EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB

NURSYAZWANI BINTI MAT LAZIM

Bachelor (Hons) of Civil Engineering

UNIVERSITI MALAYSIA PAHANG

EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB

NURSYAZWANI BINTI MAT LAZIM

Thesis submitted in partial fulfillment of the requirements for the award of degree of the Bachelor (Hons) of Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : **NURSYAZWANI BINTI MAT LAZIM**

Date of birth : **26 AUGUST 1992**

Title : **EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB**

Academic Session : **2014/2015**

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☐	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that University Malaysia Pahang reserves the right as follows:

1. The thesis is the property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

________________________	________________________
SIGNATURE	SIGNATURE OF SUPERVISOR
920826035130	DR NOOR NABILAH BT SARBINI
(NEW IC NO./PASSPORT NO.)	NAME OF SUPERVISOR
Date:	Date:

SUPERVISOR'S DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree Bachelor of Civil Engineering"

Signature:
Name of Supervisor: DR. NOOR NABILAH BINTI SARBINI
Position:
Date:

Signature:
Name of Co-supervisor:
Position:
Date:

STUDENT'S DECLARATION

"I hereby declare that the work in this thesis entitled **Effect of Fibre Hybridization to the Behaviour of Oil Palm Shell Concrete Slab** is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree."

Signature:

Name: NURSYAZWANI BINTI MAT LAZIM

ID Number: AA11128

Date:

DEDICATION

Special Dedication for both of my beloved parents,

Mat Lazim bin Ismail & Nooraini binti Mat Salleh.

Your sacrifices and contribution that you gave too high values

I appreciate that will last everlasting

ACKNOWLEDGEMENTS

Firstly, thanks to the Almighty for His grace given me the opportunity to finish writing this thesis. Deepest gratitude and sincere thanks goes to my respected supervisor, Dr. Noor Nabilah binti Sarbini for her instruction, guidance, advice and encouragement she has given as my supervisor. I also sincerely thanks for the time spent proofreading and correcting my many mistakes. All the knowledge and guidance given will be used as best as possible.

For my beloved parents, family and friends, I want to thank for your encouragement, support and prayers along the way I finish writing this thesis. Finally, thanks to all the parties involved either directly or indirectly throughout the writing of this thesis. May you always be loved and blessed by Allah S.W.T.

Thank you.

Abstract

Oil palm shell (OPS) is considered as a waste material originating from the oil palm industry. On the other hand, steel fibre can act as an unconventional material to reduce the sensitivity of OPS concrete. Hybridization of fibre leads to improvements on the mechanical and ductility characteristics of the concrete. In this research, the effect of steel hybrid fibre on the compressive strength and ultimate shear failure concrete slab were studied. Cube compressive strength and combined bending and shear tests for the slab were conducted. OPS that were used are from Kilang Panching while steel fibres are from a factory at Klang. In this study, aspect ratio and volume fraction were emphasized in selecting the most suitable type of steel fibre. The results on the cube compressive strengths shows range of 12.4 MPa – 14.9 MPa, 10.2 MPa – 12.7 MPa and 12.0 MPa – 13.7 MPa for B1, B2 and B3 cubes, respectively. The values were slightly lower than the design concrete strength of 20 MPa. On the other hand, the ultimate shear failure gives range of 36.0 kN – 60.5 kN, 37 kN – 46 kN, 38 kN – 47 kN for B1, B2 and B3 slabs, respectively. As a conclusion, slabs with longest length of steel fibre, SF60 shown better structural performance compared with other length. In terms of hybridization effect, it shows none improvement to the structural slab.

Abstrak

Tempurung kelapa sawit (OPS) dianggap sebagai bahan buangan yang berasal daripada industri kelapa sawit. Sebaliknya, gentian keluli pula boleh bertindak sebagai bahan tidak konvensional untuk mengurangkan sensitiviti OPS konkrit. Penghibridan gentian membawa kepada penambahbaikan kepada ciri-ciri mekanikal dan kemuluran konkrit. Dalam kajian ini, kesan gentian keluli hibrid pada kekuatan mampatan dan kegagalan ricih muktamad papak konkrit telah dikaji. Kekuatan mampatan kiub dan lenturan gabungan dan ujian ricih untuk papak telah dijalankan. OPS yang digunakan adalah dari Kilang Panching manakala gentian keluli adalah dari sebuah kilang di Klang. Dalam kajian ini, nisbah aspek dan jumlah pecahan telah diberi penekanan dalam memilih jenis gentian keluli yang paling sesuai. Keputusan pada kekuatan mampatan kiub menunjukkan julat antara 12.4 MPa – 14.9 MPa, 10.2 MPa – 12.7 MPa dan 12.0 MPa – 13.7 MPa untuk B1, B2 dan B3 kiub masing-masing. Nilai adalah sedikit lebih rendah daripada kekuatan konkrit reka bentuk iaitu 20 MPa. Sebaliknya, kegagalan ricih muktamad memberikan julat antara 36.0 kN – 60.5 kN, 37.0 kN – 46.0 kN, 38.0 kN – 47.0 kN untuk B1, B2 dan B3 papak masing-masing. Kesimpulannya, papak dengan gentian keluli paling panjang, campuran SF60 menunjukkan prestasi struktur yang lebih baik berbanding dengan panjang yang lain. Dari segi kesan penghibridan, ia menunjukkan tiada peningkatan untuk struktur papak.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	American Society for testing and Materials
AIV	-	Aggregate Impact Value
BS	-	British Standard
LWC	-	Lightweight Concrete
LWA	-	Lightweight Aggregate
OPC	-	Ordinary Portland cement
OPSC	-	Oil Palm Shell Concrete
OPS	-	Oil Palm Shell
SFRC	-	Steel Fibre Reinforced Concrete
SFRSCC	-	Steel Fibre Reinforced Self-Consolidating Concrete
SF	-	Steel Fibre

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is the most widely used of construction substantial all over the world. In normal weight concrete, it is made up from cement, coarse aggregates, fine aggregates, water and admixtures. Recent years, oil palm shell (OPS) and steel fibre have taken place as the replaced aggregate and reinforcement inside the concrete. The properties of steel fibre reinforced concrete improved the tensile and bending strength, greater ductility, and greater resistance to cracking and hence improved impact strength and toughness.

In ground-supported slabs, there are two main reasons why steel fibres are used. One of it is to control the development and formation of cracks that is caused by the early age plastic shrinkage and restrained long-term drying shrinkage. Another reason is to provide a degree of post-cracking load-carrying capacity such as the ability of the slab itself to carry load after the first crack has formed during the slab flexure.

Nowadays, lightweight concrete (LWC) has become one of the concrete used in construction. LWCs have many advantages. These advantages include saving on reinforcement, foundation cost, saving on formwork, better fire resistance, durability, heat isolation and frost resistance (Neville, 2008). However, the disadvantages of this concrete included lower mechanical properties and more cement is required compared to the normal concrete, greater shrinkage and higher material cost. Thus, such disadvantages justify the effort to resolve the problems with the existing LWC.

1.2 PROBLEM STATEMENT

Using lightweight aggregate (LWA) in the production of lightweight concrete (LWC) is the most popular method. Common natural LWAs include diatomite, pumice, scoria, volcanic cinders and tuff (Neville, 2008). Other type of LWA that popular in an agriculture field is oil palm shell (OPS). In Malaysia, it has a lot of the residue because Malaysia is one of the world leaders in the production and export of OPS. Generally, the mechanical properties of lightweight aggregate concrete (LWAC) are lower than ordinary concrete (Polat, 2010). One way to enhance the mechanical properties of the LWAC is through the using of steel fibre.

Steel fibre is the most commonly used of all fibre in most structural and non-structural purposes (Mehta and Monteiro, 2006). The addition of steel fibre in LWAC improved the mechanical properties of the concrete especially the tensile strength, impact strength and toughness (Ramados and Namagani, 2008). Steel fibre concretes have much higher fracture energy compared to the plain concrete (Peng et al., 2008).

The approach of using fibre reinforced concrete is expected to be the one of the method that can improve strength of lightweight aggregate concrete. Most research on oil palm shell (OPS) focuses on improving the mechanical properties. Furthermore, only several studies have been conducted or reported on the properties of OPS concrete containing steel fibre. Therefore, this study is conducted to investigate the volume content of steel fibre on the compressive strength and the optimum volume of OPS to be replaced with the coarse aggregate.

1.3 RESEARCH OBJECTIVES

The research objectives are:

i. To study the structural behaviour of oil palm shell concrete (OPSC) slab reinforced with steel fibre.
ii. To determine the effect of fibre hybridization to the behaviour of oil palm shell concrete slab.

1.4 SCOPE OF STUDY

The scopes of this study are:

i. The specimens tested are cubes and slabs; 9 cubes and 3 slabs for each batches with sizes (100 mm × 100 mm × 100 mm) and (350 mm × 500 mm × 100 mm) respectively.
ii. The cement grade used is 20 MPa.
iii. The type of fibre used in this research is steel fibre with L/D ratio is 80, length is 60 mm and the diameter is 0.75 mm with hooked-ends (SF60) and steel fibre with a length of 35 mm, aspect ratio of 65 and the diameter is 0.55 mm with hooked-ends (SF35).
iv. The type of lightweight aggregate used in this research is oil palm shell.
v. Volume fraction of steel fibre used in this research is 1.00%.
vi. The tests that have carried out are:
    i. Cube compressive strength test
    ii. Combined bending and shear test

1.5 RESEARCH SIGNIFICANCE

This study aim is to determine the effect of steel fibre hybridization in order to produce high strength of lightweight aggregate concrete. Essentially, fibres act as crack arrester which is restricting the development of cracks thus transforming in an inherently brittle (Vairagrade and Kene, 2013). For OPS concrete to be accepted for structural application, further investigations need to be conducted to improve the previous researches. Lightweight concrete using OPS as coarse aggregates is able to produce concretes with compressive strengths of more than 20MPa (Teo et al., 2006). Previous research shows that OPS can be used as replacement for conventional stone aggregates in concrete production.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Lightweight concrete (LWC) has become popular in recent years due to its advantages over the conventional concrete. Besides, it gives economical and structural benefits to the construction industry. Modern technology of the concrete also helped in a promotion and application of LWC. The use of aggregates from by-products or solid waste materials from agriculture industries is highly desirable in promoting them as replaced aggregates. Oil palm shell from oil palm industry is used to replace coarse aggregates in this study. This chapter review the information related to the oil palm shell concrete and steel fibre reinforced concrete.

2.2 LIGHTWEIGHT CONCRETE

The advantages of lightweight concrete (LWC) are well recognized in reducing the dead load thus allows for greater design flexibility and cost savings for structural (Alengaram et al., 2013). Using oil palm shell (OPS) in producing LWC is reducing the production cost. The use of alternative materials to replace conventional materials is being an advantage of LWC as OPS made from waste material (Short A, Kinniburgh W., 1978).

Lightweight aggregates such as expanded clay, slate, shale or blast furnace slag is a type of environmental-friendly material that used in the construction industry for making lightweight aggregate concrete (Bremner, 2001). The best alternative to achieve sustainable development of concrete is by use of waste materials instead of raw materials in the concrete mixture (Pelisser et al., 2011). Thus, oil palm shell can be used as it is one of waste material. OPS is generally used as granular filter material for water treatment, floor roofing and road based material (Alengaram et al., 2013).

One characteristics of OPS is; it is lighter than the conventional coarse aggregate. Lightweight concrete that use OPS as coarse aggregate is able produce concretes with compressive strengths of more than 25 MPa (Teo et al., 2005). Mannan and Ganapathy (2004) has studied on structural performance of OPS concrete. A slab with 125 mm thick and length 3.1 m was tested with a live load of 1.5 kN/m^2. It is observed that when load of 8.25 kN/m^2 is applied, the first crack is observed and the deflection was only 9.56 mm compared to an allowable deflection of 12.4 mm. From the result, it can be concluded that OPS can increased the strength of the concrete.

2.2.1 Advantages and Disadvantages of Lightweight Concrete

Lightweight concrete have many advantages compared to the other concrete. Table 2.1 summarized the advantages and disadvantages of the lightweight concrete.

Table 2.1: Advantages and disadvantages of the lightweight concrete

Advantages	Disadvantages
a) Faster and simplest the construction b) More economic in transportation and reduce the forces in work c) Reduce the dead load that directs faster to build and lower cost d) A marked reduction in heaviness of frame structure, foundation or piles e) Easy for do nailing and sawing work compared with conventional concrete f) Do not settle and not required the compaction of the concrete. g) Free flowing and spread freely to fill the voids	a) Slightly sensitive with the absence of water content in the concrete b) Time for mixing is longer compared with conventional concrete. It is to ensure that the mixture was mixed properly. c) Inability to deliver a consistent compressive strengths and density all over the entire area d) Porous and shows poor resistance to heavy scratch. e) Has low tensile strength and thus fracture easily.

Although there are disadvantages due to the use of LWC, it is still preferable in construction industry where the cost can be minimized. However, from the disadvantages of LWC it has made an effort to resolve these problems. The most popular method of LWC production is through the use of lightweight aggregate.

2.3 FIBRE REINFORCED CONCRETE

There are several types of fibre which are natural fibre, steel fibre, synthetic fibre and basalt fibre. Fibre reinforced concrete has gained various attentions in building construction for a couple of years. Fibre such as synthetic fibre liked nylon and polypropylene has excellent resistance of fibre in aggressive environments and it improves post-cracking ductility (Hamoush et al., 2010).

For natural fibre, it can be used in concrete as reinforcement. Reinforced concrete with polypropylene fibres which are used as fibrillated film to increase bond strength with cement matrix is well-established (Hannant et al., 1978). Using shorter fibres with low fibre-content for achieving workability and higher fibre content for better cohesiveness in wet state is recommended.

Ramakrishnan and Ananthanarayana (1968) investigated the ultimate strength and behaviour of 26 single-span beams. It is resulted that the beams failing by diagonal tension when ultimate load using splitting strength is applied. Comparison between theoretical and experimental investigations on the compressive strength and elastic modulus of coir and sisal fibre reinforced concretes for various volume fractions was also carried out by Ramakrishna and Sundararajan (2002). It was observed that both experimental and analytical values of elastic modulus had shown 15% discrepancy, which can be regarded as comparatively small. Ramakrishna and Sundararajan (2002) also suggested based on rheological properties of fresh mortar, it is recommended to use shorter fibres with low fibre-content for achieving workability and higher fibre content for better cohesiveness in wet state.

Toledo Filho et al. (2003) reported their study on development of vegetable fibre-mortar composites of improved durability. Several approaches were proposed to improve the durability of vegetable fibre-cement composites. These included carbonation of the matrix in a CO_2-rich environment; the immersion of fibres in slurried silica fume prior to incorporation in ordinary Portland cement matrix. It was suggested that immersion of natural fibres in a silica fume slurry before the addition to the cement based composites was found to be effective in reducing embrittlement of the composites in the environment.

2.3.1 Steel Fibre Reinforced Concrete

Steel fibres for reinforcing concrete are manufactured from cold-drawn wire, steel sheet and other forms of steel. Most common type of steel fibres used in floors is wire fibre. They vary in length up to 60 mm with aspect ratios from 20 to 100 and with variety of cross sections. Aspect ratio is the ratio of length of fibre to its diameter. It is influenced the properties and the behaviour of the fibre reinforced concrete. Mehrdad Mahoutian et al have proposed that adding of fibres into the concrete is an efficient method of increasing the mechanical properties of concrete. The addition of fibres significantly improves many of the engineering properties of mortar and concrete, and the impact strength and toughness as well.

Figure 2.1: Hook End Steel Fibre

Figure 2.2: Crimped Steel Fibre

There are some types of steel fibre used in concrete. Hook end steel fibre has diameter 4 mm to 1 mm. It tensile strength is more than 1100 MPa with the aspect ratios from 40 to 100. This type of fibre used for shotcreting of underground caverns, tunnel segments, slope stabilization and retaining walls. It is also has high tensile strength which resulted in higher toughness levels. It requires less labour to place concrete compared to the bar reinforcement. The crimped steel fibre has the high dragging resistance strength, which is up to 1100 MPa. It comes in various sizes which are 40 mm, 50 mm and 60 mm and the diameters are 0.5, 0.75, 0.9 and 1.0 with the aspect ratio 40 to 80 (tradeindia.com)

Steel Fibre Reinforced Concrete (SFRC) is a composite material. It consists of hydraulic cements with steel fibres that are dispersed. The steel fibres reinforce concrete superior in withstanding tensile stresses (wiki.org). Therefore, the flexural strength of fibre reinforced concrete is greater than un-reinforced concrete. Other benefits of SFRC are resistance to fracture, disintegration, and fatigue. Bencardino et al. (2008) have studied on the compressive behaviour of steel fibre reinforced concrete. The result from the experiment shows that the toughness of SFRC increases with the product of the volume fraction and the aspect ratio of the fibres.

Recently, steel fibre reinforced concrete has attained acknowledgment in numerous engineering applications. It has become more frequent to substitute steel reinforcement with steel fibre reinforced concrete. The most common applications are tunnel linings, slabs, and airport pavements (brighthubengineering.com).

2.3.1.1 Compressive Strength of Steel Fibre Reinforced Concrete

The compressive strength of concrete is usually considered as the most precious assets in concrete (Neville, 1995).

Chih-Ta Tsai et al. (2003) presents the way durability has been introduced to steel fibre reinforced concrete in Taiwan. It is generally acknowledged that steel fibres are added to improve the toughness, abrasion resistance, and impact strength of concrete. However, a locally developed mixture design method, the densified mixture design algorithm (DMDA), was applied to solve not only the entanglement or balling problem of steel fibres in concrete or to produce steel fibre reinforced self-consolidating concrete (SFRSCC) with excellent flow-ability, but also to increase the durability by reduction in the cement paste content. By dense packing of the aggregates and with the aid of pozzolanic material and superplasticizer (SP), concrete can flow honey-like with less entanglement of steel fibres. Such SFRSCC has already been successfully applied in several projects, such as construction of a low radiation waste container, bus station pavement, road deck panel, and two art statues.

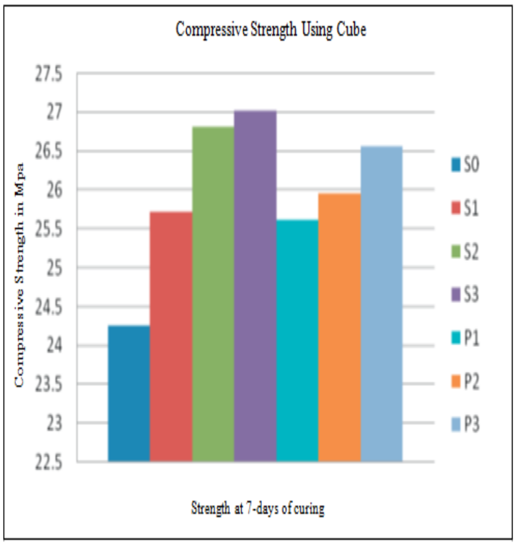
As known, most of the lightweight aggregate concrete is inferior in the tensile strength as well as higher brittleness. Shafigh et al. (2011) have researched on enhancing the compressive strength of oil palm shell concrete (OPSC) by varying the size of the OPS and developed high strength OPSC with a cement content of 550 kg/m^3. It resulted in increasing the compressive strength but however it will be offset by the increased brittleness of the concrete.

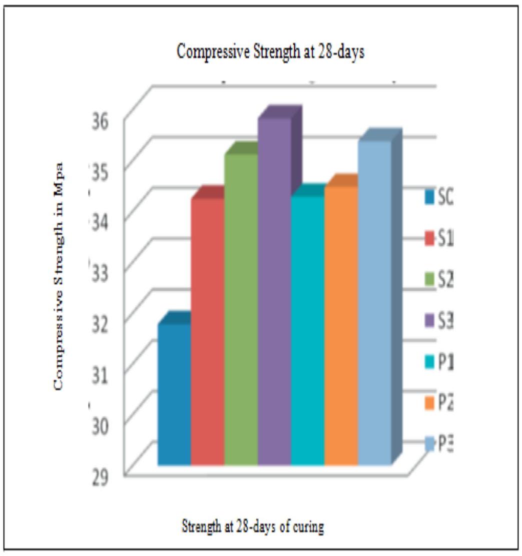
Banthia et al. (2007) have been reported that the addition of specified quantity of steel fibres is known to increase the tensile capacity of the fibre reinforced concrete (FRC) along with its post-failure ductility. The post-failure ductility is extremely useful in cases where tensile strength is not adequate to characterize the mechanical response of concrete. After the cracking of matrix, the steel fibres function as a crack bridging mechanism, in which the fibres undergo fibre pull-out, thus delaying the crack formation and limit the crack propagation. De-bonding and pulling out of fibres from FRC require higher amount of energy, resulting in the increased toughness and ductility of concrete.

Vairagade and Kene (2013) tested the compressive strength by doing two types of specimens which are cube specimen and cylinder specimen. Compressive strength of control concrete and FRC were calculated by dividing failure load with cross sectional area. It is observed that when fibers in discrete form present in the concrete, propagation of crack is restrained which is due to the bonding of fibers in to the concrete and it changes its brittle mode of failure in to a more ductile one and improves the post cracking load and energy absorption capacity. Result of compressive strength for M-20 grade of concrete on cube specimen with different fibres for different proportions as shown below. S for steel fibre while P for polypropylene.

Table 2.2: Test result of compressive strength using cube specimens

Batch No	Fibre Notation	No of Days	Average Compressive Strength (N/mm^2)
1	S0	7	24.26
		28	31.78
2	S1	7	25.72
		28	34.25
3	S2	7	26.80
		28	35.12
4	S3	7	27.01
		28	35.83
5	P1	7	25.61
		28	34.29
6	P2	7	25.95
		28	34.48
7	P3	7	26.56
		28	35.38





(a) 7-days (b) 28-days

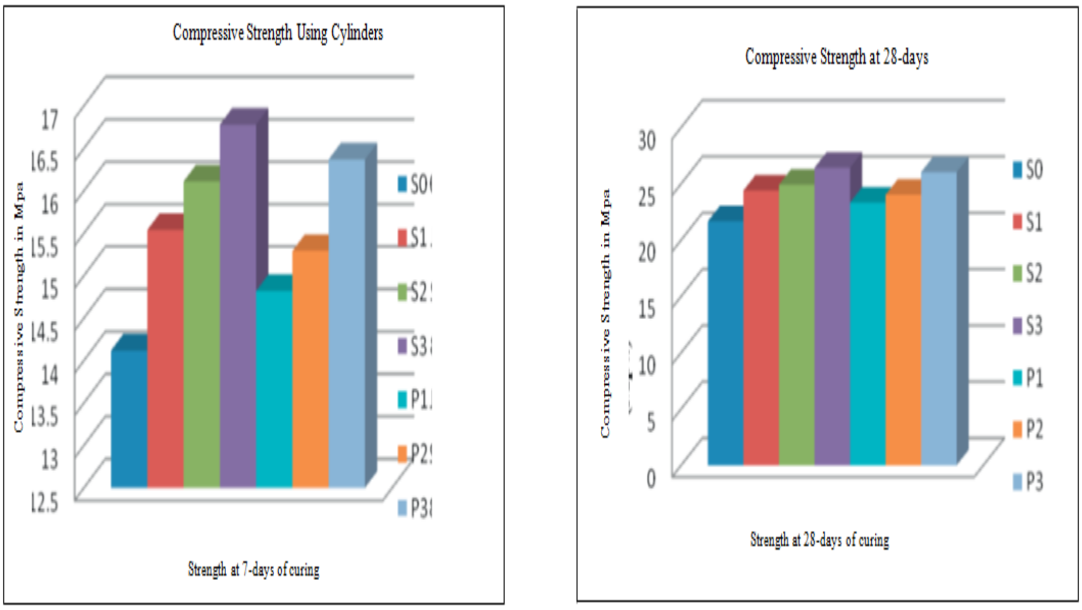
Figure 2.3: Comparison of percentage increase in compressive strength using cube at 7 and 28 days of curing

From figure 2.3, it can be observed that addition of 0.5% 50 mm copper coated crimped round steel fibre having aspect ratio 53.85 with maximum compressive strength in comparison with other steel fibres for both 7 and 28 days of curing. In non-metallic fibres, addition of 24 mm cut length fibrillated polypropylene at 0.4% by weight gives maximum compressive strength with compared to 15 mm and 20 mm cut length. Thus, it can be concluded that compressive strength is dependent on length of polypropylene fibres.

The results of compressive strength using cylindrical specimens are summarized in Table 2.3.

Table 2.3: Test result of compressive strength using cylindrical specimens

Batch No	Fibre Notation	No of Days	Average Compressive Strength (N/mm^2)
1	S0	7	14.12
		28	21.67
2	S1	7	15.54
		28	24.40
3	S2	7	16.11
		28	24.92
4	S3	7	16.78
		28	26.43
5	P1	7	14.82
		28	23.33
6	P2	7	15.29
		28	24.02
7	P3	7	16.37
		28	26.04



(a) 7-days (b) 28-days

Figure 2.4: Comparison of percentage increase in compressive strength using cylinder at 7 and 28 days of curing

It can be observed that maximum strength for M20 grade of concrete was obtained by addition of 0.5%, 50 mm copper coated crimped round steel fibres having aspect ratio 53.85. Along with S3, fibrillated polypropylene fibres of 24 mm cut length at higher doses, at 0.4% also gives strength nearly equal to that of steel fibre S3. Addition of 0.4%, 24 mm polypropylene fibres increase 11.32% compressive strength using cube specimen and increase 18.16% using cylindrical specimen. Here, it can be concluded that the ratio of compressive strength of cylinders to the compressive strength of cube was found to be nearly 3:4.

2.3.1.2 Flexural Strength of Steel Fibre Reinforced Concrete

One of the significant benefits on the addition of steel fibre in concrete is its improved post-cracking tension. Kumar et al. (1972) reported investigations which contributed widely to the prediction of ultimate loads, failure patterns and deflections of deep beams. Kong et al. (1970) have reported the results of a study on 35 simply supported deep beams. The effects of seven different types of web reinforcement on deflections, crack width, crack patterns, failure modes and ultimate loads in shear were studied. It is observed that the effectiveness of the various types of web reinforcement depends on the span-to-depth ratio and shear span-to-depth ratio.

While Shanmugam and Swaddiwudhipong (1984) carried out an experimental investigation to study the ultimate load behaviour of steel reinforced concrete deep beams. A total 18 beams consisting of plain concrete and fibre reinforced beams were tested. It was observed that the addition of steel fibre resulted in increased failure loads and changes in modes of failure.

2.3.1.3 Previous Research on Steel Fibre Reinforced Concrete Application to Structure

There are many uses of steel fibre reinforced concrete in the scope of construction. Steel fibres are generally used for providing concrete with enhanced toughness and post-crack load carrying capacity. Typically loose or bundled, these fibres are generally made from carbon or stainless steel and are shaped into varying geometries such as crimped, hooked-end or with other mechanical deformations for anchorage in the concrete. Fibre types are classified within ACI 544 as Types I through V and have maximum lengths ranging from 30 mm – 80 mm and can be dosed at 6 kg/m^3 to 67 kg/m^3.

Steel-fibre-reinforced concrete finds one of its most prominent applications in tunnel construction. The frequently encountered stress-resultant combination of high compressive forces and relatively low bending moments in a tunnel lining can predominantly be matched by using the material properties of steel-fibre-reinforced concrete only. The material‘s resistance against concentrated loads assures a remarkably low maintenance costs. The use of this material simplifies the construction process and accelerates the speed of execution. Interest in the use of steel-fibre-reinforced concrete in tunnel construction is rising as a result of the flexibility which the use of this material permits and the cost-savings achieved compared to the use of conventional reinforced-concrete solutions.

Steel fibre concrete is manufactured in various grades, deformations and sizes to suit most concrete flooring applications. Usually, steel fibre concrete was used in heavily trafficked industrial paving (scrap yards), industrial ground bearing slabs, and suspended slabs on piles and impermeable concrete slabs. The benefits using this fibre are reduced overall construction cost over steel, increased crack control and eliminate concern associated with correct placement of reinforcement and correct cover.

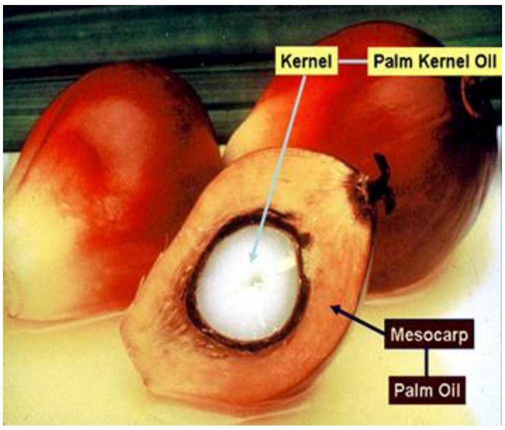
It has been reported that the addition of specified quantity of steel fibres can increase the tensile capacity of the fibre reinforced concrete along with its post-failure ductility (Banthia et al., 2007). Steel fibres act as a crack bridging mechanism which is delaying the crack formation and limit the crack propagation (Koksal et al., 2008).

L. Sorelli and F. Toutlemonde have focused on the application of SFRC in tunnel lining segments, as an alternative to conventional RC segments. Because of the structural applications of Steel Fibre Reinforced Concrete (SFRC) have recently been increasing due to the improvement of material properties, such as in the material toughness under tension and durability, it is critically reviewed considering the post-cracking resistant mechanism.

2.4 OIL PALM SHELL

Oil palm shell is the hard endocarp that surrounds the palm kernel. During the palm oil extraction process it is separated from the kernel. Oil palm shells are naturally sized, hard and lighter compared to the conventional aggregates. Oil palm shell (OPS) is a solid waste from oil palm industry. OPS for this study was taken from Kilang Sawit Panching located at Panching, Kuantan Pahang. OPS that taken here is wet so it was dried out before used as aggregates. Lightweight concrete which incorporating with OPS seems to be good in mechanical properties and durable performance (Teo et al., 2009).

Oil palm shell (OPS) is considered as a waste material produce from the extraction of palm oil in South East Asian countries. OPS aggregates are composed of different shapes. Pre-treatment is necessary for OPS aggregates before used in concrete because it contains dust and oil coating. The shells have been left under a shed for air-drying. OPS are light and naturally sized; they are ideal for substituting aggregates in lightweight concrete construction. Being hard and of organic origin, they will not contaminate or leach to produce toxic substances once they are bound in concrete matrix. OPS concrete can potentially be utilized in lightweight concrete applications that require low to moderate strength such as pavements and infill panel for flooring.



(a) OPS (b) Dumping of OPS at landfill

Figure 2.5: Oil palm shell

Ahmed and Sobuz (2011) have studied on reinforced concrete beams made of lightweight concrete with normal strength concrete. It shows that it have satisfactory shear and flexural performance. While a research that studied by Shafigh et al. (2011) shows that OPS can be used as lightweight aggregate for producing high strength lightweight concrete.

Struble and Godfrey (2004) stated that three component of sustainability which are environment, economy and society are given less attention in developed countries. It can be concluded that, OPS lightweight concrete can meet the requirement of sustainability. In addition, a low cost house along with a foot bridge constructed using OPS lightweight aggregate is being monitored for structural performance (Teo et al., 2006).

2.4.1 Previous Research on Oil Palm Shell as a Lightweight Aggregate

Mo et al. (2014) have investigated the impact resistance of OPS concrete panels due to the improvement aggregate impact value (AIV) of OPS compared to the conventional aggregates. It is found that AIV of OPS is 2 times lower than the crushed granite aggregate. While Alengaram et al. (2008) reported that the ductility of reinforced concrete beams was about 2 times higher than the corresponding reinforced normal weight concrete beam.

OPS can be used as road pavement, kerb-stones, concrete drains and flooring slabs (Mannan et al., 2004). Improvement of mechanical properties of OPS concrete can be done by using smaller size of OPS aggregates (UJ et al., 2010). This could be achieved through the use of crushed OPS aggregates. Mo et al. (2014) stated that impact and ductility characteristics are enhanced by adding fibres in the OPS concrete.

Basri et al. (1998) have studied on the workability, density and compressive strength of OPS lightweight concrete over 56 days under three curing conditions. It is found that the fresh OPS concrete have better workability while its 28 days air-dry density was 19%-20% lower than conventional concrete. The compressive strength at

56 days also was 41%-50% lower compared to conventional concrete. The results were still within the range of structural lightweight concrete.

Wang and Wang (2013) found that the increase of compressive strength up to 23% with the addition of 2.0% steel fibre using lightweight cellular shale aggregate. On the other hand, Lee and Song (2010) found that 1.0% addition of steel fibre increased the compressive strength of lightweight cellular expanded shale concrete by 37%.

OPS aggregates are porous in nature thus it have low bulk densities. Although, OPS aggregates are porous, the resulting OPS concrete was reasonably impermeable. Low water cement ratios increases the strength of concrete thus enhance its resistance to cracking due to the internal stresses (Mindess et al., 2003). Therefore, it can be concluded that the permeability of OPS concrete is mostly caused by internal cracking of the paste-aggregate interface.

Compared to most types of concrete, OPS concrete developed better strength when stored in water than in air. The compressive strengths obtained at 28 days were approximately 35%-65% higher than the minimum required strength of 17 MPa for structural lightweight concrete (ASTM C 330). Generally, lightweight concretes have higher water absorption values than typical normal weight concretes (Newman, 1993).

2.5 SUMMARY

Fibres with different sizes and material can affect the brittleness of concrete. So, to improvise the brittleness of concrete fibre can be added. From the experiment result discussed before, the compressive strength of concrete can be increased by addition of fibre. Fibre that can be added to the concrete may be polypropylene, steel fibres and other fibres. However, due to superior strength enhancement shown by steel fibre, this type of fibre is chosen in this research.

In general, the addition of steel fibres increased the compressive strength of concrete. The high steel fibre content which is more than 0.75% enhanced the compressive strength of oil palm shell fibre reinforced concrete. Briefly, it can be concluded that the overall effect of fibres in arresting the crack and its propagation enhanced the mechanical properties of oil palm shell concrete. Furthermore, the contribution of fibres to stress redistribution caused lower strain and improved the modulus elasticity produced in the oil palm shell concrete which is higher compared to the steel fibre oil palm shell concrete. With steel fibres as additive to the lightweight concretes, its loading capacity is increased, the cracks are controlled and it shows a great resistance to dynamic and sudden loadings while decreasing the crack width. Furthermore, it also increases the resistance of the concrete against deformation and increases the tensile strength (Mohammadi et al., 2008).

In a nutshell, OPS can be used as a replacement for the coarse aggregates in concrete production. OPS concrete behaves similar to other structural lightweight aggregates concrete. OPS concrete also shows good potential as structural members in low-cost housing construction. OPS lightweight concrete efficiency factor is more than for the expanded clay and normal weight concrete. OPS concrete has greater drying shrinkage than expanded clay lightweight concrete however it reduces to 35% at 90 day age and beyond.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discussed on the methodology to conduct this research. In this research, the structural behaviour of the lightweight concrete slab with the addition of steel fibre and the effect of fibre hybridization to the behaviour of oil palm shell concrete slab were determined and investigated.

Figure 3.1 shows the flowchart of the study. This flowchart is to ensure the flow of the study can be done smoothly. First of all, before proceed with the experiment; sample preparations were prepared which is consisted formwork and raw materials. Some of the raw materials are cement, water, fine aggregates, oil palm shell and steel fibre. After that, next processes were proceeded which are mixing, casting, curing and testing. Results from the testing were analysed and tabulated.

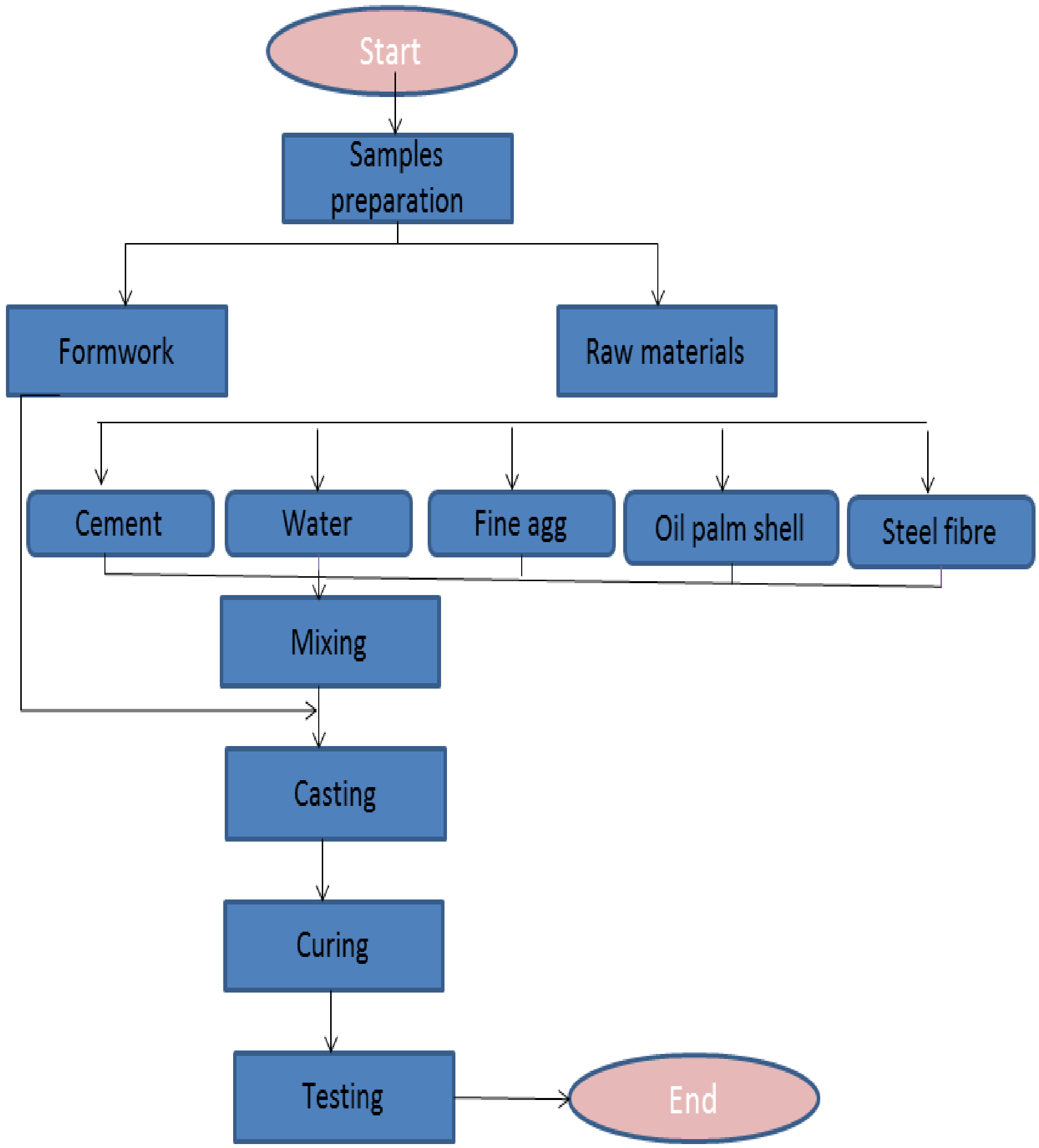


Figure 3.1: Flowchart of research

3.2 CONCRETE RAW MATERIALS

3.2.1 Oil Palm Shell Aggregates

In this study, the size of OPS used is between 5 mm-10 mm. It was air dry for about a week before it can be used. It was taken from an oil palm factory at Panching.

Figure 3.2: Samples of OPS aggregates

3.2.2 Steel Fibres

Steel fibres used in this study are SF60 which have length of 60 mm with aspect ratio of 80 and the diameter is 0.75 mm and SF35 which have length of 35 mm and the diameter is 0.55 mm. These steel fibres are known as hooked end steel fibre. These fibres were bought from a factory at Klang.

(a): HE steel fibre (SF60)

(b): HE steel fibre (SF35)

Figure 3.3: Hooked end steel fibre

3.2.3 Steel Reinforcement

Steel reinforcement used in this study is having size of 12 mm and 8 mm. Size of 12 mm is used as main bar while size of 8 mm as a link bar. Figure 3.4(a) shows the picture high strength steel while Figure 3.4(b) shows the picture of mild steel.

(a): High strength steel

(b): Mild steel

Figure 3.4: Steel reinforcement

3.2.4 Ordinary Portland cement

Ordinary Portland Cement (OPC) as shown in Figure 3.5 has been used for this study. OPC is the most common type of cement in general use around the world as a basic material of concrete or mortar. It is usually originates from limestone and comes in powder. The sieved OPC was kept in an airtight container to prevent air moisture contact as hydrated cement particle would affect the formation of a calcium silicate hydrate gel.

Figure 3.5: Ordinary Portland cement

3.2.5 Water

Water is one of the most significant components to produce concrete whether it is the conventional concrete or lightweight concrete. The water used should free from any impurities that can be harmful to the process of hydration of cement and durability of concrete. The main material on concrete was water where once the water mixed together with cement it was acted as the paste that binds the fine aggregates and the cement. Water causes hardening of concrete through hydration. The water used must be clean and free from any impurities that could be dangerous for hardening of concrete, durability, volume stability and change in colour. In this study, the water used is normal clean tap water.

3.2.6 Fine Aggregates

Normally the fine aggregate consist of natural sand or manufactured sand. In BS 3797:1990 has stated that fines sand for concrete is the particles with that passed the 5.0 mm in sieve test with an even distribution of sizes should be used for foamed concrete. Figure 3.6 shows the picture of fine aggregate used in this study.

Figure 3.6: Fine aggregate

3.3 MIX DESIGN

Table 3.1 shows the composition of the raw materials per 1 m^3 that were used in this study. In summary, 230 kg water, 762 kg fine aggregate, 400 kg cement, 1011 kg oil palm shell and 78.5 kg of steel fibre were used for 1 m^3 concrete mix volume. 0.8 kg per m^3 of super plasticizers was used in reference with the weight of cement.

Table 3.1: Mix design proportion per $1m^3$

Materials	Water (kg)	Fine Aggregate (kg)	Cement (kg)	Oil Palm Shell (kg)	Super plasticizers (kg)
Per $1m^3$	230	762	400	1011	0.8

3.4 CASTING PROCESS

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

The concrete is mixing after the material proportion was calculated and then the materials that were calculated were poured into the container little bit by little bit to make sure the mix of the concrete completely mixed. For the first material, all weighed sand and ops is poured into the container and followed by the cement. Then, the water is poured and mixed together with other materials until they mixed well and the remaining material is added repeatedly until all of the cement and fine aggregates is poured. Before oil palm shell is mixed with other material, cement and fine aggregates must mixed properly to avoid any lumps between them. The mixture is turned into uniformly grey after both cement and fine aggregates is mixed.

3.4.1 Specimen Preparation

Concrete specimens that are representative of a distinct batch of concrete must be sampled and analyzed for the purpose of quality control. Tests are performed on concrete cube specimens and slabs specimens to evaluate the compressive strength of the concrete. The formwork of the samples was prepared using the plywood with thickness of 6 mm. Plywood is easy to cut and shape and makes the jobs to do the formwork much easier. The sizes used for the specimens are 100 mm × 100 mm ×100 mm and 350 mm × 500 mm × 100 mm for cube and slabs respectively. Formwork is the walls that support the concrete until it harden or in other word, is a mould or box which fresh concrete can be poured and compacted so that it will flow to the inner of the formwork. Once the formwork was sorted and completed, other specimens also checked such as the quantities of steel fibre, oil palm shell, aggregates and cement that need to be used in this study. Figure 3.7 shows the mould for both specimens.

In this study 3 batches are involved which are batch 1, 2, and 3. The details for each batch are summarized in the table below.

Table 3.2: Details of Batches

Batch No	Details
Batch 1(B1)	100 % OPS + SF 60 (1%)
Batch 2(B2)	100 % OPS + SF 35 (1%)
Batch 3(B3)	100 % OPS + SF 60 (1%) + SF 35 (1%)

(a) Cube

(b) Slab

Figure 3.7: Mould for specimens

3.4.2 Method of Casting

In this study, the concrete was mixed manually due to some problem. All samples were casted in the laboratory for different batches. In preparing the specimens, at first, fine aggregates and oil palm shell is properly mixed and then cement was added. All the materials were mixed together. Water was added at interval time after the cement and aggregates are properly mixed. Fresh concrete workability was investigated immediately after the final mixing of concrete using slump test. The cubes were cast by filling each mould in three layers; each layer was compacted with a vibrator. The layer compacted with the vibrator to ensure the concrete is uniformly distributed. After slump test was achieved required result, all specimens were left in the moulds for 24 hours. They were removed from the mould and transferred into an area to cover with wet sack for curing.

Figure 3.8: Fresh concrete

Figure 3.9: Fresh concrete after leveling

3.4.3 Curing

The important role on the strength of concrete is curing which it is the process to stop the fresh concrete from drying very quickly. This is because if the concrete is too dry, the bonding in the concrete will not function and will make the concrete is being weak and easy to crack. So, curing process is very important in any concreting work to avoid from any cracking or forming of honey comb. For this research study, the type of curing condition used is wet sack curing. Basically, concrete was cured in duration of 7, 14 and 28 days but for this research, the samples were cured for 7 days and 28 days only. The cubes and slabs were put under the wet sack and leave. The wet sacks were watered every day in order to ensure the hardened and the strength of the specimens.

Figure 3.10: Curing with wet sack

3.5 CONRETE WORKABILITY TEST

In accordance with relevant British Standards (BS EN 12350-2:2009), the slump test is important as it determines the consistency of fresh concrete. BS EN 12350-2 specifies a method for determining the consistence of fresh concrete by the slump test. The slump test is sensitive to changes in the consistence of concrete, which correspond to slumps between 10 mm and 210 mm. If the slump continues to change over a period of 1 min after de-moulding, the slump test is not suitable as a measure of consistence. The test is not suitable when the maximum size of aggregate in the concrete is greater than 40 mm.

The fresh concrete is compacted into a mould in the shape of a cone. When the cone is withdrawn upwards, the distance the concrete has slumped provides a measure of the consistency of the concrete. This is the basic principle of the slump test. The sample of the concrete is obtained in accordance with BS EN 12350-1(British Standards Institute, 2009).

Figure 3.11 shows how the slump test was conducted. The concrete was compacted in the mould by using rod. It was compacted every 3 layer. Every layer was compacted for 25 times using the rod.

Figure 3.11: Slump test

3.6 CUBE COMPRESSIVE STRENGTH TEST

For the compressive strength testing of the cubes, the procedures of testing is based on BS EN 12390-3-2009. Compressive strength is the primary physical properties of concrete that being used for quality control purposes for lightweight foamed concrete. It is the ability of concrete to sustain the axial load. For the compressive strength test, the machine use is Compression Testing Machine as shown in Figure 3.12. It is a testing machine of appropriately capacity for the test and equipped with a means of providing the level of loading specified.

Each cube was placed based on the direction of application of load whether in bed position or stretcher position in the testing machine. Before the machine is started, the dimension of the surface of sample was set-up on the machine for the result of compressive strength. Smooth surface of cube was chosen to do the test. The load was applied onto the sample without shock. The appropriate loading rate is maintained as far as possible right up to failure. The test was stopped when the maximum load applied had failure the cube and the machine was automatically shows the result of maximum loading and maximum strength of the sample tested. Then, the data was recorded for every sample.

Figure 3.12: Compressive strength test

Cube compressive strength test was conducted to determine the maximum load of the samples. In this testing, the load is applied continuously towards the sample until it is failed to resist more loading. By referring to the testing, the data maximum load and maximum strength for every sample is recorded until all the samples are tested. The compressive strength test is based on the procedures stated in BS EN 12390-3:2009.

The comparison between 28 days compressive strength of control mixes with crushed oil palm shell is expected to increase. Thus, it shows crushing of oil palm shell improved the compressive strength of oil palm shell concrete. Shafigh et al (2011) explained that the enhancement of the compressive strength is due to the increased number of broken edges found in the crushed oil palm shell. In general, the addition of steel fibre increased the compressive strength of concrete.

3.7 COMBINED BENDING AND SHEAR TEST

A reliable assessment of the shear strength can be obtained only from tests under combined stresses. Slab testing was done using magnes frame machine. From the machine, the data that were collected are load and deflection. Every sample for each batches are testing to know the maximum load and the pattern of the crack. Figure 3.13 shows the illustration of the arrangement for the testing. Middle third flexural loading was applied on the oil palm shell concrete slabs through hydraulic jack. The specimens were placed under magnes frame machine and linear variable displacement transducers (LVDT) were attached to measure the deflection readings. During this experiment also, the cracking on the specimens were observed.

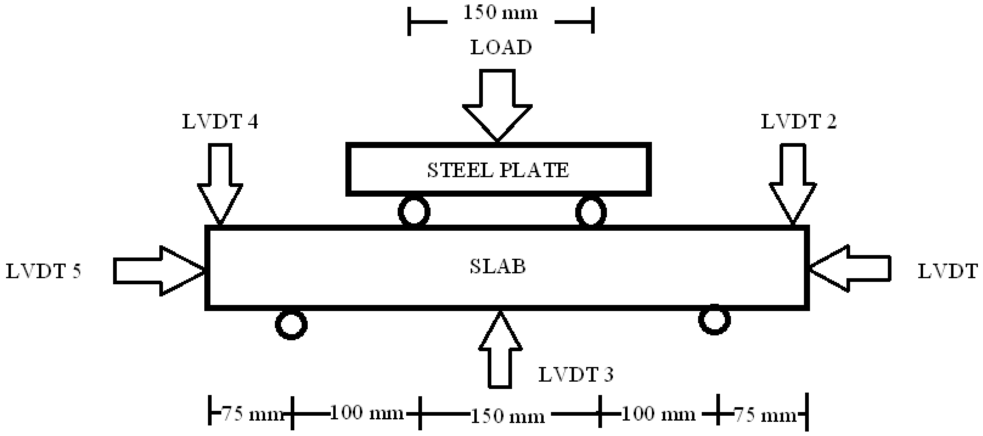


Figure 3.13: Illustration for slab testing

Slab was tested by doing combined bending and shear test. Before the test was conducted, the apparatus was set-up a day before to ensure the flow of experiment was smooth without any delay. Figure 3.14 shown the actual set up during experiment. The equipments that were used during the experiment are:

1) 5 linear variable displacement tranducer (LVDT)
2) Magnes Frame
3) Steel roller
4) Steel plate
5) Hydraulic jack
6) Load cell

Figure 3.14: Actual view during slab test

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 INTRODUCTION

The results obtained from the experimental test was analysed and discussed in this section. Data obtained from the experiment were compared due to the effect of different size of steel fibre with the same volume fraction.

4.2 CUBE COMPRESSIVE STRENGTH

Cube compressive strength test were conducted to determine the maximum load of the cube sample with different mixes. In this testing, the load was applied continuously subjected to the sample until the sample was failed to resist more loading. Referring to the testing, the data of maximum load and maximum strength for every sample were recorded. This testing was conducted based on the procedures stated in BS EN 12390-3:2009.

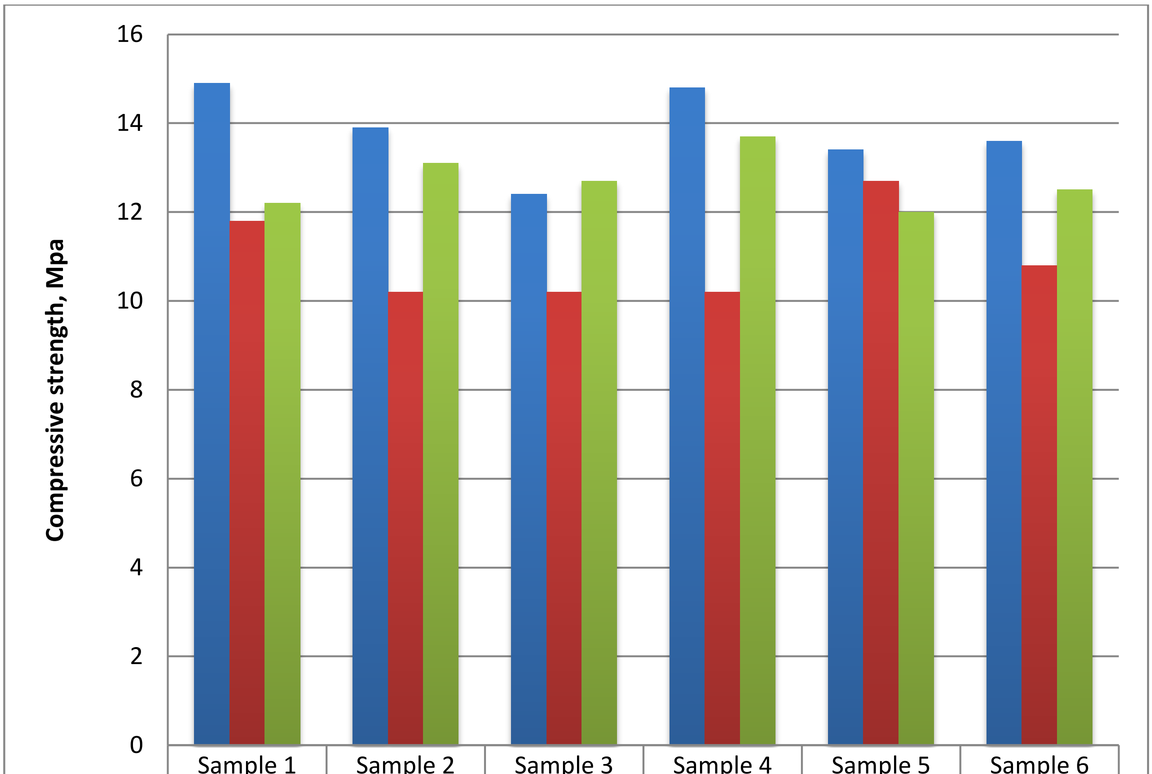
4.2.1 Compressive Strength of Cube Concrete with Different Mixes

Table 4.1 shows the compressive strength of cubes with different mixes which are curing under wet sack. From the table, we can see that Batch 1 have the highest compressive strength at 28-days followed by Batch 3 and lastly Batch 2. As mentioned before, Batch 1 mix consist of 100% OPS + 1% SF60 while Batch 2 is 100% OPS + 1% SF35 and Batch 3 is 100% OPS + (1% SF60 + 1% SF35). Here, it can be concluded that SF60 contributed in the strength of the cube. The longer the steel fibre, the higher the strength will be.

Table 4.1: Compressive strength with different mixes at 28-days

	Cube compressive strength (MPa) at 28-days		
Sample	**Batch 1**	**Batch 2**	**Batch 3**
1	14.9	11.8	12.3
2	13.9	10.2	13.1
3	12.4	10.2	12.7
4	14.8	10.2	13.7
5	13.4	12.7	12.0
6	13.6	10.8	12.5

Based on the graph, for sample 1 Batch 1 has the highest compressive strength which is 14.9 MPa, followed by Batch 3 which is 12.3 MPa and lastly sample 1 for Batch 2 that is 11.8 MPa. For sample 2 also, Batch 1 has the highest compressive strength which is 13.9 MPa. For the sample 2, it shows the same trend with sample 1 where Batch 1 has the highest strength followed by Batch 3 and Batch 2. Compressive strength for sample 3 shows almost the same value for Batch 1 and Batch 3 which are 12.4 MPa and 12.7 MPa respectively. Batch 2 has the lowest compressive strength which is 10.2 MPa. Sample 4 and sample 6 shows the same trend for each batch were batch 1 have the highest compressive strength and Batch 2 have the lowest compressive strength. For sample 5, Batch 1 has highest strength which is 13.4 MPa. From the overall result, a conclusion can be made. Steel fibre that has longest length produces highest strength. In this study, SF60 gives the highest strength in the compressive test.



	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Batch 1	14.9	13.9	12.4	14.8	13.4	13.6
Batch 2	11.8	10.2	10.2	10.2	12.7	10.8
Batch 3	12.2	13.1	12.7	13.7	12	12.5

Figure 4.1: Compressive strength with different mixes at 28-days

4.2.2 Failure Mode of Cube

Failure mode of cube specimens was discussed in this section. Failure mode refers to the way in which something might break down. Here, compression test was conducted on the cube specimens. Under pure uniaxial compression loading, the failure cracks generated are approximately parallel to the direction of the load. Figure 4.2 shows cube concretes with some crack formed at an angle to the applied load. Most of the specimens for every batch formed the same crack pattern.

Figure 4.2: Cube concretes with some crack

4.3 SLAB RESULTS

4.3.1 Relationship between Load and Mid-span Deflection

In slab specimens, it is failed in shear. First crack was occurred in flexural region then followed by a sudden failure at the ultimate load.

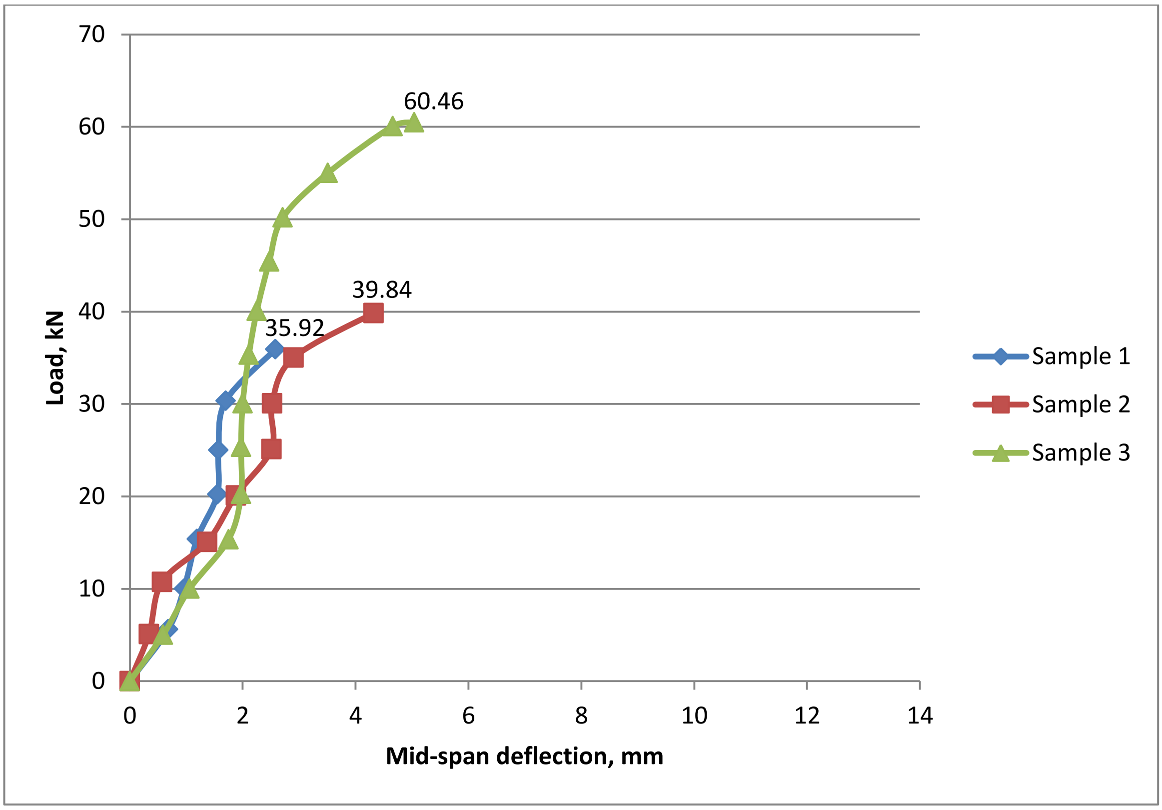
The graph patterns of the load-deflection of the specimens under flexural loading of all the mixes are shown in Figure 4.4. Figure 4.3(a) is for batch 1, Figure 4.3(b) is for batch 2 and Figure 4.3(c) is for batch 3. It can be seen from the curve of the oil palm shell concrete specimen did not exhibit any post failure characteristics. The addition of the fibres in the oil palm shell concrete significantly enhanced the post-failure strengths of the concrete after the formation of first crack. The mixes with 1% SF60 which is Batch 1 produced larger flexural toughness.

Figure 4.3(a) shows the deflection for first batch. For the maximum load for first sample is 35.92 kN with the deflection of 2.58 mm. While for the second sample is 39.84 kN with the deflection of 4.32 mm and the last sample is 60.46 kN with the deflection of 5.04 mm. From this result, it can be concluded that the bigger the load applied the bigger the deflection. Batch 1 for the third sample may have an error due to the unusual result. It is may be cause by the compaction of the concrete during pouring the concrete into the formwork. It is compacted very well compared to the other two samples.

The addition of fibres increased the deflection of oil palm shell concrete. The comparison between the specimens prepared using different types of fibres shows that SF60 produced highest deflection. This might be due to the length of the fibres. Its slower the crack propagation hence allows the specimens to deflect more.

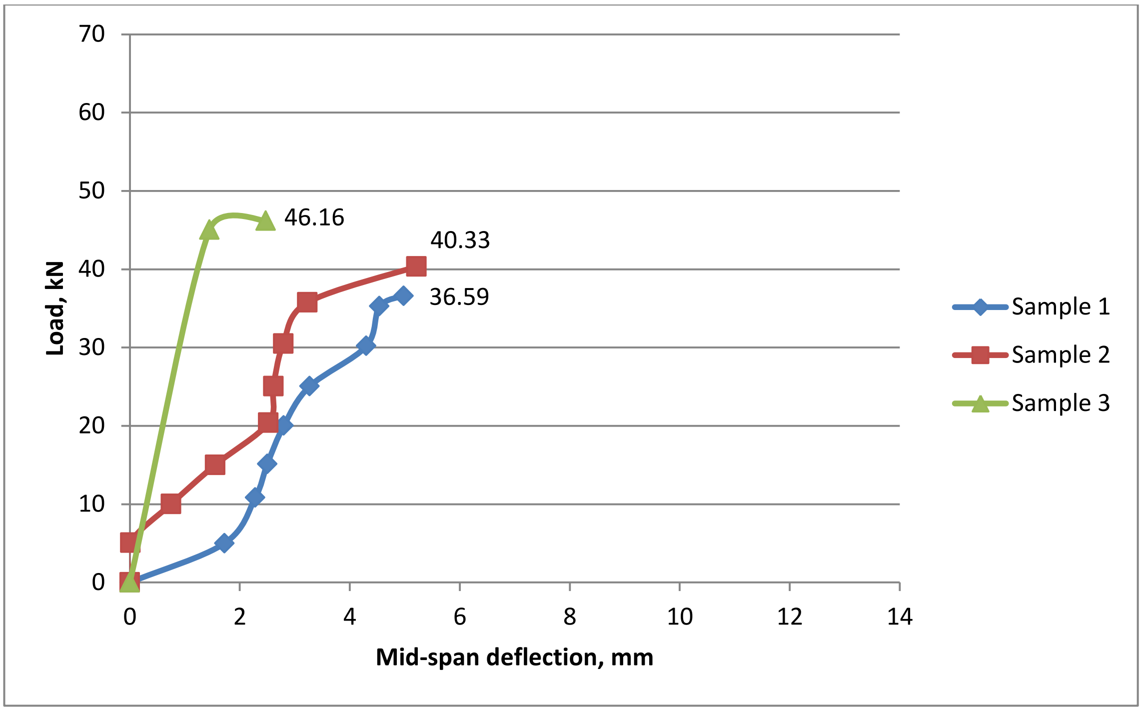
Figure 4.3(b) shows the deflection for first batch. For the maximum load for first sample is 36.59 kN with the deflection of 4.98 mm. While for the second sample is 40.33 kN with the deflection of 5.21 mm and the last sample is 46.16 kN with the deflection of 2.47 mm. From this result, it can be concluded that the bigger the load applied the bigger the deflection. This batch produce less strength compared to the batch 1 and it may be because of the type of fibre used.

While in hybrid fibre system, the stiff steel fibre improves the first crack stress and ultimate strength. Figure 4.3(c) shows the deflection for third batch. For the maximum load for first sample is 46.76 kN with the deflection of 10.76 mm. While for the second sample is 38.03 kN with the deflection of 6.33 mm and the last sample is 43.36 kN with the deflection of 6.89 mm. The observation on the effect of hybrid fibre in the first crack deflection is a proof to the above statement. The addition of high amount of steel fibres resulted in higher first crack deflection.

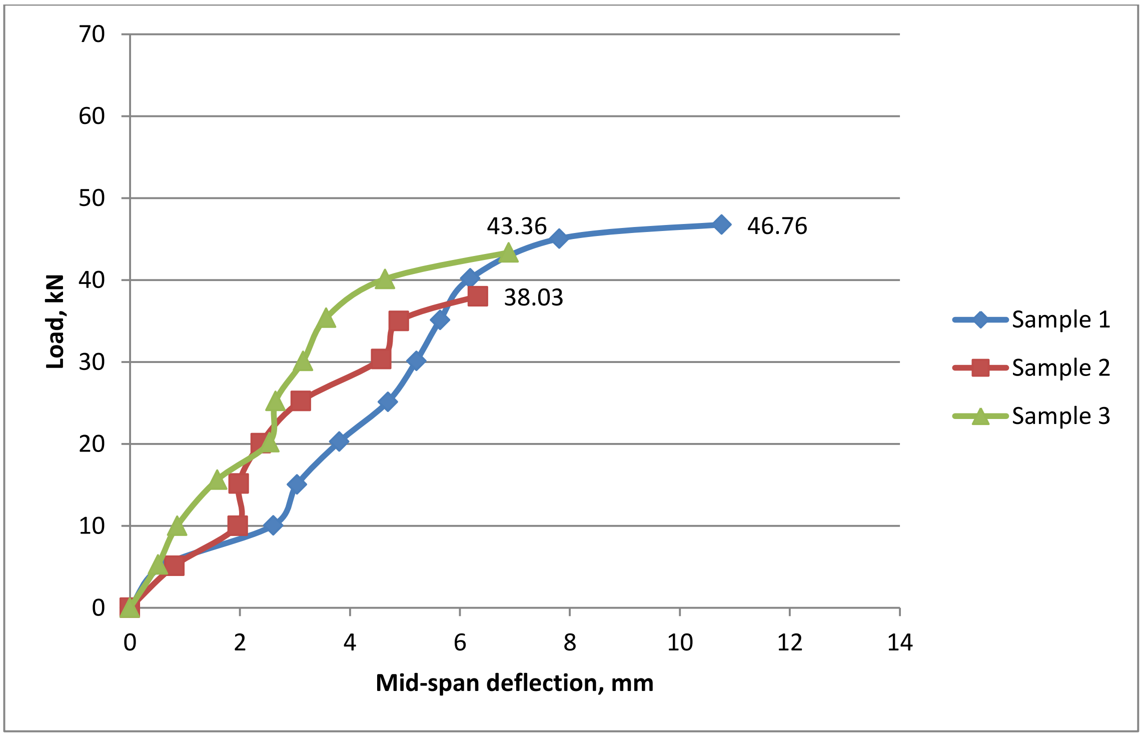


(a) Graph of load vs deflection for B1

Figure 4.3(a): Relationship between load and mid-span deflection for all batches



(b): Graph of load vs deflection (Batch 2)



(c): Graph of load vs deflection (Batch 3)

Figure 4.3: Continued

4.3.2 First Crack Load

During the experiment was conducted, the cracking was observed and marked it with marker pen. It was observed every second to find the first crack with it loading. Table 4.2 shows the value of the first crack for every sample in every batch. From the table, it can be concluded that for every sample in every batch; the first crack occur around the range of 30 kN - 35 kN. For a better understanding, the graph was plotted to show the distribution of the first crack.

For Batch 1, the first crack of first sample occurred at 30.35 kN with the deflection of 1.7 mm, second sample at 30.05 kN with the deflection of 2.52 mm and third sample is at 45.41 kN at 2.47 mm.

For Batch 2, the first crack of first sample occurred at 25.05 kN with the deflection of 3.27 mm, second sample at 30.49 kN with the deflection of 2.79 mm and third sample is at 37.68 kN at 1.47 mm.

While for the Batch 3, the first crack of first sample occurred at 35.12 kN with the deflection of 5.64 mm, second sample at 25.23 kN with the deflection of 3.11 mm and third sample is at 20.20 kN at 2.54 mm.

Table 4.2: First crack load

	First Crack (kN)		
Sample	**Batch 1**	**Batch 2**	**Batch 3**
1	30.35	25.05	35.12
2	30.05	30.49	25.23
3	45.41	37.68	20.20

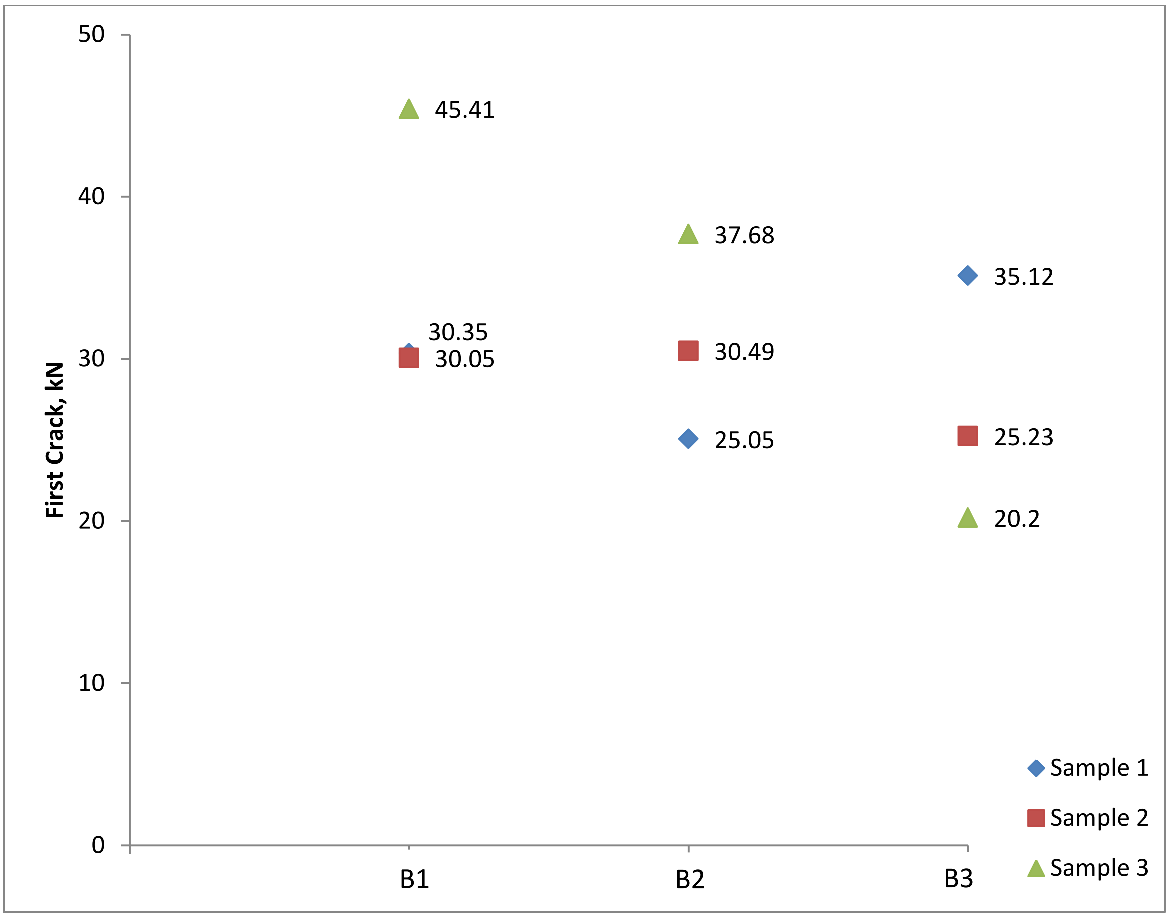


Figure 4.4: Graph of first crack

4.3.3 Ultimate Shear Load

A shear load is a force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force. When a paper is cut with scissors, the paper fails in shear. Here, the slabs were applied with the load and it fails in shear. Figure 4.5 summarize the data on the ultimate shear load of the specimens for every batch.

Sample 3 of batch 1 shows the highest ultimate load among sample in the batch. The value is 60.46 kN. 35.92 kN and 39.84 kN are the ultimate shear load for sample 1 and sample 2 respectively.

Samples in batch 2 and batch 3 shows likely data on the ultimate shear load which are 36.59 kN, 40.33 kN, 46.16 kN and 46.76 kN, 38.03 kN, 43.36 kN respectively.

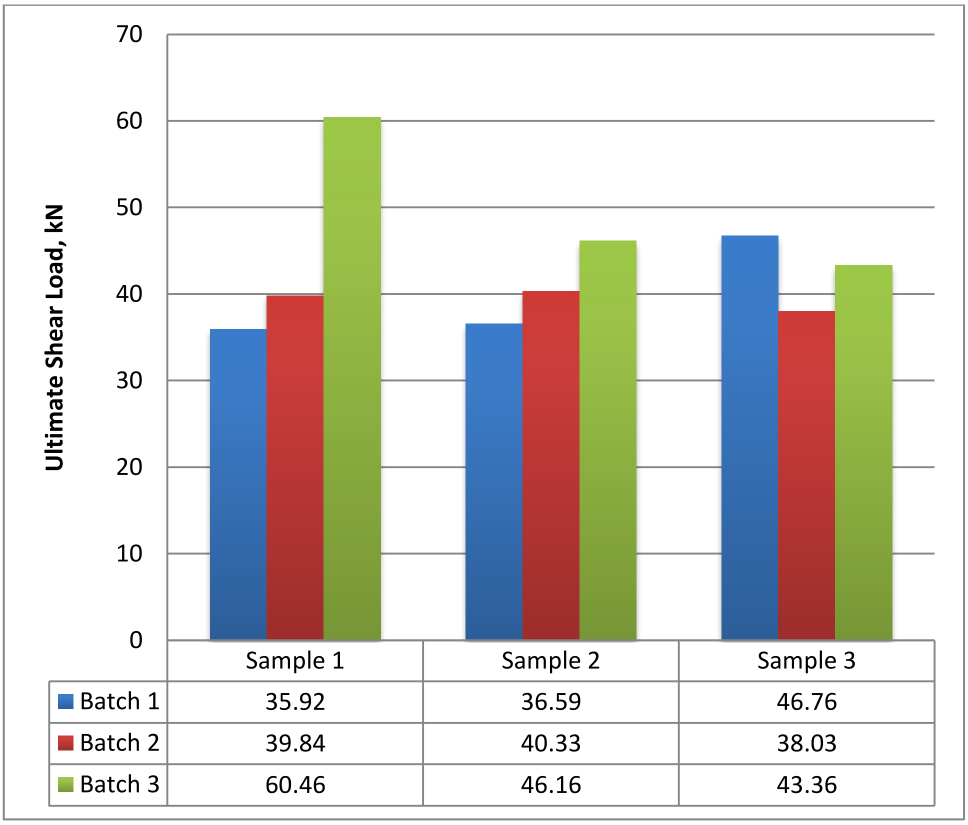


Figure 4.5: Graph of ultimate shear load

4.3.4 Failure Mode

For Batch 1, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 30.35 kN, sample 2 is 30.05 kN and sample 3 is 45.41 kN the crack started to form at the flexural region. Figure 4.6(a) shows the failure mode of the slabs for sample 1, Figure 4.6(b) for sample 2 and Figure 4.6(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.6: Failure mode B1

(c): Failure mode for sample 3

Figure 4.6: Continued

For Batch 2, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 25.05 kN, sample 2 is 30.49 kN and sample 3 is 37.68 kN the crack started to form at the flexural region. Figure 4.7(a) shows the failure mode of the slabs for sample 1, Figure 4.7(b) for sample 2 and Figure 4.7(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.7: Failure mode for B2

(c): Failure mode for sample 3

Figure 4.7: Continued

For Batch 3, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 35.12 kN, sample 2 is 25.23 kN and sample 3 is 20.20 kN the crack started to form at the flexural region. Figure 4.8(a) shows the failure mode of the slabs for sample 1, Figure 4.8(b) for sample 2 and Figure 4.8(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.8: Failure mode for B3

(c): Failure mode for sample 1

Figure 4.8: Continued

Based on the picture of the failure mode for all specimens for every batch, it can be concluded that all of them fail at the flexural region. It can be observed that the cracking is in shear mode.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter presented the conclusion that was made based on the experiment and data analysis that have be done in the research. Several recommendations also being discussed in this chapter to improve the outcomes and results for this research study.

5.1 CONCLUSION

Based on the experimental result and analysis obtained, the objectives of this research study that have been stated in the early of this research have been achieved. From the results obtained in this research, the following conclusion can be drawn.

1. The structural behaviour of OPSC slab was improved with the usage of long steel fibre with lower aspect ratio which resulted in larger increase of ultimate shear strength. Of all of the tested fibres, the SF60 showed the best performance in strength.
2. The effect of fibre hybridization to the behaviour of OPSC slab shown none improvement to the structural performance of the slabs.

5.2 RECOMMENDATION

Based on the personal experience in conducting research and experimental results that has been performed, there are several recommendations suggested. Several modifications should be made to the standard experimental procedures with respect to the scope of the study. This study can help for a better understanding of oil palm shell concrete in construction industry. The testing should be conducted in different time of curing for every sample to provide broader understanding of the compressive strength behaviour. Besides that, the oil palm shell should be dry longer and the fibre on the oil palm shell should be removed to get a better result on the strength of the concrete.

EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB

NURSYAZWANI BINTI MAT LAZIM

Bachelor (Hons) of Civil Engineering

UNIVERSITI MALAYSIA PAHANG

EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB

NURSYAZWANI BINTI MAT LAZIM

Thesis submitted in partial fulfillment of the requirements for the award of degree of the Bachelor (Hons) of Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2015

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name	:**NURSYAZWANI BINTI MAT LAZIM**
Date of birth	:**26 AUGUST 1992**
Title	:**EFFECT OF FIBRE HYBRIDIZATION TO THE BEHAVIOUR OF OIL PALM SHELL CONCRETE SLAB**
Academic Session	: **2014/2015**

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☐	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that University Malaysia Pahang reserves the right as follows:

1. The thesis is the property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

_______________________	_______________________
SIGNATURE	SIGNATURE OF SUPERVISOR
920826035130	DR NOOR NABILAH BT SARBINI
(NEW IC NO./PASSPORT NO.)	NAME OF SUPERVISOR
Date:	Date:

SUPERVISOR'S DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree Bachelor of Civil Engineering"

Signature:
Name of Supervisor: DR. NOOR NABILAH BINTI SARBINI
Position:
Date:

Signature:
Name of Co-supervisor:
Position:
Date:

STUDENT'S DECLARATION

"I hereby declare that the work in this thesis entitled **Effect of Fibre Hybridization to the Behaviour of Oil Palm Shell Concrete Slab** is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree."

Signature:

Name: NURSYAZWANI BINTI MAT LAZIM

ID Number: AA11128

Date:

DEDICATION

Special Dedication for both of my beloved parents,
Mat Lazim bin Ismail & Nooraini binti Mat Salleh.
Your sacrifices and contribution that you gave too high values
I appreciate that will last everlasting

ACKNOWLEDGEMENTS

Firstly, thanks to the Almighty for His grace given me the opportunity to finish writing this thesis. Deepest gratitude and sincere thanks goes to my respected supervisor, Dr. Noor Nabilah binti Sarbini for her instruction, guidance, advice and encouragement she has given as my supervisor. I also sincerely thanks for the time spent proofreading and correcting my many mistakes. All the knowledge and guidance given will be used as best as possible.

For my beloved parents, family and friends, I want to thank for your encouragement, support and prayers along the way I finish writing this thesis. Finally, thanks to all the parties involved either directly or indirectly throughout the writing of this thesis. May you always be loved and blessed by Allah S.W.T.

Thank you.

Abstract

Oil palm shell (OPS) is considered as a waste material originating from the oil palm industry. On the other hand, steel fibre can act as an unconventional material to reduce the sensitivity of OPS concrete. Hybridization of fibre leads to improvements on the mechanical and ductility characteristics of the concrete. In this research, the effect of steel hybrid fibre on the compressive strength and ultimate shear failure concrete slab were studied. Cube compressive strength and combined bending and shear tests for the slab were conducted. OPS that were used are from Kilang Panching while steel fibres are from a factory at Klang. In this study, aspect ratio and volume fraction were emphasized in selecting the most suitable type of steel fibre. The results on the cube compressive strengths shows range of 12.4 MPa – 14.9 MPa, 10.2 MPa – 12.7 MPa and 12.0 MPa – 13.7 MPa for B1, B2 and B3 cubes, respectively. The values were slightly lower than the design concrete strength of 20 MPa. On the other hand, the ultimate shear failure gives range of 36.0 kN – 60.5 kN, 37 kN – 46 kN, 38 kN – 47 kN for B1, B2 and B3 slabs, respectively. As a conclusion, slabs with longest length of steel fibre, SF60 shown better structural performance compared with other length. In terms of hybridization effect, it shows none improvement to the structural slab.

Abstrak

Tempurung kelapa sawit (OPS) dianggap sebagai bahan buangan yang berasal daripada industri kelapa sawit. Sebaliknya, gentian keluli pula boleh bertindak sebagai bahan tidak konvensional untuk mengurangkan sensitiviti OPS konkrit. Penghibridan gentian membawa kepada penambahbaikan kepada ciri-ciri mekanikal dan kemuluran konkrit. Dalam kajian ini, kesan gentian keluli hibrid pada kekuatan mampatan dan kegagalan ricih muktamad papak konkrit telah dikaji. Kekuatan mampatan kiub dan lenturan gabungan dan ujian ricih untuk papak telah dijalankan. OPS yang digunakan adalah dari Kilang Panching manakala gentian keluli adalah dari sebuah kilang di Klang. Dalam kajian ini, nisbah aspek dan jumlah pecahan telah diberi penekanan dalam memilih jenis gentian keluli yang paling sesuai. Keputusan pada kekuatan mampatan kiub menunjukkan julat antara 12.4 MPa – 14.9 MPa, 10.2 MPa – 12.7 MPa dan 12.0 MPa – 13.7 MPa untuk B1, B2 dan B3 kiub masing-masing. Nilai adalah sedikit lebih rendah daripada kekuatan konkrit reka bentuk iaitu 20 MPa. Sebaliknya, kegagalan ricih muktamad memberikan julat antara 36.0 kN – 60.5 kN, 37.0 kN – 46.0 kN, 38.0 kN – 47.0 kN untuk B1, B2 dan B3 papak masing-masing. Kesimpulannya, papak dengan gentian keluli paling panjang, campuran SF60 menunjukkan prestasi struktur yang lebih baik berbanding dengan panjang yang lain. Dari segi kesan penghibridan, ia menunjukkan tiada peningkatan untuk struktur papak.

TABLE OF CONTENTS

CHAPTER 3 RESEARCH METHODOLOGY

CHAPTER 4 RESULT AND DISCUSSION

CHAPTER 5 CONCLUSION AND RECOMMENDATION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	American Society for testing and Materials
AIV	-	Aggregate Impact Value
BS	-	British Standard
LWC	-	Lightweight Concrete
LWA	-	Lightweight Aggregate
OPC	-	Ordinary Portland cement
OPSC	-	Oil Palm Shell Concrete
OPS	-	Oil Palm Shell
SFRC	-	Steel Fibre Reinforced Concrete
SFRSCC	-	Steel Fibre Reinforced Self-Consolidating Concrete
SF	-	Steel Fibre

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is the most widely used of construction substantial all over the world. In normal weight concrete, it is made up from cement, coarse aggregates, fine aggregates, water and admixtures. Recent years, oil palm shell (OPS) and steel fibre have taken place as the replaced aggregate and reinforcement inside the concrete. The properties of steel fibre reinforced concrete improved the tensile and bending strength, greater ductility, and greater resistance to cracking and hence improved impact strength and toughness.

In ground-supported slabs, there are two main reasons why steel fibres are used. One of it is to control the development and formation of cracks that is caused by the early age plastic shrinkage and restrained long-term drying shrinkage. Another reason is to provide a degree of post-cracking load-carrying capacity such as the ability of the slab itself to carry load after the first crack has formed during the slab flexure.

Nowadays, lightweight concrete (LWC) has become one of the concrete used in construction. LWCs have many advantages. These advantages include saving on reinforcement, foundation cost, saving on formwork, better fire resistance, durability, heat isolation and frost resistance (Neville, 2008). However, the disadvantages of this concrete included lower mechanical properties and more cement is required compared to the normal concrete, greater shrinkage and higher material cost. Thus, such disadvantages justify the effort to resolve the problems with the existing LWC.

1.2 PROBLEM STATEMENT

Using lightweight aggregate (LWA) in the production of lightweight concrete (LWC) is the most popular method. Common natural LWAs include diatomite, pumice, scoria, volcanic cinders and tuff (Neville, 2008). Other type of LWA that popular in an agriculture field is oil palm shell (OPS). In Malaysia, it has a lot of the residue because Malaysia is one of the world leaders in the production and export of OPS. Generally, the mechanical properties of lightweight aggregate concrete (LWAC) are lower than ordinary concrete (Polat, 2010). One way to enhance the mechanical properties of the LWAC is through the using of steel fibre.

Steel fibre is the most commonly used of all fibre in most structural and non-structural purposes (Mehta and Monteiro, 2006). The addition of steel fibre in LWAC improved the mechanical properties of the concrete especially the tensile strength, impact strength and toughness (Ramados and Namagani, 2008). Steel fibre concretes have much higher fracture energy compared to the plain concrete (Peng et al., 2008).

The approach of using fibre reinforced concrete is expected to be the one of the method that can improve strength of lightweight aggregate concrete. Most research on oil palm shell (OPS) focuses on improving the mechanical properties. Furthermore, only several studies have been conducted or reported on the properties of OPS concrete containing steel fibre. Therefore, this study is conducted to investigate the volume content of steel fibre on the compressive strength and the optimum volume of OPS to be replaced with the coarse aggregate.

1.3 RESEARCH OBJECTIVES

The research objectives are:

i. To study the structural behaviour of oil palm shell concrete (OPSC) slab reinforced with steel fibre.
ii. To determine the effect of fibre hybridization to the behaviour of oil palm shell concrete slab.

1.4 SCOPE OF STUDY

The scopes of this study are:

i. The specimens tested are cubes and slabs; 9 cubes and 3 slabs for each batches with sizes (100 mm × 100 mm × 100 mm) and (350 mm × 500 mm × 100 mm) respectively.
ii. The cement grade used is 20 MPa.
iii. The type of fibre used in this research is steel fibre with L/D ratio is 80, length is 60 mm and the diameter is 0.75 mm with hooked-ends (SF60) and steel fibre with a length of 35 mm, aspect ratio of 65 and the diameter is 0.55 mm with hooked-ends (SF35).
iv. The type of lightweight aggregate used in this research is oil palm shell.
v. Volume fraction of steel fibre used in this research is 1.00%.
vi. The tests that have carried out are:
    i. Cube compressive strength test
    ii. Combined bending and shear test

1.5 RESEARCH SIGNIFICANCE

This study aim is to determine the effect of steel fibre hybridization in order to produce high strength of lightweight aggregate concrete. Essentially, fibres act as crack arrester which is restricting the development of cracks thus transforming in an inherently brittle (Vairagrade and Kene, 2013). For OPS concrete to be accepted for structural application, further investigations need to be conducted to improve the previous researches. Lightweight concrete using OPS as coarse aggregates is able to produce concretes with compressive strengths of more than 20MPa (Teo et al., 2006). Previous research shows that OPS can be used as replacement for conventional stone aggregates in concrete production.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Lightweight concrete (LWC) has become popular in recent years due to its advantages over the conventional concrete. Besides, it gives economical and structural benefits to the construction industry. Modern technology of the concrete also helped in a promotion and application of LWC. The use of aggregates from by-products or solid waste materials from agriculture industries is highly desirable in promoting them as replaced aggregates. Oil palm shell from oil palm industry is used to replace coarse aggregates in this study. This chapter review the information related to the oil palm shell concrete and steel fibre reinforced concrete.

2.2 LIGHTWEIGHT CONCRETE

The advantages of lightweight concrete (LWC) are well recognized in reducing the dead load thus allows for greater design flexibility and cost savings for structural (Alengaram et al., 2013). Using oil palm shell (OPS) in producing LWC is reducing the production cost. The use of alternative materials to replace conventional materials is being an advantage of LWC as OPS made from waste material (Short A, Kinniburgh W., 1978).

Lightweight aggregates such as expanded clay, slate, shale or blast furnace slag is a type of environmental-friendly material that used in the construction industry for making lightweight aggregate concrete (Bremner, 2001). The best alternative to achieve sustainable development of concrete is by use of waste materials instead of raw materials in the concrete mixture (Pelisser et al., 2011). Thus, oil palm shell can be used as it is one of waste material. OPS is generally used as granular filter material for water treatment, floor roofing and road based material (Alengaram et al., 2013).

One characteristics of OPS is; it is lighter than the conventional coarse aggregate. Lightweight concrete that use OPS as coarse aggregate is able produce concretes with compressive strengths of more than 25 MPa (Teo et al., 2005). Mannan and Ganapathy (2004) has studied on structural performance of OPS concrete. A slab with 125 mm thick and length 3.1 m was tested with a live load of 1.5 kN/m^2. It is observed that when load of 8.25 kN/m^2 is applied, the first crack is observed and the deflection was only 9.56 mm compared to an allowable deflection of 12.4 mm. From the result, it can be concluded that OPS can increased the strength of the concrete.

2.2.1 Advantages and Disadvantages of Lightweight Concrete

Lightweight concrete have many advantages compared to the other concrete. Table 2.1 summarized the advantages and disadvantages of the lightweight concrete.

Table 2.1: Advantages and disadvantages of the lightweight concrete

Advantages	Disadvantages
a) Faster and simplest the construction b) More economic in transportation and reduce the forces in work c) Reduce the dead load that directs faster to build and lower cost d) A marked reduction in heaviness of frame structure, foundation or piles e) Easy for do nailing and sawing work compared with conventional concrete f) Do not settle and not required the compaction of the concrete. g) Free flowing and spread freely to fill the voids	a) Slightly sensitive with the absence of water content in the concrete b) Time for mixing is longer compared with conventional concrete. It is to ensure that the mixture was mixed properly. c) Inability to deliver a consistent compressive strengths and density all over the entire area d) Porous and shows poor resistance to heavy scratch. e) Has low tensile strength and thus fracture easily.

Although there are disadvantages due to the use of LWC, it is still preferable in construction industry where the cost can be minimized. However, from the disadvantages of LWC it has made an effort to resolve these problems. The most popular method of LWC production is through the use of lightweight aggregate.

2.3 FIBRE REINFORCED CONCRETE

There are several types of fibre which are natural fibre, steel fibre, synthetic fibre and basalt fibre. Fibre reinforced concrete has gained various attentions in building construction for a couple of years. Fibre such as synthetic fibre liked nylon and polypropylene has excellent resistance of fibre in aggressive environments and it improves post-cracking ductility (Hamoush et al., 2010).

For natural fibre, it can be used in concrete as reinforcement. Reinforced concrete with polypropylene fibres which are used as fibrillated film to increase bond strength with cement matrix is well-established (Hannant et al., 1978). Using shorter fibres with low fibre-content for achieving workability and higher fibre content for better cohesiveness in wet state is recommended.

Ramakrishnan and Ananthanarayana (1968) investigated the ultimate strength and behaviour of 26 single-span beams. It is resulted that the beams failing by diagonal tension when ultimate load using splitting strength is applied. Comparison between theoretical and experimental investigations on the compressive strength and elastic modulus of coir and sisal fibre reinforced concretes for various volume fractions was also carried out by Ramakrishna and Sundararajan (2002). It was observed that both experimental and analytical values of elastic modulus had shown 15% discrepancy, which can be regarded as comparatively small. Ramakrishna and Sundararajan (2002) also suggested based on rheological properties of fresh mortar, it is recommended to use shorter fibres with low fibre-content for achieving workability and higher fibre content for better cohesiveness in wet state.

Toledo Filho et al. (2003) reported their study on development of vegetable fibre-mortar composites of improved durability. Several approaches were proposed to improve the durability of vegetable fibre-cement composites. These included carbonation of the matrix in a CO_2-rich environment; the immersion of fibres in slurried silica fume prior to incorporation in ordinary Portland cement matrix. It was suggested that immersion of natural fibres in a silica fume slurry before the addition to the cement based composites was found to be effective in reducing embrittlement of the composites in the environment.

2.3.1 Steel Fibre Reinforced Concrete

Steel fibres for reinforcing concrete are manufactured from cold-drawn wire, steel sheet and other forms of steel. Most common type of steel fibres used in floors is wire fibre. They vary in length up to 60 mm with aspect ratios from 20 to 100 and with variety of cross sections. Aspect ratio is the ratio of length of fibre to its diameter. It is influenced the properties and the behaviour of the fibre reinforced concrete. Mehrdad Mahoutian et al have proposed that adding of fibres into the concrete is an efficient method of increasing the mechanical properties of concrete. The addition of fibres significantly improves many of the engineering properties of mortar and concrete, and the impact strength and toughness as well.

Figure 2.1: Hook End Steel Fibre

Figure 2.2: Crimped Steel Fibre

There are some types of steel fibre used in concrete. Hook end steel fibre has diameter 4 mm to 1 mm. It tensile strength is more than 1100 MPa with the aspect ratios from 40 to 100. This type of fibre used for shotcreting of underground caverns, tunnel segments, slope stabilization and retaining walls. It is also has high tensile strength which resulted in higher toughness levels. It requires less labour to place concrete compared to the bar reinforcement. The crimped steel fibre has the high dragging resistance strength, which is up to 1100 MPa. It comes in various sizes which are 40 mm, 50 mm and 60 mm and the diameters are 0.5, 0.75, 0.9 and 1.0 with the aspect ratio 40 to 80 (tradeindia.com)

Steel Fibre Reinforced Concrete (SFRC) is a composite material. It consists of hydraulic cements with steel fibres that are dispersed. The steel fibres reinforce concrete superior in withstanding tensile stresses (wiki.org). Therefore, the flexural strength of fibre reinforced concrete is greater than un-reinforced concrete. Other benefits of SFRC are resistance to fracture, disintegration, and fatigue. Bencardino et al. (2008) have studied on the compressive behaviour of steel fibre reinforced concrete. The result from the experiment shows that the toughness of SFRC increases with the product of the volume fraction and the aspect ratio of the fibres.

Recently, steel fibre reinforced concrete has attained acknowledgment in numerous engineering applications. It has become more frequent to substitute steel reinforcement with steel fibre reinforced concrete. The most common applications are tunnel linings, slabs, and airport pavements (brighthubengineering.com).

2.3.1.1 Compressive Strength of Steel Fibre Reinforced Concrete

The compressive strength of concrete is usually considered as the most precious assets in concrete (Neville, 1995).

Chih-Ta Tsai et al. (2003) presents the way durability has been introduced to steel fibre reinforced concrete in Taiwan. It is generally acknowledged that steel fibres are added to improve the toughness, abrasion resistance, and impact strength of concrete. However, a locally developed mixture design method, the densified mixture design algorithm (DMDA), was applied to solve not only the entanglement or balling problem of steel fibres in concrete or to produce steel fibre reinforced self-consolidating concrete (SFRSCC) with excellent flow-ability, but also to increase the durability by reduction in the cement paste content. By dense packing of the aggregates and with the aid of pozzolanic material and superplasticizer (SP), concrete can flow honey-like with less entanglement of steel fibres. Such SFRSCC has already been successfully applied in several projects, such as construction of a low radiation waste container, bus station pavement, road deck panel, and two art statues.

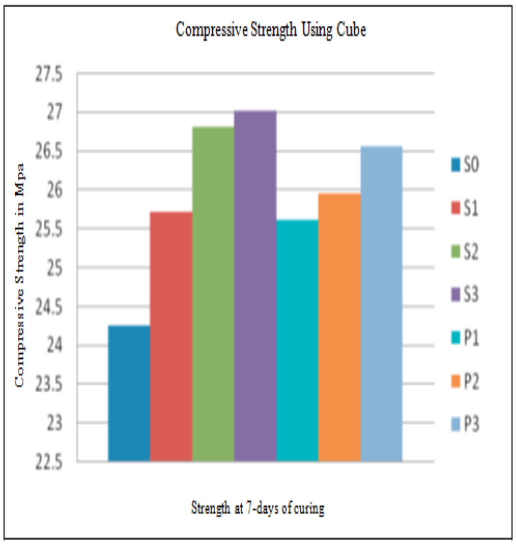
As known, most of the lightweight aggregate concrete is inferior in the tensile strength as well as higher brittleness. Shafigh et al. (2011) have researched on enhancing the compressive strength of oil palm shell concrete (OPSC) by varying the size of the OPS and developed high strength OPSC with a cement content of 550 kg/m^3. It resulted in increasing the compressive strength but however it will be offset by the increased brittleness of the concrete.

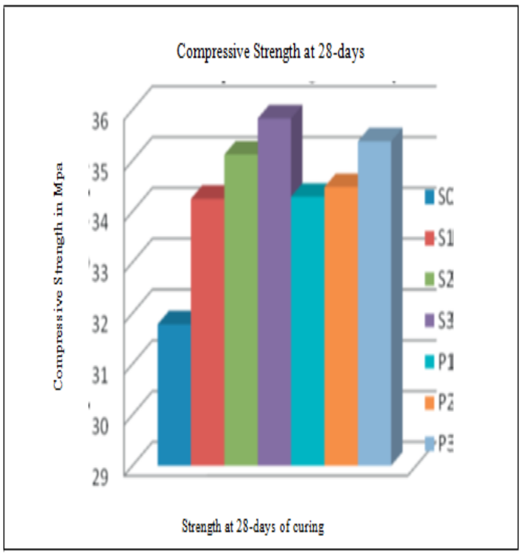
Banthia et al. (2007) have been reported that the addition of specified quantity of steel fibres is known to increase the tensile capacity of the fibre reinforced concrete (FRC) along with its post-failure ductility. The post-failure ductility is extremely useful in cases where tensile strength is not adequate to characterize the mechanical response of concrete. After the cracking of matrix, the steel fibres function as a crack bridging mechanism, in which the fibres undergo fibre pull-out, thus delaying the crack formation and limit the crack propagation. De-bonding and pulling out of fibres from FRC require higher amount of energy, resulting in the increased toughness and ductility of concrete.

Vairagade and Kene (2013) tested the compressive strength by doing two types of specimens which are cube specimen and cylinder specimen. Compressive strength of control concrete and FRC were calculated by dividing failure load with cross sectional area. It is observed that when fibers in discrete form present in the concrete, propagation of crack is restrained which is due to the bonding of fibers in to the concrete and it changes its brittle mode of failure in to a more ductile one and improves the post cracking load and energy absorption capacity. Result of compressive strength for M-20 grade of concrete on cube specimen with different fibres for different proportions as shown below. S for steel fibre while P for polypropylene.

Table 2.2: Test result of compressive strength using cube specimens

Batch No	Fibre Notation	No of Days	Average Compressive Strength (N/mm^2)
1	S0	7	24.26
		28	31.78
2	S1	7	25.72
		28	34.25
3	S2	7	26.80
		28	35.12
4	S3	7	27.01
		28	35.83
5	P1	7	25.61
		28	34.29
6	P2	7	25.95
		28	34.48
7	P3	7	26.56
		28	35.38





(a) 7-days

(b) 28-days

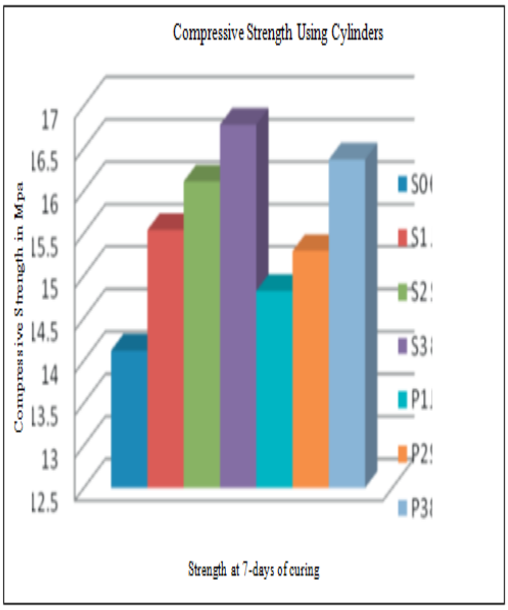
Figure 2.3: Comparison of percentage increase in compressive strength using cube at 7 and 28 days of curing

From figure 2.3, it can be observed that addition of 0.5% 50 mm copper coated crimped round steel fibre having aspect ratio 53.85 with maximum compressive strength in comparison with other steel fibres for both 7 and 28 days of curing. In non-metallic fibres, addition of 24 mm cut length fibrillated polypropylene at 0.4% by weight gives maximum compressive strength with compared to 15 mm and 20 mm cut length. Thus, it can be concluded that compressive strength is dependent on length of polypropylene fibres.

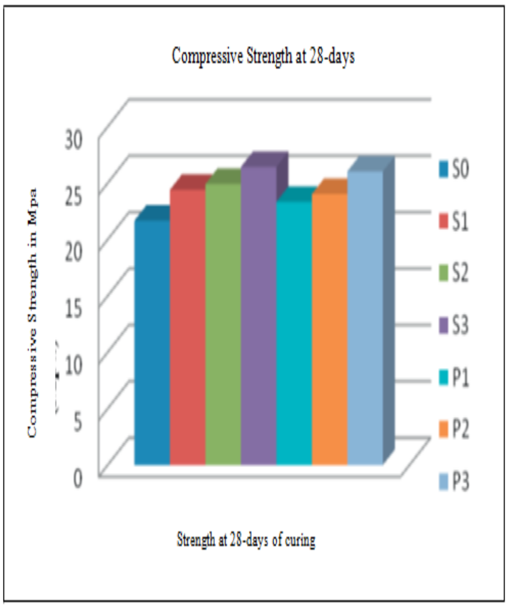
The results of compressive strength using cylindrical specimens are summarized in Table 2.3.

Table 2.3: Test result of compressive strength using cylindrical specimens

Batch No	**Fibre Notation**	**No of Days**	**Average Compressive Strength (N/mm^2)**
1	S0	7	14.12
		28	21.67
2	S1	7	15.54
		28	24.40
3	S2	7	16.11
		28	24.92
4	S3	7	16.78
		28	26.43
5	P1	7	14.82
		28	23.33
6	P2	7	15.29
		28	24.02
7	P3	7	16.37
		28	26.04



(a) 7-days



(b) 28-days

Figure 2.4: Comparison of percentage increase in compressive strength using cylinder at 7 and 28 days of curing

It can be observed that maximum strength for M20 grade of concrete was obtained by addition of 0.5%, 50 mm copper coated crimped round steel fibres having aspect ratio 53.85. Along with S3, fibrillated polypropylene fibres of 24 mm cut length at higher doses, at 0.4% also gives strength nearly equal to that of steel fibre S3. Addition of 0.4%, 24 mm polypropylene fibres increase 11.32% compressive strength using cube specimen and increase 18.16% using cylindrical specimen. Here, it can be concluded that the ratio of compressive strength of cylinders to the compressive strength of cube was found to be nearly 3:4.

2.3.1.2 Flexural Strength of Steel Fibre Reinforced Concrete

One of the significant benefits on the addition of steel fibre in concrete is its improved post-cracking tension. Kumar et al. (1972) reported investigations which contributed widely to the prediction of ultimate loads, failure patterns and deflections of deep beams. Kong et al. (1970) have reported the results of a study on 35 simply supported deep beams. The effects of seven different types of web reinforcement on deflections, crack width, crack patterns, failure modes and ultimate loads in shear were studied. It is observed that the effectiveness of the various types of web reinforcement depends on the span-to-depth ratio and shear span-to-depth ratio.

While Shanmugam and Swaddiwudhipong (1984) carried out an experimental investigation to study the ultimate load behaviour of steel reinforced concrete deep beams. A total 18 beams consisting of plain concrete and fibre reinforced beams were tested. It was observed that the addition of steel fibre resulted in increased failure loads and changes in modes of failure.

2.3.1.3 Previous Research on Steel Fibre Reinforced Concrete Application to Structure

There are many uses of steel fibre reinforced concrete in the scope of construction. Steel fibres are generally used for providing concrete with enhanced toughness and post-crack load carrying capacity. Typically loose or bundled, these fibres are generally made from carbon or stainless steel and are shaped into varying geometries such as crimped, hooked-end or with other mechanical deformations for anchorage in the concrete. Fibre types are classified within ACI 544 as Types I through V and have maximum lengths ranging from 30 mm – 80 mm and can be dosed at 6 kg/m^3 to 67 kg/m^3.

Steel-fibre-reinforced concrete finds one of its most prominent applications in tunnel construction. The frequently encountered stress-resultant combination of high compressive forces and relatively low bending moments in a tunnel lining can predominantly be matched by using the material properties of steel-fibre-reinforced concrete only. The material‘s resistance against concentrated loads assures a remarkably low maintenance costs. The use of this material simplifies the construction process and accelerates the speed of execution. Interest in the use of steel-fibre-reinforced concrete in tunnel construction is rising as a result of the flexibility which the use of this material permits and the cost-savings achieved compared to the use of conventional reinforced-concrete solutions.

Steel fibre concrete is manufactured in various grades, deformations and sizes to suit most concrete flooring applications. Usually, steel fibre concrete was used in heavily trafficked industrial paving (scrap yards), industrial ground bearing slabs, and suspended slabs on piles and impermeable concrete slabs. The benefits using this fibre are reduced overall construction cost over steel, increased crack control and eliminate concern associated with correct placement of reinforcement and correct cover.

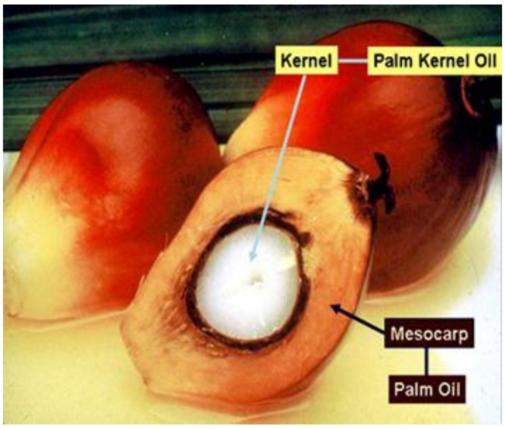
It has been reported that the addition of specified quantity of steel fibres can increase the tensile capacity of the fibre reinforced concrete along with its post-failure ductility (Banthia et al., 2007). Steel fibres act as a crack bridging mechanism which is delaying the crack formation and limit the crack propagation (Koksal et al., 2008).

L. Sorelli and F. Toutlemonde have focused on the application of SFRC in tunnel lining segments, as an alternative to conventional RC segments. Because of the structural applications of Steel Fibre Reinforced Concrete (SFRC) have recently been increasing due to the improvement of material properties, such as in the material toughness under tension and durability, it is critically reviewed considering the post-cracking resistant mechanism.

2.4 OIL PALM SHELL

Oil palm shell is the hard endocarp that surrounds the palm kernel. During the palm oil extraction process it is separated from the kernel. Oil palm shells are naturally sized, hard and lighter compared to the conventional aggregates. Oil palm shell (OPS) is a solid waste from oil palm industry. OPS for this study was taken from Kilang Sawit Panching located at Panching, Kuantan Pahang. OPS that taken here is wet so it was dried out before used as aggregates. Lightweight concrete which incorporating with OPS seems to be good in mechanical properties and durable performance (Teo et al., 2009).

Oil palm shell (OPS) is considered as a waste material produce from the extraction of palm oil in South East Asian countries. OPS aggregates are composed of different shapes. Pre-treatment is necessary for OPS aggregates before used in concrete because it contains dust and oil coating. The shells have been left under a shed for air-drying. OPS are light and naturally sized; they are ideal for substituting aggregates in lightweight concrete construction. Being hard and of organic origin, they will not contaminate or leach to produce toxic substances once they are bound in concrete matrix. OPS concrete can potentially be utilized in lightweight concrete applications that require low to moderate strength such as pavements and infill panel for flooring.



(a) OPS

(b) Dumping of OPS at landfill

Figure 2.5: Oil palm shell

Ahmed and Sobuz (2011) have studied on reinforced concrete beams made of lightweight concrete with normal strength concrete. It shows that it have satisfactory shear and flexural performance. While a research that studied by Shafigh et al. (2011) shows that OPS can be used as lightweight aggregate for producing high strength lightweight concrete.

Struble and Godfrey (2004) stated that three component of sustainability which are environment, economy and society are given less attention in developed countries. It can be concluded that, OPS lightweight concrete can meet the requirement of sustainability. In addition, a low cost house along with a foot bridge constructed using OPS lightweight aggregate is being monitored for structural performance (Teo et al., 2006).

2.4.1 Previous Research on Oil Palm Shell as a Lightweight Aggregate

Mo et al. (2014) have investigated the impact resistance of OPS concrete panels due to the improvement aggregate impact value (AIV) of OPS compared to the conventional aggregates. It is found that AIV of OPS is 2 times lower than the crushed granite aggregate. While Alengaram et al. (2008) reported that the ductility of reinforced concrete beams was about 2 times higher than the corresponding reinforced normal weight concrete beam.

OPS can be used as road pavement, kerb-stones, concrete drains and flooring slabs (Mannan et al., 2004). Improvement of mechanical properties of OPS concrete can be done by using smaller size of OPS aggregates (UJ et al., 2010). This could be achieved through the use of crushed OPS aggregates. Mo et al. (2014) stated that impact and ductility characteristics are enhanced by adding fibres in the OPS concrete.

Basri et al. (1998) have studied on the workability, density and compressive strength of OPS lightweight concrete over 56 days under three curing conditions. It is found that the fresh OPS concrete have better workability while its 28 days air-dry density was 19%-20% lower than conventional concrete. The compressive strength at

56 days also was 41%-50% lower compared to conventional concrete. The results were still within the range of structural lightweight concrete.

Wang and Wang (2013) found that the increase of compressive strength up to 23% with the addition of 2.0% steel fibre using lightweight cellular shale aggregate. On the other hand, Lee and Song (2010) found that 1.0% addition of steel fibre increased the compressive strength of lightweight cellular expanded shale concrete by 37%.

OPS aggregates are porous in nature thus it have low bulk densities. Although, OPS aggregates are porous, the resulting OPS concrete was reasonably impermeable. Low water cement ratios increases the strength of concrete thus enhance its resistance to cracking due to the internal stresses (Mindess et al., 2003). Therefore, it can be concluded that the permeability of OPS concrete is mostly caused by internal cracking of the paste-aggregate interface.

Compared to most types of concrete, OPS concrete developed better strength when stored in water than in air. The compressive strengths obtained at 28 days were approximately 35%-65% higher than the minimum required strength of 17 MPa for structural lightweight concrete (ASTM C 330). Generally, lightweight concretes have higher water absorption values than typical normal weight concretes (Newman, 1993).

2.5 SUMMARY

Fibres with different sizes and material can affect the brittleness of concrete. So, to improvise the brittleness of concrete fibre can be added. From the experiment result discussed before, the compressive strength of concrete can be increased by addition of fibre. Fibre that can be added to the concrete may be polypropylene, steel fibres and other fibres. However, due to superior strength enhancement shown by steel fibre, this type of fibre is chosen in this research.

In general, the addition of steel fibres increased the compressive strength of concrete. The high steel fibre content which is more than 0.75% enhanced the compressive strength of oil palm shell fibre reinforced concrete. Briefly, it can be concluded that the overall effect of fibres in arresting the crack and its propagation enhanced the mechanical properties of oil palm shell concrete. Furthermore, the contribution of fibres to stress redistribution caused lower strain and improved the modulus elasticity produced in the oil palm shell concrete which is higher compared to the steel fibre oil palm shell concrete. With steel fibres as additive to the lightweight concretes, its loading capacity is increased, the cracks are controlled and it shows a great resistance to dynamic and sudden loadings while decreasing the crack width. Furthermore, it also increases the resistance of the concrete against deformation and increases the tensile strength (Mohammadi et al., 2008).

In a nutshell, OPS can be used as a replacement for the coarse aggregates in concrete production. OPS concrete behaves similar to other structural lightweight aggregates concrete. OPS concrete also shows good potential as structural members in low-cost housing construction. OPS lightweight concrete efficiency factor is more than for the expanded clay and normal weight concrete. OPS concrete has greater drying shrinkage than expanded clay lightweight concrete however it reduces to 35% at 90 day age and beyond.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discussed on the methodology to conduct this research. In this research, the structural behaviour of the lightweight concrete slab with the addition of steel fibre and the effect of fibre hybridization to the behaviour of oil palm shell concrete slab were determined and investigated.

Figure 3.1 shows the flowchart of the study. This flowchart is to ensure the flow of the study can be done smoothly. First of all, before proceed with the experiment; sample preparations were prepared which is consisted formwork and raw materials. Some of the raw materials are cement, water, fine aggregates, oil palm shell and steel fibre. After that, next processes were proceeded which are mixing, casting, curing and testing. Results from the testing were analysed and tabulated.

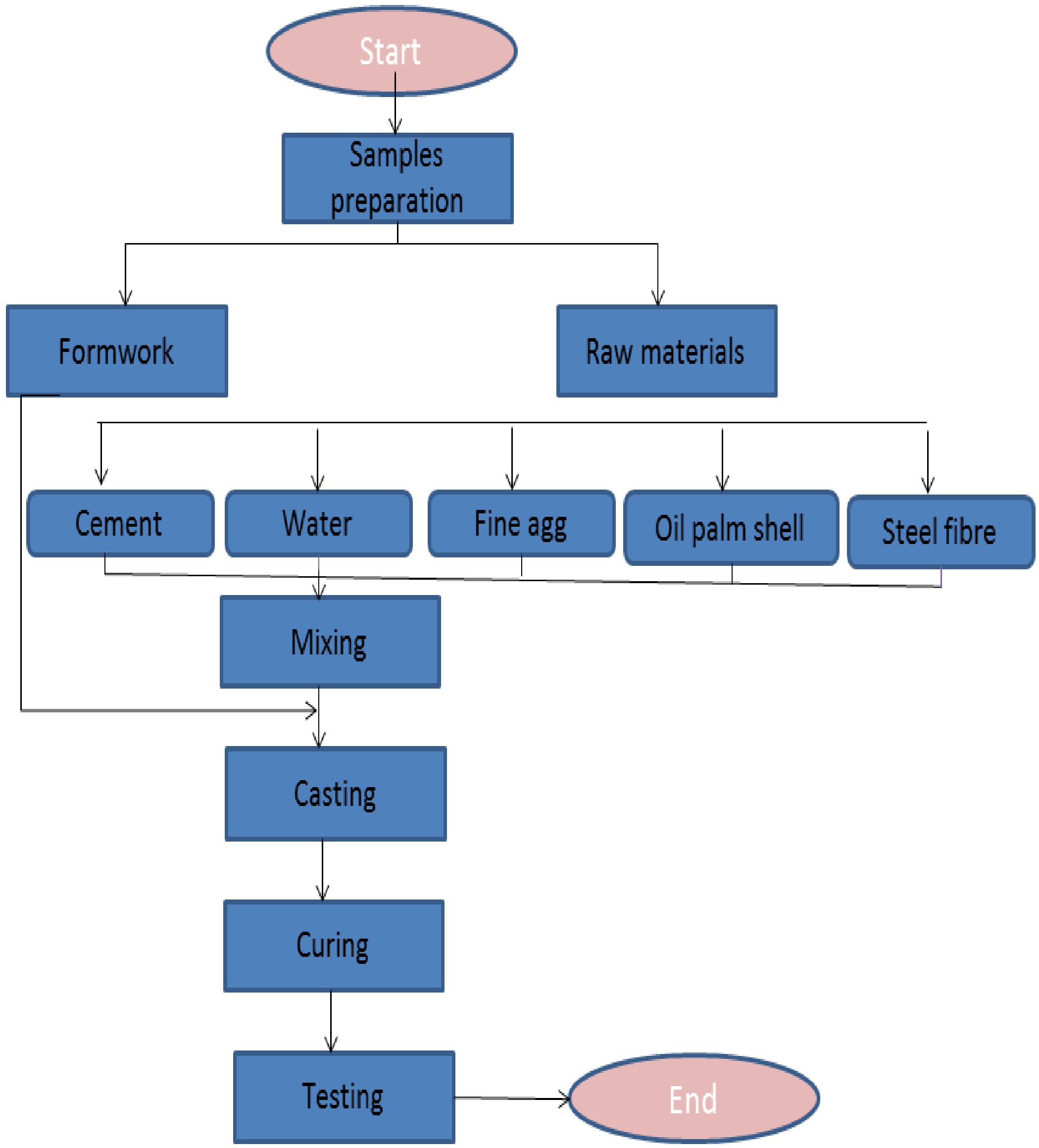


Figure 3.1: Flowchart of research

3.2 CONCRETE RAW MATERIALS

3.2.1 Oil Palm Shell Aggregates

In this study, the size of OPS used is between 5 mm-10 mm. It was air dry for about a week before it can be used. It was taken from an oil palm factory at Panching.

Figure 3.2: Samples of OPS aggregates

3.2.2 Steel Fibres

Steel fibres used in this study are SF60 which have length of 60 mm with aspect ratio of 80 and the diameter is 0.75 mm and SF35 which have length of 35 mm and the diameter is 0.55 mm. These steel fibres are known as hooked end steel fibre. These fibres were bought from a factory at Klang.

(a): HE steel fibre (SF60)

(b): HE steel fibre (SF35)

Figure 3.3: Hooked end steel fibre

3.2.3 Steel Reinforcement

Steel reinforcement used in this study is having size of 12 mm and 8 mm. Size of 12 mm is used as main bar while size of 8 mm as a link bar. Figure 3.4(a) shows the picture high strength steel while Figure 3.4(b) shows the picture of mild steel.

(a): High strength steel

(b): Mild steel

Figure 3.4: Steel reinforcement

3.2.4 Ordinary Portland cement

Ordinary Portland Cement (OPC) as shown in Figure 3.5 has been used for this study. OPC is the most common type of cement in general use around the world as a basic material of concrete or mortar. It is usually originates from limestone and comes in powder. The sieved OPC was kept in an airtight container to prevent air moisture contact as hydrated cement particle would affect the formation of a calcium silicate hydrate gel.

Figure 3.5: Ordinary Portland cement

3.2.5 Water

Water is one of the most significant components to produce concrete whether it is the conventional concrete or lightweight concrete. The water used should free from any impurities that can be harmful to the process of hydration of cement and durability of concrete. The main material on concrete was water where once the water mixed together with cement it was acted as the paste that binds the fine aggregates and the cement. Water causes hardening of concrete through hydration. The water used must be clean and free from any impurities that could be dangerous for hardening of concrete, durability, volume stability and change in colour. In this study, the water used is normal clean tap water.

3.2.6 Fine Aggregates

Normally the fine aggregate consist of natural sand or manufactured sand. In BS 3797:1990 has stated that fines sand for concrete is the particles with that passed the 5.0 mm in sieve test with an even distribution of sizes should be used for foamed concrete. Figure 3.6 shows the picture of fine aggregate used in this study.

Figure 3.6: Fine aggregate

3.3 MIX DESIGN

Table 3.1 shows the composition of the raw materials per 1 m^3 that were used in this study. In summary, 230 kg water, 762 kg fine aggregate, 400 kg cement, 1011 kg oil palm shell and 78.5 kg of steel fibre were used for 1 m^3 concrete mix volume. 0.8 kg per m^3 of super plasticizers was used in reference with the weight of cement.

Table 3.1: Mix design proportion per $1m^3$

Materials	Water (kg)	Fine Aggregate (kg)	Cement (kg)	Oil Palm Shell (kg)	Super plasticizers (kg)
Per $1m^3$	230	762	400	1011	0.8

3.4 CASTING PROCESS

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

The concrete is mixing after the material proportion was calculated and then the materials that were calculated were poured into the container little bit by little bit to make sure the mix of the concrete completely mixed. For the first material, all weighed sand and ops is poured into the container and followed by the cement. Then, the water is poured and mixed together with other materials until they mixed well and the remaining material is added repeatedly until all of the cement and fine aggregates is poured. Before oil palm shell is mixed with other material, cement and fine aggregates must mixed properly to avoid any lumps between them. The mixture is turned into uniformly grey after both cement and fine aggregates is mixed.

3.4.1 Specimen Preparation

Concrete specimens that are representative of a distinct batch of concrete must be sampled and analyzed for the purpose of quality control. Tests are performed on concrete cube specimens and slabs specimens to evaluate the compressive strength of the concrete. The formwork of the samples was prepared using the plywood with thickness of 6 mm. Plywood is easy to cut and shape and makes the jobs to do the formwork much easier. The sizes used for the specimens are 100 mm × 100 mm ×100 mm and 350 mm × 500 mm × 100 mm for cube and slabs respectively. Formwork is the walls that support the concrete until it harden or in other word, is a mould or box which fresh concrete can be poured and compacted so that it will flow to the inner of the formwork. Once the formwork was sorted and completed, other specimens also checked such as the quantities of steel fibre, oil palm shell, aggregates and cement that need to be used in this study. Figure 3.7 shows the mould for both specimens.

In this study 3 batches are involved which are batch 1, 2, and 3. The details for each batch are summarized in the table below.

Table 3.2: Details of Batches

Batch No	Details
Batch 1(B1)	100 % OPS + SF 60 (1%)
Batch 2(B2)	100 % OPS + SF 35 (1%)
Batch 3(B3)	100 % OPS + SF 60 (1%) + SF 35 (1%)

(a) Cube (b) Slab

Figure 3.7: Mould for specimens

3.4.2 Method of Casting

In this study, the concrete was mixed manually due to some problem. All samples were casted in the laboratory for different batches. In preparing the specimens, at first, fine aggregates and oil palm shell is properly mixed and then cement was added. All the materials were mixed together. Water was added at interval time after the cement and aggregates are properly mixed. Fresh concrete workability was investigated immediately after the final mixing of concrete using slump test. The cubes were cast by filling each mould in three layers; each layer was compacted with a vibrator. The layer compacted with the vibrator to ensure the concrete is uniformly distributed. After slump test was achieved required result, all specimens were left in the moulds for 24 hours. They were removed from the mould and transferred into an area to cover with wet sack for curing.

Figure 3.8: Fresh concrete

Figure 3.9: Fresh concrete after leveling

3.4.3 Curing

The important role on the strength of concrete is curing which it is the process to stop the fresh concrete from drying very quickly. This is because if the concrete is too dry, the bonding in the concrete will not function and will make the concrete is being weak and easy to crack. So, curing process is very important in any concreting work to avoid from any cracking or forming of honey comb. For this research study, the type of curing condition used is wet sack curing. Basically, concrete was cured in duration of 7, 14 and 28 days but for this research, the samples were cured for 7 days and 28 days only. The cubes and slabs were put under the wet sack and leave. The wet sacks were watered every day in order to ensure the hardened and the strength of the specimens.

Figure 3.10: Curing with wet sack

3.5 CONRETE WORKABILITY TEST

In accordance with relevant British Standards (BS EN 12350-2:2009), the slump test is important as it determines the consistency of fresh concrete. BS EN 12350-2 specifies a method for determining the consistence of fresh concrete by the slump test. The slump test is sensitive to changes in the consistence of concrete, which correspond to slumps between 10 mm and 210 mm. If the slump continues to change over a period of 1 min after de-moulding, the slump test is not suitable as a measure of consistence. The test is not suitable when the maximum size of aggregate in the concrete is greater than 40 mm.

The fresh concrete is compacted into a mould in the shape of a cone. When the cone is withdrawn upwards, the distance the concrete has slumped provides a measure of the consistency of the concrete. This is the basic principle of the slump test. The sample of the concrete is obtained in accordance with BS EN 12350-1(British Standards Institute, 2009).

Figure 3.11 shows how the slump test was conducted. The concrete was compacted in the mould by using rod. It was compacted every 3 layer. Every layer was compacted for 25 times using the rod.

Figure 3.11: Slump test

3.6 CUBE COMPRESSIVE STRENGTH TEST

For the compressive strength testing of the cubes, the procedures of testing is based on BS EN 12390-3-2009. Compressive strength is the primary physical properties of concrete that being used for quality control purposes for lightweight foamed concrete. It is the ability of concrete to sustain the axial load. For the compressive strength test, the machine use is Compression Testing Machine as shown in Figure 3.12. It is a testing machine of appropriately capacity for the test and equipped with a means of providing the level of loading specified.

Each cube was placed based on the direction of application of load whether in bed position or stretcher position in the testing machine. Before the machine is started, the dimension of the surface of sample was set-up on the machine for the result of compressive strength. Smooth surface of cube was chosen to do the test. The load was applied onto the sample without shock. The appropriate loading rate is maintained as far as possible right up to failure. The test was stopped when the maximum load applied had failure the cube and the machine was automatically shows the result of maximum loading and maximum strength of the sample tested. Then, the data was recorded for every sample.

Figure 3.12: Compressive strength test

Cube compressive strength test was conducted to determine the maximum load of the samples. In this testing, the load is applied continuously towards the sample until it is failed to resist more loading. By referring to the testing, the data maximum load and maximum strength for every sample is recorded until all the samples are tested. The compressive strength test is based on the procedures stated in BS EN 12390-3:2009.

The comparison between 28 days compressive strength of control mixes with crushed oil palm shell is expected to increase. Thus, it shows crushing of oil palm shell improved the compressive strength of oil palm shell concrete. Shafigh et al (2011) explained that the enhancement of the compressive strength is due to the increased number of broken edges found in the crushed oil palm shell. In general, the addition of steel fibre increased the compressive strength of concrete.

3.7 COMBINED BENDING AND SHEAR TEST

A reliable assessment of the shear strength can be obtained only from tests under combined stresses. Slab testing was done using magnes frame machine. From the machine, the data that were collected are load and deflection. Every sample for each batches are testing to know the maximum load and the pattern of the crack. Figure 3.13 shows the illustration of the arrangement for the testing. Middle third flexural loading was applied on the oil palm shell concrete slabs through hydraulic jack. The specimens were placed under magnes frame machine and linear variable displacement transducers (LVDT) were attached to measure the deflection readings. During this experiment also, the cracking on the specimens were observed.

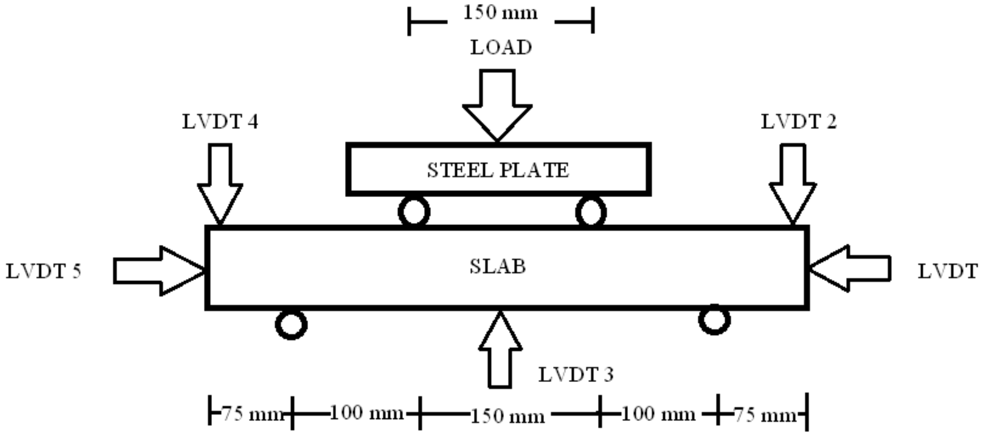


Figure 3.13: Illustration for slab testing

Slab was tested by doing combined bending and shear test. Before the test was conducted, the apparatus was set-up a day before to ensure the flow of experiment was smooth without any delay. Figure 3.14 shown the actual set up during experiment. The equipments that were used during the experiment are:

1) 5 linear variable displacement tranducer (LVDT)
2) Magnes Frame
3) Steel roller
4) Steel plate
5) Hydraulic jack
6) Load cell

Figure 3.14: Actual view during slab test

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 INTRODUCTION

The results obtained from the experimental test was analysed and discussed in this section. Data obtained from the experiment were compared due to the effect of different size of steel fibre with the same volume fraction.

4.2 CUBE COMPRESSIVE STRENGTH

Cube compressive strength test were conducted to determine the maximum load of the cube sample with different mixes. In this testing, the load was applied continuously subjected to the sample until the sample was failed to resist more loading. Referring to the testing, the data of maximum load and maximum strength for every sample were recorded. This testing was conducted based on the procedures stated in BS EN 12390-3:2009.

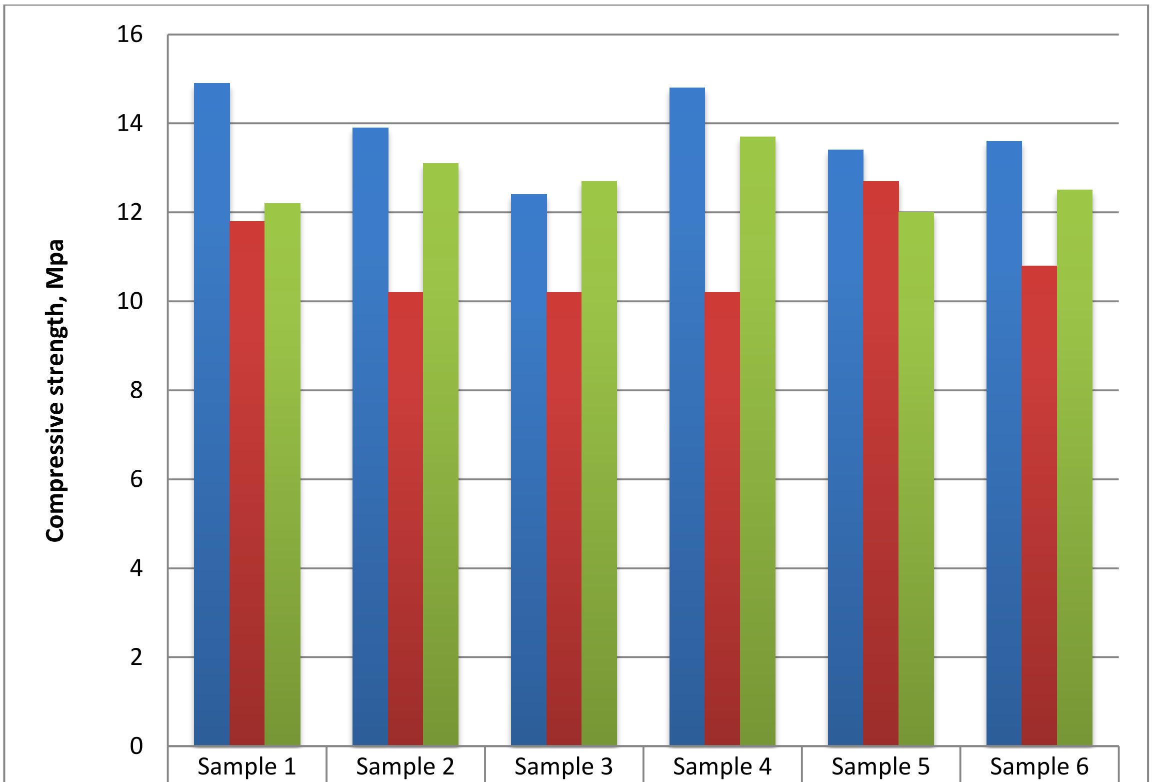
4.2.1 Compressive Strength of Cube Concrete with Different Mixes

Table 4.1 shows the compressive strength of cubes with different mixes which are curing under wet sack. From the table, we can see that Batch 1 have the highest compressive strength at 28-days followed by Batch 3 and lastly Batch 2. As mentioned before, Batch 1 mix consist of 100% OPS + 1% SF60 while Batch 2 is 100% OPS + 1% SF35 and Batch 3 is 100% OPS + (1% SF60 + 1% SF35). Here, it can be concluded that SF60 contributed in the strength of the cube. The longer the steel fibre, the higher the strength will be.

Table 4.1: Compressive strength with different mixes at 28-days

	Cube compressive strength (MPa) at 28-days		
Sample	**Batch 1**	**Batch 2**	**Batch 3**
1	14.9	11.8	12.3
2	13.9	10.2	13.1
3	12.4	10.2	12.7
4	14.8	10.2	13.7
5	13.4	12.7	12.0
6	13.6	10.8	12.5

Based on the graph, for sample 1 Batch 1 has the highest compressive strength which is 14.9 MPa, followed by Batch 3 which is 12.3 MPa and lastly sample 1 for Batch 2 that is 11.8 MPa. For sample 2 also, Batch 1 has the highest compressive strength which is 13.9 MPa. For the sample 2, it shows the same trend with sample 1 where Batch 1 has the highest strength followed by Batch 3 and Batch 2. Compressive strength for sample 3 shows almost the same value for Batch 1 and Batch 3 which are 12.4 MPa and 12.7 MPa respectively. Batch 2 has the lowest compressive strength which is 10.2 MPa. Sample 4 and sample 6 shows the same trend for each batch were batch 1 have the highest compressive strength and Batch 2 have the lowest compressive strength. For sample 5, Batch 1 has highest strength which is 13.4 MPa. From the overall result, a conclusion can be made. Steel fibre that has longest length produces highest strength. In this study, SF60 gives the highest strength in the compressive test.



	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Batch 1	14.9	13.9	12.4	14.8	13.4	13.6
Batch 2	11.8	10.2	10.2	10.2	12.7	10.8
Batch 3	12.2	13.1	12.7	13.7	12	12.5

Figure 4.1: Compressive strength with different mixes at 28-days

4.2.2 Failure Mode of Cube

Failure mode of cube specimens was discussed in this section. Failure mode refers to the way in which something might break down. Here, compression test was conducted on the cube specimens. Under pure uniaxial compression loading, the failure cracks generated are approximately parallel to the direction of the load. Figure 4.2 shows cube concretes with some crack formed at an angle to the applied load. Most of the specimens for every batch formed the same crack pattern.

Figure 4.2: Cube concretes with some crack

4.3 SLAB RESULTS

4.3.1 Relationship between Load and Mid-span Deflection

In slab specimens, it is failed in shear. First crack was occurred in flexural region then followed by a sudden failure at the ultimate load.

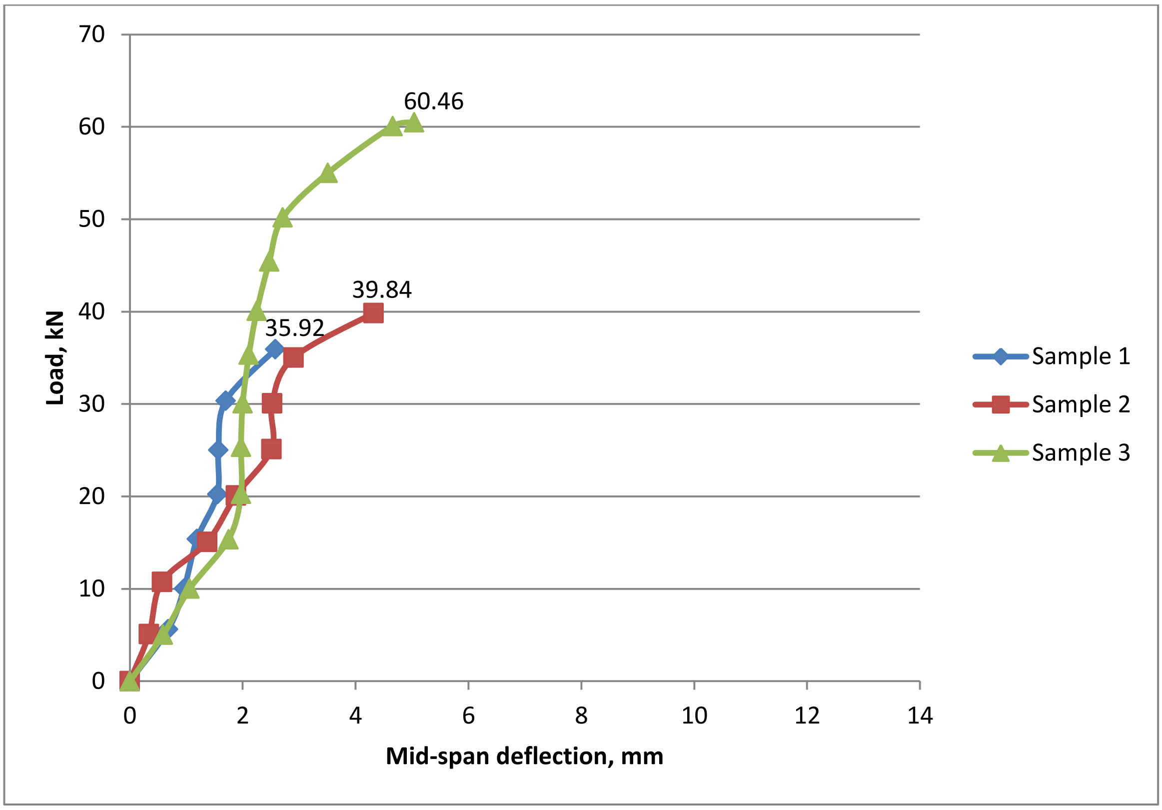
The graph patterns of the load-deflection of the specimens under flexural loading of all the mixes are shown in Figure 4.4. Figure 4.3(a) is for batch 1, Figure 4.3(b) is for batch 2 and Figure 4.3(c) is for batch 3. It can be seen from the curve of the oil palm shell concrete specimen did not exhibit any post failure characteristics. The addition of the fibres in the oil palm shell concrete significantly enhanced the post-failure strengths of the concrete after the formation of first crack. The mixes with 1% SF60 which is Batch 1 produced larger flexural toughness.

Figure 4.3(a) shows the deflection for first batch. For the maximum load for first sample is 35.92 kN with the deflection of 2.58 mm. While for the second sample is 39.84 kN with the deflection of 4.32 mm and the last sample is 60.46 kN with the deflection of 5.04 mm. From this result, it can be concluded that the bigger the load applied the bigger the deflection. Batch 1 for the third sample may have an error due to the unusual result. It is may be cause by the compaction of the concrete during pouring the concrete into the formwork. It is compacted very well compared to the other two samples.

The addition of fibres increased the deflection of oil palm shell concrete. The comparison between the specimens prepared using different types of fibres shows that SF60 produced highest deflection. This might be due to the length of the fibres. Its slower the crack propagation hence allows the specimens to deflect more.

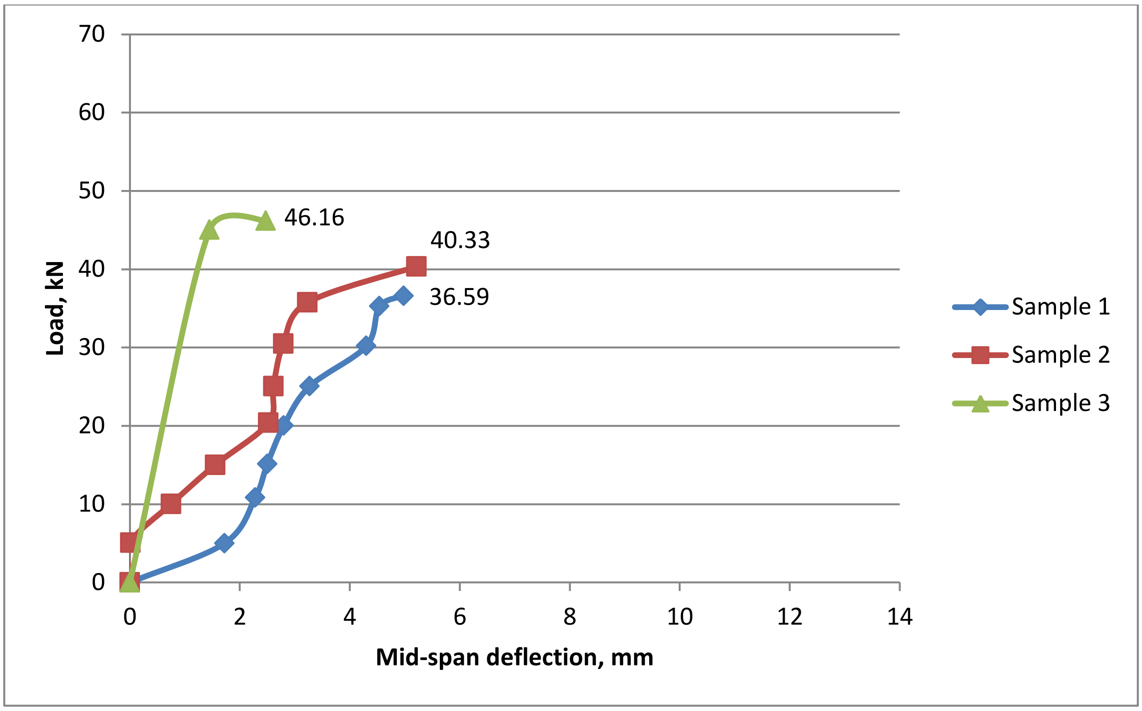
Figure 4.3(b) shows the deflection for first batch. For the maximum load for first sample is 36.59 kN with the deflection of 4.98 mm. While for the second sample is 40.33 kN with the deflection of 5.21 mm and the last sample is 46.16 kN with the deflection of 2.47 mm. From this result, it can be concluded that the bigger the load applied the bigger the deflection. This batch produce less strength compared to the batch 1 and it may be because of the type of fibre used.

While in hybrid fibre system, the stiff steel fibre improves the first crack stress and ultimate strength. Figure 4.3(c) shows the deflection for third batch. For the maximum load for first sample is 46.76 kN with the deflection of 10.76 mm. While for the second sample is 38.03 kN with the deflection of 6.33 mm and the last sample is 43.36 kN with the deflection of 6.89 mm. The observation on the effect of hybrid fibre in the first crack deflection is a proof to the above statement. The addition of high amount of steel fibres resulted in higher first crack deflection.

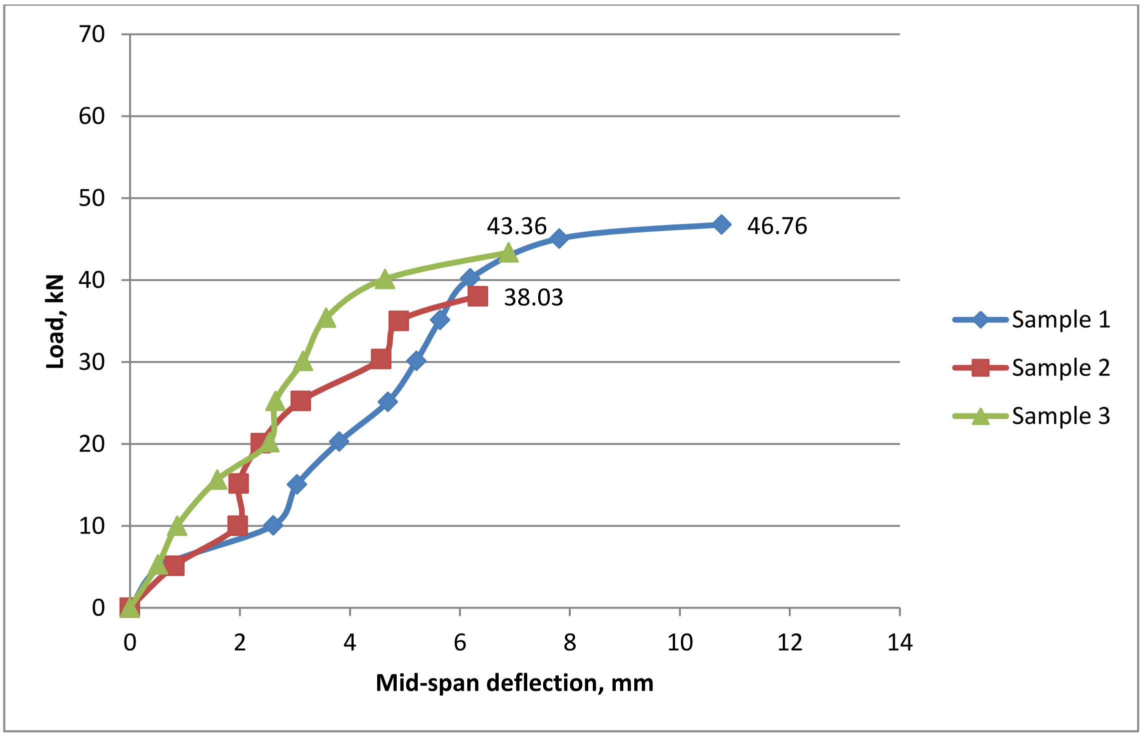


(a) Graph of load vs deflection for B1

Figure 4.3(a): Relationship between load and mid-span deflection for all batches



(b): Graph of load vs deflection (Batch 2)



(c): Graph of load vs deflection (Batch 3)

Figure 4.3: Continued

4.3.2 First Crack Load

During the experiment was conducted, the cracking was observed and marked it with marker pen. It was observed every second to find the first crack with it loading. Table 4.2 shows the value of the first crack for every sample in every batch. From the table, it can be concluded that for every sample in every batch; the first crack occur around the range of 30 kN - 35 kN. For a better understanding, the graph was plotted to show the distribution of the first crack.

For Batch 1, the first crack of first sample occurred at 30.35 kN with the deflection of 1.7 mm, second sample at 30.05 kN with the deflection of 2.52 mm and third sample is at 45.41 kN at 2.47 mm.

For Batch 2, the first crack of first sample occurred at 25.05 kN with the deflection of 3.27 mm, second sample at 30.49 kN with the deflection of 2.79 mm and third sample is at 37.68 kN at 1.47 mm.

While for the Batch 3, the first crack of first sample occurred at 35.12 kN with the deflection of 5.64 mm, second sample at 25.23 kN with the deflection of 3.11 mm and third sample is at 20.20 kN at 2.54 mm.

Table 4.2: First crack load

	First Crack (kN)		
Sample	**Batch 1**	**Batch 2**	**Batch 3**
1	30.35	25.05	35.12
2	30.05	30.49	25.23
3	45.41	37.68	20.20

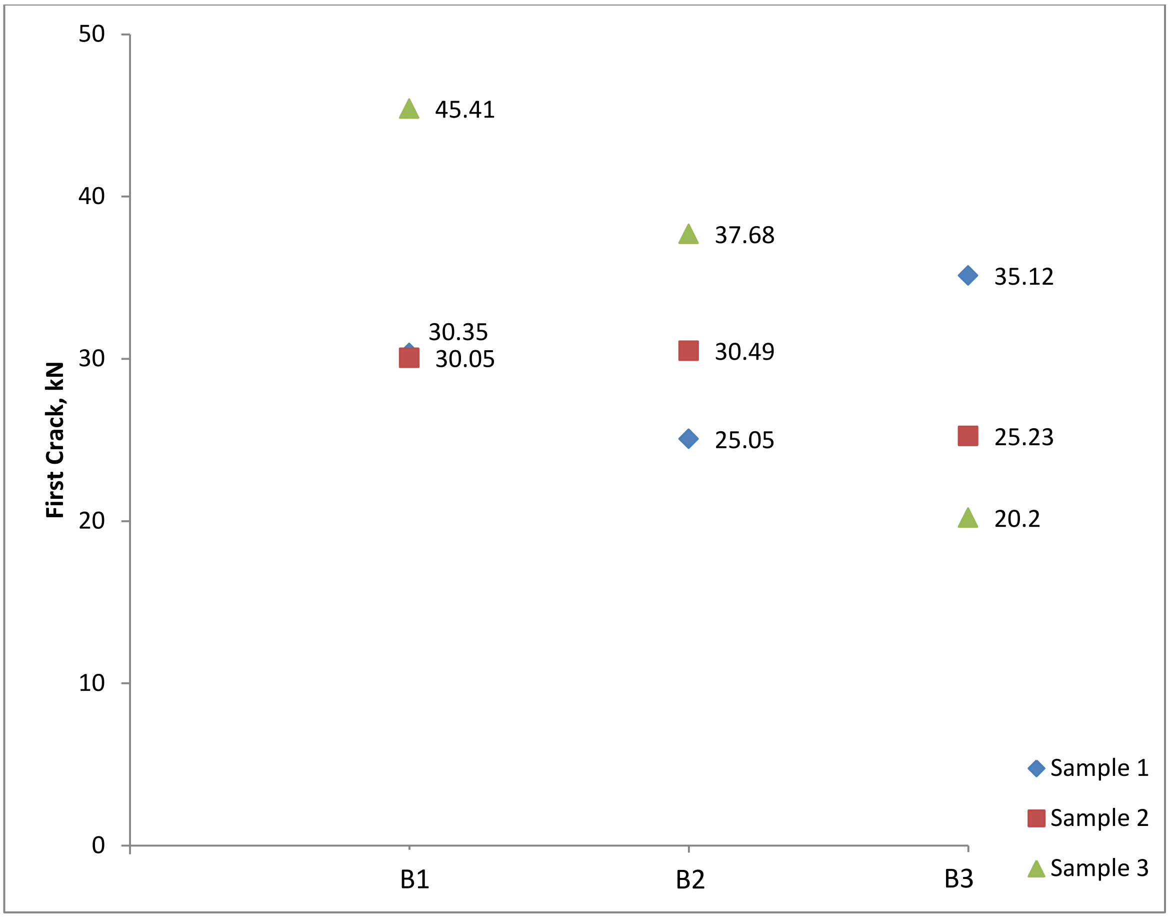


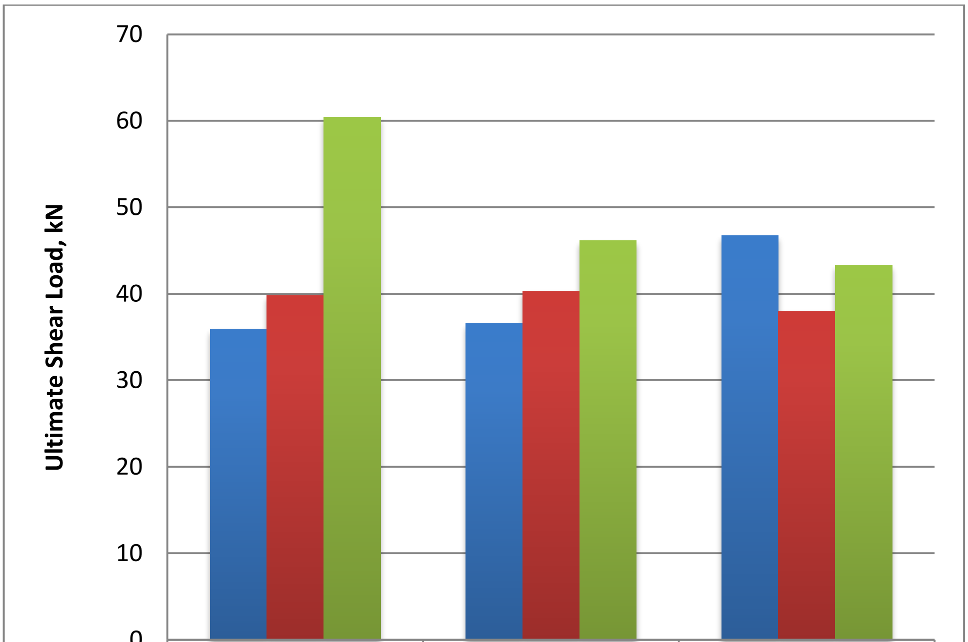
Figure 4.4: Graph of first crack

4.3.3 Ultimate Shear Load

A shear load is a force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force. When a paper is cut with scissors, the paper fails in shear. Here, the slabs were applied with the load and it fails in shear. Figure 4.5 summarize the data on the ultimate shear load of the specimens for every batch.

Sample 3 of batch 1 shows the highest ultimate load among sample in the batch. The value is 60.46 kN. 35.92 kN and 39.84 kN are the ultimate shear load for sample 1 and sample 2 respectively.

Samples in batch 2 and batch 3 shows likely data on the ultimate shear load which are 36.59 kN, 40.33 kN, 46.16 kN and 46.76 kN, 38.03 kN, 43.36 kN respectively.



	Sample 1	Sample 2	Sample 3
Batch 1	35.92	36.59	46.76
Batch 2	39.84	40.33	38.03
Batch 3	60.46	46.16	43.36

Figure 4.5: Graph of ultimate shear load

4.3.4 Failure Mode

For Batch 1, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 30.35 kN, sample 2 is 30.05 kN and sample 3 is 45.41 kN the crack started to form at the flexural region. Figure 4.6(a) shows the failure mode of the slabs for sample 1, Figure 4.6(b) for sample 2 and Figure 4.6(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.6: Failure mode B1

(c): Failure mode for sample 3

Figure 4.6: Continued

For Batch 2, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 25.05 kN, sample 2 is 30.49 kN and sample 3 is 37.68 kN the crack started to form at the flexural region. Figure 4.7(a) shows the failure mode of the slabs for sample 1, Figure 4.7(b) for sample 2 and Figure 4.7(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.7: Failure mode for B2

(c): Failure mode for sample 3

Figure 4.7: Continued

For Batch 3, the slab deflected during the early loading increment but without any sign any sign of visible crack. Upon reaching the first crack load for sample 1 is 35.12 kN, sample 2 is 25.23 kN and sample 3 is 20.20 kN the crack started to form at the flexural region. Figure 4.8(a) shows the failure mode of the slabs for sample 1, Figure 4.8(b) for sample 2 and Figure 4.8(c) for sample 3.

(a): Failure mode for sample 1

(b): Failure mode for sample 2

Figure 4.8: Failure mode for B3

(c): Failure mode for sample 1

Figure 4.8: Continued

Based on the picture of the failure mode for all specimens for every batch, it can be concluded that all of them fail at the flexural region. It can be observed that the cracking is in shear mode.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter presented the conclusion that was made based on the experiment and data analysis that have be done in the research. Several recommendations also being discussed in this chapter to improve the outcomes and results for this research study.

5.1 CONCLUSION

Based on the experimental result and analysis obtained, the objectives of this research study that have been stated in the early of this research have been achieved. From the results obtained in this research, the following conclusion can be drawn.

1. The structural behaviour of OPSC slab was improved with the usage of long steel fibre with lower aspect ratio which resulted in larger increase of ultimate shear strength. Of all of the tested fibres, the SF60 showed the best performance in strength.
2. The effect of fibre hybridization to the behaviour of OPSC slab shown none improvement to the structural performance of the slabs.

5.2 RECOMMENDATION

Based on the personal experience in conducting research and experimental results that has been performed, there are several recommendations suggested. Several modifications should be made to the standard experimental procedures with respect to the scope of the study. This study can help for a better understanding of oil palm shell concrete in construction industry. The testing should be conducted in different time of curing for every sample to provide broader understanding of the compressive strength behaviour. Besides that, the oil palm shell should be dry longer and the fibre on the oil palm shell should be removed to get a better result on the strength of the concrete.

REFERENCES

Che Muda, Z., Salah, F.A.S., Lun Y.T. 2012. Impact behaviour enhancement of oil palm shells concrete slab by geogrid reinforcement. *International Journal of Scientific & Engineering Research, Volume 3, Issue 11, November 2012.*

Jumaat, M.Z., Mo, K.H., Alengaram, U.J. 2014. Flexural toughness characteristics of steel-polypropylene hybrid fibre-reinforced oil palm shell concrete. *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Jumaat, M.Z., Mo, K.H., Yap, K.K.Q., Alengaram, U.J. 2014. The effect of steel fibre on the enhancement of flexural and compressive toughness and fracture characteristics of oil palm shell concrete.

Kobayashi, K., and Cho, R. 1981. Flexural behaviour of polyethylene fibre reinforced concrete. *The International Journal of Cement Composites and Lightweight Concrete, Volume3, Number 1*

Shafigh P, Ghafari, H., Mahmud, H., Jumaat, M.Z. 2011. Effect of steel fibre on the mechanical properties of oil palm shell lightweight concrete. *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Sachan, A.K. and Kameswara Rao, C.V.S. 1990. Behaviour of fibre reinforced concrete deep beams. *Journal Cement & Concrete Composites 12 (1990) 211-218*

Soutsos, M.N., Le, T.T., Lampropoulos, A.P. 2012. Flexural performance of fibre reinforced concrete made with steel and synthetic fibres.

Sivaraja, M., Kandasamy, Velmani, N., and Pillai, M.S. 2009. Study on durability of natural fibre concrete composites using mechanical strength and microstructural properties. *Bull. Mater. Sci., Vol. 33, No. 6, December 2010, pp. 719-729. Indian Academy of Sciences.*

Shafigh, P., Ghafari, H., Mahmud, H., Jumaat, M.Z. 2014. A comparison study of the mechanical properties and drying shrinkage of oil palm shell and expanded clay lightweight aggregates concretes. . *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Testing Fresh Concrete, Slump.test. 2009. BS EN 12350-2:2009. British Standard Institute.

Testing Hardened Concrete, Compressive Strength of Test Specimens. 2009. BS EN 12390-3:2009. British Standard Institute.

Teo, D.C.L., Mannan, M.A., Kurian, V.J., Ganapathy, C. 2006. Lightweight concrete made from oil palm shell: structural bond and durability properties. *Civil Engineering Program, School of Engineering and Information Technology, University Malaysia Sabah*

Vairagrade, V.S. and Kene K.S. 2013. Strength of normal concrete using metallic and synthetic fibres.

Vajje, S., Krishnamurty, N.R. 2013. Study on addition of the natural fibres into concrete. *International Journal of Scientific & Technology Research Volume , Issue 11, November 2013*

REFERENCES

Che Muda, Z., Salah, F.A.S., Lun Y.T. 2012. Impact behaviour enhancement of oil palm shells concrete slab by geogrid reinforcement. *International Journal of Scientific & Engineering Research*, *Volume 3*, *Issue 11*, *November 2012.*

Jumaat, M.Z., Mo, K.H., Alengaram, U.J. 2014. Flexural toughness characteristics of steel-polypropylene hybrid fibre-reinforced oil palm shell concrete. *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Jumaat, M.Z., Mo, K.H., Yap, K.K.Q., Alengaram, U.J. 2014. The effect of steel fibre on the enhancement of flexural and compressive toughness and fracture characteristics of oil palm shell concrete.

Kobayashi, K., and Cho, R. 1981. Flexural behaviour of polyethylene fibre reinforced concrete. *The International Journal of Cement Composites and Lightweight Concrete, Volume3, Number 1*

Shafigh P, Ghafari, H., Mahmud, H., Jumaat, M.Z. 2011. Effect of steel fibre on the mechanical properties of oil palm shell lightweight concrete. *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Sachan, A.K. and Kameswara Rao, C.V.S. 1990. Behaviour of fibre reinforced concrete deep beams. *Journal Cement & Concrete Composites 12 (1990) 211-218*

Soutsos, M.N., Le, T.T., Lampropoulos, A.P. 2012. Flexural performance of fibre reinforced concrete made with steel and synthetic fibres.

Sivaraja, M., Kandasamy, Velmani, N., and Pillai, M.S. 2009. Study on durability of natural fibre concrete composites using mechanical strength and microstructural properties. *Bull. Mater. Sci., Vol. 33, No. 6, December 2010, pp. 719-729. Indian Academy of Sciences.*

Shafigh, P., Ghafari, H., Mahmud, H., Jumaat, M.Z. 2014. A comparison study of the mechanical properties and drying shrinkage of oil palm shell and expanded clay lightweight aggregates concretes. . *Department of Civil Engineering, Faculty of Engineering, University of Malaya*

Testing Fresh Concrete, Slump.test. 2009. BS EN 12350-2:2009. British Standard Institute.

Testing Hardened Concrete, Compressive Strength of Test Specimens. 2009. BS EN 12390-3:2009. British Standard Institute.

Teo, D.C.L., Mannan, M.A., Kurian, V.J., Ganapathy, C. 2006. Lightweight concrete made from oil palm shell: structural bond and durability properties. *Civil Engineering Program, School of Engineering and Information Technology, University Malaysia Sabah*

Vairagrade, V.S. and Kene K.S. 2013. Strength of normal concrete using metallic and synthetic fibres.

Vajje, S., Krishnamurty, N.R. 2013. Study on addition of the natural fibres into concrete. *International Journal of Scientific & Technology Research Volume , Issue 11, November 2013*