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PALM KERNEL SHELL AS AN ALTERNATIVE AGGREGATE ON HIGH PERFORMANCE CONCRETE CONCRETE

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Abstract. Coarse aggregates commonly used in concrete are coarse natural aggregates, which are broken stones or gravel. Continuous rock exploration can cause environmental damage or even more severe ecosystem damage. Therefore it is necessary to substitute an alternative aggregate. Indonesia has the second largest oil palm plantation (*Elaeis guineensis Jacq*) in the world after Malaysia. Plantations are renewable resources, so palm oil is also potential to be used as an alternative to diesel fuel. Palm kernel shells are palm oil industry wastes which are generally underutilized. Palm kernel shells can be used as an alternative to coarse aggregate, because oil palm shells have the advantage of being hard, tough and good durability due to the high content of lignin and silica dioxide (SiO_2), such as hard wood, but low cellulose content so it is not easy rot. The strength of the palm oil shell is quite good. In addition, the aggregate gradation also fulfills the requirements without a breakdown process, which has a thickness of 2-4 mm and a maximum width of 15 mm. The volume of oil palm shells is + 600 kg/m^3, so it will produce significant light weight concrete. The concrete studied was concrete with a coarse aggregate of tenera palm kernel shells, with fine aggregates of natural sand, and a Portland Composite Cement (PCC), but the PCC content was reduced and replaced by FA which varied from 0%, 5%, 10 %, 15%, 20 and 25%. Concrete also added superplasticizer (SP). SP is used to reduce water use, because the shell absorbs water. SP levels also vary, namely 0%, 1%, and 1.2%. The weight of the volume of concrete with various levels of fly ash and SP is 1700-1800 kg/m^3, so it can be classified as lightweight concrete. Increased FA levels will increase compressive strength, but only up to 10%, after which the strength decreases. Compressive strength of specimens with SP 0% and FA 10% is 17.92 MPa, for SP levels of 1% and FA 10% is 22.15 MPa, while for SP levels of 1.2% and FA 10% is 19.35 MPa . So that it can be concluded that the palm shell as bio-material (renewable resources) can be used as a substitute for natural coarse aggregates. The optimum fly ash level is 10%, and to reduce water use SP 1%. The use of oil palm shells as a substitute for gravel means reducing the waste of the palm oil industry, while reducing rock exposures. In addition, in Indonesia there are many areas where there are no rock sources while oil palm plantations are quite extensive.

Keywords: palm shells, fly-ash, lightweight concrete

I. INTRODUCTION

Indonesia is located in an active earthquake zone, so the effect of earthquake forces on building structures such as inertial forces arising from earthquake acceleration can be reduced by reducing the mass of the building. In addition, in an effort to reduce house prices, one way that can be taken is by utilizing locally available materials, this makes concrete construction the first choice for the community to build a building. Concrete has a large compressive strength, is resistant to fire, is easily formed, does not require special expertise in its manufacture, does not require special care in its use, and its building materials are easily available in nature, so concrete construction is superior especially in terms of cost.

The nature of concrete is strongly influenced by the composition and quality of its constituent materials, namely aggregate as filler material, as well as hydraulic cement and water as a binder. The aggregate as filler, occupies 70% of the volume of concrete, which consists of 30% fine aggregate and 40% coarse aggregate. Coarse aggregates commonly used are natural coarse aggregates, namely split or gravel. But sometimes splits or gravels are hard to come by, so they have to be brought in from other areas that require large costs. While the palm oil plantations and industries are spread throughout almost all parts of Indonesia, produce underutilized shell waste.

According to the 2014-2016 Palm Oil Commodity Statistics Indonesia [1], oil palm plantations (*Elaeis guineensis Jacq*.) Are the largest plantations in Indonesia, reaching 10,668,425 hectares, which are spread throughout most of the archipelago. While the productivity of palm oil in 2015 reached 31,284,306 tons or 3 tons / hectare / year. The share of high-value oil palm plants is the fruit arranged in a bunch, called FFB (fresh fruit bunches). The average factory can process 1,200 tons of FFB per day, which operates for 300 days per year. Palm fruit in the coir (mesocarp) section produces crude palm oil (CPO) as much as 20-24%, and the palm kernel part (kernel) produces palm kernel oil (PKO) as much as 3-4%. The palm oil industry waste consists of 22% of OPEFB (oil palm empty fruit bunches) which is used as organic fertilizer and paper pulp, 12.5% of fiber used as fillers for car seats, and 5-6% of shells which are only used for fuel and a mixture of local road pavement.

Palm kernel shells can be used as an alternative to coarse aggregate, because oil palm shells have the

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advantage of being hard, tough and good durability due to the high content of lignin and silica dioxide (SiO_2), such as hard wood, but low cellulose content so it is not easy rot. In addition, the aggregate gradation also fulfills the requirements without a breakdown process, which has a thickness of 2-4 mm and a maximum width of 15 mm. Another advantage is that it is hard and tough because it contains a lot of dioxy silica (SiO_2), is hard and tough, and has a small volume weight of + 600 kg / m3, so it will produce light weight concrete, which is smaller than 1850 kg/m^3, or so-called lightweight concrete, while normal concrete has a heavy volume ranging from 2000-2500 kg/m^3. Coconut shell aggregate concrete will produce light weight concrete, which will reduce the mass of the building, so that the dimensions of building structural elements can be minimized, which is useful to reduce the effects of earthquakes on buildings.

The purpose of this study was to utilize palm oil shell waste as coarse aggregate to obtain light weighted concrete; get the treatmentof the best oil palm shells from the four treatments that will be carried out; get the proportion of mix (*mix design*) lightweight concrete with crude coconut shell aggregate. This research is a development of previous studies, where the novelty of this study was treatment of the shell to reduce its weakness, namely slip between aggregates and slip by mortar due to the oil content on the shell surface, with a study period of 6 (six) month, starting in May 2018.

Earthquake forces acting on a structure are strongly influenced by several aspects, including mass distribution, building shape, building rigidity and ductility. The aspect that is directly influenced by the material is the building mass. The earthquake load that works can be reduced through a reduction in building mass that can be achieved including through the use of lightweight aggregate concrete.

Concrete is a mixture of fillers called aggregates, which are bound by a mixture of hydraulic cement and water, so it becomes solid. This mixture is expected to receive a load on the structure. The nature of concrete is strongly influenced by the composition and quality of its constituent materials, therefore the concrete planned to be able to withstand the load must have an optimal comparison between the aggregate and the binding material in accordance with the desired mix requirements, in this case the manufacture of lightweight concrete with high performance.

Lightweight Concrete Behavior

Concrete has drawbacks that must be considered, namely having its own heavy weight. To overcome these shortcomings, the weight of concrete is reduced by using lightweight aggregates, forming lightweight concrete with a weight volume smaller than 1850 kg per m^3 (ACI [2]). Many natural lightweight aggregates are obtained from pumice, lava, and tuff. Artificial lightweight aggregates, with basic materials such as slate, clay, or fly ash, are made through the combustion process (Besari [3]). High performance lightweight concrete is with light weight concrete with compressive strength greater than or equal to 5000 psi or 34.5 MPa (Holm [4]). High performance lightweight concrete is the right material for areas with high earthquake risk because it has a high compressive strength with a relatively low weight. High performance lightweight concrete has the disadvantages of having shrinkage, crawl and large deformation, so it needs to be combined with normal concrete

Lightweight Concrete Press Strength

Concrete quality is measured by the ability of concrete to carry compressive stress. While the other voltage is expressed as a function of the compressive stress. The compressive strength of concrete is strongly influenced by coarse aggregate characteristics, factor w/c (water-cement ratio), density, time and quality of care and other factors such as additives. The light coarse aggregate, which occupies nearly +40% of the volume of concrete, gives a significant influence on the compressive strength of concrete, especially some of its characteristic properties such as specific gravity and volume, surface texture, raw materials and aggregate gradation distribution. FIP Manual [5] shows the relationship between the density of mildly expanded expanded aggregate particles to the compressive strength of concrete, which is linear, as shown in Figure 1.

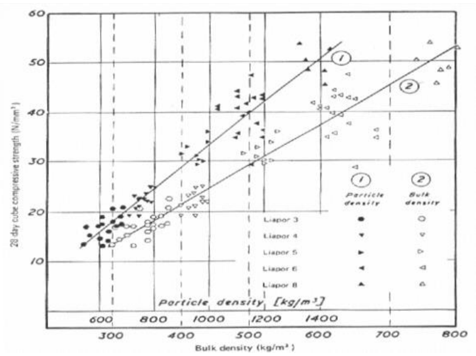

Figure 1. Relationship between bekah clay specific gravity to compressive strength of concrete cube

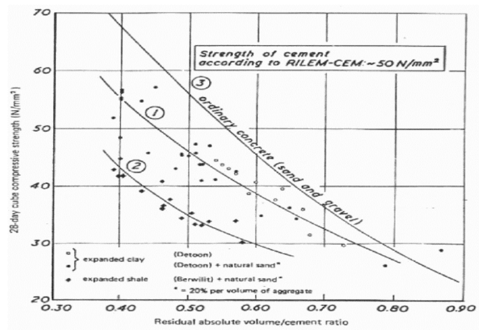

Figure 2. Relationship of absolute volume / factor w / c to concrete compressive strength

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Figure 2 shows a comparison between lightweight concrete and normal concrete. In the same factor w/c, the compressive strength of lightweight concrete is smaller than normal concrete. For example, for a factor w/c = 0.4, the normal concrete compressive strength is 68 MPa, while expanded clay is 55 MPa.

Specific gravity, volume weight, maximum aggregate size and aggregate gradation initially affect the weight of the concrete volume, and then the weight of the concrete volume will affect the concrete compressive strength. Research in various countries shows that the greater the volume of concrete the higher the compressive strength of concrete and the increase is not linear, as shown in Figure 3.

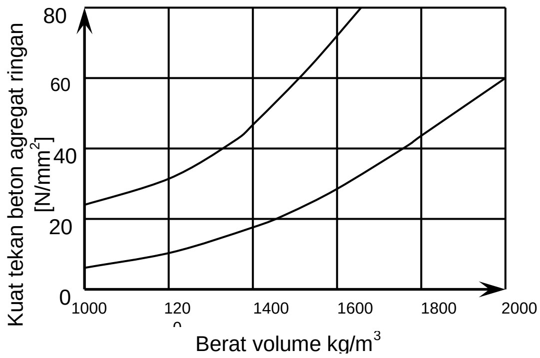

Figure 3. Relationship between the weight of light concrete and the compressive strength of concrete

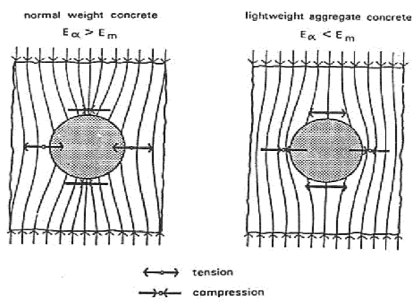

Figure 4. The phenomenon of normal concrete cracks and lightweight concrete due to compressive forces

The compressive strength of lightweight concrete is closely related to the stress-strain relationship between aggregates and mortar around the aggregate in concrete. Unlike normal concrete, there is a phenomenon of surrounding mortar and aggregate stress which is difficult to predict when lightweight concrete receives compressive loads. Due to differences in strength when getting external loads, the outer surface of light coarse aggregates accepts tensile stress while normal aggregates receive compressive stress, as shown in Figure 4. This is one of the causes of the strength of lighter lightweight aggregates.

The high absorption aggregate has an air chamber structure that can be interconnected so that it has low strength. In addition, formations of the contact area (formation contact zone) between aggregate and cement are formed in the form of space (void) where absorption water (absorp and bleeding water) will be made to create a low compressive strength.

Unlike normal concrete, in light concrete the development of initial strength is high but after 14 days it shows a small increase (low strength hardening) and tends to be flat. This is due to the phenomenon of the surrounding mortar and aggregate stress and the inaccuracy of reserves of light coarse aggregate absorption water when the cement hydration process occurs. This increase is in line with the speed of the cement hydration process which generally rises sharply in the first one to two weeks and afterwards is only an improvement in cement hydration.

In general, the normal and light weight stress-strain forms are the same, but the shape of the initial lightweight concrete curve is sloping due to the smaller modulus of elasticity (Ec) of concrete, as shown in Figure 5. Normal concrete peak strain is generally around 0.002 while high quality concrete (>41 MPa) around 0.0025 to 0.004. In lightweight concrete the peak strain is greater due to the modulus of elasticity is small. In high strength concrete, generally it has low ductility (6) where after peak loads are reached immediately the voltage drops without significant increase in strain, and the strain breaks before the voltage reaches zero.

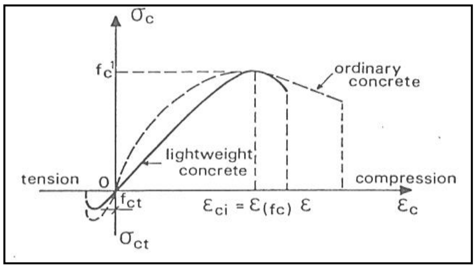

Figure 5. The stress-strain relationship of lightweight concrete and normal concrete

At the same quality, the tensile strength of lightweight concrete is 30% smaller than normal concrete. This is due to the low strength of light coarse aggregates and the light stress concrete phenomenon. The tensile strength of lightweight concrete is also influenced by the high absorption rate so that when dry it occurs around the aggregate and mortar stress due to concrete shrinkage. In addition, the irregular aggregate shape and rough surface have better tensile strength than smooth aggregate surfaces.

The value of tensile strength of lightweight concrete on the quality of concrete spreads within certain hose limits as in Table 1. Testing of split tensile strength is carried out on the test cylinder which is placed horizontally on the test machine. Load is given on the test object incrementally until the test cylinder is split.

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Table 1. The relationship of the tensile strength of lightweight concrete with concrete compressive strength

compressive strength [MPa]	the tensile strength [MPa]
10	0.9 – 1.3
20	1.4 – 2.0
30	1.8 – 2.7
40	2.2 – 3.3
50	2.5 – 3.8
60	2.8 – 4.2

Source : *FIP Manual of Lightweight Aggregate Concrete, 1983 [5]*

Coarse Aggregate Coconut Shell

Research on the use of lightweight aggregates using organic materials has not been done because the weathering process in organic materials is feared to reduce the strength of concrete. While the use of organic materials, such as bamboo as a substitute for reinforcement, as well as palm fiber and coco fiber as fillers of concrete to increase tensile strength, has been widely carried out.

The research that has been done (Artiningsih [6]) is the use of coconut shells (Cocos nucifera) as a substitute for natural coarse aggregates. The research conducted was testing compressive strength, tensile strength, and modulus of elasticity of concrete cylinders. Variation of the test specimen is the level of coconut shell against the coarse natural aggregate, which is 0% shell - 100% split (BTK 0/100), 25% - 75% (BTK 25/75), 50% - 50% (BTK 50/50) , 75% - 25% (BTK 75/25), and 100% - 0% (BTK 100/0). The results of the testing of material characteristics indicate that coconut shells have a specific gravity of 1300 kg / m3, while the specific gravity of broken rocks is 2500 kg / m3, so the use of coconut shells as coarse aggregates will produce light weight concrete. The compressive strength test results show that the greater the percentage of shell, the compressive strength decreases. BTK 25/75 decreased by 18%, BTK 50/50 by 46%, BTK 75/25 by 47%, and BTK 100/0 by 54%. The volume weight test results showed that the greater the percentage of shells, the lower the volume weight, so that the 100/0 BTK test material (aggregate shells without mixtures) weighed concrete volume 1750 kg/m^3, which qualifies as lightweight concrete. The test results show that planning the mixture needs to be reformulated to obtain proportions that are in accordance with the characteristics of the coconut shell.

The disadvantage of the results of preliminary research on coconut shells is the need to adjust the gradation of the dimensions of coconut shell fragments by breaking shells. In addition, the thickness of the shell is quite thin, only 3-5 mm, also a drawback of this study, because it causes the aggregate to overcrowd, resulting in a lack of cement matrix between shell aggregates, which causes a lack of shell aggregate bonds. This causes a sharp decrease in compressive strength.

Crude Aggregate Palm Oil Shell

Palm oil (*Elaeis guineensis Jacq*.) Is one of the plantations that has a bright future, so that oil palm plantations are spread in almost all parts of Indonesia. The share of high-value oil palm plants is the fruit arranged in a bunch. Palm fruit in coir (fruit flesh or mesocrap) produces Crude Palm Oil (CPO) as much as 20-24%, while part of seed meat (endosperm) produces palm kernel oil (PKO) 3-4% . The waste of palm oil processing consists of solid waste, liquid waste, and gas waste. Solid waste consists of empty bunches and shells. Shell is a fairly large palm oil processing waste, which reaches 60% of oil production. Shells can be processed into charcoal which has the potential to be used as activated carbon. But until now the new shell charcoal industry is limited to coconut shells, while oil palm shells have not been utilized, except only for fuel and road pavement.

The shell is a hard layer with a thickness of 2-8 mm. This hardness is caused by the high content of silica (SiO_2). In addition the shell also contains a lot of lignin, while the methoxyl content is almost the same as wood. The hard, ductile nature of oil palm shells, high silica content, lack of hygroscopic, fairly thick cross section, and relatively small width (20-30 mm), the oil palm shell is expected to be used as a coarse aggregate substitute for concrete production. In addition, the weight of the shell volume is lighter so that it can produce concrete with a lighter weight, or so-called lightweight concrete.

Research that has been done (Artiningsih [7]) is the use of oil palm shells as a coarse aggregate substitute to produce lightweight concrete. Variation of the test object is the use of fly-ash (FA), superplasticizer (SP), and optimum water-cement ratio (w/c ratio). The results showed that oil palm shells can be used as an aggregate substitute for lightweight concrete, with an average weight of 1760 kg/m^3 produced. The biggest compressive strength is 22 MPa and the largest split tensile strength is 2MPa, which is a concrete mixture with w/c ratio 0.32, using FA with a concentration of 10%, SP with a concentration of 1%, and a slump value of 75 mm.

II. RESEARCH METHODS

Limitation of Research

Specimen plans for research are:

1. The material used is composed of coarse aggregates, used Dura oil palm shells, obtained from Pekanbaru; fine aggregate, used sand from Cimangkok, Sukabumi; Testing of the physical properties of the aggregate is based on the ASTM [8] testing standard C136-92; The binding material used is type 1 portland cement PCC (portland cement composite) produced by PT. Indocement Tunggal Prakarsa Tbk. with a Three Wheel trademark, according to ASTM C150-92 standards. No physical testing of cement is carried out; Fly-ash (FA) as substitute for cement, fly-ash from Suralaya PLTU industrial waste is used,

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according to ASTM C618-92 standards grouped in class F; The additive used is a superplasticizer (SP) high-range water reducer to reduce water usage but increase slack. The superplasticizer used was Sikament NN from PT. Sika Nusantara Pratama, according to ASTM C494-92 standards. No physical testing of superplasticizer was carried out; Bentonite mineral additives are used so that the shell can be evenly distributed in the mixture.

2. The study was carried out in 2 stages, namely: Stage 1, carried out 2 treatments on palm shells including treatment-1: without treatment, treatment-2: soaked for 24 hours; The second stage, the variation of SP 1%, and variations in FA levels 0%, 5%, 10%, 15%, 20%, and 25% of the weight of cement.
3. The mixed planning standard used is ACI 211.4R-93 [9] (Guide for Selecting Proportions for High Strength Concrete with Portland Cement and Fly Ash) to obtain light aggregate levels and mixed proportions
4. Test specimens in the form of cylinders with a diameter of 150 mm and a height of 300 mm, amounting to 120 pieces
5. Care for curing according to ASTM C192 standard, which is soaking test specimens in the treatment pool
6. Instrumentation used, namely; universal testing machine, for testing compressive strength and split tensile strength, with testing procedures according to ASTM C39-94 standards; combine compresso-extensometer, for testing modulus of elasticity and poisson numbers, with procedures according to ASTM C469-94 standard; data logger, to record simultaneously and automatically longitudinal strain data, transverse strain, and load magnitude.
7. Testing of test specimens against compressive strength testing is carried out on cylinders placed vertically and given an incremental uniaxial load until they collapse, and the ultimate load is recorded; splitting test, carried out on cylinders placed horizontally and given an incremental load until the cylinder is split, and the ultimate load is recorded; testing of modulus of elasticity and poisson-ratio, performed on cylinders placed vertically and given uniaxial loads incrementally up to 40% of ultimate load, then recorded the load size, vertical strain and transversal strain.

The research that will be conducted is a continuation of a series of previous studies. The research that will be conducted is an experimental study, including: Material testing to determine the physical and mechanical properties of the material. The results of the test characteristics of material characteristics are used for planning concrete mixes; Making a mixed concrete mix plan using the ACI 211.2-91 and ACI 211.4R-93 guidelines; Perform 2 different treatments on palm shells, then the treated shells are used to make cylindrical specimens of 6 pieces each, to be tested at the age of 7 and 28 days; The production of 108 cylindrical test objects is based on the results of treatment; Testing the compressive strength of cylindrical specimens was carried out at the concrete ages 7, 14, 21, and 28 days, while the testing of split tensile strength, elastic modulus, and cylinder poisson-ratio was carried out at 28 days of concrete life. Concrete reaches a strong plan at the age of 28 days, so all tests are carried out at the age of 28 days. Compressive strength testing at various ages to determine the development history of concrete strength, to compare with the history of normal concrete strength; Evaluate the test results to get the best treatment

Material Check

Physical examination of concrete-forming materials, namely crude palm oil shell aggregates, fine aggregates of natural sand, portland cement, fly ash (FA), and superplasticizers (SP), using ASTM testing standards, namely the Annual Book of ASTM Standards volume 04.02: Concrete and Aggregates .

1. Aggregate

The coarse aggregates used in the study are bio-material coarse aggregates, namely oil palm shells resulting from the waste of the palm oil industry in Pekanbaru plantations. The chemical composition and mechanical properties of oil palm shells were not tested. Examination of the physical properties of oil palm shells is carried out in the Laboratory of ITB Structures and Materials, including gradations, specific gravity, absorption, volume weight, water content, and destruction rates, which can be seen in Table 2.

The fine aggregate used in the study was sand from Sukabumi. Examination of the aggregate physical properties includes gradation and modulus of fineness, specific gravity, water absorption, content weight, moisture content, and sludge content, which can be seen in Table 2. Sand slurry levels did not meet the requirements, so washing needs to be done.

Table 2. Physical properties of aggregates of oil palm shells and sand

CHECKING TYPE	Sand	Oil Palm Shells
apparent spesific gravity	2.674	1.478
bulk dry spesific gravity	2.489	1.093
bulk spesific gravity SSD	2.558	1.353
water absorption [%]	3.306	23.84
sludge levels	5.043	-
water content [%]	7.81	5.70
heavy volume weight [kg/liter]	1.455	0.673
volume weight (DRUW) [kg/liter]	1.272	0.602
Modulus of smoothness	2.941	-
wear and tear [%]	-	23.25

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2. Fly Ash

Fly ash used in the research is the waste of the Suralaya Steam Power Plant industry. The fuel used is coal originating from Bukit Asam, Tanjung Enim, South Sumatra. In this study no testing of the chemical composition of fly ash was carried out, but data from previous studies were used, with specific gravity of 1.70.

3. Cement

The study used Portland Cement Composite (PCC) produced by PT. Indocement. In this study no physical testing was carried out, but based on PCC technical specifications from PT. Indocement, namely specific gravity is 3.05.

4. Superplasticizer

Superplasticizer is an additional chemical that is used as one way to increase the ease of implementation of concrete workability by reducing the amount of water but can still be worked on, so that it can improve the level of the mixture of concrete. The superplasticizer used is from PT. Sika Nusa Pratama, namely sikament NN which is in accordance with ASTM C494-92 (Standard Specification for Chemical Admixtures for Concrete) standards

Concrete Mixing Planning

Based on the results of the examination and data on the physical properties of the material, a mixed plan was made using the ACI 211.2-91 (Standard Practice for Selecting Proportions for Structural Light Concrete) and ACI 211.4R-93 methods (Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash), as shown in Table 3.

Table 3. Mixed plans based on ACI 211.2-91 and ACI 211.4R-93

METHOD	ACI 211.2-91		ACI 211.4R-93	
material	mass kg	volume m3	mass kg	volume m3
PCC	354.33	0.12	352.46	0.12
coarse aggregate	450.91	0.33	457.64	0.42
fine aggregate	790.43	0.31	519.05	0.23
water	216.55	0.22	215.00	0.22
air	-	0.03	-	0.02
fly ash	10%		10%	
SP	1%		1%	

From the results of mixed planning, obtained; ACI 211.2-9, fine aggregate mass of 790.43 kg and coarse aggregate of 450.91 kg, while specific gravity of fine aggregate is 2,674 and coarse aggregate is 1,478, resulting in a coarse aggregate volume of 0.33 m^3 and fine aggregate of 0.31 m^3 of 1 m3 of concrete; ACI 211.4R-93, fine aggregate mass of 519.05 kg and coarse aggregate of 457.64 kg, resulting in a crude aggregate volume of 0.42 m^3 and fine aggregate of 0.23 m^3; The aim of the study was to obtain lightweight concrete. It is seen that the coarse aggregate volume based on ACI 211.4R-93 is greater than ACI 211.2-91, so it is used by ACI 211.4R-93

Making Test Items

Cylinder specimens with a diameter of 150 mm and a height of 300 mm. The making of the test object is carried out in two stages. The first step is for treatment testing. The first test specimens were 6 each for compressive strength testing at 7 and 28 days.

The results of the first treatment test are used to make the second stage of the test object. The specimens for the compressive strength test were 3 pieces for each variation, which were tested at 7, 14, 21 and 28 days. The test material for splitting test amounted to 3 pieces for each variation, and was only tested at 28 days. Test specimens for testing modulus of elasticity and poisson numbers are 3 for each variation, and only at 28 days. The number and types of test objects can be seen in Table 4.

Table 4. Variation and Amount of Test Items

variation	Information	compressive strength test		tensile test	E & μ	TOTAL
		day	total	total	total	
B321000	w/c 0.32, SP 1.0%, FA 0%	4	3	3	3	18
B321005	w/c 0.32, SP 1.0%, FA 5%	4	3	3	3	18
B321010	w/c 0.32, SP 1.0%, FA 10%	4	3	3	3	18
B321015	w/c 0.32, SP 1.0%, FA 15%	4	3	3	3	18
B321020	w/c 0.32, SP 1.0%, FA 20%	4	3	3	3	18
B321025	w/c 0.32, SP 1.0%, FA 25%	4	3	3	3	18
total test specimen		72		18	18	108

Test of Cylinder Test Objects

a. compressive strength testing, to obtain a concrete stress-strain stress curve, using Universal Testing Machine (UTM) with a testing procedure according to ASTM C39-94 standard, ie cylindrical test specimens placed vertically and given an uniaxial load incrementally until they collapse, and recorded ultimate load .

The amount of compressive strength of concrete is calculated by the equation:

$$f_c' = \frac{P}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ 1$$

note :

f_c' = concrete compressive strength [MPa]
P = maximum compressive load [N]
A = surface area of the test object [mm^2]

b. splitting test, to obtain the tensile stress-strain curve of concrete, using UTM with a test procedure according to ASTM C39-94 standard, ie cylindrical specimens are placed horizontally and given an incremental load until the cylinder is split, and the ultimate load is recorded.

The amount of tensile strength of the concrete is calculated by the equation:

$$f_{sp} = \frac{2P}{\pi L D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ 2$$

note :

fsp = split tensile strength [MPa]
P = maximum compressive load [N]
L = length of test object [mm]
D = cross section diameter of test object [mm]

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c. Modulus of elasticity is the ratio of stress to strain below the allowable limit. The purpose of testing is to determine the strength and resistance of the material to the existence of changes in shape / deformation.
According to SNI the modulus of elasticity for normal concrete is determined by the equation below:

$$E_c = 4700\sqrt{f_c'} \quad \text{.......... 3}$$

According to ACI 363R-92,
for normal quality concrete 21 MPa <fc '<83 MPa:

$$E_c = 3220\sqrt{f_c'} + 6900 \quad \text{.......... 4}$$

for lightweight concrete:

$$E_c = (w_c)^{1.5}\, x\, 0.043\sqrt{f_c'} \quad \text{.......... 5}$$

In testing with ASTM C469-87 standards, the magnitude of the elastic modulus is calculated using the equation:

$$E = \frac{S_2 - S_1}{\varepsilon_2 - 0.00005} \quad \text{.......... 6}$$

note :
E = Modulus of elasticity [MPa]
S_2 = voltage at at 40% peak voltage [MPa]
S_1 = voltage at strain of 5x10-5 [MPa]
ε_2 = longitudinal strain at stress S_2 [MPa]

d. Poisson-ratio is a ratio of lateral strain to axial (longitudinal) strain obtained by uniaxial loading. For normal concrete poisson numbers generally range from 0.15 to 0.2, while for normal concrete high quality poisson numbers range from 0.2 to 0.28.
The amount of poisson-ratio is calculated using the equation:

$$\upsilon = \frac{\varepsilon_{t2} - \varepsilon_{t1}}{\varepsilon_2 - 0.00005} \quad \text{.......... 7}$$

note :
ν = poisson-ratio
ε_2 = longitudinal strain when the voltage reaches S2
ε_{t1} = transverse strain when the voltage reaches S1
εt_2 = transverse strain when the voltage reaches S2.

III. RESULTS AND DISCUSSION

1. Slump

The results of slump measurements show that the planning of the mixture using 1% superplasticizer makes the amount of water that can be reduced is greater. Slump measurement results can be seen in Table 5.

Table 5. Slump of fresh concrete for each mixture

Test Item Code	Ratio Water - Cement		Fly Ash [%]	Slump [cm]
	early	Correction		
B321000	0.42	0.32	0.00	7.50
B321005	0.42	0.32	5.00	7.50
B321010	0.42	0.32	10.00	7.50
B321015	0.42	0.32	15.00	7.50
B321020	0.42	0.32	20.00	7.50
B321025	0.42	0.32	25.00	7.50

2. Volume Weight

The results of the measurement of the average volume weight of cylindrical specimens with various variations of FA content at 28 days can be seen in Table 6. The average volume weight is 1783.39 kg/m^3.

Table 6. Weight of volume [kg/m^3] average of each variation

Test Item Code	W/C RATIO	SP [%]	FA [%]	Volume Weight [kg/m^3]
B321000	0.32	10	0	1796.90
B321005	0.32	10	5	1798.79
B321010	**0.32**	**10**	**10**	**1800.67**
B321015	0.32	10	15	1776.16
B321020	0.32	10	20	1764.85
B321025	0.32	10	25	1762.96

3. Press Strength

The observation of the collapse pattern in concrete with the crude palm oil shell aggregate turned out to be split failure. Generally split collapse occurs in high quality concrete. But in reality, the concrete compressive strength achieved is not too high. This is because destruction occurs on the aggregate interface due to the volume of coarse aggregates greater than fine aggregates, so that the bonds between coarse aggregates and mortars are less. Therefore it can be sought to enhance the quality of concrete by increasing the volume of mortar. Concrete strength test results can be seen in Table 7.

Table 7. Compressive strength [MPa] on average for each variation

Test Item Code	W/C RATIO	SP [%]	FA [%]	Compressive Strength [MPa]
B321000	0.32	10	0	19.2606
B321005	0.32	10	5	20.8014
B321010	**0.32**	**10**	**10**	**22.1496**
B321015	0.32	10	15	20.8014
B321020	0.32	10	20	17.3091
B321025	0.32	10	25	16.0929

4. Splitting Strength

Split tensile testing is carried out on 28 days old concrete. The results of testing the tensile strength can be seen in Table 8 below.

Table 8. Split tensile strength on average for each variation at 28 days

Test Item Code	W/C RATIO	SP [%]	FA [%]	Split Tensile Strength [MPa]
B321000	0.32	10	0	1.6051
B321005	0.32	10	5	1.7473
B321010	**0.32**	**10**	**10**	**1.8827**
B321015	0.32	10	15	1.4540
B321020	0.32	10	20	1.4354
B321025	0.32	10	25	1.3518

5. Modulus of Elasticity and Poisson-Ratio

The modulus of elasticity and poisson-ratio tests were carried out on 28 days of concrete. The test results can be seen in Table 9 below.

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Table 9. Modulus of elasticity and poisson-ratio on average for each variation at 28 days

Test Item Code	Compressive Strength [MPa]	Modulus elasticity [MPa] value	Modulus elasticity [MPa] ACI 363R-23	Poisson value
B321000 B321005 B321010	19.2606	11773.48	14419.69	0.5735
B611015	17.3091	11096.63	13263.76	0.4830
B611020	16.0929	10754.99	12768.82	0.4563
B611025	15.4141	9719.27	12256.83	0.4088

IV. CONCLUSION

From the results of the study, some conclusions can be drawn as follows:

1. The crude aggregate of an oil palm shell is a material that easily absorbs water. This can be seen from the amount of water absorption, which is around 24% at 24-hour immersion. The strength of the oil palm shell aggregate used in the study is quite good. This can be seen in the wear testing experiment, which is equal to 21% in dry conditions, while SNI 03-1750-1990 requires a maximum of 32%. The aggregate gradation also meets the requirements, but the maximum aggregate size is only 12.5 mm.
2. The use of water in mixing fresh concrete must be considered, because the specific gravity of the shell is quite small, so that if excessive water use will cause floating palm shells, especially in mixing using SP. Slump exceeded the plan, so that when using SP slump it was maintained according to plan (50-75 mm), as a result there was a considerable correction of water, which was seen in changes in w/c, from 0.42 to 0.32. This happens because the water content in the palm shells is high due to being soaked 24 hours.
3. The results of the comparison of treatment indicate that the shell without treatment causes the strength of the resulting concrete to decrease. Conversely, water-treated shells have better strength. This is because the shell contains oil, which causes slippage between the aggregates
4. The compressive strength test results show that the increase in FA levels will increase strength, but the FA level is greater than 10% the strength decreases again.
5. The weight of the oil palm shell aggregate concrete volume is 1760-1800 kg/m^3, with an average of 1780 kg/m^3, so that the concrete can be classified as lightweight concrete. Increased compressive strength will increase volume weight. Compressive strength increases with increasing levels of SP which causes a reduction in water content, so it can be concluded that the reduction in water content will increase the compressive strength and volume weight.
6. The destruction of the compressive test occurs on mortar and aggregate interfaces. This is because the volume of coarse aggregates is greater than fine aggregates, so the bonds between coarse aggregates and mortars are less.
7. The largest concrete compressive strength is 22.15 MPa, which is a concrete mixture with w / c 0.32, FA content of 10%, SP 1%, and 75 mm slump
8. The biggest splitting strength is 1.88 MPa, which is a concrete mixture with w/c 0.32, FA content 10%, SP 1%, and 75 mm slump

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