The Influence of Replacement of Fine Aggregates with Slag Waste on Content Weight and Compressive Strength in Paving Block

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Abstract

Road construction is increasing time to time, causing the demand for paving blocks to boost. On the other hand, the metal casting industry is also experiencing an increase, which negatively impacts the form of slag waste with a high enough silica content. Therefore, it is hoped that the hydration process between cement and fine aggregate forms an interface or maximum strength. This study aims to determine the effect of using slag as fine aggregate with replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% of the paving blocks' content weight and compressive strength. This research conducted experimental quantitative descriptive methods. In this study, the independent variables consisted of slag replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% of the paving block volume and the dependent variables were compressive strength. Based on the research results, the use of slag with replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% of the paving blocks' volume could affect the paving blocks' content weight and compressive strength. Paving blocks with the replacement of slag produced normal content weight in all percentages, and produced maximum compressive strength value was 42 MPa at 50% slag replacement of the paving blocks' volume.

Keywords
Content Weight, Compressive Strength, Paving Block, Slag Waste Replacement

1. Introduction

Road construction is increasing with time. Based on the Central Bureau of Statistics data in Central Java Province in 2019, the number of roads in Central Java Province reached 22,767 KM (Statistic Centre Burueu (BPS), 2020). It has caused the demand for paving blocks needs to increase. It is since paving blocks are an option for road paving apart from asphalt, which is environmentally friendly and economically in local region . Hence, it can affect material availability, which is a natural resource. Natural resources, over time, will undoubtedly be depleted and irreversible. Based on these problems, it is necessary to have an innovation to replace materials (Anggraeni et al., 2017).

Paving blocks are a component of building materials made of Portland cement, sand, and water with a specific ratio so that their characteristics are almost close to that of mortar. Paving blocks function to cover the soil's surface and channel rainwater so that rainwater can enter the ground because there are gaps between the paving blocks. The advantages of paving blocks are easy installation and maintenance and have a good aesthetic value because they have various shapes from rectangular to multi-faceted and can also be colored during the manufacturing process to make them look more attractive in use.

One of the materials in forming paving blocks is sand. Sand is an aggregate with grains ranging in size from 0.15 to 4.75 millimeters. According to the Proceedings of the National Academy of Sciences of the United States of America, sand constituted a large but declined share of the total supply in the 20th century from 47% in 1900 to 38% in 2010. This number will certainly decrease every year. Moreover, the number of uses is higher than the number of renewals. In addition to the increasing use of sand, which makes its availability decrease, excessive use of sand can also damage nature. Thus, there is a need for an alternative to substitute for sand in making concrete, especially paving blocks (Krausmann et al., 2017). Mieslenna & Wibowo (2019) stated that the industrial sector had experienced significant growth in the last three decades. One of them is the metal casting industry. The development of the metal casting industry and the increasing use of metal products can negatively impact environmental pollution because this metal casting industry produces left-unattended waste (Tangadagi at al. 2020). The waste in question is slag waste from a metal casting process.

Slag itself results from the metal burning process, heated at a temperature of ± 1600º C and is in the form of a liquid, which will crystallize over time. Slag has an irregular shape, sharp, solid like a stone, shiny black color, and various shapes. This slag usually has a chemical composition, such as Silica, Alumina, Ferrous Oxides, Magnesia, and Alkalis. The high silica content in the slag is expected to have the hydration process between cement and fine aggregate form a maximum interface or strength. From this explanation, it is necessary to research the use of slag waste as an alternative material to replace fine aggregate with replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% of the paving blocks' volume (Abundant, 2013).

1.1 Objectives

The objectives to be achieved in this research are:

a) To determine the effect of slag as fine aggregate on the paving blocks' content weight and compressive strength
b) To determine the effect of slag as fine aggregate with replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% of the sand volume on the paving blocks' compressive strength

2. Literature Review

2.1 Paving Block

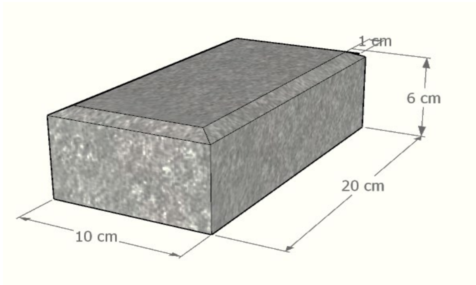

Figure 1. Paving Block

A paving block is a building material composed of a mixture of fine aggregate, Portland cement or other adhesive materials, and water with or without other added ingredients, which do not reduce the paving block's quality. Paving blocks are divided into several qualities based on their strength. The criteria for the paving blocks' physical strength in accordance with the requirements can be seen in the following table.

Table 1. Paving Block's Physical Strength Based on SNI-03-0691-1996

Quality	Compressive strength (MPa)		Wear resistance (mm/ minute)	
	Mean	Min	Mean	Max
A	40	35	0.090	0.103
B	20	17.0	0.130	0.149
C	15	12.5	0.160	0.184
D	`0	8.5	0.219	0.251

The following shows the quality criteria for paving blocks based on their content weight.

Table 2. Density Classification of Concrete Masonry

Density Classification	Oven-Dry Density of Concrete (kg/m^3)
Light Weight	Less than 1680
Medium Weight	1680-2000
Normal Weight	2000 or more

Source: ASTM C-90

2.2 Paving Blocks' Content Weight

The content weight test of paving blocks was carried out to determine how much effect the replacement of some fine aggregates with slag in terms of the content weight. The paving blocks' content weight was tested by dividing the weight of dry paving blocks by the volume. The calculation formula is as follows:

Content weight = A/B .... (1)

Description:
A = The weight of dry paving blocks
B = The volume of paving blocks

2.3 Paving Blocks' Compressive Strength.

Compressive strength is the maximum compressive strength that a paving block can bear per unit area. Mathematically, the paving blocks' compressive strength is calculated as follows:

Compressive strength = P/A .... (2)

Description:
P = Maximum load
A = The area of the compressed plane.

2.4 Slag Waste.

Slag is the waste produced from the metal casting process in the form of irregular blocks with shiny black color.

Figure 2: Slag Waste

The slag occurs due to the clumping of silica, potassium, and soda minerals in the metal smelting process or the melting of these minerals from the smelter due to high heat processing. With a large enough silica composition in the slag, it is hoped that the hydration process that occurs between cement and aggregate will produce paving blocks of good quality (Herlangga 2014, Jalil, Affan et al. 2019).

Table 3. Chemical Content In Slag

Compound	Total (%)
Lime (CaO)	26.51
Silica (SiO2)	35.19
Alumina (Al2O3)	6.01
Ferrous oxide (Fe2O3)	19.58

3. Methods

This research was carried out in various places, namely slag waste obtained from CV Salwa Logam Jaya Ceper, Klaten. The samples in this study was paving blocks with the replacement of slag as fine aggregates with variations of 0%, 45%, 50%, 55%, 60%, and 65% of the paving blocks' volume. The sample in this study was five paving blocks in each variation for content weight or total 55 samples. Paving blocks in this study had a plan as quality A, with a cement: sand: FAS (cement water factor) of 1: 4: 0.4 (Klarens et al., 2016). Paving blocks were composed of the following materials: Portland cement type I according to SNI 15-0302-2004, sand according to SNI 03-6820-2002, water according to SK SNI S-04-1989-F, and slag with a maximum grain size of 4.75 mm. Testing of the paving blocks' content weight and compressive strength was based on SNI 03-0691-1996. The data

analysis technique employed was the uniformity analysis of variations according to the SNI 03-6815-2002 control standards. The method of data analysis used Quantitative descriptive analyses.
Statystic Hypothetic used in this study is associative Hypothetyc with formulation as follow:

H0 : $\mu 1 = \mu 2$,
H1 : $\mu 1 \neq \mu 2$

Information:
Ho = There is not affected at replacement of part of slag waste to the bataco's compressive strength.
H1= There is affected at replacement of part of slag waste to the bataco's compressive strength.

4. Results and Discussion.

In this study contain two steps of results, first result of laboratory test, consist materials tests, and contain weigt test compared with SNI Standards, and the second is data analysis to show the R square to analysis is affect or not affect of correlation between independent and dependent variables.

4.1 Result

1) Paving Block Content Weight Testing

Table 4 showed the value of contain weights. It indicates that the replacement of slag waste as fine aggregate with replacement variations of 45%, 50%, 55%, 60%, and 65% . the result of contain weight always encrease align with the additional of slag waste.

Table 4. Average of Contain Weight Bataco in Various Slag Waste

Slag Variation (%)	Contain Weight (Kg/m3)	Information
0%	2303.302	*Normal Weight*
45%	2381.933	*Normal Weight*
50%	2422.757	*Normal Weight*
55%	2440.442	*Normal Weight*
60%	2445.391	*Normal Weight*
65%	2447.540	*Normal Weight*

Table 4 exhibits an increase in content weight at each additional variation of the slag replacement. The increase in the paving block's content weight was caused by several factors, such as the materials and the materials' composition used. With a large enough specific gravity of the slag, 2.86 gr/cm3, the increase in the percentage of slag substitute material was followed by increasing the paving blocks' content weight.

2) Paving Block Compressive Strength Testing.

The results of the compressive strength test with variations a slag waste replacement percentage are as follows.

Table 5. Results of Compressive Strength

Slag	Average Compressive Strength (MPa)	Standard Deviation	Description
0%	52.600	23.0148	Enough
45%	41.500	24.1108	Enough
50%	42.000	21.9189	Enough
55%	40.200	20.8229	Good
60%	34.850	16.4392	Very good
65%	31.550	21.9189	Enough

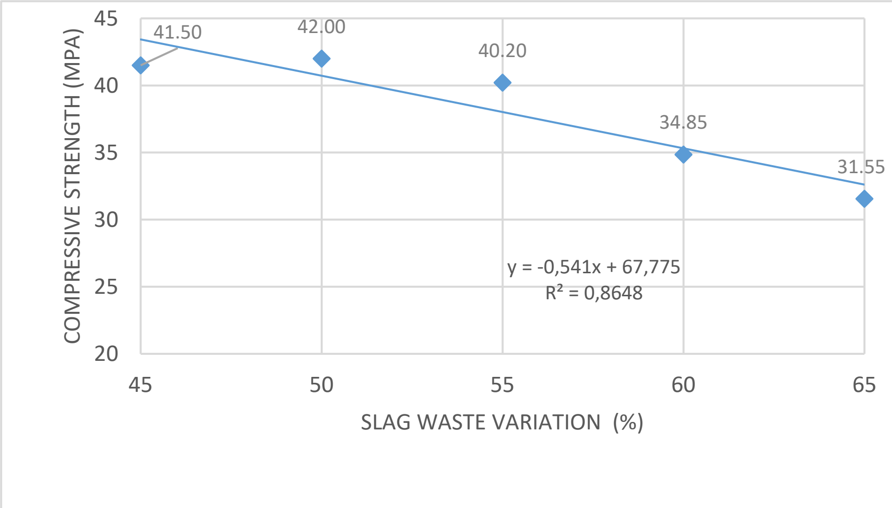

Figure 3. Graph of Paving Block Compressive Strength Testing Result

Information:
Compressive Strength Test Results:
- Vertycal coord, Compressive strength (MPa)
- Horyzontal coord, Slag Waste Variation (%)

From Figure 4, the R square value was 0.8648. It signifies that the replacement of slag as fine aggregate with replacement variations of 45%, 50%, 55%, 60%, and 65% affected 86.48% of the paving blocks' compressive strength.

Table 6. The Quality Of Paving Blocks

Slag Variation	Average Compressive Strength (MPa)	Description
0%	52.600	Quality A
45%	41.500	Quality A
50%	42.000	Quality A
55%	40.200	Quality A
60%	34.850	Quality B
65%	31.550	Quality B

This test's results revealed that the replacement of slag as fine aggregate for paving blocks has decreased along with the increase in the percentage of slag change factor from the decrease in the paving blocks' compressive strength with the replacement of the fine aggregate slag compared to normal paving blocks due to the constituent aggregates. Chemical constituents vital in the cement hydration process are CaO (Lime) and SiO2 (Silica), and slag has both compounds . However, due to the coarse grain of the slag and the slippery surface, it makes bonding with cement more difficult than sand. The greater the variation in the percentage used, the more slag is used and the more difficult the process, both in the mixing and compaction processes. Thus, in some samples, it caused the concrete surface to be less than optimal and porous on the paving blocks. Table 5 showed the results of uniformity analysis of variations based on the SNI 03-6815-2002 control standard.

4.2. Discussion

1) Effect of Slag Waste as fine aggregates to the Paving Blocks contain weight.

The test results showed that the replacement of fine aggregates with slag waste led to a 3.4% increase in content weight in a variation of 45% to 6.26% in the 65% variation. The increasing of paving blocks containing weight is caused by several factors such as the material used and the composition of the materials used. The addition of slag waste continuously will cause bataco quality to decrease (Table 4).

2) Effect of Replacements of slag waste to The Paving Blokcs Compressive Strength

The result of the test stated that the effect of slag waste replacement as fine aggregates to the paving blocks showed a lower compressive strength compared with the normal paving blocks. On the other hand, paving blocks with replacement of fine aggregate with variations of 45%, 50%, and 55% are still categories as A quality with 35 Mpa compressive strength. In case of paving block's materials replacement of slag waste yield the increasing of containing weight align with the variation percentage.

The results of the slag waste replacement as fine aggregates test proofed the paving block strength decreased. Figure 4 indicates that normal paving blocks have the largest compressive strength. Furthermore, at the variation of 45% paving block compressive strength decreased by 21.10% and rose again in the variation of 50%, finally in the next variation compressive strength decreased by 20.02% compared. The results obtained from this study are in line with research from (Anggraeni et al., 2017) which showed that paving blocks with slag waste replacement materials have a maximum press strength on the mixture of 50%. The factor of decreased strengthening in the paving block with the replacement of the slag waste as fine aggregate compared to the normal paving block is caused by its component aggregates. The results of the examination of materials in accordance with SK-SNI 03-1968-1990 in the study showed that the slag waste used entered into the gradation of zone I where the slag used categories into the rough category. The results of this study are also in line with research (Praveen, et al., 2013) which shows an increase in the replacement of steel waste mixtures will cause a decrease in the paving blocks' compressive strength.

5. Conclusion

The conclusions that could be obtained from the data analysis results and discussion in this study are:

a) Paving blocks with slag replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% could affect the paving blocks' content weight contunue encreased.
b) Paving blocks with slag replacement variations of 0%, 45%, 50%, 55%, 60%, and 65% could affect the paving blocks' compressive strength by 86.48%, or 40 MPA and category of quality A.

6. Suggestion

The suggestions proposed by the researchers based on the research that has been conducted are as follows:

a) The replacement of slag on a paving block should pay attention to the size of the slag grains because it can affect the paving block's strength.
b) Slag waste refinement should use a machine.
c) The use of slag waste as a replacement paving block should be socialized to the community to reduce slag or metal casting waste in saving the environment.
d) Research is needed on how to neutralize slag waste so that it does not categorize it into hazardous waste.
e) The use of slag waste in paving blocks can be further developed to produce better quality paving blocks.
f) Innovations for using waste as a substitute for paving blocks can be continuously developed so that the other waste than slag waste can be better managed.

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