BEHAVIOUR OF OIL PALM SHELL REINFORCED CONCRETE BEAM PARTLY REPLACED BY PALM OIL FUEL ASH

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Thesis submitted in fulfilment of the requirements for the award of the

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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering in Civil Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis 'Behaviour of Oil Palm Shell Reinforced Concrete Beam Partly Replaced By Palm Oil Fuel Ash' 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.

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ABSTRACT

In Malaysia, issue of natural contamination coming about because of transfer of Palm Oil Fuel Ash (POFA) which is a by-item from palm oil mill has started exploration to consolidate this waste in Oil Palm Shell (OPS) lightweight concrete structural. The current investigates the behaviour of oil palm shell reinforced concrete beam partly replaced by palm oil fuel ash. All mixes were casted in total of 4 reinforced concrete beam and 24 cubes with OPS RC mixes were producing by replaced 20% of POFA on cement, sand and aggregates were fabricated and tested. The flexural test and compressive test is conducted in accordance to BS EN 12390 – 3 and BS EN 12390 – 5 at the age of 7 and 28 days. The Data presented include the load – deflection curves, ductility, compressive strength and cracking pattern. From the result, it was observed that mixes with replaced POFA on cement would enhance the strength of concrete and from the flexural test shows that with replacement on cement, the ductility of beam is better than others replacement.

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LIST OF SYMBOLS

kg/m3	Kilogram per cubic metre
mm	Millimetre
MPa	Megapascal
%	Percent
μm	Micrometre
°C	Degree Celsius
fc	Compressive strength
P	Maximum load applied to the specimen
N	Newton
kN	Kilo Newton
Ac	Cross sectional area of the specimen
mm2	Square milimetre
s	Second
Ø	Diameter
N/mm2	Newton per square millimeter

LIST OF ABBREVIATIONS

MPOB	Malaysian Palm Oil Board
USA	United States of America
ACI	American Concrete Institute
LWAC	Lightweight aggregate concrete
ASTM	American Society for Testing and Materials
RCB	Reinforced Concrete Beam
NRMCA	National Ready Mix Concrete Association
OPS	Oil palm shell
POFA	Palm oil fuel ash
MS	Malaysia Standard
BS-EN	British Standard
OPC	Ordinary Portland Cement
SSD	Saturated Surface Dry
POME	Palm Oil Mill Effluent
RM	Ringgit Malaysia
EFB	Empty Fruit Bunch
OPF	Oil Palm Fibre

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

Oil palm product was the biggest industry in Malaysia. Malaysia currently reported a 39% of world palm oil production and 44% of world exports. For oils & fats, Malaysia has recorded to produced locally 12% and 27% of the world total production and export of oil and fats was reported by Malaysia Palm Oil Board (MPOB). Thus, making Malaysia one of the biggest producer and exporter of palm oil and palm oil product. However, the presence of these palm oil waster has created a major disposal problem. According to Economic & Industry deparment MPOB, (2014), in 2014 Malaysia had produced 19.9 million tonnes of palm oil based on 5.39 million hectares of land used for its plantation. Despite the obvious benefits, oil palm mill also significantly contributed to environmental degradation, both at the input and the output activities. On the output , manufacturing process generated large quantities of solid waste, wastewater and air pollution. Thus it is expected that million of waste tons of palm oil waste will be produced annually due to its productivity.

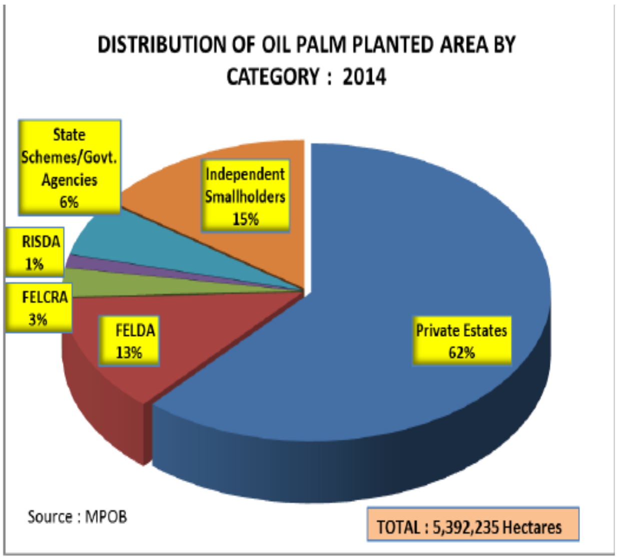


Figure 1 : Distribution of oil palm planted area in 2014.

(Source : MPOB, 2014)

Environmental issue has gained great attention in discussion among our society in recent years, the decision made in political, economic and social sectors are now seriously offering more attention to the environmental issues. With the increase in the development projects in Malaysia, the demand for the supply towards material such as cement and the aggregate iherently increases. This phenomenon inturn caused more natural resources to be extrected in order to produce such construction materials. Continuos proliferation in deforestation may lead to depletion of natural aggregate as well as ecological imbalance. There are some alternatives to reduce the usage of natural aggegate and created environmental friendly reinforced concrete beam. The present study to find out the behaviour of OPS and POFA in reinforced concrete beam from oil palm industry which is a waste in the production of concrete material.

1.2 PROBLEM STATEMENT

Concrete is among the most widely utilized material for building and construction material around the world. Nowadays, lightweight aggregate concrete has gain the development industry interest simply because of the benefits offered from this lightweight concrete in terms of decrease in member size, longer spans, improved fire resistance, smaller foundations and better thermal properties. However, producing this particular concrete requires usage of sand, cement and oil palm shell in higher amount compared to normal concrete. Success in reducing the amount of cement by replacing other waste material as partial cement replacement would produce a bit more environmental friendly construction material.

Oil palm product was the biggest production in Malaysia and it contribute to a major environment pollution. The types of waste from palm oil mill were, Empty Fruit Bunch (EFB), Oil Palm Shell (OPS), Oil Palm Fibre (OPF) and Palm Oil Fuel Ash (POFA). EFB can be used to generate energy and been banned in Malaysia because the process to produce energy can cause air pollution reported by N.Abdullah and F. Sulaiman (2013). After combustion for the production steam for palm oil mill the ash will be carried away by wind because the physical properties of ash is small particle and light. This situation will created a health hazard to local community which was lung disease. According to M.H Ahmad (2008), the demand for oil palm product increased every year and the goverment of Malaysia, required the addition of landfill area to place waste from industrial and it cost a lot of money to spend on transporting the waste. For the coarse aggregate, due to higher demand in development for building the cost for coarse aggregate and cement became more expensive due to limitation of natural resources and the natural resources will decrease and depleted.

By using POFA and OPS from palm oil mill as a partial cement, coarse aggregate and sand replacement into concrete mix design was already carried out by the other researcher and found by using POFA and OPS can solved the problem. In this experiment, it is to determine the behaviour of OPS reinforced concrete beam partly replaced by POFA because this experiment have not been conducted by the other researcher.

1.3 OBJECTIVE

The objective of this experiment are:

I. To study potential of POFA as partially sand, cement, or aggregate replacement in OPS reinforced concrete beam.
II. To study the structural behaviour of OPS reinforced concrete beam when the material such as sand, cement and OPS is partially replaced with POFA.

1.4 SCOPE OF STUDY

1. The scope of the experiment was covered the application of the POFA as a partial replacement in material.
2. This experiment was carried out to determine the performance of OPS reinforced concrete beam with three type of mix design for reinforced concrete beam partial sand, cement and OPS with 20% replacement with POFA and 0% of POFA as a control design.
3. This experiment was focusing on structural behaviour on compressive strength, flexural strength, workability, cracking pattern and also mode of failure of OPS reinforced concrete beam partly replace by POFA.

4. Workability testing was conducted according to BS EN 12390 – 2 for every mix design.
5. According to BS EN 12390 – 3, the compressive strength test will be conducted at the age 7 and 28 days of curing specimen.
6. For flexural test was conducted according to BS EN 12390 – 5 with 150 mm x 200 mm x 1500 mm.
7. Cracking pattern and mode of failure was observed during the test.

1.5 SIGNIFICANT OF STUDY

Findings out of this research would provide informative data on the potency of palm oil fuel ash (POFA) content as partial sand, cement and oil palm shell replacement towards the compressive strength performance and flexural strength performance of oil palm shell reinforced concrete beam (OPS RCB). The end result with this study would provide additional information on the strength performance of oil palm shell reinforced concrete beam containing POFA subjected to different type of replacement on materials. The success in integrating POFA to create oil palm shell reinforced concrete beam would reduce materials consumption by the industry and contribute towards minimising the disposal of those by-products. This effort would consequently ensures the sustainability of the palm oil industry.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Conventional concrete were widely used in Malaysia for construction because the conventional concrete have a great strength. It have been used in many diffrent structure to produce a hight strength structure such as dam, pavement, building or bridge.Normal mixing material for the conventional concrete were made from cement, sand, water, superplasticizer and gravel as coarse aggregate. Concrete have a great compressive strength not effect on corrosive. By using concrete can be easily handle and cast into any desired shape. The dry density for the conventional concrete have higher self-weight due to aggregates up to 2240 kg/m3 - 2400 kg/m3 stated by National Ready Mixed Concrete Association (NRMCA).

The common and popularity used of concrete as a construction material came out from its advantages than other construction material and availability. Durability of concrete it does not easily lose its quality as does steel and timber, which corrodes, decays with satisfactorily high compressive strength and has fairly high fire resistance as compared to that steel and timber. The effective use of such low-density concrete significantly cuts down on thesize orcross a part of a structural element (Neville, 2005). The application of this concrete contributes towards the decrease in dead load of building that in return reduces the dimensions of the foundation that translates into lower cost. Furthermore, the application of such lightweight concrete in construction the simplicity of handling for any workers at site, hence the project easier and faster when compared toordinary concrete. This has been used effectively in filling voids, wall partitions, panels, sound and much more applications. Lightweight concrete is regarded as an innovative technology that meets the specified requirement of the construction industry.

2.2 LIGHTWEIGHT REINFORCED CONCRETE

Lightweight concrete in construction industry has become popular in the few decades. NRMCA stated, the structural lightweight has density between 1440 kg/m^3 – 1840 kg/m^3 compared to normal weight concrete with a density 2240 kg/m^3 - 2400 kg/m^3 and Abdullah K. and Zamri N.A (2014) stated, the density of ligtweight concrete is in range of 300 kg/m3 until 1850 kg/m^3. For the structural application the strength should be greater than 17.0 MPa. To produce lightweight product the mixture was made from low density for coarse aggregate. The main purpose used of lightweight of structural was to minimize the selfweight load which was dead load of a concrete structure. For the structural lightweight can be designed with material replacement can be designed to produce similar strength or higher than normal weight concrete. By reducing reinforcement steel and volume of concrete can result in the lower overall cost in construction. The porosity of lightweight aggregates, for example, oil palm shell can gives a wellspring of water to inside curing of the concrete that gave proceeded with improvement of concrete durability and quality. In basic component the lightweight cement has been utilized for bridge deck,wall element, beams, and concrete frame building and some more. The reinforced lightweight concrete beam can be manufactured with lightweight material such as oil palm shell as a replacement for coarse aggregate and palm oil fuel ash as a replacement for fine aggregate, binder or also replacement for coarse aggregates. According to Teo D.C.L et al., (2006), by using waste product such as OPS in concrete production solved the environmental pollution problem and also help conserved natural resources.OPS was one of the waste product from palm oil mill that can use as a coarse aggregate in concrete production. Futhermore, Abdullah K. and Zamri N.A. (2014), by using OPS can produce as lightweight aggregate because OPS has a low density and can reduce the cost of concrete production.

2.3 MATERIALS

2.3.1 PROPERTIES OF PALM OIL FUEL ASH (POFA)

Pozzolans was characterized as a siliceous or siliceous and aluminious material that has next to zero cementitious worth. In finely partitioned structure and within the sight of dampness, it will chemical responded with calcium hydroxide (lime) at ordinary temperatures to form mixes having cementitious properties (ACI, 2010). POFA is a waste shows up as ash originated from palm oil mill waste. As indicated by Abdul Awal (1998), POFA has great pozzolanic properties that encouraged the substitution of bond in concrete and mortar. The POFA silicious property about more than 50 % content made it possibly to be used as bond substitution material in the solid development, stated by Karim et al., (2011). Awal and Hussin (1997) affirms that POFA fulfilled the necessities as pozzolanic material and grouped POFA in the middle of Class C and Class F as indicated by ASTM C618-94a (1995). Different analysts Abdullah et al., (2008), grouped it as a Class F in agreement to ASTM C618-94a (1995). The distinction in the grouping of POFA was because of the variety in the chemical composition of POFA coming about because of burning temperature and material source that was most certainly not same starting with one production line then onto the next. The chemical composition of POFA were given in Table 2.1

Table 2.1: Chemical composition of POFA
(Source : Abdullah K. and Zamri N.A. (2014))

Chemical composition	**Percentage (%)**
Silicon dioxide (SiO_2)	51.55
Sulphur oxide (SO_3)	0.61
Lost of ignition (LOI)	5
Sodium oxide (Na_2O)	0.07
Pottasium oxide (K_2O)	5.5
Aluminium oxide (AL_2O_3)	4.64
Ferric oxide (Fe_2O_3)	8.64
Calcium oxide (CaO)	5.91
Magnesium oxide(MgO)	2.44
BET surface area (m^2/g)	2.54

2.3.2 UTILISATION OF PALM OIL FUEL ASH (POFA) IN CONCRETE

According to the Abdullah K. And Zamri N.A., (2014), and Tangchirapat et. al., (2007), replacement of POFA in cement content which was around 20% would be able to produce lightweight concrete thats suitable for structural application and at 20% of replacement give highest compressive strength. However, Awal & Hussin, (2011), studied that POFA concrete gained highest strength at 30% of the replacement level was replaced in particular design mixed as showm in Figure 2. For corrosion resistance properties of steel in concrete is improved when replacement POFA at 20% stated by Sulaiman, (2014) and POFA being a pozzolanic material has been used as a partial cement substitute to produce various types of concrete by Abdul Awal, (1999).

In Ahmad M.H (2008) studied, with the optimum amount of POFA achieved higher strength with full hydration process and also give extra interlocking bond between the material to give more stronger in concrete strength that can achieve strength at 48 Mpa in 90 days. The chemical analysis shows that POFA was a good pozzolanic material and fullfilled the standard ASTM C618-94a. Awal and Hussin, (1997), classified POFA was in grouped between class C and class F and POFA have much silica content than the OPC.

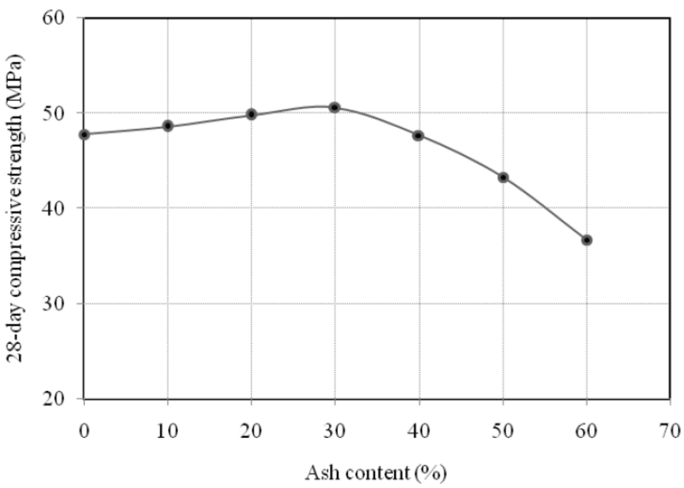


Figure 2 : Effect of ash content on compressive strength of concrete

(Source: Awal & Hussin, 2011)

According to Tangchirapat, (2012) who has studied the use of POFA to improve strength, sulfate resistance and water permeability of concrete containing high amount of recycled concrete aggregates. Sooraj V.M (2013) reviewed that the compressive strength of mixes with POFA at 7 and 28 day have the higher strength at 29.41 N/mm^2 and 35.63 N/mm^2 at 20% cement replacement. According to Abdullah K. And Zamri N.A., (2014) with 20% replacement of POFA able to produce lightweight concrete suitable for structural application. The fineness of POFA have discussed by M. Warid Hussin (2009), the ground POFA with high fineness of 10 µm can produce high strength durable concrete than 45 µm and the compressive strength for 10 µm at 28 days is 58.65 Mpa higher than 45 µm is 54.80 Mpa.

Based on, Fadzil (2015) by utilized POFA as a partial sand replacement there was hydration process and no reduction in the amount cement would took place in circulated air through in plain cement created same quality advancement and by utilizing POFA as an incompleted substitution figure out how to decrease voids in cement.. Deo S.V. and Pofale A. D. (2015) reported, in term of compressive strength reveals with 12% - 27% replacement of sand with POFA was higher than normal concrete and reduction of voids due to finer fly ash. In R. Siddique (2002) studied, fly ash or POFA are very convienient used in structural concrete because in with sand replacement the compressive strength, splitting tensile strength, flexural strength and modulus of elasticity were higher than normal concrete.

2.3.3 THE PROPERTIES OF OIL PALM SHELL

Oil palm shell was acquired after palm oil natural product experienced a few phases of procedure to deliver oil in the factory, specifically cleansing, threshing, pressing, depericarping and cracking. The types of oil palm tree as often as possible found in Malaysia were tenere, oleifera, psifera and dura. The shell includes roughly 10% to 50% of the aggregate piece of the oil palm fruitlets. The oil palm shell shading range from dull chestnut to dark. Oil palm shell was by and large made out of various shapes, for example, generally explanatory or semi-circular, parabolic, flaky and other irregular shape was stated by Teo D.C.L et al.,(2006b). Oil palm shell has diverse shapes relying upon the breaking example of nut and by hardware. The surfaces of the shells were generally smooth for both inward and raised appearances.

According to Okpala, (1990) and Basri et al., (1999), oil palm shell was 60% lighter than crushed granite, however it was still in the range of most common lightweight aggregates. As compared to conventional gravel aggregate, the higher of porosity of shell it will cause it to possess higher water absorption. This likewise brought on oil palm shell demonstrates a lower gedree of bulk density than the the value of granite stone. Muntohar and Rahman, 2014 stated in any case, the shell was hard and does not effectively endure weakening. Oil palm shell additionally has great absorbance to stun as the total effect quality is much lower contrasted with routine totals. Table 2.1 and 2.2 demonstrated the chemical composition and the characteristic of oil palm shell.

2.3.4 UTILISATION OF OIL PALM SHELL IN CONCRETE

Oil palm shell (OPS) which was a form of agriculture solid waste from oil palm mill industries and malaysia was the largest provided amount of oil palm in every years. According to Teo D.C.L et al., (2005), OPS as used as a coarse aggregate replacement in lightweight concrete abled to produce concrete with compressive strength of more than 25 Mpa. As followed ASTM C330-89, at 28 days the compressive strength of OPS concrete were between 20 to 24Mpa and it satisfied the requirement for sturctural lightweight concrete. From Daneshmand (2011) studied, shows that the normal concrete attained the maximum high strength than OPS aggregate replacement but according to (Portland Cement Association Standard) with 10% OPS also can produce hight strength concrete with compressive strength reach 52.2 N/mm^2 . That was natural because OPS was an organic material and happen to be lighter and less strong than coarse aggregates. In Mannan M.A. and Ganapathy.G (2001) studied, the flexural strength of OPS concrete were between 2.75 MPa and 4.00 Mpa and it was approximately 14% - 17% of its compressive strength anf for norlmal concrete ,the flexural strength was usually approximately 15% of compressive strength.

The comparison between OPS aggregates and conventional granite aggregate properties as shown in Table 2.2. Al-khaiat and haque (1998) reported that structural lightweight concrete with high water absorption were less sensitive to poor curing as compared to normal concrete especially in early age due to the internal water supply from OPS.

Table 2.2 : Comparison properties of aggregates OPS and Granite
(Source : Teo D.C.L et al.,2006)

Properties	OPS aggregates	Granite aggregates
Maximum aggregate size, mm	12.5	12.5
Shell thickness, mm	0.5 - 3.0	-
Bulk density, kg/m^3	590	1490
Specific gravity	1.17	2.59
Fineness modulus	6.08	6.66
Los angeles abrasion value %	4.9	20.3
Aggregate impact value (AIV) %	7.51	13.95
Aggregate crushing value (ACV) %	8	19
24-hour water absorption. %	33	0.67

2.3.5 ORDINARY PORTLAND CEMENT

Ordinary portland cement (OPC) was the world most used binder for construction materials. Because of its great mechanical properties, durability, low cost and accessibility of the crude materials yet creation of OPC has a few real downsides in exhaustion of regular living space and fossil powers promotion high discharge of CO2 and other greenhouse gas (A.R Sakulich). The need for environmental friendly construction were important and alternative cementitious binder comprising alkali-activated palm oil fuel ash could be considered as a substitue for OPC.

With specification requirements of ASTM C 150-05 (2005) for type I, II, III, IV and V. In general normal concrete, type I was suitable to use in conctruction. Portland cement can be characterized by thier chemical composition although they rarely are for pavement apllication. When orinari portland cement mixed with water its chemical compound constituents undergone a series of chemical reaction that caused the concrete started to harden.this reaction with water is called hydration and with these reaction determined how ordinary protland cement hardens and gain strength.

2.4 SUMMARY

The palm oil industry in Malaysia generates a huge quantity of wastes including palm oil fuel ash and oil palm shell. The clear presence of these oil palm wastes has created an important disposal problem aside from contributing towards environmental pollution. Previous studies show that OPS has been used as a lightweight aggregate for producing structural lightweight aggregate concrete. To cut back the utilization of cement, several researches have already been performed on the utilization of ground granulated blast furnace ash and fly ash as partial cement replacement. However, research integrating palm oil fuel ash as partial sand, cement and oil palm shell replacement in oil palm shell reinforced concrete beam remains unexplored, and there is no publication neither on the mechanical properties nor cracking and mode of failure performance readily available for this research. Therefore within this research, the performance of palm oil fuel ash as partial sand, cement and oil palm shell replacement in oil palm shell reinforced concrete beam towards mechanical were investigated. The mechanical testing involved are slump test, compressive strength and flexural strength.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This experiment applied on the samples, methods and the type of testing applied. For the first explaination was on the details of mixing material used for the sample preparation. To produce OPS reinforced concrete beam, the explaination on trial mix method that been used will be further explained after mixing material. Secondly, the steps to produce OPS reinforced concrete beam will be explained and followed by the types of test conducted throughtout the experiment to determine the behaviour of the OPS reinforced concrete beam include compressive strength, workability, flexural strength and modulus of elasticity. The entire experiment is broken down as in the flowchart in figure 3.1.

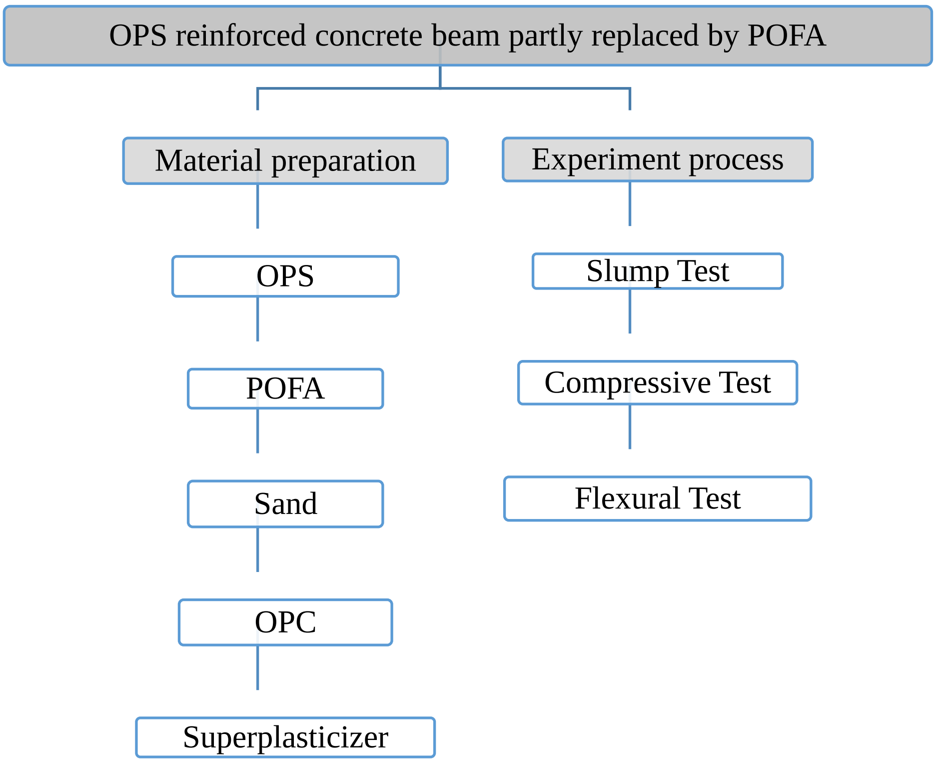


Figure 3.1 : Flowchart for entire experiment.

3.2 PREPARATION OF MATERIALS

3.2.1 OIL PALM SHELL

In this experiment, oil palm shell (OPS) showed in figure 3.2 was used as lightweight coarse aggregate. The OPS were collected from palm oil mill are located in the state of pahang. Before using it in concrete, pre-treatment is necessary for OPS aggregate because its contains dust and oil coating. According to K. Muthusamy, Z. Nur Azzimah (2015) and A.S.M.A Awal & M.W Hussin (1999), the OPS were sieved using 10 mm sieve and then washed to remove dust and oil coating. OPS were air dried until it turn into saturated surface dry (SSD) condition. After the drying process, the OPS were crushed using jaw crusher in order to obtain smaller size. The crushed OPS were sieved with 5 mm sieve to remove smaller size. Only OPS aggregates retained in 5 mm sieved were used as coarse aggregate.the physical properties of the OPS as shown in table 3.1. The process of OPS aggregate preparationis shown in form of flowchart as in figure 3.3.

Figure 3.2 : Oil palm shell (OPS).
(Source : Abdullah K. And Zamri N.A, 2014)

Table 3.1 : OPS Physical properties.

(Source : Abdullah K. And Zamri N.A, 2014)

Physical Properties	Crushed OPS
Specific gravity	2.3
Fineness modulus	5.80
Bulk density (compacted) (kg/m3)	596
Water absorption (24 hour)	22.22
Moisture content	13.83

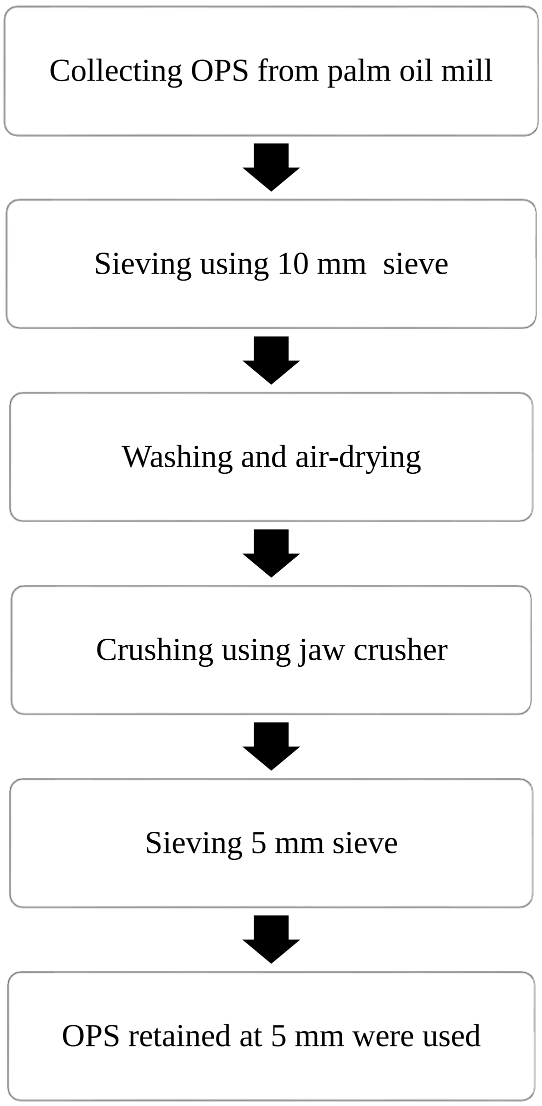


Figure 3.3 : Preparation of OPS aggregate

(Source : Abdullah K. And Zamri N.A, 2015)

3.2.2 PALM OIL FUEL ASH (POFA)

Palm oil ash (POFA) as hown in Figure 3.4 was also collected from palm oil mill at kilang sawit Sungai Jernih loacated in the state of Pahang. According to Abdullah K. And Zamri N.A , (2014) the collected POFA through a few process as shown in flowchart Figure 3.5. the collected POFA were dried in the oven for 24 hours with temperature of 110 ± 5 ^{o}C to remove moisture in ash. After 24 hours dried in the oven, POFA was sieved through 300 µm sieved to remove the larger particle of POFA. Then, POFA was ground 30 000 cycles to obtain finer ash complying with ASTM C618 – 05 (2005) enable to be used as partial cement replacement.

In this study and accordance to ASTM C618 – 05 (2005) th maximum amount of pozzolanic material can be obtained when grinding and sieved wet on 45 µm sieve is 70 % ash pass through by 4 kg of ash. 60 % were retained on 45 µm sieve when the wet sieve test was conducted on unprocessed POFA. In table 3.2 , the chemical composition of POFA which is grouped as class C in accordance to ASTM C618 – 05 (2005).

Figure 3.4 : POFA

(Source : Abdullah K. And Zamri N.A, 2014)

Table 3.2 : Chemical composition of POFA.

(Source : Abdullah K. And Zamri N.A, 2014)

Chemical composition	Percentage (%)
Silicon dioxide (SiO_2)	51.55
Aluminium oxide (AL_2O_3)	4.64
Frerric oxide (Fe_2O_3)	8.64
Calcium oxide (CaO)	5.91
Magnesium oxide (MgO)	2.44
Sodium oxide (Na_2O)	0.07
Pottasium oxide (K_2O)	5.50
Sulphur oxide (SO_3)	0.61
Lost of ignition (LOI)	5.00
BET surface area (m^2/g)	2.54

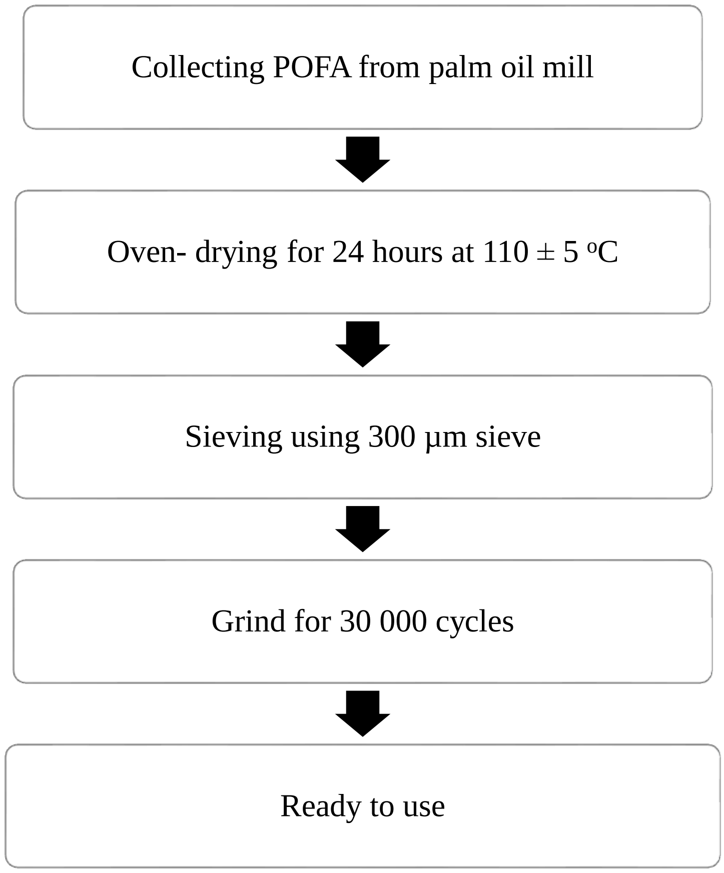


Figure 3.5 : Preparation process of POFA

(Source : K. MuthusamyZ. Nur Azzimah, 2015)

3.2.3 SAND

In this experiment the river sand in Figure 3.6 was used**.** The physical properties of river sand such as water absorption, specific gravity and fineness modulus is 0.95 %, 2.6 and 2.56 respectively. Fine aggregate were oven dried at the temperature of 110 ^{o}C for 24 hours and stored in container to prevent it getting wet due to excesive moisture condition or rain.

Figure 3.6 : River sand.

3.2.4 ORDINARY PORTLAND CEMENT

As in ASTM C150 – 92 (1992), Ordinary portland cement with type 1 was used in this experiment. The chemical composition OPC is shown in table 3.3. this type of cement is suitable for structural used, brick, precast and all general purpose. The cement need to stored away from the damp floor and stacked together to avoid chemical reaction.

Table 3.3 : The chemical composition for OPC (Source : M.W Hussin, 2009)

Chemical composition	Percentage (%)
Silicon dioxide (SiO_2)	28.2
Aluminium oxide (AL_2O_3)	4.9
Frerric oxide (Fe_2O_3)	2.5
Calcium oxide (CaO)	50.4
Magnesium oxide (MgO)	3.1
Sodium oxide (Na_2O)	0.2
Pottasium oxide (K_2O)	0.4
Sulphur oxide (SO_3)	2.3
Lost of ignition (LOI)	< 0.9
BET surface area (m^2/g)	2.4

3.2.5 SUPERPLASTICIZER

The superplasticizer used throughout in this experiment is SIKA Visco® - 2199. This superplacticizer was purchased at Kimia Sdn Bhd, Negeri Sembilan. For this type of superplasticizer, it meets the requirement in ASTM C494 – 05 (2005) for type A water – reducing admixture.

3.2.6 WATER

In this experiment, clean supplied tap water is free from impurities was used for mixing and curing purposes. The existance of impurities in water will affect the quality and strength of concrete.

3.4 EXPERIMENTAL PROGRAM

The mechanical properties of the samples namely compressive strength and flexural strength were investigated using cubes (150 mm x 150 mm x 150 mm) and reinforced concrete beam (150 mm x 200 mm x 1500 mm) respectively. All the samples were subjected to types of curing namely continuous water curing and spray curing. To produce OPS reinfored concrete beam, several common step are followed fot this experiment work. Firstly, make sure all the apparatus and equipment was clean and free from debris also for the mold for beam and cube should be clean and oiled. Secondly, prepared and calculate all the amount of OPS, POFA, cement, superplasticizer, and water accurately. Next, when all material is already prepared, the material were added into concrete mixer and start mixing all the material to produce concrete. Finally, once the mixing concrete is ready and taken out and filled in the mould of beam and cube. The pouring stage should make be in 3 stages and every stage with 25 – 30 blows for compaction or the mold is placed on vibrating table for compaction process. After the compaction process is finished, the concrete should be covered up with gunny sack for curing stage and demould after 1 day.

3.4.1 MIXTURE PROPORTION

According to Zamri N.A., (2014), from the trial mix results has been conducted, the most elevated compressive quality is 34.62 MPa with 95 mm droop esteem by utilizing 1% superplasticizer and water to bond proportion of 0.45. This mix is chosen as the best ideal mix because of the great compressive strength and slump loss portrayed. Among all the mix that are 10%, 20%, 30%, 40% and 50%, the most noteworthy compressive strength created is 20% which meant by 20% POFA replacement in lightweight aggregate concrete. Similar to the other researcher, which is with 20% replacement of POFA the concrete become more denser and achieved maximum strength for aerated concrete and tend to influence the strength of concrete to give the highest compressive strength was stated by Tangchiparat et. al (2013), Hussin M.W and Abdullah K. (2009). Therefore, the 20% has been chosen to be the most ideal mix design and were utilized all through this experiment. List of materials to create control design is B1 and by replaced 20% of POFA on cement is B2, sand is B3 and aggregates is B4 examples is arranged in Table 3.4.

Table 3.4 : Mix design for 20% replacement.

Material	OPS RC (B1)	POFA replacement (kg)		
		Cement 20% (B2)	Sand 20 % (B3)	OPS 20% (B4)
OPS	32	32	32	25.6
POFA	0	8.7	15.14	6.4
OPC	43.5	34.8	43.5	43.5
Water	19.58	19.58	19.58	19.58
Sand	75.69	75.69	60.55	75.69
Super-plasticizer	0.445	0.445	0.445	0.445

3.4.2 SLUMP TEST

Slump test is used to assess the workability and consistency of fresh concrete. Slump test were conducted according to BS EN 12350-2 (2000). Before conducting the test, the internal surface of the mould was thoroughly cleaned and freed from superfluous moisture. The mold is then placed on a smooth, horizontally leveled rigid and non-absorbent surface such as a rigid plate. During the filling process, the mould is held firmly in place by standing on the two foot pieces provided in the slump cone. The mould was filled in three layers, each approximately one-third of the height of the mould when tamped. Each layer is tamped 25 times of the tamping rod with the strokes being distributed uniformly over the cross-section of the layer. After the top layer is rodded, the concrete is struck off the level with a sawing and rolling motion of the tamping rod. The mould is removed from the concrete immediately, in 5 s to 10 s by raising it slowly in the vertical direction. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. The difference in height in mm is the slump of the concrete.

3.4.2 COMPRESSIVE STRENGTH TEST

Compressive strength of concrete cube is the major testing to estimate the concrete strength. The dimension of the concrete cube is 150 mm x 150mm x 150 mm and following the procedures stated in BS EN 1881-116 and BS EN 12390-3. A total of 24 cube specimens with appriximately six cube as control specimens, eighteen cube as OPS reinforced conrete beam replaced by 20% POFA as a partial sand, cement, OPS replacement were test. All the cube specimens will go through to water curing until the testing date. The compressive strength test will be conducted at the age 7 and 28 days of curing specimens. Based on BS EN 1881 – 116, remove the cube from curing while the cube still wet and before that the cube samples was weighed and recorded. Befor placing the cube in the testing machine, ensure that all testing machine bearing surface are wiped clean and other extraneous was removed. The cube place with arefully at the center of the lower plate andthe load was apllied. The value of maximun concrete strength was appreared and take it directly from the machine or can be calculated with the equation, (BS EN 12390 – 3).

Compressive strength, $f_c = \frac{p}{Ac}$ (Eg 3.1)

Where;

P = Maximum load applied to the specimen (N)

A_c = Cros sectional area of the specimen (mm^2)

3.4.4 FOUR POINT BENDING TEST

Flexural strength test was important in a concrete to measure the concrete flexibility and also the bending properties of the material. The flexural strength of OPS RCB for all samples was measured in accordance with BS EN 12390 – 5: 2009 by using samples with size of 150 mm x 200 mm x 1500 mm. The samples for flexural strength test were consist of one control OPS reinforced concrete beams and also four OPS reinforced concrete beam containing 20% of POFA was replaced on sand, cement and OPS. All the samples were subjected to one type of curing namely sprau curing. The flexural test was cariied out at the age of 7 and 28 days. This test was performed by using flexural testing machine with four point loading. The flexural machine consists of two supporting rollers and two load applying rollers that need to be wipe clean in order to remove grit. The maximum load read that was also known as the breaking load was recorded.

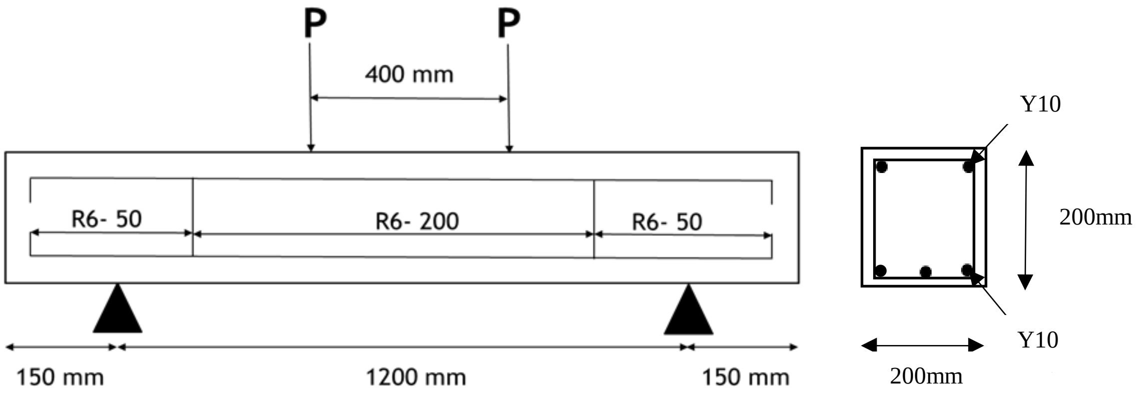


Figure 3.9 : 4 Point Bending Testing arrangement.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this particular chapter, all results of the laboratory test is going to be discussed and compared between control concrete design and 20% partly replaced with palm oil fuel ash on sand, cement and oil palm shell. the laboratory test involved are compressive to check the potency of concrete and flexural test to discover the behaviour of reinforced concrete beam in term of deflection and cracking behaviour within the concrete.

Stated above in the earlier chapter, the aim of these experimental is to discover the ultimate flexural load and deflection and then to identify the mode of failure of each one of the beam samples. The result of every one of the test is going to be between control concrete design and 20% partly replaced with palm oil fuel ash on sand, cement and oil palm shell. The experimental resulting bending moment, maximum load and maximum deflection also are includes on this chapter to in comparison with control concrete design. The discussion and comparison is going to be discussed further in details within through this chapter.

4.2 SLUMP TEST

Table 4.1 demonstrates the influence of varied sort of replacement palm oil fuel ash as partial sand, cement and oil palm shell replacement towards concrete workability at the age of 28 days. It was discovered which the workability of OPS RCB with POFA was reasonably satisfactory around the expected range. The slump values of OPS RCB with a variety of replacement of POFA on sand, cement and oil palm shell were measured between 80 and 100 cm. Slump with POFA replacement 20% produces true slump having a medium degree of workability on types of concrete B1, B2, B3 and B4. Replacement on B2 with POFA leads to the driest mix but shows the same slump result. However, the concrete segregation is inherently because of porous particle of POFA compared to OPC, which essentially leads to an increased absorption of water when utilising in excess of optimum amount that therefore causes concrete segregation. Dry mixture essentially results in low cohesion which then causes the slump to collapse. Exactly the same dry mixture seemed to be developed within the concrete mixture on B3 replacement by POFA. The most effective slump is the most suitable exhibited by all type replacement in B1, B2, B3 and B4 by POFA with 85 mm slump.

4.3 COMPRESSIVE STRENGTH

The purpose of the test is to determine the compressive strength of OPS RC in difference between the design mixes control and the concrete containing POFA as partially replacement on sand, cement and OPS. The compressive strength of concrete is the valuable properties in the concrete as it describe the overall strength of cocnrete and also because most hardened concrete in connection is exerted by compressive stress. The compressive strength for all type of concrete cube is recorded at 7 and 28 days of curing period. Table 4.2 below show the result of the compressive strength of all concrete type.

Table 4.2 : Result of compressive strength.

Type	7 Days				28 Days			
	Max Strenght (Mpa)			Average	Max Strenght (Mpa)			Average
B1	12.011	11.191	11.873	11.69	13.035	12.731	12.614	12.79
B2	17.925	17.861	15.896	17.23	20.957	20.814	20.495	20.76
B3	14.348	14.603	14.473	14.47	16.658	16.049	15.963	16.22
B4	16.897	16.564	16.589	16.68	19.032	18.877	19.351	19.09

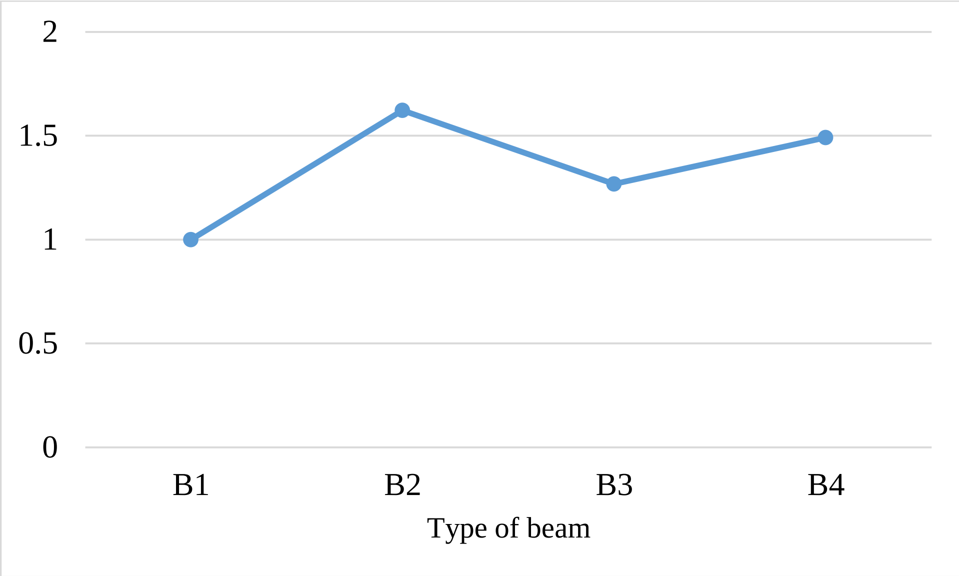


Figure 4.1 : Compressive strength ratio at 28 days.

From the result above, it shows that the compressive strength of B1 at 7 and 28 days are 11.69 Mpa and 12.79 Mpa. It is clearly indicates that the strength increase for B1 concrete but not very much as it increased about 1.1 Mpa or 9% from 7 to 28 days. In this case, having low strength and low increase in strength for B1 concrete due to type of properties of OPS. From the other researcher, by using OPS as a coarse aggregate replacement in lightweight concrete able to produce concrete with compressive strength of more than 25 Mpa wasn stated by Teo D.C.L, Mannan M.A and Kurian V.J (2005) and according to Shafigh P., Jumaat M.Z. and Mahmud H. (2011), by using OPS as a lightweight aggregate the OPS can achieve the compressive strength is 43 MPa and 48 MPa at 28 days and have high workability.

Table 4.3 show the result of compressive strength for B2, from the result show that the compressive strength at 7 and 28 days are 17.23 MPa and 20.76 MPa. The strength increased is higher than B1 concrete which is about 47 % or 62 % increased from 7 and 28 days as compared to B1. By using POFA as partial cement replacement prove that the strength can be increased in strength and according to Abdullah K. and Zamri N.A. (2014), POFA tend to influence the strength of concrete by 20% replacement to give the increment in compressive strength.

For the B3 concrete, the result shows that the compressive strength at 7 and 28 days are 14.42 Mpa and 16.22 MPa. From the result shows that the strength concrete for B3 is higher which is about 23 % or 26 % increased from 7 and 28 days as compared to B1 and POFA can improve the strength of concrete for B3. By using POFA passing 300 µm exhibit higher value which is replace on sand was stated by Zamri N.A, (2014) and for mix concrete B4 show in the result, the value of compressive strength is the second higher value at 7 and 28 days are 16.68 Mpa and 19.09 MPa which is about 42 % or 49 % increased from 7 and 28 days as compared to B1. For all beam were design for strength 30 MPa and the all beam are not achieved the strength target because the thickness of shell are too thin compared to the others researcher.

4.4 4 POINT BENDING TEST

Flexural test for beam were tested after 28 days of curing. The objective of this test is to determine the structural behaviour of OPSRC beams, load-deflection curves, ductility, cracking pattern and to identify the mode of failure. All beam were tested through four point bending test with a distance 400 mm distance between the two loading point and 1200 mm distance between two support point as shown in Figure 4.1.

Figure 4.2 : Testing arrangement.

4.4.1 LOAD DEFLECTION CURVE

The experimental test result are plotted according to load deflection curves of OPS-RC beams. The load – deflection curves for OPS RC beam is illustrated in Figure 4.2. The primary parameters are summarised in Table 4.3. These main parameters included load at yield (P_y) and it's corresponding deflection (δ_y), the maximum load (P_{max}) representing the load-carrying capacity and related delflection (δ_{max}), the ultimate load (P_u) and its associated deflection (δ_u) as well as the ductility ratio (μ) defined as $\mu = \delta_u / \delta_y$. The result of OPS-RC beams were compare with design control of OPS RC beams.

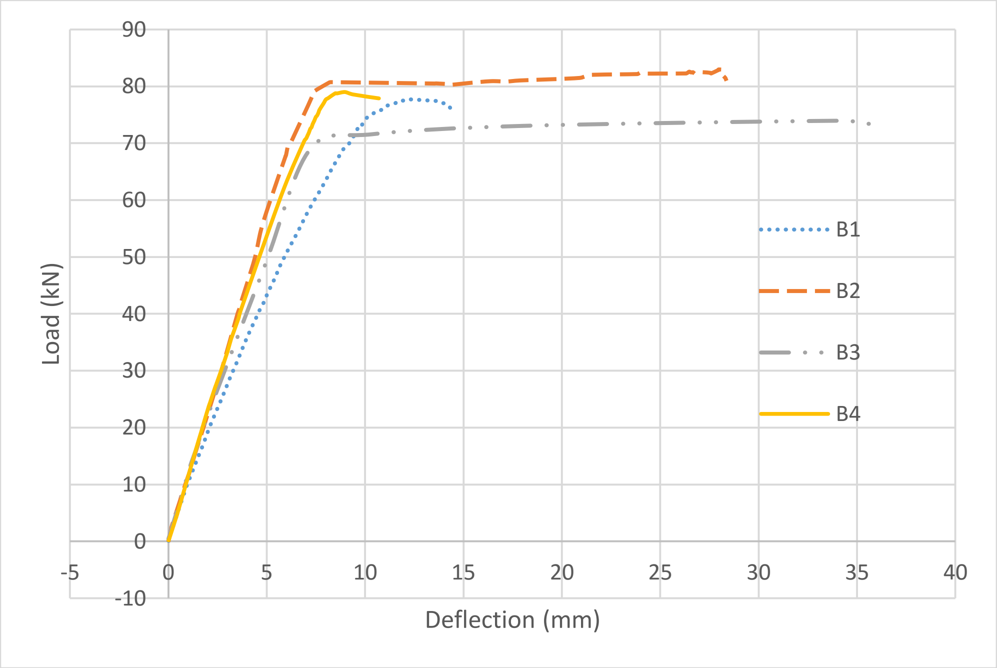


Figure 4.3 : Load-deflection curves for OPS RC beam.

Table 4.3: Result load – deflection for OPS RC beam.

Type	P_y	δ_y	P_{max}	δ_{max}	P_u	δ_u	$\mu = \delta_u / \delta_y$
B1	64.78	7.20	77.72	12.20	75.80	14.40	2.00
B2	68.89	6.04	82.97	27.98	81.30	28.33	4.69
B3	66.06	5.73	73.95	34.10	72.92	35.91	6.27
B4	62.11	5.88	78.99	8.98	77.88	10.70	1.82

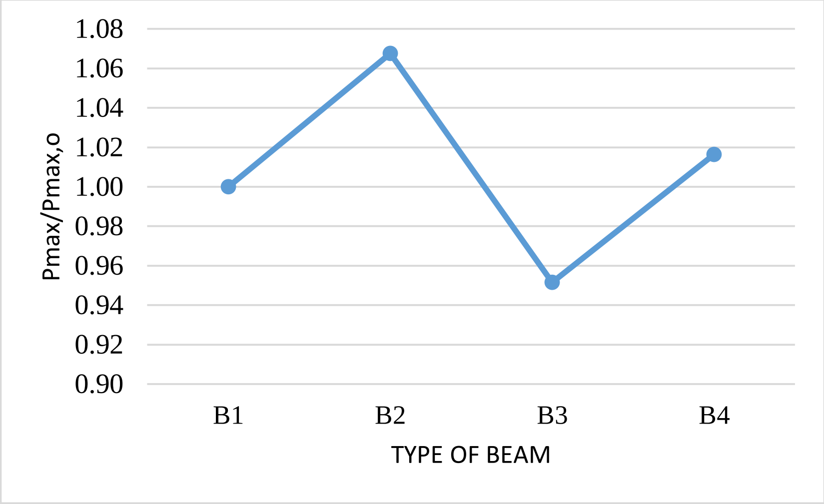


Figure 4.4 : Maximum load ratio

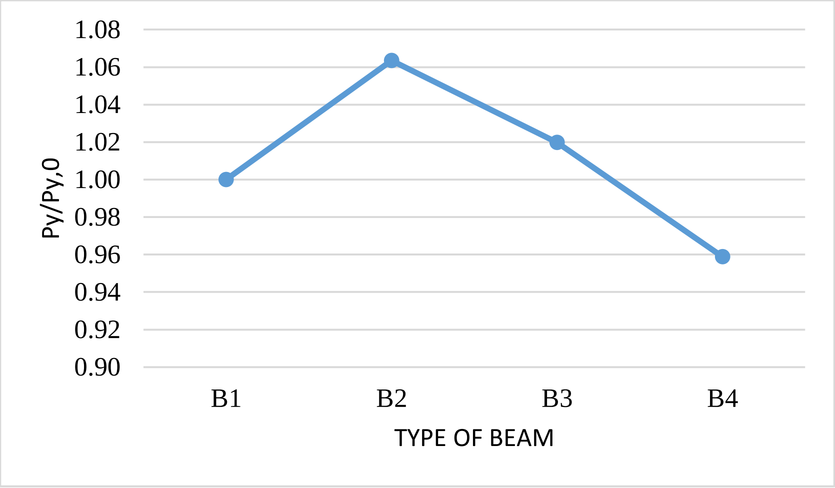


Figure 4.5 : Load at yield ratio

From the load – deflection curves summary primary parameter could be observed in Table 4.2 from Figure 4.3, suggest that the 20% replacement of POFA in sand, sand, cement and oil palm shell increased the P_y and P_{max} of OPS RCB on B2 increased up to 53% and 7% respectively as compared to the B1. Similar with Sooraj V.M (2013), with 20% POFA partly replacement on cement can achieved the highest flexural strength. It also could be observed on load deflection curves in Table 4.2 that, the B3 at Py and Pmax increased up to 48% and 126% respectively as compared to beam B1. However, the beam B3 and B4 was observed the Py and Pmax also increased up to 39% and 2% for B3 and 39% and 2% for B4 as compared to beam B1.

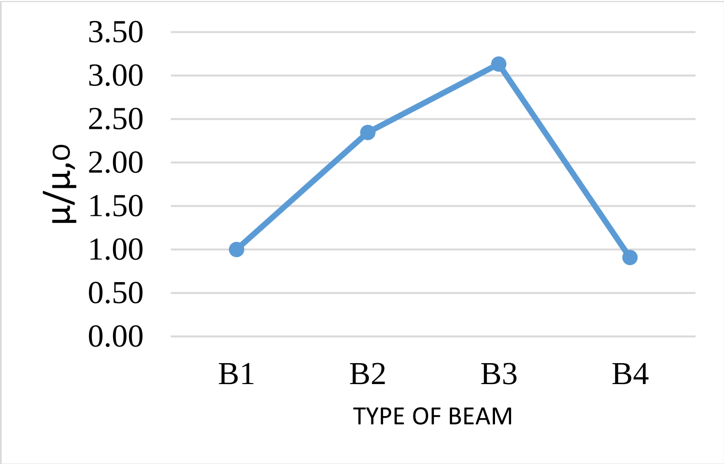


Figure 4.6 : Ductility ratio

The ductility was considered as vital properties that must definitely be possessed by every reinforced concrete beam. The ductility of OPS RC can also be fundamental significant because any member should really be able to undergoing large deflection at near maximum load carrying capacity, giving ample cautioning towards the imminence of failure. In this particular experiment, with this investigation, satisfactory ductility ratio is observed for OPS RCB in Figure 4.5. The outcome show how the ductility of OPS RCB which replaced with 20 % of POFA has improved significantly. The highest improvement of ductility was obtained by beam B3 that the ductility increased up to 126 % wheres, beam B2 the ductility increased up to 69 % as compared to the beam B1. However, on beam B4 which is the ductility of the beam decreased down to 34 % as compared to beam B1. In accordance with Teo D.C.L, Mannan M.A and Kurian V.J (2006), that is the ductility ratio is more than 3, which shows good ductility the behaviour of OPS beam.

4.4.2 CRACKING AND MODE OF FAILURE

The failure in beam because of the load applied to it may be cause by many factors for examples, shear failure, flexural concrete crushing and flexural tension. Shear link is provided inside the beam for it have full flexural strength and to back up the shear capacity from the beam. The deflection takes place when the concrete and reinforcement are compatible together within the beam structure.

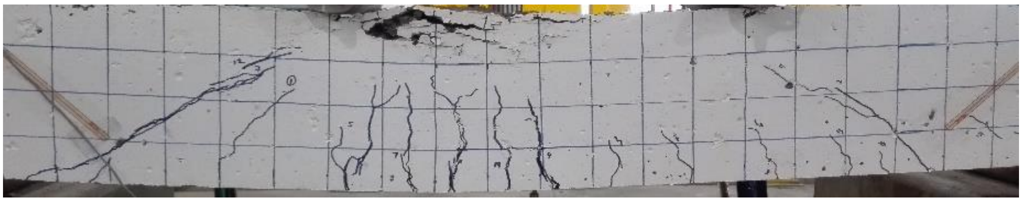
Table 4.4 : Result of 1st load and type of failure.

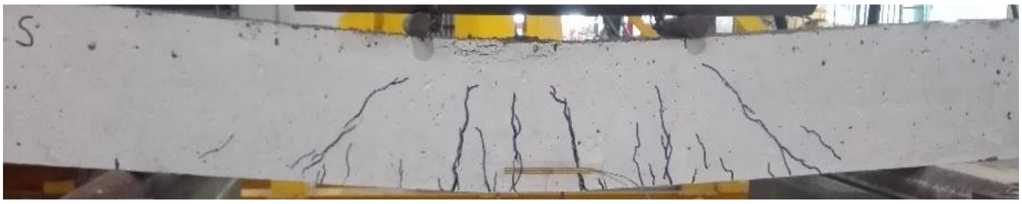
Types	1st Crack load (kN)	Type of failure
B1	17.45	Shear
B2	51.97	Bending - Shear
B3	33.08	Bending
B4	28.88	Shear

The load at first cracking and the mode of failure of the beam samples are shown in the Table 4.4. the load at first cracking for beam B1 and B2 are 17.45 kN and 51.97 kN respectively show that the load increased up to 20 % as compared to the beam B1. However, the first cracking for the beam B3 and B4 are 33.08 kN and 28.88 kN respectively, show that the required the load at first cracking increased up to 90 % and 66 % respectively as compared to the beam B1. The first crack load for the beam B1 is lower than the others beam because the POFA tend to influenced the strength of concrete and give the higest flexural strength.

The mode of failure was observed for B1, B2, B3 and B4 beams as shown in figure. The initial cracks began to take place in all the beams with concrete crushing in the compression zone. Since all beam designed as reinforced concrete beam, the failure of the beam is started by yielding before followed failure in the compression zone as can be seen at Figure. As shown in Figure 4.3 (a), (d), the beam B1 and beam B4 the cracking started at the middle of span before the cracking start to spread to incline cracking to shear zone and the type of failure for B1 and B4 is shear failure according to the observation during the testing. As shown in Figure 4.3 (b) and (c) for the beam B2 and B3, the cracking started at the middle of span before it continued cracking in the middle and also the cracking start to spread to incline cracking to shear zone and the type of failure for B2 and B3 is bending – shear and bending failure respectively according to the observation during the testing.

a)


b)


c)


d)


Figure 4.7: Type of cracking pattern a) B1 b) B2 c) B3 d) B4.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter concludes the entire experimental study findings extracted from the results in accordance with the objectives listed in the previous chapter. This section also highlights the salient outcomes of palm oil fuel ash as partial sand, cement and oil palm shell replacement in oil palm shell reinforced concrete beam towards mechanical performance. In addition to the conclusion, several suggestions are suggested for future investigations may also be included in this section.

5.2 CONCLUSION

5.2.1 THE POTENTIAL OF POFA AS PARTIAL REPLACEMENT

The results obtained provides the important information required in order to meet the first objective of these studies, namely the potential of POFA content as partial sand, cement and oil palm shell replacement within the workability, along with the compressive strength of OPS RCB. Based on the 28-day compressive strength, it had been found that the replacement of 20% POFA in OPS RCB on B2, B3 and B4 beam has increased its strength as compared with B1 OPS RCB. The highest compressive strength was exhibited by the B2 beam with replacement by POFA with 20% greater than the control specimen, B1 beam. This indicates that the replacement of POFA in B2 produces the largest amount of C-S-H gel from hydration process and pozzolanic reaction that densify the concrete structure that in turn provides higher compressive strength and have the highest potential to used as replacement in reinforced concrete. In this studied the oil palm shell used as a coarse aggregate are not suitable because the thickness of the shell was thin and it was affecting the strength of concrete.

5.2.2 STRUCTURAL BEHAVIOUR OF OPS RCB

From the results obtained ,the flexural strength of OPS RCB with replacement of POFA shows the similar trend of result with compressive strength and the result show that the POFA also increased up the flexural strength as compared to control samples due to the pozzolanic reaction, B1 beam. The highest load at yield and maximum load was exhibited by B2 with 57 % and 7 % respectively higher than B1 beam. The ductility was considered as vital properties that must definitely be possessed by every reinforced concrete beam. The highest improvement of ductility was obtained by beam B3 that the ductility increased up to 126 % wheres, beam B2 the ductility increased up to 69 % as compared to the beam B1. For the mode of failure the initial cracks began to take place in all the beams with concrete crushing in the compression zone and the type of failure beam for B1 and B4 was shear failure. For the beam B2 and B3 the mode of failure was bending failure.

5.3 RECOMMENDATION

The following suggestion are made to improved and further expand the studies of OPS RCB containing POFA as a partial replacement:

1. The type of oil palm shell should be used is dura because the thickness of shell very thick and can improve the strength in concrete.
2. Structural behaviour of OPS RCB partly replaced with POFA containing crushed clinker as a partial sand replacement is also should be investigated.

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