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## Preface

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## Influence of PT Vale's Granulated Gradation Nickel Slag Aggregate on Compressive Strength of Concrete

E. H. Sujiono, V. Zharvan, S. N. Yunita and S. Samnur

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## Influence of PT Vale's Granulated Gradation Nickel Slag Aggregate on Compressive Strength of Concrete

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# Influence of PT Vale's Granulated Gradation Nickel Slag Aggregate on Compressive Strength of Concrete

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**Abstract.** Influence of granulated gradation nickel slag aggregate on compressive strength of concrete has been investigated. In this study, the influence of granulated gradation nickel slag aggregate with aggregate size LS 9.50 mm, LS 5.60 mm, LS 2.36 mm, LS 2.00 mm and the combination of those fourth aggregate size on compressive strength and microstructure of concrete has reported. The concrete was prepared according to SNI 03-1972-1990. Samples then characterized using universal testing machine controller respect to ASTM C39M-01 method to obtain the compressive strength value and scanning electron microscope to obtain morphology of all samples. Results show that sample with nickel slag aggregate size at 5.60 mm has highest compressive strength value at  $(44.05 \pm 1.93)$  MPa. Characterization of microstructure shows a good interface between aggregate and cement paste. The morphology after compressive testing shows that cracks were occurred in the cement paste, not between aggregate and paste interface. It can be concluded that the aggregate size of nickel slag was directly proportional to the compressive strength of the concrete depending on the bond between cement paste and the size of nickel slag aggregate.

**Keywords.** Aggregate, compressive strength, concrete, morphology, and nickel slag.

## 1. Introduction

Concrete is a composite material made of aggregate that bonded together by liquid cement. Concrete can be visualized as a multi-phase composite material that made up of three phases: mortar, mortar/aggregate interface and the coarse aggregate phase [1, 2, 3]. Its major components are cement, water, and aggregates with 50 % to 60 % of the total volume depending on the mix proportion [2]. The coarse aggregate in normal concrete is from rock fragments that characterized by high strength [3]. The larger percentage of coarse aggregate in the concrete mix makes it contribute to the strength of concrete [4].

PT Vale Indonesia produces about 3000 t of nickel slag in solid form every week [5]. On the other hand, those waste materials generated a big problem to the environment. Slag is a waste produced during manufacturing of pig iron and steel [6]. Previous research showed that chemical composition of nickel slag contains majority oxides such as SiO<sub>2</sub> 38.85 %, MgO 23.60 %, FeO 29.75 % and Al<sub>2</sub>O<sub>3</sub> 4.38 % in wt%. Besides, concrete with 100 % aggregate of nickel slag has compressive strength value 36.7 MPa [7]. According to that fact, it can be concluded that concrete with nickel slag as an aggregate can be used in industry.



In this paper, the obtain influence of aggregate size on concrete that built from Portland cement, sand and nickel slag from PT. Vale as aggregate is presented. Furthermore, analyses of mechanical properties and morphology of samples were reported.

## 2. Materials and methods

The raw materials including Portland's cement, sand, water and nickel slag (grain size: 9.50 mm) were mixed together according to SNI 04-1972-1990 composition for making high-quality K-350 concrete (compressive strength value: 31.20 MPa). The paste then molds into three cubes with dimension  $(5 \times 5 \times 5)$  cm<sup>3</sup> is shown in Figure 1 and let them dried. All of the concrete then cured by dipping into the water for seven days according to SNI 03-2847-2002. The same procedure was repeated by varying the aggregate size of nickel slag at 5.60 mm, 2.36 mm and 2.00 mm also the combination of those fourth aggregate size (9.50 mm, 5.60 mm, 2.36 mm and 2.00 mm). The compressive strength test of concrete was carried out according to ASTM C39M-01 using universal testing machine controller (*Testometric*) and then characterized using SEM-EDS (*Tescan Vega3*) to investigate surface morphology and the interface zone.



**Figure 1.** Concrete with nickel slag (aggregate size:9.50 mm) as aggregate.

## 3. Results and discussion

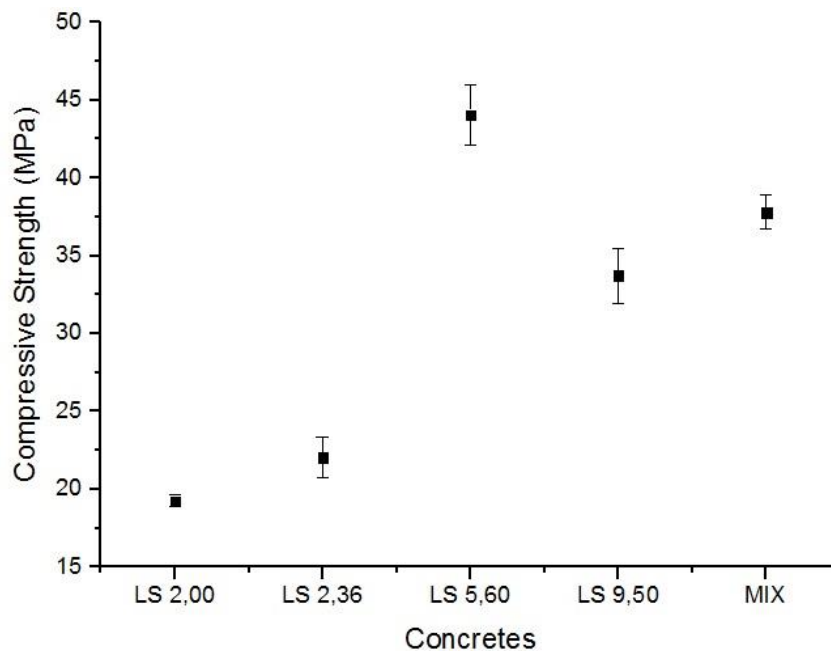
### 3.1. Compressive strength of concrete

The result of the compressive strength of concrete is shown in Figure 2. Based on Figure 2, it can be seen that compressive strength of concrete linearly increase as increasing of aggregate size and reach a maximum value of compressive strength,  $(44.05 \pm 1.93)$  MPa, at concrete with aggregate size 5.60 mm. These increases could be attributed to the differences in the wetted surface in concrete batches. The smaller aggregates in concrete have a larger wetted area than larger aggregates, and when concrete in the curing process it leaves pores when microcracks start that makes low compressive strength in concrete with smaller sized aggregates [1]. Furthermore, the strong bond between cement paste and aggregate makes this material to maintain fracture until to maximum limit before the nickel aggregate crushed [8]. Table 1 shows the values of compressive strength for each sample.

**Table 1.** Compressive strength values of concrete

Concrete Sample	Compressive Strength (MPa)
LS 2.00	$19.23 \pm 0.37$
LS 2.36	$22.01 \pm 1.32$
LS 5.60	$44.05 \pm 1.93$
LS 9.50	$33.72 \pm 1.77$
MIX	$37.80 \pm 1.10$

The compressive strength then decreases when the size of the aggregate increase. Concrete that has a mix of aggregate size has the highest compressive strength value at  $(37.80 \pm 1.10)$  MPa compare with high-quality K-350 concrete with compressive strength value 31.20 MPa. Vilane et al. also report the effect of aggregate size on the compressive strength of concrete and he found that aggregate at size 9.50 mm has compressive value at 15.34 MPa [1] which is lower than our result  $(33.72 \pm 1.77)$  MPa due to the mechanical characteristic of nickel slag aggregate [7].

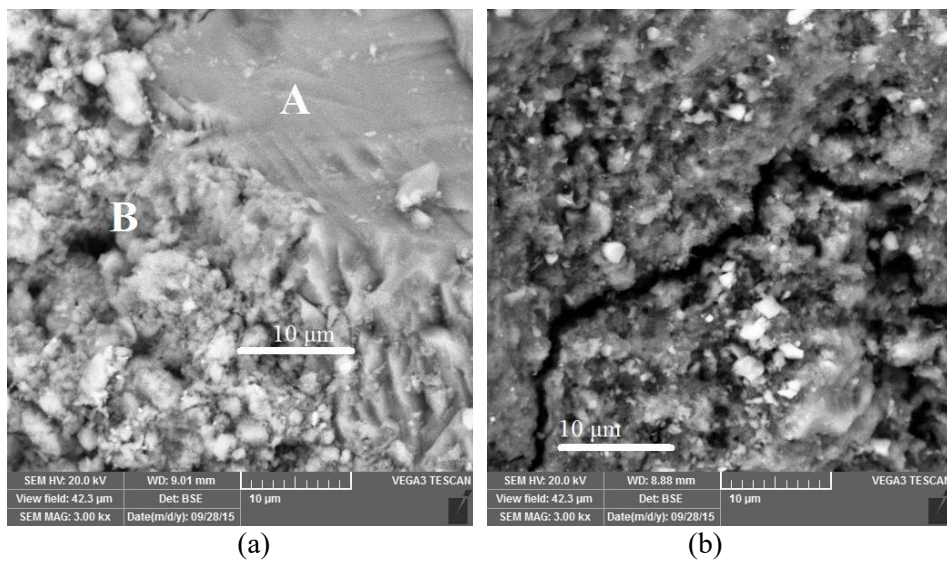


**Figure 2.** The compressive strength of concrete as a variation of nickel slag aggregate size.

Increasing of compressive strength is attributed to large interface distance among particles and when the addition of aggregate size increase leading to the formation a brittle material that it stables to microcracks, hence the fracture of material was occurred [9]. Besides, increasing the aggregate size makes the bond between matrix-aggregate became weaker that makes the value of compressive strength decrease [7].

### 3.2. Morphology of concrete

Morphology of concrete before and after the compressive test can be seen in Figure 3. Figure 3(a) shows the morphology of concrete before compressive strength test. It gives information that there is a good bond between cement paste and aggregate of nickel slag. Also, there was no void due to the presence of high  $\text{SiO}_2$  on nickel slag. It also shows the solid-smooth surface indicated as nickel slag aggregate [5].



**Figure 3.** SEM micrograph of concrete (a) before and (b) after compressive strength test (A= nickel slag, B= cement paste).

Morphology of concrete after compressive strength test was shown in Figure 3(b). It can be seen that there was a crack, about 1  $\mu\text{m}$  width, present on the concrete due to the effect of compressive testing. Figure 3(b) also gives information that crack did not present in the interface zone between matrix (cement paste) and aggregate (nickel slag) but in the matrix only.

The result of EDS is shown in Table 2. It gives information that  $\text{SiO}_2$  has a high percentage of the concrete about 35.74 %, then CaO 32.12 % and  $\text{Al}_2\text{O}_3$  16.62 %. The highest percentage of  $\text{SiO}_2$  on the concrete due to present of nickel slag aggregate [10] that makes a strong bond between nickel slag aggregate and Portland cement [8].

**Table 2.** EDS results of concrete

Compound	Percentage (wt %)
$\text{SiO}_2$	35.74
CaO	32.12
$\text{Al}_2\text{O}_3$	16.62
FeO	4.88
MgO	3.66
$\text{Na}_2\text{O}$	3.30
$\text{K}_2\text{O}$	1.26
$\text{TiO}_2$	0.79
$\text{Cr}_2\text{O}_3$	0.35
MnO	0.24
$\text{P}_2\text{O}_5$	0.16

#### 4. Conclusions

The influence of nickel slag grain size aggregate on compressive strength and morphology of concrete has been investigated. It was found that concrete has highest compressive strength value at 44.05 MPa with aggregate size 5.60 mm. Morphology of concrete shows that the interface zone between mortar and slag nickel aggregate has a good bond due to the presence of silica ( $\text{SiO}_2$ ) in nickel slag that binding with cement paste.

### Acknowledgments

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