TENSILE FATIGUE OF CONCRETE WITH POLYVINYL ALCOHOL

by

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

JANUARY 2008

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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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(CIVIL ENGINEERING)

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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.

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ABSTRACT

The project entitled mechanical properties of tensile fatigue of fiber reinforced concrete by using polyvinyl alcohol (PVA), which involves the project to further researches and experiments.

In the previous project, concretes of Grade 40 with dimension of 150x150x150 mm^3 were being used where the 1 % of PVA in the FRC is supposed to have the maximum tension load compared to plane concrete and others design. To make this project to archive the target strength, the project involves in some changes, where concretes is redesign at Grade 30 with dimension of 100x100x100 mm^3.

The works on the concrete batching and casting have been done completely in the late December 2007 and early of this January. All of the designs are concrete contains 1%, 2% and 3% of fibers. The objective of this project is to run the static and dynamic tests on the 60^{th} and 90^{th} days after the curing process for each. Therefore, for every week, the concrete cubes have to be inspected to keep them in a good condition.

ACKNOWLEDGEMENTS

First and foremost, thanks to God for this opportunity and guidance through every moment of this Final Year Project (FYP). His blessing made all complicated things possible.

I am vastly indebted to many people who have helped and inspired me, in various ways, to start, continue, and complete this Final Year Project. My very gratitude goes to my very supportive Supervisor, Dr. Victor R Macam, for assisting and strengthening my resolve. His generous permission to use passages from his work is grateful acknowledged. Without his advices and supervisions, this study may not be completed successfully.

A special credit is owed to Mr. Kalaikumar and Miss Niraku Rosmawati Ahmad for being such a dedicated and supportive Coordinator for this course. And thanks to Mr. Johan and Mr. Meo for being supportive in this project from the beginning. AP Ir. Dr Hj. Muhd Fadhil Nuruddin and AP Ir. Dr. Arazi Idrus may not realize how their lecture and tutor have influenced this study. Their indirect contribution is highly appreciated. The compliment also goes to all colleagues for their precious assistance and morale supports.

Lastly, my appreciation goes to my family for their eternal love and support. To all of them I want to express my sincere gratitude.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

The concept of reinforcing brittle building materials with various forms of fiber has been known since ancient times. Mud huts made using baked clay reinforced with straw and masonry mortar reinforced with animal hair are early examples of fiber reinforced materials in construction. The first modern and sophisticated example of fiber reinforced construction material produced with controlled and predictable level of quality was asbestos-cement, a material manufactured in thin-section forms such as flat or corrugated sheet and pipe by combining asbestos fibers with a slurry of cement and water, sometimes with finely divided silica, sand or other additives included.

Asbestos-cement manufactured by Hatschek, Magnani or Mannville processes has been effectively and widely utilized in sheeting, roofing and cladding panels and in pipe since about 1900. In its final dewatered forms the fiber content by volume is 6-8% in sheeting, 8-10% in pipe, and 14-21% in fire-resistant boards, with fibers typically less than 5 mm in length (Concrete society 1973, Ryder 1975). From about 1970 its use has decline because of the hazard to human health now associated with breathing asbestos fibers, and considerable effort has been directed towards finding alternatives that are comparably effective for thin-section prefabricated applications in terms of engineering properties and cost. Like asbestos-cement, these newer fiber-cement composites with fibers such as glass, carbon and aramid are characterized by relatively high fiber content, more than 2% by volume, and by a production process that blends the fibers into a cement-based slurry without coarse aggregate thus avoiding the possible damage that fragile fiber types suffer in a conventional concrete mixing process with coarse aggregate included.

A quite different category of fiber-reinforced cementitious materials is the range of fiber range of fiber-reinforced concretes made possible by including more robust discontinuous fibers as an ingredient of concrete in a conventional mixing process along with other ingredients like aggregate and admixtures. The fiber content in these composites is much lower than in fiber-cement composites, typically not more than 1.5% by volume and sometimes as little as 0.1% by volume, and the fiber length is longer, 15-65 mm. apparently this idea originated with a French patent in 1918 based on uniformly mixing small longitudinal bodies (fibers) of iron, wood or other materials into concrete (Naaman, 1985). The patent also suggested that fiber elements must be rough, or be roughened, and that the ends should be bent, features that are used today to improve the pullout resistance of fibers from concrete. Other patents followed (Naaman, 1985), although the concept did not really take hold until the 1960's when smooth straight steel fibers produced by cutting wire or sheet metal became more widely available commercially (U.S Patent Office, 1969, 1970, 1972). In addition to steel, other types of fiber that have since emerged specifically for use with conventionally mixed concrete containing coarse aggregate include polypropylene, polyethylene and various types of polyester.

The reason for using fibers for both categories of composite is to enhance the properties of an inherently weak, brittle and crack-prone cementitious matrix. Depending on fiber type and fiber content, this enhancement may include in varying degrees improvements in tensile or flexural strength, ductility, toughness or energy absortion capability, impact resistance, fatigue resistance, resistance to cracking, permeability, and durability. However, amid the myriad of benefits claimed in available literature on the subject, particularly some of the promotional produced on by fiber manufacturers, the user should recognize that the amount of fibers present is a major factor influencing the extent and degree of property enhancement. In this regard it is the volume fraction of fibers per unit volume of composite that is fundamentally important when comparing the effects produced by different types of fiber, even though it is convenient for practical purposes to batch fibers by weight per unit volume of composite.

1.2 PROBLEM STATEMENT

Fiber reinforced concrete is an alternatives way purposely to increase strength of concrete theoretically. In the early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. Unfortunately, there was a need to find a replacement for the asbestos used in concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete, and research into new fiber reinforced concretes continues today. Thus, in this project, student is given a task to work on polyvinyl alcohol (PVA) as the fiber in FRC. Fibers used in concrete could control plastic shrinkage cracking and drying shrinkage cracking, besides lowering the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, so it can not replace moment resisting or structural steel reinforcement. Some fibers reduce the strength of concrete. Besides, PVA is a water-soluble synthetic polymer.

The first part of this project has been done in the FYP 1 and report has mentioned about the minor problem undergone. The target strength of the concrete and the dimensions itself are the problems for the compaction testing which the expected maximum load are very much higher compared to the maximum load the machines can provide; the Dynamic Test Machine is manufactured with a maximum load of 500 KN and the Ultimate Testing Machine with maximum load of 1000 KN. For the tensile test, the apparatus set up was the problem in the previous part. The problem in setup step has affected the result which produced unstable graph line of Load (stress) against Time (day).

Therefore, in the second part of this project, the static test will be retested to get the better result compared to the previous test. This action will make sure the effectiveness of the fibers in the concrete is proved to have a higher tensile strength compared to plane concrete. The concrete cubes dimension has been changed to 100x100x100 (mm^3) and the design strength is grade 30, compared to the previous concrete design with grade 40 and dimension 150x150x150 (mm^3).

Unfortunately, regarding on some technical problems, this project which the main objective is to learn mechanical failure of tensile fatigue of the concrete has to be postponed and continued by other FYP student in next semester.

1.2.1 Availability of Machine Usage

Machine usage availability is the latest problem here. At first, this project is going to be tested by using a dynamic testing machine for static test and dynamic test, which will be apply for all type of the concrete design. The concrete design with 1% of PVA is the first from three designs to undergo the static test because it reaches the recommended life time of curing process earlier due to the early manufacturing of it. To provide a good result for this test compare to the work done in the previous semester, dynamic testing machine is the perfect choice because it is provided with software which shows the result of the load testing completed with a graph, for example graph of load (kN) against time (sec). And so on for the static test for concrete design with 2% and 3% of PVA. This could bring a better way to show how the existent of the fibers in the concrete affect the concrete strength.

Unfortunately, during the mid semester break, both of the dynamic machines at Building 13 and Block J was broken. Until now, the machines are still under maintenance. And in this month, the curing process for concrete design with 2% and 3% of PVA has reached the target life time on the 5th of March and 6th of March respectively. In order to run the static tests, student has to make a choice either to wait until the dynamic testing machine to be repaired and available to be used as usual, or to change a plan to use other machine with is available to be used during that week. Waiting is the first action taken. But after the mid semester break has past, it is not a good idea to keep follow this step. So the static test of the concrete design with 2% and 3% of PVA has to be run by using compression machine but still in the same method. Only the result is not provided with graph of load (kN) against time (sec). One other thing is the usage of two different machines to run a same test. Do all machines provided in the civil department laboratory have a same reading error? This situation has brings the issue on the result for these three designs. How to compare the maximum load of two different concrete designs by two different machines which the unknown reading error? Further observation should be done later and will be explained in the next progress report.

1.3 OBJECTIVES

The objectives to run this project are:

- To prepare fiber reinforced concrete (FRC) with polyvinyl alcohol (PVA) at grade G30, with dimension of 100x100x100 mm^3.
- To learn the characteristics and mechanism of the FRC itself compare to normal concrete which is mixture of cement and aggregates.
- To study and do experiments on the mechanical failure of the composite material, regarding on the tensile fatigue.

Generally, this project will be divided into several steps which will be discussed further. In order to achieve the objectives, this project will be done according to time frame and planned schedule. Besides, the experiments are also planned based on the information obtained from the literature review and later the results obtained will be compared to the reference material. The scope of the study will also focus on tensile fatigue mechanism of the fiber reinforced concrete.

The main objective of this project is to study and test the tensile fatigue which could be done by using dynamic test method. Unfortunately, many technical problems occurred during the critical time in this late semester which disturbs the project schedule. In order to solve this situation, student and supervisor have agreed to continue this project for the next semester which will be done by other FYP student hopefully.

CHAPTER 2
LITERATURE REVIEW

2.1 FATIGUE OF TENSILE STRESS

In materials science, fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic or fluctuating strains at nominal stresses that cause structural failure. The maximum values are often significantly less than the ultimate tensile stress, and may be below the yield stress of the material. Factors that affect fatigue-life are as below:

- Magnitude of stress including stress concentrations caused by part geometry.
- Quality of the surface
- Material Type.
- Surface defect geometry and location.
- Significantly uneven cooling of castings
- Size, frequency, and location of internal defects.
- Environmental conditions and exposure time can cause erosion, corrosion, or gas-phase brittle, which all affect fatigue life.
- The operating temperature over which the part is exposed to affects fatigue life.

Fatigue may be defined as a process of progressive, permanent internal structural changes in a material subjected to repeated loading. There are three (3) common ways in which stresses may be applied which are axial, torsion effect, and flexural. Examples of these are seen in Figure 1. In concrete, these changes are mainly associated with the progressive growth of internal micro cracks, which results in a significant increase of irrecoverable strain. At the micro level, this will manifest itself as changes in the material's mechanical properties.

Fatigue loading is usually divided into two (2) categories i.e. low-cycle and high-cycle loading. Low-cycle loading involves the application of a few load cycles at high stress levels. On the other hand, high cyclic loading is characterized by a large number of cycles at lower stress levels.

Concrete is a heterogeneous material which is inherently full of flaws such as pores, air voids, and shrinkage cracks. The mechanism of fatigue failure in concrete can be divided into three (3) stages. The first stage involves the weak regions within the concrete and is termed flaw initiation (crack initiation). The second stage is characterized by slow and progressive growth (crack propagation) of the inherent flaws to a critical size and is known as micro cracking. In the final stage, when a sufficient number of unstable cracks have formed, a continuous or micro crack will develop, eventually leading to failure. Fatigue crack growth can be divided into two (2) stages; the first stage is a deceleration stage, where the rate of crack growth decreases as the crack grows and the second stage is an acceleration stage, where there is a steady increase in the crack growth rate right up to failure.

2.2 TENSILE STRESS

Tensile stress (or tension) is the stress state leading to expansion; that is, the may be increased until the reach of tensile strength, namely the limit state of stress.
The formula for computing the tensile stress in a rod is:

$$\sigma = \frac{F}{A}$$

Where;

σ is the tensile stress, *F* is the tensile force; *A* is the cross-sectional area with units; N/m^2, also called Pascal, Pa.

Many of the mechanical properties of a material can be extracted from a tensile test. In a tensile test, a sample is strained at a constant rate and the stress needed to maintain this strain rate is measured. The stress and strain can either be measured in terms of engineering stress and strain or true stress and strain. The elastic modulus, the ultimate tensile stress, the fracture stress, the modulus of toughness, and the modulus of resilience can all be determined from a tensile test.

The suitable tensile test for this project is to run split tensile test because all the samples for each designs are in cubic shape with dimension of $100x100x100\ mm^3$. Split tensile practices the load at one point of the top and bottom surface of the cube sample.

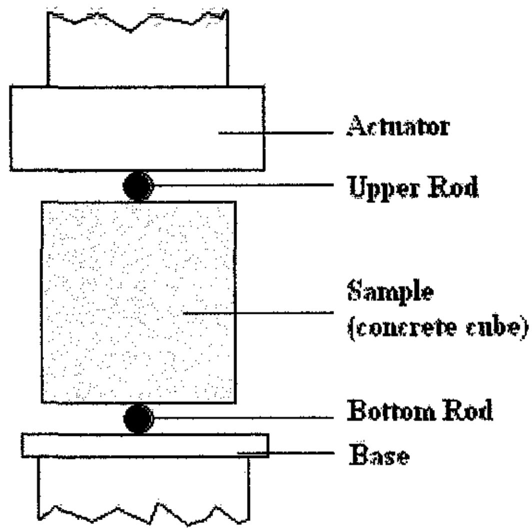


Figure 2.1 Apparatus setup for the split tensile test

The maximum load reaches as well as the existence of micro crack at the points where the cube touches the two points of load pointing. Micro crack leads to bigger crack and in this level, concrete normally will split into two components. The surface area appears in unsmooth surface and we could see the fibers inside the concrete volume.

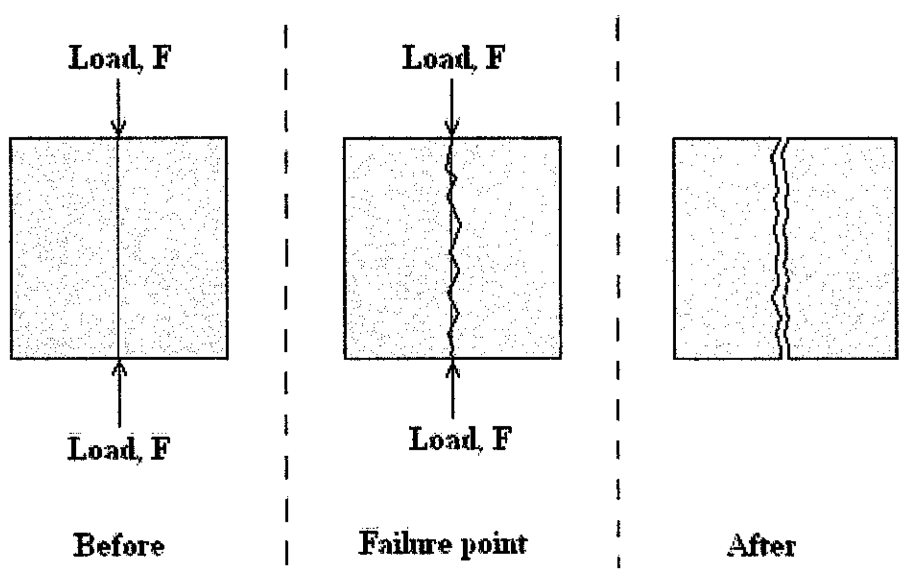


Figure 2.2 Flow towards cracking

Split test will shows the maximum tensile load which the concrete cube could withstand until the first crack appeared, or simply the initial fail point. The maximum load is then to be applied into an equation to calculate stress at the maximum load. It is important to get the stress of each concrete designs. Tensile stress at maximum load is determined by applying this equation of stress:

$$\sigma = \frac{F}{A} = \frac{2.P}{\pi.D.L}$$

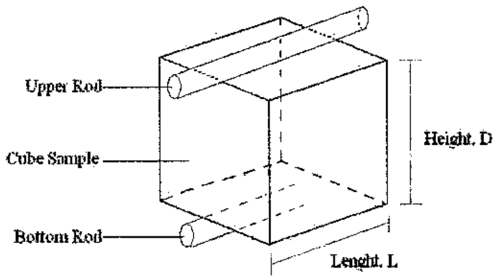
Where;

σ is tensile stress

F or P is load or maximum tensile loading

D is diameter of sample (in this case height)

L is length of the sample



2.3 SUPERPLASTICIZER

The use of super plasticizers (high range water reducer) has become a quite common practice. This class of water reducer was originally developed in Japan and Germany in the early 1960s; they were introduced in the United States in the mid-1970s. Super plasticizers are linear polymers containing Sulfonic acid groups attached to the polymer backbone at regular intervals (Verbeck, 1968). Most of the commercial formulations belong to one of four families:

- Sulfonated melamine-formaldehyde condensates (SMF)
- Sulfonated naphthalene-formaldehyde condensates (SNF)
- Modified lignosulfonates (MLS)
- Polycarboxylate derivatives

The sulfonic acid groups are responsible for neutralizing the surface charges on the cement particles and causing dispersion, thus releasing the water tied up in the cement particle agglomerations and thereafter reducing the viscosity of the paste and concrete (Mindess and Young, 1981).

ASTM C 494 was modified to include high-range water-reducing admixtures in the edition published in July 1980. The admixtures were designated Type F water-reducing, high range admixtures and Type G water-reducing, high-range, and retarding admixtures (Mielenz 1984).

The main purpose of using superplasticizers is to produce flowing concrete with very high slump in the range of 7-9 inches (175-225 mm) to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The other major application is the production of high-strength concrete at w/c's ranging from 0.3 to 0.4 (Ramachandran and Malhotra 1984).

The ability of superplasticizers to increase the slump of concrete depends on such factors as the type, dosage, and time of addition of superplasticizer; w/c; and the nature or amount of cement. It has been found that for most types of cement, superplasticizer improves the workability of concrete. For example, incorporation of 1.5% SMF to a concrete containing Type I, II and V cements increases the initial slump of 3 inches (76 mm) to 8.7, 8.5, and 9 inches (222, 216, and 229 mm), respectively.

The capability of superplasticizers to reduce water requirements 12-25% without affecting the workability leads to production of high-strength concrete and lower permeability. Compressive strengths greater than 14,000 psi (96.5 MPa) at 28 days have been attained (Admixtures and ground slag 1990). Use of superplasticizers in air-entrained concrete can produce coarser-than-normal air-void systems. The maximum recommended spacing factor for air-entrained concrete to resist freezing and thawing is 0.008 inch (0.2 mm). In superplasticized concrete, spacing factors in many cases exceed this limit (Malhotra 1989; Philleo 1986). Even though the spacing factor is relatively high, the durability factors are above 90 after 300 freeze-thaw cycles for the same cases (Malhotra 1989). A study conducted by Siebel (1987) indicated that high workability concrete containing superplasticizer can be made with a high freeze-thaw resistance, but air content must be increased relative to concrete without superplasticizer. This study also showed that the type of superplasticizer has nearly no influence on the air-void system.

One problem associated with using a high range water reducer in concrete is slump loss. In a study of the behavior of fresh concrete containing conventional water reducers and high range water reducer, Whiting and Dziedzic (1989) found that slump loss with time is very rapid in spite of the fact that second-generation high range water reducer are claimed not to suffer as much from the slump loss phenomenon as the firstgeneration conventional water reducers do. However, slump loss of flowing concrete was found to be less severe, especially for newly developed admixtures based on copolymeric formulations.

The slump loss problem can be overcome by adding the admixture to the concrete just before the concrete is placed. However, there are disadvantages to such a procedure. The dosage control, for example, might not be adequate, and it requires ancillary equipment such as truck-mounted admixture tanks and dispensers. Adding admixtures at the batch plant, beside dosage control improvement, reduces wear of truck mixers and reduces the tendency to add water onsite (Wallace 1985). New admixtures now being marketed can be added at the batch plant and can hold the slump above 8 inches (204 mm) for more than 2 hours.

Figure 2.3 Picture of super plasticizer which is provided at laboratory in Building 13

2.4 WATER

The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is likely to shrink more and be uneconomical. A properly designed concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent. Portland cement's chemistry comes to life in the presence of water. Cement and water form a paste that coats each particle of stone and sand. Through a chemical reaction called hydration, the cement paste hardens and gains strength. The character of the concrete is determined by quality of the paste. The strength of the paste, in turn, depends on the ratio of water to cement. The water-cement ratio is the weight of the mixing water divided by the weight of the cement. High-quality concrete is produced by lowering the water-cement ratio as much as possible without sacrificing the workability of fresh concrete. Generally, using less water produces a higher quality concrete provided the concrete is properly placed, consolidated, and cured.

Almost any natural water that is drinkable and has no pronounced taste or odor may be used as mixing water for concrete. However, some waters that are not fit for drinking may be suitable for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability. Specifications usually set limits on chlorides, sulfates, alkalis, and solids in mixing water unless tests can be performed to determine the effect the impurity has on various properties. Soon after the aggregates, water, and the cement are combined, the mixture starts to harden. All Portland cements are hydraulic cements that set and harden through a chemical reaction with water. During this hydration reaction, a node forms on the surface of each cement particle. The node grows and expands until it links up with nodes from other cement particles or adheres to adjacent aggregates. The building up process results in progressive stiffening, hardening, and strength development. Once the concrete is thoroughly mixed and workable it should be placed in forms before the mixture becomes too stiff.

Curing begins after the exposed surfaces of the concrete have hardened sufficiently to resist marring. Curing ensures the continued hydration of the cement and the strength gain of the concrete. Concrete surfaces are cured by sprinkling with water fog, or by using moisture-retaining fabrics such as burlap or cotton mats. Other curing methods prevent evaporation of the water by sealing the surface with plastic or special sprays (curing compounds). Special techniques are used for curing concrete during extremely cold or hot weather to protect the concrete. The longer the concrete is kept moist, the stronger and more durable it will become. The rate of hardening depends upon the composition and fineness of the cement, the mix proportions, and the moisture and temperature conditions. Most of the hydration and strength gain take place within the first month of concrete's life cycle, but hydration continues at a slower rate for many years.

2.5 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.

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.

Particle shape and surface texture of aggregates influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Generally, flat and elongated particles are avoided or are limited to about 15 percent by weight of the total aggregate. Unit-weight measures the volume that graded aggregate and the voids between them will occupy in concrete. The void content between particles affects the amount of cement paste required for the mix.

Angular aggregate increases the void content. Larger sizes of well-graded aggregate and improved grading decrease the void content. Absorption and surface moisture of aggregate are measured when selecting aggregate because the internal structure of aggregate is made up of solid material and voids that may or may not contain water. The amount of water in the concrete mixture must be adjusted to include the moisture conditions of the aggregate. Abrasion and skid resistance of an aggregate are essential when the aggregate is to be used in concrete constantly subject to abrasion as in heavy-duty floors or pavements. Different minerals in the aggregate wear and polish at different rates. Harder aggregate can be selected in highly abrasive conditions to minimize wear.

Flakey is the term applied to aggregate or chippings that are flat and thin with respect to their length or width. Aggregate particles are said to be flakey when their thickness is less than 0.6 of their mean size. 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.

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. 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.

CHAPTER 3

METHODOLOGY

3.1 PROJECT PROCESS FLOW

Generally, the project methodologies are base on the following flow chart of activities:

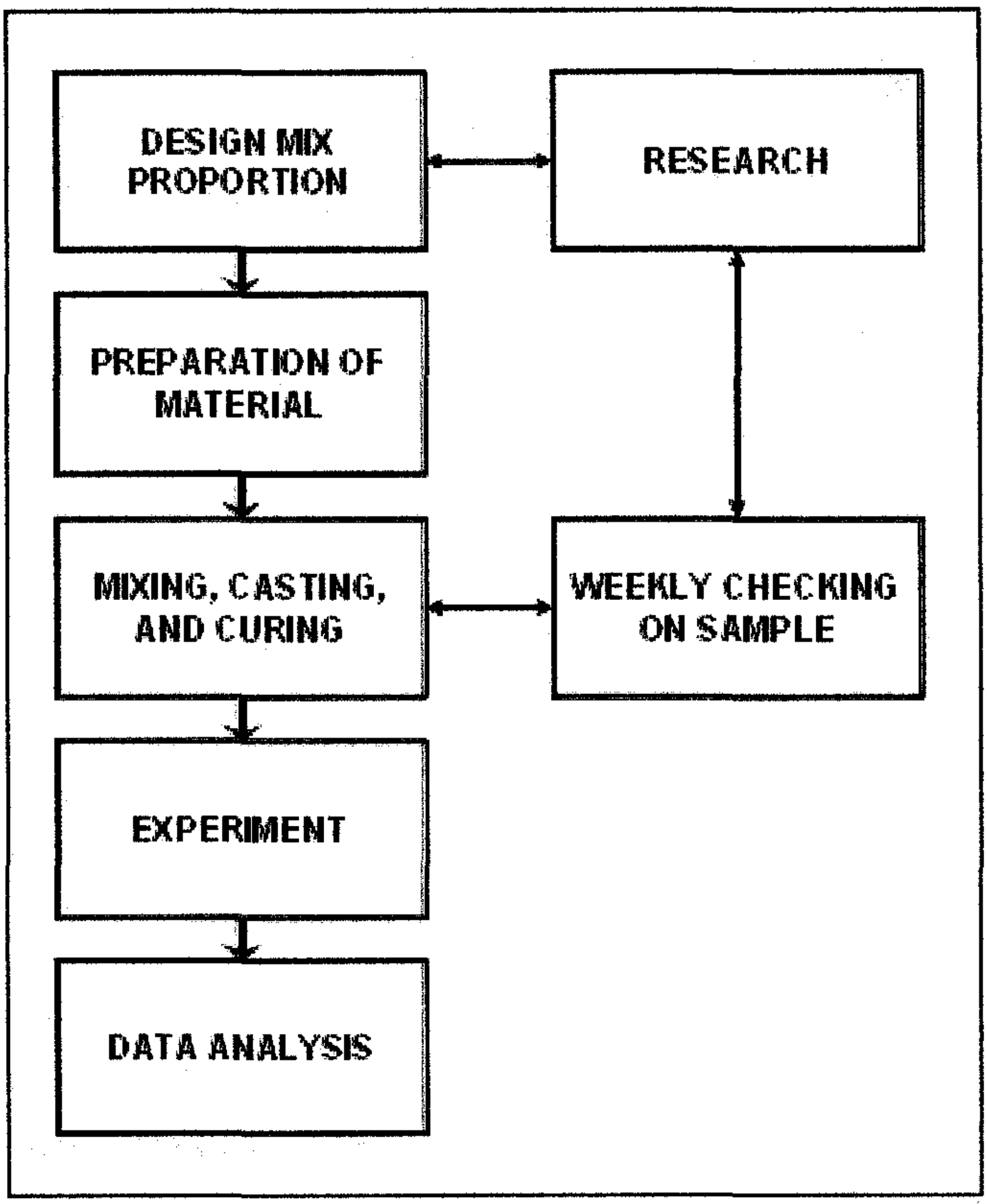


Figure 3.1 Flow chart of activity

3.2 STATIC TEST

The tensile static test is run on 18th February for concrete design with 1% of PVA and on 19th March 2008 for concrete with 2% and 3% of PVA. The tests have been run at two laboratory of civil department, Building 13 and Block J. The concrete with 1% PVA is tested using dynamic machine to get the benefit from the software which provides result data together with graph of load against time. There are dynamic testing machine and ultimate testing machine in Building 13, but both machines are still under maintenance and still no date line is posted.

Therefore, the test has to be done at Block J where the lab also provides dynamic testing machine with maximum load of 2000 KN. Static test for concrete with 2% and 3% of PVA is ran on the 19th March 2008 by using compression machine at Building 13 due to the broken dynamic testing machine at Block J, which means both dynamic machines in civil department are under maintenance.

Tensile split test were run on concrete cube sample to measure the maximum load acquired on the 60th day (in this case 63rd day regarding on technical problem) and in the same time observation on failure behavior of the sample was done.

3.3 DYNAMIC TEST

Dynamic test should be done in the middle on the April after all of the samples have been complete the 90th days of curing. For this project, the curing process period is extended to 93 days in order to uniform the period for all samples of each design. Due to major problems where machines are under maintenance and unavailable of technician support, there have been a change of plan where the date of this test should be postponed to other dates which is changeable.

Unfortunately, in the middle of April, the machine at Block J was damaged after some part of the machine, or more detail the actuator, has been broken after a postgraduate student use it for his project. And the machine at Block 13 has been fixed as well as the technician confirmation. Unfortunately, there are still incoming problem which has not allowed student to use it yet. In the late of April, all the equipment including the both dynamic testing machines have been fixed perfectly and checked for their condition which are safe and ready to back on track. At this time, both machines have been booked by other student doing their project.

Supervisor has noticed these situations and has made an agreement with student to end this project at this point due to time constraint. Therefore, tensile fatigue which is tested by using dynamic test is postponed to next semester under other FYP student to complete this project.

3.4 CONCRETE CASTING

In order to run this project smoothly, student must redesign and cast the concrete. There are tests to be run on the concrete itself before taken to the further test, slump test before put into mould, and curing in humid chamber. The concrete mix produced will be used in concrete lab. Several mix proportions will be adopted and each output of the concrete with PVA will be analysed to get the best mix proportions. The produced mix will be tested to know the compressive strength, splitting tensile strength, water absorption by immersion and also elasticity modulus. Slump and heat of hydration tests also will be conducted. Slump test is a measurement of workability or fluidity of the concrete. The slump of fresh concrete is tested once the mixing is completed. It is carried out conforming to BS 1881: Part 102: 1983.

For this second project, many modifications and changes have been done in order to avoid any uncomfortable situation. Super plasticizers have been added to design preparation at certain amount while concrete batching due to get a high workability of fresh concrete for a better slump test result. The dimensions and grades of concrete cube sample are changed from of 150x150x150 mm^3 to of 100x100x100 mm^3 at grade G40 and G30 respectively. The batching process of concrete is set to use the table vibrator in order to uniform the time of vibration. Compare to the previous project, the vibration technique was using a normal vibrator, and are not good enough and was very hard to constant the vibration timing.

3.5 CONCRETE MIX DESIGN

Concrete mix proportion for 30 MPa target strength

Specification for concrete cubes for 100 mm^3 mould is 12 numbers of cubes for each type of fiber reinforced concretes with different percentages of Polyvinyl Alcohol (PVA) contain in the concrete. So, 36 cubes are needed for 1%, 2% and 3% of PVA in concrete.

1 cube (100 mm^3 mould)	=	0.001 m^3
Water-cement ratio (w/c)	=	0.63 unit
Water amount (weight)	=	0.195 kg
Cement amount (weight)	=	0.3095 kg
Aggregate (type fine)	=	0.7898 kg
Aggregate (type coarse)	=	1.261 kg
Super plasticizer 0.15%	=	5.803 g
• 1% PVA	=	3.095 g
• 2% PVA	=	6.190 g
• 3% PVA	=	9.285 g

CHAPTER 4
RESULT AND DISCUSSION

4.1 SLUMP TEST

Table 4.1 Table of slump test and concrete surface observation

Concrete Design	Slump Test (mm)	Observation (while doing the test)
1% PVA	95	The surface of fresh concrete look wet, which shows better slump value compared to the previous work in FYP I.
2% PVA	45	The surface of fresh concrete is dryer than concrete at 1% of PVA. Workability is not very good.
3% PVA	55	The surface of fresh concrete look dryer compared to concrete at 1% of PVA. However, workability is satisfied.

Slump test of the fresh concrete is handled with care to make sure the value is correct and nearly any errors do not exist. All the apparatus being used in concrete batching are set to be in wet condition by using water in order to get a high workability. This action include mixer (small blue coloured mixer is used for all concrete), scoop, wheel barrow and slump test apparatus. Generally, increasing of fiber content will lead to lower workability where the slump value decreasing. Therefore, concrete is designed with super plasticizer with an amount of 5.803 gram for all design as a constant value, to make sure they are under control which gives a good slump value.

From the table above, concrete with fiber content of 1% show a good result with a slump value of 95mm reaching to target slump of 100mm. Compared to previous work in FYP I, the slump is low, 62mm, but still in good condition. Slump value for PVA 2% should be higher than PVA 3% but the result show the reverse. This is because of lack handling for the PVA 2% where the apparatus wetness condition is not fully control.

There are interruptions in working time that causing the wet surface become dryer a little bit and this condition result in small technical error. However, the slump value has been improved where slump value of 2% PVA and 3% PVA are 45mm and 55mm compare to previous work in FYP with values of 25mm and 0mm. Basically, the super plasticizer functions very well although in a very small amount at 0.15% of cement (OPC) weight.

4.2 VIBRATING TABLE

Table 4.2 Vibrating table observation

Concrete Design	Quantity of cube mould on the vibrating table	Round of pouring (based on small scoop)	Time (s)
1% PVA	4	3	16
		1	7
		Complete	8
	4	3	16
		1	7
		Complete	8
	4	3	16
		1	7
		Complete	7
2% PVA	4	3	16
		1	7
		Complete	7
	4	3	16
		1	7
		Complete	8
	4	3	16
		1	7
		Complete	8

3% PVA	4	3	16
		1	7
		Complete	9
	4	3	16
		1	7
		Complete	8
	4	3	16
		1	7
		Complete	9

Vibrating table usage is better compared to normal concrete vibrator. Time is set to 30 seconds for every sample with maximum range of 2 seconds. From the observation, 3 round of small scoop with load of fresh concrete can fill half of the height of the mould and it is set as the first round. Then, vibrating table is set 'ON' for 16 seconds. Second round of pour need only 1 round of scoop with about 7 to 8 seconds of vibration. Finally, to level the top surface sample concrete is poured in small amount until the elevation of top concrete is roughly level and same compare to other sample. This step needs a vibration around 7 to 9 seconds.

4.3 TENSILE TEST

Test Date : 18.2.2008 - 63rd days of curing process (17.2.2008)

Machine : Dynamic testing machine

Table 4.3 Concrete Design 1% of PVA

Sample No.	Maximum Load (kN)	Weight (kg)	Density (kg/m^3)
1	154.96	2.41	2410
2	none (fail)	2.42	2420
3	152.46	2.41	2410

Test Date : 19.3.2008 - 63^{rd} days of curing process (5.3.2008)

Machine : Compression Machine with pace rate at 3.00

Table 4.4 Concrete Design 2% of PVA

Sample No.	**Maximum Load (kN)**	**Weight (kg)**	**Density (kg/m^3)**
1	117.0	2.39	2390
2	116.8	2.40	2400
3	116.9	2.40	2400

Test Date : 19.3.2008 - 63^{rd} days of curing process (5.3.2008)

Machine : Compression Machine with pace rate at 3.00

Table 4.5 Concrete Design 3% of PVA

Sample No.	**Maximum Load (kN)**	**Weight (kg)**	**Density (kg/m^3)**
1	113.2	2.39	2390
2	108.0	2.38	2380
3	100.2	2.37	2370

From the static test, the result shows the maximum tensile load which the concrete could withstand until the first crack appeared, or simply the initial fail point. The maximum load is then to be applied into an equation to calculate stress at the maximum load. It is important to get the stress of each concrete designs. Tensile stress at maximum load is determined by applying this equation of stress:

$$\sigma = \frac{F}{A} = \frac{2.P}{\pi.D.L}$$

Tensile stress values are shown by tables below:

Table 4.6 Tensile stress at the maximum load for PVA content of 1 %

Sample	**Maximum Load (kN)**	**Tensile Stress (MPa)**
1	154.96	9.865
2	-	-
3	152.46	9.706
Average	153.71	**9.785**

Table 4.7 Tensile stress at the maximum load for PVA content of 2 %

Sample	**Maximum Load (kN)**	**Tensile Stress (MPa)**
1	117.0	7.442
2	116.8	7.436
3	116.9	7.442
Average	116.9	**7.442**

Table 4.8 Tensile stress at the maximum load for PVA content of 3 %

Sample	**Maximum Load (kN)**	**Tensile Stress (MPa)**
1	103.2	6.520
2	108.0	6.875
3	100.2	6.379
Average	103.8	**6.608**

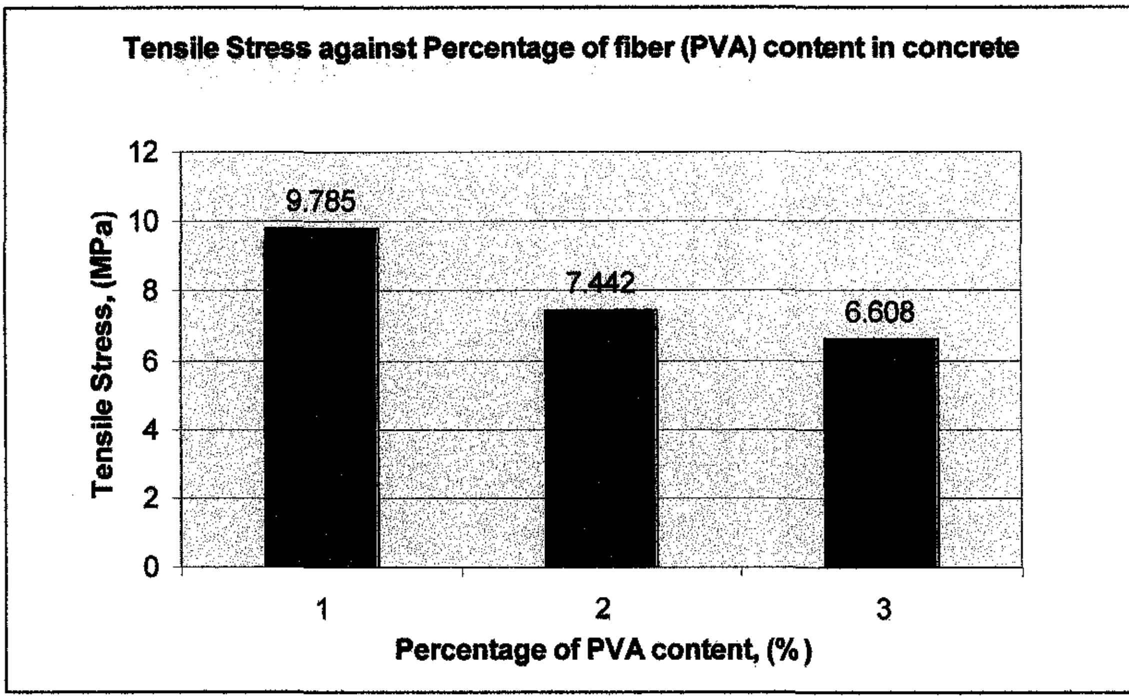


Figure 4.1 Graph of tensile stress against percentage of PVA in concrete

Based on the Table 4.6, 4.7 and 4.8, they show the value of tensile stress for each fiber contents of 1%, 2% and 3% respectively. The tensile stress is calculated by using the equation as stated previously in page 22, where the maximum load is applied into it. To simplify the result, data of average tensile stress for each design is then to be transfer into a form of graph. Graph in Figure 4.1 shows the average tensile stress value for each design where stress is stated in unit 'MPa'.

The test of static test should be done on the 60th day. But due to the problem on the dynamic testing machine at block J, the test had to be postponed on Monday 18th February 2008, which is the 63rd day of the concrete lifetime. This action will and had changes a little bit on the strength of the concrete cubes it self but it is considered as acceptable. In order to make a fair for the other 2 design of concrete, the day of running the static test is change on the 63rd day of the concrete life time, which is tested on 19th March 2008.

The graph shows the highest value of stress for 1% of PVA content in concrete at 9.785MPa and follows by 2% and 3% of PVA with stress values of 7.442MPa and

6.608MPa. This simply shows that the 1% PVA is greater than 2% PVA, and 2% PVA greater than 3% PVA. However, we can not make a conclusion on this statement where the higher the fiber contents in concrete, the lower the tensile stress because it is general.

Many works done by other researchers have a different result by comparing among them. Sigh and Mohammadi, in the journal entitled 'flexural strength of steel fibrous concrete contain mixed steel fibers', have found that the optimum flexural strength was shown by 1.0% of fiber in concrete, compared to other two sample with design of 1.5% and 2.0% of fibers. Dong-II Chang and Won-Kyu Chai, in the journal entitled 'flexural fracture and fatigue behavior of steel fiber reinforced concrete structures', have found that the fatigue strength with 2,000,000 repeated loading cycles in FRC with fiber contents of 0.5%, 1.0% and 1.5% are about 71%, 74% and 78% respectively of the first crack static flexural strength, which means the optimum fiber content is 1.5%.

Basically, the existence of fibers in concrete structure does improve the tensile stress a lot. The stress of PVA 1% is 9.785MPa which is 32.6% of the designed concrete strength to withstand compression load of 30MPa. Normally, plain concrete with no addition of fiber has percentage of tensile stress at 5 % to 20 % of the design strength. For PVA 2% and PVA 3%, the tensile stress values of 7.442MPa and 6.608MPa have a stress strength percentage of 24.81% and 22.03% respectively compared to the designed or target compression load. Even though PVA 2% and 3% have lower strength compared to PVA 1%, there are still stronger than plain concrete in aspect of tensile stress.

4.4 DYNAMIC TEST

Dynamic test for fatigue failure mechanism has been cancelled for this project and is to be continued by the next FYP student for the next semester to continue and complete the test. As mentioned before, because of circumstances that could not be avoided, has effected the time constrain for student to be able to finish this project as planned in an initial stage. Although this project is stopped here, additional researches should be done for further improvement in this project. And this situation could bring for better preparation and experiment.

CHAPTER 5
CONCLUDING SUMMARY

5.1 CONCLUSION

Fiber reinforced concrete (FRC) with 1% of polyvinyl alcohol (PVA) has a bigger maximum tension load compared to FRC with 2% and 3% of PVA. Based on the result, the average stress strength for concrete with fiber content of 1%, 2% and 3% are 9.785MPa, 7.442MPa and 6.608MPa respectively. From this observation, the more amount of fiber in concrete, the lower tensile stress for the concrete to withstand until the first crack. This is because the bonding effect in the concrete between the surfaces of polymer and aggregates and cement paste. By logical thinking, fibers are very effective in order to increase the tension stress. When there are too many of fibers in concrete volume, the reaction of cement paste, aggregate and fibers should be decreased where many of the volume has been taken by the existence of fibers which lowering the effectiveness of cement paste to bond all the material in the concrete.

5.2 RECOMMENDATION

This project may take a longer time to be completed than the expected. Good preparation and planning are fully recommended in order not to rush in any action taken. In other words, there should be more additional researches to improve knowledge regarding all topics in this project.

Besides, the types of design should be more various to get more effective result in comparing them. For a suggestion, design fiber content in concrete with percentages of 0.5%, 1%, 1.5% and 2.0%, or 1%, 1.2%, 1.4%, 1.6%, 1.8% and 2.0%. By doing this way, the exact optimum percentage of fiber content will be more accurate and those can decrease cost include manufacturing cost in the future later on. But, the work should be more detail and with high accuracy especially in process of mixing, casting and safe curing.

Regarding on the laboratory facilities, there should be a better maintenance and services schedule. This action is to ensure any broken or damages on apparatus could be fixed immediately and always in a good condition. The project working activity was done smoothly without any internal and external problem from the beginning of the project which is in the middle of December 2007 until reaching the middle working progress of this project on March. Tensile test for all sample designs have been run without problems and there is no need to be rush in order to complete the test and this is good. Besides, at this range of time, the machines in laboratory are available to be used and technicians are always there for any help. But in the late April, there are technical problems regarding on the machines where the dynamic machines in Block J and Building 13 are under maintenance for several times. This situation has caused other problem regarding on waiting list to use the machine.

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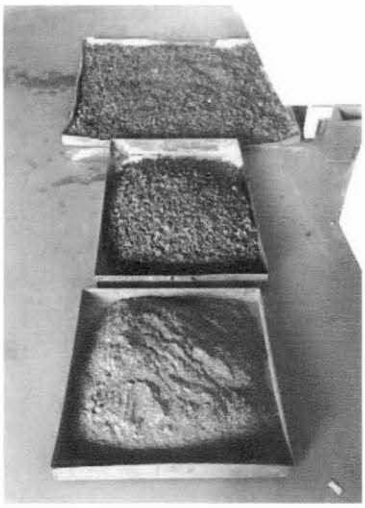
APPENDIX

Concrete Preparation Process

1.) Aggregate preparation



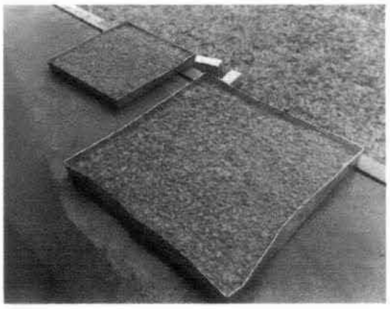


Figure 1c

Figure 1a Figure 1b

Figure 1a Fine and coarse aggregates are kept in a control mode in laboratory

Figure 1b Sieving machine is used to control the sizes of aggregate

Figure 1c SSD is prepared in a tray for a day before able to use it

2.) Concrete Batching Process

Figure 2a Figure 2b

Figure 2a Picture of mixer provided in Building 13

Figure 2b Slump test for fresh concrete before batch into mould

3.) Concrete Pouring Process

Figure 3a Concrete is poured into cubic mould and vibrated by vibrator table

4.) Curing Process

Figure 4a Curing tank for all samples. From left; curing tank of fiber content 1%, 2 and 3%

5.) Modification of Apparatus

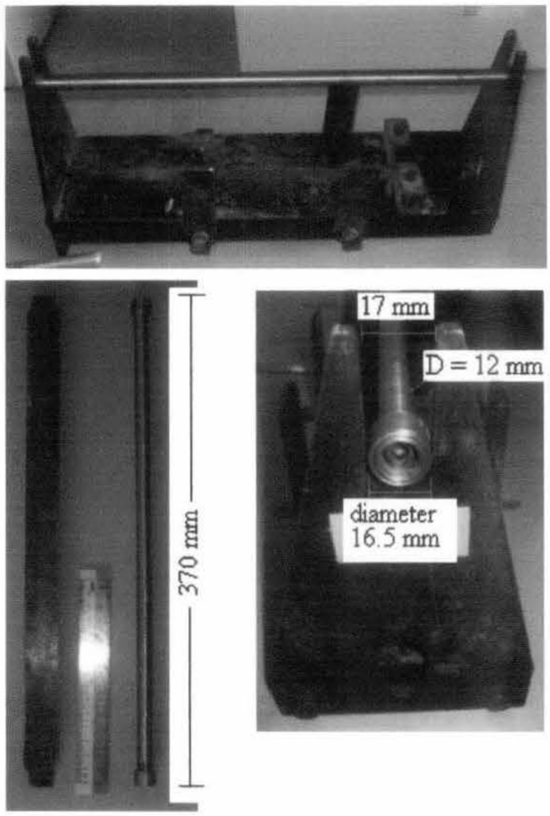


Figure 5a Pictures of modification for one part of the apparatus to hold cube sample. Rectangular shaped rods are replaced by cylindrical shaped rods.

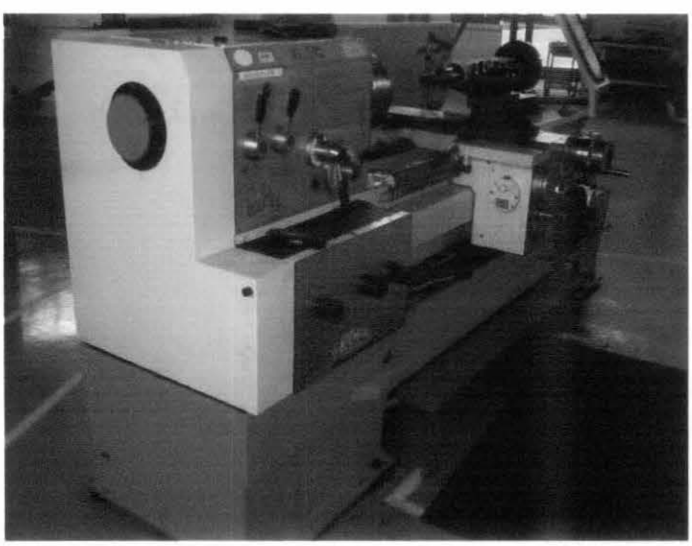


Figure 5b Lathe Machine at Building 20, used to modify and fabricate steel rod

6.) Tensile Test

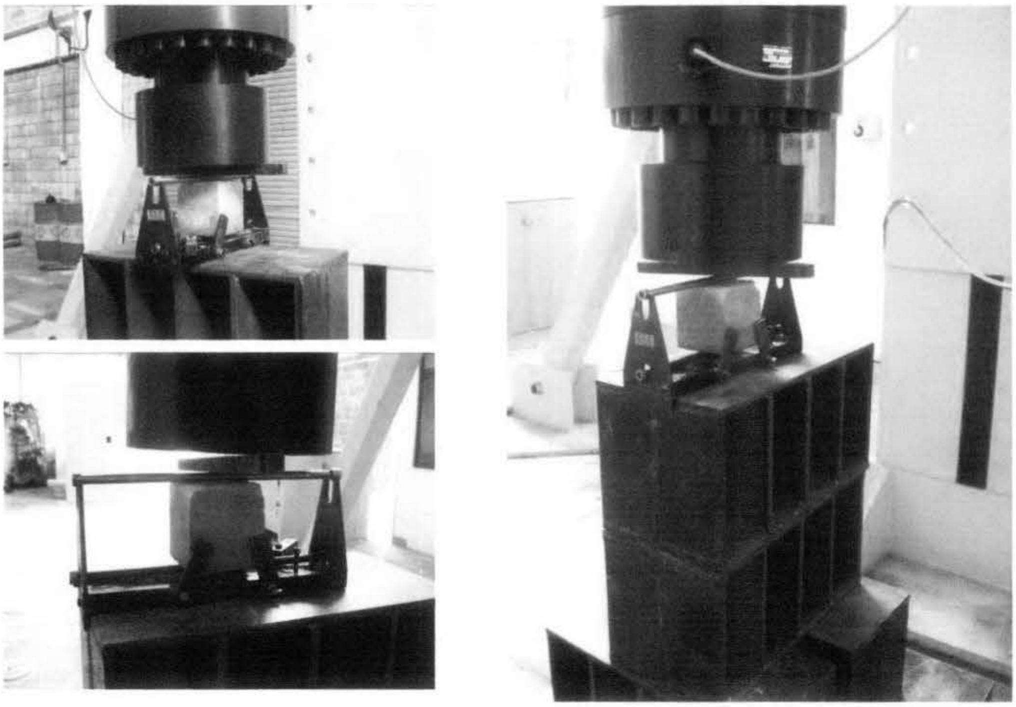


Figure 6a Pictures above show an apparatus setup for the split tensile method.

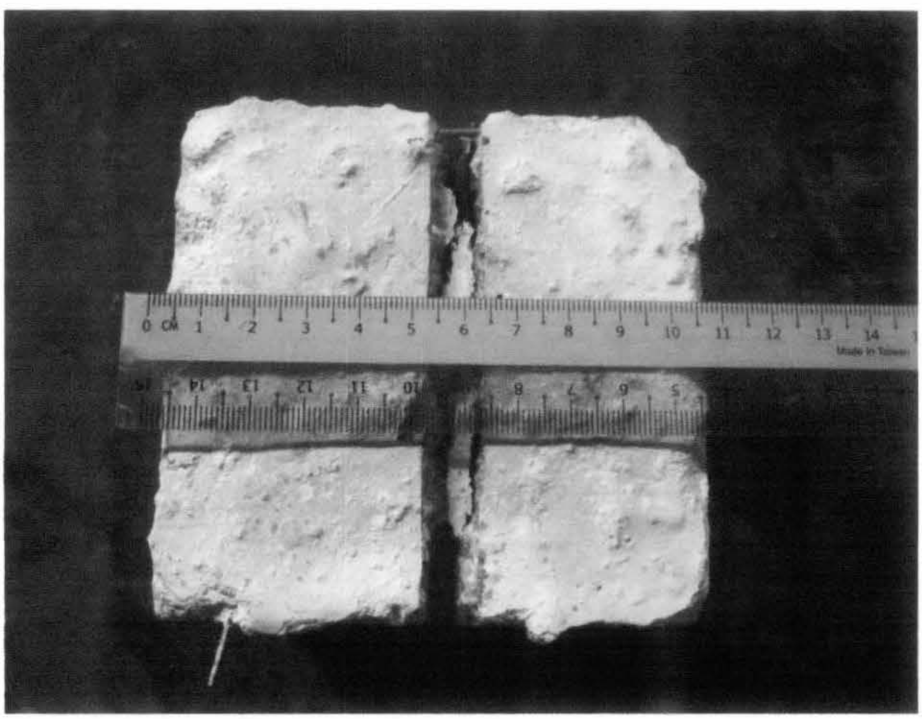


Figure 6b Picture of a sample after done with split tensile. Concrete with fiber content of 1%

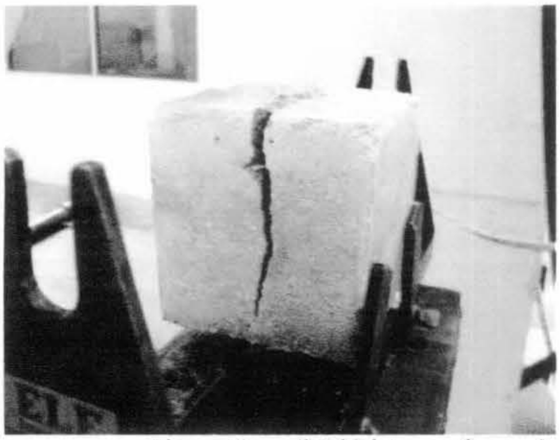
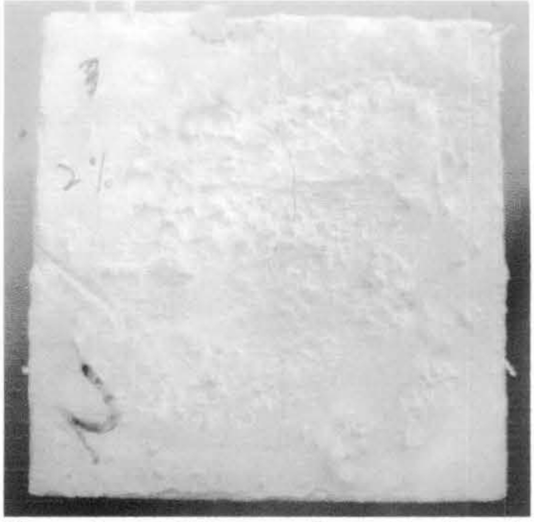


Figure 6c and 6d Picture of samples with cracks after done the tensile test



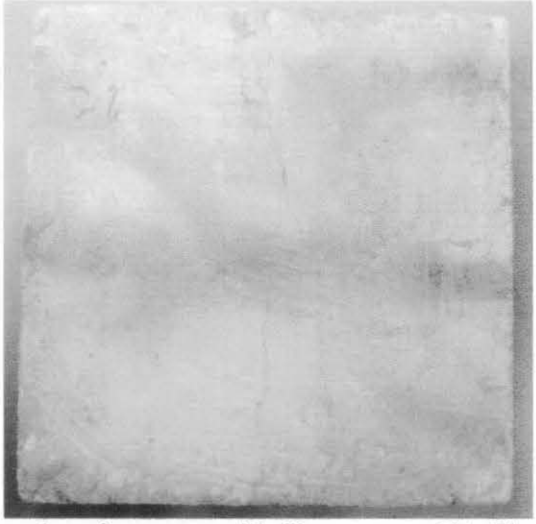


Figure 6e and 6f Pictures show side view of two samples of concrete with fiber content 2%. There are smooth and tiny cracks which move vertically in centre of the cube.

Figure 6g Compression which is used to test on concrete with fiber content 2% and 3%

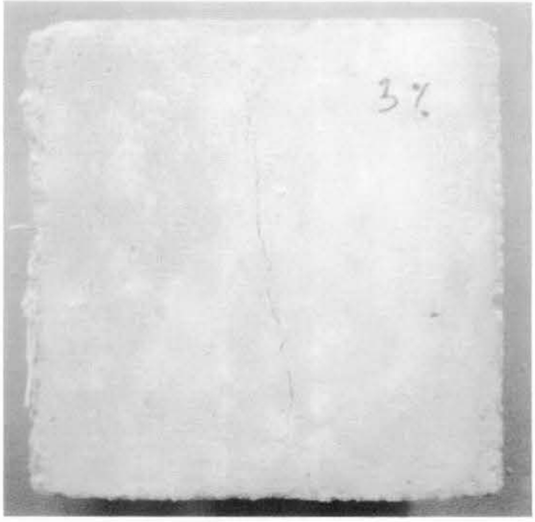


Figure 6h and 6i Pictures show the crack at the side of concrete samples with 3% fiber content

Figure 6j Dynamic Testing Machine, which is always have problem and broke down. There is a note on white paper stated "Under Maintenance".