Properties of concrete paving blocks made with nickel slags

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Abstract. This study is a follow-up of nickel slag waste used for building construction materials. Paving blocks were made using a mixture of cement and aggregates in a ratio of 1: 3 and 1: 5 which used a mixture of nickel slag waste and natural sand with aggregate gradation in zone III of the rather fine sand category based on SNI 03-2834-2000. Sand substitution with nickel slag waste has used a variation of the composition of the mixture of 0% (without slag), 25%, 75%, and 100% (without sand). The behaviour would be obtained the compressive strength value of paving blocks and average water absorption. Paving blocks compressive strength were tested at the age of 28 days, while the average value of water absorption was performed by immersing the paving block specimens for 24 hours. The physical strength and absorption value of paving block water refer to SNI 03-0691-1996. The results showed that the use of nickel slag waste in making paving blocks could increase the compressive strength of paving blocks, while water absorption in all compositions and variations of the paving blocks mixture was decreased in line with the increase of nickel slag composition.

1. Introduction

Paving blocks are a mixture of composite materials consisting of a binder (generally a mixture of hydraulic cement and water), fine aggregate (generally sand) with or without additives. Regular paving blocks are paving blocks that have a content weight of 2200-2500 kg/m\textsuperscript{3} using regular aggregates that are broken or unbroken [1]. The use of paving blocks as a material to cover and harden the soil surface has been commonly used with several advantages including having a better ability to absorb air and having a cavity between the installation that can be used to drain and absorb water into the layer below [2].

Due to the increasing use of paving blocks, the need for mixed materials for making paving blocks is also increasing [3], alternative materials to substitute for aggregates in a mixture of paving blocks, either partially or as a substitute material, continue to be carried out to obtain new materials as a substitute for the natural aggregate. One of the alternative materials for paving block mixtures is nickel slag waste, and this is due to the form of nickel slag waste that resembles aggregate or sand and gravel material which is generally used in a mixture of paving block materials [4]. Nickel slag is a type of residue from the industrial process, which is a result of the smelting process of nickel ore after going through the combustion and filtering process. The nickel ore smelting process produces waste in the form of a huge amount of slag. The slag must be handled or used properly because it has the potential to cause environmental problems and social phenomena in the community. Thus, the use of nickel slag waste as a mixture of paving blocks aims to reduce the effect of environmental pollution and can have economic value [5].
Research by [6] on the use of nickel slag in making paving blocks, the nickel slag used comes from the waste of nickel slag from PT. Antam in Pomalaa, Southeast Sulawesi. In this study, the composition of the mixture in the volume ratio of cement and sand, namely 1:3, 1:4 and 1:5 with nickel slag content in the mixture as a substitute for sand is 0%, 25%, 75% and 100%, the results show that some the size of the specimen meets the required size. Nickel slag can increase the compressive strength, where the 75% and 100% slag content fulfils category I based on SNI 03-0691-1996 and can reduce water absorption.

In this research, nickel slag waste from PT. Virtue Dragon Nickel Industry (VDNI), located in Morosi District, Konawe Regency, Southeast Sulawesi Province as a substitute for sand in making paving blocks. This study aims to determine the compressive strength and water absorption of paving blocks by substituting the use of sand using nickel slag waste.

2. Material and method

2.1. Materials and tools
Nickel slag waste from PT. VDNI (Figure 1), was used in this research. The sample was filtered to meet the grading of sand in zone III based on SNI-03-2834-2000, while the sand used was obtained from Lafeu Village, Bungku Pesisir District, Central Sulawesi, whose grading is also in zone III sand grading based on [7].

![Figure 1. Nickel slag waste](image)

Testing of the characteristics of the sand and slag material used in this study is based on the relevant SNI method. Paving blocks are made manually using a mould measuring 20 cm x 10 m x 8 cm. Volume of mould is 0.0016 m³.
2.2. Mixed formula

The volume ratio between cement and sand in the mixture are 1:3 and 1:5, while the percentage of nickel slag in the mixture is 0%, 25% and 75%. The water-cement ratio used is 0.45; the material composition for each variation of the mixture is presented in Table 1 and Table 2:

| Sample code | Nickel slag composition | Cement (gram) | Sand (gram) | Nickel slag (gram) | Water (gram) | Water/cement ratio |
|-------------|-------------------------|---------------|-------------|-------------------|--------------|--------------------|
| Pb01-0      | 0                       | 4800          | 14400       | 0                 | 2160         | 0.45               |
| Pb01-25     | 25                      | 4800          | 10800       | 4680              | 2160         | 0.45               |
| Pb01-75     | 75                      | 4800          | 3600        | 14040             | 2160         | 0.45               |
| Pb01-100    | 100                     | 4800          | 0           | 18720             | 2160         | 0.45               |

| Sample code | Nickel slag composition | Cement (gram) | Sand (gram) | Nickel slag (gram) | Water (gram) | Water/cement ratio |
|-------------|-------------------------|---------------|-------------|-------------------|--------------|--------------------|
| Pb02-0      | 0                       | 3200          | 14400       | 0                 | 1440         | 0.45               |
| Pb02-25     | 25                      | 3200          | 10800       | 4680              | 1440         | 0.45               |
| Pb02-75     | 75                      | 3200          | 3600        | 14040             | 1440         | 0.45               |
| Pb02-100    | 100                     | 3200          | 0           | 18720             | 1440         | 0.45               |

2.3. Testing

For each variation of the mixture and the age of the test, five specimens were made so that the total test specimen was 40 specimens (Figure 2). The compressive strength test (Figure 3) based on SNI 03-0691-1996 was tested at the age of 28 days using three specimens each for each variation of the mixture. The water absorption test also refers to SNI 03-0691-1996 with the number of test objects for each variation of the mixture is two pieces. The specimens were immersed in water until they were saturated for 24 hours then weighed in a dry surface. Then dried for about 24 hours at a temperature of approximately 105°C and weighed in a dry state until the weight on two weighing times is not more than 0.2% of the previous weighing.

Figure 2. Making paving block test objects
2.4. Analysis
The calculation of the compressive strength and water absorption of paving blocks refers to eq. (1) and eq. (2).

\[ f_c = \frac{P}{A} \quad (1) \]

\[ W_{abs} = \frac{a-b}{b} \times 100\% \quad (2) \]

Where \( f_c \) is the compressive strength of paving block; \( P \) is the maximum load (N); \( A \) is a surface of stress (mm²); \( W_{abs} \) is the percentage of water absorption (%); \( a \) is the weight of the wet sample (kg), and \( b \) is the weight of the dry sample (kg).

3. Result

3.1. Aggregate test
The aggregate test results used in the paving block mixture are presented in Table 3 below:

| No. | Properties of materials | Unit          | Result | Specification |
|-----|-------------------------|---------------|--------|---------------|
|     | Sand                   | Nickle slag   | Specification |
| 1.  | Bulk density           | gr/cm³        | 1.53   | 1.58          | >1.2          |
| 2.  | Clay, Silt Content     | (%)           | 2.62   | 0.59          | <5            |
| 3.  | Bulk specific gravity  | -             | 2.49   | 2.20          | <3            |
| 4.  | SSD specific gravity   | -             | 2.58   | 2.23          |               |
| 5.  | Water absorption       | (%)           | 2.26   | 1.41          |               |
| 6.  | Moisture content       | (%)           | 0.50   | 0.16          | <3            |

3.2. Compressive strength test
The results of the compressive strength test at 28 days of the age of the specimen are presented in Figure 4 and Figure 5.
Figure 4. Compressive strength of paving blocks with mixed ratio 1: 3

Figure 5. Compressive strength of paving blocks with mixed ratio 1: 5

Figure 4 and Figure 5 show that there is a significant increase in compressive strength in paving blocks in both 1: 3 and 1: 5 mix compositions due to an increase in the percentage of nickel slag waste in the mixture. The test results show that the compressive strength increases along with the increment in the amount of nickel slag waste used in the mixture, it is following the research that has been conducted by previous researchers [6,8]. Based on SNI-03-0691-1996, the composition of paving block mixtures for all variations of the mixture meets B quality.
3.3. Water absorption

This test aims to determine the amount of water absorbed by paving blocks when dry. The number of specimens in this experiment consisted of two specimens for each variation of the addition of nickel slag, which represented the entire test object made. The results of water absorption test are presented in Figure 6 and Figure 7.

![Figure 6](image1.png)

**Figure 6.** Water absorption of paving blocks with mixed ratio 1: 3

![Figure 7](image2.png)

**Figure 7.** Water absorption of paving blocks with mixed ratio 1: 5

The figure shows that there is a significant decrease in water absorption in paving blocks along with an increase in the percentage of nickel slag waste in the mixture [6], this is due to the characteristics of the nickel slag material from the test results of the material (Table 3) which has a smaller water absorption value when compared to the use of natural sand.
Based on SNI-03-0691-1996, almost all compositions and variations of the mixture meet the required water absorption requirements, namely 3% to 10%, except for the 1: 5 mixture composition with variations in the addition of 0% and 25% nickel slag waste, the absorption of water value respectively 13.2% and 12.81%.

4. Conclusion
The use of nickel slag waste in making paving blocks can increase the value of the resulting paving block compressive strength, and the highest compressive strength value is obtained in a paving block mixture using nickel slag at a composition of 1: 3 and a mixture variation of 0% sand: 100% nickel slag waste. There is a decrease in water absorption in all compositions and variations of the mixture and met the requirements for the water absorption value based on SNI-03-0691-1996 of 3% to 10%, except for the composition of the mixture 1: 5 with variations 0% and 25% of nickel slag waste substitution, water absorption values are 13.2% and 12.81%, respectively. Future utilization of nickel slag waste as an eco-material for road construction can be considered because of its compressive strength and absorption.

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References
[1] Badan Standardisasi Nasional. 1996 SNI 03-0691-1996: Bata Beton (Paving Block), Jakarta: BSN
[2] Gencel O, C. Ozel, F. Koksal, E. Erdogmus, G. Martínez-Barrera, and W. Brostow 2012 Properties of concrete paving blocks made with waste marble J. Clean. Prod. 21 pp 62–70 doi: 10.1016/j.jclepro.2011.08.023
[3] Ngii E, B. Mursidi, and Y. Y. Umar 2020 Potential Use of Pomalaa Nickel Slag as a Substitute for Sand in Brick Making IOP Conf. Ser. Mater. Sci. Eng. 797 doi: 10.1088/1757-899X/797/1/012012
[4] Astini V 2018 Utilization of Fly Ash and Nickel Slag PT-Antam as Material Subtitution for Concrete Mater. Sci. Forum
[5] Wang GC, 2018 The utilization of slag in civil infrastructure construction
[6] Jalali NA et al. 2017 Penggunaan slag nikel dalam pembuatan paving block pp 166–171
[7] Badan Standardisasi Nasional 2000 SNI 03-2834-2000 Tata cara pembuatan rencana campuran beton normal Jakarta: BSN
[8] Dimitrioglou N, P. E. Tsakiridis, N. S. Katsiotis, M. S. Katsiotis, P. Perdikis, and M. Beazi 2016 Production and Characterization of Concrete Paving Blocks Containing Ferronickel Slag as a Substitute for Aggregates Waste and Biomass Valorization 7 pp 941–951 doi: 10.1007/s12649-015-9465-1