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The Utilization of Nickel Slag and Oyster Shell to Improve the Concrete Strength

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ABSTRACT

The increasing mining industry activity will produce increasing industrial waste. Nickel slag is one of the wastes produced from the nickel refining process by-products that have not been optimally utilized. The chemical composition of nickel slag is mostly silica with a percentage of 47.93%. Silica can be used as a material for making concrete, where a high percentage of silica is expected to strengthen the concrete structure. This study was conducted to determine the effect of nickel slag on the compressive strength of concrete and the right composition in the concrete mixture. The research method used an experimental method with different nickel slag compositions (0%, 5%, 10%, 15%, and 20%) with concrete compressive strength testing at the age of 28 days. The results of the concrete compressive strength test were that the higher the nickel slag content, the higher the compressive strength and flexural strength of the concrete. The addition of shells with different variations (0%, 5%, 10%, 15%, and 20%) showed that the best results were with the addition of 10% shells with a compressive strength of 28.1 MPa. Meanwhile, the water absorption capacity with the lowest absorption power was obtained by adding 20% nickel slag, which was 8.95 %.

1. Introduction

There are two industries in Obi Island, South Halmahera, North Maluku Province that play the major roles in the growth of the community's economy, namely PT. Megah Surya Pertiwi, which is a subsidiary of Harita Nikel, the nickel refining industry and PT. Karya Alam Bahari, a pearl cultivation industry. The nickel refining industry produces slag waste and cause the accumulation of solid waste of nickel slag.

Slag is formed from hot liquid waste that is released so that it becomes natural rock with solid slag and porous slag. Nickel slag is divided into three types, namely high, medium, and low slag [1]. Silica is the main component of slag, where slag contains around 49.64% silica, so it can be used as a material for making concrete. The presence of slag for a long period of time will affect air quality [2]. Activities at PT. Karya Alam Bahari produces waste in the form of shells. Shell waste that is not handled properly will cause a foul odor due to the emergence of meat residue in the shell or the decomposition of salt by microbes into gases such as hydrogen sulfide, ammonia, and amines. If the shells are deposited in the sea, it causes the marine population to experience infections that have a negative impact on the quality of life [6]. Shells have almost the same content as semen, namely the chemical compound pozzolan which contains lime (CaO), aluminum oxide, and silica. [7]. Nickel slag and shell waste have not been optimally utilized in the area around Obi Island. If this waste is not processed or utilized further, it can damage the ecosystem and the environment which can harm humans, animals, and plants.

The use of slag as aggregate in the manufacture of construction materials such as concrete has been carried out by [8] the results showed the compressive strength of 28-day-old concrete for samples with slag concentrations of 0% (control), 25%, 50%, 75%, and 100% reached 17.61 MPa, 13.65 MPa, 17.24 MPa, 17.34 MPa, and 21.95 MPa. Other research conducted by Mustika et al. [1] which utilized nickel slag waste in the manufacture of paving blocks can increase the compressive strength value of paving blocks, and the highest compressive strength value was obtained in a paving block mixture using nickel slag in a composition of 1:3 and a mixture variation of 0% sand: 100% nickel slag waste.

Based on the above explanation, one of the efforts to reduce the environmental impact due to the increasing productivity of the mining industry is to utilize nickel slag as a coarse aggregate in the concrete mixture, so the purpose of this study is to determine the effect of slag as a substitute for coarse aggregate in the concrete mixture and to obtain the optimal correlation of slag percentage to the compressive strength of concrete.

2. Research Methodology

2.1. Materials

The materials used in this study include nickel slag obtained from PT. Surya Megah Pertiwi, oyster shells from PT. Karya Alam Bahari, portland cement, gravel, and water.

2.2. Procedures

2.2.1 Preparation of Seashell

The shells are first crushed using a crusher. Then they are ground using a grinder until they pass through a 200-mesh sieve.

2.2.2 Production of Test Specimens

The test specimens were prepared in several steps. First, the preparation the tools and materials which used in the study. Nickel slag was crushed dan screened in the size of -20 mesh. The same preparation with nickel slag was also applied for oyster shell. Materials i.e., nickel slag, oyster shell, sand, aggregate, Portland cement, and water were weighed and mixed in the mixing unit until homogenous. The mixture was molded in the shape of cube with dimension of 15 x 15 x15 cm. The test specimens were then left in the mold for 24 hours. After 24 hours the test specimens were removed from the mold. The specimens were let to cure for 28 days, then the concrete compressive strength test was carried out. The procedure is also presented in the Figure 1.

2.2.3 Test Parameters Compressive Strength

The testing procedure is carried out based on SNI 1974-2011, where the test object is placed on the press machine centrally [4]. To calculate the compressive strength of concrete, measurable parameters are needed, namely the compressive load (compressive force f) through compression testing and the area of the sample by measuring the diameter of the concrete and the height of the concrete. Determination of the compressive strength value of concrete uses the equation [5]:

$$P = \frac{F}{A}$$

Description:
P = compressive strength (kg/cm^2)
F = compressive load (kg)
A = cross-sectional area of the cylinder (cm^2)

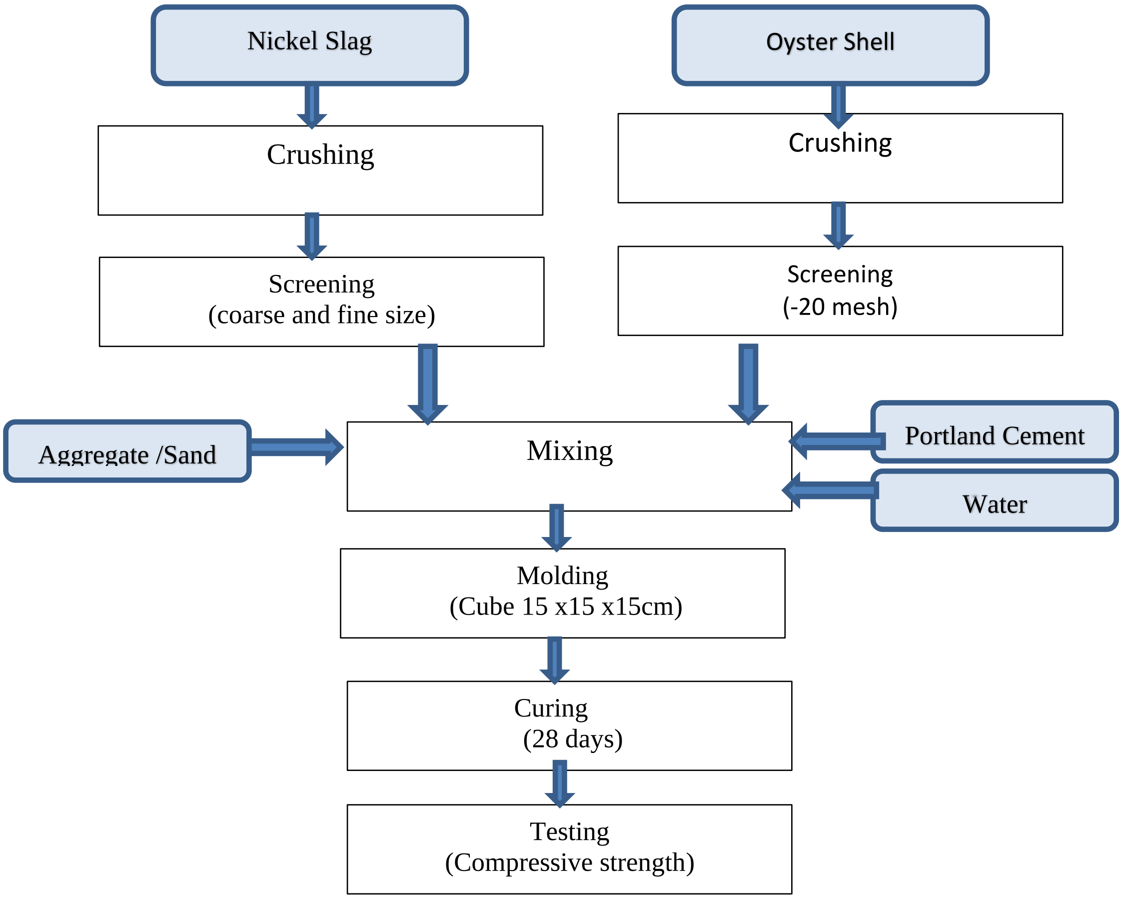

Fig. 1 Procedure of research

3. Results and Discussion

3.1. Effect of Addition of Nickel Slag on Concrete Strength Test

Concrete compressive strength testing was carried out at the age of 28 days, this is because at the age of 28 days the concrete strength has reached 100%. The results of the concrete compressive strength test are presented in Figure 2.

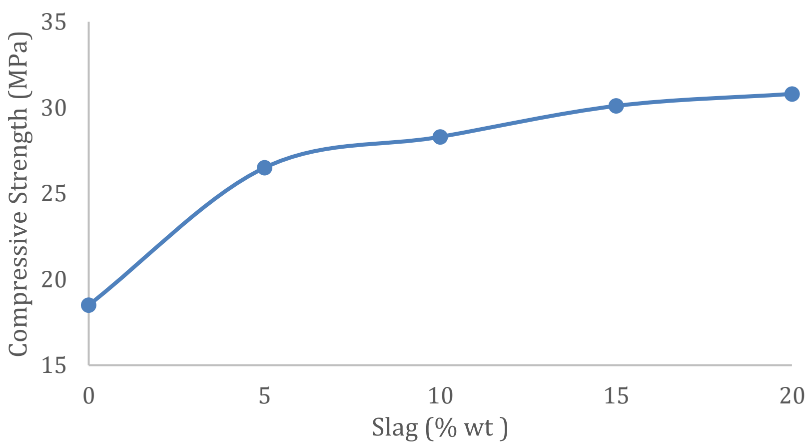

Fig. 2 Comparison of Slag Content to Concrete Compressive Strength

Figure 2 shows that the compressive strength of concrete increases with increasing nickel slag content up to 20%. At a content of 0%, the compressive strength of concrete is 18.5 MPa, when nickel slag is added 5%, the compressive strength of concrete increases to 26.5 MPa. Furthermore, increasing the nickel slag content to 10% and 15% each produces a concrete compressive strength of 28.3 MPa and 30.1 MPa. The maximum increase is seen at 20% nickel slag, with a compressive strength reaching 30.8 MPa. It can be concluded that the addition of nickel slag makes a positive contribution to the microstructure of concrete which is smaller than cement, fine particles of nickel slag fill small gaps in cement and hydration products, thereby increasing the density of cement which causes interlocking between particles to increase.

Several factors that affect the compressive strength of concrete are the ratio of water and cement in the mix design, and aggregate properties, where the higher the level of aggregate hardness, the greater the strength of the concrete, and are influenced by the silica content in the material and the composition of the material, concrete must be composed of varying aggregate grains [3].

3.2. The Effect of Adding Seashells on Concrete Compressive Strength Tests

The results of concrete compressive strength tests on the addition of shells with varying compositions can be seen in the Figure 3.

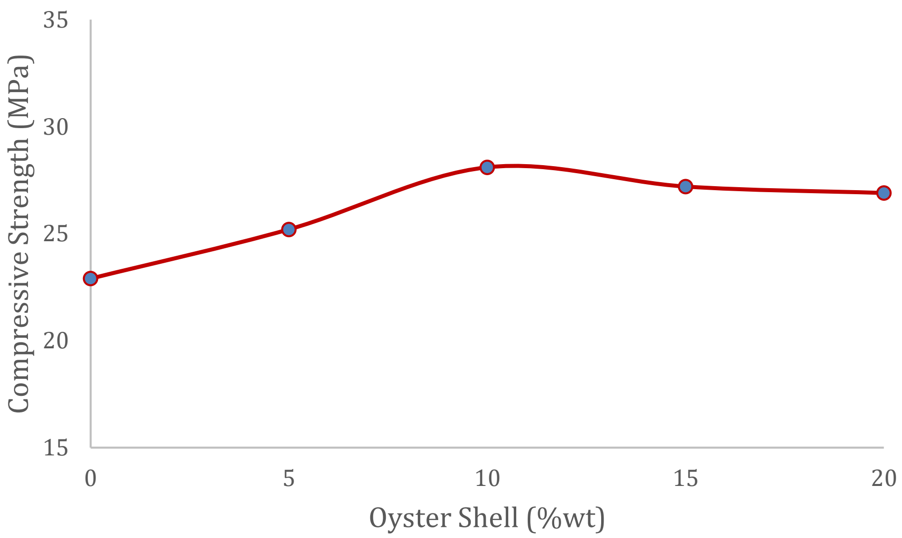

Fig. 3 Comparison of Shell Content to Concrete Compressive Strength

Figure 3 shows that there is an increase of up to 10% in shell content. Concrete without the addition of shells has a concrete compressive strength of 22.9 MPa, then there is an increase of 25.2 MPa at the addition of 5% shells and the concrete reaches an optimal compressive strength of 28.1 MPa with the addition of 10% shells. However, after the addition of 15% and 20%, there is a decrease in the concrete compressive strength of 27.2 MPa and 26.9 MPa respectively.

The increase in compressive strength is caused by the nature of the shell which increases the density of the concrete microstructure. The decrease in concrete compressive strength at the shell content can be caused by uneven particle distribution or poor bonding between the shell and cement paste. A previous study that conducted by Zhu et al. [9] revealed that replacing aggregate with shells resulted in a decrease in concrete compressive strength due to the large number of macro pores caused by the irregular shape of the shell sand particles and the concrete hydration process was disturbed by dirt and organic materials.

3.3. Effect of Addition of Nickel Slag on Flexural Strength Test of Concrete

The flexural strength test of concrete aims to measure the ability of concrete to withstand bending loads or moments that cause concrete to deflect. The results of the flexural strength test of concrete are presented in the following table:

Table 1 Flexural Strength of Concrete at 28 Days

Composition	Percentage Of Material (%)				
Sand	80	75	70	65	60
Cement	10	10	10	10	10
Shell	10	10	10	10	10
Slag	0	5	10	15	20
Total	100	100	100	100	100
Flexural Strength of Concrete (Mpa)	13440	15488	18176	21216	21984

Based on the table above, shows that the higher the content of nickel slag used in the concrete mixture, the higher the flexural strength of the concrete produced. This is in accordance with research conducted by previous researchers [1]. Shows that nickel slag can function as an effective additive in increasing the flexural strength of concrete. The mineral content in nickel slag contributes to increasing the density and resistance of the concrete microstructure, thereby increasing resistance to flexural forces.

3.4. Effect of Addition of Nickel Slag on Concrete Absorption Test

The purpose of the absorption test on concrete is to measure how much concrete is able to absorb water or other liquids. The water absorption is presented in the following table.

Table 2 Concrete Absorption Capacity at 28 Days

Composition	Percentage Of Material (%)				
Sand	80	75	70	65	60
Cement	10	10	10	10	10
Shell	10	10	10	10	10
Slag	0	5	10	15	20
Total	100	100	100	100	100
Concrete Absorption Capacity	12.00	11.52	11.38	12.22	8.95

Table 2 shows that the addition of nickel slag to the concrete composition affects the absorption capacity of the concrete. With the addition of 20% nickel slag has an absorption capacity of 8.95 MPa lower than other treatments. This shows that concrete with a composition of 20% nickel slag has lower porosity. Although in nickel slag there are pores or cavities that allow water absorption, nickel slag is produced from combustion at high temperatures, lack of oxygen in the granules or grains, and the surface of the nickel slag grains becomes more waterproof.

4. Conclusion

Nickel slag and oyster shells can be effective alternative materials in increasing the compressive strength and flexural strength of concrete and can increase the concrete's resistance to water at the right material content or composition. The addition of nickel slag 20% has given the highest compressive strength. While, the addition of oyster shell 10% has given the highest compressive strength.

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