Potential Use of Pomalaa Nickel Slag as a Substitute for Sand in Brick Making

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Abstract. The latest variance of nickel slag from PT.Antam Pomalaa has that material gradation size equivalent to sand has, so it has potentially as a sand substitute material. The study aims to determine the use of fine nickel slag as a substitute for sand in brick making. Nickel slag used is variation of 0%, 25%, 50%, 75% and 100% against of total weight of sand. The brick is designed with a cement – sand ratio of 1 : 7. The experimental is a hollow brick with dimension of 40 cm×18 cm×10 cm. Compressive test is done after brick curing along 28 days. The maximum result of compressive test is obtained in the use of 50 % nickel slag of 19.58 kg/cm² compared to the brick without nickel slag of 12.92 kg/cm². The conclusion that by using a fine nickel slag type of FeNi 4 up to 50 % on production, it can reduce sand use and improve the strength up to 51%.

1. Introduction
South East of Sulawesi has become one of regions that included in specific Economy Zone and in cement Center of National Mining Industries. The one of the biggest mining in South East of Sulawesi is a nickel mining managed by PT. Antam Pomalaa. Byproduct that is produced is nickel slag to reach a number 1 million tone of weight in 2018. A new variant of nickel slag is FeNi 4 , with distribution size passed the sieve number 4 is more than 90%. Based on material size distribution, nickel slag FeNi 4 as equal as sand aggregate [1]. This become opportunity to use nickel slag FeNi 4 of PT. Antam Pomalaa as a fine aggregate to substitute a river sand for many constructions.

Since in 2014, Indonesian government has released regulation that stated that nickel slag is a category of hazardous waste [2]. Yet, level of hazardous of nickel slag has still on level 2, It means that it has a delayed effect and indirect effect to the environment and people [3]. Beside that, some researchers concluded that the level of metal leachate is still below of requirement standart if it is used for concrete aggregate as backfill material and road pavement [4, 5, 6]. This is indicated that nickel slag can be considered as a green environment material on construction made of cement.

The using nickel slag on construction together with cement is called solidification mechanism. This solidification can cause chemical stability and bind the pollutant within solid matrice [7]. Characteristic of nickel slag is latent that can not react if only with water (H₂O). Yet, It has a highly reaction if together with calcium and other compound contained in cement [8,9].

Brick is a building component based on cement that consist in mix of sand, cement, and water with a certain composition. Hollow brick has characteristic of a good heat conductor, its weight lighter than 1/3 of compact brick and more sound absorber [10, 11]. A strength of brick is influenced by a number

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of water cement ratio and a number of sand to cement ratio in the mix. Sand is used commonly a fine gradation [12] with a minimum compressive strength of qualities I,II,III, and IV respectively 65 kg/cm², 45 kg/cm², 30 kg/cm², dan 17 kg/cm².

Even though a new variant of nickel slag FeNi 4 sizing likely to sand, but a former researcher result showed that a unit weight of nickel slag is heavier than a normal aggregate [13,14,15]. Based on above result, so the aim of this research is to analyze the level of nickel slag substitution against normal sand used on hollow brick making.

2. Material and Method
The experiment is done into two steps, 1). A trial mix step is to find a composition and water cement ratio on a normal brick as control, 2). Step of brick making by using nickel slag

2.1. Material and equipment
Composition of material used are Tonasa cement, sand of Pohara, FeNi 4 nickel slag from PT. Antam Pomalaa, and water clean from PDAM company. Material characteristic of sand and slag are examined according to SNI/AASHTO/ASTM, whereas material cement and water are observed by visual. Qualification and characteristic of material will be used into mix design.

A main equipment used is a manual compression of brick, a hollow type of 40×10×18 cm in length×wide×hight that is shown on Figure.1. A net volume of hollow brick is 0.0056 m³.

![Figure 1. Dimension of brick hollow mould](image)

2.2. Mix design
Mix design of brick is calculated based on ratio of cement and sand weight using volume absolute method. Composition of materials on each variation are shown on Table 1 and Table 2 as following:

| Trial | Mix design (cement : sand) | Water/Cement Ratio | Weight of material (kg/m³) | Sand | Cement | Water |
|-------|---------------------------|--------------------|---------------------------|------|--------|-------|
| 1     | 1: 8                      | 0.4                |                           | 2028.77 | 253.60 | 101.44 |
| 2     | 1: 8                      | 0.5                |                           | 1978.60 | 247.32 | 123.66 |
| 3     | 1: 8                      | 0.6                |                           | 1930.84 | 241.36 | 144.81 |
| 4     | 1: 7                      | 0.4                |                           | 1977.38 | 282.48 | 112.99 |
Table 2. Mix design of slag nickel brick for ratio cement : sand (1:7) using water/cement ratio 0.4

| Variation by types | Code of Samples | Composition (slag : sand) | Weight of material (kg/m³) |
|--------------------|-----------------|---------------------------|----------------------------|
|                    |                 |                           | Slag | Sand | Cement | Water |
| Normal brick       | Nb              | 0% : 100%                 | -    | 1977.4 | 282.5 | 113.0 |
| Slag brick-25      | Sb-25           | 25% : 75%                 | 520.4 | 1561.1 | 260.2 | 104.1 |
| Slag brick-50      | Sb-50           | 50% : 50%                 | 1068.4 | 1068.4 | 267.1 | 106.8 |
| Slag brick-75      | Sb-75           | 75% : 25%                 | 1646.5 | 548.8  | 274.4 | 109.8 |
| Slag brick-100     | Sb-100          | 100% : 0%                 | 2193.7 | -     | 313.4 | 125.4 |

2.3. Testing

Each variation of mix is made three test samples so that 15 bricks to be tested. Compressive strength is taken after brick 28 days of age. A peak load accepted when sample test has already broken. However observation of brick quality is done by looking a visual deformation and shape.

2.4. Analysis

Analysis on volume weight and compressive strength of brick is defined by eq.(1) and eq.(2).

\[
W = \frac{w}{v} \quad (1)
\]

\[
f_c = \frac{P}{A} \quad (2)
\]

Where \(W\) is volume weight of brick (kg/m³); \(w\) is weight of brick (kg); \(v\) is volume of brick (m³); \(f_c\) is compressive strength of brick; \(P\) is maximum load (kg); \(A\) is a surface of stress (m²).

3. Result and Discussion

3.1. Result of material testing

Empirical result of normal sand and slag sand as following:

Table 3. Properties of normal sand and slag sand.

| Properties of material          | Pohara Sand | Slag Sand | Specification SNI |
|--------------------------------|-------------|-----------|-------------------|
| SSD specific gravity           | 2.48        | 2.83      | 2.4 - 2.9         |
| Absorption                     | 0.81 %      | 0.66 %    | < 3%              |
| Bulk density                   | 1.65 gr/cm³ | 1.40 gr/cm³ | 1.4 – 1.9        |
| Clay, Silt Content             | 1.32 %      | 0.10 %    | < 5 %             |
| Moisture content               | 0.53 %      | 1.32 %    | < 3 %             |

Tabel 3 shows that material of sand slag accepted the requirement as material for concrete brick. Test result of unit weight of nickel sand slag FeNi 4 is higher than normal sand has. A number of unit weight of sand slag is 2.8 indicated that it has in the level of heavy aggregate. Aggregate with unit weight between 2.5 to 2.7 gr/cm³, it will produce concrete that has 2.3 gr/cm³ of unit weight. When aggregate has a high unit weight and high compressive strength as well.
3.2. Exposure of normal brick making
The results of bricks in the preliminary test with the composition as shown in Table 1 are presented as follows:

| Mix | Water Cement Ratio |
|-----|--------------------|
| 1:8 | 0.4                |
| 1:8 | 0.5                |
| 1:7 | 0.4                |
| 1:7 | 0.6                |

**Figure 2.** A common brick using normal sand (pohara river), mix of 1:8 with 0.4 and 0.5 water cement ratio.

**Figure 3.** A common brick using normal sand (pohara river), mix of 1:8 and 1:7 with 0.6 and 0.4 water cement ratio.

From the equipment test result of a normal brick using Pohara Sand, we have a composition of mix 1:7 and water cement ratio 0.4.

3.3. Exposure of sand slag brick making
In preparing to sand slag brick making, we make a normal brick as control and comparison according to the result of experiment shown in Figure 4.

**Figure 4.** A normal brick as control, mix 1:7 and water cement ratio 0.4.

The exposure of sand slag brick based on composition on Table 2 as following:
From testing result shown that slag brick 100% is not accepted a visual formation (SNI 03-0349-1989) because of occurring deformation on test object with composition 1 cement : 7 aggregate and 0.4 water cement ratio. So we do not continue a test object of slag 100%.

3.4. Weight examination of slag brick result
The examination of volume weight of each nickel slag variation is shown below.

Based on figure as shown, it can be seen that weight of brick is increasing because of using slag in the mix. The more slag using the more weight of brick produced. The number of weight of brick increasing about 5% of normal brick weight (without slag). A increasing of weight is caused of a heavier unit weight of slag than normal sand.

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3.5. Compressive strength examination of slag brick

Compressive strength test of slag brick in variations can be seen below.

The figure shown that compressive test of normal brick (test object as control) is lower than a minimum requirement number 17 kg/cm². This condition indicated that composition design of normal brick need more improvement of water cement ratio to meet the requirement of strength.

The using of nickel slag FeNi 4 a number of 25% and 50% will improve the compressive strength of slag brick against a normal brick a number of 45% and 52%. However, by using nickel slag a number of 75% the compressive strength decreased even though it is still higher than a normal brick strength.

An increasing of brick strength using nickel slag FeNi 4 is occurred because of the aggregate texture of nickel slag are rough and sharp. This is in line with the research [14,15] that concluded an increase in strength of concrete due to use of sand slag. A decreasing of brick strength by using of 75% of nickel slag can be caused of higher weight of slag material. Fig. 7 shows that weight of brick increase because of slag nickel addition. For composition of 1 : 7 with water cement ratio of 0.4, using 75% nickel slag FeNi 4 aggregate is not enough optimum to increase compressive strength of slag brick. Mix design modification is needed to find a strength of mix that is higher than 50% of slag using.

4. Conclusion

Using nickel slag FeNi 4 as substitute of sand in concrete brick making can increase its compressive strength, in the same time a volume weight become higher. Best composition and maximum strength we have on 50% slag FeNi 4 : 50% normal sand from Pohara river.

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