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Effects of Mechanical Properties on Unconventional Concrete where Coarse Aggregate is replaced by Palm Oil Clinker (POC)

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ABSTRACT

This work is regarding the investigation on compressive strength, flexural strength and tensile strength of unconventional concrete using waste material. The material used in this project is palm oil clinker and it has been used to replace conventional coarse aggregate in concrete. The main objective of this research is to support the usage of waste product which helps to reduce the usage of conventional construction materials that are decreasing in terms or quantity and increasing in terms of price. The rate at which extinction of natural resources and pollution is increasing day by day is becoming alarming. The pollution of the environment in causing irreparable damage to the earth and it can be avoided by the usage waste materials which can be easily obtained. Other than that, factors affecting the mechanical properties of concrete are studied throughout the literature review. This has been done in order to combine information gained into this research and provide a better solution for palm oil clinker concrete. The various tests were performed on five different types of concrete mix with different percentage of palm oil clinker as a coarse aggregate replacement. This is to study the characteristic of palm oil clinker in concrete and as well as the changes that it makes in the strength of concrete. From the result obtained, due to its water absorbing characteristic, size and shape, palm oil clinker increase the bonding between aggregate by filling in the voids. Furthermore palm oil clinker enables internal curing which allows concrete strength to be higher. It has reduced the porosity of concrete, which means it has increased the strength of concrete. Lastly, palm oil clinker as coarse aggregate replacement in concrete has a major impact in the future of construction industry by drastically increasing the strength of concrete as well as the eradication of waste.

Keywords : POC As Coarse Aggregates, Mechanical Properties, Concrete Mix, Waste Product.

I. INTRODUCTION

This research investigates the mechanical properties of untraditional concrete mix design where coarse aggregate (CA) is replaced by waste material which is Palm oil clinker (POC). The aim of this paper is to enable sustainable concrete design mix as well as to obtain higher strength of lightweight concrete in an economical way. Malaysia is one of the largest exporters of palm oil which accounts for 39% of world palm oil production and 44% of world export. Palm oil is usually extracted after several processing operations from the fruit which comprise of the flesh, seed and kernel. During the production palm oil, large amount of waste is produced. POC is considered as a by-product waste produced from burning of palm oil fiber and oil palm shell inside the boiler under high temperature. POC is a major source of waste in the manufacture of palm oil. It is produced abundantly and dumped into the environment.

Figure 1. Disposal of POC

Conventional concrete comprise of cement, water, fine aggregate and coarse aggregate. Due to the increase in the demand in these products in the construction industry, the depletion of the environment has in turn been drastically increased. POC enables the concrete to be a lightweight concrete. The benefits of using lightweight concrete have brought enormous positive contributions to the construction industry. With the implementation of this method, the usage of natural sources which is obtained by excavation of mountain, rivers or on the ground can be eradicated. These natural resources are reducing day by day which in turn making construction costs to go higher. These natural resources need to be taken care of as it is the habitat for both plants and animals. The ecosystem will be affected when deforestation take place because plants play a major role in balancing the gas cycle in the atmosphere and reduces the heat on earth. Extinction of protected species can also happen if the appropriate measures are taken as soon as possible. Usage of waste materials needs to be implemented in order to save the environment as well as to run the construction industry obstacle free.

II. METHODS AND MATERIAL

This chapter is briefly on the methods that are used to achieve the objective of this project. The main goal of this project is to obtain the Mechanical properties of concrete containing different percentage of palm oil clinker as a replacement of coarse aggregate. There will be one standard mix and mix with four different percentage of POC. The percentage of POC used will be 0%, 12.5%, 25%, 37.5% and 50% Through the mechanical property, the most suitable mix with high strength can be obtained and apply it in concrete technology for future use.

Before proceeding with the mechanical properties, each material that is used in concrete will be tested. Some of the key experimental analysis in this research is:

- Determination of trial mix design
- Determination of moisture content for CA and FA
- Determination of water absorption for CA and POC
- Sieve Analysis for CA and FA
- Testing of cement
- Determination of workability of concrete
- Compressive Strength Test
- Tensile Splitting Test
- Flexural strength Test

The most common materials used in this research are cement (ordinary Portland cement), fine aggregate (sand), coarse aggregate (crushed stone), Palm oil clinker (POC), superplasticizer (conplast sp2000) and water.

After careful investigation at various cement plant, a suitable trial mix design was obtained from CEMEX CONCRETE Sdn Bhd. After the sampling of numerous number of cubes a design mix ratio of 1:1.6:2.1 was obtained. The trial mix design proportion is often devised by taking into consideration the physical properties of each and every material. The standard deviation is obtained by the grade of concrete required. In this investigation high strength concrete of grade 40 has been taken into consideration.

A trial mix design proportion for normal OPC concrete has been used for all analytical and experimental analysis. A standard deviation of 4.6 N/mm^2 was used in the trial mix design. The size of coarse aggregate is 20 mm whereas the maximum size of fine aggregate used was 5 mm. The amount of superplasticizer used was 350ml per kg of cement. The slump was devised to be between 75 to 125 mm. From the trial mix design, all the quantities of materials for all the concrete specimens were calculated prior to batching of concrete.

Water content experiment is to determine the water content in a sample to check the percentage of moisture retained in an original sample. This can be used to determine the porosity of sample as well as its ability to keep water inside it. In order to check the percentage of water in a sample, it has to be dried in an over at 100 degrees Celsius for 24 hour. Water has a boiling point at 100 degrees Celsius and this is the part where the water particles in the sample change into gas particles. Voids occur when water evaporates and dry mass of a sample can be obtained. Sand and crushed stone will be tested for water content experiment. Palm oil clinker cannot be tested for this experiment because POC that will be used in this project has already been dried during the processing of POC. Percentage of moisture content can be obtained when the differences between the original weight of sample and weight dried sample is divide with the weight of original sample.

Water absorption experiment is done to examine the ability of a sample to absorb water. The strength of specimen can be determine through this experiment where the sample with high absorption rate is not suitable to be used in concrete, because of high porosity which cause Mechanical properties. Both crushed stone and POC will be soaked in the water for thirty minutes and 24 hours to check the ability of sample in absorbing water. Before proceeding with this experiment, samples are dried overnight in the oven to ensure that the sample is dry and has empty voids.

Sieve analysis were done for both sand and crushed stone in this experiment. Objectives of sieve analysis are to obtain the sizes of particle in the sample and to check the suitability of the materials. Sand and crushed stone are dried in the oven for 24 hours at 100 degrees Celsius to remove the water. Weight of both sand and crushed stone was measured. Aggregates are place in the sieve analysis machine for 10 minutes and retaining aggregates on each sieve will be recorded.

Tests on cements are mostly sensory. The color of the cement should be uniform. The cement should be grey color with a light greenish shade. The cement should not contain any traces of hard lumps. Such lumps are normally formed by the absorption of moisture from the atmosphere. Any bag of cement containing lumps should be rejected. When touched or rubbed in between fingers, cement should feel smooth. If it is felt rough, it indicates adulteration with sand. If hand is inserted in a bag of cement, it should feel cool and not warm. If cement is thrown in a bucket of water, the particles should float for some time before it sinks. Slump test and compacting factor tests are commonly used workability tests for concrete. The degree of workability of concrete depends on the results obtained from slump test and compacting factor tests.

Steps towards the mechanical properties are displayed below:

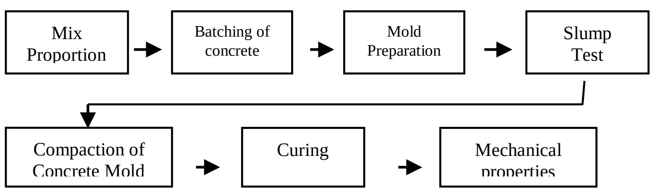

Figure 2. Steps towards mechanical properties

Once batching of concrete is done, the molds which have been previously oiled with mechanical engine oil are filled according to the required standard procedures. Every 50mm layer is tampered 25-30 times. Each stroke is penetrated in the underlying layer and the bottom layer is rodded throughout its depth. Once the top layer has been compacted, the surface of the concrete is filled until the finished level with the top of the mold. Using a trowel bar, the concrete is flattened and the latter is place to dry away from rain and sun.

Curing is carried out to prevent the loss of moisture from the concrete while maintaining a good temperature regime. The curing process enables the prevention of the development of varying temperature gradients in concrete. Once the specimen is dried after 24hrs, it is marked and removed from the molds and immediately submerged in clean fresh water until taken out for respective testing according to curing periods.

Table 1. The amount of material used for each specimen

Design Mix	Total no. of materials for beams	Total no. of materials for cylinders	Total no. of materials for cubes
C (Kg)	399	134.05	86.2
FA (Kg)	638	214.45	137.9
CA (Kg)	628.35	211.13	135.75
POC (Kg)	209.65	70.38	45.25
W (L)	151.5	51	33
Sp (mL)	5187	1743	1125
w/c	0.38	0.38	0.38
Remarks	-	-	-
No. of specimen	45	45	45

Table 2. Mechanical property distribution after respective curing period for each specimen.

Days of curing	7	14	28
0% POC	3	3	3
12.5% POC	3	3	3
25% POC	3	3	3
37.5% POC	3	3	3
50% POC	3	3	3

Three major mechanical properties were observed in this research:

- Compressive strength test
- Tensile Splitting test
- Flexural test

NOTE: 45 samples were made for each mechanical property

Compressive strength test which is one of the major mechanical properties was carried out once curing period was done, the specimen was removed and excess water is wiped out from the surface. The dimensions of the specimen were taken to the nearest 0.01mm. The surface of the bearing machine was cleaned and the specimen was placed in the machine in such a way that the load is applied to the opposite sides of the cube casted. The specimen was aligned centrally on the base plate of the load bearing machine. The movable portion was rotated gently by hand so that the specimen touches the top surface. The load was applied gradually and continuously at the rate of 140kg/cm2/minute till the specimen fails. The maximum load was recorded and the results were compared.

Flexural strength test is a measure of an unreinforced concrete beam to resist failure in bending. Once the respective curing period is completed, the beam is taken out form the curing tank. The span length was 450 mm. The specimen was placed in the testing machine, correctly centered and with the longitudinal axis of the specimen at right angles to the longitudinal axes of the upper and lower rollers.

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The mold of cylinder should be of metal of thickness approximately 3mm. The mold is capable of being opened longitudinally so that the sample can be removed easily. The internal diameter of the mold was 150 mm and the height is 300mm. Each mold comprise of a metal base plate which should be coated with a thin film of mechanical engine oil before use, in order to prevent adhesion of concrete. Once the cylinder specimen is ready after its curing period, the latter is aligned so that the ends are vertical and centered over the bottom plate of the compressive strength machine. A load of approximately 14-21kg/cm2/minute was applied continuously without shock and the breaking load was recorded.

III. RESULTS AND DISCUSSION

Due to porosity in aggregates, water can be absorbed into the body of the particles or retained on the surface of the particle as a layer of moisture. Moisture content for fine aggregate is 1.62 % while for coarse aggregate is 2.61%. Due to the porosity and voids in coarse aggregate, it retains more water in pores of aggregate. Percentage of moisture content will affect the strength of the palm oil clinker. It might cause segregation; excess of water which enable failure in concrete strength.

The water absorption experiment is done to determine amount of water absorbed by materials when it is soaked in the water. For this experiment, both crushed stone and palm oil clinker were tested and the duration of this experiment were fixed to 30 minutes and 24 hours to determine how much water were absorbed. Dry sample were used in order to compare in this experiment. Absorption rate of 1.5% was obtained for crushed stone and compare to palm oil clinker, absorption rate was 7%. Palm oil clinker has a higher absorption rate and it helps concrete for internal curing. This will increase the strength of concrete at the later stage.

Sieve analysis result can be seen From thegraph below, the coarse aggregate is not suitable for use as concrete material. Only sieve size of coarse aggregate about 10mm-20mm is within the standard limit. Others fail to achieve the standard.

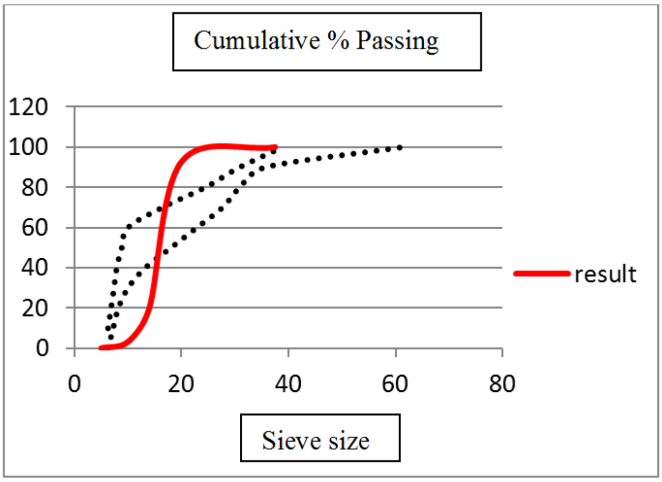

Figure 3: Sieve analysis for coarse aggregate

From the graph below, almost all points of result plotted are within standard limit; therefore tested fine aggregate is suitable for usage as concrete material or college, university, city, state and zip can be listed. If you list the email address make sure the Hyperlink is not attached. If the email address turns a color that means the hyperlink is active. Right click on the address and select Remove Hyperlink. There are 3 basic types of setups that will be encounter: One author, multiple authors from the same institution and multiple authors from multiple institutions. If the paper has one author use the affiliation layout as shown at the top of this document where all the author information is listed under the paper title. For multiple authors, from the same institution, list the common university, then list the email addresses at the end in the same order as the authors appear in the Author Listing. For

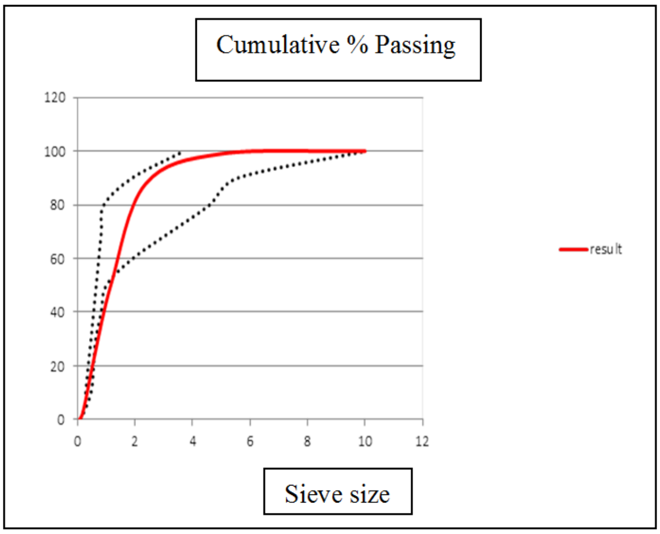

Figure 4: Sieve analysis for coarse aggregate

Batching of concrete takes usually 10-15 minutes. It comprise of rotating and stirring until all the surface of aggregate is coated with cement paste and all the ingredients of the concrete becomes a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer.

According to the trial mix design the workability should be within the range of 100mm to 150mm. After computing the slump test, an average value between the range of 110mm to 120mm was obtained for concrete cubes batch. For cylinder a higher value of workability was obtained, this may be due to several factors such as high moisture content, inadequate mixing or insufficient amount of superplasticizer. Concrete batch for beams has a workability of 100mm to 120mm.

After casting of the required specimen, the latter was placed in a dry place away for rain and sun for 24hrs.

Figure 5. Casting of cubes, cylinder and beams

After the samples have been dried, the molds are removed gently to avoid any damage.

Figure 6. Specimen after removing molds

The concrete samples are then placed in a curing tank for 7, 14 and 28 days according the required scheduled for experimental tests to be carried out. The mix designation and date of testing on each sample is written down for ease of recognition of each specimen. The water tank is placed in an appropriate place so that the water condition is not affected.

Once curing is done the sample is removed and excess water is wiped off. Each specimen is weight and the dimension is measured. The relative weight of concrete cubes consisting of 0 % POC is much higher compared to the different mix having 12.5% to 50 % POC. The weight is 20% lower compared to conventional concrete. The reduction in weight will enable a lower overall weight of the structure thus enabling the cost and design of the construction to be more efficient. According to BS Code the density of conventional concrete is between the range 2240kg/m3 to 2400kg/m3 compared to lightweight concrete which falls between 1440kg/m3 to 1840kg/m3. In this research study, the average density is approximately 1800kg/m3 to 1950kg/m3 which comply with BS standards.

Table 3. Average weight of concrete specimen

	AVERAGE WEIGHT OF CUBES(KG)	AVERAGE WEIGHT OF CYLINDER (KG)	AVERAGE WEIGHT OF BEAMS (KG)
0 % POC	7.58	12.25	34.52
12.5 % POC	7.20	10.46	32.90
25% POC	6.88	9.21	30.12
37.5% POC	6.56	8.79	28.12
50 % POC	6.21	8.32	27.19

Table 4. Compressive strength test results of cubes.

% POC	AVERAGE 7 DAYS CUBE STRENGTH	AVERAGE 14 DAYS CUBE STRENGTH	AVERAGE 28 DAYS CUBE STRENGTH
0%	26.00	34.32	42.36
12.5%	23.99	34.09	42.99
25%	22.65	34.39	44.06
37.5%	25.93	36.87	45.96
50%	20.65	25.59	37.05

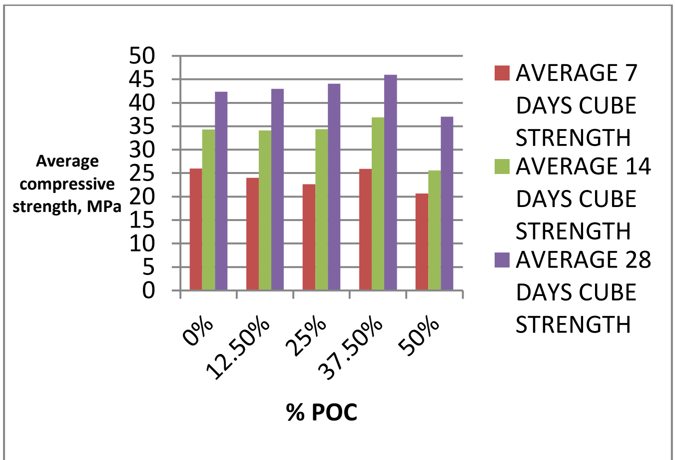

Figure 7. Compressive strength results

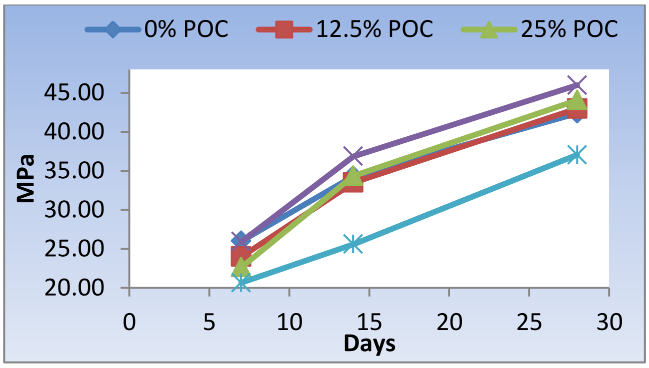

Figure 8. Compressive Strength vs curing period

The graph above shows that 37.5% POC concrete has higher strength compared to 0% POC which is conventional concrete. 37.5 % POC gives the optimum strength compared to the other percentage of POC used. 37.5% POC concrete achieve approximately 6% higher strength compared to normal conventional concrete. For 7 days curing period, the relative strength is similar to conventional concrete. 50% POC concrete shows a significant poor result compared to 0% POC concrete.

For tensile splitting results, the same method is applied. The specimen is centrally aligned and the load is continuously applied to determine tensile splitting. The extra length of the cylinder is considered negligible after computing load according the area.

Table 5. Tensile splitting test results of cylinders.

% POC	AVERAGE 7 DAYS CUBE STRENGTH	AVERAGE 14 DAYS CUBE STRENGTH	AVERAGE 28 DAYS CUBE STRENGTH
0%	2.65	3.47	4.36
12.5%	2.3	3.37	4.30
25%	2.26	3.46	4.38
37.5%	2.65	3.73	4.67
50%	2.04	2.55	3.68

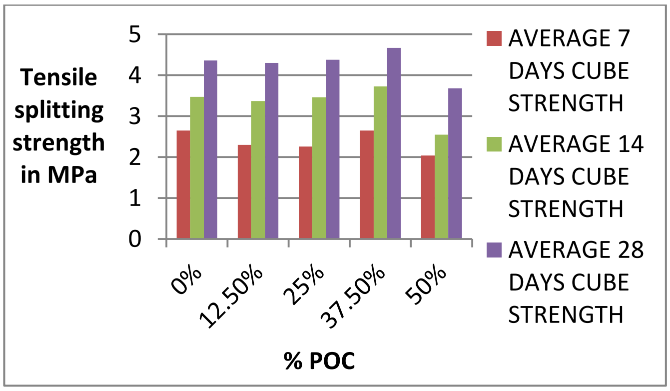

Figure 9. Tensile splitting results

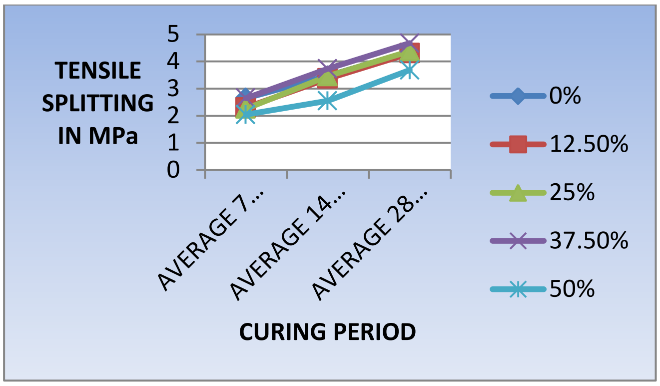

Figure 10. Tensile splitting results

The result above shows that 37.5% POC concrete achieve higher tensile splitting test compared to conventional concrete.

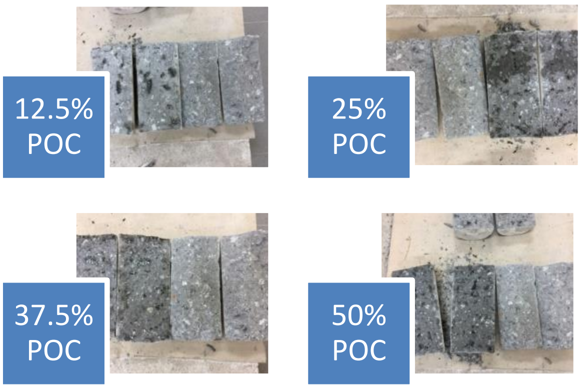

Figure 11. Microscopic view of poc as coarse aggregate compared to gravel

After being weight and measured, the beams were subjected to flexural strength to compare. The span length was 450 mm which is three times the width of the beam

Figure 12. Determination of flexural strength

The test specimen was turned on a side perpendicular to the position as cast, before placing it on the supports. The specimen was placed in the testing machine, correctly centered and with the longitudinal axis of the specimen at right angles to the longitudinal axes of the upper and lower rollers. The load is applied gradually until the beam fails. The table below shows an example of the load application progress on the beam. The result obtain is in KN, it is then computed using the three point loading formula to compute the modulus of rupture in MPa. The three point loading formula was used to compute the results to MPa.

$$\sigma = \frac{3FL}{bd^2}$$

Table 6. Modulus of rupture of beams

% POC	AVERAGE 7 DAYS CUBE STRENGTH	AVERAGE 14 DAYS CUBE STRENGTH	AVERAGE 28 DAYS CUBE STRENGTH
0%	2.59	3.45	4.31
12.5%	2.4	3.34	4.3
25%	2.26	3.45	4.37
37.5%	2.59	3.67	4.63
50%	2.07	2.46	3.71

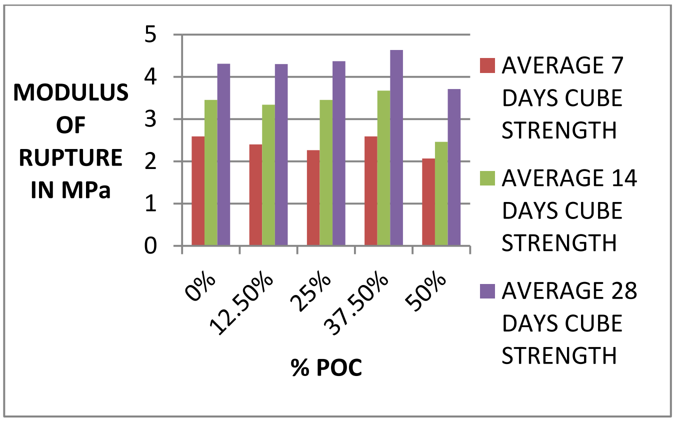

Figure 13. Modulus of rupture results

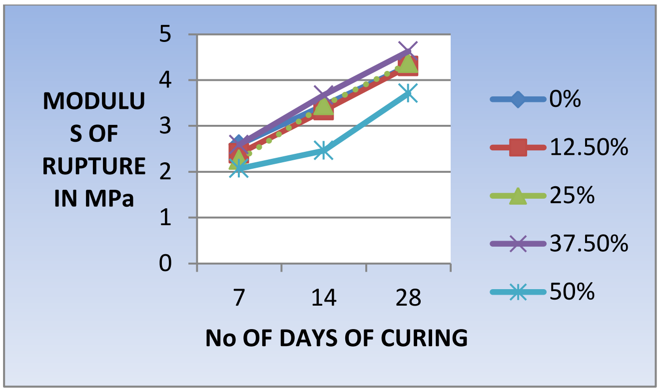

Figure 14. Tensile splitting results

Modulus of rupture results is highest for 37.5% POC concrete. 37.5 %of POC is the optimum percentage obtain. The result shows 5% higher strength in 37.5 % POC compared to conventional concrete that is 0% POC.

For 50 % POC, the modulus of rupture fails whereas 12.5% and 25% POC achieve similar results.

Behavior of concrete specimen using Solidworks software.

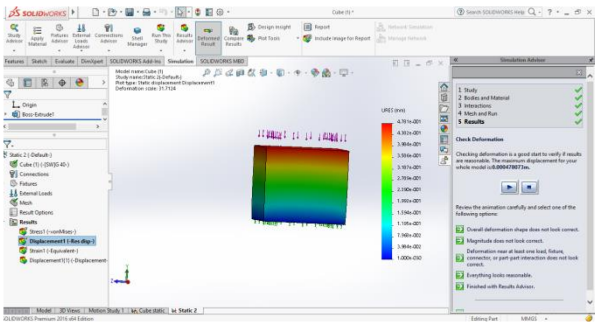

Figure 15. Displacement in cube under compression

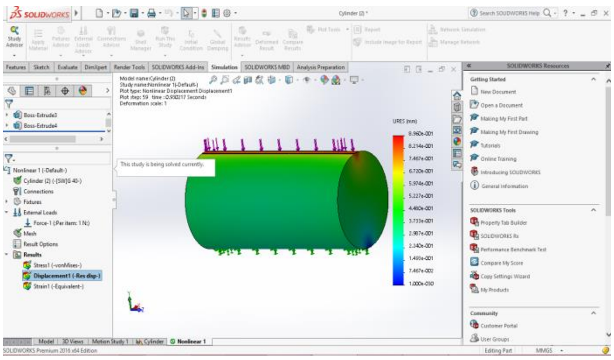

Figure 16. Displacement in cylinder under tensile splitting

IV. CONCLUSION

One of the main disadvantages of conventional concrete is the self-weight of concrete. Density of normal concrete is of the order of 2200 to 2600. This self-weight will make it to some extend an uneconomical structural material. On the other side, light weight concrete has a density between the range 1800 to 1940 kg/m3, enabling the overall design load to be much lesser compared to conventional concrete.

Lightweight concrete reduces the dead load, increase the progress of building and lowers the hauling and handling cost.

The weight of building on foundation is an important factor in the design, particularly in case of weak soil and tall structures. In framed structure, the beam and column have to carry load of wall and floor. If these wall and floor are made of light weight concrete it will result in considerable cost efficiency in the construction industry.

Light weight aggregate include pumice, saw dust rice husk, thermocole beads, formed slag, palm oil clinker and others. In this research, POC has been used to substitute conventional coarse aggregate which is gravel.

Structural lightweight aggregate's cellular structure such as POC provides internal curing through water entrainment which is especially beneficial for high-performance concrete.

POC is a waste product found abundantly as waste products in Malaysia, it is produced by the incineration of palm oil clinker and it is usually disposed in the environment destroying the flora and the fauna.

Its use in the construction industry will be beneficial both economically and environmentally. It will also enable construction at a faster rate and will enable higher strength of concrete.

From the assistance of journals and research papers, tests were done in order to obtain appropriate information and results. With the guidance gained from literature review, procedures required in the preparation of palm oil clinker in determining the mechanical properties were carried out. Objectives of the project has been achieved through the experiments and information required.

Investigation on concrete using palm oil clinker as coarse aggregate on the mechanical properties of concrete shows a decreased in spaces between the aggregates and an increases in closeness between the materials. Thus, concrete which depend more on compression rather than tension has an increased strength. Shape and size of aggregates has influenced in the bonding of material. Smaller sized palm oil clinker has filled in the empty spaces which are caused by bigger sized coarse aggregates and this improves the growth of strength.

Besides that, ability of palm oil clinker to have higher water absorption rate has affected the strength of concrete. It provides internal curing in enhancing the growth of strength of concrete at the later period.

The three major mechanical properties investigated in this research has shown that POC has the potential of replacing normal conventional coarse aggregate at optimum quantity.In all the three cases 37.5% POC replacement with conventional coarse aggregate has achieved higher results compared to conventional concrete which comprise of 0% POC.

POC concrete has been proven to be much better in terms of stress compared to conventional concrete. This research proves that the usage of POC in the construction industry is beneficial as well as economical. The strength obtained is higher by approximately 5% compared to conventional concrete. Higher results can be achieved due to porosity of POC which enables internal curing.

POC has been proven to be one of the major substituent of coarse aggregate but further analysis is required to show whether it is free from attacks of pest and termites.

V. ACKNOWLEDGMENT

I would like to express my sincere gratitude and thankfulness to Mr Ir.Mohd Nasir Hussin , my project coordinator and Dr. Manal, my second supervisor, all of whom have given me support and encouragement to complete my work.

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