THE EFFECT OF HIGH STRENGTH CONCRETE BY USING SILICA FUME AND USED ENGINE OIL AS ADDITIVE

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by;

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CERTIFICATION OF ORIGINALITY

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

IZZAT AMIN BIN MOHD YAZID

ABSTRACT

High strength concrete was produced using locally available materials. Nowadays, there are many research conducted based on the processed and unprocessed industrial by-products and domestic wastes as raw material in cement and concrete. This is a positive environmental impact due to the ever-increasing cost of waste disposal and sticker environmental regulation. In order to use a given structural material to its best economic advantage, it is important to understand its properties fully. Thus, fresh and hardened properties of high strength concrete should be investigated properly. Investigation on the effect of high strength concrete by using used engine oil was conducted. The previous research showed that used engine oil have potential on increasing concrete strength and also acting as air-entraining chemical admixture to the concrete. The main objective of the research was to investigate the effectiveness of the combination of used engine oil and silica fume on fresh and hardened properties due to high strength concrete. The test done was slump test for properties of fresh concrete while for properties of hardened concrete the tests were cube crushing strength, split cylinder and porosity test. The main variables included the dosage of used engine oil, the water to binder ratio of the concrete and the cement content. 10% silica fume was used as cement replacement material for six trial mixes. Based on the results obtained, the compressive strength at 28 days for each mixes except for mix SF550a and SF600b had reached 50MPa which is the target strength for this study and the highest strength achieved was 76MPa. The porosity obtained was also low for each mixes which is good for the strength development of the concrete. However, the tensile strength obtained from this research quiet low and it also decreased due to time. This turned out because of cracking and dry shrinkage occurred in the concrete mixes. From this researched, it showed that concrete containing used engine oil and silica fume with mix proportion 1:1.5:2.5 can produce high strength concrete.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Compressive strength, which have been influenced the used of high-performance concrete for economic reasons. While it is evident that a sample of this size cannot claim adequately to cover this subject (CEB 1994), these selected cases provide an insight as to why owners, designers, contractors and concrete producers have found their own particular reasons to use high-performance concrete.

In order to use a given structural material to its best economic advantage, it is important to understand its properties fully. Fresh and hardened properties of high strength concrete should be investigated properly. Silica fume is using as admixtures in the mix proportion. Used engine oil can be used as same as air entrainment. Investigation on the effect of using used engine oil as an additive will be conducted.

1.2 Problem Statement

Civil structures today such as building are design higher and stronger compare to previous years. Simultaneously the construction cost becomes higher. Thus huge structures such as tall buildings, longer bridges and huge damps required higher performance or strength of concrete as well as economic in order to achieve any design that is desired. There is a need for a study to develop a high-strength concrete proportion/mixture yet is cost effective.

Over the years, it has been increasing of industrial wastes and by-products either solid based and/or liquid based chemical in all over the world. Even though the environmental agencies over the country have their laws and regulations regarding the safe handling or disposal of them, but there was a big chunk of such waste are illegally disposed off, which may cause severe environmental disorder.

It was estimated that less than 45% of used engine oil being collected worldwide while the remaining the 55% is thrown by the end user in the environment. Used oil affects both marine and human life. Oil in bodies of water raises to the top forming a film that blocks sunlight, thus stopping the photosynthesis and preventing oxygen replenishment leading to the death of underwater life. In addition, used oil contains some toxic materials that can reach human trough the food chain. Health hazards range from mile symptoms to death. The main source of contaminants in used oil is due to the breakdown of additives and the interaction of these substances with others found in nature. In this context, the proper management of used oil is essential to eliminate or minimize potential environment impacts.

The previous study on the effects of used engine oil on concrete is limited to the medium strength concrete with used engine oil below 0.3% without any chemical admixtures or cement replacement materials. Therefore, the study on high strength concrete containing higher used engine oil and silica is very beneficial to the concrete industry. The successful of producing high strength concrete by using used engine oil is an advantage in order to produce an economical material for carrying vertical loads and also give the effort to utilize liquid chemical waste.

1.3 Objectives of Project

This study will be focus on the potential use of used engine oil (a hazardous waste) as additive in concrete. The main objective of the project is to establish the optimum concrete mix proportion for high strength concrete that contain used engine oil, silica fume, OPC, water and aggregates. The optimum mix proportion is produced based on fresh and hardened properties.

1.4 Scope of Work

With the mixes of Portland cement, water, silica fume, fine and course aggregates and used engine oil at 3% and 4% of cement weight, make several tests to cast a High Strength Concrete (HSC) which is more than 50MPa of compressive strength. The tests are slump test for properties of fresh concrete and while for properties of hardened concrete is cube crushing strength, split cylinder and porosity test.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Concrete has been one of the most commonly used building materials in the world. The exploring of research and applications on concrete materials seems never to end. Usually, there are only four kinds of ingredients composed of the concrete, which are cement, water, fine aggregates and coarse aggregates. With the increasing development of civil engineering, such as high-rise buildings and long-span bridges, higher compressive strength concrete is needed. When the compressive strength of concrete is higher than 50 MPa, it is usually defined as high strength concrete (HSC).

In high strength concrete, admixtures and additives are added into the mix. Frequently, there are three kinds of admixtures, including silica fume, fly ash, and blast furnace slag. Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable.

High-strength concrete is a very economical material for carrying vertical loads in high-rise structures. Until a few years ago, 42 MPa concrete was considered to be high strength. Today, using silica fume, concrete with compressive strength in excess of 105 MPa can be readily produced.

2.2 High Strength Concrete

High strength concrete (HSC) has many definitions. The FHWA definition states that "HSC is concrete that has been designed to be more durable and, if necessary, stronger than conventional concrete." Concrete so designated should meet significantly more stringent criteria than those required for normal structural concrete. It should give optimized performance characteristics and should have high workability, very high fluidity, and minimum or negligible permeability. Serviceability as determined by crack control and deflection control, as well as long-term environment effects, are equally important as durability parameters.

ACI defines high strength concrete as "concrete meeting special combinations of performance and uniformity requirements that cannot always be achieve routinely using conventional constituents and normal mixing, placing, and curing practices." According to ACI Committee 363, concretes with compressive strength higher than 50 MPa are usually defined as high-strength concrete (HSC).

High-strength concretes are characterized by a low porosity and show an internal structure more uniform at the matrix-aggregate interface than normal strength concretes (NSC). HSC is very effective in multistory buildings as it reduces the cross-sectional area of the structural elements. It is also effective in pavements because of less abrasion and longer durability (Shoaib et. al., 1995).

Until the late 1960s, 35 MPa and 42 MPa were considered as HSC while in the mid 1980s, 55 MPa concrete was considered as HSC. Perhaps by the end of this century, 150 MPa will be branded as HSC.

Bill Price (2003) defines high strength concrete as "concrete with a compressive strength greater than covered by current codes and standards." In United Kingdom this would include concrete with a characteristic compressive strength of 60 MPa or more, but in Norway the design code already includes concrete with characteristic cube strengths up to 105 MPa (Helland, 1996) as does the forthcoming Eurocode (CEN,2002).

Therefore for the purpose of this study, concrete with characteristic concrete (cube) strength greater than 50 MPa will be considered as 'high strength'.

2.2.1 Selection and Mix Design of HSC

It should be recognized that there is no single or unique composition for high strength concrete. HSC can be made with a range of materials and mix designs which will produce slightly differing properties.

2.2.1.1 Cements

HSC can be produced with most available Portland cements, but those cements that are particularly coarsely ground are usually unsuitable (Metha and Aitcin, 1990). Special cements have been developed for HSC in Norway which are more finely ground and with lower tricalcium aluminate (C_3A) content (Helland, 1996) but elsewhere normal commercial products are generally employed.

Silica fume is almost ubiquitous in HSC as it has approximately three times the cementing efficiency (on a weight for weight basis) as Portland cement. This facilitates the achievement of high strength without excessive cement contents. Silica fume is available in Europe (and elsewhere) both in the form of a water-based slurry and as a densified powder (Concrete Society, 1993). To be effective it should always be used in conjunction with superplasticizer. It is usually incorporated into concrete at 5-15 per cent by weight of total binder.

PFA and GGBS have also been used successfully together with Portland cement and silica fume (Burg and Ost, 1992), albeit at lower levels than in conventional structural concrete. The reasons for use include improvements in pumping performance and reducing in heat evolution. The use of metakaolin (a highly reactive pozzolan) has also been proposed for HSC although not yet used very extensively. As different sources in cementitious materials may interact of materials may often be required.

All cements should comply with appropriate national or international standards.

2.2.1.2 Admixtures

The role of admixtures is much more significant in HSC than for more conventional concretes. To produce workable concretes at very low levels of water/cement ratios (typically below 0.30), without needing unacceptably high cement content, requires the use of superplasticizers. Melamine-based, naphthalene-based and polycarboxylate ether-based superplasticizers have been used successfully, either individually or in combination. The dosage rates of the superplasticizer can be very high (up to 3 per cent by weight of cement) in order to achieve the required workability. It should be noted that there is generally a saturation dosage of superplasticizer above which no further increase in workability will occur. This can easily be determined by the use of flow cone (Aitcin et al., 1994). The efflux time measured at the same free water/cement ratio for a series of admixture dose rates. This will enable the maximum effective level of admixture addition (i.e. minimum efflux time) to be identified.

Lignosulphonate-based superplasticizers may also be combined with melamine superplasticizers in order to extend their workability retention. Compatibility between different admixtures used in combination as well as compatibility between admixtures and different cement types must be considered when materials are selected (again flow cone test may be useful).

2.2.1.3 Aggregates

Fine aggregates for HSC should be selected to reduce the water demand. Rounded particles are thus preferred to crushed rock fines where possible.

As most HSC concrete mixes contain a large amount of fine material in cement (often greater than 500 kg/m^3), it is accepted practice to utilized slightly coarser grading of fine aggregate than is normal for conventional structural concrete (Aitcin, 1994). The finest fractions of fine aggregate are no longer essential to increase workability or prevent segregation; a coarser grading (fineness modulus 2.7 to 3.0 or BS 882 Class C) (British Standards Institution, 1992) is therefore appropriate. The gradings curve of the fine aggregate should, however, generally be smooth and free gap grading to optimized the water demand.

The requirements for coarse aggregates have been examined earlier. However, the particle shape should ideally be equidimensional (i.e. elongated or flanky) and the grading should once again be smooth with no gaps in the grading between fine and coarse fractions. According to Metha and Aitcin (1990) "a maximum aggregate size 10-14 mm is usually selected although aggregates up to 20 mm may be used if they are strong and free of internal flaws of fractures". This can, however, only be evaluated from trial mixes.

As the influence of aggregates on the performance of high strength concrete is of particular significance it may be possible to achieve the required strength on a project using local aggregate supplies alone. Importation of aggregate supplies or blending materials from number of sources may be required in order to optimize performance.

2.2.1.4 Concrete mix design

Whilst a number of studies have considered the development of a rational or standardized method of concrete mix design for HSC, no widely accepted method is currently available. The main requirements for successful and practical HSC are low water/cement ratio combined with high workability and good workability retention characteristics. In the absence of standard mix design method, the importance of trial mixes in achieving the desired concrete performance in increased.

The following factors should, however, be considered when designing a high strength concrete mix (Table 2.1).

i. The appropriate free water/cement ratio should be selected either experience or by reference to published data. This will typically be range 0.25-0.30.

ii. The cement composition should be selected to maximize strength and other performance requirements. At its simplest this will be Portland cement blended with 5-10 percent silica fume

iii. Proportion coarse and fine aggregate to give smooth overall grading curve in order to keep the water demand low. The proportion of fine aggregate is generally around 5 per cent lower (as proportion of total aggregate) than for

iv. Normal strength concrete. Care must be taken, however, not to make the mix too deficient in fine aggregate, particularly where the concrete is to be dumped.

v. Use the saturation dosage of admixture (of admixtures), determine with a flow cone, to produce workability.

Table 2.1: Commercial mix design from North America (data from Burg and Ost, 1992)

	1	2	3	4	5
Cement (kg/m^3)	564	475	487	564	475
Fly ash (kg/m^3)	-	59	-	-	104
Microsilica (kg/m^3)	-	24	47	89	74
Coarse agg. (kg/m^3)	1068	1068	1068	1068	1068
Fine agg. (kg/m^3)	647	659	676	593	593
Water (L/m^3)	158	160	155	144	151
Superplasticizer (L/m^3)	11.61	11.61	11.22	20.12	16.45
Retarder (L/m^3)	1.12	1.04	0.97	1.47	1.51
Free water/cement ratio	0.281	0.287	0.291	0.220	0.231
90-day cylinder strength (MPa)	86.5	100.4	96.0	131.8	119.3

2.3 Properties of High Strength Concrete (HSC)

2.3.1 Fresh Concrete

Normal practice (particularly in North America, but also in Europe), is to produce high workability HSC. Slumps in excess of 200mm are common, particularly where HSC is used in areas of congested reinforcement. In most cases, however, the flow table is a more appropriate way of assessing the workability of the concrete on site than is the slump test.

It is has found that HSC often appears to require more effort to compact than a more conventional concrete of a similar slump (often termed 'sticky'). This is probably due to combination of high cement content and high levels of admixture. HSC is essentially thixotropic in that whilst it flows easily under the influence of vibration, flow ceases once the vibration is removed (John Newman and Ban Seng Choo, 2003).

HSC is also characterized by significantly lower bleeding than more conventional concretes. If the concrete contains a high silica fume content (> 10 % of total cement), bleeding may be eliminated altogether. The absence of bleeding can lead to difficulties with finishing and also increase the importance of effective early curing in order to prevent plastic cracking.

As the total content of cementitous materials in HSC is typically high (often in excess of 500 kg/m^3), the heat of hydration of the concrete would also be expected to be high. In fact, whilst the heat generation is higher than for lower strength, it does not rise in proportion to cement content. The low water content of a typical HSC may not enable all the cementitious material to hydrate fully. Consequently the inhibition of continued hydration also acts to limit the generation of heat. However, if HSC is used in massive section, the normal precautions will still be required to minimize thermal cracking (Bamforth and Price, 1995).

2.3.2 Hardened Concrete

2.3.2.1 Strength

HSC is obviously characterized by high compressive strength. When measured on standard water cured cubes, however, the rate of early strength gain is similar to that of lower strength concrete. If metakaolin is used, the strength gain may be slightly more rapid than for microsilica-based HSC (Calderone *et al.*, 1994). In some cases when retarding admixtures or very high superplasticizer levels are used the early strength gain may even be lower than normal.

Another characteristic of HSC (particularly when containing silica fume) is that continued strength gain beyond 28 days is often very small, and this is even more so when in-situ strength is considered. However, long-term strength gain is dependent on the type and combination of cementitious materials in the concrete.

The build-up of heat within structural elements accelerates the hydration of the cement and hence the development of strength. Using temperature-matched curing techniques to monitor the development of in-situ strength has indicated that in-situ strength can rise rapidly from about 8 hours after casting. Greater than 100 MPa has been recorded at an age of 24 hours (Price, 1996).

As with conventional normal strength concrete, the tensile strength of HSC increases as compressive strength rises. However, care should be taken in extrapolating existing relationships between compressive and tensile strengths, as the tensile strength does not increase pro-rata with compressive strength (Ahmad and Shah, 1985). Factors such as aggregate shape and composition will also have an influence.

2.3.2.2 Elastic modulus and stress-strain behavior

The elastic modulus of HSC is generally higher than that of normal strength concrete. The increase of elastic modulus is not pro-rata to increases in compressive strength and some existing relationships between these properties are thought to overestimate the elastic modulus at compressive strengths over 100 MPa (American Concrete Institute, 1992) the effects of the shape and mineralogy of the coarse aggregate also has a significant influence over elastic modulus (Aitcin and Mehta, 1990). Stiffer aggregates such as siliceous flints etc. will achieve a much higher modulus than softer granites and limestones at a given level of compressive strength (Nilsen and Aitcin, 1992). It is recommended that if elastic modulus is an important factor in the design, the modulus of the concrete is actually measured on the concrete proposed for use in the project (Concrete Society, 1998).

It is generally recognized that the stress-strain behaviour of HSC differs from that of normal strength concrete. In HSC, the ascending part of the stress-strain curve becomes steeper and more linear, remaining linear to a higher proportion of the ultimate stress. The increased compatibility in elastic modulus between a high strength binder and aggregate particles reduces the degree of microcracking around the aggregate during loading. This in turn results in increased linearity of the ascending limb. The strain at maximum stress is slightly higher than for normal strength concrete but descending portion of the curve is, however, significantly steeper. The brittle behaviour of HSC has implications in terms of secondary reinforcement details, for ensuring ductile behaviour of structures (Concrete Society, 1998).

2.3.2.3 Creep and shrinkage

The creep of HSC (expressed as either specific creep or creep coefficient) appears to be significantly lower than that of normal strength concrete. However, the available information on creep of HSC is relatively limited and further research is required.

Relatively little information is available on the drying shrinkage characteristics of HSC. However, in general due to the low initial water content of the concrete and its low intrinsic vapour permeability, drying shrinkage is thought to be lower than for normal strength concrete.

On the other hand, autogenous shrinkage of HSC can be significantly. Autogenous shrinkage is a reduction in volume occurring without loss of water to the atmosphere (Aitcin, 1999). The combination of low initial water content and silica fume leads to self-desiccation when sufficient water for continued hydration is not available and hence shrinkage. Autogenous shrinkage in HSC is also more rapid than in normal strength concrete. In one study, the autogenous shrinkage of 100 MPa concrete was 110 microstrain, compared with only 40 microstrain for a 40 MPa concrete (de Larrard and Le Roy, 1992). In certain circumstances, the high autogenous shrinkage may be a significant influence on the proposed design.

2.3.2.4 Durability

It is not possible to give a detailed description here of the durability aspects of HSC. However, this can be summarized as follows:

- The low free water/cement ratio required to produce HSC also generally confers enhanced durability on the concrete. When combined with the use of silica fume, significant reductions in water permeability and chloride ingress have been observed (Helland, 1996). HSC is often used in parking structure in North America in order to prevent deterioration resulting from the extensive use of de-icing salts.
- Other areas, in which HSC has found applications on durability grounds, are, as a consequence of its improved abrasion resistance compared to normal strength concrete (Gjorv *et al.*, 1990) and its increased resistance to attack by aggressive chemicals (Nischer, 1995).
- When used in severe freezing and thawing conditions, some air entrainment should still be used even though adequate protections will be achieved at lower air content than that required by normal strength concrete (Hammer and Sellevold, 1990). Air entrainment is more difficult in low water content, superplasticized pastes and higher than normal amounts of air-entrainment admixtures may be needed (Mailvaganam, 1999) to establish a satisfactory air void system. In typical UK conditions, non-air-entrained HSC will be resistant to frost damage.

- Although HSC generally contain high cement contents, the presence of silica fume is thought to prevent ASR (Gudmundsson and Olafsson, 1996). The very low internal moisture content of the concrete will also prevent the swelling and expansion of any gel informed if potentially reactive aggregates are used.

2.4 Pozzolanas

High-performance concrete can be made using Portland cement alone as cementitious material. However, a partial substitution of Portland cement by one or combination of two or three supplementary cementitious materials, when available at competitive prices, can be advantageous, not only from an economic point of view but also from a rheological, and sometimes strength (Aitcin, 1998).

One of the common materials classified as cementitious is pozzolana. According to ASTM 618-94a, pozzolana define as a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely devided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It is essential that pozzolana be in a finely divided state as it is only then that silica can combine with calcium hydroxide (produce by the hydrating Portland cement) in the presence of water to form stable calcium silicate which have cementitious properties (Neville, 1995).

Modern pozzolanic cements are a mix of natural or industrial pozzolans and Portland cement. In addition to underwater use, the pozzolana's high alkalinity makes it especially resistant to common forms of corrosion from sulphates. Once fully hardened, the Portland cement-Pozzolana blend may be stronger than Portland cement due to its lower porosity, which also makes it more resistant to water absorption and spalling .

Some industrial sources of materials with pozzolanic properties are: Class F (silicious) fly ash from coal fired power plants, silica fume from silicon production, rice husk ash from rice paddy-fields (agriculture), and metakaolin from oil sands operations.

Metakaolin, a powerful pozzolan, can also be manufactured, and is valued for making white concrete.

Other industrial waste products used in Portland composite cements include Class C (calcareous) fly ash and ground granulated blast furnace slag.

2.4.1 Pozzolana Reaction on Concrete

Pozzolana contain some form of vitreous reactive silica which, in the presence of water, can combine with lime, at room temperature, to form calcium silicate hydrate of the same type as formed during the hydration of Portland cement. Pozzolanic reaction can be written in the following manner:

$$\textbf{Pozzolan + lime + water} \rightarrow \textbf{calcium silicate hydrate}$$

It must noted that at room temperature this reaction is generally slow and can take several months for completion. However, the finer and the more vitreous the pozzolan, the faster its reaction with lime (Aitcin, 1995).

As has been previously seen, Portland cement hydration liberates a large amount of lime as a result of the hydration of C_3S and C_2S (30% of the anhydrous cement mass). Such lime contributes very little to the strength of the hydrated cement paste and can be responsible for durability problems since it can be leached out easily by water. This leaching action results in an increase in the porosity of the cement paste matrix, and thus in a higher leachability. The only positive feature of this lime in concrete is that protects and passivates the reinforcing steel (Aitcin, 1995).

2.5 Used Engine Oil as an Alternative

Used engine oil can be define as any oil refined from crude oil or synthetic oil that as a result of its use, storage, or handling has become unsuitable for its original purpose, but which may be suitable for further use. Used oil includes crankcase oil, compressor oil, cutting oils, synthetic oils, etc.

Mindess and Young (1981) has been reported that the leakage of oil into the cement in older grinding units result in concrete with greater resistance to freezing and thawing. This implies that adding used engine oil to the fresh concrete mix could be similar to adding an air-entraining chemical admixture, thus enhancing some durability properties of concrete while serving as another technique of disposing the oil waste.

The study of the effect of used engine oil on properties of concrete has been carried out by Bilal et. al.(2003). Mixes was contained with 0.075, 0.15 and 0.30% used engine oil by weight of cement. The result shows that used engine oil acted as a chemical plasticizer improving the fluidity and almost doubling the slump of the concrete mix. Furthermore, used engine oil also increased the air content of the fresh concrete mix (almost double), whereas the commercial chemical air-entraining admixture almost quadrupled the air content. They also found that used engine oil maintained the concrete compressive strength whereas the chemical air-entraining admixture caused a loss of approximately 50% compressive strength at all ages. Bilal also carried out the study for the effect of used engine oil on structural behavior of reinforced concrete elements by using 0.15% used engine oil by weight of cement. The result shows that used engine oil could be used in concrete to improve fluidity and air content without adversely affecting strength properties and structural behavior.

In this study, used engine oil is used as an additive to replace superplacticiser and also be used as same as air entrainment. Air entrainment is recommended principally to improve the freeze–thaw resistance of hardened concrete. As the water in moist concrete freezes, it produces osmotic and hydraulic pressures in the capillaries and pores of the cement paste and aggregate. If the pressure exceeds the tensile strength of the paste or aggregate, the cavity will dilate and rupture. The accumulative effect of successive freeze–thaw cycles and disruption of paste and aggregate, eventually cause significant expansion and deterioration of the concrete. Deterioration is visible in the form of cracking, scaling and crumbling. Entrained air voids act as empty chambers in the paste for the freezing and migrating water to enter, thus relieving the pressures described above and preventing damage to the concrete. Deicing chemicals used for ice and snow removal can cause and aggravate surface scaling of concrete pavements. Properly designed and placed air-entrained concrete will withstand deicers for many years.

Air-entrained concrete made with a low water cement ratio and an adequate cement factor with low tricalcium aluminate cement will be resistant to attack from sulfate soils and waters. Also, the expansive disruption caused by alkali-silica reactivity is reduced through the use of air entrainment. Results of some carbonation tests reported on plain and air-entrained concrete indicate that air entrainment lowers the carbonation, and therefore provides better protection to reinforcing bars against corrosion due to carbonation. Entrained air improves the workability of concrete, reduces segregation and bleeding in freshly mixed and placed concrete, and increases pump-ability of fresh concrete if introduced in low percentages up to 6%. At constant water cement ratios, increases in air will proportionally reduce strength. For moderate-strength concrete, each percentile of entrained air reduces the compressive strength approximately 2–6%. Air entrainment also reduces the flexural strength, the splitting tensile strength, and the modulus of elasticity of hardened concrete. The recommended amount of air to be used in air-entrained concrete depends on many factors such as type of structure, climatic conditions, number of freeze–thaw cycles, extent of exposures to deicers, and extent of exposure to sulfates or other aggressive chemicals in soil or waters.

The advantages of adding air-entraining agents or admixtures to the concrete mixture, whether in liquid or powder form are as follows:

a. Reducing the water/cement ratio is used (part of the design mixture water is replaced by the liquid additive).
b. Improving the durability of the concrete surface by reducing or eliminating the freezing and thawing effects.

c. Increasing the concrete resistance to deicing chemical.

Good quality control of air content has to be maintained, particularly the mixing and vibrating process of the concrete. Overmixing and overvibration can drive out entrapped air bubbles, thereby losing the air-entraining component in the mixture. Also, aggregate grading is important since larger ungraded aggregates cause larger unevenly distributed air voids that weaken the concrete and render it less resistant of frost cycles.

2.6 Silica Fume as an Admixture

Since the 1950s, high strength concrete (HSC) is widely produced as an appropriate substitute for normal-strength concrete (NSC). The lower water to cement ratio (w/c) and higher content of binder are needed to produce HSC. Consequently, high-range water-reducing admixtures (HRWRA) are used to achieve the required workability.

In HSC admixtures and additives are added into the mix. Frequently, there are three kinds of admixtures, including silica fume, fly ash, and blast furnace slag. Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor. Silicon metal and alloys are produced in electric furnaces. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most important use of this material is as a mineral admixture in concrete.

Figure 2.1: Silica fume (figure from the web site of Silica Fume Association, http://www.silicafume.org)

Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO_2 content, silica fume is a very reactive pozzolan when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

High-strength concrete is a very economical material for carrying vertical loads in high-rise structures. Until a few years ago, 6,000 psi concrete was considered to be high strength. Today, using silica fume, concrete with compressive strength in excess of 15,000 psi can be readily produced. The structure shown at the above right used silica-fume concrete with a specified compressive strength of 12,000 psi in columns reaching from the ground through the 57th story. The greatest cause of concrete deterioration in the US today is corrosion induced by deicing or marine salts. Silica-fume concrete with a low water content is highly resistant to penetration by chloride ions. More and more transportation agencies are using silica fume in their concrete for construction of new bridges or rehabilitation of existing structures. Silica-fume concrete does not just happen. A specifier must make a conscious decision to include it in concrete to achieve desired concrete properties. Assistance in specifying silica-fume concrete for high strength or increased durability can be obtained from the SFA or from major admixture suppliers.

Silica fume for use in concrete is available in wet or dry forms. It is usually added during concrete production at a concrete plant as shown in the photo. Silica fume-concrete has been successfully produced in both central-mix and dry-batch plants. Assistance is readily available on all aspects of handling silica fume and using it to produce consistent, high-quality concrete.

Silica Fume has been used as an addition to concrete up to 15 percent by weight of cement, although the normal proportion is 7 to 10 percent. With an addition of 15 percent, the potential exists for very strong, brittle concrete. It increases the water demand in a concrete mix; however, dosage rates of less than 5 percent will not typically require a water reducer. High replacement rates will require the use of a high range water reducer.

i. *Effects on Air Entrainment and Air-void System of Fresh Concrete.*

   The dosage of air-entraining agent needed to maintain the required air content when using Silica Fume is slightly higher than that for conventional concrete because of high surface area and the presence of carbon. This dosage is increased with increasing amounts of Silica Fume content in concrete (Admixtures and ground slag 1990; Carette and Malhotra 1983).

ii. *Effects on Water Requirements of Fresh Concrete.*

   Silica Fume added to concrete by itself increases water demands, often requiring one additional pound of water for every pound of added Silica Fume. This problem can be easily compensated for by using HRWR (Admixtures and ground slag 1990).

iii. *Effects on Consistency and Bleeding of Fresh Concrete.*

   Concrete incorporating more than 10% Silica Fume becomes sticky; in order to enhance workability, the initial slump should be increased. It has been found that Silica Fume reduces bleeding because of its effect on rheologic properties (Luther 1989).

iv. *Effects on Strength of Hardened Concrete.*

Silica Fume has been successfully used to produce very high-strength, low-permeability, and chemically resistant concrete (Wolseifer 1984). Addition of Silica Fume by itself, with other factors being constant, increases the concrete strength. Incorporation of Silica Fume into a mixture with HRWR also enables the use of a lower water-to-cementitious-materials ratio than may have been possible otherwise (Luther 1990). The modulus of rupture of Silica Fume concrete is usually either about the same as or somewhat higher than that of conventional concrete at the same level of compressive strength (Carette and Malhotra 1983; Luther and Hansen 1989).

v. *Effects on Freeze-thaw Durability of Hardened Concrete.*

Air-void stability of concrete incorporating Silica Fume was studied by Pigeon, Aitcin, and LaPlante (1987) and Pigeon and Plante (1989). Their test results indicated that the use of Silica Fume has no significant influence on the production and stability of the air-void system. Freeze-thaw testing (ASTM C 666) on Silica Fume concrete showed acceptable results; the average durability factor was greater than 99% (Luther and Hansen 1989; Ozyildirim 1986).

vi. *Effects on Permeability of Hardened Concrete.*

It has been shown by several researchers that addition of Silica Fume to concrete reduces its permeability (Admixtures and ground slag 1990; ACI Comm. 226 1987b). Rapid chloride permeability testing (AASHTO 277) conducted on Silica Fume concrete showed that addition of Silica Fume (8% Silica Fume) significantly reduces the chloride permeability. This reduction is primarily the result of the increased density of the matrix due to the presence of Silica Fume (Ozyildirim 1986; Plante and Bilodeau 1989).

vii. *Effects on ASR of Hardened Concrete.*

Silica Fume, like other pozzolans, can reduce ASR and prevent deletrious expansion due to ASR (Tenoutasse and Marion 1987).

Silica fume is available in two conditions: dry and wet. Dry silica can be provided as produced or densified with or without dry admixtures and can be stored in silos and hoppers. Silica Fume slurry with low or high dosages of chemical admixtures are available. Slurried products are stored in tanks with capacities ranging from a few thousand to 400,000 gallons (1,510 m3) (Admixtures and ground slag 1990; Holland 1988).

CHAPTER 3
METHODOLOGY

3.1 Project Identification

The methodologies that have been followed through finishing this project are as shown below:

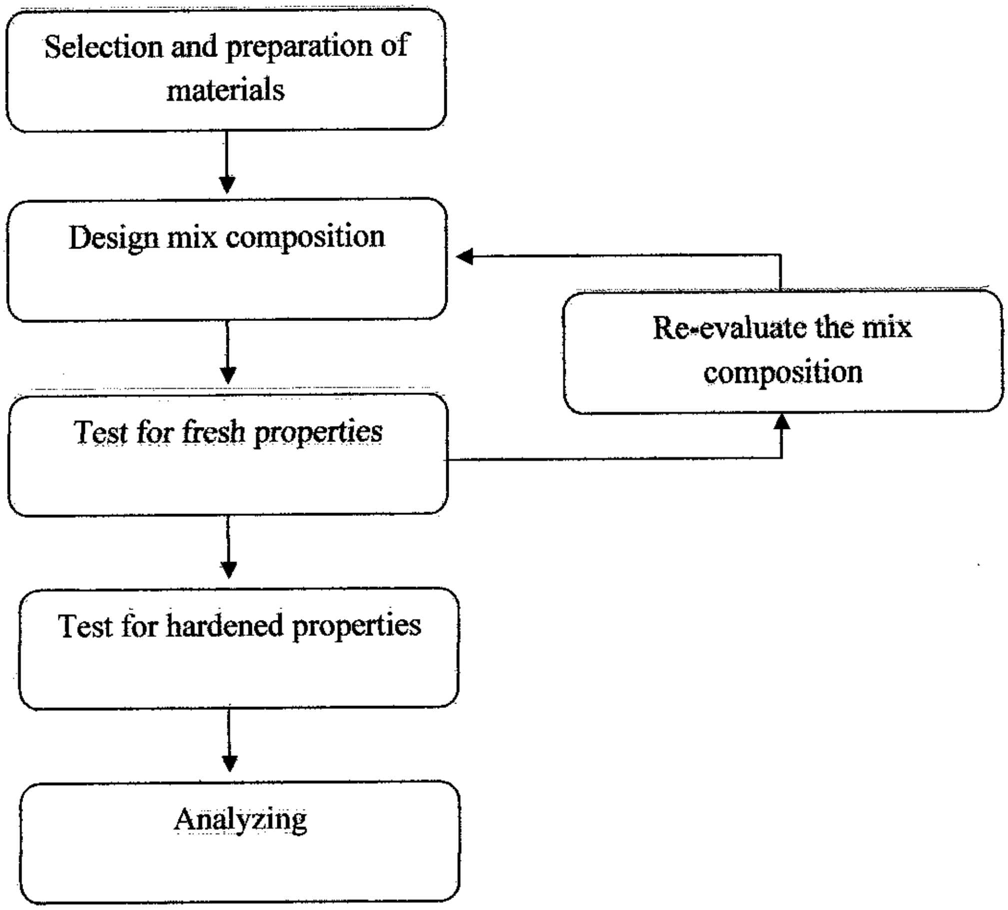

Figure 3.1: Flow chart of activities

3.1.1 Literature Review

Literature review was conducted to expose to the previous studies that has been done on the topic of the project. Literature review is a research based on the journals, publications and also reference books from the library. The idea on how to conduct the project was planned from the knowledge gained from the literature review.

3.1.2 Discussion

Weekly meeting with the supervisor was conducted to ensure that the project is going on the right path. The meetings lead to a better understanding besides in depth researches. Ideas were exchange at the meetings.

3.2 Selection of Materials

The materials used for mix design are cements, fine aggregate, course aggregate, water, silica fume and used engine oil. There are three types of samples should be done which are cube test, split cylinder, and plank slab.

The cementitious material that has been used in this study was Ordinary Portland Cement while the admixtures were silica fume and used engine oil. For gravel as course aggregate used is 20mm nominal maximum gravel. For sand as fine aggregate used was 3.35mm nominal maximum sand.

Six trial mixes were made with water/binder ratios (w/b) of 0.36 to 0.46 for silica fume. Water and admixture was measured in percentage by weight proportion of cement used. Six trial mixes includes a concrete 10% silica fume. Twelve cubes of 150 mm were cast in order to study the mechanical behavior of each mixes. The trial mixing conducted until the mix is properly compacted.

Ordinary Portland Cement (OPC) Type 1 was used in this research, according to BS EN 197-1 2000. OPC Type 1 was preferred because the observation on concrete properties can be done in normal hydration process hence the advantages of silica fume usage in concrete can be optimized.

Aggregate that used to prepare concrete are confirming to BS 882: 1992. In this experimental program, water reducer such as used engine oil. Chemical composition and physical properties of Portland cement, silica fume and used engine oil were given in Table 3.1.

Table 3.1: Chemical compositions of OPC, silica fume and used engine oil

Chemical Composition	Ordinary Portland Cement (%)	SF (%)	Used Engine Oil (%)
SiO_2	21.98	91.7	-
Al_2O_3	4.65	1	-
Fe_2O_3	2.27	0.9	0.43
CaO	61.55	1.68	15.9
MgO	4.27	1.8	-
SO_3	2.19	0.87	37.0
K_2O	1.04	-	-
Na_2O	0.11	0.1	-
CaO	-	-	15.9
P2O5	-	-	8.95
ZnO	-	-	17.7
Cl-	-	-	15.9

3.3 Mix Design Proportion

This project includes six types of mixes in order to evaluate the effect of used engine oil with silica fume due to high strength concrete. Material used are Portland cement, Silica fume, sand as fine aggregates, Crushed Bassalt or Gravel of 20 mm maximum size for crushed aggregates and used engine oil with ratio of cement on fine and coarse aggregates are to 1:1.5:2.5. Table 3.2 shows each type of mixes that are going to be cast in 3, 7, 28 and 90 days for cubical crushing strength test and porosity observation and as well as for split cylinder test in 28 and 90 days.

Table 3.2: Mix proportion (Quantities are in kg/m3 of concrete)

Mix	w/b	SF (%)	Used Engine Oil (%)	Cement (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)
SF500a	0.36		3			
SF500b	0.46		4	500	690	1150
SF550a	0.46		3			
SF550b	0.4		4	550	670	1120
SF600a	0.46		3			
SF600b	0.46	10	4	600	650	1090

3.4 Concrete Mixing

The physical properties of density and strength of concrete are determined, in part, by the proportions of the three key ingredients, water, cement, and aggregate. The proportioning ingredients can be done by volume or by weight. Proportioning by volume is less accurate, however due to the time constraints of a class time period this may be the preferred method.

A basic mixture of mortar can be made using the volume proportions of 1 water : 2 cement : 3 sand. Most of the mixing activities in lab can be conducted using this basic mixture. Another "old rule of thumb" for mixing concrete is 1 cement : 2 sand : 3 gravel by volume. Mix the dry ingredients and slowly add water until the concrete is workable. This mixture may need to be modified depending on the aggregate used to provide a concrete of the right workability. The mix should not be too stiff or too sloppy. It is difficult to form good test specimens if it is too stiff. If it is too sloppy, water may separate (bleed) from the mixture.

Below is how concrete mixing for this project was done:

- The aggregates were mixed in the mixer for 1minute.
- The cements, silica fume, used engine oil and half of the water were added into the mixer and mix for 8 minutes.

- Another half of the water is added and mix for 1 minute.
- The mixer was stopped and slump test was done before it can be use for casting.
- Equipment used: Mixer and Slump test

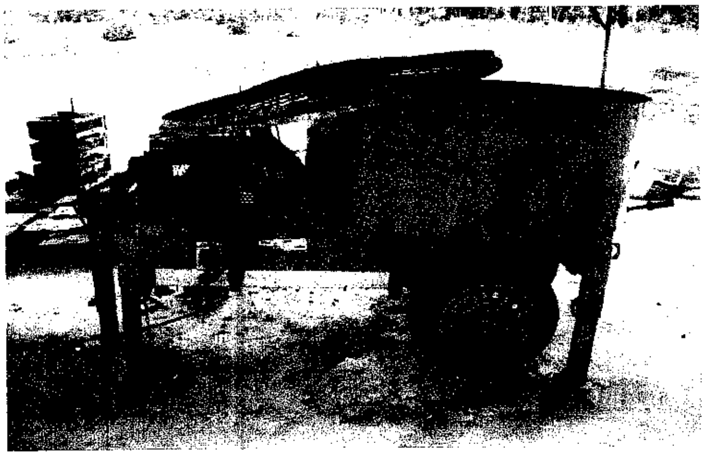

Figure 3.2: Mixer Machine

3.5 Concrete Casting

Fresh concrete will then poured into cube, slab and cylinder. The purpose is to cure the concrete and perform several tests on the concrete. After pouring the fresh concrete in the mould, it will be vibrated in order to prevent from honey comb or void spaces of air in the concrete to exist. This is because honey comb could affect the strength or characteristics of the specimens.

The used engine oil content and water to binder ratio were advised to obtain concrete that could be compacted easily. The specimens were compacted by external vibration, varying the vibration time according to its consistency. After casting the specimens in the moulds, they were covered with polythene sheet to prevent evaporation and left for 24 hours. Eventually, all specimens were removed from the moulds and were transferred into the water bath at room temperature for curing until the desired age of testing at 3, 7, 28 days and 90 days. The purpose of curing is to avoid shrinkage cracking due to temperature fluctuation and also to gain the maximum strength of the concrete.

Figure 3.3: Vibrator

Table 3.3: Samples of test

Test	Item per mix	Age (day)				Total Sample
		3	7	28	90	
Compression Stress	3	√	√	√	√	12
Porosity	3	√	√	√	√	12
Split Cylinder Test	3			√	√	6

Size of cube and slab are as stated below:

Cube = 150mm x 150mm x 150mm

Slab = 200mm x 300mm x 40mm

Cylinder = 100mm (diameter) x 200mm

3.6 Hardened Concrete Tests

Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics if its history is unknown. For new concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures. The 'concrete cube test' is the most familiar test and is used as the standard method of measuring compressive strength for quality control purposes. Concrete beam specimens are cast to test for flexural strength and cast cylinders can be used for tensile strength. Specimens for many other tests can be made at the same time to assess other properties.

3.6.1 Compression Test

Comparative performance of hardened concrete is investigated by measuring the development of compressive strength with curing age of 3, 7, 28 and 90. The compressive strength was taken as the maximum compressive load it could carry per unit area.

Figure 3.4: Compression machine (ADR 1500)

The compression strength test is used to estimate the concrete strength in a structure. The strength is calculated from the failure load divided by the cross sectional area resisting load. For compression test, the load is applied directly but for indirect tensile test, splitting tensile test is used.

Procedure:

i. The specimen is removed from curing tank and the surface water is wiped and the specimen is grit off.
ii. Each specimen is weight to the nearest kg.
iii. The top and lower platens of the testing machine are cleaned. The sample is carefully centered on the lower platen and it is ensured that the load will be applied to two opposite cast faces of the sample.
iv. The data is been set up depends on the size of the sample tested and the pace rate automatically set constantly. For this experiment, the rate of the cube (150x150x150mm) is 6.80 and for cylinder (200x100mm) is 0.94.
v. Without shock, the load is applied and increased continuously at a nominal rate within the range of 0.2 N/mm^2 to 0.4 N/mm^2 until no greater load can be sustained. The maximum load applied to the cube is recorded.
vi. The type of failure and appearance of cracks is noted.
vii. The stress of each is calculated by dividing the maximum load by the cross sectional area. For automatic machine the stress is already stated.

3.6.2 Porosity Test

Porosity of concrete is an important factor is classifying its durability. Generally, concrete of a low porosity will afford better protection to reinforcement within it than concrete of high porosity.

There are no vacuum absorption tests in the British Standards, although an earlier version of BS 3921 did contain such a test. There are a number of variations on vacuum absorption in the RILEM tests in which various reduced and soaking times are recommended.

The porosity test for this project is using vacuum saturation method. Vacuum saturation is a method of assessing the total water absorption porosity of a material. Porosity can be determined by measuring its weight gain and expressing this as a percentage of the mass of the sample.

Procedure:

i. The core samples are putted inside the vacuum desiccators for 30 minutes.

ii. After 30 minutes, the desiccator is filled by water until all the samples are submerged. Experiment is run for 6 hours.

iii. The desiccator is off and let the samples for overnight.

iv. The next day, the samples is wipe and the weight of saturated surface dry samples in air (W_{sat}) and weight of saturated surface dry samples in water (W_{water}) is weighted using Buoyancy Balance.

v. Then, the samples are putted in oven for 24 hours.

vi. After one day, the samples are taken off and the weight of oven dry samples (W_{oven}) is weighted.

vii. The porosity can be calculated using formula:

$$P = \frac{W_{sat} - W_{oven}}{W_{sat} - W_{water}} \times 100$$

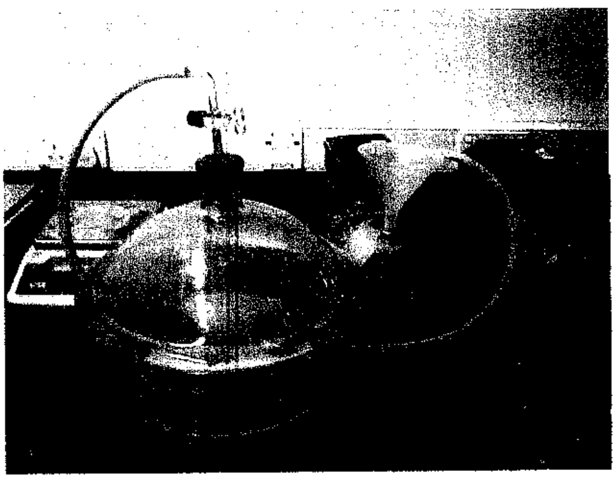

Figure 3.5: Desiccator

3.6.3 Split Cylinder Test

Comparative performance of hardened concrete is investigated by measuring the development of its split cylinder test with curing age of 28 and 90. This test is similar to the compression test in order to obtain its maximum tensional strength by using the compression machine (ADR 1500). It differs to the compression test by locating the cylinder into its holder then only places it into the machine.

This method consists of molding a concrete cylinder with an installed steel tube or reinforcing bar through its center upon which strain gages are mounted (Figure 3.6). The tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure. The definition of failure can vary according to material type and design methodology. This is an important concept in engineering, especially in the fields of material science, mechanical engineering and structural engineering.
There are three typical definitions of tensile strength:

- Yield strength: The stress at which material strain changes from elastic deformation to plastic deformation, causing it to deform permanently.
- Ultimate strength: The maximum stress a material can withstand.
- Breaking strength: The stress coordinate on the stress-strain curve at the point of rupture

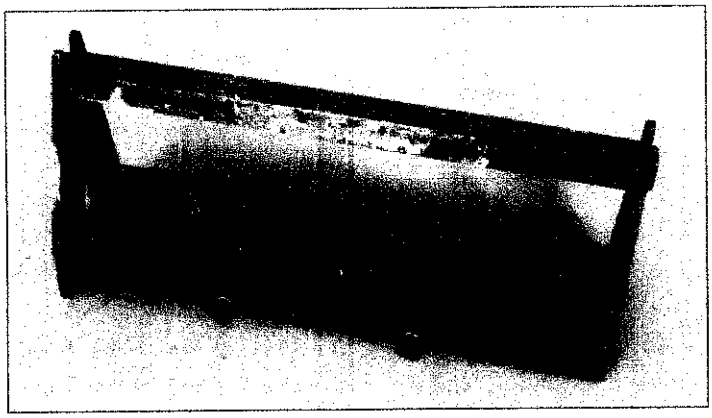

Figure 3.6: Cylinder holder

CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

Concrete properties can be divided into two which is fresh and hardened concrete. In this study, slump test was conducted to measure the workability of concrete in fresh state. Hardened concrete measured by conducting compressive strength test, split cylinder test and porosity test. These parameters are required in order to establish the performance of concrete containing used engine oil and silica fume.

4.2. Fresh Properties

4.2.1. Slump Test

Slump test is the test that most widely used in measuring the workability of fresh concrete because of the simplicity of the apparatus required and the test procedure. The slump test has been found to be useful in ensuring the uniformity among different batches of supposedly similar concrete under field condition.

In this study, the mixes can be divided into two based on the water to binder ratio. The first category is w/b ration 0.36 to 0.40 and the second is w/b ratio above 0.4 as shown in table 4.1. From the result obtained, category 1 give lower slump as compared to category 2. It shows that w/b ratio affected the workability of concrete. Comparison between the slump of mixes illustrated in Figure 4.1.

Beside that, because of high cement content along with 10% of silica fume (compare to cement content), the workability (slump) was very low (≤ 10-20 mm) because of a dry concrete. High cement content could not be hydrated well of these drying shrinkage would be same. The used of used engine oil as an admixture not contribute to the workability of concrete.

Table 4.1: Mix proportion and slump

Category	Mix	w/b	SF (%)	UEO (%)	Cement (kg/m³)	Fine Agg. (kg/m³)	Coarse Agg. (kg/m³)	Slump (mm)
1	SF500a	0.36	10	3	500	690	1150	0
	SF550b	0.4		4	550	670	1120	15
2	SF500b	0.46		4	500	690	1150	15
	SF550a	0.46		3	550	670	1120	50
	SF600a	0.46		3	600	650	1090	12
	SF600b	0.46		4	600	650	1090	30

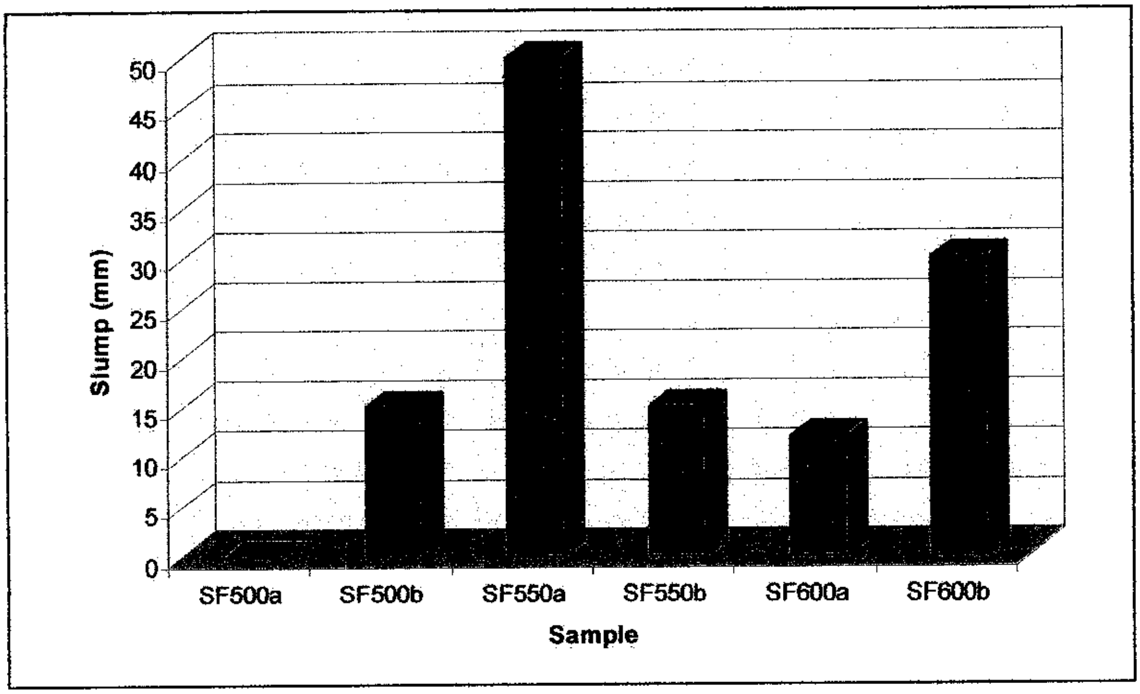

Figure 4.1: Slump for each sample of concrete mixes

4.3 Hardened Properties

4.3.1 Compressive Strength

Compressive strength of each mix was measured at the age 3, 7, 28 and 90 days and the result is shown in Table 4.2. From the result obtained, the maximum compressive strength was achieved by mix SF500b which is up to 76.30 MPa and 79.19 MPa at 28 and 90 days respectively. The minimum compressive strength came from mix SF550a which is 35.4 MPa and 44.42 MPa at 28 and 90 days respectively. Mix from category 1 give average result. It was noted that the higher w/b ratio give a lower strength. A strength development of concrete obtained in figure 4.2.

Table 4.2: Compressive strength

Category	Mix	w/b	Compressive strength (MPa)			
			3 days	7 days	28 days	90 days
1	SF500a	0.36	29.15	50.4	51.64	55.82
	SF550b	0.4	56.42	59.15	61.58	62.15
2	SF500b	0.46	35.26	53.67	76.39	79.19
	SF550a	0.46	28.83	33.74	35.4	44.42
	SF600a	0.46	45.27	55.27	61.78	64.28
	SF600b	0.46	34.74	41.13	48.51	55.65

It was noted that the finer particles size enables silica fume to act as filler that seeped into the tiny spaces between cement particles and as well as spaces between cement particles and aggregate. A greater surface area providing space for nucleation of C-S-H and calcium hydroxide $CaOH)_2$. This will accelerate the reactions and form smaller calcium hydroxide crystals.

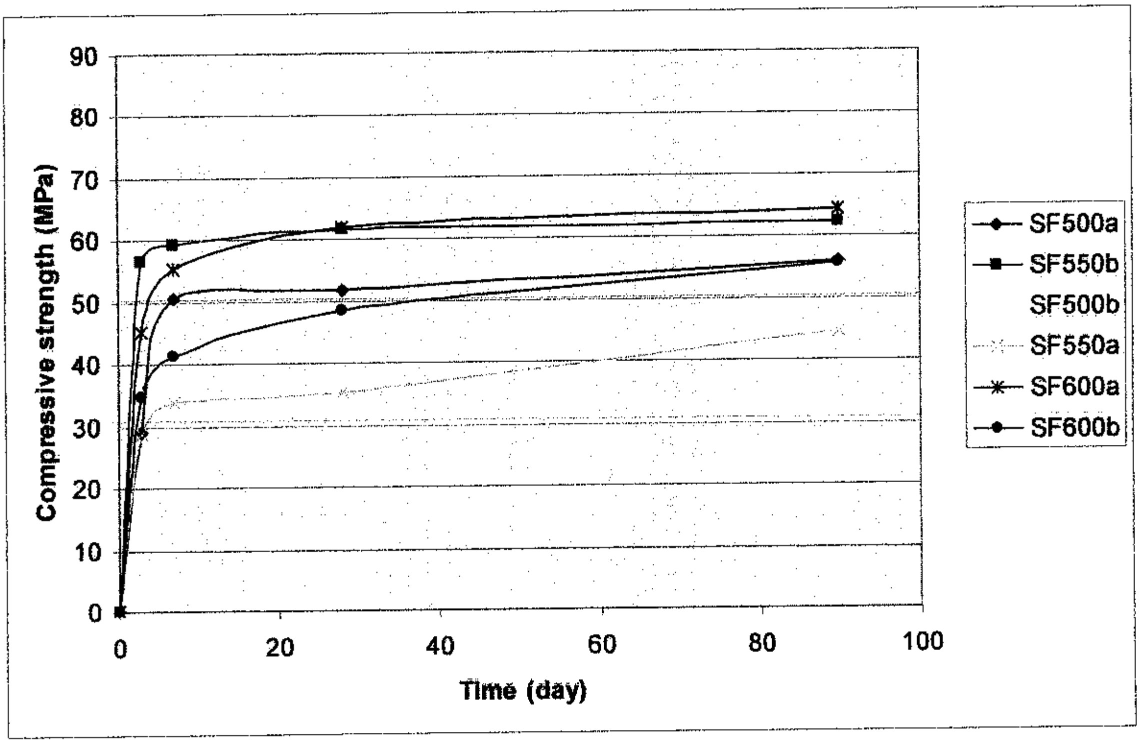

Figure 4.2: Strength development of concrete containing used engine oil

The improvement of compressive strength is due to the pozzolanic reaction between Portland cement and silica fume. According to Gambhir [6], about 40% of Portland cement is composed of the primary mineral tricalcium silicate, which on hydration forms calcium silicate hydrate (C-S-H) and calcium hydroxide, $Ca(OH)_2$. In these mixes, silica fume act as pozzolana because of a very high non crystalline silica (SiO_2) glass content which is the principal reactive constituent of pozzolana. This silica combines with the calcium hydroxide released on the hydration of Portland cement. Calcium hydroxide in hydrated Portland cement as such does not contribute to development of strength, but by adding pozzolana such as silica fume will utilized with reactive silica. Slowly, and gradually it forms additional C-S-H which is a binder and fills up the space, and give impermeability and ever-increasing strength.

On the other hand, used engine oil did not act as a water reducer because of a high water to binder ratio for easily compacted. Because of a slippery used engine oil can be seeped up a tiny particle into the spaces between cement particles and as well as spaces between cement particles and aggregate.

4.3.2 Tensile Strength

The tensile strength governs the cracking behavior and affects other properties such as stiffness, damping action, bond to embedded steel, and durability of concrete. It is also of importance with regard to the behavior of concrete under shear loads. The tensile strength is determined either by direct tensile tests or by indirect tensile tests such as flexural or split cylinder tests.

For this experiment, the tensile strength test is determined by indirect tensile tests which are used split cylinder test. Tensile strength test was measured for every 28, and 90 days. Tensile strength was been tested using Compressive Strength Test Machine by constant pace rate 0.94. Each result for tensile strength is the average of three test values. Three cylinders were tested for splitting tensile strength (ASTM C496-96).

Table 4.3: Tensile strength

Category	Mix	w/b	Tensile (Mpa)	
			28 days	90 days
1	SF500a	0.36	5.41	5.17
	SF550b	0.4	2.46	2.55
2	SF500b	0.46	4.45	4.03
	SF550a	0.46	3.3	2.78
	SF600a	0.46	2.59	2.3
	SF600b	0.46	2.78	2.53

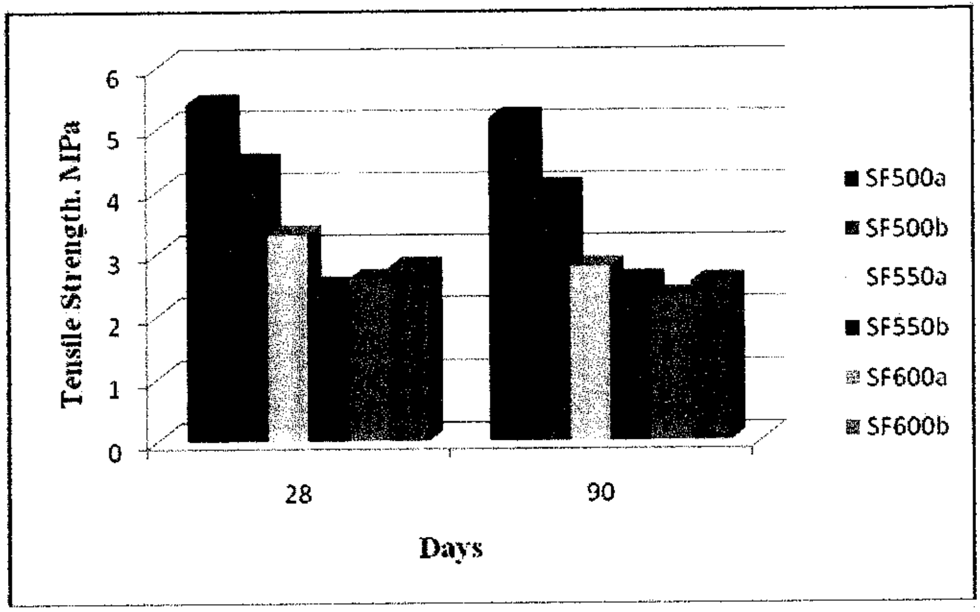

Figure 4.3: Tensile strength for each mixes at 28 days and 90 days obtained from split cylinder test

From figure 4.3, it shows that the tensile strength for each sample of mixes had decreased due to time from 28 days to 90 days except for mix SF550b. This occurred because of there was cracking inside the cylinder. This cracking may happen due to the way of the mixes were compacted. If the mixes were not well compacted, air bubbles or void will occur. Air bubbles in the molds will become weak points during strength tests. Other factor that contributed to above data occurred because of hydrated cement paste is known to contain numerous discontinuities – pores, microcracks and void, but the exact mechanism through which they affect the strength is not known. A. M. Neville (2002) reported that "the voids themselves need not act as flaws, but the flaws may be cracks in individual crystal associated with the voids or caused by shrinkage or poor bond" (p. 290).

From figure 4.3, it showed that mix SF500a gained the highest tensile strength compared to other mixes. This happen because of larger shrinkage occurred in higher water/cement ratio. According to A. M. Neville (2002) , " as far as a shrinkage of the hydrated cement paste itself is concerned, shrinkage is larger the higher the water/cement ratio because the latter determines the amount of evaporable water in the cement paste and the rate at which water can move towards the surface of the specimen" (p. 429). Besides that, mixes SF600a and SF600b with high cement content achieved low tensile strength because of dry concrete. High cement content could not be hydrated well of these drying shrinkage would be same.

There are also several factors that contribute to the values obtained such as the mixture was not compacted well, the materials was not in a good condition such as the wet aggregate, and there was others wastes mix with the materials that can affect the quality of the strength. Sometimes it might caused by the machine error when the reading was taken. Regarding the effect of freezing and thawing, Marzouk and Jiang (1994) reported that after 700 cycles, the modulus of rupture of high strength concrete was reduced by 15% whereas the reduction was 60% for normal strength concrete.

4.3.3 Porosity

Porosity of each mix was measured at the age 3, 7, 28 and 90 days and the result is shown in Table 4.4. Porosity define as the total volume of the overall volume of pores larger than gel pores, expressed as a percentage of the overall volume of the hydrated cement paste, is a primary factor influencing the strength of the cement paste.

Table 4.4: Porosity of concrete samples

Category	Mix	w/b	Porosity (%)			
			3 days	7 days	28 days	90 days
1	SF500a	0.36	11.24	10.8	7.18	6.65
	SF550b	0.4	10.3	10.22	7.21	7.10
2	SF500b	0.46	11.06	10.79	10.2	8.59
	SF550a	0.46	12.43	11.55	10.2	9.48
	SF600a	0.46	12.5	11.66	8.81	8.00
	SF600b	0.46	12.31	12.22	12.17	11.03

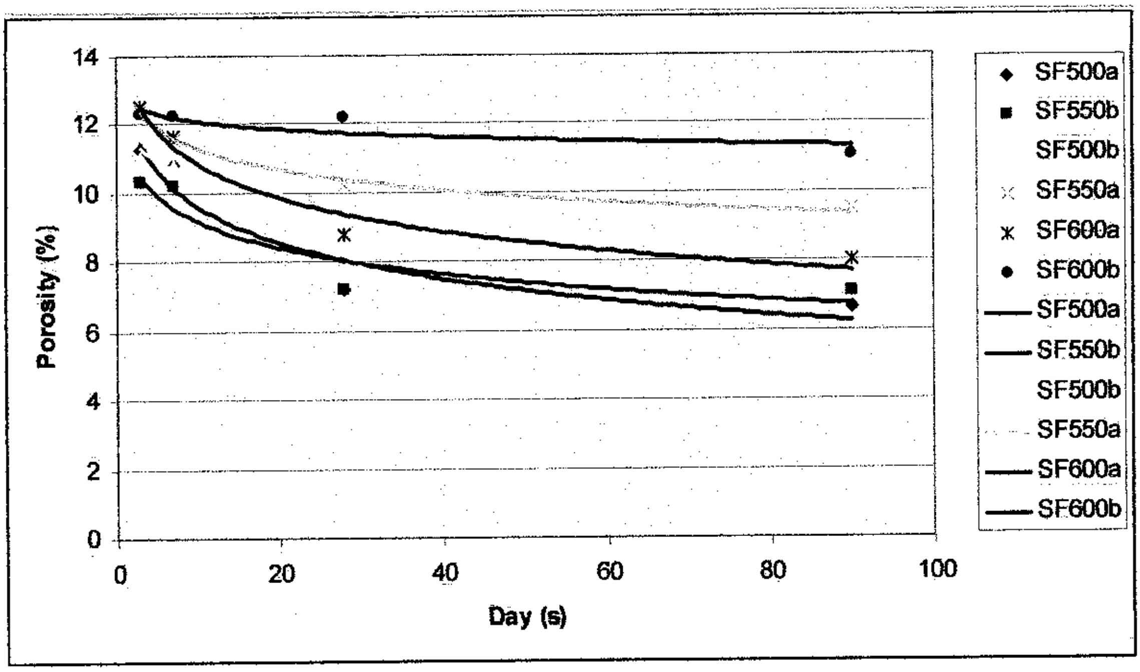

Figure 4.4: Porosity of concrete sample

From the result obtained, porosity of all samples decreased with increasing of time. From the result obtained, the mixes contain lower w/b ratio give lower porosity value compare to the mixes with higher w/b ratio. This is due to the hydration process in the concrete that will leave the pores after the process completed. That means, the higher water content the higher porosity. Theoretically, the more lower the porosity, the more good of the concrete itself.

As shown in figure 4.4, mix SF500a gained the lowest porosity at 90 days while mix SF600b gained the highest porosity compared to other mixes. This may happen because of higher cement is more difficult to hydrate and its make the mix become dry. This is because micro cracking inside the concrete will occur start from the pore. The difference in porosity between concrete and neat cement paste, increase with the progress of hydration and arises from the presence in concrete of some pores larger than those which can exist in neat cement paste.

Although aggregates are porous, it should be noted that their pores are normally discontinuous in a concrete matrix, being completely enveloped by cement paste. Detached voids or pores in concrete, including entrained air bubbles that are discontinuous similarly do not contribute significantly to concrete permeability. Concrete porosity is usually expressed in terms of percentage by volume of concrete. It is the interconnectivity of pores, rather that total porosity that determines a concrete's permeability. A concrete with a high proportion of disconnected pores may be less permeable that a concrete with a much smaller proportion of connected, or continuous pores. With greater particularity, it is the overall nature of the matrix pore structure that ultimately affects its permeability. The size, distribution, interconnectivity, and shape of pores are all determining factors in the overall permeability of a concrete matrix.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This paper presented the results of a research study on the effect of high strength concrete by using used engine oil and silica fume. It showed that, concrete mix of SF500b which contained 4% of used engine oil, 10% of silica fume, 500 kg/m^3 of cement, 690 kg/m^3 of fine aggregates and 1150 kg/m^3 of coarse aggregates is the optimum mix proportion that achieved 76 MPa of compressive strength at 28 days. Besides, high strength concrete can be produced with high w/c such as 0.46 with the addition of an additive such as used engine oil. Even though the mixes need higher w/b, but the result was quite high and achieved the target strength (50MPa). Thus, it is possible to produce high strength concrete with 3% and 4% of used engine oil which is we can turn the waste into value.

5.2 Recommendation

For further improvements, a few key areas where further researchers can be carried out in order to obtained an accurate data on characteristics of a peat soil and improvements methods are listed below:

i. From the observation made based on this research, that mixing concrete in high volume for its mixing proportion could affect the characteristics of the hardened concrete. Thus, casting cubes, cylinders and slabs separately are appropriate so that more accurate results could be obtained.
ii. Compare with superplasticiser.
iii. Mix with a variety of used engine oil (1%, 5%, 10%)
iv. Mixing the proportion of the mix design according to the flow of mixing concrete is essential where water is to be mix at the most end of the procedure for these mixes

v. Vibration needs to be done in a short period of time in order to avoid from honey comb because if it takes too long to vibrate, most of its course aggregates will be at the bottom part of the mould. This will make the value for testing become inaccurate.

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APPENDIX A

Table 1: Compressive strength data for 3, 7, and 28, and 90 days

Mix SF500a

day(s)	3			7			28			90		
weight (kg)	7.425	7.739	7.729	8.113	8.330	8.180	8.075	7.906	8.047	8.179	7.873	7.900
sample peak load(kN)	629.6	682.2	385.1	1011	1384	1257	1026	1183	1141	1066	1256	1001
sample stress(MPa)	27.98	30.32	17.12	44.93	61.50	55.86	45.58	52.56	50.72	47.36	55.82	44.49
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	29.15			50.4			51.64			55.82		

Mix SF500b

day(s)	3			7			28			90		
weight (kg)	8.111	8.069	8.297	8.228	8.214	8.243	8.151	8.103	8.138	8.216	8.175	8.281
sample peak load(kN)	736.0	850.8	544.4	1217	1203	1203	1782	1544	1656	1391	1302	1660
sample stress (MPa)	32.71	37.81	24.20	54.07	53.49	53.46	79.19	68.63	73.59	61.68	57.86	73.78
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	35.26			53.67			76.39			79.19		

Mix SF550a

day(s)	3			7			28			90		
weight (kg)	7.948	7.813	7.948	7.876	8.016	7.968	7.978	7.690	7.755	7.942	8.046	7.794
sample peak load(kN)	652.2	644.8	596.9	769.1	749.0	678.8	511.4	791.3	801.6	1026	885.1	1089
sample stress (MPa)	28.99	28.66	26.53	34.18	33.29	30.17	22.73	35.17	35.65	45.58	39.34	48.40
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	28.83			33.74			35.4			44.42		

Mix SF550b

day(s)	3			7			28			90		
weight (kg)	2.430	2.436	2.478	2.423	2.454	2.428	2.512	2.424	2.447	2.424	2.432	2.450
sample peak load(kN)	346.1	549.2	279.2	591.0	656.6	592.0	616.7	611.7	618.9	608.8	849.8	634.1
sample stress (MPa)	34.61	54.92	57.92	59.10	65.66	59.20	61.67	61.17	61.89	60.88	84.95	63.41
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	56.42			59.15			61.58			62.15		

Mix SF600a

day(s)	3			7			28			90		
weight (kg)	2.443	2.380	2.415	2.473	2.429	2.469	2.430	2.402	2.396	2.453	2.462	2.478
sample peak load(kN)	323.6	433.9	471.5	561.4	509.3	544.0	612.9	622.7	595.5	544.6	562.9	628.0
sample stress (MPa)	32.36	43.39	47.15	56.14	50.93	54.40	61.29	62.27	59.55	54.46	56.29	62.80
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	45.27			55.27			61.78			64.28		

Mix SF600b

day(s)	3			7			28			90		
weight (kg)	2.320	2.328	2.348	2.329	2.362	2.360	2.376	2.358	2.346	2.330	2.375	2.388
sample peak load(kN)	335.2	348.6	358.4	395.0	400.4	422.1	482.6	469.2	487.6	515.6	594.8	559.2
sample stress (MPa)	33.52	34.86	35.84	39.50	40.04	42.21	48.26	46.92	48.76	51.56	59.48	55.92
pace rate	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Ave stress (MPa)	34.74			41.13			48.51			55.65		

APPENDIX B

Table 2: Tensile strength data for 28 and 90 days

Mix SF500a

day(s)	28			90		
weight (kg)	3.705	3.623	3.713	3.721	3.701	3.689
sample peak load(kN)	167.6	150.5	172.4	158.3	150.2	165.4
sample stress (MPa)	5.335	4.792	5.488	5.034	4.783	5.306
pace rate	0.94	0.94	0.94	0.94	0.94	0.94
Average stress (MPa)	5.41			5.17		

Mix SF500b

day(s)	28			90		
weight (kg)	3.712	3.713	3.584	3.710	3.705	-
sample peak load(kN)	138.5	153.1	128.2	126.6	77.2	-
sample stress (MPa)	4.408	4.873	4.081	4.029	2.457	-
pace rate	0.94	0.94	0.94	0.94	0.94	-
Average stress (MPa)	4.45			4.03		

Mix SF550a

day(s)	28			90		
weight (kg)	3.575	3.601	-	3.662	3.621	3.627
sample peak load(kN)	100.1	107.5	-	91.6	85.5	82.9
sample stress	3.185	3.421	-	2.916	2.721	2.639
pace rate	0.94	0.94	-	0.94	0.94	0.94
Average stress (MPa)	3.3			2.78		

Mix SF550b

day(s)	28			90		
weight (kg)	3.748	3.743	3.706	3.723	3.739	3.768
sample peak load(kN)	86.2	73.1	72.6	86.0	76.1	78.0
sample stress	2.743	2.327	2.310	2.738	2.424	2.483
pace rate	0.94	0.94	0.94	0.94	0.94	0.94
Average stress (MPa)	2.46			2.55		

Mix SF600a

day(s)	28			90		
weight (kg)	3.685	3.676	3.691	3.751	3.623	3.760
sample peak load(kN)	90.1	65.0	89.2	66.0	60.7	90.1
sample stress	2.869	2.069	2.841	2.102	1.932	2.867
pace rate	0.94	0.94	0.94	0.94	0.94	0.94
Average stress (MPa)	2.59			2.3		

Mix SF600b

day(s)	28			90		
weight (kg)	3.547	3.589	3.585	3.612	3.554	-
sample peak load(kN)	95.4	78.3	88.1	62.4	96.4	-
sample stress	3.036	2.491	2.804	1.993	3.069	-
pace rate	0.94	0.94	0.94	0.94	0.94	-
Average stress (MPa)	2.78			2.53		

APPENDIX C

Table 3: Porosity data for 3, 7, and 28, and 90 days

Mix SF500a

day(s)	3			7			28			90		
weight in air (g)	233.2	221.0	226.8	240.0	231.9	239.8	250.2	245.2	230.5	237.7	252.6	251.3
weight in water(g)	81.3	73.6	78.5	88.7	80.2	87.8	82.4	98.4	87.6	91.7	93.4	94.8
weight dry	216.4	204.9	209.4	221.1	214.2	224.7	215.0	236.6	221.0	227.8	242.0	241.1
porosity	11.24			10.8			7.18			6.65		

Mix SF500b

day(s)	3			7			28			90		
weight in air (g)	198.3	195.6	195.1	185.2	190.8	184.7	221.4	225.1	213.4	296.3	298.0	285.5
weight in water(g)	64.5	62.7	60.4	56.3	60.1	54.0	94.8	88.8	93.6	119.9	121.1	112.9
weight dry	183.6	180.7	180.3	170.5	176.7	169.9	236.9	230.1	235.4	281.1	282.8	270.7
porosity	11.06			10.79			10.2			8.59		

Mix SF550a

day(s)	3			7			28			90		
weight in air(g)	200.7	196.5	199.7	197.7	200.5	198.2	221.9	221.3	212.9	215.3	224.3	216.5
weight in water(g)	63.5	62.2	62.8	60.9	63.5	61.7	94.3	85.5	93.1	86.4	90.2	87.5
weight dry	182.6	181.3	182.2	181.0	185.3	182.7	236.4	227.3	234.9	203.0	211.5	204.3
porosity	12.43			11.55			10.2			9.48		

Mix SF550b

day(s)	3			7			28			90		
weight in air(g)	170.1	184.1	181.6	184.2	192.1	189.1	255.5	247.2	231.5	230.0	234.8	230.8
weight in water(g	46.6	53.5	53.6	56.4	59.6	58.5	82.4	98.4	87.6	83.6	88.9	84.2
weight dry	158.0	169.7	168.7	169.9	176.8	174.3	215.0	236.6	221.0	212.2	218.1	214.4
porosity	10.3			10.22			7.21			7.10		

Mix SF600a

day(s)	3			7			28			90		
weight in air(g)	200.2	196.3	208.6	199.1	200.8	193.9	239.8	229.2	243.4	232.4	236.5	230.1
weight in water(g)	61.8	55.6	69.1	63.3	65.5	60.7	97.7	85.1	94.9	83.8	86.3	82.4
weight dry (g)	181.4	178.9	192.5	182.5	184.8	178.0	226.8	216.8	230.5	215.9	220.3	213.7
porosity	12.5			11.66			8.81			8.00		

Mix SF600b

day(s)	3			7			28			90		
weight in air (g)	193.9	189.3	180.8	190.8	197.8	188.6	249.8	237.9	233.0	294.6	285.7	289.5
weight inwater(g)	59.8	49.5	44.4	58.6	62.7	56.7	100.3	92.3	91.7	116.7	110.9	113.7
weight dry	176.8	172.3	164.4	175.3	181.9	172.9	231.3	220.4	215.6	275.2	266.4	269.9
porosity	12.31			12.22			12.17			11.03		