregates size give tensile stress of 2.282 N/mm^2 at 28 days and 19.43 N/mm^2 for the compressive stress. In comparison, the SCA decreased the tensile stress by 31.43% and 25.64% in compressive stress compare to the control mix.
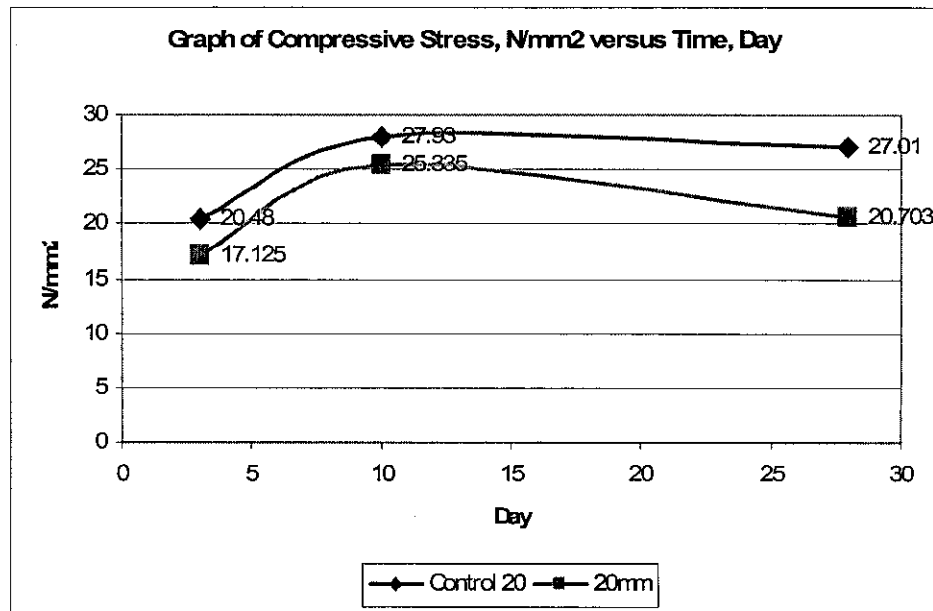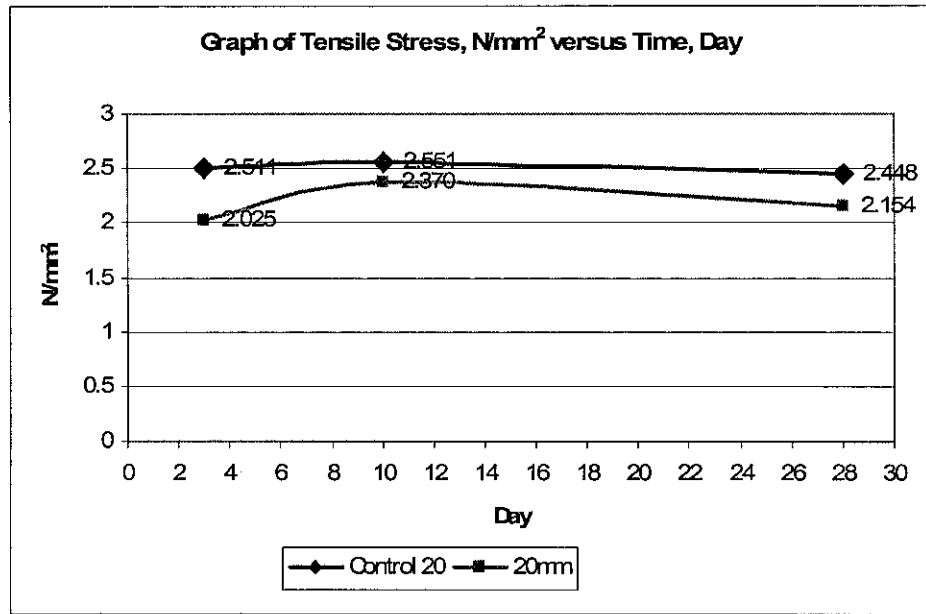
Figure 4.5: Effect of 20mm SCA coated aggregate to concrete strength

From Figure 4.5, the concrete with 20mm SCA coated aggregates size give tensile stress of 2.154 N/mm^2 at 28 days and 20.703 N/mm^2 for the compressive stress. In comparison, the SCA decreased the tensile stress by 12% and 23.61% in compressive stress compare to the control mix.

4.1.3 Effect of aggregate size of 5mm in mortar.

The results from the test on this mortar mix cannot be compared to the results from the test on the 10mm, 14mm and 20mm concrete since the target strength are different. The maximum compressive stress of the mix is 14.92 N/mm^2. Split tensile test and compression test were done and the results are as follow:
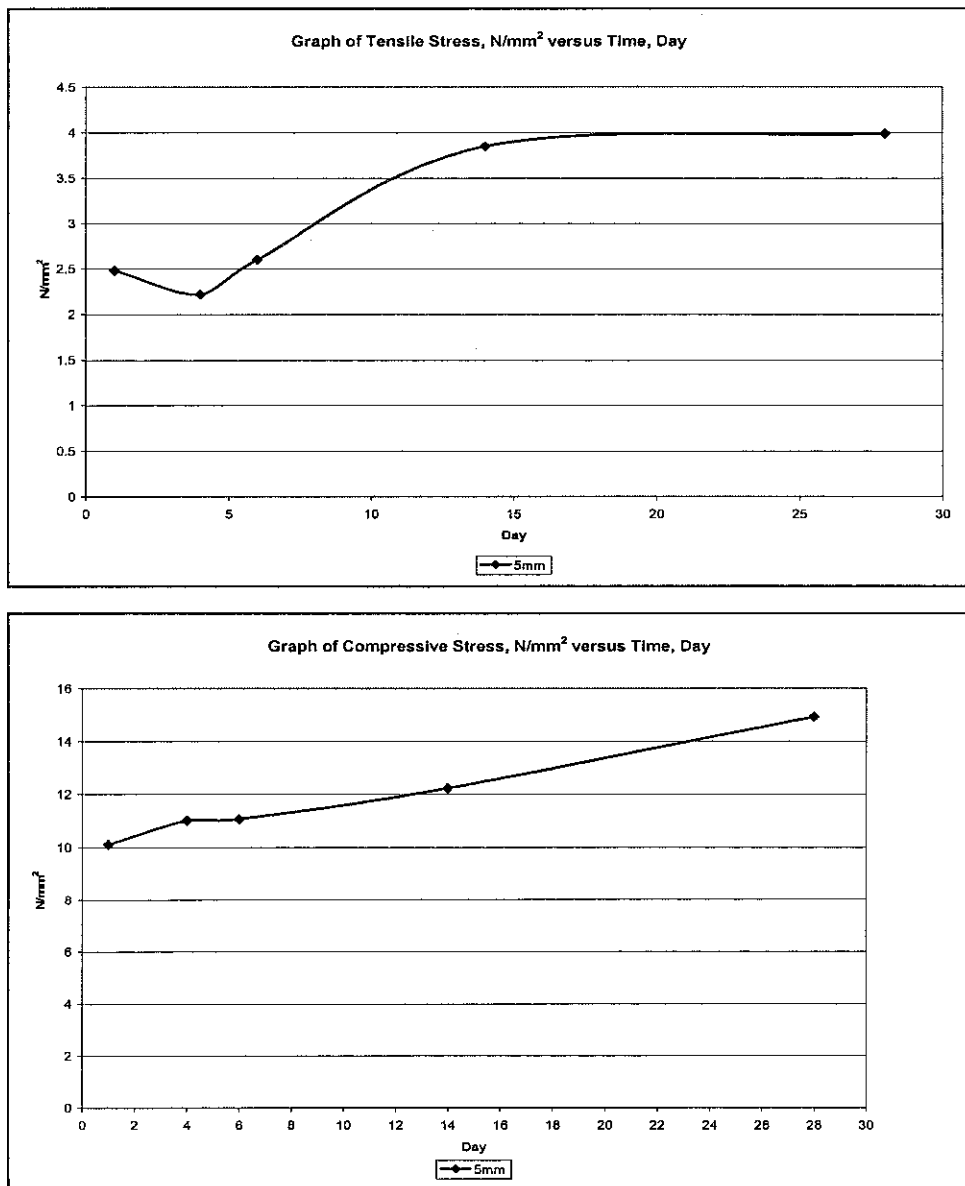
Figure 4.6: Result of split tensile and compression test

From Figure 4.6, we can see that the maximum split tensile strength of the mortar is 3.99 N/mm^2 at 28th day and abnormal slump in the graft at Day 4 occurs. This happened due to high value in weight which means lower value of load over area that led to lower stress.
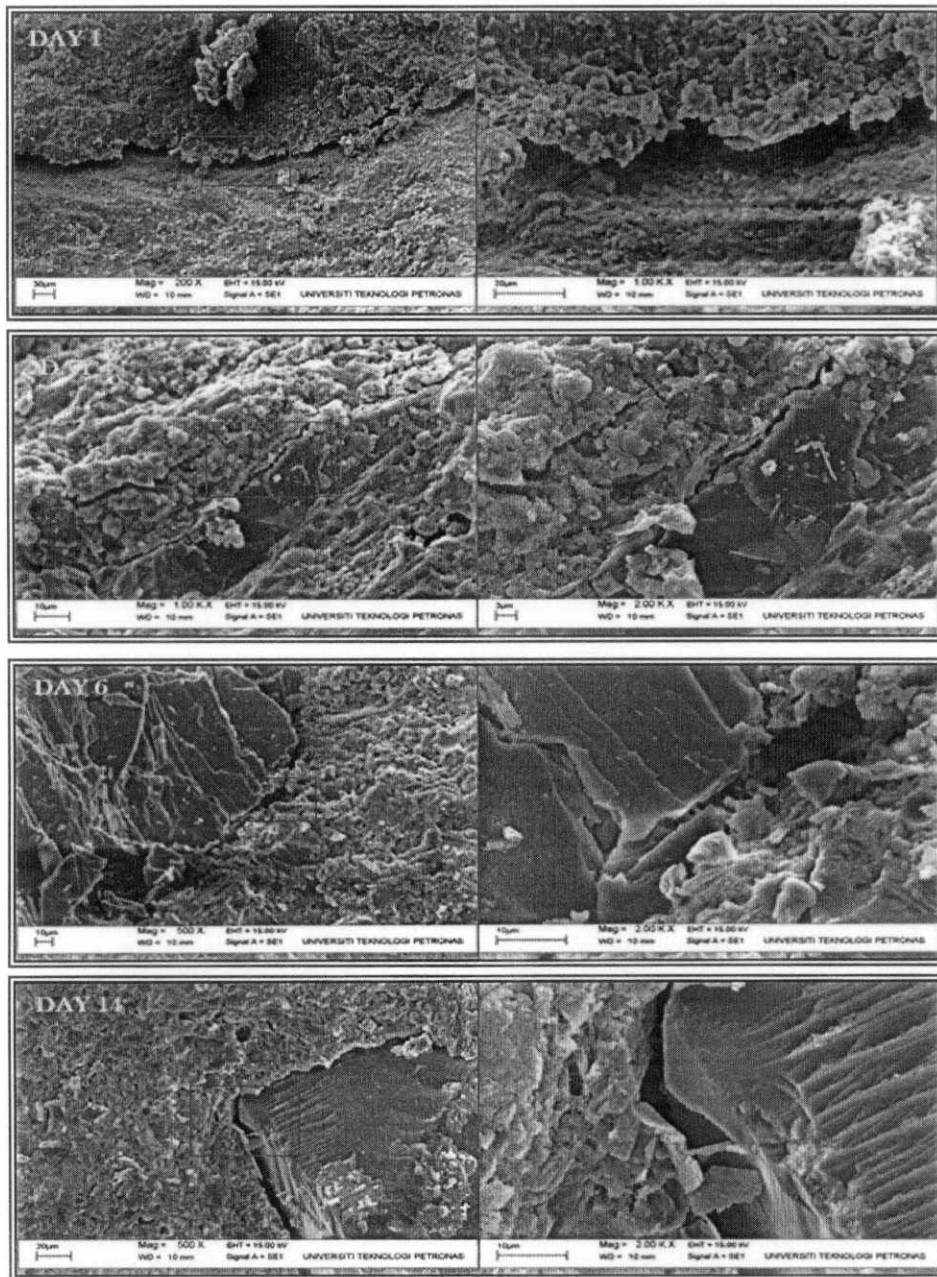
4.1.4 Scanning Electron Microscope (SEM)

Figure 4.7: View of phase between aggregate size of 5mm and cement paste.

As we can see from Figure 4.7, the ITZ in between the aggregate and the cement paste there are empty spaces that we can call as pores. These pores might weaken the concrete due to minimum bonding between the aggregate and the cement paste. Several factors might lead to this problem and one of them is the absorption of water at the surface of the aggregate by the cement paste during hydration process. Another factor that might cause this problem is the cement particles are too large to fill in this pores. However, no CH crystal can be seen. Deeper view need to be done in order to show the presence of the CH crystal orientation at the pores area.

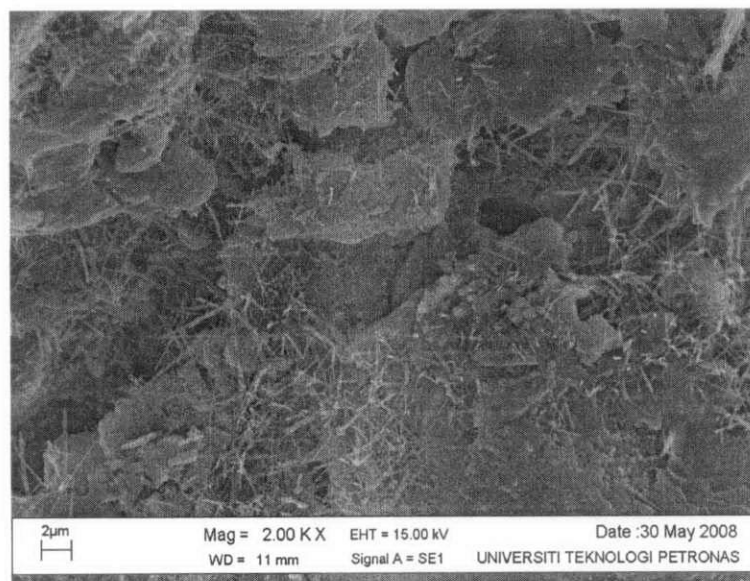Figure 4.8: Interface of 10mm SCA treated aggregate concrete under SEM.

Figure 4.8 shows the surface of the 10mm SCA treated aggregate concrete under SEM at the very edge of the aggregate. From the picture it is clearly shows the presence of needle-like C-S-H structure and the pore at that area that might effect the strength of ITZ and directly the strength of the tensile strength of the concrete.

4.2 Summary and Comparison of Results

This study is done to verify and observe the effect of different sizes of aggregate to the tensile strength of concrete and at the same time find the optimum aggregate size that will result in highest tensile strength. From the split tensile test, the 14mm aggregate give the highest value of tensile strength at 28 days and from the flexural test, it is proved that smaller aggregate size will result in higher flexural strength compare to the aggregate with greater size as shown in Figure 4.2 above.

Looking at the results for the effect of SCA treated aggregates towards the strength of concrete, we can see that at 28 days all compressive stress give lower value compare to the compressive strength of the control mix. Same goes to the tensile stress except for the 10mm aggregate that give some increment in the tensile strength compare to the control mix. This might due to larger surface area of the aggregate that give more contact between the aggregates and the cement paste matrix.

Observing the failure path of the SCA treated concrete, most of the failure happen at the interface of the aggregates which indicate that there are big difference in strength between the aggregates and the cement paste matrix. In this case, the strength of the aggregate is not fully utilized.

From the SEM result, it shows that the occurrence of pores at the ITZ between the cement paste and the aggregate lead to concrete weakness in tensile strength. Some ideas to improve this properties is by adding mineral admixture that can act as micro cement to fill the pores and give greater bonding between the cement paste and the aggregate. Another alternative is to find some kind of chemical that can prevent water from stick at the surface of the aggregate which later will leave pores at the ITZ. Further study need to be done in order to achieve the goal of this project.

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CHAPTER 5

CONCLUSION AND RECOMMENDATION

This Final Year Project is concern in producing High Tensile Strength Concrete since concrete is known very weak in tension and in construction it always assume as zero. In order to achieve this goal, study on Interfacial Transition Zone (ITZ), the bond between cement paste and aggregate and also the aggregate effect towards concrete tensile strength would give clear view for modification to be made.

In this first semester, the focus was on the literature review concerning about the concrete properties, the concrete strength and factor that influenced the concrete strength and also the test that might be considered to achieve the objective of the project. Some study regarding the effect of different size in aggregate towards the ITZ that lead to tensile strength of the concrete was done to aggregate size of 10mm, 14mm and 20mm. As a recommendation, the use of cylinder sample instead of cube sample for the split tensile test is more appropriate base on the equipment provided in the lab.

For the second semester, the focus was on the silane coupling agent to coat the aggregate to make it water repellent before conducting the concrete mix to increase the tensile strength properties of the concrete. Base on the result obtain, we can conclude that silane coupling agent (SCA) most likely not an alternative to increase the tensile strength of a concrete. However, further study can be done on the method of mixing and on how to use the SCA correctly since those are the grey area of this project.

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APPENDICES

Mix Proportioning

Table I: Approximate compressive strength of concrete

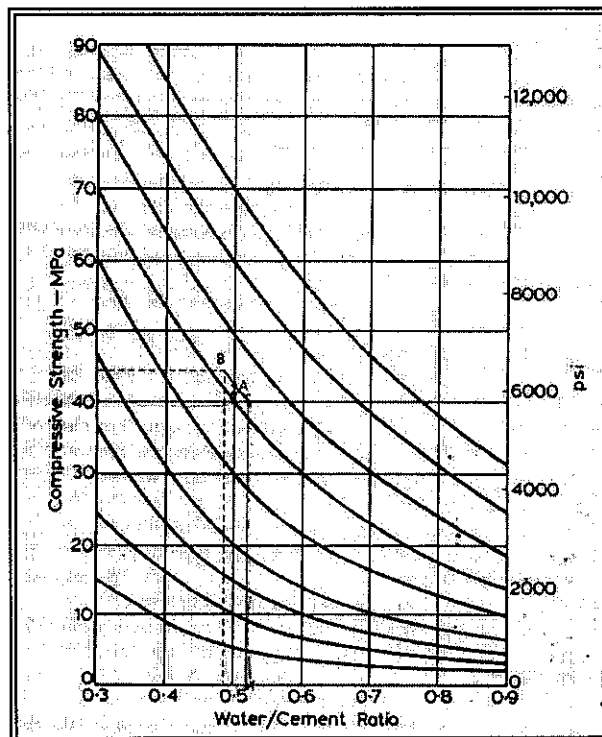| Table 14.9 Approximate Compressive Strengths of Concretes Made with a Free Water/Cement Ratio of 0.5 According to the 1988 British Method[14.11]					
Type of cement	Type of coarse aggregate	Compressive strength* (MPa (psi)) at the age of (days):			
		3	7	28	91
Ordinary Portland (Type I) Sulfate-resisting Portland (Type V)	Uncrushed	22 (3200)	30 (4400)	42 (6100)	49 (7100)
	Crushed	27 (3900)	36 (5200)	49 (7100)	56 (8100)
Rapid-hardening Portland (Type III)	Uncrushed	29 (4200)	37 (5400)	48 (7000)	54 (7800)
	Crushed	34 (4900)	43 (6200)	55 (8000)	61 (8900)
*Measured on cubes.					

Figure I: Relation between compressive strength and free water/cement ratio

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Table II: Approximate free water contents required for various levels of workability

Table 14.10 Approximate Free Water Contents Required to Give Various Levels of Workability According to the 1988 British Method[14.11] (Crown copyright)

| Aggregate		Water content, kg/m³ (lb/yd³) for:				
Max size, mm (in.)	Type	Slump, mm (in.)	0–10 (0–⅜)	10–30 (⅜–1)	30–60 (1–2½)	60–180 (2½–7)
		Vebe time, s	> 12	6–12	3–6	0–3
10 (⅜)	Uncrushed		150 (255)	180 (305)	205 (345)	225 (380)
	Crushed		180 (305)	205 (345)	230 (390)	250 (420)
20 (¾)	Uncrushed		135 (230)	160 (270)	180 (305)	195 (330)
	Crushed		170 (285)	190 (320)	210 (355)	225 (380)
40 (1½)	Uncrushed		115 (195)	140 (235)	160 (270)	175 (295)
	Crushed		155 (260)	175 (295)	190 (320)	205 (345)
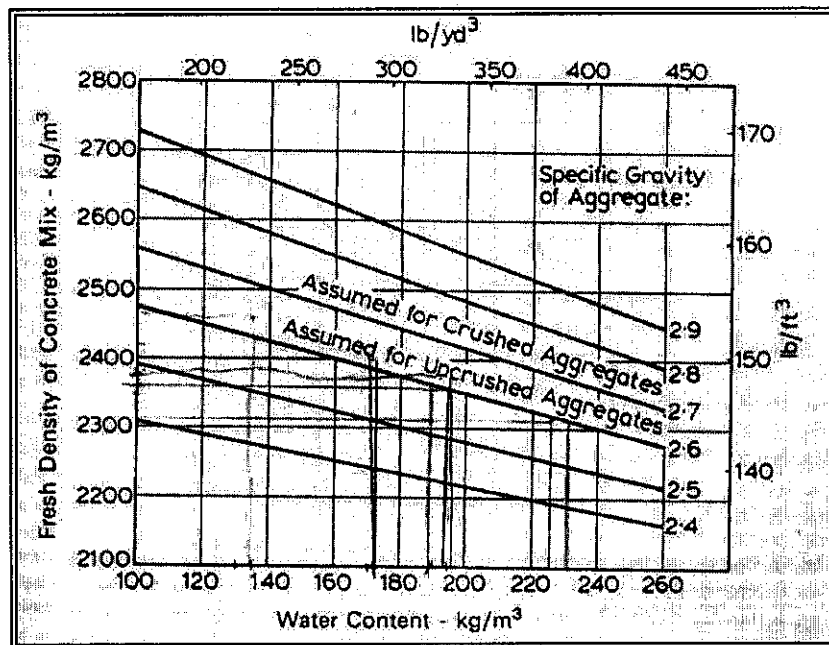
Figure II: Estimate wet density for fully compacted concrete

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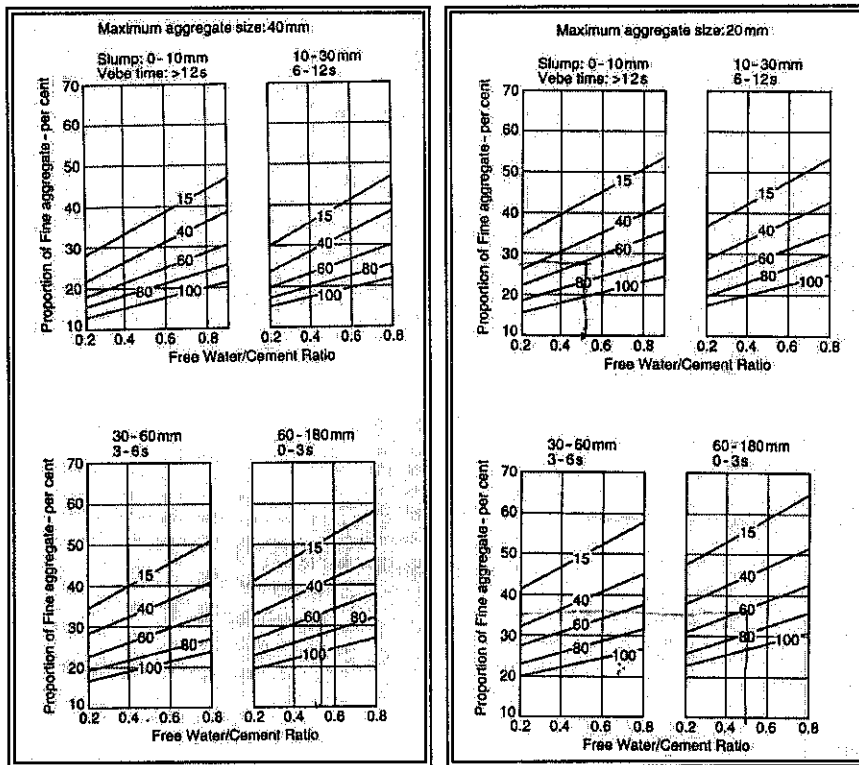
Figure III: Recommended proportion of fine aggregate as a function of free water/cement ratio for various workability and maximum size.

Concrete mix design form

Stage	Item		Reference or calculation	Values
1	1.1	Characteristic strength	Specified	30 N/mm² at 28 da
				Proportion defective 5 per cer
	1.2	Standard deviation	Fig 3	N/mm² or no data 8 N/mm
	1.3	Margin	C1	$(k = \underline{1.64}\ )\ 1.64 \times 8 = 13.12$ N/mm
	1.4	Target mean strength	C2	$30 + 13.12 = 43.12$ N/mm
	1.5	Cement type	Specified	OPC/~~SRPC/RHPC~~
	1.6	Aggregate type: coarse		crushed
		Aggregate type: fine		uncrushed
	1.7	Free-water/cement ratio	Table 2, Fig 4	0.55 } Use the lower value
	1.8	Maximum free-water/cement ratio	Specified	

	2.1	Slump or V-B	Specified	Slump 75 mm or V-B s
	2.2	Maximum aggregate size	Specified	10 mm
	2.3	Free-water content	Table 3	233 kg/m³

	3.1	Cement content	C3	$233 \div 0.55 = 423.6$ kg/m³
	3.2	Maximum cement content	Specified	kg/m³
	3.3	Minimum cement content	Specified	kg/m³ — Use if greater than Item 3.1 and calculate Item 3.4
	3.4	Modified free-water/cement ratio		

	4.1	Relative density of aggregate (SSD)		2.7 known/assumed
	4.2	Concrete density	Fig 5	2365 kg/m³
	4.3	Total aggregate content	C4	$2365 - 423.6 - 233 = 1708.4$ kg/m³

	5.1	Grading of fine aggregate	BS 882	Zone 3
	5.2	Proportion of fine aggregate	Fig 6	43 per cent
	5.3	Fine aggregate content	} C5	$1708.4 \times 0.43 = 734.6$ kg/m³
	5.4	Coarse aggregate content		$1708.4 - 734.6 = 973.8$ kg/m³

Quantities	Cement (kg)	Water (kg or l)	Fine aggregate (kg)	Coarse aggregate (kg)
er m³ (to nearest 5 kg)	425	235	735	915
r trial mix of 0.034 m³	14.45	7.99	25	33.15

s are optional limiting values that may be specified (see Section 7).

MN/m² = 1 MPa (see footnote on page 8).

ary Portland cement; SRPC = sulphate-resisting Portland cement; RHPC

y = specific gravity (

1 Concrete mix design form

Stage	Item		Reference or calculation	Values

1

1.1 Characteristic strength — Specified — 30 N/mm² at 28 days

Proportion defective 5 per cent

1.2 Standard deviation — Fig 3 — _____ N/mm² or no data ___8___ N/mm²

1.3 Margin — C1 — $(k = 1.64)$ $1.64 \times 8 = 13.12$ N/mm²

1.4 Target mean strength — C2 — $30 + 13.12 = 43.12$ N/mm²

1.5 Cement type — Specified — OPC/~~SRPC~~/~~RHPC~~

1.6 Aggregate type: coarse — crushed
Aggregate type: fine — uncrushed

1.7 Free-water/cement ratio — Table 2, Fig 4 — 0.55

1.8 *Maximum free-water/cement ratio* — Specified — } Use the lower value

2

2.1 Slump or V-B — Specified — Slump 75 mm or V-B ____ s

2.2 Maximum aggregate size — Specified — 14 mm

2.3 Free-water content — Table 3 — 219 kg/m³

3

3.1 Cement content — C3 — $219 \div 0.55 = 398.2$ kg/m³

3.2 *Maximum cement content* — Specified — _____ kg/m³

3.3 *Minimum cement content* — Specified — _____ kg/m³ — Use if greater than Item 3.1 and calculate Item 3.4

3.4 Modified free-water/cement ratio

4

4.1 Relative density of aggregate (SSD) — 2.7 known/assumed

4.2 Concrete density — Fig 5 — 2390 kg/m³

4.3 Total aggregate content — C4 — $2390 - 348.2 - 219 = 1772.8$ kg/m³

5

5.1 Grading of fine aggregate — BS 882 — Zone 3

5.2 Proportion of fine aggregate — Fig 6 — 39 per cent

5.3 Fine aggregate content — } C5 — $1772.8 \times 0.39 = 691.4$ kg/m³

5.4 Coarse aggregate content — $1772.8 - 691.4 = 1081.4$ kg/m³

Quantities	Cement (kg)	Water (kg or l)	Fine aggregate (kg)	Coarse aggregate (kg)
per m³ (to nearest 5 kg)	400	220	690	1080
per trial mix of 0.034 m³	13.6	7.48	23.5	36.72

s are optional limiting values that may be specified (see Section 7).

MN/m² = 1 MPa (see footnote on page 8).

ary Portland cement; SRPC = sulphate-resisting Portland cement; RHPC

y = specific grav...

1 Concrete mix design form

Stage	Item		Reference or calculation	Values

1.1 Characteristic strength — Specified — 30 N/mm² at 28 days

Proportion defective — 5 per cent

1.2 Standard deviation — Fig 3 — N/mm² or no data — 8 N/mm

1.3 Margin — C1 — $(k = 1.64)$ $1.64 \times 8 = 13.12$ N/mm

1.4 Target mean strength — C2 — $30 + 13.12 = 43.12$ N/mm²

1.5 Cement type — Specified — OPC/~~SRPC/RHPC~~

1.6 Aggregate type: coarse — crushed
Aggregate type: fine — uncrushed

1.7 Free-water/cement ratio — Table 2, Fig 4 — 0.55

1.8 *Maximum free-water/cement ratio* — *Specified* — Use the lower value

2.1 Slump or V-B — Specified — Slump 75 mm or V-B ___ s

2.2 Maximum aggregate size — Specified — 20 mm

2.3 Free-water content — Table 3 — 205 kg/m³

3.1 Cement content — C3 — $205 \div 0.55 = 372.73$ kg/m³

3.2 *Maximum cement content* — *Specified* — kg/m³

3.3 *Minimum cement content* — *Specified* — kg/m³ — Use if greater than Item 3.1 and calculate Item 3.4

3.4 Modified free-water/cement ratio

4.1 Relative density of aggregate (SSD) — 2.7 known/assumed

4.2 Concrete density — Fig 5 — 2410 kg/m³

4.3 Total aggregate content — C4 — $2410 - 372.73 - 205 = 1832.27$ kg/m³

5.1 Grading of fine aggregate — BS 882 — Zone 3

5.2 Proportion of fine aggregate — Fig 6 — 34 per cent

5.3 Fine aggregate content — C5 — $1832.27 \times 0.34 = 623$ kg/m³

5.4 Coarse aggregate content — $1832.27 - 623 = 1209.3$ kg/m³

Quantities	Cement (kg)	Water (kg or l)	Fine aggregate (kg)	Coarse aggregate (kg)
per m³ (to nearest 5 kg)	375	205	625	1210
per trial mix of 0.034 m³	12.75	6.97	21.25	41.14

ics are optional limiting values that may be specified (see Section 7).

1 MN/m² = 1 MPa (see footnote on page 8).

nary Portland cement; SRPC = sulphate-resisting Portland cement; RHPC
sity = specific...