

Early Age Physical Properties of Porous Concrete Containing Slag Nickel Aggregate under Compression

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Early Age Physical Properties of Porous Concrete Containing Slag Nickel Aggregate under Compression

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Abstract. The scope of this research is to make hollow concrete using Nickel Slag and compare it with crushed stone aggregate. The purpose of this study was to determine the amount of workability, porosity, permeability, and tensile strength of porous concrete, and to determine the effect of the 05-10 and 10-20 grading of the aggregate on the tensile strength, porosity and permeability of porous concrete. This study used an experimental method using aggregates with uniform gradations. The aggregates used are nickel slag and crushed stone with uniform gradations of 05-10 and 10-20. The cement water factor (FAS) used in the mix design is 0.35 and the cavity in the concrete is 20%. Workability testing is carried out after the fresh concrete is finished. mixed with the composition according to the mix design. Tensile strength test, with the compressive strength machine method performed at the age of the concrete 3 and 7 days. From the analysis with qualitative methods, porous concrete containing nickel slag and crushed stone in gradations 5 - 10 and 10 - 20 obtained the highest compressive strength values in the nickel slag aggregate mixture 5-10 and 10-20 of 10.70 Average - average 10.51 MPa, Modulus of elasticity of 6316.43 average 6054.68 MPa, and Poisson Ratio of 0.1651 Average 0.1598.

1. Introduction

Cavity concrete is a special type of concrete with a cavity volume ranging from 15-25% which is applied as a layer of the road surface which allows rainwater to pass through and enter the ground [1]. Thereby reducing surface runoff and increasing groundwater levels. Typically porous concrete uses little or no fine aggregate and has enough cement paste to coat coarse aggregate surfaces and to maintain cavity interconnectivity. Porous concrete was traditionally used for parking areas, traffic light areas, and sidewalks for pedestrians [2].

The dynamic development forces the construction industry to continue to innovate in the manufacture of concrete. One of them is by utilizing nickel slag waste as raw material for making concrete. Tin mining nickel slag is very abundant in South Sulawesi Province. Concrete porosity is the amount / amount of pore content contained in the concrete. Concrete pores are not completely covered by cement paste. These pores are usually filled with air (air voids) or filled with water (water filled space) which are interconnected and are called concrete capillaries. These concrete capillaries will remain even though the water used has evaporated, so these capillaries will reduce the density of the resulting concrete. Trapped air bubbles and evaporating water are the main sources of cavities / pores in the concrete. Concrete that has a small number of pores is waterproof, dense, and strong. While the permeability of concrete is the ease with which a liquid or gas can pass through the concrete. Permeability is also defined as the nature of the pass ability of liquids or gases. Good concrete is concrete that is relatively



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impermeable to water / gas, or in other words, it has low permeability, and it cannot be completely impermeable to water [3].

Dense and strong concrete is obtained using a minimum amount of water consistent with the degree of workability given to provide maximum density. The degree of density must be considered in relation to the method of compaction and the type of construction, in order to avoid the need for excessive work to achieve the maximum density. Engineering porous concrete is mainly produced from cement, coarse aggregate with a special particle size distribution and water, and uses compaction crafts that are outstanding with more than 20% porosity in general. The technology of manufacturing porous concrete applied to highway pavements differs from the manufacture of ordinary concrete in many aspects, including constituent materials, tests carried out and adjustments, proportional mix,

In this research, the aggregate used in mixing porosity concrete is Nickel Slag. Because one of the solid wastes from mining results from nickel processing. It is estimated that in the future many countries will experience a water crisis. Even though Indonesia is one of the 10 water-rich countries, our country is threatened with a water crisis as well as a result of a weak management system for water resources development and the environment in general. This is reflected in the decreasing quality of water, both surface water and ground water, very large fluctuations in river water discharge, inefficiency in water use, and very inadequate regulations.

2. Materials and Methods

2.1. Physical Testing Methods for Aggregate Concrete Nickel Slag

The nickel slag used comes from Sorowako, South Sulawesi, which is managed by PT. Vale Indonesia. Figure 1 shows Nickel Slag Aggregates measuring 1-2 cm and Figure 1 shows Nickel Slag Aggregates measuring 0.5-1 cm. Table 2 shows the physical characteristics of Nickel Slag aggregate. Nickel slag in this research is a substitute for crushed stone aggregate taken from PT. Vale Indonesia, located in East Luwu district, South Sulawesi Province. This test is carried out based on the Indonesian National Standard regarding concrete requirements for structural buildings. It can be seen that the physical properties of the coarse aggregate used in this study meet the specifications of the Indonesian National Standard (SNI) for the required Hollow concrete.



Figure 1. TN size 1-2 cm



Figure 2. TN size 0.5-1 cm

Table 1. Physical Characteristics of Nickel Slag Aggregates and Specific Gravity Cracked Rocks

Properties	Nickel and Cracked Stone Testing Methods
Specific Gravity	
a. Bulk / Dry	
b. Surface Saturated Dry	SNI 03-1969-2008
c. Apparent	
Abrasion (%)	SNI 2417-2008
Water Absortion (%)	SNI 03-1971-1990

Table 2. Properties of Nickel Slag Aggregates

ANGULAR SLAG						
	WEIGHT	UNIT	BJ. ALL	BJ. DRY	BJ.SSD	ADOPTION
A	PICNOMETER WEIGHT	1,576	gr			
B	SSD EXAMPLE WEIGHT	500	gr			
C	PICNOMETER WEIGHT + WATER + SSD EXAMPLE	1059	gr	3.41	3.20915	3.26797 4
D	PICNOMETER WEIGHT + WATER	712	gr			1,83299389
E	EXAMPLE DRY WEIGHT	491	gr			

Table 3. Aggregate Properties of Cracked Stone

BROKEN STONE						
	WEIGHT	UNIT	BJ. ALL	BJ. DRY	BJ.SSD	ADOPTION
A	PICNOMETER WEIGHT	1,576	gr			
B	SSD EXAMPLE WEIGHT	500	gr			
C	PICNOMETER WEIGHT + WATER + SSD EXAMPLE	1031	gr	2.83	2.56	2,659
D	PICNOMETER WEIGHT + WATER	709	gr			3,7344
E	EXAMPLE DRY WEIGHT	482	gr			

8.2 Physical properties of Portland composite cement (PCC)

Composite portland cement (PCC = Portland Composite Cement) is cement made from grinding portland cement slag and gypsum with inorganic materials [7]. More than one kind of inorganic material can be mixed, for example, blast furnace slag, pozzolan, silicate compounds, limestone and so on. These inorganic materials include blast furnace slag, pozzolan, silicate compounds, limestone with a total content of anorganic material of 6% - 35% of the mass of Portland composite cement. The physical properties of PCC are shown in Table 4, and the chemical constituents in Table 5 [8].

Table 4. Physical Properties of Portland Cement Composite (PCC)

Material	Description
Portland Composite Cement (PCC)	SSD density = 3.08 g / cm ³ Specific surface area (SSA) = 3410 cm ² / g

Table 5. Chemical Compounds of Portland Cement Composite (PCC)

Chemical compounds (%)	PCC
Magnesium Oxide (MgO)	0.99

Sulfur trioxide (SO ₃)	1.81
Silicon dioxide (SiO ₂)	18.39
Aluminum oxide (Al ₂ O ₃)	5.15
Ferric oxide (Fe ₂ O ₃)	3.14
Calcium oxide (CaO)	61.79
Loss of ignition (LOI)	4.61

2.3 Mix Design of Porous Concrete (1 m³ & 1000 Liter)

Porous concrete is made from 100% Nickel Slag mixed with PCC cement. Water. Superplisizer. after being mixed for 24 hours then the water curing specimen was treated. The composition of the mixture can be seen in Table 6 and Table 7.

Table 6. Porous Concrete mixture composition (1 m³)

Cement (kg)	Nickel slag / crushed stone (kg)	Water (kg)	Superplisizer (kg)
228.57	2100.65	80	1.14
228.57	1710.12	80	1.14

Table 7. Porous Concrete mixture composition (1000 Liter)

Cement Liter	Nickel / Cracked Stone Slag Liter	water Liter	superplisizer Liter	Air Content Liter	Total Liter
75.94	644.37	80	1	200	1000
75.94	642.90	80	1	200	1000

3. Experimental Procedure

3.1 Compressive Strength test

The compressive strength of porous concrete was tested after 3 and 7 days with a standard cylinder size of 10 x 20 cm based on SNI-1974: 2011 [9] with a loading rate of 0.3 mm / s as Figure 3, Figure 3 shows the method of testing the compressive strength with porous concrete .

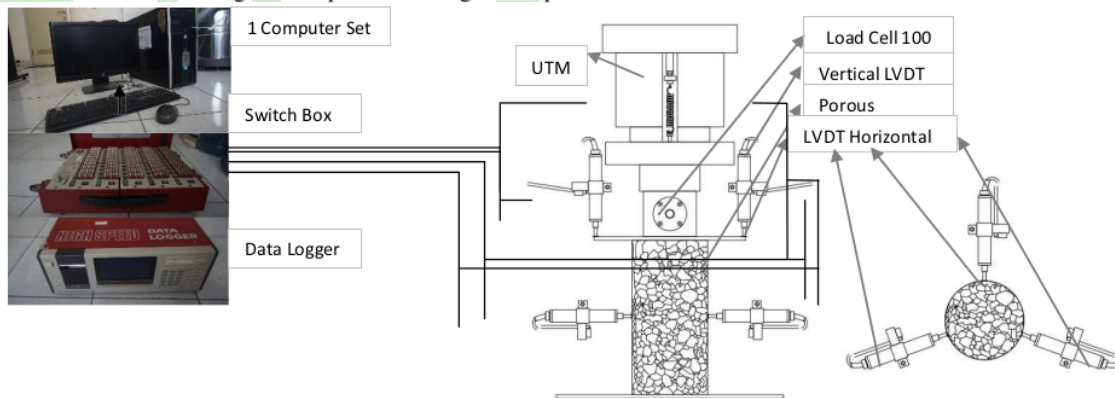


Figure 3. Compressive strength test method

3.2 Modulus of Elasticity

The modulus of elasticity is the ratio of normal tensile or compressive stress to strain. The modulus of elasticity depends on the age of the concrete, the properties of the aggregate and the cement loading, the type and size of the specimen. From the 10 x 20 cm concrete cylinder compressive test, the modulus of elasticity of the concrete is calculated using the formula ASTM C 469-94 [10] and the volumetric strain is calculated by the formula [11]:

$$\varepsilon_v = \alpha + 2L \varepsilon_l \quad (1)$$

$$E_c = \frac{S_2 - S_1}{s_l - 0.00005} \quad (2)$$

Where:

- E_c = chord modulus of elasticity, MPa,
- S_2 = stress corresponding to 40% of ultimate load,
- S_1 = stress corresponding to a longitudinal strain, ε_1 , and
- ε_l = lateral strain produced by stress S_2

3.3 Poisson ratio

When a one-way force is applied to the material which results in strain and causes the material to displace, lateral and axial strains were measured using 3 LVDT [11] in a horizontal direction and placed in the center of the specimen. The displacement reading and calculation of the poisson ratio are carried out using 3 pieces of the LVDT tool with the following formula (2) (3)

$$\varepsilon_l = \frac{\delta_1 + \delta_2 + \delta_3}{3} \times 2 \quad (3)$$

$$v = \frac{s_l - s_1}{s_l - 0.00005} \quad (4)$$

Where:

- ε_l = lateral strain produced by stress S_2
- δ_1 = LVDT1 displacement reading
- δ_2 = LVDT2 displacement reading
- δ_3 = LVDT3 displacement reading
- D = Diameter of Test object
- v = poisson ratio
- ε_{l1} = lateral strain at the stress level S_1
- ε_{l2} = lateral strain at the stress level S_2

4. Result and Analyses

4.1. Nickel Slag Aggregate and Aggregate Broken Stone

The nickel slag used comes from PT. Vale Indonesia, which is located in East Luwu district, while Batu Broken comes from the jenneberang river, Gowa Regency, South Sulawesi Province. Table 8. Shows the physical characteristics of Nickel Slag and Crushed Stone. The nickel slag used has a surface specific gravity of 3.24 to 3.20. absorption 1.83 to 1.83. and the abrasion is 1.42 to 1.44% respectively, while the crushed stone used has a surface specific gravity of 2.57 to 2.56. absorption 3.73 to 3.72. and abrasion of 3.52 to 3.54% respectively.

Table 8.. Nickel Slag Aggregate Properties

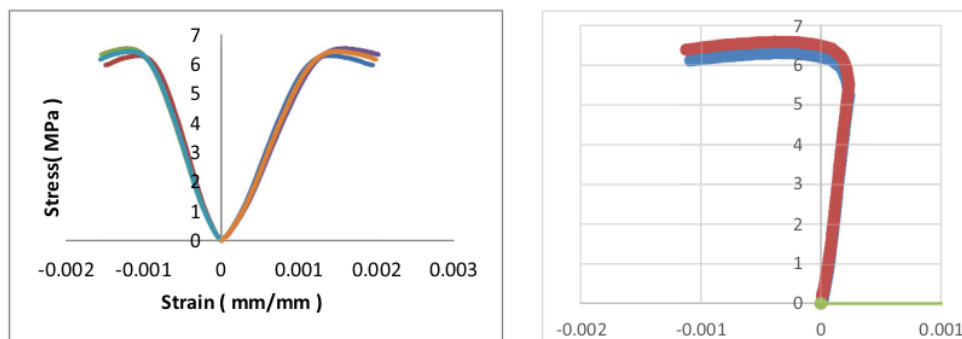
Properties	Nickel Slag Aggregate Properties		Aggregate Properties of Cracked Stone	
	5-10 (mm)	10-20 (mm)	5-10 (mm)	10-20 (mm)
Specific Gravity				
a. Bulk / Dry	3.24	3.20	2.56	2.57
b. Surface Saturated Dry	3.26	3.26	2.66	3.28
c. Apparent	3.41	3.41	2.84	3.44
Abrasion (%)	1.42	1.44	3.52	3.54
Water Absortion (%)	1.83	1.83	3.73	3.72

4.2 Concrete Porous Compressive strength

Based on direct observation. The results of the porous concrete compressive test are shown in Figure 6. Effect of Nickel Slag Aggregate and Broken Stone are 2 important variables that affect the compressive strength in this study. Compressive strength increases with age with compressive strength at 7 days of age being higher than that of 3 days. The compressive strength of porous concrete with Nickel Slag Aggregate at the age of 3 days ranges from 6.39 to 6.43 MPa while for crushed stone ranges from 3.90 to 4.02 MPa. Then the compressive strength of porous concrete with nickel slag at the age of 7 days ranged from 10.32 to 10.51 MPa while for broken stone ranged from 8.65 to 8.75 MPa.

4.3 Stress Strain. Elasticity modulus and poisson ratio

Figure 4 shows the relationship between the 3-day age stress strain of porous concrete with Nickel Slag Aggregate where from the peak stress that occurs, namely 4855.82 to 5062.08 MPa, there is a vertical load of 0.000411 to 0.000516 mm / mm and for horizontal strain of 0.0000612 to 0.0000750 mm / mm. Figure 4 shows the relationship between the stress strain of porous concrete and broken rock aggregates where from the peak stress that occurs, namely 1.459 to 1.527 MPa, there is a vertical fray of 0.000422 to 0.000456 mm / mm and for horizontal strain of 0.0000425 to 0.0000535 mm / mm.

**Figure 4.** Stress and Strain Porous Nickel Spacing 3 days

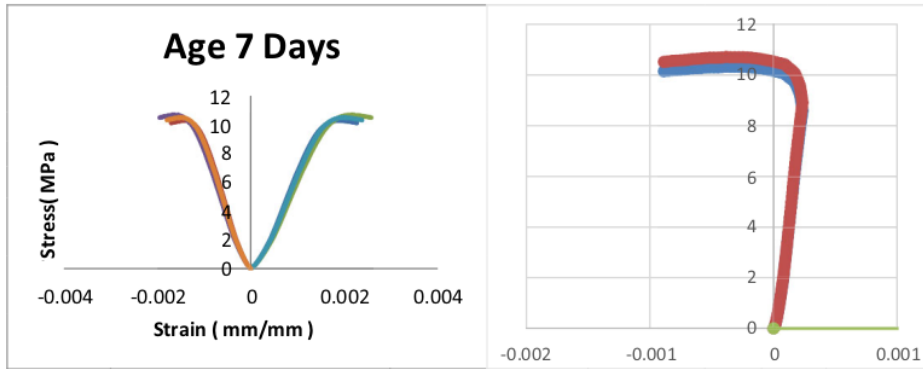


Figure 5. Stress and Strain Porous Nickel Spacing 7 days

13 Figure 5 shows the relationship between the 3-day age stress strain of porous concrete with the Aggregate of Broken Stone where the peak stress occurs, namely 4855.82 to 5062.08 MPa, there is a vertical fray of 0.0011526 to 0.000516 mm / mm and for horizontal strain of 0.0000612 to 0.0000750 mm / mm. Figure 7 shows the relationship between the stress strain of porous concrete and broken rock aggregates where from the peak stress that occurs, namely 1.459 to 1.527 MPa, there is a vertical fray of 0.000422 to 0.000456 mm / mm and for horizontal strain of 0.0000425 to 0.0000535 mm / mm.

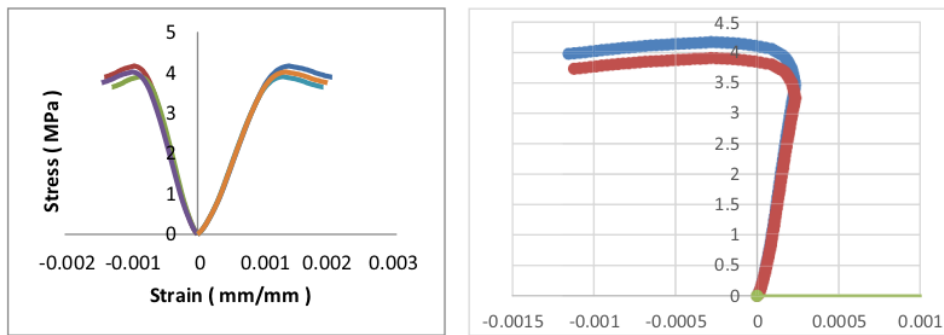


Figure 6. Stress and Strain Porous Concrete with fiber polypropylene size 38 mm in 7 days

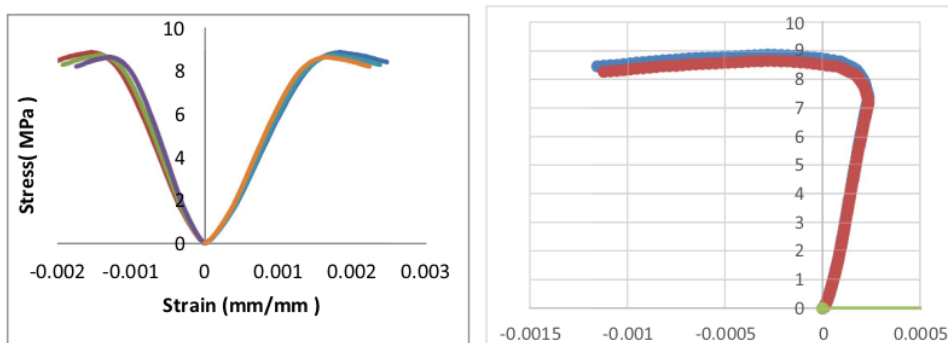


Figure 7. Cracking stages of concrete in compression

Figure 9 shows the crack pattern of 3 days of cavity concrete, with nickel slag material and crushed stone. There is a similarity in the crack pattern in the specimen, namely the crack pattern parallel to the load direction so that it is columnar in shape. Figure 9 shows the crack pattern of 7 days of cavity concrete with Nickel Slag material and crushed stone. There is a similarity in the crack pattern in the specimen, namely the crack pattern parallel to the load direction so that it is columnar in shape.



Figure 8. Crack Pattern of 3 days porous concrete with Slag Nickel and Broken Stone



Figure 9. Crack Pattern of 7 days porous concrete Slag Nickel and crushed stone

Cavity concrete with Nickel Slag Material has a crack pattern variation that is almost the same as that of crushed stone material, namely the crack pattern is in the same direction as the load. The length and width of the crack pattern decreases as the concrete ages, this explains that the strength of cavity concrete with nickel slag fibers and crushed stone increases with increasing age of the concrete. From Table 9, the calculation results are obtained using the formula from ASTM C 469-94 regarding the calculation of the Modulus of Elasticity of Porous Concrete with Nickel Slag with water curing treatment for 3 days of 5307.84 to 4855.82 MPa and Poisson Ratio of 0.1354 to 0.1476 while for 7 days of 5728.95 to 6316.43 MPa and Poisson Ratio of 0.1551 to 0.1651 Modulus of elasticity of porous concrete with broken stone with water curing treatment for 3 days of 3515.22 to 3487.07 MPa and Poisson Ratio of 0.1007 to 0.1221 while for 7 days of 5505.77 to 5711.72 MPa and Poisson Ratio of 0.1574 to 0.1699 .

Table 9. Modulus Elasticity and Poisson Ratio of Porous Concrete

No.	Porous Concrete Variations	Sample Code	Curing	Day	Voltage MPa	Modulus of Elasticity (Ec) MPa	Poisson Ratio (v)
1	Nickel Slag	A	Water	3 Day	6.30	5307.84	0.1354
2		B	Water		6.54	4855.82	0.1458
3		C	Water		6.43	5062.08	0.1476
Average					6.42	5075.24	0.1429

4		D	Water		10.32	6316.43	0.1551
5	Nickel Slag	E	Water	7 Day	10.70	5728.95	0.1651
6		F	Water		10.53	6118.68	0.1592
		Average			10.51	6054.68	0.1598
7		A	Water		4.17	3487.07	0.1113
8		B	Water	3 Day	3.90	3515.22	0.1007
9		C	Water		4.02	3495.10	0.1221
		Average			4.03	3499.13	0.1113
10	Broken Stone	D	Water		8.87	5505.77	0.1809
11		E	Water	7 Day	8.74	5657.23	0.1716
12		F	Water		8.65	5972.18	0.1574
		Average			8.75	5711.72	0.1699

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