The Use of Nutmeg Shell as a Lightweight Concrete Material

Budiman[1,a], Imran[2,b], and James WTP [3,c]
[1,2,3] Department of Civil Engineering, State Polytechnic of Fakfak, Fakfak Regency, 98612, Indonesia
[a] budiman@polinef.id
[b] Imran@polinef.id
[c]jameswtp@gmail.com

Abstract–- Lightweight concrete is concrete that has a lighter density than concrete in general. Nutmeg shell utilization as coarse aggregate is expected to be the added material in the lightweight concrete mixture. The purpose of this study is to determine characteristics of the concrete aggregate and the compressive strength of the concrete design based on the DOE (Department of Environment) method and the SNI Standard. In this research, the use of nugmet shell was varied as follows: 10%, 20%, 30%, 40% and 50% of the concrete weight. The research result shows that the amount of nugmet shell used into the concrete mixture affects the compressive strength of the concrete characteristics (f_{ck}'). The compressive strength of the concrete characteristics increases with the increase in the amount of nutmeg shell used in the concrete mixture. The compressie strength increases consecutively from 28.42 kg /cm^2, 31.65 kg / cm^2 to 32.68 kg /cm^2 with the increase in the amount of nutmeg shell: 10%, 20% and 30%. Then, it decreases into 29 , 09 kg /cm^2 and 27.38 cm^2 with further increasing 40% and 50% nutmeg shell of the concrete weight. The average weight of the concrete mixture using nutmeg shell was 1202 kg/m^3 with the maximum compressive strength value of 3.2 MPa, thus it could be categorized as the lightweight concrete.

Keywords*-- *lightweight concrete, nutmeg shells, characteristics compressive strength

I. Introduction

SNI03-2847-2002 describes concrete as a construction material containing the mixture of Portland cement or other hydraulic cements, fine aggregate, coarse aggregate, and water. The additives that form solid mass are optional [1].

The additives are materials except the main components of concrete (water, cement, and aggregate) which are added to the concrete mixture. This aims to change one or more concrete properties whilst all in fresh condition or after hardening, for example the accelerating hardening, increasing ductility (reducing brittle properties), reducing hardening cracks, etc. [2].

The use of other materials such as natural fibers in lightweight concrete mixtures may affect the behavior of the concrete structure as a whole. The effect of this change needs to be investigated to provide accurate information regarding the behavior and capacity of the concrete from the nutmeg waste.

Fakfak Regency as an area that has abundant agricultural products has potential to provide additional natural materials. Nutmeg agricultural production reaches 4,000 tons/year, with a land area of 16,010 hectares [3]. The amount of production is comparable to the resulting nutmeg shell, if left unchecked it will become waste. Waste that is left without treatment will result in the environmental problems.

The use of nutmeg shell as an additional material in the concrete mixture has very good prospects in the future because of its abundant availability and their characteristics of being hard and light, so that if it is mixed in concrete it will reduce the weight of the concrete itself and will produce lightweight concrete.

Lightweight concrete has a lower density than normal concrete. According to [1], lightweight concrete is concrete that contains light aggregate and has a density of not more than 1900 kg/m^3, while according to [4], light concrete has a density between 1000-2000 kg/m^3.

The use of natural additives in concrete mixture has previously been studied [5], examined palm fiber and

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nutmeg shells as additives to normal concrete. The results show that the compressive strength of concrete using 0.25% palm fiber sample is 70.32 kg/cm^2. Moreover, the use of 0.25% and 0.50% nutmeg shell samples produces concrete with compressive strength of 80.03 kg/cm^2 and 86.13 kg/m^2, increase 16.34% and 22.26%. Other previous researches examined the effect of banana fiber mixture on concrete [6], the effect of coconut shell substitution (endocarp) on concrete mixtures as fiber material for noise absorbtion [7], the manufacture of lightweight concrete from plastic added artificial aggregate [8], the effect of candlenut shells as a substitute for coarse aggregate on the mechanical properties of concrete [9].

This research use nutmeg shell as coarse aggregate for lightweight concrete. The purpose of this study is to determine the characteristics and compressive strength of concrete. The use of nutmeg shell proportion as a light aggregate material is 10%, 20%, 30%, 40% and 50% of the concrete volume with a test life of 3.7 and 28 days.

II. Literature Review

a. Light Concrete

Lightweight concrete has a density of not more than 1900 kg/m^3 [10] and has a compressive strength value of 0.35-6.90 Mpa while [11] provides a limitation for lightweight concrete, namely concrete with a weight below 1800 kg/m^3. A according to [12] lightweight concrete has a density between 1000 kg/m^3 and 2000 kg/m^3.

Types of lightweight concrete based on concrete weight and compressive strength [10] and [11] were presented in Table 1 and Table 2.

Table 1. Types of lightweight concrete [10]

Weight concretes (kg/m^3)	**Compressive strength (MPa)**	**Types lightweight concretes**
240-800	0.35-6.9	Low-Density concretes
800-1440	6.9-17.3	Moderate Strength lightweight concretes
1440-1900	>17.3	Structural lightweight concretes

Table 2. Types of lightweight concrete by [11]

Weight concretes (kg/m^3)	**Compressive strength (MPa)**	**Types lightweight concretes**
1400-1800	>17	Structural lightweight concretes
500-800	7-14	Masonry concretes
<800	0.7-7	Insulating concretes

Normal concrete is obtained by mixing Portland cement, water and aggregate, while for lightweight concrete the constituent materials are very dependent on the type of lightweight concrete. According to [13], there are 3 types of lightweight concrete, namely lightweight aggregate concrete, foam concrete and concrete without fine aggregate. The same thing was also conveyed by [14], several methods that can be used to reduce the weight of concrete include the following:

1) Making gas / air bubbles in the cement mix.
2) Using light aggregate, for example fired clay, pumice stone or artificial aggregate.
3) Making concrete without using fine aggregate grains (non-sand concrete).

Several parameters that affect the fine aggregate (sand) in determining the quality of the concrete are sludge content, moisture content, volume weight, absorption, specific gravity, fineness modulus and organic content [12].

The level of sludge is the percentage of size that passes filter No.200 according to ASTM and British Standards or 80 DIN (Germany) or standard filter hole size = 0.075 mm. Laboratory testing is generally carried out by the washing method according to ASTM C-117 (2000 Sieve in Mineral Aggregate by Washing) Standard Test Method for Materials. Tolerance for testing the fine aggregate sludge content is 0.2% -6%.

The water content in the aggregate is greatly influenced by the amount of water contained in the aggregate. The bigger the difference between the original aggregate weight and the aggregate weight after oven drying, the more water is contained by the aggregate and vice versa. Tolerance of testing moisture content in fine aggregate is 3% -5%.

The volume weight is the ratio between the dry aggregate weight and its volume. The aim is to

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determine the weight of the fine aggregate. The test tolerance for fine aggregate is 1.4 kg / ltr-1.9 kg / ltr.

The absorption is the percentage by weight of water that can be absorbed by the material to the weight of dry aggregate. Tolerance of testing fine aggregate 0.2% -2% and coarse aggregate 0.2% -4%.

The specific gravity is the ratio between the weight of dry aggregate and the weight of distilled water whose content is the same as the aggregate content in a saturated state at a certain temperature. The test tolerance for fine aggregate is 1.6% -3.3%.

The organic ingredients are materials contained in aggregates that can cause damage to concrete. The organic substances contained in fine aggregates generally come from destroyed plants, especially in the form of humus and organic sludge. Harmful organic substances include sugar, oil and fat. Sugar can inhibit cement binding and the development of concrete strength, while oil and grease can reduce cement binding capacity. The test tolerance for fine aggregates is less than a value of 3.

B. Compressive strength

Reference [15] provides an understanding of the compressive strength of concrete, which is the amount of load per unit area, which causes the concrete specimen to crumble when loaded with a certain compressive force, which is generated by a compression machine.

III. Research Methodology

A. Research Design

The primary data collection fort his research is the result of testing of aggregate characteristics. This test consists of testing the level of sludge, moisture content, volume weight, absorption, and density, modulus of fineness and roughness modulus. After testing the characteristic the aggregate, it is continued with concrete mix design with CP (nutmeg shell) percentage equal to10%, 20%, 30%, 40% and 50% to volume concrete weight by using cylinder size 15x30 cm. Concrete testing was performed after concrete immersion at age 3, 7 and 28 days. The study sample design is presented inTable1.

Table 1. Sample research design

No.	Sample of concrete specimen	Percentage of nutmeg shell %	Testing (days)
1	9 sample	10	3, 7, 28
2	9 sample	20	3, 7, 28
3	9 sample	30	3, 7, 28
4	9 sample	40	3, 7, 28
5	9 sample	50	3, 7, 28
∑	54 sample	-	-

B. Research Stage

The stages of the research can be seen in Figure 1.

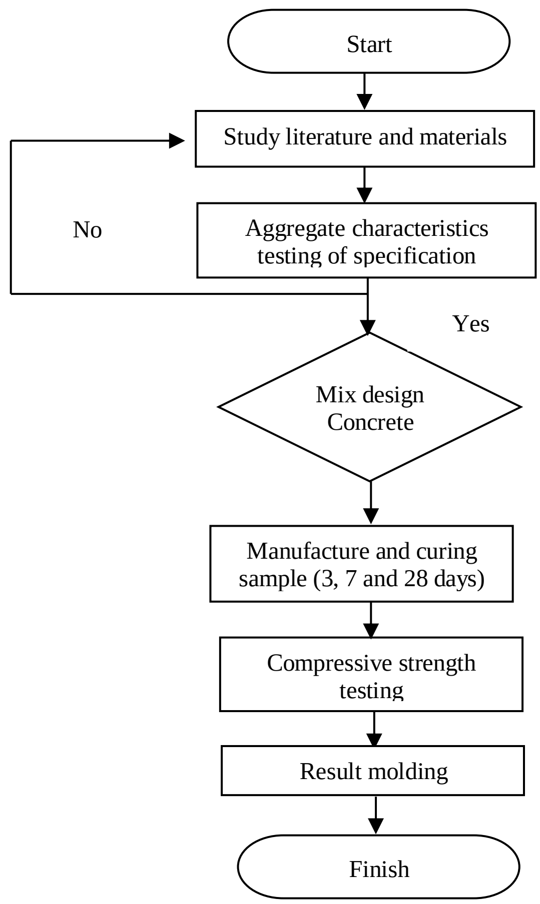

Figure 1. Flowchart of research stages

C. Characteristic Testing

Aggregate characteristic testing uses in this study is refered to Ref [16] as shown in Table 2.

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Table 2. Types of testing method for the concrete aggregate

No	Types of testing method	Standard
1	Filter Analysis	SNI03-1968-1990
2	Specific Weight and Fine Aggregate Absorption	SNI03-1970-1990
3	Specific Weight and Absorption of Coarse Aggregates	SNI03-1969-1990
4	Water Content	SNI03-1971-1990
5	Volume Weight	SNI03-4804-1998

D. Compressive Strength Testing

Compressive strength of the concrete obtained from laboratory test using compression machine were analyzed by using compressive strength equation [15]:

$$fc = \frac{P}{A} \quad (1)$$

where:
fc = compressive strength (kg/cm^2)
P = load (kg)
A= the weighted cross-sectional area (cm^2)

IV. Results and Discussion

The characteristics of fine aggregate (sand) resulting from laboratory tests were presented in Table 3.

Table 3. The result of fine aggregate testing

No	Aggregate characteristics	Interval	Testing result	Description
1.	Mud level	Max. 5%	4.00 %	Qualified
2.	Water content	0.5 - 5%	2.33 %	Qualified
3.	Volume weight	1.4 - 1.9 kg/liter	1.53	Qualified
4.	Absorption	0.2 – 2%	1.01 %	Qualified
5.	Specific weight			
	Real S.W	1.6 - 3.3	1.737	Qualified
	Dry-based S.W	1.6	1.768	Qualified
	Dry-surfaced S.W	1.6	1.754	Qualified
6.	Roughness modulus	1.50 – 3.80	2.656	Qualified

Based on table 1 on testing the characteristics of fine aggregate, the value of sludge content is 4% and contains organic content which is suitable for use. According to [12] and [17], fine aggregate should not contain more than 5% sludge and not contain organic which can damage concrete. It is used to fill the space between coarse aggregates and provide discomfort. The modulus of fineness of 2.72 fulfills the requirements for zone 4 in the fine category. The graph of the test results for fine aggregate grains is shown in Figure 2.

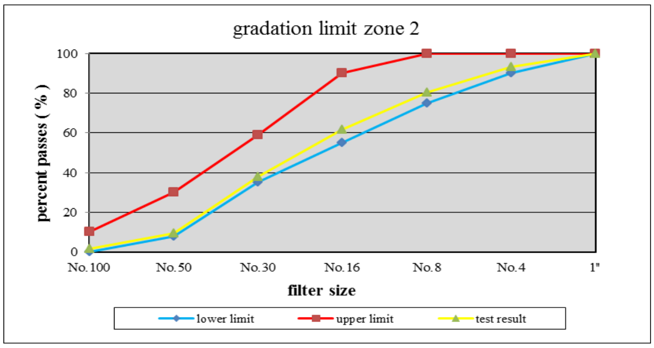

Figure 2. Graphic of fine aggregate gradation

To investigate the strength of the concrete quality that will be produced using fine aggregate (sand) and coarse aggregate from nutmeg shells is conducted by calculating the aggregate with the cement water factor (W/C) = 0.71 as shown in Tables 4, 5, 6, 7 and 8.

Table 4. The results of concrete mix design with nutmeg shell 10%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for one sample (kg)
Water	198.626	0.742	1.263	11.371
Cement	267.605	1.000	1.702	15.321
Sand	699.955	2.615	4.452	40.076
CP 10%	21.990	0.082	0.139	1.259
$\sum$	1.188		7.559	68.030

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Table 5. The results of concrete mix design with nutmeg shell 20%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for one sample (kg)
Water	198.626	0.742	1.263	11.371
Cement	267.605	1.000	1.702	15.321
Sand	699.955	2.615	4.452	40.076
CP 20%	23.32	0.087	0.148	1.335
∑	1.189		7.567	68.106

Table 6. The results of concrete mix design with nutmeg shell 30%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for one sample (kg)
Water	198.626	0.742	1.263	11.371
Cement	267.605	1.000	1.702	15.321
Sand	699.955	2.615	4.452	40.076
CP 30%	34.98	0.130	0.222	2.002
∑	1.201		7.641	68.773

Table 7. The results of concrete mix design with nutmeg shell 40%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for one sample (kg)
Water	198.626	0.742	1.263	11.371
Cement	267.605	1.000	1.702	15.321
Sand	699.955	2.615	4.452	40.076
CP 40%	46.64	0.174	0.296	2.670
∑	1.212		7.716	69.441

Table 8. The results of concrete mix design with nutmeg shell 50%

Concrete material	Weight (kg/m^3)	Ratio to the amount of the cement (kg)	Weight for one sample (kg)	Weight for one sample (kg)
Water	198.626	0.742	1.263	11.371
Cement	267.605	1.000	1.702	15.321
Sand	699.955	2.615	4.452	40.076
CP 40%	58.30	0.217	0.370	3.338
∑	1.224		7.790	70.109

Based on the calculation of the results of the design above, it is obtained that the difference in weight of light concrete with 10% nutmeg shells is obtained 1,188 kg/m^3, 20% of 1,189 kg/m^3, 30% of 1,201 kg/m^3, 40% of 1,212 kg/m^{3}and 50% of 1,224 kg/m^3. The weight value of the concrete shows that the use of nutmeg shell on the concrete affects the weight of the concrete itself and the compressive strength value of the concrete characteristics. The results of the calculation of the mix design mixture of concrete with nutmeg shells, then analyzed the volume weight value of fresh concrete by means of the average weight of fresh concrete divided by the volume of cylindrical specimens as in Table 9.

Table 9. The weight volume of freshly concrete

No	Sample	Volume of Freshly Concrete (kg/m^3)
1	Nutmeg shell concrete 10%	1865,6
2	Nutmeg shell concrete 20%	1837,3
3	Nutmeg shell concrete 30%	1792,4
4	Nutmeg shell concrete 40%	1780,2
5	Nutmeg shell concrete 50%	1774,8

Based on table 9, the weight of nutmeg shell concrete for 10% is 1865.6 (kg/m^3) while for 50% it is obtained 1774.8 (kg/m^3), a decrease of 4.86%. The greater the percentage value of nutmeg shells used in the lightweight concrete design mix, the lighter the volume weight of the fresh concrete. This shows that the use of nutmeg shells has an effect on the weight of the concrete itself.

Based on the results of the analysis of the test value of the compressive strength of concrete using nutmeg shells at the age of 28 days, it shows that light concrete with the use of nutmeg shells as coarse aggregate in the concrete mixture affects the compressive strength of the concrete characteristics (fck'). The compressive strength values for the characteristics of concrete at a composition of 10%, 20% and 30% were obtained at 28.42 kg/cm^2, 31.65 kg/cm^2 and 32.68 kg/cm^2 which increased while the use of nutmeg shells at 40% and 50% compositions was obtained. The values of 29.09

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kg/cm^2 and 27.38 kg/cm^2 decreased at the age of 28 days as in Table 10.

Table 10. The value of Compressive Strength Characteristics of Concrete

No	Sample	Value f'c (kg/cm^2)
1	Nutmeg shell concrete 10%	28.42
2	Nutmeg shell concrete 20%	31.65
3	Nutmeg shell concrete 30%	32.68
4	Nutmeg shell concrete 40%	29.09
5	Nutmeg shell concrete 50%	27.38

Based on table 10, there was an increase in the value of the compressive strength of concrete (fck ') at the composition of 20% and 30% of 10.20% and 13.03% and began to decrease in the composition of 50% by 3.65%. The decrease in the compressive strength value is influenced by the higher percentage of nutmeg shells that are used in the concrete mix, thereby reducing the volume of concrete that should be filled with cement paste.

The increase in the value of the compressive strength of concrete (fck') occurred starting at the composition of 20% and 30% at 10.20% and 13.03% and begin to decrease at the composition of 50% by 3.65%. The decrease in the compressive strength value is influenced by the higher percentage of nutmeg shells that are used in the concrete mix, thereby reducing the volume of concrete that should be filled with cement paste.

Lightweight concrete according to [12] and [13] is concrete with a concrete weight below 1860 kg/m^3 with types of lightweight concrete consisting of structural, lightweight and very light structural concrete. Lightweight concrete from nutmeg shells has an average weight of 1202 kg/m^{3}and a maximum compressive strength value of 3.2 MPa so that the concrete is in the lightweight structure category.

According to Ref [10] and [11] lightweight concrete with low density has a concrete weight of 240 kg/m^3 - 800 kg/m^{3}with a compressive strength value of 0.35-6.90 Mpa. The range of compressive strength values, lightweight concrete from nutmeg shell is included in the lightweight concrete category with low density, so it can be concluded that nutmeg shell has the opportunity to be used as a building material for lightweight concrete. To get the right composition for its use, it is necessary to carry out further studies both for lightweight concrete and for normal concrete.

V. Conclusion

Some points can be concluded from this research as follows:

1. The use of nutmeg shell makes the concrete mixture lighter, the lightweight concrete, and contributes to increase the compressie strength of the concrete when using the nutmeg shell till 30% of the concrete weight.
2. The compressive strength of the lightweight concrete decreases when increasing the use of nutmeg shell more than 30% of the concrete weight.

Research suggestions and recommendations are as follows:

1. Further research is needed in determining the appropriate composition for both lightweight concrete and normal concrete
2. Further research is needed using a smaller percentage interval
3. It is recommended to use nutmeg shell as coarse aggregate in light concrete with a low density scale and intended for light structures, besides saving costs, it can also reduce waste that has an impact on the environment.

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