The Effect of Clamshell Ash Substitution to the Mechanical Properties of Concrete

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Abstract. Concrete is the main material for construction that is widely used throughout the world. The more widespread use of concrete and the increasing scale of development also shows more and more concrete needs in the future. The era development of this rapid globalization era has resulted in the increasing number of used goods/waste whose existence can be a problem for life, one of which is the presence of clamshell ash. For this reason, many things have been done in order to recycle to overcome the problem of the existence of this waste. One of them is that clamshell ash can be used as a substitute for cement in a concrete mixture. This research uses clamshell ash and lime with variations of 0%, 5%, 10%, 15%, and 20% from the use of cement.

The substitution of clamshell ash and lime affects the strength of the concrete. There are an increase in slump value with the substitution of clamshell ash by 8, 9, 11, 13, 14 and lime substitution by 8, 8, 5, 10, 12, 13. There are a decrease in compressive strength on the substitution of clamshell ash by 89.18%, 74.09%, 67.87%, 64.92% of normal concrete and compressive strength on lime substitution by 69.84%, 58.53%, 57.05%, 55.82% of normal concrete. There are a decrease in split tensile strength in the substitution of clamshell ash by 95.96%, 92.3%, 81.7%, 75.8% of normal concrete and split tensile strength on lime substitution by 87.93%, 81.33%, 65%, 92%, 48.37% of normal concrete.

1. Introduction
Clamshell ash comes from the processing of clamshell waste which is cleaned and mashed up by using a grinding machine until it becomes ash.

Table 1. Chemical composition of clamshell ash and lime

| Component | Level of clamshell ash (% Berat) | Level of lime (% Berat) |
|-----------|---------------------------------|------------------------|
| CaO       | 55,1038                         | 34,6476                |
| SiO₂      | 0,924                           | 0,564                  |
| Fe₂O₃     | 0,0017                          | 0,0242                 |
| MgO       | 0,9475                          | 0,1865                 |
| Al₂O₃     | 1,2283                          | 7,7558                 |

2. Scope of problem
1. Concrete quality of f’c = 20 Mpa
2. The samples used are cylinders with a diameter of 15 cm and a height of 30 cm for compressive strength, split tensile strength and absorption test.
3. The samples used for the macrostructure test is 10 cm in diameter and with a height of 1 cm.
4. Tests.
   - Compressive strength
   - Split tensile strength
   - Absorption
   - Macrostructure
5. The substitution of clamshell ash and lime used in each samples are 5%, 10%, 15% and 20%.

3. Objectives
The objectives of this research are
1. To know the workability of fresh concrete that uses clamshell ash as a substitute for cement in a concrete mixture.
2. To know the mechanical behavior of concrete that uses clamshell ash and lime as a substitute for cement in a concrete mixture and compares it with normal concrete. Mechanical behavior studied includes: compressive strength, split tensile strength, absorption and macrostructure.

4. Research method
The method used in this research is an experimental test in the laboratory. The characteristics of the material used are as follows:

4.1. Clamshell ash
The clamshell ash used in this research comes from the processing of clamshell waste obtained from the waste of boiled clamshell stall located on Jalan Gagak Hitam (Ringroad). Clamshells are cleaned first by soaking it for 4 hours, then cleaned by brushing and then dried under the sun. After the shells are clean and dry, the shells are mashed by using a grinding machine until it becomes ash in Kapur Karya Tunggal Refinery, jalan Bunga Sakura I.

4.2. Samples
In this research, the samples are cylindrical with a diameter of 15 cm and a height of 30 cm. Tests are carried out after concrete reaches 28 days curing. The samples with the variation of clamshell ash and lime used can be seen in table 2

| Variation                        | Compressive Strength of 28 days curing | Split Tensile Strength of Umur 28 days curing | Absorption of 28 days curing | Number of samples |
|----------------------------------|----------------------------------------|---------------------------------------------|------------------------------|-------------------|
| Normal Concrete                  | 3                                      | 3                                           | 3                            | 9                 |
| Concrete + 5% clamshell ash      | 3                                      | 3                                           | 3                            | 9                 |
| Concrete + 5% lime               | 1                                      | 1                                           | 1                            | 3                 |
| Concrete + 10% clamshell ash     | 3                                      | 3                                           | 3                            | 9                 |
| Concrete + 10% lime              | 1                                      | 1                                           | 1                            | 3                 |
| Concrete + 15% clamshell ash     | 3                                      | 3                                           | 3                            | 9                 |
| Concrete + 15% lime              | 1                                      | 1                                           | 1                            | 3                 |
| Concrete + 20% clamshell ash     | 3                                      | 3                                           | 3                            | 9                 |
| Concrete + 20% lime              | 1                                      | 1                                           | 1                            | 3                 |
| Total of Samples                 |                                        |                                             |                              | 57                |
5. Research location

Concrete Technology and Engineering Materials Laboratory, Civil Engineering, Faculty of Engineering, University of Sumatra Utara for the compressive strength, split tensile strength and absorption test. Mechanical Technology Laboratory and Metallurgy Laboratory, Department of Mechanical Engineering, Faculty of Engineering, University of Sumatra Utara for the macrostructure test and Analytical Chemistry Laboratory, Faculty of Mathematics & Natural Sciences, University of Sumatra Utara for the chemical composition of clamshell ash and lime.

6. Results and discussion

6.1. Slump

The test results of slump value (ASTM C143-90 A) with the substitution of the clamshell ash and lime can be seen in graph 1 below:

6.2. Compressive strength

Concrete compressive strength test (ASTM C39-86) is carried out at 28 days of curing which is intended to obtain an overview of the development of concrete compressive strength by substituting clamshell ash and lime and the results are compared with normal concrete.

Figure 1. Graph of slump value to the substitution of clamshell ash and lime

Figure 2. Graph of compressive strength test results
From the test results of concrete cylinders at 28 days curing, the results show that there is a decrease in strength at each level addition of clamshell ash and lime usage. So as to obtain a graph that decreases as the addition of shell and lime ash. A decrease in compressive strength occurs due to the content of silica compounds found in the clamshell ash and lime is very low. The calcium silicate compound is responsible for the mixed hardening process. Besides calcium silicate hydrate which is obtained from its active silica, tricalcium aluminate hydrate is also formed.

The strength of cement paste plays the most important role which is directly influenced by the quality of cement, water and its porosity. The small porosity will increase the strength of the cement paste and is greatly influenced by the water-cement ratio (w / c) in the mixture. The determining aggregate quality is its strength, its surface roughness and its gradation, besides being guaranteed to be free from dirt and reactive chemicals.

6.3. Split tensile strength

Concrete split tensile strength test (ASTM C496–96) is carried out at 28 days curing which is intended to obtain an overview of the tensile stress of concrete with the substitution of clamshell ash and lime and the results are compared with normal concrete.

![Graph of split tensile strength test results](image)

**Figure 3.** Graph of split tensile strength test results

6.4. Absorption

Absorption test (ASTM C642-97) is carried out at 28 days curing which is intended to obtain an overview of the absorption of concrete with the substitution of clamshell ash and lime and the results are compared with normal concrete.

![Graph of absorption test results](image)

**Graph 4.** Graph of absorption test results
6.5. Macrostructure

Macrostructure observation (ASTM B-276) that is 100-200 times magnification by using the optical microscope type Rax Vision No.545491, MM-10A, 230V 50.

- Normal concrete

![Macrostructure of normal concrete](image1)

**Figure 5.** Macro photo of normal concrete at 100× and 200× magnification

- 20% clamshell ash substitution

![Macrostructure of clamshell ash substitution](image2)

**Figure 6.** Macro photo of clamshell ash substitution at 100× and 200× magnification

- 20% lime substitution

![Macrostructure of lime substitution](image3)

**Figure 7.** Macro photo of lime substitution at 100× and 200× magnification

The figures above show the results of macrostructure test on normal concrete, the substitution of clamshell ash and the substitution of lime with 100× and 200× magnification. Visually, the samples can be seen directly and from the figures above, it can be seen that some defects in the porosity form where this will certainly result in a decrease in the mechanical properties of the concrete because it can
be the source/start of cracking. The porosity value of normal concrete is less than the concrete mixture with the substitution of clamshell ash and lime.

The greater the percentage of clamshell ash and lime, the greater the porosity that occurs. So that there is a decrease in compressive strength, tensile strength and an increase in absorption value of concrete.

7. Conclusions

1. Substitution of clamshell ash and lime on concrete mixtures of 5%, 10%, 15% and 20% of cement use increases the slump value so that the workability of the concrete decreases.
2. The substitution of 5%, 10%, 15% and 20% clamshell ash of cement use in the concrete mixture decreases the compressive strength by 89.18%, 74.09%, 67.87%, 64.92% from each variation of normal concrete and split tensile strength by 95.96%, 92.3%, 81.7%, 75.8% from each variation of normal concrete.
3. 5%, 10%, 15% and 20% lime substitution of cement use in concrete mixture decreases the compressive strength value by 69.84%, 58.53%, 57.05%, 55.82% from each variation of normal concrete and split tensile strength by 87.93%, 81.33%, 65.92%, 48.37% from each variation of normal concrete.
4. Substitution of clamshell ash has greater compressive strength and split tensile strength than the substitution of lime. The greatest compressive strength in the substitution of clamshell ash is at a 5% percentage of 20.53Mpa and meet the planned concrete quality.
5. The greater the percentage of clamshell ash and lime mixture, the greater the porosity that occurs. So that there is a decrease in compressive strength, tensile strength and an increase in absorption value of concrete.

8. Suggestions

1. Further research is needed by using clamshell ash with different types of clamshells or other types of added material as a comparison material in planning concrete work.
2. Clamshell ash contains all the main chemical elements of cement even though in a lower percentage so that it can be used as a substitute for some cement if the appropriate technology is developed for proper utilization.
3. The combination of clamshell ash waste with other materials can also be considered in order to obtain better results.

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