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# TESTING OF NUTMEG SHELL AS A NORMAL CONCRETE MATERIAL IN TERMS OF VOLUME WEIGHT AND COMPRESSIVE STRENGTH VALUE

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***Abstract.*** Normal concrete uses fine aggregate and coarse aggregate with concrete density 2200 kg/m$^3$-2400 kg/m$^3$ with a compressive strength of about 15-40 MPa [1]. 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: 0%, 0,25%, 0,50%, 0,75% and 1% of the cement weight. The results showed that the use of nutmeg shells as a normal concrete affected the specific gravity and the value compressive strength of concrete. The higher the percentage of nutmeg shells, the lower the specific gravity and compressive strength of the concrete. The average value of density to nutmeg shell concrete (NSC) 2254.72 (kg/m$^3$) and normal concrete 2304.32 (kg/m$^3$). The compressive strength of normal concrete is 224.2 kg/cm$^2$ and the nutmeg shell concrete (NSC) the composition of 0.25% and 0.5% obtained by 129.6 kg/cm$^2$ and 140.0 kg/cm$^2$ increases the use of nutmeg shell 0.75% and 1% obtained value of 117.6 kg/cm$^2$ and 118.1 kg/cm$^2$ decreased at the age of 28 days. The compressive strength of normal concrete 22 MPa while the maximum nutmeg shell concrete (NSC) 14 MPa, so it does not meet the quality of normal concrete in general.

*Keywords: aggregate characteristics, nutmeg shell, volume weight, characteristics compressive strength*

## 1. INTRODUCTION

The use of concrete as a building material has been very popular in Indonesia because it can utilize local materials such as gravel, sand, cement and water which are easily obtained at relatively low prices [1]. Sometimes in certain areas it is very limited to get aggregate, especially gravel and river sand. Fakfak Regency is one of the regencies in West Papua Province with limited aggregate availability. Bomberay district with a distance of 200 km, one of the sub-districts that supplies the aggregate demand for construction in Fakfak [2], most of it must be imported from outside provinces such as Sulawesi. The limited natural resources in providing aggregates for the manufacture of concrete is a very important problem so that an alternative is needed to replace part or all of the aggregate. One example of efforts to overcome these limitations is the use of nutmeg shells for coarse aggregate material in the manufacture of concrete, both lightweight concrete and normal concrete.

The use of nutmeg shells as a concrete material has been previously tested as a lightweight concrete constituent. The results showed that the nutmeg shell reduced the weight of the concrete volume, the higher the percentage used in the concrete mixture, the lighter the weight of the concrete. The maximum compressive strength value is 32.68 kg/cm$^2$ (3.2 MPa) with 30% nutmeg shell percentage and 1792.4 kg/m$^3$ concrete weight obtained [3]. According to [4], lightweight concrete has a specific gravity of not more than 1900 kg/m$^3$ while according to [5] lightweight concrete has a density between 1000-2000 kg/m$^3$. According to [6], 1998 lightweight concrete has a compressive strength value of 0.35-6.90 MPa, so that the nutmeg shell meets the specifications as a lightweight concrete constituent material. From these results the researchers developed further research by utilizing nutmeg shells as a partial substitute for coarse aggregate in normal concrete.

According to [1] normal concrete is concrete that uses sand aggregate as fine aggregate and gravel as coarse aggregate and has a concrete density between 2200 kg/m$^3$-2400 kg/m$^3$ with a compressive strength of about 15-40 MPa.

Research conducted [7] utilizes waste concrete as a partial replacement for coarse aggregate in normal concrete. The use of aggregate proportions of 25%, 50%, 75% and 100% of the total weight of natural aggregates. The results showed that the most optimum proportion was the aggregate proportion of 25% while [8] in his research the use of broken concrete as an alternative to partially substitute coarse aggregate as a concrete mixture of K-250 Kg/cm$^2$. The use of 100% waste concrete compared to the new aggregated concrete found that the average compressive strength at 28 was 257.12 Kg/cm$^2$ for normal concrete and 191.14 Kg/cm$^2$ for waste concrete.

Based on the explanation above, the author examines the development of nutmeg shells as a partial substitute for coarse aggregate in normal concrete mixtures. The research objective is to determine the specific gravity of concrete and the value of the compressive strength of concrete. The proportions of the mixture to be used are 0%, 0.25%, 0.5%, 0.75% and 1% of the cement weight with the stages of characteristic testing, making mix design specimens, each mix design being tested by slum test, making samples from cylindrical mold with a diameter of 15 cm and a height of 30 cm, concrete treatment at the age of 3, 7 and 28 days and a compression test with MTS STH Compression.

## 2. METHODS

### 2.1 Research Design

This experiment is a laboratory experiment which includes testing the characteristics of coarse aggregate and fine aggregate consisting of sieve analysis, silt content, moisture content, volume weight, fineness and coarseness modulus, organic content in sand. If the aggregate characteristics meet the standards, then proceed with the mix design, each mix design is carried out with a slum test, making samples from cylindrical molds with a diameter of 15 cm and a height of 30 cm, treatment of concrete at the age of 3, 7 and 28 days and a compression test with MTS STH Compression. The study sample design is presented as in Table 1.

Table 1. Sampel Reseacrh Design

| No | Sample of concrete specimen | Percentage of LCP (%) | Testing (days) |
|---|---|---|---|
| 1 | 9 Sample | 0 | 3, 7, 28 |
| 2 | 9 Sample | 0,25 | 3, 7, 28 |
| 3 | 9 Sample | 0,50 | 3, 7, 28 |
| 4 | 9 Sample | 0,75 | 3, 7, 28 |
| 5 | 9 Sample | 1 | 3, 7, 28 |
| ∑ | 36 sample | - | - |

### 2.2 Research Stages

The stages of research, prepare tools and materials. The material consists of sand, cement, water and nutmeg shells then by testing the characteristics of the aggregate. Several parameters that affect the fine aggregate (sand) and coarse aggregate in determining the quality of the concrete are sludge content, moisture content, volume weight, absorption, specific gravity, fineness modulus and organic content [9]

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 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.

If the test of the characteristics of the aggregate meets the criteria, it is continued with designing a concrete mix (mix design) with f'c 17,5 MPa. Making the composition of the concrete mixture with nutmeg shell variations of 0%, 0,25%, 0,50%, 0,75% and 1% of the weight cement. Concrete maintenance for 3,7 and 28 days. Testing the compressive strength of concrete with a target of f'c 17,5 Mpa, data analysis and conclusions.

### 2.3 Characteristic Testing

Aggregate characteristic testing uses study literatures as shown in Table 2.

Table 2: Aggregate testing method

| Types of testing | Method |
|---|---|
| Filter Analysis | SNI 03-1968-1990 |
| Specific Weight and Fine Aggregate Absorption | SNI 03-1970-1990 |
| Specific Weight and Absorption of | SNI 03-1969-1990 |
| Water Content | SNI 03-1971-1990 |
| Volume Weight | SNI 03-4804-1998 |

Source: Attamimi [10].

### 2.4 Compressive Strength Testing

Concrete compressive strength test results using compression machine test were analyzed by using compressive strength equation [11]:

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

In which:
fc = compressive strength (kg/cm2)
P = load (kg)
A= the weighted cross-sectional area (cm2)

## 3. RESULTS AND DISCUSSION

### 3.1 Testing of Aggregate Characteristic

The results of the characteristic test of coarse aggregate (gravel) are as in Table 3 whereas the results of fine aggregate testing (sand) as in Table 4.

Table 3. The Result of Coarse Aggregate Testing

| Aggregate Characteristics | Interval | Testing result | Description |
|---|---|---|---|
| Mud levels | Max. 1% | 0.270% | Qualified |
| Water content | 0.5 - 2% | 0.50% | Qualified |
| Volume weight | 1.4 - 1.9 kg/litre | 1.61 | Qualified |
| Absorption | 0.2 – 2% | 2.04% | Qualified |
| Specific weight | | | |
| Dry-based S.W | 1.6 | 2.450 | Qualified |
| Dry-surfaced S.W. | 1.6 | 2.579 | Qualified |
| Roughness Modulus | 5.5 – 8.5 | 8.390 | Qualified |

The results of the test in table 3, it is explained that the slurry content test on the coarse aggregate obtained a value of 0.27% meets the requirements and is feasible. According to [5] the coarse aggregate should not contain more than 1% silt. The coarse aggregate modulus in the zone is 4.75 - 40 mm. The graph of the results of the coarse aggregate gradation test is shown in Figure 1.

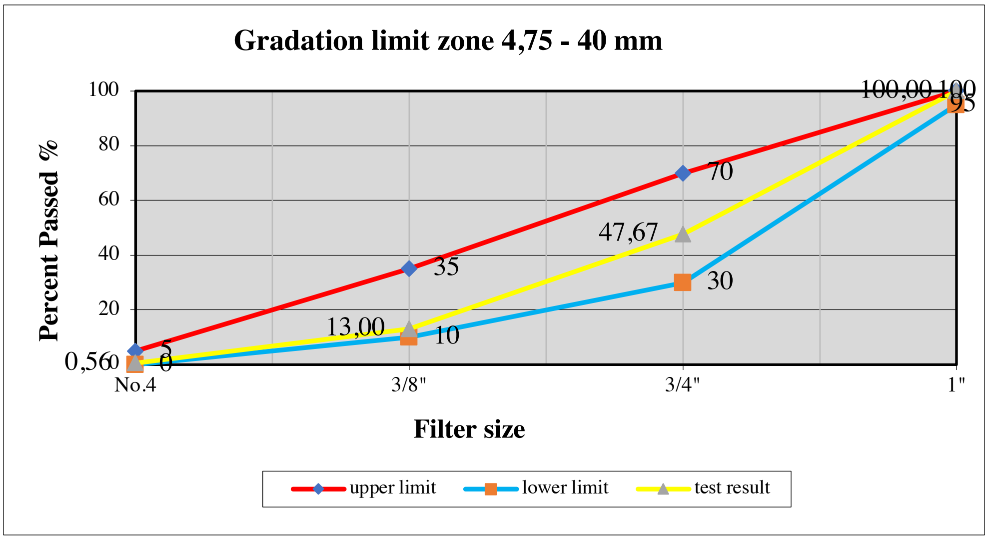


Figure 1. Graphic of coarse aggregate gradation (gravel)

Table 4. The Result of fine Aggregate Testing

| Aggregate Characteristics | Interval | Testing result | Description |
|---|---|---|---|
| Mud levels | Max. 5% | 3.60% | Qualified |
| Water content | 0.5 - 5% | 2.24% | Qualified |
| Volume weight | 1.4 - 1.9 kg/litre | 1.51 | Qualified |
| Absorption | 0.2 – 2% | 1.08% | Qualified |
| Specific weight | | | |
| Real S.W. | 1.6 - 3.3 | 2.330 | Qualified |
| Dry-based S.W | 1.6 | 2.280 | Qualified |
| Dry-surfaced S.W. | 1.6 | 2.300 | Qualified |
| Roughness Modulus | 1.50 – 3.80 | 3.660 | Qualified |

The result of table 4 the characteristics of the fine aggregate, the mud content value obtained is 3.6% which meets the requirements and is suitable for use in concrete mixtures. According to [1] fine aggregate must not contain more than 5% silt and must not contain organics that can damage the concrete. Its use is to fill the spaces between coarse aggregates and provide smoothness. The sand fineness modulus value of 3.66 meets the requirements of zone 1 by entering the coarse sand category. The graph of the results of the fine aggregate grain gradation test is shown in Figure 2.

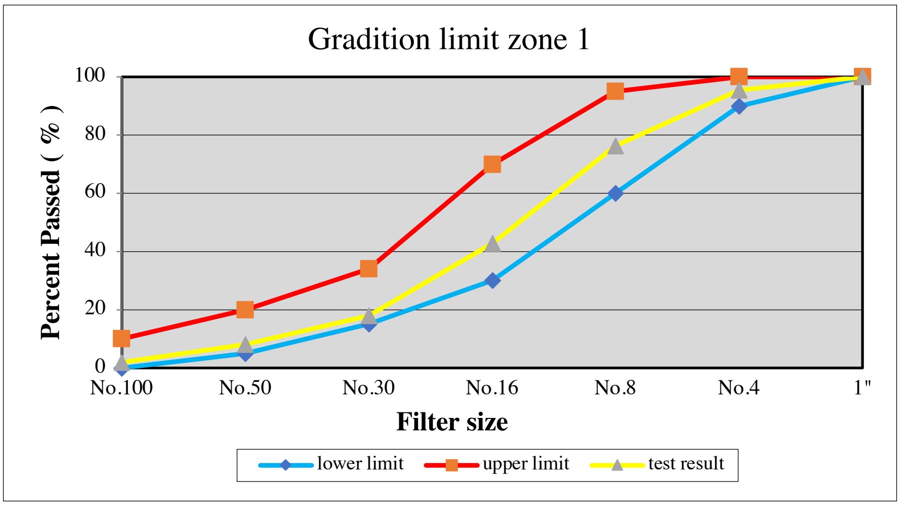


Figure 2. Graphic of fine aggregate gradation (sand)

Knowing the strength of the quality of concrete that will be produced using coarse aggregate (gravel) and fine aggregate (sand) used concrete quality f'c 175 MPa. Calculation of the combination of aggregates obtained 30% sand and 70% crushed stone in a concrete mixture (mix design) with a water-cement factor (W/C) = 0.75 as shown in Table 5 while for the use of nutmeg shell (CP) as a partial replacement material in coarse aggregate. using a composition of 0%, 0.25%, 0.50%, 0.75% and 1% by weight of cement as shown in Table 5, 6, 7, 8 and 9.

Table 5. Mix Design of Normal Concrete

| Concrete material | Weight ($kg/m^3$) | Ratio to the amount of the cement (kg) | Weight for one sample (kg) | Weight for 9 sample (kg) |
|---|---|---|---|---|
| Water | 2.44.49 | 0.7859 | 1.555 | 13.998 |
| Cement | 311.11 | 1.000 | 1.979 | 17.812 |
| Sand | 487.43 | 1.5668 | 3.101 | 27.908 |
| Gravel | 1106.9 | 3.5581 | 7.042 | 63.379 |
| Total | 2,150.0 | | 13,678 | 123.099 |

Table 6. Mix Design of Nutmeg Shell Concrete (NSC) 0,25%

| Concrete material | Weight ($kg/m^3$) | Ratio to the amount of the cement (kg) | Weight for one sample (kg) | Weight for 9 sample (kg) |
|---|---|---|---|---|
| Water | 2.44.49 | 0.7859 | 1.555 | 13.998 |
| Cement | 311.11 | 1.000 | 1.979 | 17.812 |
| Sand | 487.43 | 1.5668 | 3.101 | 27.908 |
| Gravel | 1101.5 | 3.540 | 7.007 | 63.070 |
| NSC | 5.392 | 0.017 | 0.034 | 0.3088 |
| Total | 2,150.0 | | 13,678 | 123.099 |

Table 7. Mix Design of Nutmeg Shell Concrete (NSC) 0,50%

| Concrete material | Weight (kg/m$^3$) | Ratio to the amount of the cement (kg) | Weight for one sample (kg) | Weight for 9 sample (kg) |
|---|---|---|---|---|
| Water | 2.44.49 | 0.7859 | 1.555 | 13.998 |
| Cement | 311.11 | 1.000 | 1.979 | 17.812 |
| Sand | 487.43 | 1.5668 | 3.101 | 27.908 |
| Gravel | 1096.12 | 3.523 | 6.973 | 62.759 |
| NSC | 10.825 | 0.034 | 0.068 | 0.6198 |
| Total | 2,150.0 | | 13,678 | 123.099 |

Table 8. Mix Design of Nutmeg Shell Concrete (NSC) 0,75%

| Concrete material | Weight (kg/m$^3$) | Ratio to the amount of the cement (kg) | Weight for one sample (kg) | Weight for 9 sample (kg) |
|---|---|---|---|---|
| Water | 2.44.49 | 0.7859 | 1.555 | 13.998 |
| Cement | 311.11 | 1.000 | 1.979 | 17.812 |
| Sand | 487.43 | 1.5668 | 3.101 | 27.908 |
| Gravel | 1090.82 | 3.506 | 6.939 | 62.456 |
| NSC | 16.125 | 0.051 | 0.102 | 0.923 |
| Total | 2,150.0 | | 13,678 | 123.099 |

Table 9. Mix Design of Nutmeg Shell Concrete (NSC) 1%

| Concrete material | Weight (kg/m$^3$) | Ratio to the amount of the cement (kg) | Weight for one sample (kg) | Weight for 9 sample (kg) |
|---|---|---|---|---|
| Water | 2.44.49 | 0.7859 | 1.555 | 13.998 |
| Cement | 311.11 | 1.000 | 1.979 | 17.812 |
| Sand | 487.43 | 1.5668 | 3.101 | 27.908 |
| Gravel | 1085.45 | 3.489 | 20.716 | 62.148 |
| NSC | 21.500 | 0.069 | 0.410 | 1.231 |
| Total | 2,150.0 | | 13,678 | 123.099 |

The calculation of the above design results obtained a difference in weight based on the percentage of the need for coarse aggregate and nutmeg shell material, namely the percentage of 0.25 nutmeg shell to the weight of cement requiring coarse aggregate 1101 (kg/m$^3$) and 5.39 (kg/m$^3$) nutmeg shell, a percentage of 0.5 requiring coarse aggregate 1096.1 (kg/m$^3$)and 10.82 (kg/m$^3$)of nutmeg shell, percentage 0.75 requires coarse aggregate 1090.8 (kg/m$^3$) and 16.12 (kg/m$^3$) and percentage 1 requires 1085.4 coarse aggregate and 21.5 (kg/m$^3$) nutmeg shell. This design value shows the higher the percentage of nutmeg shells used in the concrete mixture, the lower the demand for coarse aggregate.

According the calculation of the mix design of the concrete mixture with nutmeg shells, then an analysis of the weight value of the volume of fresh concrete is carried out by means of the average weight of fresh concrete divided by the volume of the cylindrical specimen as shown in Table 10.

Table 10. The weight of fresh concrete produced

| No | Sample | Volume of Freshly Concrete (kg/m$^3$) |
|---|---|---|
| 1 | Normal Concrete | 2304,32 |
| 2 | Nutmeg Shell Concrete (NSC) 0,25% | 2241,19 |
| 3 | Nutmeg Shell Concrete (NSC) 0,50% | 2245,81 |
| 4 | Nutmeg Shell Concrete (NSC) 0,75% | 2233,23 |
| 5 | Nutmeg Shell Concrete (NSC) 1% | 2298,66 |

The results of the calculation of the volume weight of fresh concrete in normal concrete obtained 2304.32 (kg/m$^3$), 0.25% nutmeg shell concrete 2241.19 (kg/m$^3$), 0.5% nutmeg shell concrete 2245.81(kg/m$^3$), 0.75% nutmeg shell concrete was 2233.23 (kg/m$^3$) and 1% nutmeg shell concrete by weight of cement was 2298.66 (kg/m$^3$).

The volume weight value of fresh concrete decreased after using a mixture of nutmeg shell material. According to [1] normal concrete is concrete that uses sand aggregate as fine aggregate and crushed stone as coarse aggregate so that it has a concrete density between 2200 kg/m$^3$ – 2400 kg/m$^3$. This shows that the use of nutmeg shell as a substitute material as a substitute for coarse aggregate is still adequate in terms of the specific gravity of the concrete.

The results of the characteristic compressive strength test of concrete (fc) using MTS at the age of 28 days obtained the maximum compressive strength value of each sample as shown in Figures 4,5,6,7 and 8.

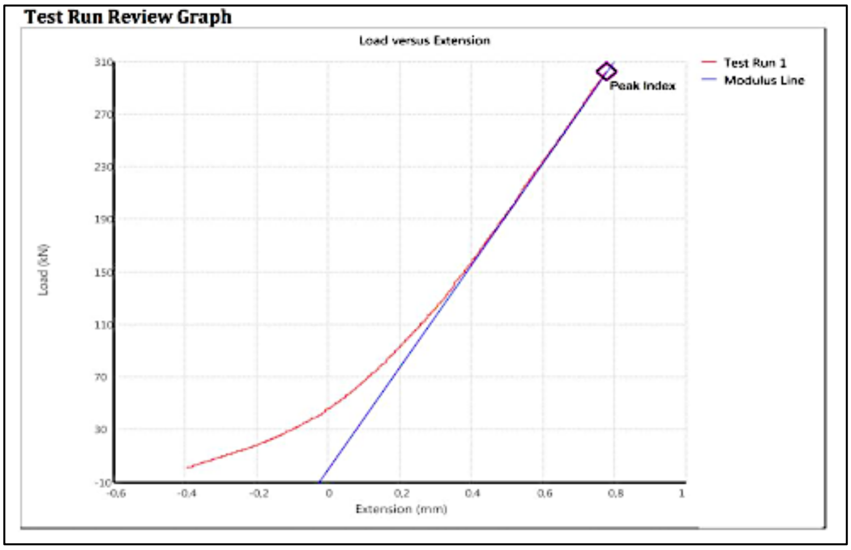


Figure 3. Test Results Normal Concrete with MTS Compression

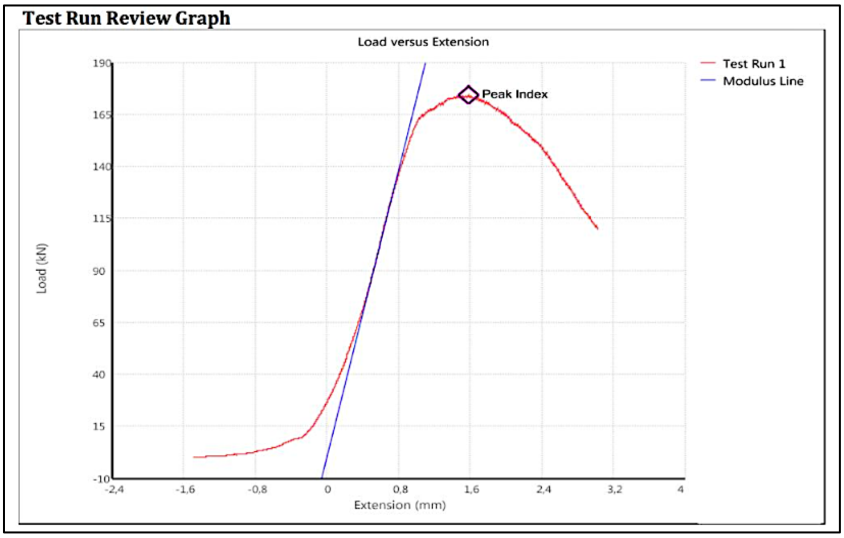


Figure 4. Test Results Nugmet Shell Concrete (NSC) 0,25% with MTS Compression

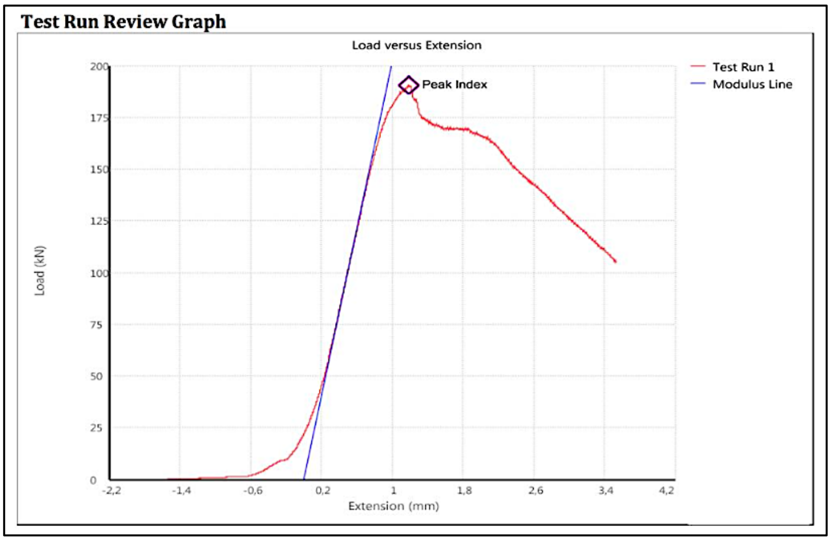


Figure 5. Test Results Nugmet Shell Concrete (NSC) 0,50% with MTS Compression

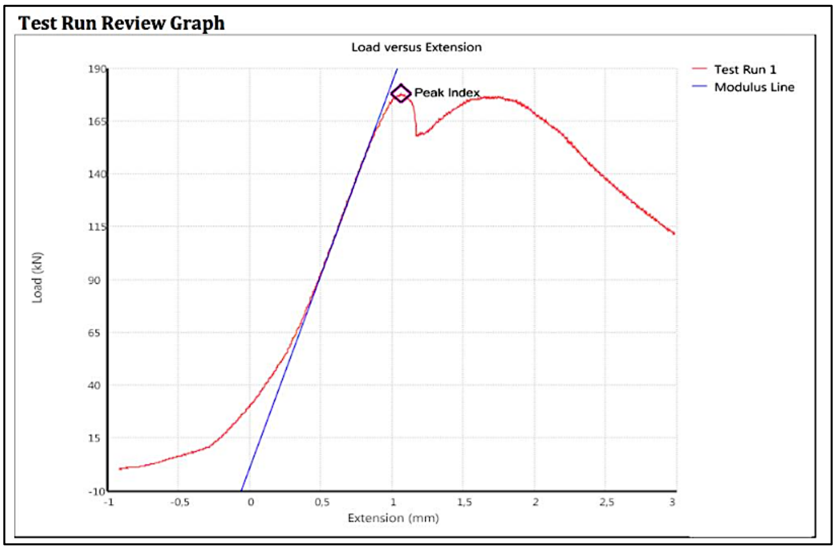


Figure 6. Test Results Nugmet Shell Concrete (NSC) 0,75% with MTS Compression

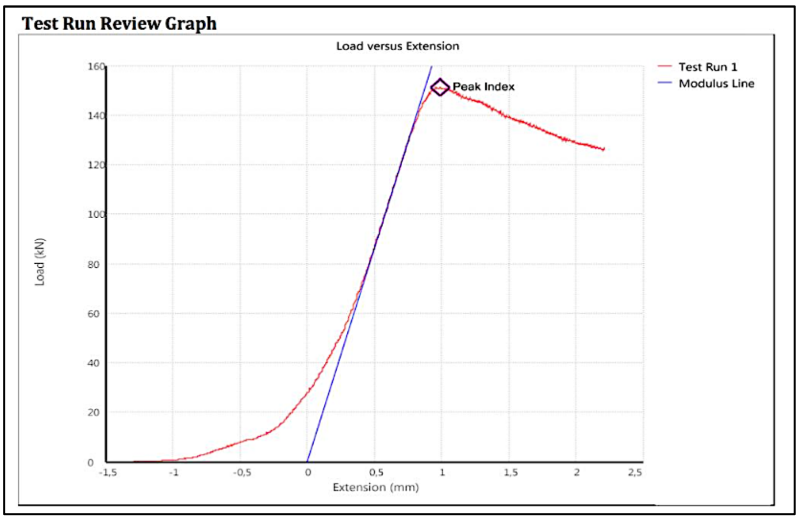


Figure 7. Test Results Nugmet Shell Concrete (NSC) 0,75% with MTS Compression

According to Figure 4,5,6,7 and 8 show the maximum compressive strength of normal concrete from 9 test samples of 302 KN while concrete using 0.25% **nutmeg** shell material as a partial replacement for maximum coarse aggregate obtained 174 KN The compressive strength value has decreased. For concrete using 0.50% nutmeg shell material, a maximum of 190 KN has increased compared to 0.25%. However, concrete using 0.75% and 1% nutmeg shell material, namely 177 KN and 151 KN, decreased. From this compressive strength value, it is concluded that the use of nutmeg shell material affects the quality of normal concrete, where the higher the percentage of the substitute material, the lower the compressive strength value.

The results of the compressive test using MTS STH Compression continued with the calculation of the characteristic compressive strength analysis (fck') where the compressive strength value (fc') was shared with a correction factor as shown in Table 11.

Table 11. The value of Compressive Strength Characteristics of Concrete

| Sample | Value read in the tool (KN) | Value analysis characteristic f'c ($kg/cm^2$) |
|---|---|---|
| Normal Concrete | 302 | 224,2 |
| Nutmeg Shell Concrete (NSC) 0,25% | 174 | 129,6 |
| Nutmeg Shell Concrete (NSC) 0,50% | 190 | 140,0 |
| Nutmeg Shell Concrete (NSC) 0,75% | 177 | 118,1 |
| Nutmeg Shell Concrete (NSC) 1% | 151 | 117,6 |

According to table 11 the results of the analysis of the value of the compressive strength of concrete with the use of nutmeg shell as a substitute for coarse aggregate with a maximum test of 28 days showed that the use of nutmeg shell as a substitute for coarse aggregate in normal concrete mixtures affects the weight of concrete and the value of the compressive strength of concrete characteristics (fck' ).

The higher the percentage of the use of nutmeg shells, the weight of the concrete decreases compared to the weight of normal concrete without nutmeg shells. The value of the compressive strength of nutmeg shell concrete at a composition of 0.25% and 0.5% was obtained by 129.6 ($kg/cm^2$) and 140.0 ($kg/cm^2$) increased, while the use of nutmeg shell at a composition of 0.75% and 1% obtained a value of 117.6 ($kg/cm^2$) and 118.1 ($kg/cm^2$) decreased at the age of 28 days.

The strength value has decreased when compared to normal concrete, which is 224.2 ($kg/cm^2$) (22 Mpa). The decrease in compressive strength is influenced by the high percentage of the use of nutmeg shells into the concrete mix so that the aggregate grains are not wrapped in mortar and reduce the volume of concrete that should be filled with cement paste. The same thing was expressed by [12], that for good concrete, each aggregate grain is completely covered with mortar. Likewise, the space between the aggregates must be filled with mortar. So the quality of the paste or mortar determines the quality of the concrete.

According to [1] normal concrete is concrete that has a compressive strength value of around 15-40 Mpa. Based on the range of compressive strength values, it shows that the results of normal concrete research without nutmeg shells are in the category of 22 MPa while concrete using nutmeg shells at the age of 28 days is a maximum of 14 MPa so it is concluded that the use of nutmeg shells as coarse aggregate material in normal concrete reduces the strength value press. The use of nutmeg shells as a concrete building material is recommended for the lightweight concrete category and can be implemented directly in the manufacture of lightweight concrete blocks.

Research on nutmeg shell as a substitute for coarse aggregate for normal concrete has an effect on the compressive strength of concrete characteristics, where the higher the percentage of substitute material used, the lower the compressive strength value. According to [7] concluded that the higher the percentage of use of substitute or substitute materials for coarse aggregate, the lower the compressive strength value, the same thing was conveyed by [8] by utilizing broken concrete as an alternative to partial replacement of coarse aggregate, [13] utilizing recycled aggregate, [14] utilizes rice husk ash and waste concrete mix, in contrast to the expression [15] which uses nickel slag as a substitute for coarse aggregate, where the higher the percentage of substitute aggregate, the higher the compressive strength of concrete will be. The relationship of this research with previous research can both contribute as a substitute for coarse aggregate in normal concrete.

## 4. CONCLUSION

### 4.1 Conclusion

Based on the results of research and data analysis that has been implemented, it can be concluded some points as follows:

1. The use of nutmeg shells as a partial replacement of coarse aggregate in the concrete mixture affects the specific gravity and the value of the compressive strength of the concrete characteristics. The higher the percentage of nutmeg shell, the density and compressive strength of the concrete decreased. The average value of the specific gravity of concrete from nutmeg shell was 2254.72 (kg/m$^3$) while normal concrete was 2304.32 (kg/m$^3$).
2. The compressive strength value of normal concrete is 224.2 (kg/cm$^2$) while the concrete from nutmeg shell at the composition of 0.25% and 0.5% is obtained by 129.6 (kg/cm$^2$) and 140.0 (kg/cm$^2$) increases while the use of nutmeg shell at the composition of 0.75% and 1% obtained values of 117.6 (kg/cm$^2$) and 118.1 (kg/cm$^2$) decreased at the age of 28 days. The compressive strength of normal concrete is 22 MPa while the maximum nutmeg shell concrete is 14 MPa.

### 4.2 Suggestion

Based on the conclusion, the suggestion or recommendation from this research is as follows:

1. The results of this study affect the specific gravity for each percentage, so it is necessary to conduct further research by examining the relationship between specific gravity and other parameters, namely the value of the modulus.
2. It is recommended to use nutmeg shell as an aggregate material for lightweight concrete, in addition to saving costs, it can also reduce waste that has an impact on the environment.

## 5. ACKNOWLEDGEMENT

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