EFFECT OF WATER TO CEMENT RATIO TO THE MECHANICAL PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT CONCRETE

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Bachelor of Engineering (Hons) in Civil Engineering

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Report submitted in fulfillment of the requirements for the award of the degree of
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ABSTRACT

Oil palm shell (OPS) is a waste material that is obtained by crushing the palm nut in the palm oil mills during the extraction of palm oil. Replacing coarse aggregate with OPS in concrete is one of the way to optimize the use of natural waste material. In this research, crushed OPS was used to replace the coarse aggregate in the production of lightweight aggregate concrete (LWAC). Various water to cement ratio was also used in this research to investigate the effect of water to cement ratio to the mechanical properties of OPS lightweight concrete. The compressive strength, splitting tensile strength, flexural strength and static modulus elasticity test were conducted. The effect of the research was studied at 7 days and 28 days. The test result showed that higher water to cement ratio gives lowest strength to the concrete. Through the results, OPS have been found useful in replaced the coarse aggregate in concrete. However, the water to cement ratio greatly affect the behaviour of OPS lightweight aggregate concrete.

ABSTRAK

Kulit kelapa sawit adalah bahan buangan yang diperolehi dengan menghancurkan biji sawit di kilang-kilang minyak sawit semasa pengekstrakan minyak sawit. Menggantikan agregat kasar dengan kulit kelapa sawit dalam konkrit adalah salah satu cara untuk mengoptimumkan penggunaan bahan buangan semula jadi. Dalam kajian ini, kulit kelapa sawit dihancurkan dan digunakan untuk menggantikan agregat kasar dalam penghasilan konkrit dengan agregat yang ringan. Air dengan simen yg mempunyai pelbagai nisbah juga digunakan dalam kajian ini untuk mengkaji kesan air kepada sifat mekanik konkrit dengan kulit kelapa sawit beragregat ringan. Kekuatan mampatan, kekuatan memecah regangan, kekuatan lenturan dan ujian modulus elastik telah dijalankan. Kesan daripada penyelidikan yang telah dikaji pada 7 hari dan 28 hari. Keputusan ujian menunjukkan bahawa air nisbah simen yang lebih tinggi memberi kekuatan terendah untuk konkrit. Melalui keputusan yang telah didapati, kulit kelapa sawit telah ditemui berguna dalam menggantikan agregat kasar dalam konkrit. Walau bagaimanapun, air nisbah simen juga banyak memberi kesan kepada sifat konkrit beragregat ringan.

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σ	Stress
E	Modulus of Elasticity

LIST OF ABBREVIATIONS

LWA	Lightweight Aggregate
LWC	Lightweight Concrete
NWA	Normalweight Concrete
OPC	Ordinary Portland Cement
OPS	Oil Palm Shell
OPSC	Oil Palm Shell Concrete

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Since today, researchers vigorously seek an invention to the concrete. One of them was using oil palm shell as a replacement of coarse aggregate in concrete. Oil palm shell (OPS) is a waste material that was obtains by crushing the palm nut in the palm oil mills during the extraction of palm oil. It can be found abundantly in South East Asia and Africa. OPS have been used as lightweight aggregates (LWAs) to produce a lightweight concrete (LWC) which is called oil palm shell lightweight aggregate concrete (OPSC) and many researchers has been working in this area. In the recent investigation, it shows that the use of crushed OPS in a concrete can produced medium and high strength concrete (U. Johnson Alengaram et al., 2013). The use industrial waste material helps to produce a sustainable material. An OPS has a better impact resistance compared to the normal weight aggregate (J. L. Clarke, 2005).

1.1 PROBLEM STATEMENT

This research is done to investigate the effects of water to cement ratio to the mechanical properties of oil palm shell lightweight concrete where the oil palm shell is used to replace the coarse aggregate used in the concrete. Various natural waste materials can be used in our surrounding. Therefore, many researchers have proposed many ways to maximize the use natural waste materials into useful things and one of them is replacing the OPS as coarse aggregate in a concrete. The types of materials used give different results either high or low strength. In this research, replacing oil palm shell in a concrete can identify the mechanical properties with different water to cement ratio used.

1.2 RESEARCH OBJECTIVE

The objectives of this research are:

i. To investigate the effects of water to cement ratio to the mechanical properties of oil palm shell lightweight aggregate concrete.
ii. To determine the optimum water to cement ratio used for the production of the oil palm shell lightweight aggregate concrete.

1.3 SCOPE OF STUDY

The scopes of this study are:

i. Type of concrete grade: 20 N/mm2
ii. Type of concrete: Oil palm shell lightweight aggregate concrete
iii. Percentage of coarse aggregate replacement to OPS aggregate: 100%
iv. Specimens: Cube (width= 100 mm, length= 100 mm, height= 100 mm)
: Cylinder (diameter= 150 mm, height= 300 mm)
: Prism (width= 100 mm, height= 100 mm, length= 350 mm)
v. Type of tests: Compressive Strength Test
: Splitting Tensile Strength Test
: Flexural Strength Test
: Elastic Modulus Elasticity Test

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Concrete is an important material used in the construction industry. It contains of hydraulic cement, water and aggregates. In a concrete, aggregates occupies nearly 60%-80% from concrete volume. The aggregates can be classified as coarse aggregates (with particle size more than 4.75 mm) and fine aggregates (with particle size less than 4.75 mm). Those aggregates are either obtained from natural sources or manufactured. Normally, concrete can be classified into normal concrete and lightweight concrete. These concretes are explained in further sections.

2.1 CONCRETE CLASSIFICATION

2.1.1 Normal concrete

Normal weight concrete known as the concrete contains common compositions of aggregates, water and cement. It has a setting time of 30 - 90 minutes depending upon moisture in atmosphere, fineness of cement. The development of the concrete strength usually starts after 7 days where the common strength value is 10 MPa (1450 psi) to 40 MPa (5800 psi). At 28 days, 75 - 80% of the concrete total strength is attained. Some of the properties for normal concrete are it is strong in compression and weak in tension, having air content of 1 - 2 % and it is not durable against severe conditions e.g. freezing and thawing.

2.1.2 Lightweight concrete

For structures such as multi-stored buildings, it is desirable to reduce the dead loads. Lightweight concrete (LWC) is most suitable for such construction works. It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following methods which are by making concrete with cement and coarse aggregate only. Sometimes, such as concrete is referred to as no-fines concrete. Suitable aggregates are natural aggregate, blast furnace slag, clinker, foamed slag, etc. Since fine aggregates are not used, voids will be created the concrete produced will be a lightweight concrete. Second is by replacing coarse aggregate by porous or cellular aggregate. Some of the advantages and disadvantages of a lightweight concrete are shown in Table 2.1.

Table 2.1: Advantages and disadvantages of lightweight concrete

Advantages	**Disadvantages**
Rapid and relatively simple construction.	Mixtures very sensitive with water content.
Significant reduction of overall weight results in saving structural frames, footing or piles	Mixing time is longer than conventional concrete to assure proper mixing.
Economical in terms of transportation as well as reduction in manpower.	Difficult to place and finish because of the porosity and angularity of the aggregate.

2.2 LIGHTWEIGHT AGGREGATE

Lightweight aggregate is a type of coarse aggregate that is used in the production of lightweight concrete products such as concrete block, structural concrete, and pavement. The lightweight aggregate (LWA) is often used compared to the normal weight aggregate (NWA) because it is more economical and it has more advantages than the normal weight aggregate. Moreover, lightweight aggregate also controls settlements; reduce live loads in formwork and increases stability. In this research, oil palm shell (OPS) will be used as a coarse aggregate with different water to cement ratio as the lightweight aggregate. Table 2.2 shows the advantages and disadvantages of lightweight aggregate.

Table 2.2: Advantages and disadvantages of lightweight aggregate

Advantages	**Disadvantages**
Improved thermal properties.	Inability to provide consistent compressive strengths and density throughout the entire area.
Savings in transporting and handling precast units on site.	
Improved fire resistance.	

An important feature of lightweight aggregate concrete is the good bond between the aggregate and the surrounding hydrated cement paste. This is the consequence of several factors. First, the rough surface texture of many lightweight aggregates is conducive to a good mechanical interlocking between the two materials. In fact, there is often some penetration of cement paste into the open surface pores in the coarse aggregate particles. Second, the moduli of elasticity of the lightweight aggregate particles and of the hardened cement paste do not differ much from one another (Neville, 1995). Besides that, lightweight aggregates are light due to the inclusion of air voids and it follows that they are absorbent, expect for the very few with sealed cells. Most lightweight aggregates are manufactured and hence are, by careful production control, uniform and consistent, which is important to mixing, placing and compaction (J. L. Clarke, 1993).

There are two types of lightweight aggregate which are natural and manufactured lightweight aggregate. Natural lightweight aggregate materials are prepared by crushing and sizing natural rock materials such as pumice, breccia, and volcanic cinders while manufactured lightweight aggregates are prepared by pyro processing shale, clay, or slate in rotary kilns or on traveling grate sintering machines.

2.3 OIL PALM SHELL

Oil palm shell (OPS) is a waste product at the time of extracting oil from oil palm tree (Okpala DC, 1990). Oil palm tree, being as in the same genera as Coconut palm tree, shares many features with it. Its scientific name is Elaeis guineensis and is found mainly in East Africa (Pantzaris TP, Ahmad MJ, 2001). A sample of OPS aggregates is shown in Figure 1. Normally, OPS aggregates are composed of different shapes as shown in the figure.

Figure 2.1: Oil palm shell

OPS is used as a lightweight aggregate in many construction such as one storey building, foot bridge, floor roofing and water treatment where it is also used as granular filter material (U. Johnson Alengaram, 2013). OPS as a lightweight concrete is having low thermal conductivity and high insulation capacity that may result in low energy consumption and greener environment.

Table 2.3 and Table 2.4 showed the physical and mechanical properties for the oil palm shell aggregate. The mechanical properties of OPS change depending on the physical properties of OPS. The physical properties result is compared with normal weight aggregate on their specific gravity, thickness and shape, surface texture, loose and compacted bulk densities, air and moisture content, water absorption and porosity.

Table 2.3: Physical behavior of OPS aggregate

Author (year)	**Specific gravity**	**Loose bulk density (kg/m3)**	**Compacted bulk density (kg/m3)**	**Moisture content (%)**	**Water absorption , 24h (1h) (%)**	**Porosity (%)**
Abdullah (1984)	–	–	620	–	–	–
Okafor (1988)	1.37	512	589	–	27.3	
Okpala (1990)	1.14	545	595	–	21.3	37
Basri et al. (1999)	1.17	–	592	–	23.32	–
Mannan and Ganapathy (2002)	1.17	–	592	–	23.32	–
Teo et al. (2006)	1.17	500 – 600	–	–	33	–
Ndoke (2006)	1.62	–	740	9	14	28
Jumaat et al. (2008)	1.37	566	620	8 – 15	23.8	–

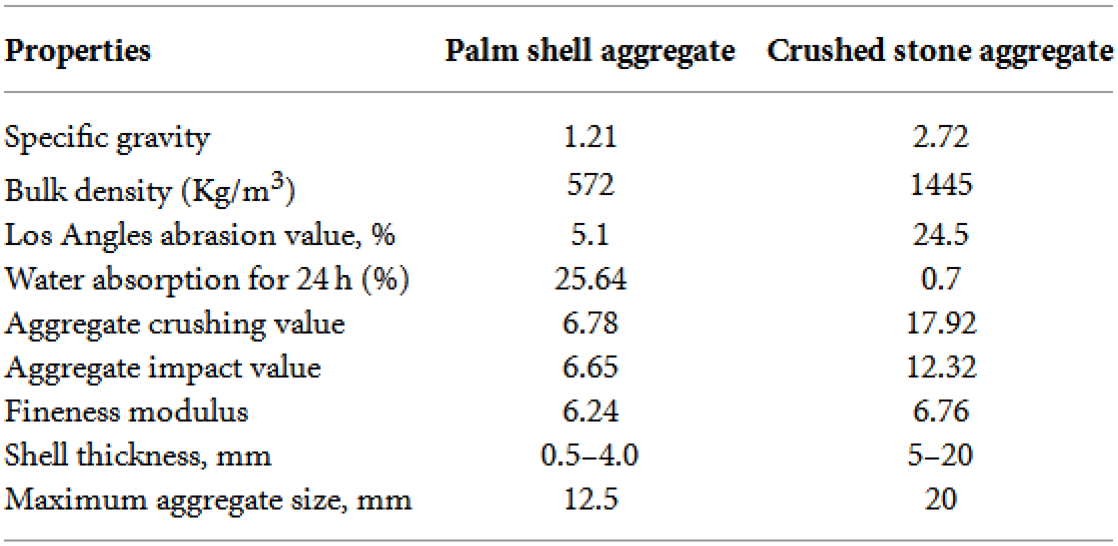
Table 2.4: Mechanical behavior of OPS aggregate

Author (year)	**Abrasion value (Los Angeles)**	**Aggregate impact value (AIV) (%)**	**Aggregate crushing value (ACV) (%)**
Okafor (1988)	–	6.00	10.00
Okpala (1990)	3.05	–	4.67
Basri et al. (1999)	4.80	–	–
Mannan and Ganapathy (2001, 2002)	4.80	7.86	–
Olanipekun (2005)	3.60	–	–
Mannan et al. (2006)	–	1.04 – 7.86	–
Ndoke (2006)	–	4.50	–
Teo et al. (2006 and 2007)	4.90	7.51	8.00
Jumaat et al. (2008)	8.02	3.91	–
Mahmud et al. (2009)	–	3.91	–

Source: U. Johnson Alengaram et al., 2013

The physical properties of OPS and crushed stone aggregate are illustrated in Table 2.5. From the table, the crushed stone aggregate has the highest value in most of the properties. The palm shell aggregate is higher than crushed stone aggregate in only one properties based on the table which is in water absorption for 24 hour (%) with 25.64 % compared to crushed stone aggregate with 0.7 %.

Table 2.5: Properties of OPS and crushed stone aggregate



Properties	Palm shell aggregate	Crushed stone aggregate
Specific gravity	1.21	2.72
Bulk density (Kg/m^3)	572	1445
Los Angles abrasion value, %	5.1	24.5
Water absorption for 24 h (%)	25.64	0.7
Aggregate crushing value	6.78	17.92
Aggregate impact value	6.65	12.32
Fineness modulus	6.24	6.76
Shell thickness, mm	0.5–4.0	5–20
Maximum aggregate size, mm	12.5	20

2.3.1 Mechanical Properties of OPS

2.3.1.1 Compressive strength

The compressive strength value is different depending on the mix design and curing conditions of the oil palm shell concrete. One of the experiments done is using OPS as lightweight aggregate and has achieved compressive strength up to 20 MPa with the w/c ratio of 0.4 (Abdullah AAA, 1997). It is almost equal to the value of the specified cylindrical compressive strength (fc) of 17 MPa. Generally, it can be seen from the experiment that the mechanical properties of oil palm shell concrete increased with decreasing w/c ratio. In addition, the probability of making steel fiber and high strength lightweight concrete (HSLWC) with crushed OPS is also investigated. As the result, they have achieved 28-day compressive strength in the range of 41–45 MPa with steel fibers but however, they achieved 28-day compressive strength of up to 48 MPa with crushed OPS and lime stone powder as filler (Shafigh P et al., 2011).

2.3.1.2 Splitting tensile strength

The splitting tensile strength also results in different range which is within 2.0-2.4 with different water/cement of 0.65-0.48 (Okafor, 1988). Many researcher reported similar values in the splitting tensile strength test and these values are about 6–10% of their respective compressive strengths. The splitting tensile strength is also depends on the curing condition and physical strength of oil palm shell (Mannan and Ganapathy, 2002).

2.3.1.3 Modulus of Elasticity

Using other lightweight aggregate concrete, the static modulus of elasticity of other LWAC varies in the range of 7.69-11.4 GPa depends on the mix design and time of curing. The results show that the E-values are quite similar to other lightweight aggregate concrete (Hossain A et al., 2010). When fine aggregate content is increased with subsequent reduction in OPKS, the higher the E-values compared to the concrete with high OPS content (Alengaram et al., 2011).

2.3.2 TYPES OF LIGHTWEIGHT AGGREGATE

2.3.2.1 Coconut Shell

Coconut shell is another type of replacement of aggregate used in the concrete. It is an agricultural biodegradable waste which is becoming popular nowadays because it is easy to hand and has low dead loads. By using coconut shell, it helps the prevention of deforestation and it is less expensive. The husk of a coconut comprises 30 per cent coconut fibers and 70 percent flesh (Bharati Vidyapeeth Deemed, 2013). Figure 2.2 shows the picture of coconut shell.

Figure 2.2: Coconut shell

2.3.2.2 Cockle Shell

Cockles are marine bivalve molluscs which act as an important source of protein in the South East Asian region. It has lead towards the generation of abundant waste shell and it can be seen that the shells is dumped and left untreated which cause unpleasant smell that is disturbing the view of the surrounding (Boey et al, 2011). As the cockle's production is increasing, the cockles shell waste also would be in a higher amount which has leads the effort of treating the waste cockles shell as one of the ingredient in mixing the concrete. At the same time, this alternative can be used to preserve the natural coarse aggregate for the use of future generation. Figure 2.3 shows the example of cockle shell.

Figure 2.3: Cockle shell

2.3.2.3 Pumice

Pumice is a super cooled liquid which formed when the molten SiO2 rich lava from the explosive eruption of a volcano cools. It has low density due to the presence of the bubbles. The mixing of pumice into concrete has provided the structural strength and insulation for the concrete. It can be found in many parts of the world where volcanoes are present. It has been used as a lightweight aggregate in concrete due to its toughness and durability that has no reaction with any of the ingredients of concrete and steel. Enough cement is used to coat and bind the aggregate together. Figure 2.4 shows an example of pumice.

Figure 2.4: Pumice

2.4 WATER/CEMENT RATIO

The water/cement ratio (w/c) is one of the major factors but not only the one influencing the strength of concrete. It is responsible mainly for the porosity of the hardened cement paste. Water/cement ratio is the water used to the quantum of cement in the mixture by weight. For proper workability, the water/cement ratio varies from 0.4 to 0.6. However, maximum strength is derived at water/ cement is 0.4. When it is decreased to less than 0.4, there is improper consistency and workability of cement and honeycombed structure. However, concrete compacted by vibrator displays higher strength even up to water/cement = 0.3. At water/cement ratio more than 0.4, the expansion of cement on hydration is insufficient to occupy the space previously filled with water. Hence, the porosity increases and strength decreases. In arriving at the water/cement values it is assumed that aggregates are saturated with the surfaces in dry condition. Suitable adjustments should be made for dry aggregates.

Table 2.6 indicates the results of the target compressive strength and the result that the researchers obtained after the test using different water to cement ratio. Most of the researchers succeeded in achieving their target strength. However, only Mannan and Ganapthay failed in achieving the target strength.

Table 2.6: Results of the target compressive strength and the result that the researchers obtained after the test using different water to cement ratio

Author/ Year	W/C Ratio	Compressive Strength, MPa	Result
Olanipekun et. al. (2006)	0.5	15	27.5
Teo et. al. (2006)	0.4	17	28.1
Olanipekun et. al. (2005)	0.50	17	22.97
Mannan and Ganapthay (2002)	0.50	25	14.40
Mannan and Ganapthay (2001)	0.60	25	11.80
Mannan and Ganapthay (2001)	0.53	28	13.65
U. Johnson Alengaram et. al. (2010)	0.41	30	37
Mahmud, H. et. al. (2009)	0.35	35	28-38

2.5 COMPARISON OF OPS WITH OTHER AGRICULTURAL WASTE

Comparison of density and strength of oil palm shell and concrete with other agricultural wastes such as oil palm clinkers, rice husk and coconut shells as coarse aggregates was done by Abdullah. From the experimental test results, he concluded that concrete made with rice husk had the lowest bulk density with 136 kg/m3 and the lowest compressive and tensile strengths. Concrete made with oil palm clinker showed the highest bulk density and 28-day compressive and tensile strengths. The 28-day compressive strength of oil palm shell with a density of 620 kg/m3 of 17.4 MPa was found lower than the concrete made with oil palm clinker that produced 29.8 MPa. Gunasekaran et al. showed that water absorption, specific gravity, impact value and bulk density of coconut shell aggregate was comparable to those of oil palm shell. The 28-day compressive strength of coconut shell concrete was found to be in the range of 5–27 MPa; however with a slump of only 5 mm, the coconut shell concrete exhibited a very poor workability. Moreover, the compressive strength, modulus of rupture, splitting tensile strength, theoretical and experimental bond strength performed on coconut shell concrete were comparable to oil palm shell. The graph of comparison of the compressive strength with types of aggregate is shown in Figure 2.5.

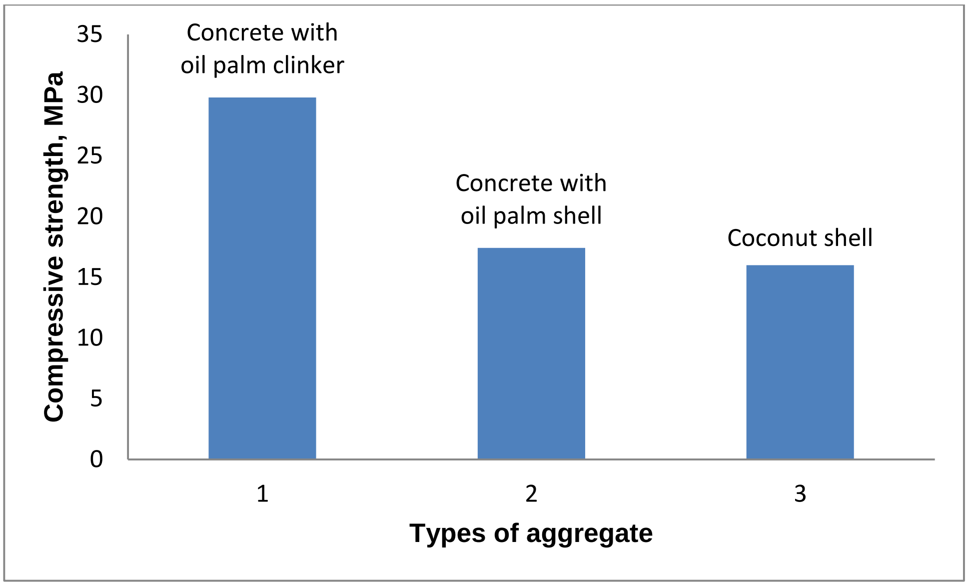


Figure 2.5: Relationship between the compressive strength and types of aggregate

2.6 SUMMARY

Water to cement ratio is one of the crucial things that affect the mechanical properties of the concrete. The result achieved is also depending on the characteristic of the material used in the concrete production. So, water to cement ratio and the type of materials used must be chosen wisely to get a better result. From the previous research, most of the researchers used low water to cement ratio in the range of 0.4 to 0.6. Lower than 0.4 will lead to improper consistency and honeycombed but, it also happened to the structure with higher water to cement ratio that is higher than 0.6. Moreover, the types of materials used also contribute to the strength of the structure produced.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 INTRODUCTION

There are several tests that are carried out in this research. They are compressive strength test, splitting tensile strength test, flexural strength test and modulus of elasticity test. The test are conducted to investigate the mechanical properties of oil palm shell concrete by using various water to cement ratio, and compared to plain concrete. The grade of concrete targeted in this research is 25 N/mm2 which achieved after 28 days. Super plasticizer admixture were also added during the mixing of the concrete that is used to modify the properties of concrete or mortar to make them more suitable to work by hand or for other purposes such as saving mechanical energy. The concrete is mixed with different water to cement ratio of 0.55, 0.60 and 0.65 with 100% of oil palm shell. Wet gunny was the curing method used in the research.

3.1 RESEARCH FLOW CHART

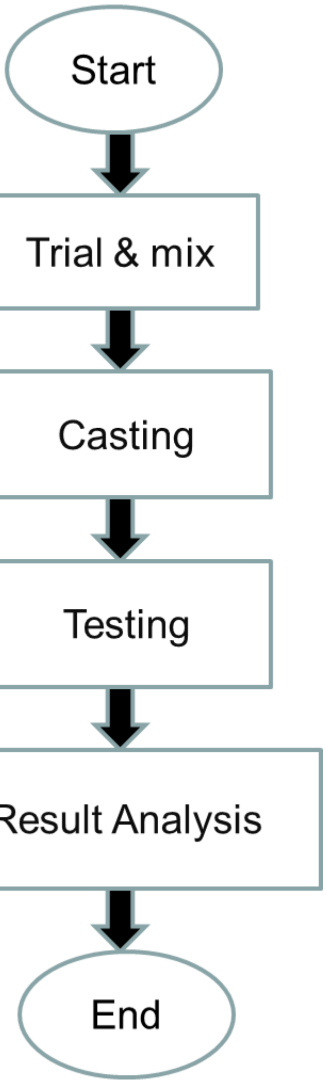


Figure 3.1: Flow chart

Figure 3.1 represents the flow chart of the process of the research. First, the research is started. Then, trial and mix is done to get the mix proportion of the concrete that achieved the target strength. Next, using the mix proportion, casting is carried out and after it is done, the specimen is cured by wet gunny for 7 and 28 days. After 7 and 28 days, testing is conducted for the specimen. The analysis is done using the results that is obtained from the testing conducted.

3.2 RESEARCH MATERIALS

3.2.1 Cement

Cement is one of the main materials used in this research. Cement is a soft grey powder that is mixed with water and other substance to make concrete. It can also be defined as the binding element that is used to bind others materials together. The type of the cement that used in this research is Ordinary Portland Cement (OPC), which is the most common type of cement use around the world. It usually contains of calcium sulfate with the ability of setting, hardening and remains stable under water. The OPC used is according to BS 12:1958, Specification for Portland Cement.

3.2.2 Oil Palm Shell (OPS)

Oil palm shell (OPS) is used as a lightweight aggregate as the replacement for coarse aggregate in this research. A crushed oil palm shell that is obtained from the factory is used for the conducted test. Table 3.1 represents the characteristics of oil palm shell used in this research. Figure 3.2 shows an example of oil palm shell used.

Table 3.1: Characteristics of OPS

Maximum Size	12.5 mm
Type	Elaeis Guineensis
Density	572 kg/m3
Amount Used	67 kg

Figure 3.2: Oil palm shell

3.2.3 Sand

Sand is defined as small loose grains of worn or disintegrated rock or a sedimentary material that is coarser than silt and finer than a granule. The diameter of sand can be found within 0.06 and 2.0 mm. This research used the river sand with diameter 600µm size. Figure 3.3 shows an example of river sand used.

Figure 3.3: River sand

3.2.4 Water

Another important materials applied in this research is water. Water is the form of liquid which are odorless, tasteless and has no smell that falls from clouds as rains and then, forms an area of water such as lakes, seas and streams. The water also can be used for drinking and washing but in this research, the purpose of the water is for the concrete to hydrate and form Calcium-Silicate-Hydrate (C-S-H) that binds the concrete together.

3.2.5 Super Plasticizer

Super plasticizer is a concrete admixture that adds to the concrete's workability despite low water-cement ratio. It is used for preparing the ultra-high performance concrete mixture. The type of super plasticizer used in this research is Sika Viscocrete-2199 which is a high range water-reducing admixture for early strength concrete. Figure 3.4 shows the example of super plasticizer used.

Figure 3.4: Super plasticizer

3.3 RESEARCH SPECIMENS

3.3.1 Cube

Firstly, the cement, water and aggregate are mixed using mix design ratio that has been calculated. The coarse aggregate will be replaced with crushed oil palm shell with volume fraction of 100% for all specimens. Then, the sand and water is poured into the mixer machine and mixed thoroughly. After that, slump test is done to the concrete. 24 of concrete cube specimens with diameter of 100 x 100 x 100 mm are casted. Figure 3.5 shows the mould for cube used in the research.

Figure 3.5: Mould for cube

3.3.2 Cylinder

Firstly, the cement, water and aggregate are mixed using mix design ratio that has been calculated. The coarse aggregate will be replaced with oil palm shell that has been crushed using volume fraction of 100% for each specimen. Then, the sand and water is poured into the mixer machine and mixed thoroughly. After that, slump test is done to the concrete. 24 concrete cylinders were casted using mould of 150 x 300 mm diameter. Figure 3.6 shows the mould of cylinder used.

Figure 3.6: Mould for cylinder

3.3.3 Prism

Firstly, the cement, water and aggregate are mixed using mix design ratio that has been calculated. The coarse aggregate will be replaced with oil palm shell that has been crushed using volume fraction of 100% for each specimen. Then, the sand and water is poured into the mixer machine and mixed thoroughly. After that, slump test is done to the concrete. Twelve prisms of concrete with diameter of 100 x 100 x 500 mm are casted. Figure 3.7 shows the mould of prism used.

Figure 3.7: Mould of prism

3.4 TEST PROGRAM

3.4.1 Slump Test

Slump cone, base plate and tamping rod are needed for slump test. First, the internal surface of the mould is ensured to be clean and damp but free from superfluous moisture before commencing the test. Then, the mould is placed on a smooth, horizontal, rigid and non-absorbent surface free from vibration and shock. While holding the mould firmly, fill it in with three layers with each layer is tamped with 25 strokes using the tamping rod. The stroke is being distributed uniformly over the cross-section of the layer. After the top layer has been tamped, the concrete level is strike off with the top of the mould with a saving and rolling motion of the tamping rod. The surface below where the concrete may have fallen onto it or leaked from the lower edge of the mould is cleaned with the mould still held down. By raising the mould vertically, it is removed from the concrete slowly and carefully to impact minimum lateral or torsional movement to the concrete. The entire operation for the slump test should be completed within 150 seconds and is measured to the nearest 5 mm immediately after the mould is removed by using a measuring scale to determine the difference between height of the mould and highest point of the specimen as shown in Figure 3.8. The slump test is done according to BS EN 12350: Part 2 (2009).

(a) After the cone is removed (b) Slump height is measured

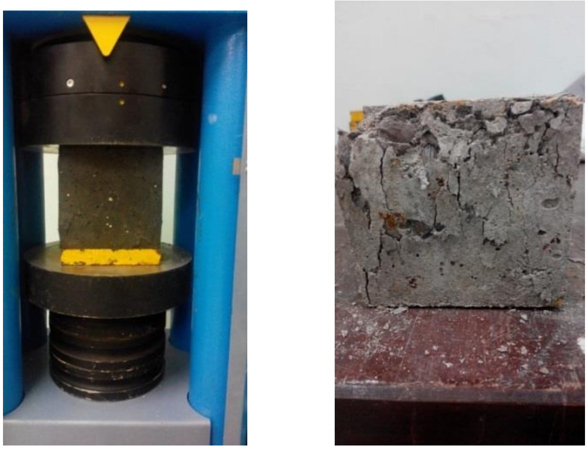
Figure 3.8: Slump test

3.4.2 Compressive Strength Test

A compressive strength testing machine according to the standards BS1881:Part116:1983 and ASTM C 39-03 has been used for testing the compressive strength of twenty-four cube specimens with diameter of 100 x 100 x 100 mm. Figure 3.9 shows the cube specimens used for the compressive strength test during and after the test is carried out.

The procedures are steps below:

i. First, the dimension and weight of each specimen is recorded.
ii. Then, the specimens are wiped clean and they are placed at the center of the testing machine.
iii. Next, the load is applied continuously until the specimen fails and the maximum load carried by the specimen during the test, type of failure and the appearance of the specimens is recorded.
iv. Lastly, the compressive strength of the specimen is calculated by taking the average of the cube specimens.



(a) During test (b) After test

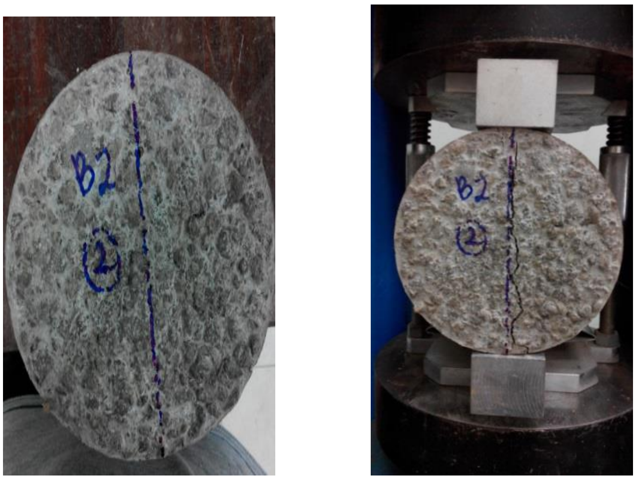
Figure 3.9: Compressive strength test

3.4.3 Splitting Tensile Strength Test

Splitting tensile strength at 28 days of curing test for three of the cylinders specimens with diameter of 150 x 300 mm is indirect measurement of tensile strength of concrete that conducted under the requirement of AASHTO T 79. Figure 3.10 shows the cylinder specimen used for the test before and after the test is conducted.

The procedures are stated below:

i. First, the length and diameter of the specimens is measured at three different positions then, the average diameter is calculated.
ii. Second, the cylindrical concrete specimen is placed on the center of the testing machine.
iii. Then, the load reading is recorded until the specimens failed.
iv. Lastly, the final length and diameter at the breaking point is measured. A tensile strength testing machine is used for the testing.



(a) Before test (b) During test

Figure 3.10: Splitting tensile strength test

3.4.4 Flexural Strength Test

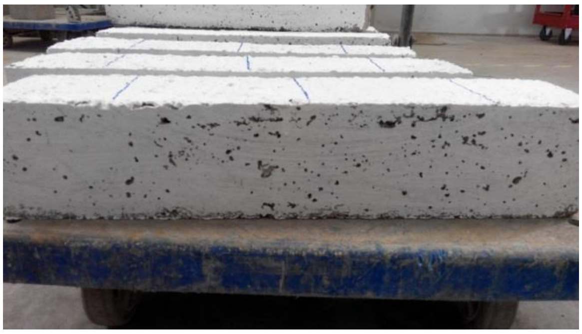
Flexural strength test at 28 days of curing test was conducted according to the requirements of BS 1881:Part118 and ASTM C 78-02 using three 100 x 100 x 350 mm of prism. Figure 3.11 shows the prism used for the testing.

The procedures are specified below:

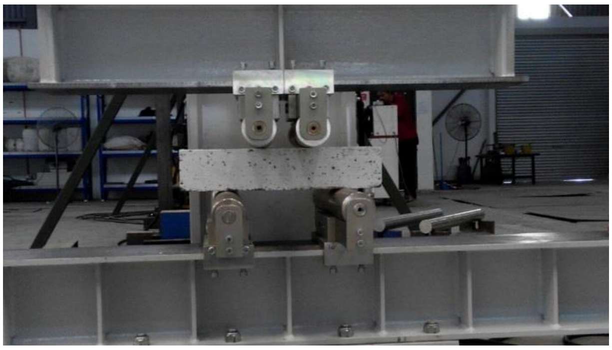
i. First, the weight and dimension of the specimens is measured. The location of supports and loading points on the surface of the specimens is indicated.

ii. Then, the specimen is turned on its side with respect to its position when moulded, and it is centered on the supporting bearing blocks. The load applied shall be brought in contact with the upper surface at the center line between the supports. Grind, cap or leather shims is used on the specimen contact surface to eliminate any gap in excess of 0.10 mm between the specimen and the load applying or support blocks.

iii. Next, the specimen is loaded continuously and without shock until rupture occurs. The maximum load carried by the specimens during testing is recorded and the specimen cross-section is measured at one of the fractured faces. For each dimension of cross-section, one measurement at each edge and one at the center of the cross-section is taken. Three measurements for each direction is used to determine the average width and depth to the nearest 1 mm (include the cap thickness if the fracture occurs at a capped section). A flexural testing machine is used for testing the specimens.



(a) Prism specimen ready to assemble in flexural machine



(b) Prism during flexural test

Figure 3.11: Flexural strength test

3.4.5 Elastic Modulus

In Elastic Modulus test, three moulded concrete cylinder with diameter of 150 x 300 mm is used. The usual method of determining the modulus of elasticity is to measure the tangent modulus. It is defined as the slope of the tangent to the stress-strain curve at some percentage of the ultimate strength of the concrete as determined by compression test. The test was carried out following the requirements of BS 1881-121-1983. Figure 3.12 shows the cylinder with strain gage used for the test.

The procedures are shown below:

i. First, the specimen needs to be aligned in the machine used before it can be loaded.

ii. Then, the specimen is loaded a total of three times where the first time is a trial run to check the seating of the gauges, the rate of loading and any other unusual set up. Therefore, there is no reading taken for the trial run. For the second and third runs, loading of 40% of the compressive strength of the companion specimen is applied to the concrete cylinder specimens.

iii. Lastly, the Elastic Modulus is calculated using the data recorded. An Elastic Modulus testing machine is used for the testing.

(a) Cylinder prepared to be tested (b) During test conducted

Figure 3.12: Modulus elasticity test

CHAPTER 4

RESULT AND DISCUSSION

4.0 INTRODUCTION

This chapter shows the results obtained from the data collection. The results was obtained from the test conducted was recorded and analyzed.

4.1 SLUMP HEIGHT

During the mixing of the concrete, slump test was done to measure the consistency of fresh concrete mix. There are several factors that affect the consistency of the fresh concrete such as concrete components ratios, cement fineness (cement surface area), air temperature and admixture used. The results of slump test carried out were recorded in Table 4.1.

Table 4.1: Results for slump test

W/C	Slump height, mm
0.55	40
0.60	60
0.65	150

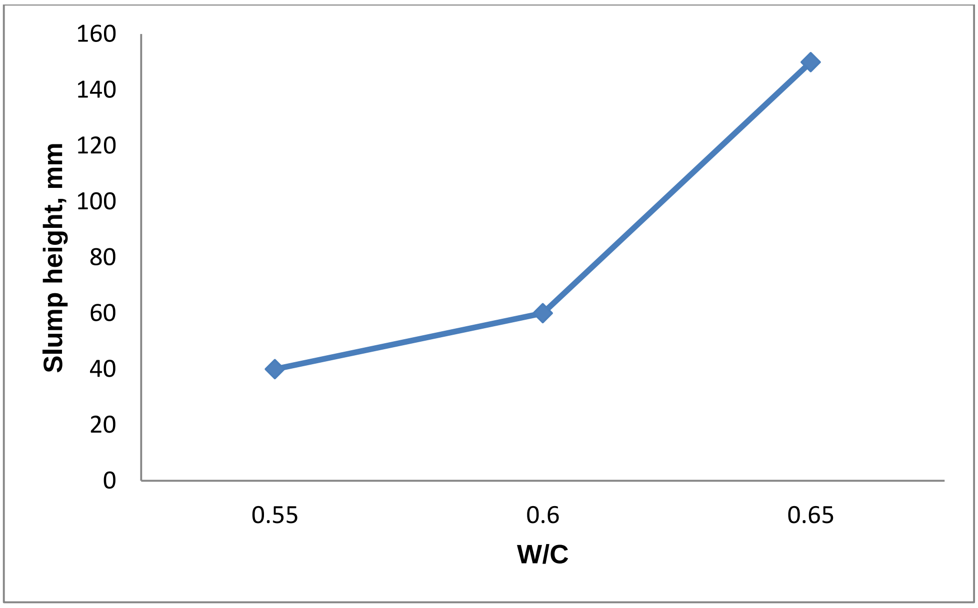


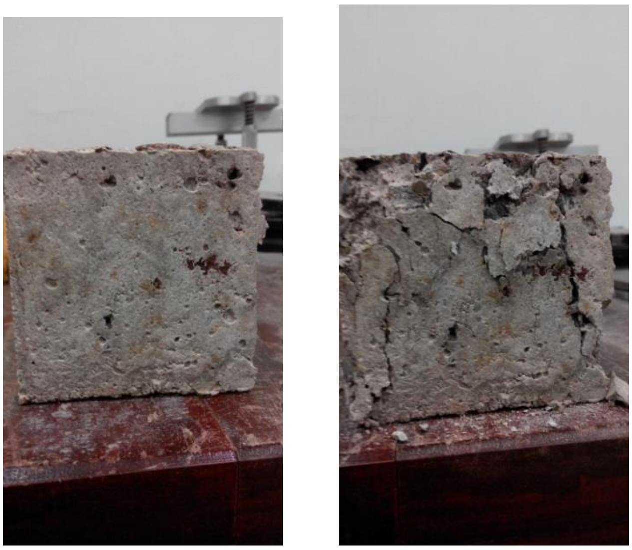
Figure 4.1: Relationship between slump height and W/C

Figure 4.1 shows the relationship between the slump heights with water to cement ratio. It shows that water to cement ratio of 0.65 has the highest dropped with 150 mm compared to 0.55 and 0.60 where both are 40 mm and 60 mm respectively. This is because of the water used in each of the water to cement ratio is different from each other and it influence the slump height. From the slump test conducted, it shows that the higher the water content, the greater the slump dropped. The slump test done indicates that water to cement ratio of 0.55 is better than 0.60 and 0.65. This is because the greater the amount of water in a concrete mix, the more dilute the cement paste will be.

4.2 COMPRESSIVE STRENGTH TEST

4.2.1 Compressive Strength Value

The compressive strength results for of OPS concrete for 7 and 28 days are shown in Table 4.2. The picture of the cube before and after the test are shown; (a) and (b) in Figure 4.2.



(a) Before test (b) After test

Figure 4.2: Cube specimens before and after test

Table 4.2: Results for compressive strength

W/C	Compressive strength, MPa	
	7 days	**28 days**
0.55	9.002	10.598
	12.477	12.538
	9.393	10.416
0.60	11.510	15.171
	12.454	14.650
	11.249	15.120
0.65	8.314	9.151
	8.397	10.308
	10.268	11.119

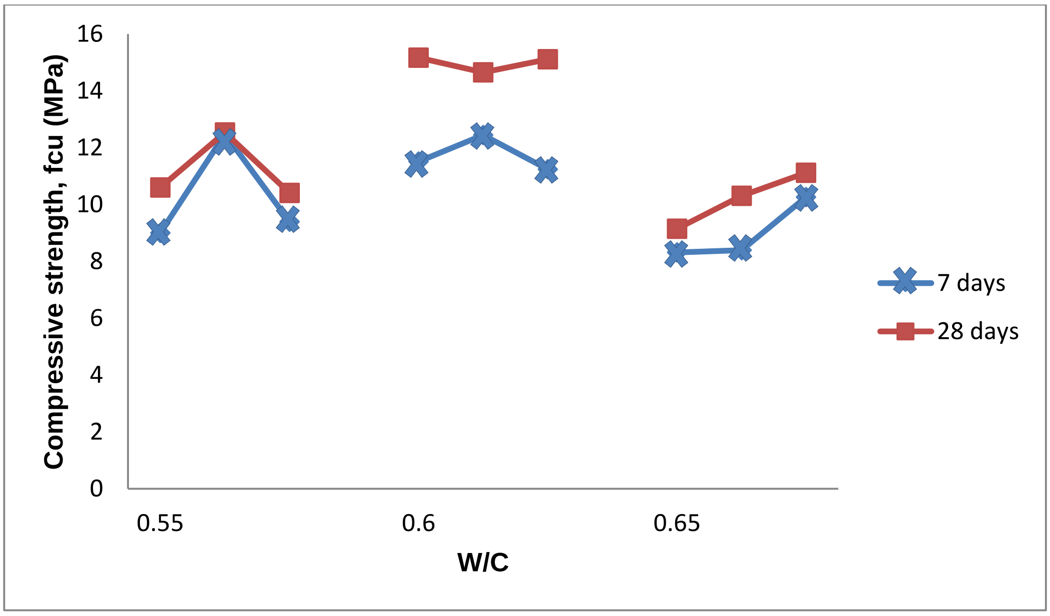


Figure 4.3: Relationship between compressive strength of cubes and W/C

Figure 4.3 represents the relationship between compressive strength of cubes with water to cement ratio for 7 and 28 days. The figure indicates that water to cement ratio of 0.60 has the highest strength for 7 and 28 days with the average for the three specimens of 11.737 MPa and 14.980 MPa respectively. Then, it is followed by water to cement ratio of 0.55 with average of 10.291 MPa and 11.184 MPa for 7 and 28 days. Water to cement ratio of 0.65 has the lowest compressive strength for both 7 and 28 days with 8.993 MPa and 10.193 MPa respectively.

The compression failure pattern indicates that OPS aggregates governed the failure as observed by broken cubes. From the broken cubes, the failure was observed due to the breakdown in the bond between OPS and the cement paste. This is because of organic effect and smoothness of OPS surface which could be overcome by treated the OPS aggregates with lime solution before mixing (Salam SA, 1982). Besides that, the honeycomb inside and on the surface of the cubes also influence the cubes strength.

4.2.2 Comparison between Cube and Cylinder Compressive Strength Value

Table 4.3 indicates the results for compressive strength for cubes and cylinder at 28 days.

Table 4.3: Results for compressive strength for cubes and cylinder at 28 days

W/C	Compressive strength, MPa (28 days)	
	Cube	Cylinder
0.55	11.184	13.265
0.60	14.980	9.243
0.65	10.193	6.753

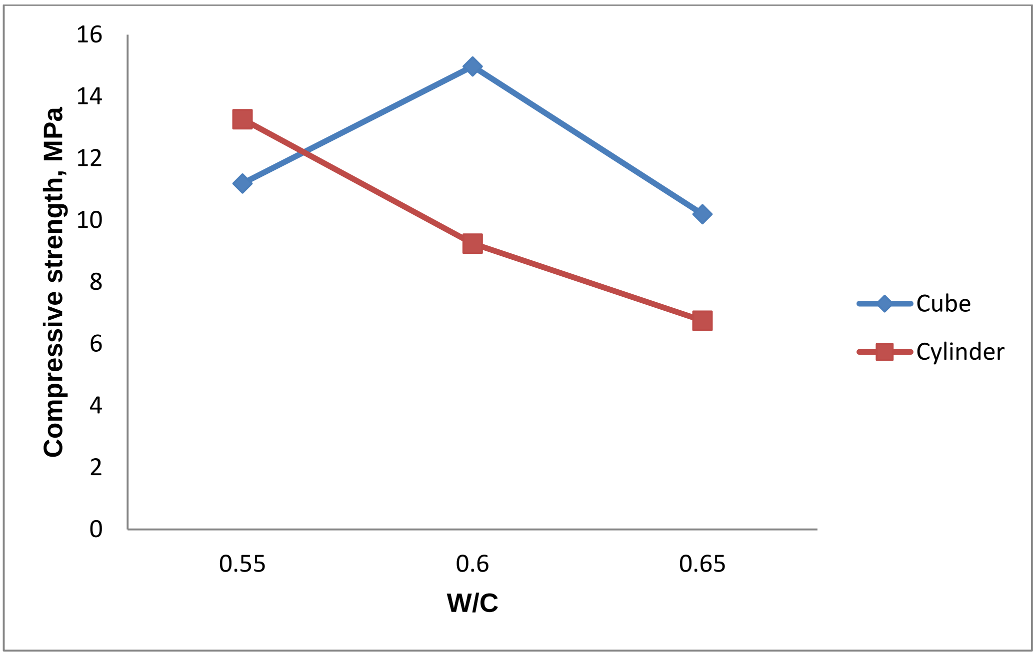


Figure 4.4: Relationship between compressive strength of cubes and cylinder and W/C

Figure 4.4 shows the relationship between compressive strength of cubes and cylinder with water to cement ratio for 28 days. From the figure, the compressive strength for the cube is increasing from 0.55 with 11.184 MPa until water to cement ratio of 0.60 with 14.980 MPa and then decrease with 10.193 MPa for 0.65. It is different with the cylinder because the compressive strength is decreasing start from water to cement ratio 0.55, 0.60 and 0.65 with 13.265 MPa, 9.243 MPa and 6.753 MPa respectively.

Table 4.4 shows the variation percentages between cubes with water to cement ratio of 0.60 and 0.65, compared with 0.55.

Table 4.4: Variation percentage of cubes

W/C	**Variation Percentage, %**	
	7 days	**28 days**
0.60	14.06	33.94
0.65	12.61	8.86

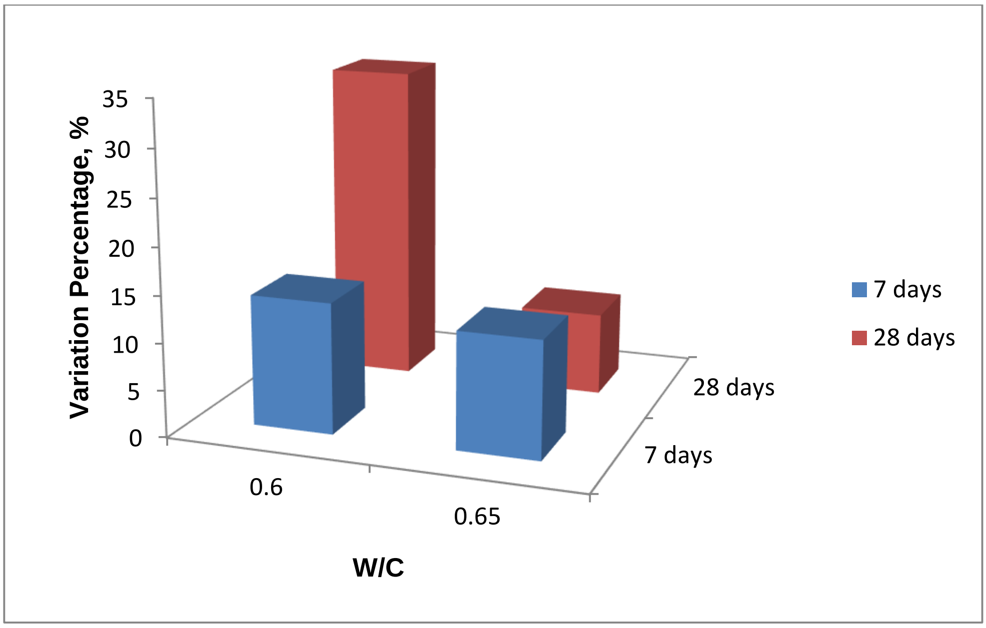


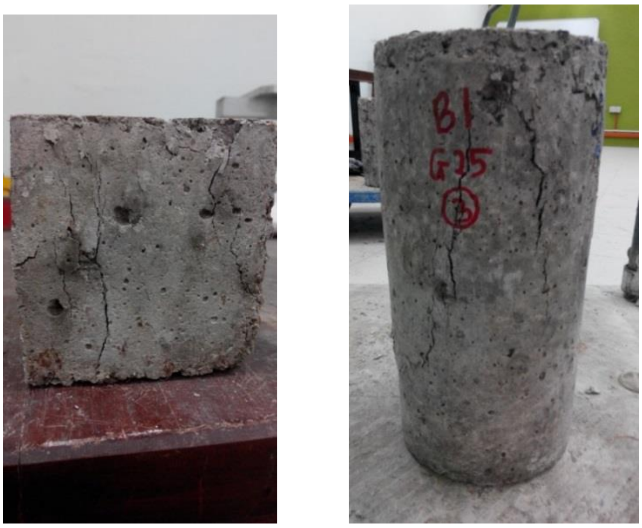
Figure 4.5: Relationship between variation percentages of cubes and W/C

Figure 4.5 indicates the relationship between the percentages of cubes with water to cement ratio. From the figure, it shows that at 7 days, the strength percentage increased with 14.06 % for water to cement ratio 0.60 and then, decreased with12.61 %

at water to cement ratio of 0.65. For 28 days, the strength percentage increased with 33.94 % for water to cement ratio 0.60. Then, the strength percentage is recorded decrease with 8.86 % which is for water to cement ratio of 0.65.

4.2.3 Mode of Failure

Under pure uniaxial compression loading, the failure cracks generated are approximately parallel to the direction of applied load with some cracks formed at an angle to the applied load as can be seen in Figure 4.6. Figure 4.6 shows the failure pattern for cube and cylinder undergoing compression strength test.



(a) Cube (b) Cylinder

Figure 4.6: Failure pattern for cube and cylinder after compressive strength test

The cube and cylinder specimen is undergoing the lateral expansion due to the Poisson’s effect which is the transverse contraction strain to longitudinal extension strain in the direction of stretching force. The steel platens of the compression testing machine do not undergo the lateral expansion to the same extent that of concrete. There exist differential tendencies of lateral expansion between steel platens and concrete cube faces; as a result of which tangential forces are induced between the end surfaces of the concrete specimen and the adjacent steel platens of the compressive strength test machine. Besides that, the lateral shear stress decreases towards the center so the cube and cylinder have near vertical cracks at cube's center.

4.3 SPLITTING TENSILE STRENGTH TEST

4.3.1 Splitting Tensile Strength Value

The splitting tensile strength results for of OPS concrete are shown in Table 4.5. The picture of the cylinder before and after the test is shown in Figure 4.7.

(a) Before test (b) After test

Figure 4.7: Cylinder specimens before and after test

Table 4.5: Results of splitting tensile strength for cylinder at 28 days

W/C	Splitting tensile strength, MPa
0.55	1.549
	1.769
	1.395
0.60	1.660
	1.422
	1.345
0.65	0.744
	0.559
	0.661

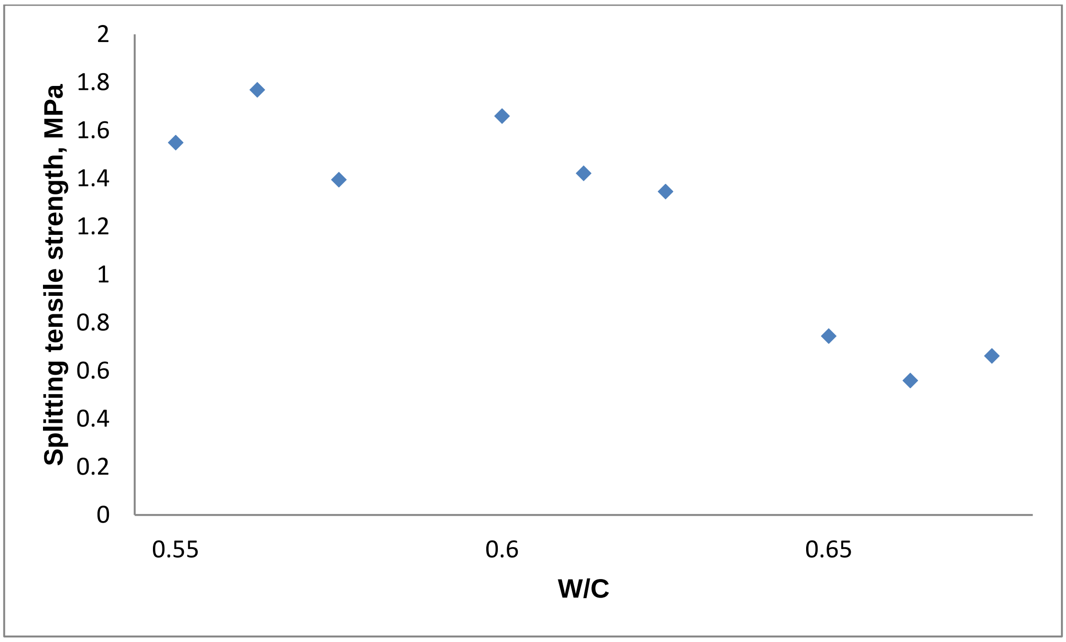


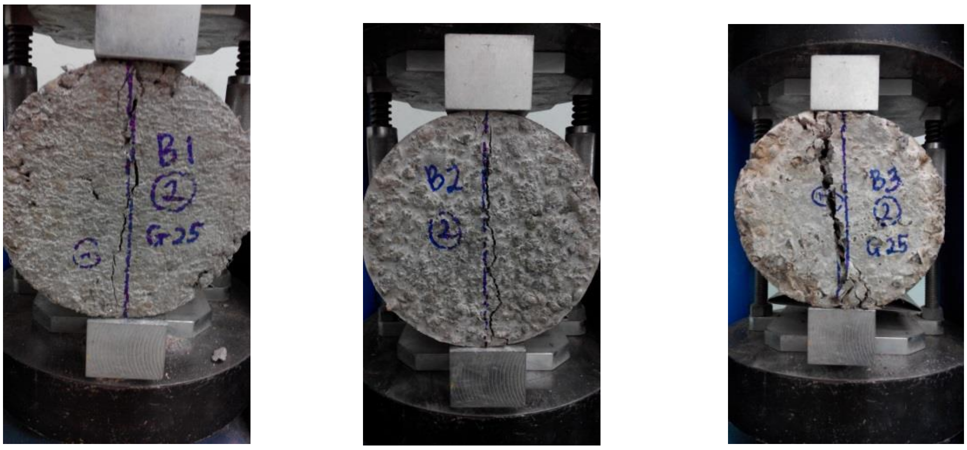
Figure 4.8: Relationship between splitting tensile strength of cylinder and W/C at 28 days

Figure 4.8 refers the relationship between splitting tensile strength of cylinder with water to cement ratio for 28 days. The results indicates that the splitting tensile strength for water to cement ratio of 0.55 is the highest followed by 0.60 and 0.65. The strength for water to cement ratio 0.55 is 1.571 MPa, 1.476 MPa for 0.60 and 0.655

MPa for water to cement ratio of 0.65 according to the average from the three specimens.

4.3.2 Mode of Failure

The initial crack is located to take place when the tensile stress reaches the uniaxial tensile strength of the material. Then, it is followed by a crack opening phase where aggregate bridging is responsible for crack bridging stress. Figure 4.9 shows the crack pattern of the cylinder after the test. Most of the crack occurs at the centerline where the load is applied. If the material is sufficiently brittle, the splitting will proceed until the specimen is divided into two halves.



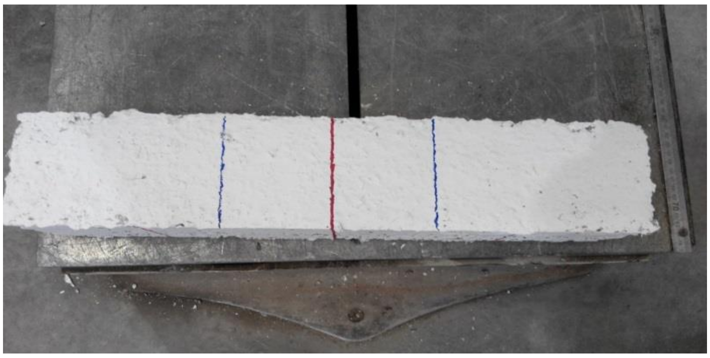
(a) W/C = 0.55 (b) W/C = 0.60 (c) W/C = 0.65

Figure 4.9: Failure mode of cylinder

4.4 FLEXURAL STRENGTH TEST

4.4.1 Flexural Strength Value

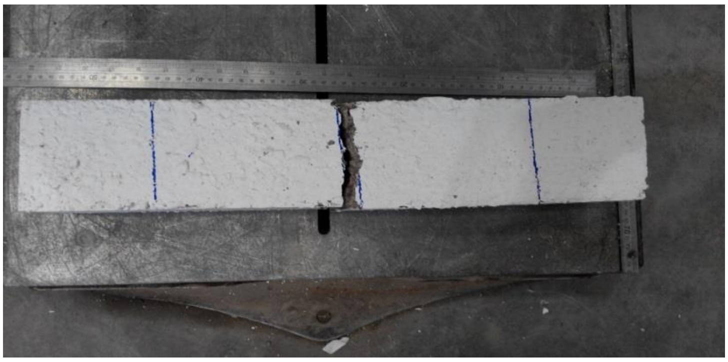
The flexural strength results for of OPS concrete at 28 days are shown in Table 4.6. The pictures of the prism from the test are shown in Figure 4.10 and Figure 4.11.



(a) Plan view

(b) Front view

Figure 4.10: Prism specimens before test



(a) Plan view

(b) Front view

Figure 4.11: Prism specimens after test

Table 4.6: Results of flexural strength for prisms at 28 days

W/C	**Stress, MPa**
0.55	1.631
	1.742
	1.686
0.60	3.610
	3.200
	3.020
0.65	1.357
	1.396
	1.326

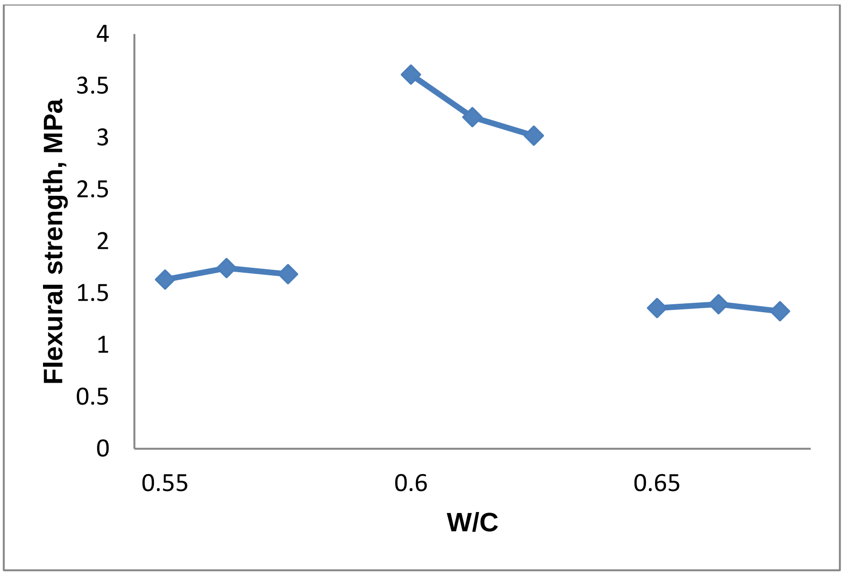


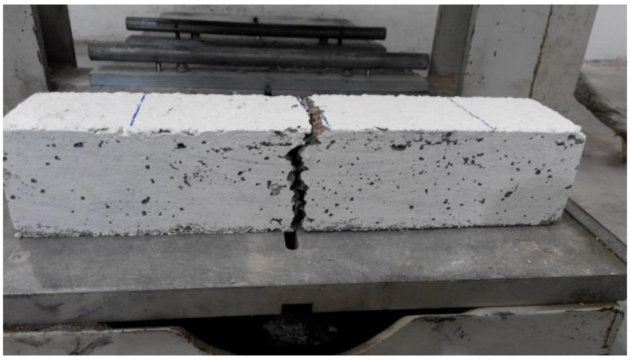
Figure 4.12: Relationship between flexural strength for prisms and W/C at 28 days

Figure 4.12 indicates the relationship between the flexural strength for prisms with water to cement ratio for 28 days. From the figure, it shows that at 28 days, the strength at water to cement of 0.60 has the highest stress with the average of 3.28 MPa. The second highest is 0.55 with 1.360 MPa and the lowest is water to cement ratio of 0.65 with 1.686 MPa.

4.4.2 Mode of Failure

The failure mode observed to take place when the tensile stress reaches the uniaxial tensile strength of the material. Figure 4.13 shows the crack pattern of the prism after the test. Most of the crack occurs at the centerline where the load is applied. Several prisms proceed until the specimen is divided into two halves as shown in Figure 4.13 because of the brittle materials. The crack also occurs mostly at the centerline because of the applied load at the center.

(a) W/C = 0.55



(b) W/C = 0.60

(c) W/C = 0.65

Figure 4.13: Failure mode of prisms

4.5 MODULUS OF ELASTICITY

4.5.1 Stress – Strain Curve

The modulus of elasticity results for of OPS concrete at 28 days are shown in Table 4.7, 4.8 and 4.9. The picture of the cylinder before; (a) and after (b) from the test are shown in Figure 4.14.

(a) Before (b) After

Figure 4.14: Cylinder with strain gauge for modulus elasticity test before and after

Table 4.7: Results of elastic of modulus for W/C 0.55

Stress, kN/mm^2 (x10^{-3})	Strain, mm/mm (x10^{-6})
0.0	0
0.1	0
0.2	-77
0.4	-176
0.7	-302
1.0	-452
1.4	-616
1.7	-797
2.1	-988
2.5	-1191
3.0	-1410
3.4	-1648
3.9	-1897
4.4	-2170
4.9	-2467
5.4	-2793
5.9	-3130
6.4	-3472
6.9	-3814
7.4	-4136
8.0	-4448
8.4	-4752
8.9	-5020
9.3	-5188
9.8	-5247
10.1	-5294
10.5	-5317
10.8	-5324
11.0	-5294
11.2	-4857
11.3	-4123
11.3	-3593
11.2	-3335
11.1	-3090
10.9	-2928
10.7	-2735
10.4	-2548
10.1	-2442
9.8	-2357
9.5	-2254
9.2	-2156
8.9	-2066
8.7	-1988
8.4	-1935
8.1	-1909

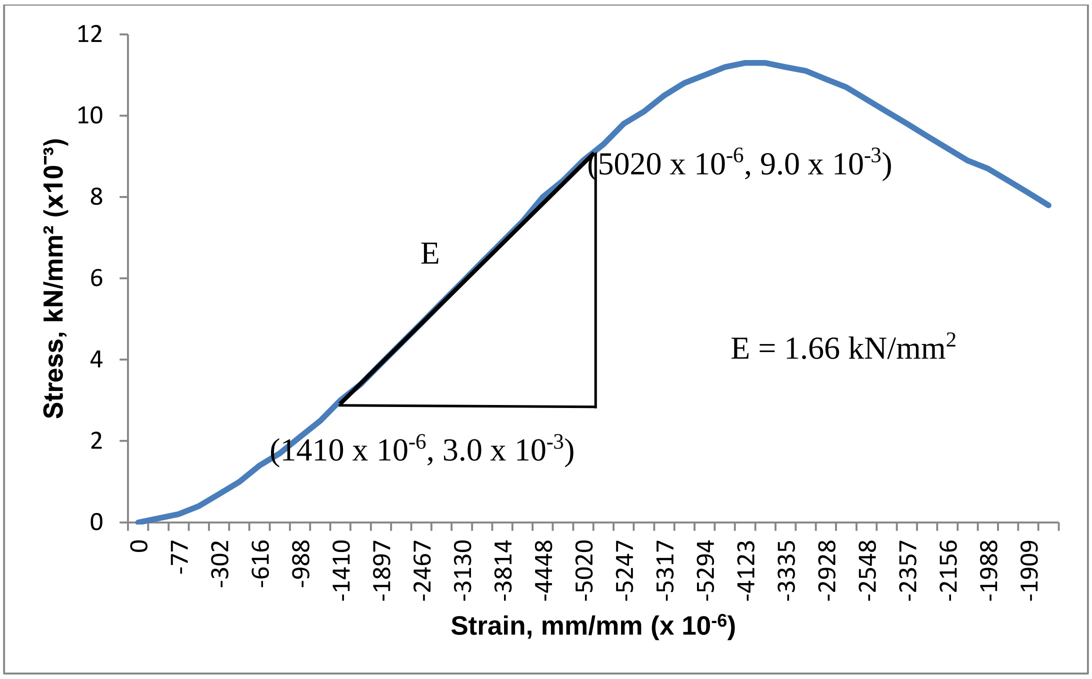


Figure 4.15: Relationship between stress and strain for W/C 0.55

Figure 4.15 represents the relationship between the stress with strain for water to cement ratio of 0.55 for 28 days. The figure shows that at 28 days, the modulus elasticity increase and achieved the peak at strain with the value of -4123 x 10^{-6} mm/mm along the stress of 11.3 x 10^{-3} kN/mm². After that, the value decrease gradually and then, started to achieve it limits. The gradient which is the elastic modulus, E, for water to cement ratio 0.55 is 1.66 kN/mm^2.

Table 4.8: Results of elastic of modulus for W/C 0.60

Stress, kN/mm^2 (x10^{-3})	Strain, mm/mm (x10^{-3})
0.0	0
0.2	0
0.4	-63
0.6	-141
0.6	-232
1.0	-334
1.4	-448
1.8	-568
2.2	-688
2.7	-804
3.2	-934
3.7	-1076
4.3	-1224
4.9	-1370
5.6	-1510
6.2	-1655
6.8	-1805
7.4	-1957
8.1	-2111
8.6	-2272
9.2	-2439
9.7	-2611
10.0	-2791
11.0	-2962
11.0	-3120
11.0	-3239
11.0	-3285
Stress, kN/mm^2 (x10^{-3}) (continued)	**Strain, mm/mm (x10^{-6}) (continued)**
11.0	-3302
11.0	-3286
11.0	-3222
11.0	-3130
10.0	-3016
9.9	-2910
9.5	-2813
9.2	-2680
8.9	-2517
8.5	-2412
8.2	-2369
7.9	-2237
7.5	-2073
7.1	-1865
7.1	-1606
7.1	-1453
7.0	-1389

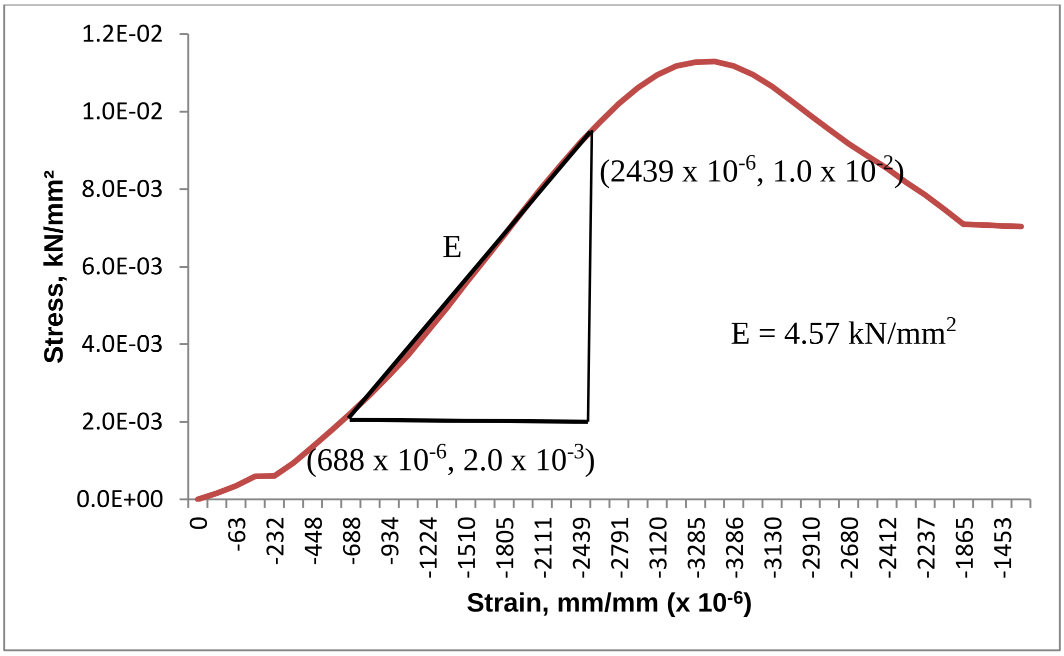


Figure 4.16: Relationship between stress and strain for W/C 0.60

Figure 4.16 represents the relationship between the stress with strain for water to cement ratio of 0.60 for 28 days. From the figure, it shows that at 28 days, the modulus elasticity increase and achieved the peak at strain with the value of -3302 x 10^{-6} mm/mm along the stress of 11.0 x 10^{-3} kN/mm². After that, the value decrease gradually and then, started to achieve it limits. The gradient which is the elastic modulus, E, for water to cement ratio 0.60 is 4.57 kN/mm^2.

Table 4.9: Results of elastic of modulus for W/C 0.65

Stress, kN/mm^2 (x 10-3)	Strain, mm/mm
0.0	0
0.2	-32
0.4	-64
0.6	-96
0.9	-129
1.2	-162
1.6	-196
2.0	-236
2.5	-277
3.0	-318
3.5	-362
4.0	-410
4.5	-453
5.0	-500
5.4	-554
5.8	-608
6.2	-659
6.5	-704
6.8	-751
7.0	-802
7.1	-849
7.2	-889
7.2	-910
7.2	-924
7.1	-927
7.1	-922
7.0	-910
Stress, kN/mm^2 (x10^{-3}) (continued)	**Strain, mm/mm (x10^{-6}) (continued)**
6.9	-890
6.8	-862
6.6	-827
6.5	-786
6.3	-734
6.1	-692
5.9	-653
5.7	-578
5.5	-501
5.3	-420
5.1	-335
4.9	-254
4.7	-201

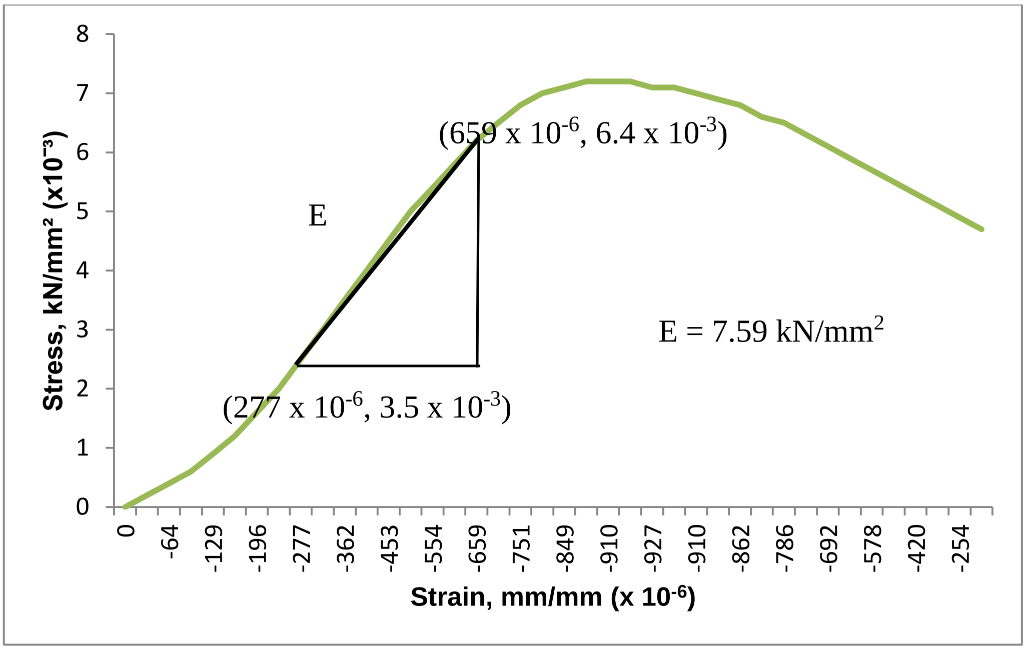


Figure 4.17: Relationship between stress and strain for W/C 0.65

Figure 4.17 shows the relationship between the stress with strain for water to cement ratio of 0.65 for 28 days. From the figure, it indicates that at 28 days, the modulus elasticity increase and achieved the peak at strain with the value of -927 x 10^{-6} mm/mm along the stress of 7.1 x 10^{-3} kN/mm². After that, the value decrease gradually and achieved it limits. The gradient which is the elastic modulus, E, for water to cement ratio 0.65 is 7.59 kN/mm^2.

4.5.2 E – value

Table 4.10 shows the results for elastic modulus, E, that is calculated from the graph.

Table 4.10: Results of E - value

W/C	**E – value (kN/mm^2)**
0.55	1.66
0.60	4.57
0.65	7.59

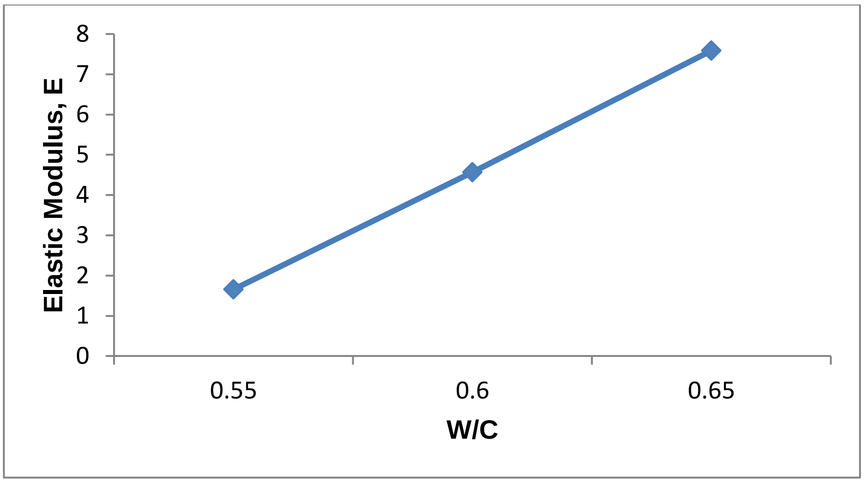


Figure 4.18: Relationship between elastic modulus and W/C

Figure 4.18 represents the relationship between elastic modulus, E and water to cement ratio. It shows that the E – value increase from water to cement ratio 0.55 to 0.65 where 0.65 has the highest E – value with 7.59. The second highest is water to cement ratio of 0.60 with 4.57 and the lowest is 1.66 for water to cement ratio of 0.55.

4.5.3 Mode of Failure

From the test conducted, the cylinder did not exhibit brittle failure when load is applied. The crack can be seen occurs at the place where the strain gage is placed. Most of the crack observed to occur near the place and at the upper surface of the cylinder as shown in Figure 4.19. Figure 4.19 shows the failure mode for all water to cement ratio.

(a) W/C = 0.55 (b) W/C = 0.60 (c) W/C = 0.65

Figure 4.19: Failure mode

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS

In this chapter, it concluded the result obtained about the test conducted in the research and the recommendation towards the future research related in this field is also provided.

Based on the result of this research, it can be concluded that:

i. The water to cement ratio influence the mechanical properties of oil palm shell. This is due to the angular and rough edges of the oil palm shell (OPS) besides the other characteristic of the oil palm shell itself.
ii. The optimum water to cement ratio used for the production of the oil palm shell lightweight aggregate concrete is 0.60. Concrete with low water to cement ratio is most suitable to use for the production of the oil palm shell lightweight aggregate concrete which is in the range of 0.55 - 0.60 in this research.

5.2 RECOMMENDATIONS

Some recommendations can be taken in this research which is dry the oil palm shell for a long time. In this research, the oil palm shell used is dried only for a few days using room temperature. By drying the oil palm shell in long time, the strength can be maximized and the target strength can be achieved. Besides that, bigger size of oil palm shell can be used to give greater strength for the concrete.

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APPENDIX

Mix Design

W/C	**Mix Design**			
	Water (kg/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Oil Palm Shell (kg/m^3)
0.55	183.15	333	710	305
0.60	200	333	710	305
0.65	216.45	333	710	305