UNIVERSITY OF SOUTHERN QUEENSLAND

FACULTY OF ENGINEERING AND SURVEYING

Effect of Admixtures on the Use of Short Fibres In Structural Concrete to Enhance Mechanical Properties.

A dissertation submitted by

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ABSTRACT

Fibre-reinforced concrete is a term used when concrete is reinforced with randomly distributed short fibres. The addition of short fibres causes a reduction in workability. On the other hand, Superplasticisers can be used to increase the workability of concrete.

The main objectives of the project were to investigate the effects of Superplasticisers on structural concrete with the addition of short-fibres, which vary from the most commonly used steel fibres, to polypropylene and fibre mesh. The behaviours of Superplasticisers on plain and fibre-reinforced concrete are compared. Lastly, data for the fresh and harden properties of the concrete were collected and analysed. The scope of this project is based on the usage of Superplasticisers in steel short-fibres, fibre mesh and polypropylene short-fibres.

To evaluate the effects of Superplasticisers on the workability of fresh short-fibre reinforced concrete, several tests were carried out. These tests consist of slump tests Vebe tests and compacting factor tests. Meanwhile, the harden properties of concrete were assessed by the conducting tests, which involved compressive strength test, indirect-strength test, flexural strength test and finally test to determine the value for the modulus of elasticity.

From the results of Vebe test and compacting factor test obtained, steel short-fibre reinforced concrete have the highest workability, which were followed by polypropylene short-fibre and Fibremesh reinforced concrete. Generally, when more then 1% of short-fibres are used to reinforce the concrete, rate of workability increases with the addition of Superplasticisers. Meanwhile, it was also found that flexural strength for fibre-reinforced concrete with the usage of Superplasticisers was higher.

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I certify that the ideas, designs and experimental work, results and analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Fong Chin CHEONG

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Concrete is a brittle material which is strong in compression and weak in tension. Findings on the reinforcement of these brittle matrixes in search of improving their mechanical properties is a continuous process since ancient periods, where straws were used to reinforced clay bricks. As from 1960's the modern development of fibre-reinforced concrete has experienced rapid growth.

However, since only a limited research was done during the early periods, the usage of fibres was confined to straight steel fibres. More modern researches and experience with the actual application of short-fibres was done as time progress, the eventual acceptance of short-fibre reinforced concrete by the construction industry had lead to introduction of several kinds of fibres, which range form the more commonly used steel short-fibre, polypropylene short-fibres, glass short-fibres, mineral fibres, to natural fibres. As the amount of research and demand for the short-fibres increases, new manufacturing techniques and applications also emerged.

The main purpose of reinforcing plain concrete with randomly distributed short-fibres is not to increase the strength of the concrete. Rather, its primary objective is to enhance the crack control ability in the post-cracking state of short-fibre reinforced concrete by the web-bridging action of short-fibres across the possible crack section. As more research and development progresses, short-fibres now possess more complex shapes and dimension in search of optimising performance of the short-fibre reinforced concrete.

In recent days, the applications of short-fibre reinforced concrete had even surpassed the usage of conventional reinforcement bars in some areas to enhance performance. Some examples of these areas are such as in thin sheet materials where conventional reinforcing bars are not feasible, in tunnel linings, blast resistance structures where the structure have to withstand high local loads or deformation, and finally in some slabs and pavements, to control tendency of possible cracks which might originate primarily by variations in temperature and humidity. However short-fibres are only usually considered as secondary reinforcement for crack control in the case of slabs and pavements.

Research and practical applications proofed that the addition of short-fibre into concrete will improve harden properties such as improved crack control, abrasion and impact resistance; but it may creates adverse effect on the fresh properties of concrete. The short-fibres tend to stiffen the concrete matrix. As a result, the workability of the freshly-mixed concrete will decrease. However, short-fibre reinforced concrete can still respond well to the usage of vibration as a mean of compaction. The stiffening effect of the concrete may be mostly overcome by the use of vibration.

Since the workability of short-fibre reinforced concrete can be significantly reduced, admixtures are introduced as a measure to this problem. Chemical admixtures such as water-reducing admixtures, Superplasticisers, and other mineral admixtures such as silica fume can be used. However, to maintain the workability of the concrete without adding additional water, Superplasticisers are preferred over normal water-reducing admixtures as it can increase the workability of short-fibre reinforced concrete greater or can even obtain a flowable concrete mixture at lower water:cement ratio.

1.1.1 Project Aim and Scope

The aim of my project is to investigate the effects with the use of Superplasticisers on structural concrete with short fibres. The scopes involved in the project are as follows:

- Investigate the effects with the use of Superplasticisers on structural concrete with different types of fibres, which vary from the steel fibres, to polypropylene and Fibremesh.
- I will also compare and determine the characteristic of Superplasticisers on plain and fibre-reinforced concrete.
- Compare the properties of short-fibre reinforced concrete both with and without the addition of Superplasticisers.
- Lastly, data for the fresh and harden properties of the concrete will also be collected and analysed.

1.2 General background

1.2.1 Fibres

Fibre-reinforced concrete is the term used when the concrete is reinforced with randomly distributed short fibres. The fibres most frequently used are steel, glass and plastic fibres. The introduction of short-fibres into the concrete has been proven to improve bending and also have an impact on strength and ductility when compared with plain concrete.

Most of the developments regarding short-fibre reinforced concrete are involved with ordinary Portland cement. However, in some cases, high alumina cement, gypsum and wide range of various special cement are also used in short-fibre reinforced concrete. The main purpose using of various types of cement was either to improve the ductility of the composite, or to minimise the interaction between short-fibres introduced and the matrix involved.

As the short-fibres are randomly distributed, therefore the concrete matrix is not effective in withstanding tensile stresses. However compared to conventional reinforcing steel bar, randomly distributed short-fibres are better in crack control rather then enhancing the bearing capacity of concrete.

1.2.2 Admixtures

40 years ago, the main admixtures used were water-reducing admixtures, retarders and accelerators. However, the use of calcium chloride as accelerators was banned as from 1977, according to Neville (2004), calcium chloride corrodes reinforced concrete. Superplaticisers is preferred because it gives many benefits such as it allows the usage of low water: cement ratios with sufficient workability.

Admixtures have plenty practical usage, where they are usually applied in site-batched, ready-mixed and in pre-cast industry. Various kinds of admixtures exist to cater for different needs of the concreting industry, such as water-reducing, workability improvement, air-entraining, set-retardance and set-accelerators.

However, the application of admixtures into concrete might cause chemical reaction, which may alter the fresh and harden properties of concrete. Furthermore, there might also be some desirable and undesirable side-effects. Therefore, it is important to assess the effect of the usage of a particular admixture.

In the actual application of admixtures in the industry, plenty information are needed. These includes the procedures for on-site usage, requirement for structural engineers regarding the structural characteristics of admixtures enhanced concrete, and the application of admixtures with regard to the normal procedures in the practice of concreting job.

1.3 Fibres

1.3.1 Introduction

The application of fibres in concrete requires due knowledge as it is essential for design purposes. High tensile strength which exists in the fibres contributes to substantial reinforcement of the concrete. Besides this, by having large values of failure strains, the introduction of short-fibres presents high extensibility in the concrete. However in practice, most fibres are far from perfect due mainly to defects on the surface which may have been the result of handling, processing, manufacturing and ageing. These flaws will alter the strength properties of the composites, which vary with fibre lengths and dimensions.

1.3.2 Steel Short-fibres

Figure 1.1: Steel Fibres

In this research project, steel fibres were chosen to be tested. Steel-fibre reinforced concrete is broadly used in variety of civil engineering applications. This might have partly been influenced by economic decisions and experience with conventional steel reinforcement. The existence of steel fibres in concrete had effectively influenced the mechanical properties of the concrete in many aspects, ranging from flexural strength, compressive strength to dynamic fractures. However, it also had adverse effect on the fresh properties, such as the reduction in workability, which leads to difficulty in finishing and moulding of the concrete.

Steel fibre reinforced concretes (also known as SFRC) were first introduced in the United States of America. Steel fibre reinforced concrete was first invented by J.P Romualdi, where the invention was afterwards patented in year 1969. It initially went into the production line from the effort of Bastille Development Corporation of Columbus, Ohio. This initially started the new era of the usage of steel fibres in construction. Short-fibre was later introduced into the industry.

There are various types of steel short-fibres which serve the purpose of reinforcing concrete composites. Short steel-fibres are produced from several different methods. Some examples of the methods used are short-fibres chopped from cold drawn wire of circular cross section, short-fibres that are cut out from thin plates, and twisting along their axis simultaneously while cutting the fibres. Short fibres can also be obtained from melted metal, which inevitably contributes to rough surface appearance.

There are some main aspects which determine its efficiency as a mean of reinforcement for concrete.

- Aspect ratio, which includes the ratio of the length to the diameter.
- Surface properties and quality.
- End anchorages the short-fibre.
- Material properties of the short-fibre involved. This includes the tensile strength and ductility of the short-fibres.

However, the efficiency of the short- fibres reinforcement in concrete relies heavily on the distribution and orientation of the fibres in the matrix during the mixing and placing of concrete. Normally, the application of short-fibres in concrete varies from 0.5% to 2%. This application rate is based on opinions from Brandt (1995) regarding the usage of short-fibres in concrete.

- Workability rapidly increases as the proportion of short-fibres added is increased.
- Porosity of concrete increases with the introduction of entrapped voids due to addition of short- fibres.
- Tendency of short- fibres to form balls when high proportions of short-fibres are used, which will eventually lead to difficulty in proper compaction for good distribution.
- Increase in total price when high short-fibres proportions are used.

1.3.2 Fibremesh

Figure 1.2: Fibremesh

Besides Fibremesh which is made of 100 percent virgin homopolymer polypropylene fibrillated fibres were also used in this project. Fibre mesh can be use to prevent and control the formation of internal cracks in concrete. It also has reinforcing effects against impact forces, effect of shattering force, material losses due to abrasion and water migration. In addition, it improves toughness to enhance the performance of the hardened concrete. Using Fibremesh also results in a reduction of plastic shrinkage and settlement cracking. Never the less, it also provides residual strength to the concrete.

According to Fibremesh Inforced e3 Product Bullein, there are a lot of inherent advantages in the usage of polypropylene Fibremesh. The usage of Fibremesh in concrete does not have a magnetic effect, it is rustproof, alkali proof, and does not need to account for any minimum amount of concrete cover. Reinforcement of Fibremesh is usually used in areas where improved toughness, resistance to intrinsic cracking and improved water toughness are needed. Some of the examples of usage are, sidewalks, driveways, water tanks, slope paving, walls, thin sections and shortcrete.

The usage of fibremesh is also compatible with the usage of all other admixtures and performance enhancing chemicals. Any finishing technique can be used for the finishing of Fibremesh reinforced concrete. In the aspect of mix design, no additional water or alteration in mix design is required, which will eventually contribute to the convenience of the usage of Fibremesh in concrete.

However, the usage of fibremesh is mainly for crack control, lowering water migration, increasing the impact capacity, shatter resistance, abrasion resistance and residual strength. Therefore, it cannot be used as a substitute to load bearing reinforcement. The usage of Fibremesh in concrete should also not result in usage of thinner concrete section compare to the original design.

1.3.4 Polypropylene Short-fibres

Figure 1.3: Polypropylene Fibres

Polypropylene fibres are one of the main types of fibre used in the market, apart from steel fibres. However, both types of fibres vary significantly in their elastic and strength properties. For 30 years, steel fibres have been commonly used in concrete flatwork and sprayed concrete applications. The emergence of polypropylene fibres has introduced to the world the possibility of having a high-performance and more cost-effective product in the market place. Polypropylene fibres also possess better durability as plastic does not rust. It also contributes to the ease in handling as it weights about one-fifth of an equivalent steel short-fibre.

The production of polypropylene started since 1954. By year 1960, polypropylene had begun to be applied as concrete reinforcement. At first, plain and straight polypropylene fibres were used, but the results are poor as the bonding in a concrete mix was inadequate. This is because the mechanical interlocking was not good. As a result, twisted polypropylene fibres were developed and are still used today. The mechanical bonds of these new developed fibres increased considerably.

Polypropylene short-fibres have low melting points. It also loses strength in conditions where temperatures are higher. However, the application of polypropylene short- fibres are increasing and spreading into areas where the effect of temperature is not significant.

There are various uses of polypropylene short-fibre reinforced concrete. It is usually mixed with fresh concrete which are used in thin-walled, pre-cast elements of a building. It is also used in some non- structural elements. It is also used as main reinforcement, such as the edge beams of bridge decks, and as secondary reinforcement in the construction of industrial floors.

1.3.5 Other Kinds of Fibres

Other then the three kinds of commonly used short-fibres as stated above, there are also some other kinds of fibres which are used for various other applications. The other types of fibres known in the industry are carbon short-fibres, glass short-fibres and natural occurring short-fibres.

1.3.5.1 Carbon Short-fibres

Carbon short-fibre applied less in the past due to its high cost. But in recent development, the cost of manufacturing of carbon short-fibres had been significantly lowered through the usage of materials such as petroleum and coal pitch. Although the actual costs of these short-fibres are still higher than polymeric short-fibres, carbon reinforced short-fibres still have distinct advantages over the use of polymeric short-fibres, as carbon short-fibres can be used in applications which require high tensile and flexural strength. Carbon short-fibres also possess modulus of elasticity as high as steel short-fibres. Nevertheless, carbon short-fibres are two to three times stronger than steel short-fibres. Furthermore, they are also relatively light with a specific gravity of about 1.9. One of its more important advantages is its resistance to the corrosive attack of most chemicals.

1.3.5.2 Glass Fibres

Glass reinforced concrete is usually applied on areas subjected to flexural and tensile tests. Glass fibres are also usually used in thin sections, usually less than 20 mm. Due to this, glass fibre reinforced concrete are used for building restoration and renovation. Their thickness of 10mm to 15mm and component weight between 20 to 30 kg/m^2 produced great benefit for renovation of existing building. This is mainly because they do no increase the dead load of the building significantly. Besides, glass fibre reinforced concrete is also available broadly and the supply is also not restricted by environmental limitations. Meanwhile, it also possesses excellent environmental resistance. Its properties are maintained even when subjected to freeze-thaw attack, ultraviolet exposure and acid rain.

1.3.5.3 Natural Occurring Fibres

Naturally occurring fibres are one of the oldest forms of fibre-reinforced composites which consist of naturally occurring fibres such as straw and horse hair. However, as technology and development progresses, currently it is possible to extract fibres from various kinds of plants such as bamboos. One of the advantages is the energy required to extract the fibres are relatively low, which makes it an economical choice. However, one of the main disadvantages of using these forms of fibres is their proneness to disintegrate in an alkaline environment. Due to this problem, efforts had been taken to improve the durability of natural fibres, such as through the use of admixtures to reduce its alkalinity and applying special treatment to the fibres. Some of the examples of natural occurring fibres which can be use in concreting are akwara, bamboo, coconut, vegetable, jute, sisal, sugarcane bagasse and wood fibres. Meanwhile, some other kinds of natural fibres are also being tested for their feasibility as a source of fibres to reinforce concrete. Examples of these fibres are palm and elephant grass fibres.

1.4 Admixtures

1.4.1 Introduction

Admixtures, used in concrete, are chemicals which are added in a relatively small proportion compared to the basic components of concrete. They are usually introduced during the mixing, batching or re-mixing stages. The quantity used is measured based on the amount of cement used and expressed as the percentage involved by mass. The term ‘admixtures’ does not involve materials other than chemicals added in small quantities. Therefore, fly ash and other pozzolans and cement substitutes which are widely used are only being considered as additional components of the concrete mix, not admixtures.

1.4.2 Category of Admixtures

Admixtures are usually categorised according to their primary effects. These effects are:

1. Workability improvement of concrete.
2. Control of setting times and early hardening.
3. Air-entrainment.
4. Water reducing.

There are also other effects, such as admixtures intended for high cohesion during under-water concreting and stability improvement due to finer ground minerals.

Admixtures which are available in the market can be found in a liquid or solid state. In actual usage, admixtures can be used in both their liquid and solid state. Admixtures of liquid form are used more often as they can be mixed with concrete more uniformly. Usually, admixtures are mixed with mixing water, or inserted into the mix in liquid form simultaneously with the mixing water.

The dosage of admixtures required to be added into the mix is usually recommended by the manufacturers. However, it often varies with other factors and circumstances. As a result, the dosage required to be inserted into the mix should often be tested. As mentioned previously, the dosage of admixtures to be used is often expressed in terms of percentage with regard to the mass of the cement in the mix.

The components of the concrete and the dosage of the admixtures both contribute to determining the effectiveness of the admixtures. The property of the cement is the main factor in influencing the effectiveness of the concrete. Additionally, a lot of admixtures are also affected by temperature. Due to this phenomenon, the possibility of applying admixtures in conditions of extreme temperatures should be determined prior to commencement of work.

Although the performances of particular types of admixtures are known, when more than one kind of admixture is used simultaneously, the effect may differ from expected. Due to this, trial batches have to be carried out to determine the effects of the combinations. Admixtures also have to be accurately measured for their amount and discharged in the correct part of the mixer at the correct rate to get the optimum result. Any variation in the procedure of concrete mixing also would affect the performance of the concrete.

There are various benefits for using admixtures. One of the reasons behind the significant increase in the usage of admixtures is mainly due to their ability to produce substantial advantages in physical and economic considerations. The usage of Superplasticisers had lead to the possibility of doing concreting under conditions and circumstances which are considered as undesirable or difficult. It also introduces the usage of a wide variety of ingredients into the mix.

Although admixtures are relatively expensive, this does not necessarily mean that it will adversely influence the overall cost of the project. This is because the usage of admixtures may result in other related savings. Some of the examples are savings in labour cost when it comes to easier compaction of concrete, or improving the durability regardless of the usage of other expensive measures.

However, although the usage of Superplasticisers may help improve the process of concreting or improve the performance of the concrete, there is no remedy for concrete made of poor quality mix ingredients, error in designing the mix proportions, and deficient handling in the process of transporting, placing and compaction of concrete.

According to Neville 1999, it is also important to acknowledge that potential interactions and varying degree of significance for each different admixtures exist, which makes it difficult to draw out a general relationship. Some important side-effects might also be significant in certain admixtures in particular applications.

1.5 Superplasticisers

Figure1. 4: Superplasticisers

1.5.1 Introduction

The area of interest underlining this project was the workability of fresh concrete. Admixtures which fall in this category range from plasticizers, Superplasticisers, water-reducing agents and high-range water reducing agents. The primary effects of these agents relate to the improvement of workability, which generally also involves the increase in early strength. It is also possible to maintain similar workability, while reducing the usage of cement.

Although practically, it is possible to control the increase of workability, reduction of water content and cement content at the same time, to obtain the optimum effect we are required to focus on one parameter and maintain the parameters of the other two components.

According to Bartos (1992), plasticisers and Superplasticisers are two types of additives used to increase the workability of the concrete. Although both of the admixtures are used for improving the workability of the concrete, they are different in nature.

Ordinary plasticisers are primarily based on lignosulphonate salts. On the other hand, Superplasticisers are mainly based on formaldehyde naphthalene sulphonate and formaldehyde melamine sulphonate. Compared to ordinary plasticisers, Superplasticisers are more capable of increasing the workability of concrete without undesirable side effects.

However, the ability of Superplasticisers to enhance the fluidity of the concrete is one of the criteria which are similar to ordinary plasticisers. The process involves the absorption of macromolecules of the polymer onto the grains of the cement, altering the electrostatic charges on the particles.

The chemical composition of the Superplasticisers also differs from ordinary plasticisers. As a result, Superplasticisers do not delay the setting times and hardening of the concrete. Furthermore, some acceleration in setting and hardening of concrete is also observed. This led to relatively short periods of effectiveness of Superplasticisers. Rapid loss in workability with time eventually occurred in early commercially available Superplasticisers.

The admixture used in this project is Superplasticisers. Superplasticisers are admixtures which reduce the water requirement and also improve the workability of the concrete. They are mainly based on two types of chemical compound, formaldehyde sulphonate and formaldehyde melamine sulphonate. The phrase Superplasticisers also differentiates itself from ordinary plasticizers, as it possesses a much greater potential of increasing the workability of the concrete without the undesirable side effects.

1.5.2 Nature of Superplasticisers

Generally, Superplasticisers are categorised into four main categories. These categories consist of sulfonate melamine-fomaldehyde condensates, sulfonate-naphthalene-formaldehyde condensates, and modified ligosulfonates. The fourth group consists of those not frequently used, including sulfonic-acid esters and carbohydrate esters. Among the four main kinds of superplasticisers, sulfonate melamine-fomaldehyde condensates and sulfonate-naphthalene-formaldehyde condensates are used more regularly in the industry at present. These two kinds of Superplasticisers are normally referred to as melamine-based Superplasticisers and naphthalene-based Superplasticisers.

1.5.3 Chemical Aspect of Superplasticisers

Basically, Superplasticisers are water-soluble organic polymers. It undergoes a complicated polymerisation process which synthesises it to produce long molecules of high molecular mass. The process contributes to the cause of Superplasticisers being relatively expensive. The characteristic of Superplasticisers can also be improved with respect to the length of molecules with minimum cross- linking. The usage of high dosage of Superplasticisers also does not lead to excessive harmful side effects due to low content of impurities.

Improving the efficiency of Superplasticisers, can be done by having a larger molecular mass within a specific limit. Although the chemical nature of Superplasticisers will have an effect, there are no general views of superiority of either naphthalene- or melamine-based Superplasticisers. The chemical properties of cement used might be one of the contributing factors.

Although most Superplasticisers are in the form of sodium salts, they can also be in the form of calcium salts. Superplasticisers in the form of calcium salts have a lower solubility compared to Superplasticisers of sodium salts. The usage of sodium salts had lead to the introduction of additional alkalis into the concrete which relates to the reaction of hydration of cement. It also contributes to a possible alkali-silica reaction. Due to this, the soda composition of the admixture should be known.

1.5.4 Effects of Superplasticisers

The main effect of Superplasticisers is due to its long molecules wrapping themselves around the cement particles, which consequently give a highly negative charge and causes them to repel each other. As a result, deflocculation and dispersion of cement particles occurs. This results in an improvement in workability of concrete. Concrete with very high workability or concrete of very high strength can be achieved by this method.

Superplaticisers can also improve the workability of concrete and still be cohesive for given water: cement ratio, and water content in a mix. As an outcome, the concrete can be easier to place or only require little or no compaction. Some of the areas where concrete with the addition of Superplasticisers is used are floor and road slabs. The term ‘flowing concrete’ is also used due to the behaviour of Superplasticisers on concrete.

Concrete of very high strength can be achieved by the usage of Superplasticisers. This is due to the ability of reducing the water: cement ratio substantially. Generally, the water content of a concrete of fixed workability can be reduced by 25 - 35 % by the introduction of Superplaticisers. Meanwhile, the one day strength of the concrete can also be increased by 50 - 70 %, as stated in Neville (1999).

Basically, the structure of hydrated cement paste does not change due to the introduction of Superplasticisers. However, it can result in a better distribution of cement particles, which consequently leads to better hydration. These indicate the reason behind the increase of strength of concrete at constant water: cement ratio.

Although most Superplasticisers do not exhibit satisfactory set retardance, naphthalene – based Superplasticisers shows retardation, however, it only applies to cement particles in the range of 4 to 30 µm, and does not apply to particles of cement which are smaller than 4 µm as they are rich in SO_3 and in the alkalies.

1.5.5 Compatibility

The establishment of a compatible Superplasticisers-cement combination is required when the use of a large dosage of Superplasticisers is needed for reduction in water cement ratio, or when re-dosage of Superplasticisers is not possible. A well- matched combination of Superplasticisers and cement will lead to a desired outcome, which is the retention of high workability for a long period, as long as 60 to 90 minutes, which may even extend to 2 hours, using only a single large dosage of Superplasticisers.

The optimum level is defined as when the dosage of Superplasticisers increases to a level where increase of Superplasticisers lead to little improvement. In actual practice, only an optimum dosage of Superplasticisers should be used. This is firstly because of economic reasons, in which excessive usage of Superplasticisers will lead to loss in profit. In addition, usage of excessive Superplasticisers should also be avoided as this might lead to segregation.

The compatibility of Superplasticisers with cement also depends on several factors, related to the physical properties of the cement used. The use of finer cement particles will inevitably lead to a higher dosage of Superplasticisers to achieve a required workability. The chemical properties of cement also play a part. A higher content of C3A will reduce the effectiveness of the Superplasticisers and the usage of calcium sulphate as a retarder also influences the effect of Superplasticisers.

In conclusion, the dosage of Superplasticisers recommended by the supplier is of little value. Further investigation and testing is required to achieve the optimum dosage of Superplasticisers as the properties of different kinds of cement vary. Additionally, in order to seek the optimum combination of Superplasticisers and cement, it is usually easier to alter the Superplasticisers. However, sometimes it is also possible to choose from cement if available.

1.5.6 Usage of Superplasticisers

a) In areas where congestion in reinforcement exists

b) In areas where access is difficult.

c) Decreasing the water: cement ratio for high-strength concrete by 15-25%.

Introduction of Superplaticisers into the concreting industry has made placing and the ability to work with concrete easier than it was before. The ability of concrete with the addition of Superplasticisers to self-compact has helped in areas where access is difficult. The introduction of Superplasticisers into concrete mix has also created the possibility to produce concrete with higher and better strength and other beneficial properties, which are also known as high- performance concrete.

The usage of Superplasticisers does not have an obvious effect on the setting time of concrete, except in some cases where excessive retardation may occur when the cements used have a very low content of C_3A. Superplasticisers can also be used when silica fume exist in the concrete mix. This is because silica fume increases the demand for water in the particular mix. In the case where it is required to re-dose the mix with more Superplasticiser, the amount required is larger than concrete which does not contain any silica fume. Therefore, due to the effect of silica fume on workability of concrete, usage of silica fume is usually associated with the presence of Superplasticisers in a particular mix.

According to Paillere, Bassat and Akman (1992), the use of Superplasticisers also does not influence properties such as shrinkage, creep, modulus of elasticity, and resistance to freezing and thawing of concrete. Meanwhile, the durability of concrete is also maintained when it is being exposed to sulphates. The presence of Superplasticisers in concrete also does not influence the rate of corrosion of reinforcement in concrete. This is because usage of Superplasticisers has no influence on the pore structure of the concrete.

Superplasticisers may influence the effect of air-entraining admixture as it may reduce the amount of entrained air. An unstable void system can occur in some situations when using some Superplasticisers with some cement and air- entraining admixtures. Although it is possible to achieve a satisfactory air entrainment of concrete with Superplasticisers, there will be a slight increase in bubble size. As a result of using Superplasticisers, some additional dosage of air- entraining admixtures is needed.

The followings are some of the considerations of usage for Superplasticisers.

a) The used of Superplasticisers have to be controlled carefully.
b) Special mixes have to be carefully designed for the use of Superplasticisers.
c) Effect of Superplasticisers might only be lasting for 30 minutes after mixing.
d) High unit cost compared to other materials used in concrete.
e) When Superplasticisers are used to create very high workability, it will lead to an increase of shrinkage and creep.

1.6 Dissertation Overview

The followings are the overview of this dissertation. It is structured to convey the project in a comprehensive manner.

Generally, this thesis consists of six chapters. The chapters begins with Introduction, which is followed by Review of Superplasticisers and Short-fibres Usage, Experimental Methodology, Test Procedures, Results and Discussion and finally ends with Conclusions and Recommendations.

Chapter 1, which entitles Introduction, discusses about the general background of short-fibres, admixtures. Furthermore, it also gives a deeper view regarding Fibremesh, steel, and polypropylene short-fibres. Meanwhile, some background of Superplasticisers was also discussed.

Chapter 2, which entitles Review of Superplasticisers and Short-fibre Usage, discusses regarding the development of Superplasticisers and short-fibres, and the researches done in the past. Various aspect and past findings were looked into in this chapter and finally an overview of the problem was done.

Chapter 3, which entitles Experimental Methodology, mainly discusses about the experimental methodology involved in the project. Test procedures and results, such as determination of particle density and water absorption and sieve analysis were discussed. Mix design for the project was also discussed in this section.

Chapter 4, which entitles Test Procedures, discusses some background information regarding the tests and the procedures involved in the respective tests.

Chapter 5, which entitles Results and Discussion, discusses about the results gathered from the fresh concrete tests and harden concrete tests. Slump test, Vebe test and Compacting Factor test were used to assess the fresh properties of the concrete. Meanwhile, In-direct tensile strength test, compression strength test, determination of Young's Modulus and Flexural Strength test were used for the assessment of harden properties of concrete.

Chapter 6 entitles Conclusion and Recommendation. As the title itself suggested, this section draws conclusion from the result gathered from the tests conducted. Furthermore, it also includes some of the author's achievement as a result of undertaking the project. Recommendations for further studies were also included in this section.

CHAPTER TWO

REVIEW OF SUPERPLASTICISER AND SHORT-FIBRE USAGE

2.1 Introduction

Since the discovery and application of Superplasticisers and short-fibres in concrete, many journals and technical papers have been published. Some of the investigations and development of the related topic are summarised is this section.

2.2 Development

Fibres

Although the use of fibres to reinforce a brittle matrix had been around for a long time, the modern-use of fibres to reinforce concrete begins to gather pace in the early 1960s. Initially, only straight steel fibres were used. The primary factors that governs the usage of short-fibres are the proportion and the dimension of the fibres used.

Later, the development of deformed fibres and high-range water reducers, which is also known as Superplasticisers, had lead to a rapid increase in the usage of short-fibres to reinforce concrete. The discovery of using short-fibres with hooked ends which offer similar ductility and toughness had caused the reduction in the usage of short-fibre proportions. Meanwhile, the addition of small portion of Superplasticisers can overcome the problem of reduction in workability due to the usage of short-fibres in concrete. The application of Superplasticisers only requires a relatively small dosage, which also enables the control of workability. As a result, various shapes of fibres such as crimped, paddled and enlarged ends were developed.

Polymeric fibres experienced a rapid growth in the 1970s. The use of polymeric fibres was mainly for the control of cracking in the early stage of setting. Among various types of polymeric materials, polypropylene was mainly used for this purpose. Carbon fibres also attracted attention as its manufacturing cost is lower compare to steel fibres. Furthermore, carbon fibres also have higher strength and modulus of elasticity compared to polymeric fibres. Asbestos fibre is another kind of fibre available in the industry. However, the use of asbestos fibre was discouraged due to health concerns. In fact, the use of asbestos fibre had been prohibited in many developed countries.

Currently, continuous researches are being conducted for the use of short-fibre reinforced concrete in structural applications, ranging from beams, columns to pre-stressed concrete structures. The availability of short-fibre for reinforcement may alter the design and construction of concrete structures. Furthermore, the idea of using Superplasticisers to improve workability had lead to the possibility of using a higher volume of short-fibres in the concrete matrix. The existence of large amount of fibres in the concrete will inevitably change the properties and performance of cementitious matrix.

Admixtures

40 years ago, the main admixtures used were water-reducing admixtures, retarders and accelerators. However, the use of calcium chloride as accelerators was banned in 1977 as according to Adam Neville 2004, it was proven to be one of the factors contributing to reinforcement corrosion. Superplaticisers gives many benefits as it allows the usage of low water: cement ratios with sufficient workability.

Development of Superplasticisers in Australia

Progressive improvement has occurred in the last four decades in the area of admixtures. Superplasticisers, which are also known as high range water reducers, were introduced into the Australian market place in 1974, according to Bruno D'Souza and Ken Fletcher, 2004.

Superplasticisers which are still commonly used are generally categorised into 3 groups. They are listed as follows.

1. Sulphonate naphthalene formaldehyde condensates (SNFC).

2. Sulphonate melamine formaldehyde condensates (SMFC).

3. Others which also includes blends of materials.

Superplasticisers, which involve the combination of several raw materials which aid in improving the performance, and includes a reduction in slump loss, were introduced in the 1980's. Although these modified plasticisers are being widely used, limitations exist in their usage. Constraints involved include extended set times, caused by relatively high dosage rate, are required to achieve low water: cement ratios and withholding slump, essential in distant haulages and hot weather conditions.

2.3 Superplasticisers

Faroung, Szwabowski, and Wild (1999) reported that although Superplasticisers are being widely used, their applications are still subjected to imprecision and uncertainty, due to insufficient qualitative and quantitative data regarding their influence on workability.

Their research also shows that plastic flow of concrete mix occurs when the shear stress values are near to the limits of maximum resistance of cohesion and internal friction. Changes in the rheological characteristic of the particular mix also occur as a result of the usage of Superplasticisers. These changes may be caused by high negative value of electro kinetic potential (or zeta potential) at the cement-water interface. Furthermore, it increases the cement dispersion in side the concrete paste, which enhances the process of dehydration, by reducing the adsorptive and the capillary forces which exist within the cement paste.

Furthermore, factors which determines the effect of Superplasticisers on a particular concrete mix does not only restrict to the type, dosage, volume and application methods of the Superplaticisers. Besides, the improvement of workability by Superplasticisers gradually diminishes with time. Lowered yield value is the main factor for the improvement in workability. The optimum dosage relays on mix composition, and can only be determined through experiment.

From the tests conducted by Faroung, Szwabowski, and Wild (1999), the results shown that w/c ratio has a great influence on the performance of various types of different Superplasticisers. Meanwhile, their research also indicated that application of the recommended dosage of Superplasticisers by the manufacturer is of little value practically, without referring to the mix composition of the particular concrete mix.

This is due to the fact that the optimum dosage of Superplasticisers besides rely on the water/cement ratio, is also depend largely on the type and volume of cement used, fineness of the cement used, and also other components involved, such as microsilica.

Bjornstrom and Chandra (2003) reported that the rate and amount of which the Superplasticisers absorbs into the cement compound influence the rheology, setting and hydration mechanism. Besides, different cement exhibits different characteristics due to its wide variability in chemical and physical properties. They assumed that the chemical compositions of the cements, such as C_3A and sulfate content, alkali and ground lime are some of the essential features which govern the rheology aspect of the cement paste.

Bjornstrom and Chandra (2003) classified Superplasticisers into four basic groups, which are Modified lignosulfonates (MLS), Sulfonated melamine formaldehyde condensates (SMF), Sulfonate naphthalene formaldehyde condensate (SNF) and Polycarboxylate ether (CE), functions as a result of their absorption onto the cement grains, which consequently acquires an electrostatic charge. These actions contribute to dispersion of cement particles and increase in the fluidity of the concrete mix. Among various kinds of chemical parameters of cement, C_3A content, specific surface area, morphology of the C_3A, the alkali content and the form of calcium sulfate inserted into the clinker during the process of grinding plays a part on exerting a major influence on the properties of the cement mixes.

Bjornstrom and Chandra (2003) also expressed that the ability of Superplasticisers to disperse cement particles relies on the type of cement used. The view that Superplasticisers does not perform in the same way with the usage of different cement coincides with Faroung, JSzwabowski, and Wild (1999).

According to Brettman, Darwin, and Donahey (1986), high- slump fresh concrete with the usage of Superplasticisers presents a lower bonding strength, compared to low and medium slump concrete of identical compressive strength, high-slump concrete, and also has an obvious drop in bonding strength if the concrete paste is not vibrated. Furthermore, Brettman, Darwin, and Donahey (1986) also concluded that when high- range water- reducers are used, the longer the concrete remains in a plastic state, which is obtained with lower concrete temperatures in their research, the lower the bonding strength of the concrete will be.

Rivera-Villareal (1997), reported that VEBE test gives result which are reliable for earth dry or slightly plastic concrete, while flow test for flowing concrete. It further states that slump test cannot be solely used to examine the effects and dosage of the fluidifying admixtures on the workability aspect of fresh concrete, which varies from earth dry state to flowing state.

Furthermore, Rivera-Villareal (1997) also stated that the increased workability obtained by the usage of Superplasticisers will be lost in a matter of about 30 minutes, which mainly relies on the dosage of Superplasticisers used. Due to this, actions have to be taken to remedy the loss of workability. Methods recommended includes delay of addition of the admixtures, split dosing of the admixtures, usage of cement with supplementary cementitious materials, and finally the introduction of retarder or other admixtures.

According to Paillere, Bassat and Akman (1992), admixtures interact with hydrating cementitious system, either by physical, chemical or physico- chemical reaction. Meanwhile, it also modifies one or more properties of concrete in either fresh, setting, hardening, or harden state of concrete. They also stated that although complex chemical reactions are known to be developed at instance between the contact of cement and water, not all of the mechanisms of the admixtures are known and understood thoroughly. These mechanisms include physical or chemical absorption and the chemical reactions of the admixtures used in the concrete mix with certain cement constituents.

Meanwhile, some secondary function of the admixtures may also result in some side effects. As these side- effects are inevitable for the usage of certain type of admixtures, preliminary investigations have to be carried out. According to Paillere, Bassat and Akman (1992), although Superplasticisers have a main function of increasing the workability of a related concrete mix, it had some secondary effects on water reduction, setting times, hardening state, air entraining, strength and durability of concrete.

Paillere, Bassat and Akman (1992) also stated that some unfavorable secondary effects which exist due to the usage of Superplasticisers are segregation when excess of water or admixtures are used. The efficiency of Superplasticisers is very sensitive to the fines content of cement and sand used in the mix. Further more, slump loss which depends on temperature and possible increase in shrinkage might occur.

Meanwhile, the air-entraining phenomena of Superplasticisers based on sulfonated naphthalene formaldehyde condensates were also examined by Tognon and Cangiano (1982). According to them, Superplasticisers causes air entrainment which relates directly to the workability of the mixes. Compared to air-entraining admixtures, air-bubbles caused by Superplasticisers are not attached to the cement particles. The sizes of the air- bubbles are two or four times higher than those caused by air- entraining agent.

Tognon and Cangiano (1982) also reported that vibration is needed when working with superplasticised self- leveling concretes to eliminate the existing entrained air. The vibration action could help to eliminate two to three percent of air- voids. However, due to the sizes of these entrained airs, it does little help against frost action.

2.4 Short-fibres

2.4.1 Application

According to Perry (2003), steel fibres are widely considered by engineers and specifies as a material suitable for reinforcing concrete, which also offers advantages such as economic and technical advantages over conventional steel floor reinforcement. The advantages also include increased toughness, tighter crack control. However, some problems were encountered, such as the appearance of steel fibres on the surface of external pavements. Due to this, synthetic fibre appears as a possible solution to it as it performed in similarly to steel fibres, but does not possesses such problems.

According to Agostinacchio and Gianluca (2003), compare to the performance of normal concrete pavements, concrete pavements which are reinforced with nylon polypropylene and 30mm-long steel fibres showed an improvement. Further that, they also concluded that although all fibres used in the test possesses a hook shape and circular section, 60mm-long steel fibre and polymer modified fibre reinforced concrete behaved in some similar way to concrete reinforced with steel bars. Therefore the performance of the fibres depends on the type of material and the dimension of the fibres adopted for use.

2.4.2 Crack Control

Sanjuan, Andrade and Bentur (1998), reported that crack- widths in adequately cured mortars are able to be controlled by polypropylene fibres. Besides, addition of fibres also reduces the corrosion rate by electrochemical measurement. Besides, no relationship between corrosion rate and crack width was found.

Hannant (2002), expressed that generally, the usage of short- fibres in harden-concrete in a 3D random distribution does not contribute to the cracking load significantly. Compared to unreinforced concrete, inclusion of short fibres in the concrete can assist in limiting the damage caused by shock or impact loads. Meanwhile, the elastic modulus does not affect the performance of reinforcement of concrete, but can affect the crack width of the concrete. He concluded that for general construction, benefits which out-weight the cost of fibres contribute to its wide usage.

Li (1992), believed that when the short-fibres in the concrete controls the microcracks in the concrete, which consequently prevents the propagation of microcracks, a phenomena which was known as pseudostrain-hardening occurs. This behavior refers to the distribution of microcracks over the whole body. After the occurrence of the initial cracking, there might be another phenomena, called multiple cracking. This occurs when the bridging fibres across the first crack, which continued to increase as the opening of the crack increases. This also led to a spread of microcracks, which latter lead to the formation of numerous sub-parallel fracture planes of the related specimen.

Rossi, Acker and Malier (1987) said that the process of cracking of concrete can be divided into three stages. The first stage involved the overall volume microcracking. The second stage involved the concentrate of microcracks which tends to concentrate to locations of principle strains. This would eventually lead to the formation of macrocracks. The third stage of the cracking process relates to the propagation of macrocrack along the direction of principle tensile strain. As a whole, the phenomena in the first stage depend on material, geometry and boundary conditions. However, the phenomena in the second and third stage depended on the conditions of the boundary of the structure regardless of the influence of the material involved.

2.4.3 Influence on Strength

Meanwhile, ShowmayHsu and ThomasHsu (1994), who researched on the stress strain behavior of steel-fibre high-strength concrete under compression, found that addition of steel fibres into a mix will lead to an increase in strain corresponding to the peak stress. However, according to them, the addition of steel fibres to high strength concrete will not lead to any significant increase in peak stress. The addition of fibre content also caused tremendous changes in the descending part of the stress strain diagram, where the slope increases with increasing fibre content. However, compare to plain concrete, the ascending part of the graph vary slightly without too much variation. Due to this, higher ductility and toughness can be achieved with the addition of a reasonable amount of fibre. According to them, problems of bulging of concrete had been encountered in the lateral direction, which was caused by the usage of fibres in the concrete mix, which acts as crack arrestors.

El-Niema (1991) stated that steel fibres distributes randomly throughout the concrete mix at a much closer spacing compared to the conventional reinforcing steel. This was due to the phenomena of fibres arresting the cracks by decreasing the stress intensity factor at the tip of the inherent internal cracks. Meanwhile, the ultimate tensile strength was also improved due to the considerable amount of energy being absorbed in the debonding and the pulling out of fibre from the concrete prior to the complete failure of concrete. Besides, the ultimate strength also depends on the percentage of fibres used in the batch of concrete.

According to El-Niema (1991), the maximum load of short-fibre reinforced concrete was controlled primarily by the pulling out of fibres gradually and the phenomena of which the stress in the fibres at the ultimate load was very much less then the yield stress of the fibre. Furthermore, he also stated that toughness was defined as the total energy absorbed by the specimen before the complete separation of the specimen. This is attained by measuring the area under the complete tension or compression stress-strain curve or the deflection curve in flexure. As a whole, the addition of fibre increases the toughness of a particular specimen drastically. However, toughness was also influenced by various factors such as fibre orientation, volume percentage of fibre, and finally the aspect ratio. Finally, El-Niema (1991), also concluded that the increase of volume percentage and aspect ratio go the fibres improved the toughness and ratio of a particular concrete.

Troittier and Banthia (1994) stated that steel fibre have a distinctive advantage over other kinds of fibres due to its high elastic-modulus, strong bonding with the cement paste, its nature of ease to deform which improves the anchorage in concrete. They also stated that fibres with only deformations at the end of the fibres are more efficient compare to fibres with deformations along the whole length. Meanwhile, the strength of the concrete also plays a part in influencing the toughness characteristics. When the strength of the concrete mix is higher, the load carrying capacity of the short-fibre reinforced concrete will experience a steeper and more sudden drop after the occurrence of the first crack.

Rossi, Acker and Malier (1987) reported that the addition of steel fibres increases the critical load required to reach the outset of macro crack significantly. They also stated that 1 % volume content of steel fibre could eventually equal to the usage of 0.15 % of flexural steel reinforcement. If an increase in the cracking strength of the concrete was required, usage of large proportions of short-fibres is an option to reduce the number of narrow microcracks. However for the control of macrocracking, longer fibres should be adopted as they are more efficient.

Bischoff (2003) stated that the effect of tension stiffening, which shows the ability of concrete to carry tension between cracks, is useful for the assessment of the post-cracking behavior of the concrete. According to him, tension stiffening in short-fibre reinforced concrete is due to the behavior between the cracks and at the location of the crack. Furthermore, Bischoff (2003) also reported that the tension stiffening of fibre reinforced concrete until it reaches the yielding point of the reinforcing steel can be predicted and calculated using the following formula, $\beta_f = \beta_c + 0.4\, f_f / f_{cr}$, where β_c represents the bond factor for the plain concrete, f_f represents the post-cracking stress after the cracking, and f_{cr} represents the cracking stress.

Nanni (1991) reported that fibre reinforced concrete had improved strain capacity, impact resistance and energy absorption and tensile strength compare to plain concrete without the usage of fibres. Furthermore, fibre also has the ability to restrain the propagations of cracks to a certain degree. Nanni (1991) had compared the results from splitting test and flexural test. He concluded that both of the test procedures relates to the first-crack strength. The addition of fibres in the concrete mix, gave pseudoductility to a cement matrix due to crack control. However, he stated that splitting test over-estimates the pseudoductility of fibre reinforced concrete, due to the bridging of fibres in the primary crack, are confined by a matrix which was under high compression, where the field of tensile stress decreases drastically from the zone of cracking. As a result, post-crack performance of a concrete specimen should be assessed by flexural test, rather then splitting test.

According to Swamy and Al-Ta'an (1981), fibre reinforced concrete improved the tensile and stiffness of the cement composites. However, there are insufficient data regarding the effect of the usage of steel fibres in reinforced concrete. They confirmed that fibres can control cracks by the increase in depth of the neutral axis and increment of flexural rigidity throughout the process of loading. Besides, the cracks which were visible along the concrete were more closely spaced. However, the effect of steel fibres on improving the ultimate flexural strength of the conventionally reinforced beam was not obvious. The main usages of steel fibres were for crack control, improving ductility and increasing the post-cracking stiffness of the concrete.

2.5 Effect of Sulfur Capping

Concrete cylinder caps, which are used in compressive strength test of concrete, are used in order to achieve a flat surface for even load distribution throughout the cylinder specimen. According to Vichit-Vadakan, Carino and Mullings (1998), load which are transferred to the cylinders will not be distributed evenly if the material used for capping of concrete cylinders does not possess adequate stiffness. Furthermore, low elastic modulus tends to occur at high lateral strain in the caps, due to Poisson's ratio. As a result, lateral tensile stresses may appear at the ends of the cylinder specimens. Due to the above reasons, it is desired that the elastic modulus of the concrete cylinder specimen capping material be similar to that of the cylinders.

Meanwhile, Vichit-Vadakan, Carino and Mullings (1998), also concluded that various different capping material has its own distinctive relationship between the dynamic elastic modulus and the cube strength of the related specimen. Meanwhile, they also expressed that the elastic modulus of different capping materials differs greatly for the same cube strength. In situations where cylinder strength is influenced by the material used in capping, evidence exists which shows that the strength of the cylinder relates to the modulus of elasticity rather than the cube strength of the capping material used in the test.

2.6 Conclusion

Through the review of the previous researches and studies, plenty efforts had been spent in investigation and research regarding the usage of Superplasticisers and various kinds of short-fibres to improve the performance of the concrete in order to achieve a desired outcome.

The area of researches involved in the past ranged from the effects of Superplasticisers as admixtures on the rheological properties of cements, further to the workability of concrete, and various other properties such as air-entrainment, setting time and other harden properties of concrete.

After due research, it was found that more researches and studies are needed to focus on the usage of short-fibre as a mean of reinforcement in concrete. And among various types of fibres, more research had been done on steel fibres compared to other kinds of fibres. This might be due to the general acceptance of steel fibres in the industry as common practice. Research which was conducted on fibre reinforced concrete involves numerous aspects. These areas are the deformation, ultimate strength in flexure, tension stiffening, cracking and stress-strain behavior in steel fibre reinforced concrete, post-cracking behavior, Young's Modulus, affect of types of fibre used, dimension and geometry in fibre reinforced concrete.

Most of researches conducted on Superplasticisers were done in the 1990's. Meanwhile, most of the studies regarding short-fibre reinforced concrete span from the early 1980's until most recently. As a whole, studies regarding the usage of fibre-reinforced concrete and Superplasticisers had gain wide acceptance, which encourages further investigations regarding the effects and performance of both materials.

So far no written research article and study was found regarding the use of Superplasticisers in short-fibre reinforced concrete. As the usage of short-fibres will reduce workability of concrete drastically, the effect of Superplasticisers on short-fibre reinforced concrete will be an area of interest. Furthermore, Superplasticisers also has a positive impact on workability and still be cohesive for given water: cement ratio, and water content in a mix. As a result, placement of concrete is easier or only requires little or no compaction.

Meanwhile, the usage of Superplasticisers can enhance a better distribution of cement particles, which consequently leads to better hydration. As a result, higher strength can be achieved at constant water: cement ratio.

Due to its various benefits, addition of Superplasticisers in concrete can be widely used in areas where congestion in reinforcement exists. It can also be applied to concreting works in areas where access is difficult. Ultimately, high-strength concrete can also be achieved by decreasing the water: cement ratio.

2.7 General Overview of Problem

As proven from the past research and through the actual experience encountered by the industry, the addition of short-fibres into concrete to enhance the mechanical properties will inevitably lead to a reduction of workability.

Due to this situation, it was suggested that some additional materials such as silica fume and Superplasticisers should be added into the concrete mix to improve the workability, which will eventually lead to an easier task of concreting, and thus reducing the time and effort needed in the placement of concrete.

Superplasticisers was chosen as the additive to be investigated, and its effects on the fresh properties and harden properties of concrete were also assessed.

CHAPTER THREE

EXPERIMENTAL METHODOLOGY

3.1 Introduction

Guide to concrete construction (2002), suggested that aggregates makes up almost 80% of the total volume of concrete. The properties of aggregates used are essential as this contributes to the performance of concrete in both its plastic and harden state.

In order to access the properties of the concrete, methods for sampling and testing aggregates used for concrete, aphalt and various other applications are contained in one of the Australian Standards, which is AS 1141 *Methods for Sampling and Testing Aggregates*.

Generally, some of the aggregates more commonly used are natural sands and gravels, crushed rocks and manufactured aggregates. Natural sands and aggregates were used in the project, as natural sands and gravels are broadly distributed throughout Australia. There are various locations where deposits of natural sand and gravel can be found. The locations are such as:

- **Stream beds**. In these areas, the depositions found are normally round and strong. This is because weaker materials are removed by the process of erosion.

- **Dunes**. Sands which are formed by wind action, tend to be uniform in sizes and generally fine.

- **Alluvial deposits**. These kind of natural sands and gravel are generally formed in the flood plains in the riverbed. Deposits found in this area may contain various types of rocks and stones, which depend on the source of the rock.

- **Marine deposits**. Aggregates accessed at the edges and bottom of lakes. However, the content of chloride may exceed acceptable level.

3.2 Properties of Aggregates for Concrete

There are various properties of concrete affecting the performance of concrete. These properties range from grading, particle shape and surface texture, density, water absorption, and properties which determine the durability of the concrete, such as dimension stability, abrasion resistance, soundness and unsound stone content. Each of the properties of the aggregates must be within an acceptable limit to produce concrete of satisfactory performance.

Grading of aggregates refers to the distribution of particle sizes in a batch of aggregates. An appropriate grading of aggregates is important as it affects the water demand of the concrete. Furthermore, it may even result in bleeding and segregation of concrete. Due to these considerations, grading of aggregates influences the design of mix proportion in order to achieve a desired workability and water-cement ratio.

Generally, aggregates with a grading curve which is continuous and relatively smooth will result in a mix with lesser large voids between the particles. As an outcome, savings in the amount of cement required can be achieved as lesser cement is required filling the gap of the cement paste.

The grading of the aggregates is determined by the result of sieve analysis, as stated in the Australian Standards, AS 1141.11. Generally, coarse and fine aggregates are separately sieved.

Particle sizes and surface texture are also considered important properties of aggregates. This is because both properties have an important role in influencing the workability of freshly mixed concrete. Besides this, they also affect the water demand and water-cement ratio of the concrete.

Generally, aggregates with round and smooth surfaces have a lower water demand compared to crushed aggregates, assuming all other circumstances are identical. When strength of the concrete comes into play, bond between coarse aggregates particles and the cement paste, and the characteristics of interlocking between aggregates are considered. As a whole, aggregates with a rough texture and cubical-shape give optimum strength.

There are several descriptions for particle shapes. Usually, particles are described as rounded, irregular, angular, flaky and elongated. Meanwhile, surface texture can be classified into few categories, such as glassy, smooth, granular, rough, crystalline and honeycombed.

Apart from the shapes stated, a flakiness index can also be used to describe the shape of an aggregate particle, which uses a slotted sieve or thickness gauge to find out the percentage by mass of flaky particles.

Angularity number is also an index of the shape of a particle. It is determined according to Australian Standards, AS 1141.16. Angularity number is a measure of relative angularity in a prescribed manner, which is based on the percentage of voids in an aggregate after compaction.

There are also some other properties which determines the durability of an aggregate. Dimension stability is the situation under changing weather conditions, extend to which aggregate swell or shrink when they are taking up water. Excessive shrinkage of aggregates may lead to subsequent shrinkage of concrete. Abrasion resistance of aggregates refers to the ability of aggregates to withstand being worn by the friction by materials of other form. This property of aggregate is also taken into consideration because degradation may occur during the process of handling, stockpiling and mixing. Any abrasion on the aggregates may generate fines which may cause an increase in fines and eventually an increase in water demand. Soundness is another property of aggregates which determines its durability. Soundness is the aggregates' ability to withstand aggressive actions exposed to the concretes. Weather is one of the main factors determining the soundness of the aggregates. Soundness of an aggregate can be determined if it has a satisfactory record from the past. However, tests can be done for aggregates not having a service record. Strength and rigidity of aggregates are important properties. This is because high-strength aggregates are required to achieve concrete of high strength. Aggregates also have to be chemically stable, which prevents them from reacting with other chemical compounds in the concrete or externally in a negative manner.

3.2.1 Density

Density is one of the properties of aggregates which determine the performance of concrete. The density of a particular aggregate is not a measurement of its quality. However, density is related to the porosity of the aggregate, in which, porosity is related to strength. The main usage of aggregate density is to proportion the concrete mixes.

The density of aggregates is mainly described in two ways.

- Particle density, which is the ratio of the mass of oven-dried particles and their saturated surface- dried volume.
- Bulk density, which is the mass of a unit volume of aggregate dried in oven.

3.3.2 Water Absorption

Water absorption is an important parameter as it significantly affects the amount of water needed in a concrete mix to achieve the required water-cement ratio. Water absorption of the aggregates tends to the main reason for the variations in slump and concrete strengths as the moisture content of the stockpiles varies. Due to these factors, prior to commencing a mix design, the moisture content of aggregates in a saturated- surface dry condition is determined. Furthermore, additional water has to be added if the moisture content of the aggregates is lower in the following batches. This is done to maintain the desired workability and strength of concrete.

Generally, water absorption is the quantity of moisture absorbed into the pores of the aggregates. All aggregates contain pores, though this is hard to identify by the naked eye. These pores may be either small, such as dense fine- grained rocks, or large, such as some light weight and porous materials. Meanwhile, as moisture also tends to appear on the surface of the aggregates, the total moisture content is the total of surface moisture and absorbed moisture content.

In the research project, aggregates of size 7mm, 10mm and 20 mm are used in the mix design. Density and water absorption of the aggregates were determined before the mix design was done.

Figure 3.1: Aggregates of Particle Size 7 mm, 10 mm and 20 mm.

3.3 Particle Density and Water Absorption

The method used for determining the particle density and water absorption of coarse aggregates are with accord to Australian Standards, AS 1141.6.1.

The following is a general outline of the method used, which conforms to the Australian Standard.

Apparatus used

The followings are the apparatus used, which also complies with AS 1141.2.

1. Wire basket - Wire basket of a suitable size with wire hangers to suspend it form the balance is used.

2. Water bath - Water bath of a suitable size able to accommodate the wire basket, with at least 50 mm of water covering the top of the immersed basket.

3. Balance - Balance of limit of performance within $\pm$ 5 g, which possesses adequate capacity for the testing.

4. Oven - Oven which operates within a temperature of 105˚C to 110˚C is used.

5. Container - Container which is suitable for the purpose of experiment is used.

6. Towers and dry clothes - Towers and day clothes are used for the purpose drying the clothes.

7. Dishes - Dishes of suitable sizes are used.

3.3.1 Test Preparations for Aggregates

1. A sample of sufficient mass, which allows the preparation of a test portion to retain at least 2 kg of on the 4.75 sieves to 40 mm sieves, is obtained.
2. The samples of aggregates were sieved over a 4.75 mm sieve. The amount of undersized materials is rejected if it accounts for more then 10% of the total.

Procedures

The test procedures used in the project were as follows, which complies with AS 1141.

1. Natural aggregates of 7mm, 10mm and 20mm, were immersed in water a room temperature. It was ensured that the water covered at least 20mm above the top of the materials. The aggregates were immersed in the water for 24 hours. Besides, the sample is stirred occasionally as there is a concern that air bubbles may exist between the aggregates.

2. After the aggregates were immersed in the water, they are then transferred into a basket. The aggregates are then immersed into the water instantly in the bath, situated below the balance. After that, the basket is also shaken to eliminate the air bubbles which may exist. The basket hanger is then attached to the balance. The basket is then weighted together with the materials in the water and then recorded.

3. The basket and aggregates were then removed from the water bath and drained. After that, all of the aggregates are transferred to another dish. As there is a need to determine the particle density and water absorption of the aggregates, the sample is prevented from drying.

4. The empty basket is then placed back into the water bath and a shaking motion of the basket is required to dislodge the air bubbles. After that, the basket is then weighted to the nearest 1 g and recorded.

5. The surfaces of the materials are then dried as the value of both particle density and water absorption are required. Finer aggregates particles were dried by rolling a cloth over them. Meanwhile, the larger aggregate particles are dried individually. Consequently, the aggregates were spread to one-stone deep over a dry cloth and then allowed to surface day. The stones are turned at least once during this period. To accelerate the process of drying a gentle current of air is used, by the use of fan. The drying process is continued until all visible films of water were taken off. However, the surface of the particles will still appear damp.

6. The aggregates tested were then dried in the oven at 105˚C to 110˚C. The mass of the aggregates were then determined and recorded.

3.3.2 Results and Analysis

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Table3.1: Weight of coarse aggregate during and after the testing

Size of aggregate	**20mm**	**10mm**	**7mm**
A, Oven dry mass of aggregate (g)	1445.0	1482.7	1724.5
B, Mass of SSD aggregate in air (g)	1463.2	1502.6	1751.8
C, Mass of SSD aggregate and wire basket in water (g)	1097.6	1125.7	1292.0
D, Mass of wire basket in water (g)	135.0	135.0	133.3

Calculations for coarse aggregate:

$$\text{Bulk Density (Dry)} = \frac{A \times 1000}{B - (C - D)}$$

$$\text{Bulk Density (SSD)} = \frac{B \times 1000}{B - (C - D)}$$

$$\text{Water Absorption} = \frac{(B - A) \times 100\%}{A}$$

20mm natural aggregate:

Size of aggregate (mm)	**A**	**B**	**C**	**D**
20	1445.0	1463.2	1097.6	135.0

$$\text{Bulk Density (Dry)} = \frac{1445.0 \times 1000}{1463.2 - (1097.6 - 135)} = 2886.54 \text{ kg/m}^3$$

$$\text{Bulk Density (SSD)} = \frac{1463.2 \times 1000}{1463.2 - (1097.6 - 135)} = 2922.89 \text{ kg/m}^3$$

$$\text{Water Absorption} = \frac{(1463.2 - 1445.0) \times 100\%}{1445.0} = 1.26\%$$

10mm natural aggregate:

Size of aggregate (mm)	A	B	C	D
10	1482.7	1502.6	1125.7	135.0

$$\text{Bulk Density (Dry)} = \frac{1482.7 \times 1000}{1502.6 - (1125.7 - 135)} = 2896.46 \text{ kg/m}^3$$

$$\text{Bulk Density (SSD)} = \frac{1502.6 \times 1000}{1502.6 - (1125.7 - 135)} = 2935.34 \text{ kg/m}^3$$

$$\text{Water Absorption} = \frac{(1502.6 - 1482.7) \times 100\%}{1482.7} = 1.34\%$$

7mm natural aggregate:

Size of aggregate (mm)	A	B	C	D
7	1724.5	1751.8	1292.0	133.3

$$\text{Bulk Density (Dry)} = \frac{1724.5 \times 1000}{1751.8 - (1292.0 - 133.3)} = 2907.60 \text{ kg/m}^3$$

$$\text{Bulk Density (SSD)} = \frac{1751.8 \times 1000}{1751.8 - (1292.0 - 133.3)} = 2953.63 \text{ kg/m}^3$$

$$\text{Water Absorption} = \frac{(1751.8 - 1724.5) \times 100\%}{1724.5} = 1.58\%$$

Table 3.2: Weight of fine aggregate during and after the testing.

Description	Mass (g)
A, Dry mass of fine aggregate	71.0
B, Mass of SSD fine aggregate	77.3
C, Mass of flask, fine aggregate and water	384.4
D, Mass of flask and water	340.4

Calculations for fine aggregate:

$$\text{Bulk Density (Dry)} = \frac{A \times 1000}{D - (C - B)}$$

$$\text{Bulk Density (SSD)} = \frac{B \times 1000}{D - (C - B)}$$

$$\text{Water Absorption} = \frac{(B - A) \times 100\%}{A}$$

Fine aggregate (sand):

Description	A	B	C	D
Sand	1724.5	1751.8	1292.0	133.3

$$\text{Bulk Density (Dry)} = \frac{71.0 \times 1000}{340.4 - (384.4 - 77.3)} = 2132.13 \text{ kg/m}^3$$

$$\text{Bulk Density (SSD)} = \frac{77.3 \times 1000}{340.4 - (384.4 - 77.3)} = 2321.32 \text{ kg/m}^3$$

$$\text{Water Absorption} = \frac{(77.3 - 71.0) \times 100\%}{71.0} = 4.01\%$$

3.3.3 Calculated Result for Aggregate Density and Water Absorption

Table 3.3: Result of particle density and water absorption of all aggregates.

Aggregate size (mm)	Particle Density (Dry) kg/m^3	Particle Density (SSD) kg/m^3	Water Absorption (%)
20	2886.54	2922.89	1.26
10	2896.46	2935.34	1.34
7	2907.60	2953.63	1.58

Table 3.4: Result of particle density and water absorption of sand.

Description	Particle Density (Dry) kg/m^3	Particle Density (SSD) kg/m^3	Water Absorption (%)
Sand	2132.13	2321.32	4.01

The tables above show the dry particle density, saturated- surface- dry particle density and water absorption for coarse aggregate of size 20 mm, 10 mm, 7 mm, and fine aggregates (sand).

For coarse aggregates of size 20 mm, the water absorption was 1.26%. Meanwhile, aggregates of size 10 mm had a water absorption of 1.34%. The water absorption for 7 mm aggregates was 1.58%. Sand also shows water absorption of 4.01%.

Aggregate dry density refers to the dry mass per unit volume of particles, while aggregate SSD density refers to the saturated-surface dry mass per unit volume of particles. A higher percentage of water absorption means the amount of water trapped inside the permeable voids of the particles, which is consequently transferred from surface-dry condition as a result of soaking of aggregates in the water for 24 hours, to oven-dry mass following the placement of the aggregates into the oven.

The calculated results show that coarse aggregates of a smaller size tend to have a higher percentage of water absorption, compared to coarse aggregates of lower percentage of water absorption, as the water absorption of aggregate size 7 mm is 1.58%, 10 mm is 1.34% and 20 mm is 1.26%. The trend of smaller aggregate sizes leading to higher percentage of water absorption also comply with sand, as sand has a water absorption of 4.01%, which is more than coarse aggregates of size 7 mm. The tables also show an increase in particle density, in both the dry and saturated surface-dry conditions, from smaller sized coarse aggregates, 7mm to larger sized coarse aggregate of 20 mm.

As all aggregates used in the project are natural aggregates, these aggregates may have been exposed to aggressive actions from weather, or the surrounding environment, such as stream beds and river beds. Smaller aggregate sizes have higher density from the tests. This may be due to smaller particles having been through more erosion and abrasion by either with other aggregates, or the effects of wind or water. As a result, the pores and voids near the surface may be eliminated to the minimum. Sand has a lower particle density in both dry and saturated surface-dry conditions. This might be due to sand being small in size, causing the particles to have more voids between each other, although all of the particles are in contact. As a result, there is more space between the particles, leading to lesser density when measured in the test.

As a whole, aggregates with higher percentage of water absorption have more permeable voids in which more water can be held.

3.4 Sieve Analysis

Sieve analysis simply refers to the process of dividing an amount of aggregates into several parts, in which each part is approximately the same sizes. Each fraction involves aggregates of the sizes within a specific limit. These specific limits refer to the sizes of the openings of the sieves.

Sieve analysis is done by a mechanical sieving machine, instead of using man-power by sieving the aggregates manually. This is because more accuracy and consistency can be achieved mechanically as the variation in effort and time applied during the process of sieving is more consistent. It could also result in the saving of time as the process of sieving can be done simultaneously for a few sizes of sieve.

The minimum amount of test portion which are taken was referred to the nominal size of aggregate, with regard to Table 1 given in Australian Standard, AS 1141.11. The table is as follows.

Table 3.5: Minimum Mass of Test Portion for Sieving

Nominal size mm	75	40	28	20	14	10	7	5	Fine aggregate	Fillers
Graded aggregate	30 kg	15 kg	5 kg	3 kg	1.5 kg	800 g	500 g	300 g	150 g	25 g
One-sized aggregate	25 kg	10 kg	4 kg	1.5 kg	700 g	500 g	300 g	200 g	100 g	-

Before the test was conducted, aggregates were separated into coarse and fine aggregates by a 4.75 mm testing sieve. These two batches were tested separately. Test portions were then being tested as the aggregates were relatively clean and free of other impurities.

Apparatus

Apparatus which complies with the Australian Standard, AS 1141.11.2 were used in the process of conducting the sieve analysis.

1. Balance - Balance of limit of performance within ± 5 g, which possesses adequate capacity for the testing.

2. Drying Oven - Oven which operates within a temperature of 105˚C to 110˚C is used, which complies with AS 1141.2.

3. Sample divider - The divider slots should be at least 10% more than the maximum size of the particle. A further requirement was that the width not be greater than twice the size of the maximum particle. However, this does not apply to sample sizes of nominal 5 mm or finer, where the maximum size should be 10 mm.

4. Sieves - The test sieves used should comply with Australian Standard AS 1152.

5. Brush - Brush used should be soft and fine.

6. Mechanical sieve shaker -Mechanical sieve shaker provides better consistency when sieving aggregates.

7. Power source - Power source is required to provide electricity to the mechanical sieve shaker.

Procedures

The test procedures are in accordance with AS 1141.11-1996. The procedures are briefly discussed as follows.

1. The sieves required for the purpose of testing are arranged in a descending order with regard to the different sizes of opening from top to bottom. The sieves are then shaken to ensure that the aggregates are distributed evenly inside each of the sieves.

2. Generally, the aggregates cannot be forced through the sieves manually by using hand, apart from sieves with openings which are greater than 19 mm.

3. The cover which encapsulates the stacks of sieves should tightened by the use of a spanner. The surrounding area of the mechanical sieve machine should be clear of people to prevent any unwanted accidents.

4. The mass retained in each of the sieves were then determined and recorded by using an electronic balance, as stated in Australian Standard.

5. The data obtained were placed into a table form to calculate the percentage of mass passing each sieve.

Figure 3.2: Mechanical Sieve Machine for Coarse Aggregates
(Aggregates of sizes 7 mm, 10 mm, 20 mm).

Figure 3.3: Mechanical Sieve Machine for Fine Aggregetes (Sand).

Figure3.4: Electronic Balance with a Suspended Bucket.

Figure 3.5: Drying Oven.

3.4.1 Calculated Result for Sieve Analysis

Table 3.6: Sieve Analysis for Coarse Aggregates

	Cumulative Percentage of Mass passing %		
Sieve Sizes \ Coarse Aggregate Sizes	20mm	10mm	7mm
19.00 mm	100.000	100.000	100.000
13.20 mm	44.476	100.000	100.000
9.50 mm	8.086	90.506	100.000
4.75 mm	0.525	1.201	18.063
2.36 mm	0.370	0.330	2.095
1.18 mm	0.357	0.305	0.746
PAN mm	0.000	0.000	0.000

Table 3.7: Sieve Analysis for Fine Aggregates

	Cumulative Percentage of Mass passing %
Sieve Sizes \ Fine Aggregate	Sand
2.36 mm	91.3442
1.18 mm	82.1884
600 µm	70.3832
300 µm	47.7793
150 µm	24.1819
75 µm	10.4546
PAN µm	0.0000

Two tables above show the cumulative percentage of mass passing the related sieve sizes for fine aggregate and coarse aggregates used in the project.

The table shows that for 20 mm coarse aggregate, 0.357% of the total mass was left on the pan. Meanwhile, 10 mm coarse aggregate had 0.305% of the total mass remaining on the pan. 7 mm coarse aggregate had 0.746% of total mass left on the pan, which appears to be the highest percentage of mass left on the pan among coarse aggregates. Fine aggregate (sand) had 10.4546% of the total mass which passes 75 µm and eventually left on the pan. 7 mm aggregate had the highest remains of coarse aggregates in the pan while 10 mm aggregate had the lowest remains of coarse aggregates in the pan. This also shows that 7 mm aggregates will possess higher water absorption. This is supported by the result taken in the previous section where water absorption is calculated as 1.58%, which is the highest among coarse aggregates.

The sieve results for the fine aggregates shows that most of the portions of the fine aggregates passed through sieve sizes of 2.36 mm, 1.18 mm, and 600 µm. Most of the fine aggregates passed through sieve sizes of 300 µm and 150 µm. There are also 10.4546% of the fine aggregates remaining on the pan, which indicated that sand also contains a lot of fines.

In conclusion, it has been found that, the amount of fine particles in a certain amount of aggregates will influence the amount of water absorption.

3.5 Mix Design

Mix design refers to the selection of concrete aggregate of appropriate mixed proportions in achieving the desired performance. Various studies have been researched on the properties of concrete with the aim of determining the appropriate selection of mix ingredients, mainly consist of coarse aggregates, sand, cement and water.

Generally, there are mainly two considerations which underlie the basics of mix design. These two criteria are the consideration for strength and the durability of the concrete. Meanwhile, there is also another important requirement which had to be satisfied, which was considerations regarding the workability of the concrete. Practically, the ease of placement of concrete has to be considered. Furthermore, not only the slump at the instance of discharge from the mixer is considered, but the slump loss due to prolong time also had to be taken into consideration. Nevertheless, due to variable needs of site conditions, the workability of concrete should be fixed after all procedures of construction were determined.

There are also some other considerations regarding the mix design. This involves considering how the concrete were transported to the location. For project require huge concrete, it is envisaged to facilitate a concrete batching plant where concrete is mixed on the site, then there is no issue about the transportation of the concrete.

As a whole, mix design which is the process of selecting the mix proportion of concrete, involves decisions regarding the suitable ingredients and proportion of concrete. Meanwhile, it also aims to produce the most affordable concrete with the required properties.

In addition, it is important to bear in mind that there will be a lot of difficulties if the required criteria were not taken into account when selection of the mix proportion is being assessed.

Generally, the aim of the mix design is to achieve the most cost efficient selection and proportion of materials. There are some limiting values of various properties of concrete are of vital importance. The following are the main points:

1. From the structural adequacy point of view, a minimum amount of compressive strength is required.

2. Usually, mix designs aims for the maximum water-cement ratio possible or minimum cement content. This is because the cost of cement is usually considerably higher then the cost of aggregates.

3. However in conditions where the concrete mass is exposed to varying temperature cycle, a maximum amount of cement is used to avoid the mass of concrete from cracking.

4. Further, in conditions where the concrete mass is exposed to a surrounding environment of low humidity, a maximum amount of cement is used to avoid the mass of concrete from cracking due to shrinkage.

5. For buildings such as gravity dams and other water retaining structures, concrete of maximum density is required.

Meanwhile, cementitious materials are also taken into considerations in some occasions. This is because different types of cements constitutes of different chemical compositions. In the project, where an addition of admixtures was required, it is also important to determine the behaviour and chemical reaction of the kind of admixtures used with the cement selected for the concrete mix.

3.5.1 Background of the Process of Mix Design

In actual conditions, the precise determination of the necessary mix proportion by the usage of tables and computer packages is impossible. This is because variations do exist in the actual materials used, and often the properties of such materials cannot be determined quantitatively. In actual practice, properties such as the aggregate shape, grading, texture, dimensional stability and abrasion resistance were hard to determine precisely. Due to these considerations, most of the time a satisfactory mix design is based on accurate calculations, intelligent estimation to establish a mix design which had minimum variation from the actual conditions.

As a result, a trial mix has to be done on the site to determine whether the mix design satisfies the initial requirements. There are also some other factors affecting the properties of concrete in actual mixing, such as efficiency in the process of handling, delay in placement of concrete into the specimen moulds, and finally due to unpredictable weather conditions, which may influence the moisture content in the air, may eventually lead to an increase or decrease in moisture content of the materials used. These contributing factors are considered to have only a minor effect on the properties of the concrete mix. Due to this reason, no adjustment is needed in the mix design. Only some minor adjustment on the site is necessary, such as addition of a little water to maintain the workability of the designed mix.

Besides, the aggregates required for the entire project also cannot be prepared initially due to lack of space to contain them. As a result, additional portions of aggregates are transported to the site when aggregates are inadequate. This was one of the reasons why the properties of the materials vary from time to time. Besides, some times a particular batch of aggregates might contain more dust, which might lead to an increase in demand of water in the mix. Due to these considerations, it is therefore important to ensure that the aggregates are from the same source and the every new batch of aggregates has to be kept in the same condition as the previous batch of aggregates.

3.5.2 Materials used

1. Aggregates of size 7mm, 10mm and 20 mm are used in the mix design.
2. Superplasticisers were used in a batch of mix.
3. Fibres which consist of polypropylene short-fibres, steel-fibres and Fibremesh were used in the project.

3.5.3 Concrete Mix Design

The method used in concrete mix design is the British method. In the British method mix design, considerations are placed on the strength, durability and workability aspect of concrete.

A characteristic strength of 32 MPa, assumed to be taken at an age of 28 days was used. According to Australian Standards HB 2.2 – 2003, concrete should be designed at 32 MPa for exposure classification B1. Exposure classification B1 included reinforced or prestressed concrete members in areas and conditions such as the interior of an industrial building subjected to wetting and drying repeatedly.

The target strength is the average strength of the concrete when tested. The target strength are calculated by the equation as follows,

$$T = C + 1.65S$$

Where, T = Target strength

C = Characteristic strength

S = Standard deviation of a large number of test results.

Calculations for the target strength in the project was as follows,

$$T = C + 1.65S, \quad \text{where } C = 32 \text{ MPa and } S = 5.34$$

$$T = (32) + 1.65(5.34)$$

$$= 40.81 \text{ MPa}$$

After the target strength had been determined, the co-responding water-cement ratio is determined. Generally the strength of concrete relates to the water-cement ratio. A lower water-cement ratio in concrete yields higher strength. In the project, the main purpose of introducing Superplasticisers was to improve the workability of the short-fibre reinforced concrete. Therefore, the water: cement ratio was kept constant.

After that, the aggregate grading curve (plot of percentage of aggregates passing versus various sieve seizes) which was done in the third chapter was used in the selection of the aggregate-cement ratio. The selection of a suitable aggregate–cement ratio depends on few criteria, which were,

- Nominal size of aggregate
- Shape classification of aggregate
- Concrete slump
- Water-cement ratio
- Choice of aggregate grading

After the aggregate-cement ration had been determined, calculations of mix quantities were carried out. The calculated water-cement ratio was 0.56 and the aggregate-cement ratio was 4.9.

As all required data are obtained, the amount of concrete needed in one batch of mix was calculated. Adjustment for the amount of water was done to accommodate corrections for moisture in the aggregates.

The amount of materials required in a mix was as below:

For 1 batch

	1 batch	Unit
Cement	21.49	kg
Water	9.72	kg
20mm	37.26	kg
10mm	10.65	kg
7mm	18.15	kg

The mix was designed to accommodate a mix of 60 Litres of concrete mix. The designed mix of 60 L was higher than what is required for the volume of concrete needed in a batch of concrete mix for the project. This was because losses of concrete during the process of mixing had to be accounted for, which also ensures that there will be adequate freshly mixed concrete for all the specimens.

In the project, specimens consist of small cylinders of 100mm x 200 mm, large cylinders of 150mm x 300mm and a beam of 150mm x 150mm x 700 mm, were adopted. The actual volume required in a mix for all the specimens was 49.95 L.

3.6 Amount of Fibres Required

0.5%, 1.0% and 1.5% were adopted as the amount of fibres required in one batch. These three values of fibre content were used for steel short-fibres, polypropylene short-fibres and fibre mesh for comparison purposes. Graphs regarding comparison between fresh property tests of the three kinds of short-fibres with different fibre content, such as Vebe tests, Slump tests and Compacting Factor tests were plotted.

Using the formula below, the minimum or critical volume of short- fibres in a mix was determined:

$$V_{cr} = \sigma_{mu} / (\sigma_{mu} + (\sigma_{fu} - \sigma_f'))$$

Where, σ_f' = stress on the matrix during the failure of matrix.

σ_{mu} = ultimate strength of the matrix.

σ_{fu} = ultimate strength of fibre.

As a result,

Amount of Fibres Required

Description of Short-fibres	0.50%	1.00%	1.50%	Total	Unit
Steel	2.34	4.68	7.02	14.04	kg
Polypropylene	0.27	0.54	0.81	1.62	kg
Fibremesh	0.273	0.546	0.819	4.68	kg

3.7 Amount of Superplasticisers Required

The dosage rate for the superplasticizers is 60 to 90 ml per bag of 40 kg cement, which were the values recommended by the manufacturer. The dosage of the superplasticizers is used to adjust the workability of the short- fibre-reinforced concrete, in which an optimum dosage rate of superplasticizers to achieve a suitable workability for high percentage application of fibres in fibre-reinforced concrete is found.

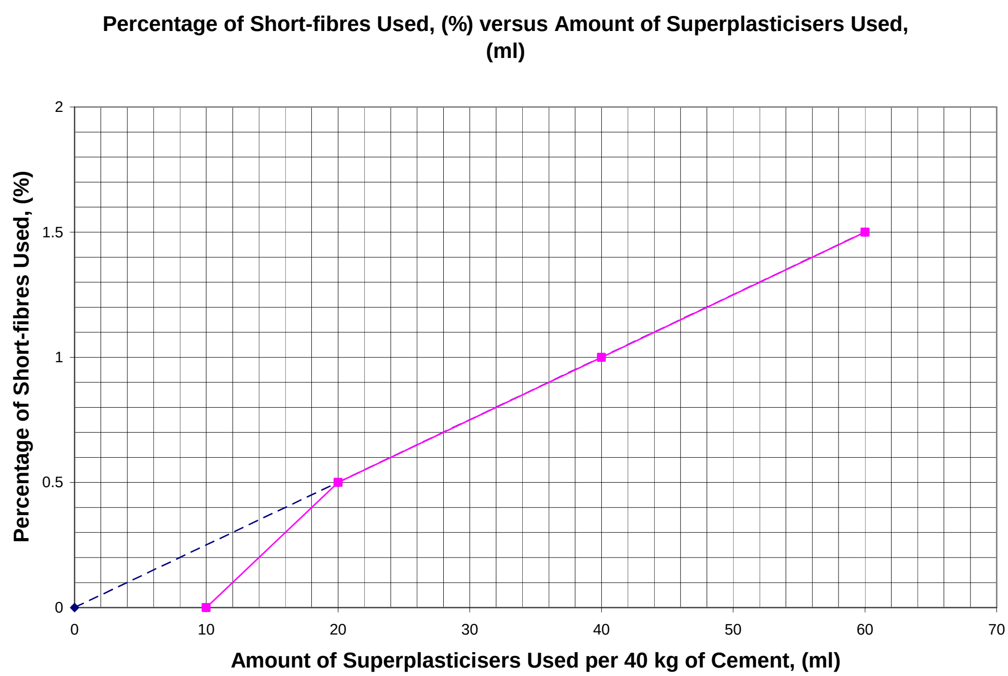

Figure 3.6: Percentage of Short-fibres versus Superplasticisers used.

As a conclusion, the dosage rate adopted in the tests were 20 ml Superplasticisers per 40 kg of cement for 0.5 % of fibres, 40 ml Superplasticisers per 40 kg of cement for 1.0 % of fibres, and finally 60 ml Superplasticisers per 40 kg of cement for 1.5% of fibres. This application rates serves the same for all three kinds of fibres used in the research, which are polypropylene short-fibres, steel short-fibres and Fibremesh.

3.7.1 Dosage of Superplasticisers

The dosage of Superplasticisers used depends mainly on whether it is used for increasing the workability of the concrete of for increasing the strength of the concrete. To increase the strength of the concrete, the dosage of Superplasticisers is higher, compare the usage of Superplasticisers to increase workability.

Usage of high dosages of Superplasticisers is possible due to the fact that Superplasticisers do not have a significant effect on the surface tension of water, which does not entrain large amount of air.

The effectiveness of Superplasticisers of a given dosage relies on the water: cement ratio of the mix. When a fixed dosage of Superplasticisers is used, the percentage of water reduction that maintains the same workability is much greater for low water: cement ratios compared to high water: cement ratios.

Compared to the use of low dosage of Superplasticisers to produce high workability of normal-strength mix, the use of a high dosage of Superplasticisers faces some problem in the selection of the admixture–cement combination, where Superplasticisers have to be compatible with the cement used in the respective mix.

As stated in the first chapter, the dosage of Superplasticisers recommended by the supplier is of little value. The compatibility of Superplasticisers with cement depends on several factors, such as the physical properties and the chemical properties of the cement used. Usage of finer cement particles will eventually lead to a higher dosage of Superplasticisers. Meanwhile, a higher content of C_3A cause reduction in effectiveness of Superplasticisers.

Due to these reasons, trial testing is required to determine the dosage of Superplasticisers which should be applied in the project. As a result, several trial tests on small batches were carried out on plain concrete prior to the commencement of the project. The primary aim of the trial mixes is to observe the performance of Superplasticisers with the cement used in the project, which basically refers to the workability of each trial batches.

3.8 Control Batch

For plain concrete with no addition of short-fibres, two batches are carried out. The first batch consists of only plain concrete, and the second batch consists of plain concrete with the addition of 10 ml of Superplasticisers. These two batches are regarded as the control batches, as the results taken from other batches will be taken to be compared with the results taken from these two batches.

3.9 Mixing of Concrete

The primary requirement when a mix was carried out was to ensure that the mix ingredients was mixed thoroughly, where fresh concrete produced consists of aggregates which were covered thoroughly by cement paste. Furthermore, the importance of achieving uniformity in the mix was also stressed. In the project, the mix ingredients involve cement, water, sand, aggregates, fibres and Superplasticisers.

3.9.1 Mechanical Concrete Mixer

There are a few requirements for the performance of a concrete mixer to be satisfactory. Firstly, the concrete mixer used has to produce a uniform mix. Secondly, it is also an important requirement that the concrete have to be discharged without affecting the uniformity of the mix.

A non-tilting mixer was used in the project. However, one of the disadvantages of using a non-tilting mixer compare to tilting mixer was the discharge rate are relatively slower. However, this was not a major concern in the research as only a small batch of concrete mix was carried out at a time. Therefore no delays occurred.

The type of non-tilting mixer used in the project is called pan-type mixer. It is generally immobile, which involves two paddles rotating around a vertical axis in a circular pan. As a result, the concrete in the pan were mixed thoroughly. Usage of pan mixer allows one to observe the concrete in the mix and subsequently allowing any further adjustments to be made. Pan mixer was suitable to be used for small scale production, such as in laboratories for research or testing purposes.

Some safety issues also were involved with the usage of the mechanical concrete mixer. The mechanical concrete mixer had to be disconnected from its power supply when it was not in use. Secondly, the lid of the mechanical concrete mixer also had to be closed when the mixer is operating. Furthermore, it was also important that more than one person was presence when the mixing process is carried out. This was because, in case any accidents occur, the other person can reach for help.

Figure 3.7: Mechanical Concrete Mixer

Apparatus

The following equipments were prepared before the process of mixing was carried out to ensure that no delay will occur in carrying out the tests for fresh properties of concrete and subsequently the placement of concrete.

1. Scoop - scoops are used for moving the materials either in preparation of the materials of for transporting the freshly mixed concrete into the moulds.

2. Leveller - Used for the finishing of concrete surface, to achieve an inviting appearance.

3. Buckets - Used as containers during the preparation of the materials.

4. Balance - Balance of limit of performance within $\pm$ 5 g, which possesses adequate capacity for the testing.

5. Container - Used as a container to store the freshly mixed concrete.

6. Power source - Power source is required to provide electricity to the mechanical concrete mixer.

7. Mechanical Concrete Mixer - A pan type mixer was used in the project to achieve a uniform mix of concrete.

Procedures

1. All required water, cement, aggregates and sand were weighted and placed aside according to the quantity determined.

2. The amount of Superplasticisers required for a particular mix was then carefully measured.

3. Before the mixing begins, safety and health issues had to be addressed. Ear plugs, mask and gloves had to be worn.

4. All of the materials were poured into the mixer to be mixed.

5. Water and short-fibres were being introduced gradually into the mixer during the process of mixing to achieve uniformity of the mix.

6. After that, the cover of the mechanical concrete mixer had to be enclosed for safety considerations.

7. The freshly mixed concrete was then discharged from the mixer and tests regarding fresh properties of the concrete were carried out.

8. It was also essential that the mechanical concrete mixer was disconnected from the power source.

3.10 Specimens

Specimens which were prepared consist of two large cylinders (150mm x 300mm), five small cylinders (100mm x 200mm), and two beams (150mm x 150mm x 700mm) are used.

The concrete was poured into the specimens. After that, the specimens were compacted, levelled and finally placed into the curing room for 28 days.

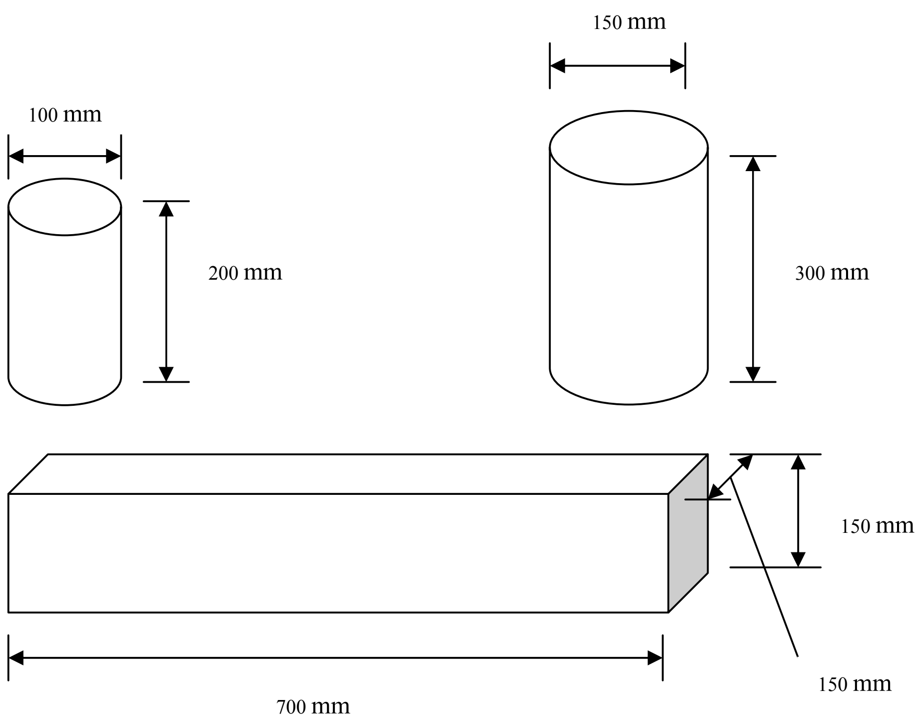

Figure 3.8: Specimens Used in the Project

Figure 3.9: Preparation of Speciemens

Figure 3.10: Preparation of Materials

3.11 Workability with Time

Superplasticisers have an effect on the cement particles, as long as the Superplasticisers molecules are adequately present to cover the exposed surface of the cement particles. However in some cases, the Superplasticisers used may be inadequate, as some of the Superplasticisers molecules are entrapped in the products of hydration of cement. Due to this, workability of concrete might be severely lost.

Due to the phenomena wherein the effectiveness of Superplasticisers declines with time, adding Superplasticisers in a few intervals can be beneficial. The additions of Superplasticisers, which also can be termed as re-dosage of Superplasticisers, are used when the concrete is being transported to another site in a truck. For restoration of adequate workability, re-dosage is required. The additions of Superplasticisers have to be enough to cater for its reaction with cement particles and on the products of hydration. Due to this, a high re-dosage of Superplasticisers is required, as a small re-dosage will turn out to be ineffective.

However, although an increase in the dosage of Superplasticisers will benefit the workability of the concrete, the problem of increasing bleeding and segregation may occur. Some side-effects may also emerge, such as set retardation and a variation in amount of entrained air. The second dosage of the Superplasticisers may be able to increase the workability of the concrete, but it has the disadvantage of a rapid decrease in workability rapidly. As a result, re-dosage of the concrete is best to be done immediately before the placement and compaction of concrete.

Recently, the through research and the development of technology, Superplasticisers which are effective for a longer period have emerged. As a result, re-dosing before the placement of concrete is not required, and problems associated with Superplasticisers re-dosing can be avoided.

However the concreting job which involves compaction and placing of concrete was carried out immediately after the mixing of concrete in this project. Therefore, there was no issue regarding Superplasticisers re-dosing.

3.12 Compaction

Compaction was one of the important procedures to produce concrete which allows the concrete specimens in the project to achieve the targeted design strength and density. Furthermore, a satisfactory compaction also had a positive effect on the finishing of concrete surfaces. However, good surface finishing does not necessary means having a good compaction.

Compaction was being carried out after the freshly mixed concrete was being placed in the specimens. The main purpose for the compacting process to be carried out was to expel the entrapped air between the voids in the freshly concrete. Voids will inevitably be reduced via this process and eventually the aggregates will be more packed, which will lead to an increase in density. As a result, the ultimate strength of the concrete will increase. Meanwhile, there are also some other desired effects, such as an improvement in durability, shrinkage and the creep characteristic of concrete. Furthermore, the effect of honey comb was minimised, which resulted in a better visual appearance.

In the project, electrical powered vibrator was used. It is relatively light and easy to be handled. There are mainly two stages in the process of compaction of concrete. The first stage was mainly meant to consolidate the concrete in the specimen. This process allows the concrete to fully fill up the specimens and therefore the mould could be fully filled up. The second stage was the reduction of air bubbles entrapped in the freshly mixed concrete. Due to this reason, when compaction was being carried out, it was to be ensured that the duration of compaction was sufficient for both the consolidation and air expulsion stages of concrete. However, excessive compaction may lead to undesired effects such as segregation.

3.13 Curing

Generally, curing is done to prevent the loss of moisture during the early hardening stage of concrete. It facilitates the process of hydration of cement. To achieve the required strength, a certain period is allowed for the process of curing. In the project, curing is done by placing the concrete specimens into a curing room, in which the moisture of the surrounded area is under controlled. As a result, curing was achieved as the surface of the concrete specimens was continuously being moistened in the curing room. Due to health considerations, mask was worn when entering the curing room.

The specimens were placed overnight to allow for setting. The specimens were then removed from the moulds during the next day and placed into the curing room for 28 days for the process of cement hydration to take place.

3.13.1 Cement Hydration

Cement hydration is the chemical reaction when cement was mixed with water. The process was rapid initially, but pace of hydration decreases later. Hydration of cement will eventually form new chemical compound, which lead to an increase of strength in concrete. Chemical reaction will be halted if sufficient moisture does not exist.

Figure 3.11: Curing Room

Figure 3.12: Electric Vibrator

Figure 3.13: Safety glasses, gloves, mouth cover and ear plugs used.

3.14 Safety & Health Issues

Safety & Health are public concerns far on top of personal interest. The safety & health issues involved in the course of the project were carefully addressed, as these were important aspects in all engineering project and research studies. All safety measures and precautions were taken to avoid any possible hazardous and danger occurrence.

When sieve analysis was being carried out, the cap of the machine was ensured to be firmly locked. Keep our distance from the machine during operation. Furthermore, as enormous noise was generated in the process, ear plugs were worn when the machine is energized.

During the preparation of materials for the concrete mix, hand gloves were worn. Hand gloves are essential for the protection of our complexion against possible abrasion and contact with cement.

When the operation machine was operating, the safety of the people in the vicinity should be taken care. The cap for the mixing machine should be always kept close when mixing is in progress.

Meanwhile, safety shoes have to be worn as there may be a risk of impact for one's foot being struck by falling object, such as during handling and transportation of the specimens for testing and curing purposes. Meanwhile, mouth mask also has to put on when entering the curing room due to health considerations.

Lastly, safety glasses also have to be worn when various tests were being carried out to provide protection for our eyes. Furthermore, maintain house-keeping to provide clean surrounding environment, and avoid any obstacles always to offer easy accessibility in case of emergency.

3.15 Summary

This chapter had covered various aspects regarding the experimental methodology involved in the project. These range from the determination of particle density and water absorption, sieve analysis, mix design, mixing process, compaction, curing and also the safety and health issues involved in the project.

The amount of short-fibres and Superplasticisers required in each batch of concrete mix were discussed. Furthermore, the need for a control batch and some background information regarding some of the aspect related to experimental methodology were also discussed.

In conclusion, the test procedures involved in the project was generally in compliance to Australian Standards whenever available. The project had been carried out smoothly without any unwanted incident due to strong emphasis on safety issues.

CHAPTER FOUR

TEST PROCEDURE

4.1 Properties of Fresh Concrete

Essentially many tests are carried out routinely on the freshly mixed concrete ensuring persistent properties such as the consistency of the concrete, air content, mass per unit volume, and sometimes also involve the bleeding characteristic of the freshly mixed concrete. Workability is strongly related the consistency of the concrete, where the related consistency refers to the ability of the freshly mixed concrete to maintain its original shape when not supported by any means, and essence that the supported concrete does not deteriorate and fall apart.

According to Bartos (1992), the importance of the properties of the fresh concrete had increased due to the emergence of a wide range of admixtures. In the past, concrete of low workability had been linked with concrete of poor strength and low durability as an outcome. However, this view had been changed recently due to the introduction of admixtures, which permits higher workability of fresh concrete, which also result in concrete of satisfactory high strength and high durability quality. Although the cost of the mix might be increased due to the introduction of the admixtures, however, the cost of the admixtures involved were often totally covered by savings in the process of the construction.

Dry mixes usually face problems as they were frequently hard to compact and, which always involved considerable energy and cost. Furthermore, potential high strength and high durability of the dry mix could not be achieved in the absent of full compaction. Meanwhile, concrete of satisfactory workability also plays a vital part in the construction of in-situ concrete.

Meanwhile, there are various desirable properties of concrete. Firstly, the concrete should be easy to mix. The materials and admixtures which are included in the concrete mix have to be rapidly and uniformly mixed throughout the concrete with a minimum energy requirement. The uniformity of mix design in following concrete mixes must also be ensured. Secondly the concrete mix must also be ensured to possess satisfactory workability to allow the concrete to fully fill up the readily prepared form work with either no or minimum compaction. It is important that the uniformity of the concrete be maintained at a satisfactory level during logistic process while concrete is transported and placed with selected methods. Lastly, the concrete is also required to be capable of achieving the required finishing or surface treatment.

As a whole, the concrete should have a satisfactory workability during the entire period of the process, which involves mixing, transporting, placing, compaction and finishing of the fresh concrete. The fresh properties of the fresh concrete were important, which was also due to one of its main advantage, which was the freedom of shaping the concrete. This advantage provides high structural efficiency, enable architects to express and allow their design to put into uniform practice.

Compared to the harden state of the concrete, error made with concrete which was still fresh may be remedied during the period of construction. However, when the concrete started to settle and harden, the errors made could be hard to remedy. In the usual procedure, defective concrete of fresh state can be rejected immediately, provided adequate supervisory effort was made to ensure the quality of the fresh concrete. However, problems still exist if the job of inspection was not done accordingly, which eventually caused defects on the structure.

Basically, fresh concrete mix consists of materials such as aggregates and some of the others solid particles which are included in the cement paste. Meanwhile, a small proportion of air may also exist in the mix. The cement paste presence in the mix acts as a binder and a separating medium for the aggregates in the mix.

Fresh concrete is a transition state where it was between the positions of initial assemble of aggregates, cement and other ingredients at the initial state of the mix and the eventual harden state of concrete. However, according to Bartos (1992), the most commonly adopted approach for the determination of fresh concrete was the determination of the initial and eventual setting times of the concrete. Generally, the initial setting times are taken as the point of time at which the internal structure of the hydrating cement paste developed until the concrete was too stiff, which inhibit effective placement and compaction of the cement paste by normal means. Meanwhile, when the concrete paste stiffness to a point at which the concrete achieves a level which was of useful and measurable strength.

Consistency

These two words are most frequently used to discuss the fresh properties of the concrete. Generally, the term ‘workability’ is used when the mixes involved any kind of aggregates which are mixed with cement. Meanwhile, the term ‘consistency’ is applied when cement is mixed with water in the absence of aggregates.

Consistency is commonly known for uniformity or regularity for liquids and suspension in other processes. Workability depends largely on various aspects, such as the ease of compaction, ability to fill various shapes, and finishing ability. Furthermore, there are several other parameters and characteristic of concrete which had been attempted by others to express workability, such as viscosity, yield stress, stability, cohesion, segregation and compactabiliy.

Workability

Workability is defined as the combination of properties of the fresh concrete, which allows it to be place, compacted and finished easily without the loss of homogeneity, according to Paillere, Bassat and Akman (1992). It involves some of the properties which are stated below.

1. **Consistency** : The relative ability to flow for freshly mixed concrete.
2. **Plasticity** : Involves the property of freshly mixed concrete, which dictates the fresh concrete’s ability to resists deformation or ease of moulding.
3. **Cohesion** : Involves the property of a freshly mixed concrete to maintain its homogeneity.
4. **Consistency Loss** : Involves the reduction in the aspect of consistency, which happens with time. This relates to an initial measurement which is taken from the same batch.
5. **Pumpability** : Involves the ability to transmit fresh concrete by pressure by the use of pressure through either a rigid pipe or a flexible conduit.

6. **Compactability** : Involves the ability of freshly placed concrete to reduce its initial volume the minimum achievable volume, by means of vibration, centrifugation, tamping or the combination of few of these methods. It aim is to mould the fresh concrete within the moulds to eliminate voids other than entrained air.
7. **Finishability** : Involves the ability of fresh concrete to be leveled, smoothed or enhance the quality of the surface to provide the desired appearance and serviceability.

Segregation refers to the non-uniform distribution of solid constituents of concrete in its fresh state.

Frost resistance refers to the condition where deterioration occurs when freezing takes place in the course of setting of concrete.

4.2 Fresh Concrete Tests

When the concrete was fully mixed, three types of tests to access the fresh properties of concrete were carried out. The tests consist of Slump test, Vebe test, and Compacting Factor test. Guide lines in the Australian Standard were followed.

4.2.1 Slump Test

Slump test was first developed in USA around 1910. This test is relatively inexpensive, easily portable and maintained. However, this test is sensitive to various factors such as the time elapse between mixing of the concrete of the concrete and their testing. Basically, slump test measures the height difference of the freshly mixed concrete, before and after the removal of the mould for the slump test.

According to Neville (1999), slump test is very effective for detecting the variations in the aspect of uniformity of the concrete, when the nominal proportions of the mix are provided. The slump test consists of a cone which was 300 mm in height, which is placed on a smooth and horizontal surface. The cone has a small opening at the top. Besides, a rod for compacting the concrete was also used in the procedure of testing.

Slump test is a test used in the site work all around the world. It gives an indication about the workability of the concrete and also very useful in detecting the variation in the uniformity of the mix.

Advantages

Slump test possesses a lot of advantages compare to other means of tests. Firstly, the equipments for slump test were relatively cheap, easily portable and maintained. Secondly, the procedure for testing is simple and fast. And the results could be obtained directly, regardless of any complicated numerical processing and conversions. Furthermore, slump tests are the most broadly used tests for fresh concrete, which is quite familiar by many operators.

Disadvantages

However, there are difficulties in developing a theoretical model for the test, in order to interpret the results obtained from the test with regard to the fundamental theological characteristics.

Apparatus

The slump test was carried out between April to September 2004 in accordance to AS 1012.3.1 – 1998:

1. Mould - the mould for the slump test consists of a hollow cone shaped mould, which was made from galvanised steel sheet. The steel sheet used usually varies between 1.5 mm to 2.0 mm. appropriate foot pieces and handles for holding the mould in position during filling of concrete. The internal surface of the mould should also be smooth. The dimension required for the mould are as follows,

   - Bottom diameter for opening – 200 $\pm$ 5 mm
   - Top diameter for he opening – 100 $\pm$ 5 mm
   - Vertical height of the mould – 300 $\pm$ 5 mm

2. Rod - the rod used for compaction of the fresh concrete consists of a metal rod of 16 + 1 mm in diameter. The rod was about 600 mm in length, with one end tapered for approximately 25 mm to a spherical shape, having approximately 5 mm of radius.

3. Scoop - scoop, which is used to move fresh concrete, was made from non-absorbent material. Besides, it also should not react with the cement paste. Scoop of rounded mouth was preferred.

4. Base plate - the base plate consists of a smooth, rigid, non-absorbent material. Meanwhile, the base plate should be designed to a minimum thickness of 3.0 mm.
5. Ruler - a ruler graduated in millimeters was used.

Procedures

1. The test was carried out immediately after the mixing of the fresh cement was completed.

2. The internal surface of the mould was thoroughly cleaned, ensured to achieve the optimum results.

3. The internal surface in the cone was moistened. This was done by using a wet cloth, which was used immediately before the slump test was carried out.

4. The mould was then placed on a smooth, horizontal surface. Besides, a leveled base plate was also placed under the apparatus. Further more, the apparatus must also be free from shock and vibration. Then, the mould was being held firmly in position, by standing of the foot pieces provided, which locked the base plate when the mould was being filled by the cement.

5. The procedure from the starting step to the last step was ensured to be carried out without any form of interruption. The test was also ensured to be completed within 3 minutes.

6. When the concrete is readily mixed, concrete is filled into the mould in three layers. Each of the layers was about one-third of the height of the mould. Furthermore, the volume at the up most layer was ensured to be sufficient to more than fill the mould after the process of rodding. When addition of concrete was being carried out at the top layer of the concrete, it was ensured that the top layer of the concrete was not compacted.

7. Each of the three layers was being rodded by 25 strokes of the rounded end of the rod. The strokes were done in a uniformly distribute manner on the surface of the exposed concrete. The rod was inclined slightly for the compaction of the bottom layer. Further more, excessive contact with the plate was avoided when roddings were carried out.

8. When filling and rodding of fresh concrete for the top layer was being carried out, the concrete above the mould was gathered. When concrete subsided after the action of rodding, more concrete was added to ensure that there was an excess of concrete at the top of the mould.

9. When the top layer was completely rodded, the excess surface of the concrete was taken off by a rolling motion of the rod. As a result, the mould was fully filled. The surplus of materials from around the base of the mould was removed, without imposing any vibration or movement on the mould. The mould was exerted with a constant downward pressure until the removal of the mould. After that, the mould was removed slowly form the concrete by raising the mould carefully and vertically, which allowed the concrete to subside.

10. The slump was immediately measured by determining the difference between the average top surface of the slump and the height of the mould, which was approximately 300 mm.

11. If the concrete slump collapsed laterally or shears, it was necessary to repeat the test with another portion of the concrete from the same mix.

Figure 4.1: Slump Test.

4.2.2 Compacting Factor Test

Compaction factor test was developed in Britain in the late 40s. This test was known in some places as Glanville's Compaction Factor test. The main purpose of this test to be conducted was to measure the degree of compaction exerted by a standard amount of work onto a sample of fresh concrete.

Compacting Factor Test is suitable for assessing fresh concrete with medium workability. The preferred value for the compacting factor was between 0.70 and 0.95. Besides, this type was used when the size of aggregates in the mix does not exceed 20mm.

The basic apparatus use for the compacting factor consists of a very heavy stand in which a base and a column were also included. The heavy column supports two huge iron-made funnel-shaped hoppers, which was mounted above each other. Meanwhile, each of the hopper was equipped with a quick release trap door. The inner surface of the hopper was ensured clean and smooth for accurate results. Lastly, a portable cylindrical iron-made container was placed at the base of the stand, which was situated directly below the two hoppers.

According to Neville (1999), the relation between compactor factor and slump test was,

Table 4.1: Description of workability and Compacting Factor

Description of workability	Compacting Factor	Corresponding Slump
Very low	0.78	0-25
Low	085	25-50
Medium	0.92	50-100
High	095	100-175

Compacting factor, which is the degree of compaction, is measured by the density ratio. It is the ratio of the density of the concrete achieved on the test to the density of same fully compacted concrete.

Advantages

Compacting factor test offers some indication of the compatibility of a fresh concrete mix.

Disadvantages

The apparatus for the compacting factor test is very heavy and not easily portable. The accuracy of the balance affects the precision of the results acquired. It also involves periodic maintenance on the apparatus involved. Furthermore, the workability aspect which offered by this test is also similar to slump test. Compare to slump test, the results from this test were obtained through calculations.

Apparatus

The compacting factor test is carried out in accordance with AS1012.3.2 1998.

1. Compacting Factor Apparatus - the apparatus for the compacting factor consists of two conical hoppers, which are mounted above a cylinder. The hoppers and cylinder were ensured to be made from materials which was not easily attacked and eroded by cement pasted.

2. Towels - Two towels were needed.

3. Scoop - scoop, which is used to move fresh concrete, was made from non-absorbent material. Besides, it also should not react with the cement paste. Scoop of rounded mouth was preferred.

4. Rod - the rod used for compaction of the fresh concrete consists of a metal rod of 16 + 1 mm in diameter. The rod was about 600 mm in length, with one end tapered for approximately 25 mm to a spherical shape, having approximately 5 mm of radius.

5. Balance - a balance which could be used to weight items to an accuracy of 0.1 percent in required.

6. Vibrator - the vibrator use must comply with the requirement of Australian Standards, AS 1012.8.

7. Level - a lever was required in the process.

Procedures

1. Firstly the internal surfaces of the hoppers and cylinders must be checked to ensure the cleanliness and free form any set concrete.

2. Just before the commencement of the test, the internal surfaces of the hoppers and the cylinders had to be moistened with a damp cloth.

3. The apparatus for the compacting factor was placed on a level rigid surface which was free from any vibration and shock.

4. Some concrete was gently placed into the upper hopper to be tested using a scoop. When the upper hopper is fully filled, the trap door is opened to allow the concrete to free fall to the lower hopper. This was done four minute after the completion of mixing.

5. At the instance when the concrete had come to a rest, the cover of the cylinder was uncovered, and the trap door for the lower hopper was opened for the free fall of concrete into the cylinder.

6. The excess of concrete which remained on the top level of the concrete cylinder was cut off by holding a trowel in each hand. The trowels were moved simultaneously from both sides across the top of the cylinder with the plane of the blades kept at a horizontal level. The outer part of the cylinder was then cleaned.

7. The mass (m_1) of the concrete in the cylinder was then determined to the nearest 10 g. this mass was also known as the 'mass of the partially compacted concrete'.

8. The cylinder was then emptied and then filled with the freshly mixed concrete at approximately 50 mm deep. Then the layers were being rodded or vibrated until full compaction was achieve. The top surface of the fully compacted concrete was then carefully strike off and finished with a level. Lastly, the outer part of the cylinder had to be clean.

9. The mass of the concrete in the cylinder had to be determined to the nearest 10 g. the mass recorded was known as ‘mass of fully compacted concrete’ (m_2).

10. The procedures involved in compacting factor value had to be carried out as soon as possible with minimum delay to ensure the accurateness of the results.

11. The compacting factor was determined by using the equation,

Compacting factor = Mass of partially compacted concrete (m_1) / Mass of fully compacted concrete (m_2)

Figure 4.2: Compacting Factor test.

4.2.3 Vebe Test

Vebe test was known to be developed by Victor Bahrner of Sweden in 1940's. This is a test developed from the remoulding test. In vebe test, the inner ring of Power's apparatus is omitted. Besides, the compaction is achieved by vibration instead of jolting.

Basically, Vebe test, is based on the measuring the time required to remold a sample of fresh concrete into a cylindrical cylinder. The process of remolding is assisted by pressure and vibration. It is good in assessing concrete of low workability. The initial stage of the test was similar to slump test, in which Vebe test was like having a slump test done inside a cylindrical test cylinder.

Vebe test was suitable for accessing concrete of low workability, stiff and dry mixes, which have very low or even to the extent of zero slump. Due to this, Vebe tests were most frequently used in the production of high-strength concrete with low workability. In these conditions, the concrete was usually compacted by the usage of intense vibration or pressure.

The test consists of a cylindrical container, which was designed to be attached to the top of a small vibrating table. Furthermore, a vertical column which was able to rotate was attached to the base. Furthermore, the column was attached with two arms, where one was used to carry a funnel and the other one supports a sleeve, which consists of vertical rod carrying a weight. A transparent plastic disc was also fixed to the end of the rod. Lastly, a mould which was made of metal which was similar the slump mould in terms of the dimensions was used. However, the mould was without the holding down brackets at the base.

Advantages

Vebe test is a good method for the assessment for concrete of low workability, dry or concrete of zero slump. Furthermore, the apparatus for the Vebe test was also well suited for laboratory factory use. The test result also can be taken directly without any further conversions or calculations.

Disadvantages

This test is only effective for the determination of concrete of very low workability. Besides, it requires a connection to the electricity supply.

Apparatus

1. Consistometer

   a. Container - a metal container with an internal diameter of 240 ± 5 mm and length of 200 ± 5 mm was used. The container must also be water-tight, fitted with handles and also protected from corrosion. The container was provided with wing-nuts to clamp it onto the vibrating table.
   b. Mould - the mould of cone shape was made of metal with thickness of at least 1.5 mm. the top and bottom part of the mould should also be opened. The mould had the diameters of,
      i. Bottom diameter - 200 ± 5 mm
      ii. Top diameter - 100 ± 5 mm
      iii. Vertical height - 300 ± 5 mm
   c. Disc - the disk was a transparent horizontal disc attached to the guide bar, and was intended to slide vertically through a guide sleeve, which was mounted onto the swivel arm. The swivel arm was fixed into position by a screw.
   d. Vibrating Table -the dimension of the vibrating table was 380 mm in length and 260 mm in width. Furthermore, the table was also supported by four rubber shock absorbers.

2. Scoop - scoop, which is used to move fresh concrete, was made from non-absorbent material. Besides, it also should not react with the cement paste. Scoop of rounded mouth was preferred.

3. Rod - the rod used for compaction of the fresh concrete consists of a metal rod of 16 + 1 mm in diameter. The rod was about 600 mm in length, with one end tapered for approximately 25 mm to a spherical shape, having approximately 5 mm of radius.

4. Stopwatch **-** a stopwatch of at least 0.5 s of digits was needed.

Procedures

The vebe test was carried out in accordance with AS 1012.3.3 1998:

1. Firstly the internal surfaces of the container and conical mould must be checked to ensure the cleanliness and free form any set concrete.

2. Just before the commencement of the test, the internal surfaces of the container and the conical mould had to be moistened with a damp cloth.

3. The apparatus was then placed on a rigid surface which was free from any form of vibration. The surface of the table was ensured to be leveled. The container was then placed on the table with two wing nuts locked to it. The conical mould was then placed concentrically inside the container and the funnel was then swung into position, and then lowered over the top of the mould. After that, the screw was being tightened to ensure that the mould stayed put.

4. When the concrete is readily mixed, concrete is filled into the mould in three layers. Each of the layers was about one-third of the height of the mould. Furthermore, the volume at the up most layer was ensure to be sufficient to more than fill the mould after the process of rodding. The scoop was being moved around the top edge of the mould to ensure the distribution of concrete within the mould as symmetrical.

5. Each of the three layers was being rodded by 25 strokes of the rounded end of the rod. The strokes were done in a uniformly distribute manner on the surface of the exposed concrete. The rod was inclined slightly for the compaction of the bottom layer. Further more, excessive contact with the plate was avoided when rodding.

6. When filling and rodding of fresh concrete for the top layer was being carried out, the concrete above the mould was gathered. When concrete subsided after the action of rodding, more concrete was added to ensure that there was an excess of concrete at the top of the mould.

7. When the top surface of the concrete had been rodded, the set-screw was loosen, then the funnel was swung backwards through 90 degrees, which followed by the tightening of the set-screws. After that, the top surface of concrete was strike off with a trowel or rod. It was important to ensure that the mould was attached to the bottom of the container during the operations.

8. After that, the mould was taken out by lifting it vertically four minutes after the completion of mixing. When the mould was raised, there should not result in any lateral or torsional displacement.

9. Then, the set-screw was loosen and the transparent disc was swung into the required position, which was over the subside cone of concrete. After that, the screw which locks the position of the transparent plate was released and then lowered until it touches the surface of concrete.

10. The set-screw was retightened and the stopwatch was kept ready.

11. The power source was switched on and the vibration was started immediately together with the stopwatch. At the instance when the entire lower surface of the transparent disc was covered with cement and the concrete was fully compacted, the time on the stopwatch was recorded and the vibrator as switched off.

12. Each test was carried out at a constant time interval after the water had been added with the other materials in the concrete.

13. Vebe value was obtained by taking the vibration time in second to the nearest 0.5s.

Figure 4.3: Vebe Test.

4.3 Properties of Harden Concrete

Harden stage of concrete is defined as the period of service life of concrete after a certain predetermined achieved strength. The harden stage of concrete is characterized by unit mass and strength, which s measured by several means.

1. **Compressive strength** : Refers to the maximum resistance by the concrete specimen to axial loading exerted on it.

2. **Flexural strength** : Refers to the calculated ultimate stresses in the outer fibre of a concrete beam specimen when the related specimen is subjected to bending.

3. **Direct tensile strength** : Refers to the maximum unit stress which a concrete specimen can resist without failure under tensile loading.

4. **Bond** : Refers to the adhesion and grip of the concrete to the existing reinforcements.

Modulus of Elasticity refers to the ratio of normal stress, which is below the limit of proportionality of concrete, to unit of deformation. **Durability** refers to the ability of concrete to endure the weathering effects, chemical attack, abrasion and other contributing factors which affect the performance of concrete.

4.4 Harden Concrete Tests

There were mainly two objectives for carrying out harden concrete tests. They were mainly for control of quality and the compliance with the specifications. These tests were conducted after the concrete specimens were cured for 28 days in the curing room. The harden concrete done in the project involves indirect tensile test, compression test, flexural test and the determination of Young’s Modulus for Fibre-reinforced concrete with the addition of Superplasticisers. The results taken from the tests were compared with the results taken from the data of fibre-reinforced concrete without the addition of Superplasticisers.

4.4.1 Compression Strength Test

Compression test is the most common test done on harden concrete. This is the test for assessing the compressive strength of concrete and it is easy to conduct. Secondly, compressive strength is one of the main desirable qualitative characteristic of concrete in relation to its strength. Furthermore, compressive strength is also an important criterion in the structural design.

However, although compressive strength is widely used in the design of structures, some problems still exist. This is due to variations in the type of test specimens, specimen sizes, types of mould used, method of curing, preparation of the end surface, condition of the testing machine and the application rate of stress during the testing. All these may affect the outcome of the results. As a result, a standard for assessing the strength of concrete is gazette in Australia.

In Australia, cylinder test is adopted for assessing the compressive strength of the concrete. Beside Australia, cylinders are also used in United States, France, Canada, and New Zealand.

<u>Apparatus</u>

The compression test was carried out in accordance with AS1012.9 - 1999.

Testing Machine - the testing machine was functioned by hydraulic pressure. It was located in the Concrete Lab in University of Southern Queensland.

Rubber caps - a rubber cap with a suitable size was used.

Gloves - a pair of gloves are needed to move the concrete in place for testing to prevent any accidents.

Rug - for cleaning purposes.

Procedures

1. After the concrete specimen had undergone the process of curing in the curing room, which aims to facilitate the process of hydration of cement in order to achieve the required strength, the concrete specimens were taken out.

2. The diameter and length of the specimens were measured immediately. After that, the weight of the concrete specimens was also taken.

3. The testing machine was then cleaned with rag. This was done to ensure the accurateness of the test.

4. Before the specimens were being tested, a rug was used to remove any loose particles on the surface of the specimens and ensure that the specimens were clean.

5. The settings of the testing machine were examined and adjusted before the tests were carried out.

6. Then, the specimen was placed on the machine, which follows by the alignment of the concrete specimen with the centre of thrust of the spherically seated steel plate. After the specimen was perfectly aligned, a rubber cap was placed onto the cylinder specimen.

7. The upper plate was then lowered until it touches with the rubber cap and a uniform bearing was obtained.

8. Pressure was then applied onto the specimen at a suitable rate. The load was applied until the specimen reached its maximum load capacity and fails. The maximum load was taken.

9. The testing machine was quickly unloaded and the upper plate was raised to allow for the removal of the specimen. The testing machine was then cleaned with a rag to allow for testing of the next specimen.

Figure 4.4: Compression Test.

Figure 4.5: Hydraulic Testing Machine.

4.4.2 In-direct Tensile Strength Test

In-direct tensile test was also known as splitting test. Concrete cylinders were used in the test. The cylinder concrete specimen was placed in a manner where its horizontal axis was between the platens of the testing machine. After that, load was applied slowly until the cylinder fails in the in-direct tension along the vertical dimension. During the process of the test, the platens of the testing machine were ensured not to rotate in a plane which was perpendicular to the axis of the cylinder.

Before the cylinder was tested, it was important to ensure that the best position for the plane of loading was determined. The selection was based on finding the position where the lines of contact with the bearing strips were the straightest and most parallel available.

<u>Apparatus</u>

The compression test is carried out in accordance with AS1012.10 - 1999.

Testing Machine - the testing machine was functioned by hydraulic pressure. It was located in the Concrete Lab in University of Southern Queensland.

Steel plate - the steel plate used had a width of at least 50 mm and a thickness greater than 20 mm. the length of the plate was also greater than specimen.

Bearing strips - two bearing strips were used. The bearing strips were made of tempered grade hardboard, which were ensured to be free from defects, and were nominally 5 mm thick and 25 mm wide, which were also longer then the specimens.

Rubber caps - a rubber cap with a suitable size was used.

Gloves - a pair of gloves are needed to move the concrete in place for testing to prevent any accidents.

Rug - for cleaning purposes.

Procedures

1. The diameter of the specimens which were in the test planes were determined to the nearest 0.2 mm by averaging the three diameters, which were measured near the ends and the middle of the specimens. Meanwhile, the length of the test specimens was also measured to the nearest millimeter. This was done by averaging two measurements of the lengths taken. The length along the lines which were in contact with the bearing strips was measured.

2. After that, the hardboard bearing strips which were placed between the top and bottom platen of the specimen were aligned.

3. The supplementary apparatus in the testing machine was positioned to ensure that the specimen was centered over the lower platen if necessary.

4. The upper plate was then lowered until it touches the steel platen and a uniform bearing was obtained.

5. Pressure was then applied onto the specimen at a suitable rate. The load was applied until the specimen reached its maximum load capacity and fails. The maximum load was taken

6. The testing machine was quickly unloaded and the upper plate was raised to allow for the removal of the specimen. The testing machine was then cleaned with a rag to allow for testing of the next specimen.

7. the indirect tensile strength of the specimens were calculated using the formula as follows,

$$T = 2000\, P / (\pi\, L\, D)$$

Where, T = indirect tensile strength in MPa.

P = maximum applied force shown on the testing machine in KN.

L = length, in mm

D = diameter in mm

Figure 4.6: Indirect-tensile Test.

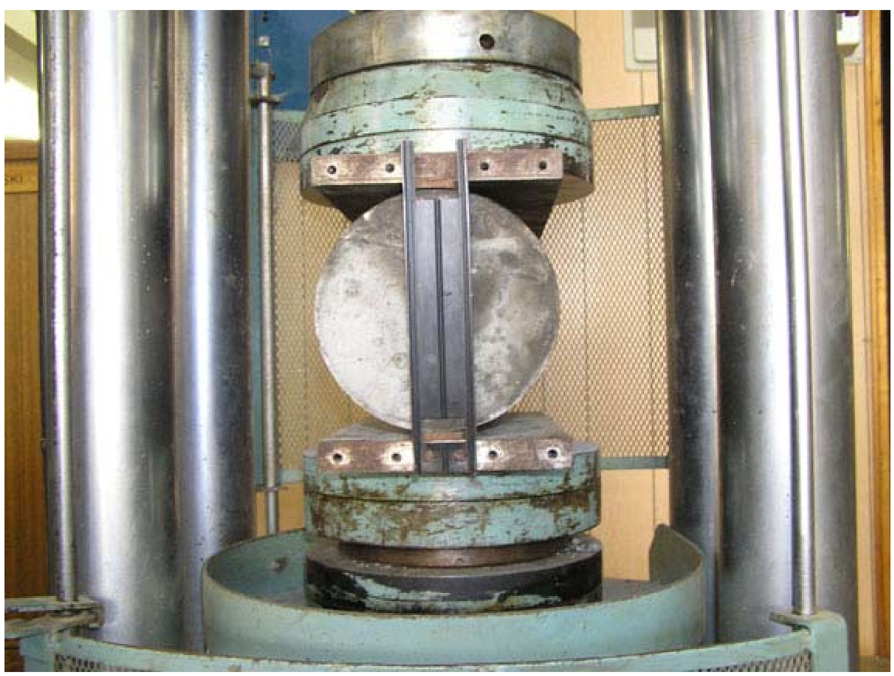

Figure 4.7: Indirect-tensile Test (Front View).

4.4.3 Flexural Strength Test

In the flexural strength test, a concrete beam which was subjected to four point loading right until failure occurs. However, for short-fibre reinforced beams, the loading was allowed for a longer time period after the failure of concrete occurs to observe the post-crack behavior of the concrete specimen.

The specimens were rejected if the edges of the beams were chipped, surface cracking occurs and honeycomb can be easily obviously seen every where on the specimens. Furthermore, surfaces of the specimens had to be in the plane so that the lines of contact between the bearing surfaces where the rollers bear would not be out of the plane more than 1 mm.

Apparatus

The compression test is carried out in accordance with AS1012.11 - 1999.

1. Testing machine - testing machine which suited the range of compressive force needed.

2. Testing apparatus - A force was applied onto the specimen by using a frame which consists of two supporting rollers and two loading rollers. Meanwhile, the frame was divided into two parts, which was the upper part and the lower part. Each of the part was located precisely in the testing machine to ensure the accurateness of the results.

3. Gloves - a pair of gloves are needed to move the concrete in place for testing to prevent any accidents.

Procedures

1. After the concrete specimen had undergone the process of curing in the curing room, which aims to facilitate the process of hydration of cement in order to achieve the required strength, the concrete specimens were taken out.

2. The diameter and length of the specimens were measured immediately. After that, the weight of the concrete specimens was also taken.

3. The testing machine was then cleaned with rag. This was done to ensure the accurateness of the test.

4. Before the specimens were being tested, a rug was used to remove any loose particles on the surface of the specimens and ensure that the specimens were clean.

5. The settings of the testing machine were adjusted before the tests were carried out.

6. Then, the specimen was placed on the machine, which follows by the alignment of the concrete specimen with the centre of thrust of the spherically seated steel plate.

7. The top rollers were then lowered until it touches with the specimen and a uniform bearing was obtained.

8. Pressure was then applied onto the specimen at a suitable rate. The load applied caused the specimen to reach its maximum load capacity and fails. However, loading was continued to examine the post-crack behavior of the beam.

9. The testing machine was stopped and the upper plate was raised to allow for the removal of the specimen. The testing machine was then cleaned with a rag to allow for the testing of next specimen.

Figure 4.8: Flexural Test.

4.4.4 Modulus of Elasticity

Modulus of elasticity is also known as Young's Modulus. It is defined as the ratio of stress over strain. When a value of stress was exerted on the concrete specimens, the will inevitably be a corresponding strain. A material was determined as perfectly elastic if strain appears and disappears upon the application of load. However in the case of concrete, stress increases with time. In reality, concrete also encounter the phenomena of creep. In this case, the concrete still contracts whether or not it was subjected to loading.

Apparatus

The compression test is carried out in accordance with AS1012.17 - 1999.

1. Testing machine - testing machine which suited the range of compressive force needed.

2. Testing apparatus - A force was applied onto the specimen by using a frame which consists of two supporting rollers and two loading rollers. Meanwhile, the frame was divided into two parts, which was the upper part and the lower part. Each of the part was located precisely in the testing machine to ensure the accurateness of the results.

3. Gloves and rugs - a pair of gloves are needed to move the concrete in place for testing to prevent any accidents. Rug was used for cleaning purposes.

4. Sulfur Capping - the capping was made from sulfur mixtures, formed against a metal plate. The thickness of the metal plate was more than 10 mm. the base of the metal plate was circle and the diameter of the metal plate was about 5 mm greater than the size of the specimen. Before applying the sulfur capping, the capping plate was thinly coated with mineral oil spray, which was followed by wiping the capping with a soft paper to distribute the mineral oil uniformly across the metal plate. The application of mineral oil prevented sulfur from adhering to the plate.

Procedures

1. After the concrete specimen had undergone the process of curing in the curing room, which aims to facilitate the process of hydration of cement in order to achieve the required strength, the concrete specimens were taken out.

2. The diameter and length of the specimens were measured immediately. After that, the weight of the concrete specimens was also taken.

3. The testing machine was then cleaned with rag. This was done to ensure the accurateness of the test.

4. Before the specimens were being tested, a rug was used to remove any loose particles on the surface of the specimens and ensure that the specimens were clean.

5. The settings of the testing machine were adjusted before the tests were carried out.

6. Then, the specimen was placed on the machine, which follows by the alignment of the concrete specimen with the centre of thrust of the spherically seated steel plate.

7. The upper plate was then lowered until it touches with the specimen and a uniform bearing was obtained.

8. Pressure was then applied onto the specimen at a suitable rate. The load applied caused the specimen to reach its maximum load capacity and fails. However, loading was continued to examine the post-crack behavior of the beam.

9. The testing machine was stopped and the upper plate was raised to allow for the removal of the specimen. The testing machine was then cleaned with a rag to allow for the testing of next specimen.

Figure 4.9: Computerised Hyraulic Testing Machine.

Figure 4.10: Sulphur Capped Cylinder.

4.5 Summary

Slump test, Vebe test and Compacting Factor test were conducted and the results were deduced to determine properties of the various kinds of short-fibre reinforced concrete with the addition of Superplasticisers. Meanwhile, In-direct tensile strength test, compression strength test, determination of Young’s Modulus and Flexural Strength test were used for the assessment of harden properties of the related short-fibre reinforced concrete.

The test procedures involved in the project was in accordance to Australian Standards. Strong emphasis were placed on safety issues when various fresh and harden concrete tests were being conducted. The results which were gathered, analysed and discussed in the following chapters.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Fresh Properties

The test results for the fresh concrete test conducted clearly indicates the difference of each test in assessing the workability of freshly mixed short-fibre reinforced concrete. For the assessment of workability, slump test, compacting factor test and Vebe test were adopted in the project as stated in the previous chapter. The addition of Superplasticisers as admixtures shows a general improvement in workability. However, the extent of improvement in workability differs when different kinds of short-fibres were used.

5.1.1 Analysis for Slump Test

The line graph below shows the results for the slump tests conducted on steel short-fibres, polypropylene short-fibres and Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers. Higher slump values indicate better workability.

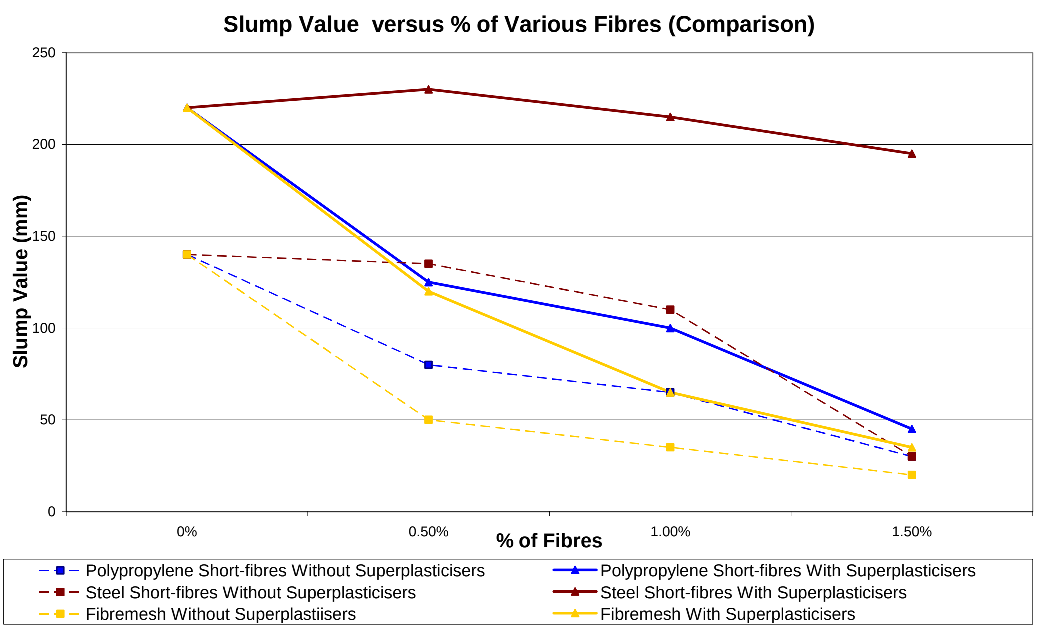

Figure 5.1: Line chart showing results of Slump Test.

Table 5.1: Results obtained from Slump Test.

Batch Type	SLUMP (mm)			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	140	80	65	30
Polypropylene short-fibres with Superplasticisers	220	125	100	45
Steel short-fibres without Superplasticisers	140	135	110	30
Steel short-fibres with Superplasticisers	220	230	215	195
Fibremesh without Superplasticisers	140	50	35	20
Fibremesh with Superplasticisers	220	120	65	35

The findings were tabulated in the line chart and evident that:

- The slump values for short-fibres reinforced concrete are higher with the addition of Superplasticisers.
- Steel short-fibre reinforced concrete generally has a better workability, compared to the other two kinds of concrete.
- Regardless of the usage of Superplasticisers, steel short-fibre reinforced concrete has the highest slump value, which followed by polypropylene short-fibre reinforced concrete.
- Fibremesh reinforced concrete has the lowest slump value.
- Varying percentage of fibre content will vary the slump values of control mixes.

The difference between the slump values of the control mixes, between plain concrete and plain concrete with the addition of Superplasticisers is 80 mm. For addition of 0.5% of fibre contents, the difference in slump of short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are 70 mm, 95 mm and 45 mm respectively. And with 0.1% of fibre contents, the difference in slump value for short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 30 mm, 105 mm and 35 mm. Meanwhile for 1.5% of fibre contents, the difference in slump values for Fibremesh, steel and polypropylene short-fibres with and without the usage of Superplasticisers, are respectively 15 mm, 165 mm and 15 mm.

From the slump results obtained, polypropylene short-fibres and steel short-fibres have a significant decrease in slump compare to the results in Fibremesh. This might due to the fact that polypropylene short-fibres, steel-short fibres and Fibremesh, were different in geometry and chemical composition.

In conclusion, slump test could not be considered as a suitable test to assess the workability of the concrete. This is due to the stiffening effects of the fibres which eventually influence the results of the slump test.

5.1.2 Analysis for Vebe Test

The Line graph below shows the results for the Vebe tests conducted on steel short-fibres, polypropylene short-fibres and Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers. Lower Vebe value indicates better workability. The data for the Vebe test are tabulated on the following page.

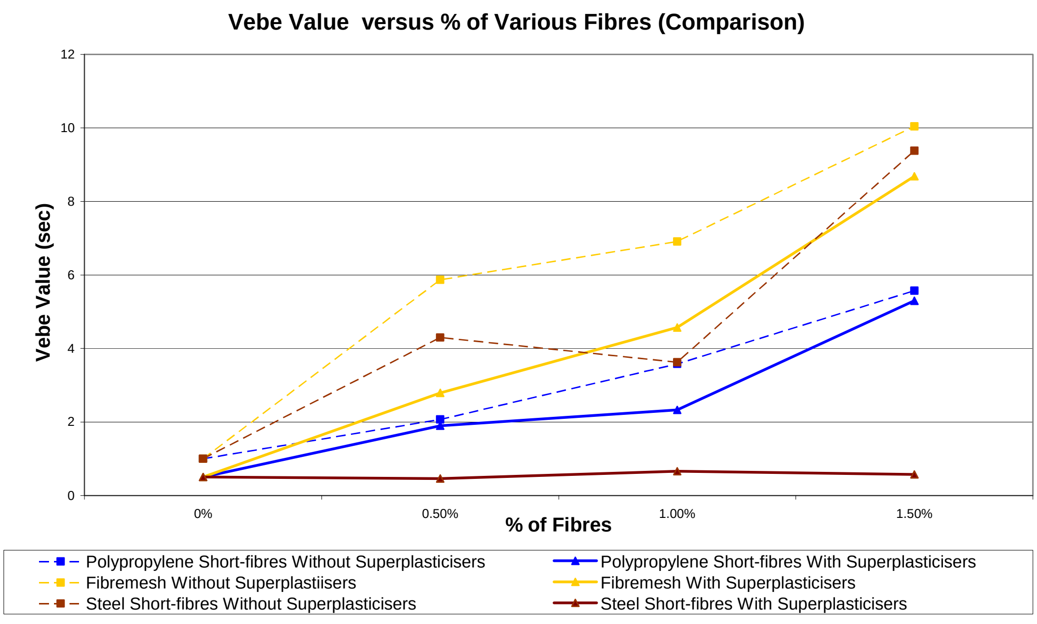

Figure 5.2: Line chart showing results of Vebe Test.

Table 5.2: Results obtained from Vebe Test.

Batch Type	VEBE (sec)			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	1.0	2.0	3.5	5.5
Polypropylene short-fibres with Superplasticisers	0.5	1.5	2.5	5.0
Steel short-fibres without Superplasticisers	1.0	4.5	3.5	9.5
Steel short-fibres with Superplasticisers	0.5	0.5	0.5	0.5
Fibremesh without Superplasticisers	1.0	6.0	7.0	10.0
Fibremesh with Superplasticisers	0.5	3.0	4.5	8.5

Vebe tests results were plotted in the line chart, generally:

- Vebe values for short-fibres reinforced concrete are lower with the addition of Superplasticisers, due to an increase in workability.
- Regardless of whether Superplasticisers are used, steel short-fibre reinforced concrete has the lowest vebe value, which follows by polypropylene short-fibre reinforced concrete.
- Meanwhile, Fibremesh reinforced concrete has the highest vebe value.

The difference between the vebe values of the control mixes, which are plain concrete and plain concrete with the addition of Superplasticisers are 0.5 sec. For 0.5% of fibre contents, the difference in vebe value of short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 3.0 sec, 4.0 sec and 1.5 sec. For 0.1% of fibre contents, the difference in vebe value for short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 2.5 sec, 3.0 sec and 1.0 sec. Meanwhile for 1.5% of fibre contents, the difference in Vebe time for Fibremesh, steel and polypropylene short-fibres with and without the usage of Superplasticisers are respectively 1.5 sec, 9.0 sec and 0.5 sec.

Compared to the usage of polypropylene short-fibres and fibre-mesh, steel fibres shows a greater decrease in Vebe time, which indicates a higher increase in workability as a result of the addition of Superplasticisers. However, Superplasticisers does not have great effect on improving the workability of Fibremesh reinforced concrete. This was shown in the graph, as the addition of Superplasticisers into the concrete mix only lead to slight improvement for mixes with 0.5% and 1.5% of Fibremesh. Vebe test is a good method for the assessment for concrete of low workability, stiff and dry mixes, such as the use of high proportions of short-fibres in the concrete mix. Vebe test better reflects the workability of the concrete compare to slump test. This is because it can overcome the stiffening effects of the fibres in concrete by a combine action of applied vibration and weight.

In conclusion, vebe test provides a better indication of the workability for short-fibre reinforced concrete. Besides, the tests had shown clearly the increase in workability due to the addition of Superplasticisers. Although the usage of short-fibre will inevitably reduce the workability of concrete, however, remedy can be done by the usage of Superplasticisers. Among the three kinds of fibres used in the research, workability of steel short-fibre reinforced concrete shows the greatest improvement as a result of the addition of Superplasticisers.

5.1.3 Analysis for Compacting Factor Test

The line graph below shows the results for the Compacting Factor tests conducted on steel short-fibres, polypropylene short-fibres and Fibremesh of different short-fibres content with and without the addition of Superplasticisers. Higher values of compacting factor indicate better workability.

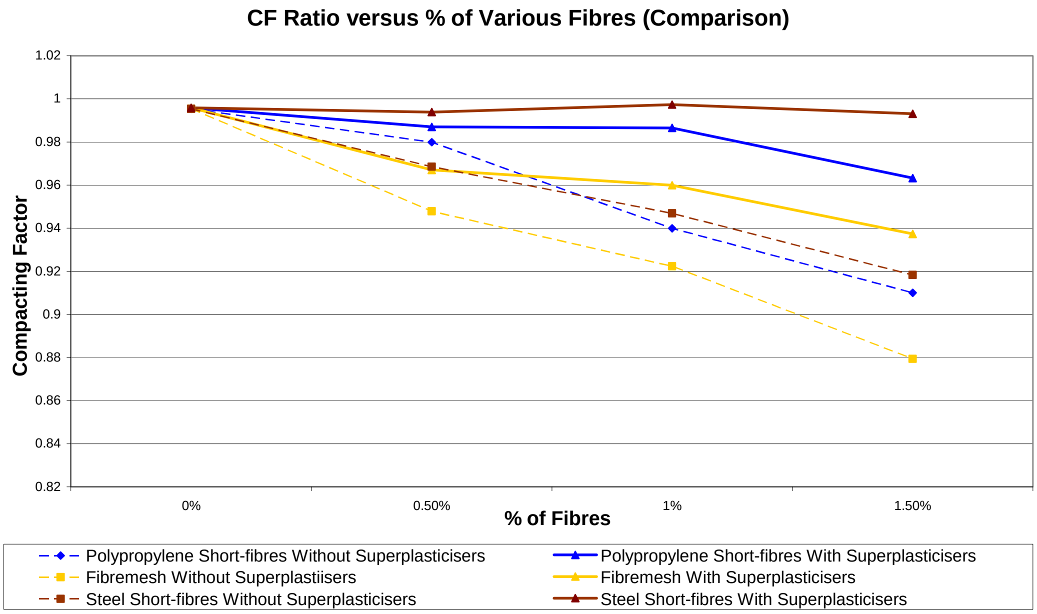

Figure 5.3: Line chart showing results of Compacting Factor Test.

Table 5.3: Results obtained from Compacting Factor Test.

Batch Type	Compacting Factor			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	0.9954	0.9799	0.9399	0.9100
Polypropylene short-fibres with Superplasticisers	0.9958	0.9870	0.9865	0.9632
Steel short-fibres without Superplasticisers	0.9954	0.9685	0.9469	0.9183
Steel short-fibres with Superplasticisers	0.9958	0.9939	0.9973	0.9931
Fibremesh without Superplasticisers	0.9954	0.9478	0.9223	0.8794
Fibremesh with Superplasticisers	0.9958	0.9670	0.9599	0.9373

From the results for the chart above, the general findings are:

- Regardless of whether Superplasticisers are used, steel short-fibre reinforced concrete has the highest compacting factor, which follows by polypropylene short-fibre reinforced concrete

- Meanwhile, Fibremesh reinforced concrete has the lowest compacting factor.

The difference between the compacting factor values of plain concrete and plain concrete with the addition of Superplasticisers are 0.0004 mm. For 0.5% of fibre contents, slump value differences between short-fibre reinforced concrete with and without the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 0.0192, 0.0254 and 0.0071. For 0.1% of fibre contents, the difference in compacting factor value for short-fibre reinforced concrete with and without the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 0.0376, 0.0504 and 0.0466. Meanwhile for 1.5% of fibre contents, the difference in compacting factor values for Fibremesh, steel and polypropylene short-fibres with and without the usage of Superplasticisers are respectively 0.0579 mm, 0.0748 mm and 0.0532 mm.

Compacting factor is generally higher for short-fibres reinforced concrete with Superplasticisers. The graph shows steel short-fibres have the most obvious increase in compacting factor with the use of Superplasticisers, compared to polypropylene short-fibres and Fibremesh. Meanwhile, Fibremesh reinforced concrete has the lowest value of compacting factor compare to polypropylene and steel short-fibres.

Generally the graph shows a linear relationship between the workability improvement of short-fibre reinforced concrete without the addition of Superplasticisers and short-fibre reinforced concrete with the presence of Superplasticisers. Although some inaccuracies may occur due human errors in measuring, however the test results provides a good assessment and understanding regarding the trend and extent of workability improvement due to the addition of Superplasticisers.

In conclusion, compacting factor test gives a good indication of the compatibility and workability of concrete. The results show that the increase of compacting factor is quite similar for all kinds of fibre due to the presence of Superplasticisers. Meanwhile, trends exist, when more then 1% of fibres are used, rate of workability increase decreases with the addition of Superplasticisers.

5.2 Harden Properties of Concrete

Strength of concrete was long considered as one of its most important properties, although, in some instances, characteristics such as durability and permeability may be considered more essential. Furthermore, the strength of concrete has a vital role in structural design, which also involves compliances with the building code. The test results for harden concrete tests conducted involved compressive strength test, in-direct tensile strength test, flexural strength test and test for the determination of Young's Modulus. The effect of addition of Superplaticisers as admixtures on the strength characteristic of various kinds of short-fibre reinforced concrete was also assessed. Generally different kinds of short-fibres reinforced concrete exhibits different performance in the respective tests conducted.

5.2.1 Analysis for Compression Strength Test

The table below shows the results for the compression strength tests conducted on steel short-fibres, polypropylene short-fibres and Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers.

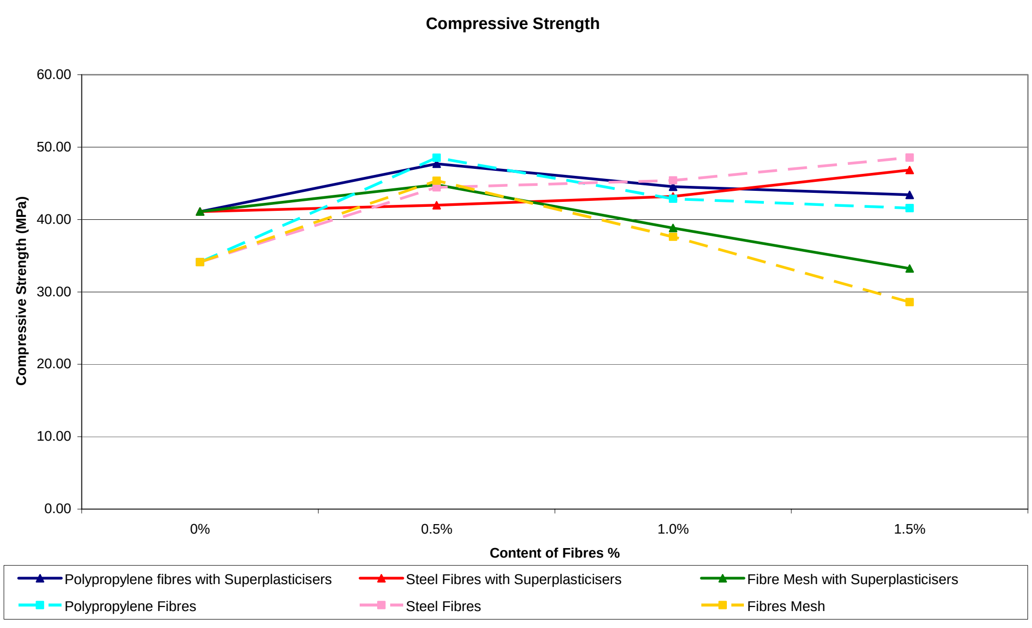

Figure 5.4: Line chart showing results of Compressive Strength Test.

Table 5.4: Results obtained from Compression Strength Test.

Batch Type	Compressive Strength (Mpa)			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	34.10	48.51	42.85	41.57
Polypropylene short-fibres with Superplasticisers	41.09	47.68	44.53	43.40
Steel short-fibres without Superplasticisers	34.10	44.44	45.40	48.55
Steel short-fibres with Superplasticisers	41.09	41.97	43.19	46.82
Fibremesh without Superplasticisers	34.10	45.34	37.60	28.60
Fibremesh with Superplasticisers	41.09	44.80	38.83	33.22

The findings from the graph above show that:

- Regardless of whether Superplasticisers are used, when the fibre contents used are 0.5 %, polypropylene short-fibre reinforced concrete has the highest compressive strength which follows by Fibremesh reinforced concrete, and lastly by steel-fibre reinforced concrete.
- For short-fibre content of 1 %, steel fibre reinforced concrete with the usage of Superplasticisers has a better compressive strength compared to polypropylene short-fibre reinforced concrete either with or without the addition of Superplasticisers.
- However, steel fibre reinforced concrete without the usage of Superplasticisers have a lower strength compare to polypropylene short-fibre reinforced concrete.
- Fibremesh reinforced concrete however has the lowest compressive strength for 1 % of fibre content in both conditions. Lastly, for 1.5 % of short-fibre content, whether Superplasticisers were used, steel short-fibre reinforced concrete have the highest compressive strength, which is followed by polypropylene short-fibre reinforced concrete.
- Fibremesh exhibits the lowest compressive strength among three kinds of short-fibres used.

The difference between the compressive strength of the control mixes, which are plain concrete and plain concrete with the addition of Superplasticisers are 6.99 Mpa. For 0.5% of fibre contents, the difference in slump of short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 5.54 Mpa, 2.47 Mpa and 0.83 Mpa. For 0.1% of fibre contents, the difference in sump value for short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 1.23 Mpa, 2.21 Mpa and 1.68 Mpa. Meanwhile for 1.5% of fibre contents, the difference in slump value for Fibremesh, steel and polypropylene short-fibres with and without the usage of Superplasticisers are respectively 4.62 Mpa, 1.73 Mpa and 1.83 Mpa.

Generally, the compressive strengths for polypropylene short-fibre and Fibremesh reinforced concrete with the addition of Superplasticisers are slightly higher compare to short-fibre reinforced concrete without any addition of admixtures. This might be due to the introduction of Superplasticisers into the concrete. As the hydrated cement paste does not change, the presence of Superplasticisers will result in a better distribution of cement particles. Eventually, improved cement particles distribution leads to better hydration, which also increases the compressive strength of the concrete.

For steel short-fibre reinforced concrete, the compressive strength is generally lower for short-fibre reinforced concrete with the addition of Superplasticisers. This may be due to segregation of steel short-fibres, as the workability of steel short-fibre reinforced concrete increases a lot with the addition of Superplasticisers. Meanwhile, the compressive strength of Fibremesh reinforced concrete decreases after addition of more then 1% of fibre content, which reaches the lowest point when 1.5 % of Fibremesh is added. This might be caused by the dimension and orientation of the fibres in the concrete. Segregation of fibres might lead to existence of some weak planes, which eventually causes lower compressive strength.

The usage of the ball bearing system for the loading machine gives a very positive result as the system automatically adjusts itself to the inconsistent surface level. This also eases the setting of the apparatus, during the transition of testing for compression and indirect tensile.

In conclusion, there are only slight changes in strength with the addition of Superplasticisers in short-fibre reinforced concrete. However, the effect of usage of Superplasticisers on workability differs from steel short-fibres to polypropylene short-fibres and Fibremesh reinforced concrete.

5.2.2 Analysis for Indirect-Tensile Strength Test

The table above shows the results for the indirect strength tests conducted on steel short-fibres, polypropylene short-fibres and Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers.

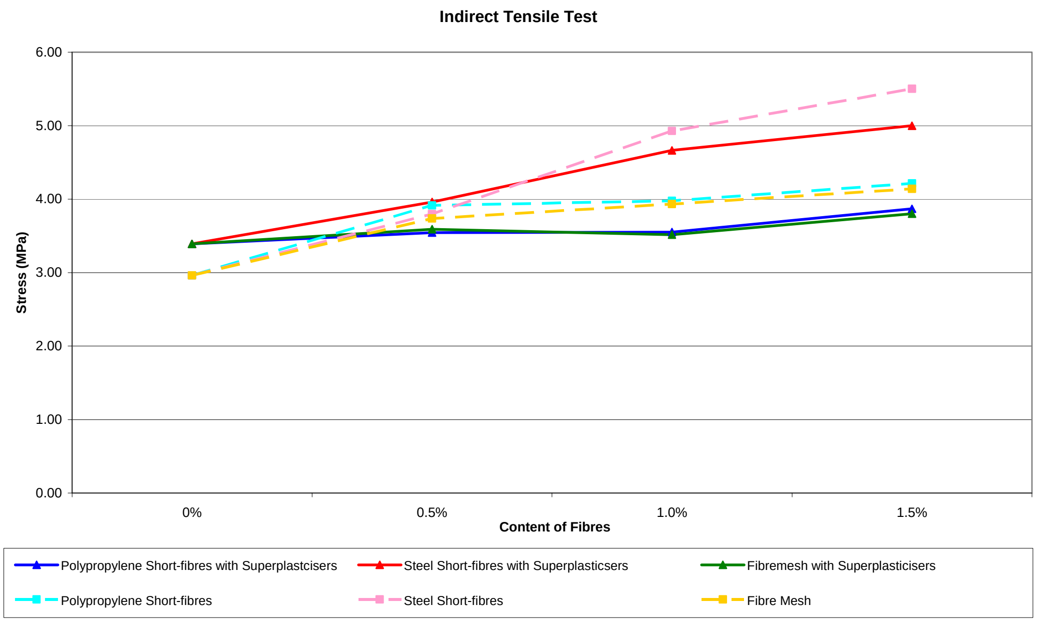

Figure 5.5: Line chart showing results of Indirect-tensile Test.

Table 5.5: Results obtained from Indirect-tensile Strength Test.

Batch Type	Indirect-tensile strength (Mpa)			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	2.96	3.92	3.98	4.21
Polypropylene short-fibres with Superplasticisers	3.39	3.54	3.55	3.87
Steel short-fibres without Superplasticisers	2.96	3.80	4.93	5.50
Steel short-fibres with Superplasticisers	3.39	3.96	4.66	5.00
Fibremesh without Superplasticisers	2.96	3.74	3.93	4.14
Fibremesh with Superplasticisers	3.39	3.59	3.52	3.80

The findings were tabulated in the line chart and evident that:

- Regardless of whether Superplasticisers are used, steel short-fibre reinforced concrete has a higher indirect-tensile strength, which is followed by polypropylene short-fibre reinforced concrete.
- Meanwhile, although the compressive strength of polypropylene and Fibremesh reinforced concrete are similar, Fibremesh reinforced concrete has the lowest compressive strength.

The difference between the indirect-tensile strength of the control mixes, which involves plain concrete and plain concrete with the addition of Superplasticisers are 0.43 Mpa. For 0.5% of fibre contents, the difference in slump of short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 0.15 Mpa, 0.16 Mpa and 0.38 Mpa. For 0.1% of fibre contents, the difference in sump value for short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 0.41 Mpa, 0.27 Mpa and 0.43 Mpa. Meanwhile for 1.5% of fibre contents, the difference in slump value for Fibremesh, steel and polypropylene short-fibres with and without the usage of Superplasticisers are respectively 0.34 Mpa, 0.5 Mpa and 0.34 Mpa.

The indirect-tensile strength does not show great variation for all kinds of fibres with different contents of fibre. However, the indirect-tensile strength is generally higher for fibre-reinforced concrete of 1 % and 1.5% fibre content without the usage of Superplasticisers.

Generally, indirect tensile strength increases with the increase of short-fibres in the concrete. The strength increase is due to the binding nature of short-fibres in the concrete matrix. Tension load the concrete specimen which is caused by an applying load was transferred to the short-fibres. This phenomenon continues until the bind between the fibres and concrete fails and being pulled out of the concrete. However, compare to plain concrete which fails suddenly upon cracking, short-fibre reinforced concrete exhibits load carrying ability in the post-cracking state. This was due to the bridging of fibres in the primary crack, which are confined by a matrix under high compression. As a whole, considerable amount of energy were being absorbed in debonding and pulling out of short-fibres from the concrete prior to the complete failure of concrete.

Overall, the indirect tensile strength for short-fibre reinforced concrete is higher without the addition of Superplasticisers. Segregation of short-fibres is thought to be the reason. This is because workability of short-fibre reinforced concrete increases addition of Superplasticisers, which might lead to segregation in the process of compaction of the concrete paste.

In conclusion, the ultimate strength also depends on the percentage of fibres used n the batch of concrete. However, the addition of Superplasticisers to short-fibre reinforced concrete may lead to segregation of fibres, which results in lower strength. Meanwhile, the addition of Superplasticisers to plain concrete will lead to a better distribution of cement particles, which eventually increases the tensile strength.

5.2.3 Flexural Strength

5.2.3.1 Analysis for Flexural Strength Test using Polypropylene Short-fibres

The table below shows the results for the flexural strength tests conducted on polypropylene short-fibres of different portion of short-fibres with and without the addition of Superplasticisers.

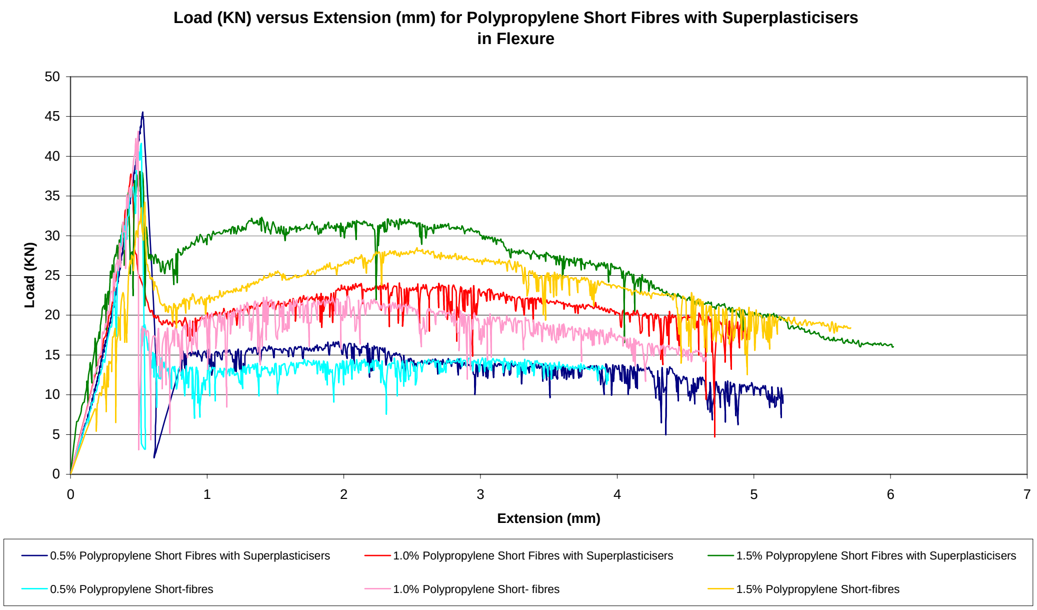

Figure 5.6: Line chart showing results of flexural strength test using polypropylene short-fibres.

The findings were tabulated in the line chart and evident that:

- Regardless of the usage of Superplasticisers, 1.5% of polypropylene short-fibre reinforced concrete has the highest compressive strength, which as followed by 1.0% of polypropylene short-fibre reinforced concrete.

- Meanwhile, content of 0.5% of polypropylene short-fibre reinforced concrete has the lowest compressive strength among the usage of three different contents of polypropylene short-fibre.

The graph clearly shows the post-cracking behavior of polypropylene short-fibre reinforced concrete. Generally, flexural strength for fibre-reinforced concrete with the usage of Superplasticisers is higher. From the results, we noticed that polypropylene short-fibres helps maintaining the strength of concrete, which prevented it from complete failure directly, which can be seen in plain concrete. As a whole, the specimen was able to carry extra load after the initial cracking. This was due to the bridging of fibres in the primary crack, confined by a matrix which was under high compression.

The results show that flexural strength for 0.5% and 1% of polypropylene short-fibres, either with or without the addition of Superplaticisers are similar. For 1.5% of polypropylene short-fibre, the flexural strength increases slightly with the addition of Superplaticisers.

The fluctuation of the line graph was due to the small variation in pressure of the hydraulic loading machine. However, this issue does not raise huge concern as the data collected still can be use. Overall, the results collected from the hydraulic loading machine were quite reasonable.

In conclusion, the usage of polypropylene short-fibres contributes to crack control, ductility improvement and increase in post-cracking stiffness of the concrete. From the result, the flexural strength of the polypropylene short-fibre reinforced concrete increase gradually with the increase of fibre content.

5.2.3.2 Analysis for Flexural Strength Test using Steel Short-fibres

The table below shows the results for the flexural strength tests conducted on steel short-fibres of different portion of short-fibres with and without the addition of Superplasticisers.

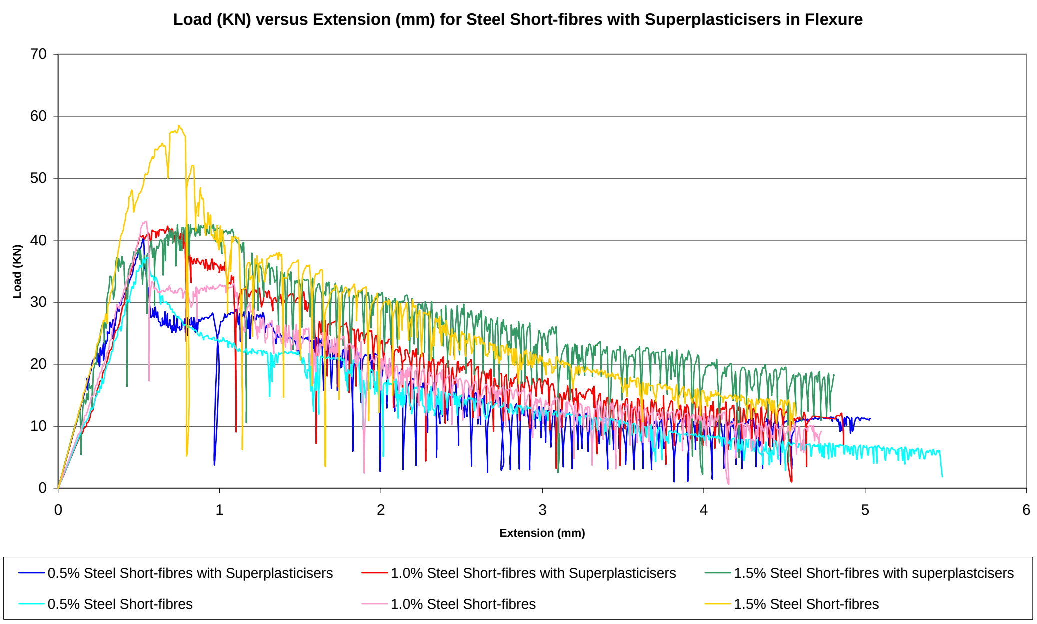

Figure 5.7: Line chart showing results of flexural strength test using steel short-fibres.

The graph clearly shows the post-cracking behavior of steel short-fibre reinforced concrete.

The findings were tabulated in the line chart and evident that:

- Flexural strength for fibre-reinforced concrete with the usage of Superplasticisers is higher.
- Regardless of whether Superplasticisers were used, generally, 1.5% of steel short-fibre reinforced concrete has a higher compressive strength, which as followed by 1.0% of steel short-fibre reinforced concrete. Meanwhile, content of 0.5% of steel short-fibre reinforced

concrete has the lowest strength among the usage of three different steel short-fibre proportions.

From the results, flexural strength for 0.5% and 1% of steel short-fibres are similar. For 1.5% of polypropylene short-fibre, the post-cracking flexural strength for the specimen is slightly higher with the addition of Superplaticisers. Meanwhile, the highest strength was achieved by 1.5% content of steel fibre reinforced concrete.

Steel short-fibres also help to maintain the strength of concrete due to the bridging of fibres in between the cracks, which is same as the previous case regarding polypropylene short fibres.

Compare to propylene short-fibre reinforced concrete in the previous graph, steel short-fibre reinforced concrete generally have a higher flexural strength in post tensioning. Meanwhile, the ultimate flexural strength for steel short-fibre reinforced concrete and polypropylene short-fibre reinforced concrete are similar.

In conclusion, the effect of Superplasticisers on the flexural strength of steel-fibre reinforced concrete was not obvious, as the results are considered very near for steel short-fibre reinforced concrete either with or without the addition of Superplasticisers.

5.2.3.3 Analysis for Flexural Strength Test using Fibremesh

The table below shows the results for the flexural strength tests conducted on Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers.

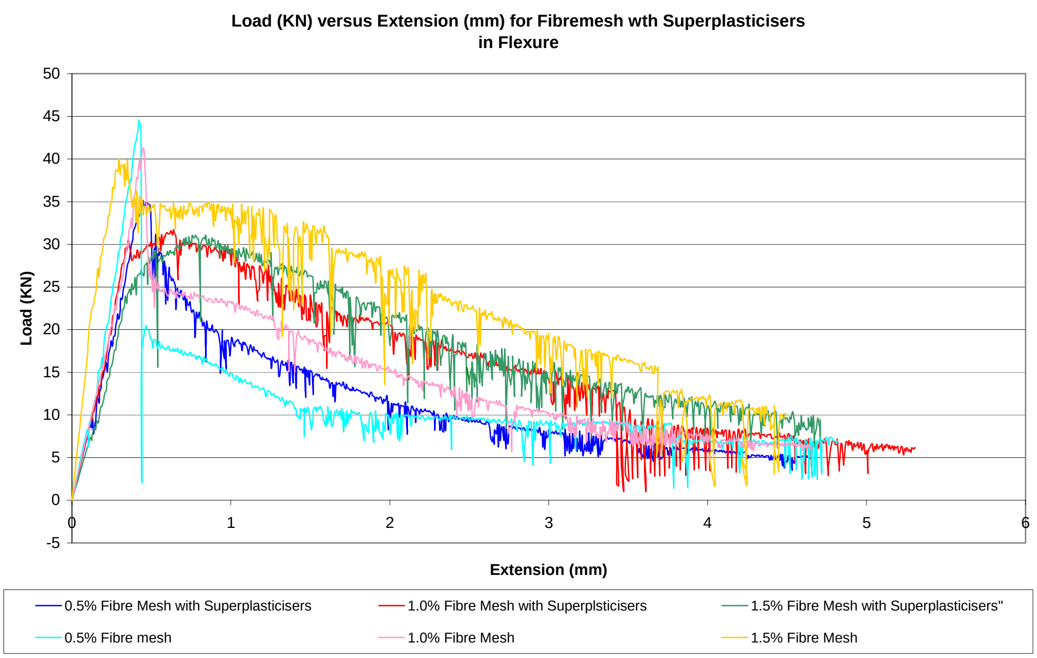

Figure 5.8: Line chart showing results of flexural strength test using Fibremesh.

The graph clearly shows the post-cracking behavior of Fibremesh reinforced concrete.

The findings were tabulated in the line chart and clearly show that:

- Generally, flexural strength for fibre-reinforced concrete with the usage of Superplasticisers is higher.
- Regardless of the addition of Superplasticisers into three of the concrete mixes with different fibre contents, 1.5% of Fibremesh reinforced concrete has the highest flexural strength, which as followed by 1.0% of Fibremesh reinforced concrete.

- Meanwhile, the specimens with 0.5% of Fibremesh reinforced concrete have the lowest compressive strength among the usage of three different contents of polypropylene short-fibre.

Compare to steel short-fibre reinforced concrete, Fibremesh reinforced concrete have a lower flexural strength in the post cracking condition. Furthermore, flexural strength in the post cracking condition also decreases at a higher rate compare to steel short-fibre reinforced concrete.

Same as polypropylene short-fibres and steel short-fibres, Fibremesh also helps to maintain concrete strength through the bridging of fibres in between the cracks. As a result, considerable amount of energy were absorbed in the process of de-bonding and the pulling out of fibres from the concrete prior to the complete failure of concrete. However, the beam specimens were not tested until complete failure by means of separation of concrete. The beam specimens were only loaded until it reaches a deflection of approximately 5mm. This was because the main objective was to assess the post-cracking behavior of various kinds of short-fibre reinforced concrete.

All three kinds of short-fibres demonstrate the behavior of flexural strength in the post-cracking conditions of concrete. Among the three kinds of fibres tested, the flexural strength of Fibremesh reinforced concrete are lower compare to the usage of steel and polypropylene short-fibres in concrete in the post-cracking state. However, steel short-fibre reinforced concrete has an advantage over polypropylene short-fibre reinforced concrete. This is because the flexural strength of steel short-fibre reinforced concrete decrease gradually, compare to polypropylene short-fibre reinforced concrete, where the flexural strength encounters a sudden drop, which follows a rise in flexural strength.

In conclusion, the usage of Superplasticisers in the three kinds of short-fibre reinforced concrete has a higher flexural strength. This might due to usage of Superplasticisers lead to a better distribution of cement particles, which improves the hydration process. In some cases, the flexural strength of the post-cracking state is similar either with or without the addition of Superplasticisers. Overall, the usage of

Superplasticisers does not bring negative impact to the flexural strength of short-fibre reinforced concrete. The introduction of short-fibres into concrete could improve the conventional reinforced concrete as it enhances the flexural strength of concrete.

5.2.4 Comments and Analysis for Modulus of Elasticity

The table below shows the results of Young's Modulus steel short-fibres, polypropylene short-fibres and Fibremesh of different portion of short-fibres with and without the addition of Superplasticisers.

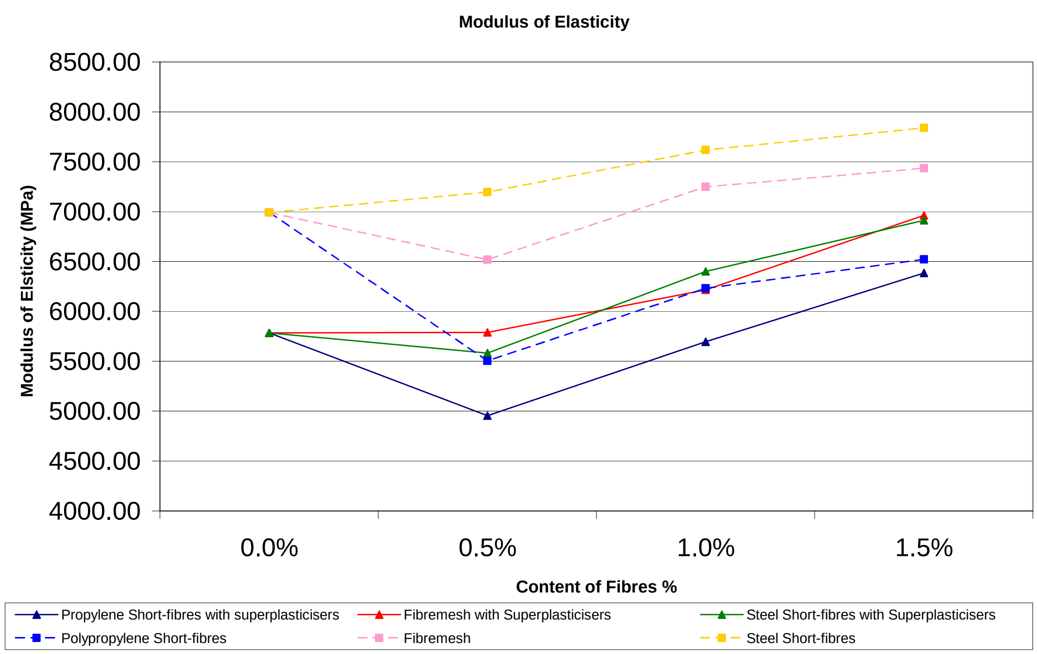

Figure 5.9: Line chart showing results of Modulus of Elasticity.

Table 5.6: Results of Modulus of Elasticity.

Batch Type	Young's Modulus (MPa)			
	0%	0.50%	1.00%	1.50%
Polypropylene short-fibres without Superplasticisers	6991.63	5504.08	6230.87	6521.87
Polypropylene short-fibres with Superplasticisers	5783.27	4954.06	5695.39	6385.08
Steel short-fibres without Superplasticisers	6991.63	7195.72	7617.90	7839.85
Steel short-fibres with Superplasticisers	5783.27	5582.06	6400.10	6912.62
Fibremesh without Superplasticisers	6991.63	6518.75	7248.27	7434.62
Fibremesh with Superplasticisers	5783.27	5789.86	6916.67	6961.71

The findings were tabulated in the line chart and evident that:

- Short-fibre reinforced concrete with the usage of Superplasticisers has a lower value of Young's Modulus.
- Regardless of whether Superplasticisers were used, 1.5% of polypropylene short-fibre reinforced concrete has the highest compressive strength, which as followed by 1.0% of polypropylene short-fibre reinforced concrete.
- Meanwhile, content of 0.5% of polypropylene short-fibre reinforced concrete has the lowest compressive strength among the usage of three different contents of polypropylene short-fibre.

The difference between the Young's Modulus of the control mixes, which involves plain concrete without the addition of Superplasticisers and plain concrete with the addition of Superplasticisers are 1208.36 Mpa. For proportion of 0.5% of fibre, the difference in slump of short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are 728.89 Mpa, 1613.66 Mpa and 550.02 Mpa respectively. For 0.1% of fibre contents, the difference in slump value for short-fibre reinforced concrete without Superplasticisers and short-fibre reinforced concrete with the addition of Superplasticisers for Fibremesh, steel and polypropylene short-fibres are respectively 331.6 Mpa, 1217.8 Mpa and 535.48 Mpa. Lastly, the difference in Young's Modulus for 1.5% of Fibremesh, steel and polypropylene short-fibres both with and without the usage of Superplasticisers are 472.91 Mpa, 927.23 Mpa and 136.79Mpa respectively.

The graph generally shows an upward trend in Young's Modulus with the increase of the percentage of short-fibres in a concrete mix. Meanwhile, short-fibre reinforced concrete with the addition of Superplasticisers generally has a lower Modulus of Elasticity. This phenomenon was thought to be cause by the addition of Superplasticisers into the short-fibre reinforced concrete reduces the strain of the specimen. As the ultimate stress of both short-fibre reinforced concrete, either with or without the addition of Superplasticisers was similar, where both showed an increase in the value of Modulus of Elasticity.

However, the results of the Young's Modulus which were taken from the lab were very much below the theoretical Young's Modulus value for concrete. One of the reasons is thought to be the effect of the equipments involved in testing. In actual testing, some deflections may occur at the loading equipments and the hydraulic loading machines. Besides, the usage of sulfur capping also contributes to a lower Modulus of Elasticity. Furthermore, the addition of short-fibres into the concrete matrix also decreases the workability of concrete. This prevents the concrete from being thoroughly mixed. As a result, the cement particles will not be distributed evenly to undergo hydration, which eventually leads to lower strength. As the strength is lower and the strain of the concrete specimens remains constant, Young's Modulus will be lower.

In conclusion, the addition of Superplasticisers to short-fibre reinforced concrete generally leads to lower Young's Modulus. Besides, lower Young's modulus was obtained compare to theoretical value of concrete might due to equipment errors, application of sulfur capping and usage of short-fibres in the concrete mix.

5.3 Conclusion

The results for both fresh and harden concrete tests conducted were analyzed and conclusions were drawn from the data colleted in each test. The results showed a definite increase in workability due to the addition of Superplasticisers to Fibremesh, polypropylene and steel short-fibre reinforced concrete. Steel short-fibre reinforced concrete showed the greatest improvement in workability due to the usage of Superplasticisers as admixtures. Meanwhile, Fibremesh reinforced concrete resulted in worst workability among the three kinds of fibres tested. The results of harden concrete tests also shown a slight difference in performance when Superplasticisers was added to the short-fibre reinforced concrete mix. The possible effect of Superplasticisers on the strength characteristic was also discussed in this chapter.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Project Achievements

The aim of the project was met as it had successfully investigated and analysed the effects of Superplasticisers being used as admixtures on structural concrete with short fibres. Various fibres tested varied from the most commonly used steel short-fibres, to polypropylene short-fibres and Fibremesh. The behaviour of Superplasticisers on plain concrete and short-fibre reinforced concrete was duly compared. Furthermore, the data collected from various tests conducted on the fresh and harden concrete were collected and analysed.

In this project, results were compared with Short-fibre reinforced concrete without the addition of Superplasticisers, from Wong (2004). The project involved fresh concrete tests such as slump test, vebe test, and compacting factor test. Meanwhile, hardened concrete tests such as compressive strength test, indirect-tensile strength test, flexural strength test and test for the determination of Modulus of elasticity were conducted. Much invaluable knowledge was also gained through the process of research and investigations regarding the area of short-fibre and additives, mainly the effects and performance of steel short-fibres, polypropylene short-fibres, Fibremesh and Superplasticisers. In the process of carrying out the practical work, knowledge regarding the design of concrete mix was enhanced through research and experience. Furthermore, many interesting problems were solved and challenges which surfaced regarding the finer aspects of the project had presented us with opportunities of attaining invaluable practical experiences beyond the textbook.

Upon completion of the project, a significant amount of knowledge and experience was gained. Apart from theoretical knowledge, valuable lessons and experienced was gathered, which involves planning, organising, research techniques, material sources and acquirement, carrying out the practical works involved, time and resource planning, result analysis and presentation, and also technical writing skills.

As a whole, undertaking of the project was very beneficial and offers a chance to improve our knowledge and more importantly, it had instilled our confidence in concrete technology. The analysis of the results from the project also provided us with a deeper knowledge in the effects of Superplasticisers on different types of short-fibre reinforced concrete, gearing us competently towards these academic pursuits.

6.2 Conclusions

The results from various tests conducted on the fresh and harden state of concrete had lead to various findings and conclusions. Focus had been made towards the effect of Superplaticisers on structural concrete with the addition of steel short-fibres, polypropylene short-fibres and Fibremesh, involved workability of concrete for the freshly mixed concrete. For the harden state of concrete, comparison between short-fibre reinforced concrete without the addition of Superplasticisers and short-fibre reinforced concrete without the addition of Superplasticisers were made. The comparisons made include the compressive strength behaviour, indirect-tensile strength behaviour, flexural strength behaviour, difference in Modulus of Elasticity and finally the energy absorbing capacity of the short-fibre reinforced concrete.

From the results obtained through the fresh concrete tests, it was found that slump test should not be considered as a satisfying test to determine the workability of the concrete. This is due to the stiffening effects of the fibres. The slump results will not show the actual workability of the concrete. However, better assessment of workability of the concrete can be done by Vebe test, as Vebe test better reflects the workability of the concrete compare to slump test. This is because stiffening effects of the fibres in concrete can be solved by a combine action of applied vibration and weight. Besides, in during the process of compaction, it was found that the vibrating action applied on the freshly mixed short-fibre reinforced concrete by the vibrating machine helped in improving the workability of the concrete. From the results of Vebe test and compacting factor test, (figure 5.2 and figure 5.3), steel short-fibre reinforced concrete have the highest workability, which were followed by polypropylene short-fibre and Fibremesh reinforced concrete.

The test results also clearly show a linear increase in workability due to the addition of Superplasticisers. Although the usage of short-fibre will cause reduction of workability of concrete, however this problem can be solved by the usage of Superplasticisers. Meanwhile, from the results of Vebe test and compacting factor test, it had shown that generally for all three kinds of fibres, when more then 1% of fibres are used, rate of workability increases with the addition of Superplasticisers.

Compression test results indicated that, generally, the compressive strengths for polypropylene short-fibre and Fibremesh reinforced concrete increases with the addition of Superplasticisers compare to short-fibre reinforced concrete without any addition of admixtures. This is because the presence of Superplasticisers in the concrete mix will lead to a better distribution of cement particles. Eventually, improved cement particles distribution leads to better hydration, which also increases the compressive strength of the concrete. Meanwhile, the addition of Superplasticisers also improves the workability of concrete, which later leads to a better compaction, and increases the strength of concrete when hardened. However, the compressive strength is generally lower for steel short-fibre reinforced concrete with the addition of Superplasticisers. This may be due to segregation of steel short-fibres, as a result of a relative higher increase in workability due to the addition of Superplasticisers. As a conclusion, the effect of usage of Superplasticisers on compressive strength is different from steel short-fibres to polypropylene short-fibres and Fibremesh reinforced concrete.

In the case of indirect-tensile strength test, generally, indirect tensile strength increases with the increase of short-fibres in the concrete. This was due to the bridging of fibres in the primary crack, which is confined by a matrix under high compression. Considerable amount of energy were being absorbed in de-bonding and pulling out of short-fibres from the concrete in the process of pulling out of fibres. Generally, indirect-tensile strength for short-fibre reinforced concrete without the addition of Superplasticisers is higher as the addition of Superplasticisers leads to segregation of fibres during the process of compaction. Meanwhile, addition of Superplasticisers to plain concrete leads to a better distribution of cement particles, which result in an increase of indirect-tensile strength.

Generally, flexural strength for fibre-reinforced concrete with the usage of Superplasticisers is higher, except for the case with the addition of 1.5% of Fibremesh to reinforce concrete with the usage of Superplasticisers. The increase in flexural strength of short-fibre reinforced concrete due to usage of Superplasticisers lead to a better distribution of cement particles, which improves the hydration process. In the case where Superplasticisers were used with the addition of 1.5% of Fibremesh to concrete, flexural strength are lower as compared to Fibremesh reinforced concrete without the addition of Superplasticisers. It was thought that the addition of Superplasticisers does not help much on increasing the workability, as the Fibremesh reinforced concrete mix was too stiff. As a conclusion, application of high dosage rate of Fibremesh is not suitable as it will be too stiff for the Superplasticisers to make an impact on workability improvement. Overall, usage of Superplasticisers does not cause a negative effect to the flexural strength of short-fibre reinforced concrete. The addition of short-fibres into conventional reinforced concrete can enhance the flexural strength of concrete.

Addition of Superplasticisers to short-fibre reinforced concrete generally leads to a lower value of Young’s Modulus. It was thought that the addition of Superplasticisers might reduce the strain of the concrete specimens. Besides, lower Young’s modulus was obtained compare to theoretical value of concrete which might due to equipment errors, such as in actual testing conditions, some deflections may occur in the loading equipments and the hydraulic loading machines. Furthermore, the application of sulphur capping will also contribute to this effect.

6.3 Recommendations for Further Study

In this project, the effects of the usage of Superplasticisers on structural concrete with the most commonly used steel short-fibres, polypropylene short-fibres and Fibremesh reinforced concrete had been assessed. However, there are some other areas worthwhile to pursue further study.

Some of these areas are:

- Investigation regarding the effect of Superplasticisers on manufactured sand can be conducted as usage of manufactured sand reduces workability greatly. Furthermore, effects regarding the fresh and harden properties as a result of the usage of Superplasticisers with manufactured sand in concrete should be assessed.

- Tests regarding effect of different types cement on Superplasticisers and its performance with time lapses can also be conducted to determine its compatibility with different kinds of cement and its performance of aging with time.

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