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Deformation Pattern of Nickel Slag Bonding on the Development of Concrete Construction

E. H. Sujiono^{1,*}, H. Husain¹, M. Mulyadi¹, S. Samnur², M. Arsyad¹

¹Laboratory of Material Physics, Department of Physics, Universitas Negeri Makassar, Makassar Indonesia

²Department of Mechanical Engineering, Universitas Negeri Makassar, Makassar Indonesia

*E-mail: e.h.sujiono@unm.ac.id

Abstract. This paper presents an experimental work to study the deformation and compressive strength on Portland cement concrete with nickel slag aggregate. The amount of nickel slag varied were towards the total mass of coarse aggregate are 0%, 20%, 40%, 60%, 80%, and 100%, respectively. Each variation of the samples was made with a dimension of 15 cm x 15 cm x 15 cm, and then through the curing process. After 28 days, the sample was checked using mechanical testing conducted to investigate the compressive strength. The surface of the concrete fracture after mechanical testing process shows that the bonding between the matrix of Portland cement and nickel slag is a very strong. The bonding has connected very well. Therefore, when the force was given, then the fractions of nickel slag aggregate will hold the connectivity until to the maximum of the pressure force value before the materials are a damaged. The maximum of pressure force caused by the cracks will follow the fracture pattern of the concrete materials. This indicates that the bonding between matrix Portland cement and nickel slag has become the key factor in construction high-quality concrete.

1. Introduction

The development of science in the field of concrete technology allows the use of solid waste as the filling material of concrete forming [1]. Concrete is the building material which is often used in the construction world. Besides being cheap and easy to obtain, the mechanical strength of concrete is one of the reasons why concrete becomes the first choice in the construction industry. The type of aggregate is one of the factors that affect the concrete's mechanical strength [2]. The compressive strength of concrete can also be influenced by the shape, and the size of the sample tested. Many studies reveal that the bigger the cross-section size of the specimen tested, the stronger the compressive strength of that concrete [3]. The mechanical nature of concrete such as tensile, modulus of elasticity, and compressive strength of concrete is very important in designing a building, and the factor which can be optimized to obtain concrete structural strength is the strength of bonding matrix between paste and aggregate [4].

Aggregate is a granular material such as sand, gravel, and crushed stone used as filling materials with cement bonding media. The characteristic of aggregate also affects the planning of concrete design and its economic value. The aggregate used in this study is the gravel of natural stone and added with nickel slag. Nickel slag is the solid waste of nickel industry. Nickel slag contains many elements of silicates so that it can contribute to improving the interface between aggregate and cement paste. Thus nickel slag is very potential to be used as concrete aggregate and as a geopolymer aggregate application [5, 6, 7].



In this article, it is discussed in detail the production process, the formation pattern of cracks, and the morphological relation to the surface with the bonding formation between the composite of Portland cement and the nickel slag aggregate and mechanical properties such as the concrete compressive strength with the additional variety of nickel slag aggregate.

2. Material and Method

The material used as the bonding matrix of coarse and fine aggregate is Portland Composite Cement (PCC) type I. The coarse aggregate of nickel slag sized 10-20 mm is obtained through the fraction process of slag nickel chunk. The fine aggregate used in this study is sand of 4.75 mm in sieve size. Based on the production standard of concrete, there are certain limitations on the aggregate gradation, both fine aggregate and coarse aggregate have the gradation and the various level of grain uniformity.

The concrete forming of cement Portland with nickel slag coarse aggregate goes through several stages. First, weighing the required material in accordance with predetermined standard dose. Second, mix all materials together while stirring for ± 3 minutes, adding water as a mixture solvent. Third, the mixture of materials and solvent is put into a molded cube with a dimension of $15 \times 15 \times 15 \text{ cm}^3$. According to reduce pores in the mold, the sample is vibrated for 15 minutes. The mixture composition of material can be seen in table 1.

The 24-hour curing process is done by covering the mold using plaster to maintain the water content of the mixture. Concrete is removed from the mold after 3 days than to maintain the inertia structure; the concrete is soaked for ± 7 days. Mechanical testing is done after the sample reaches 28 days.

TABLE 1. Material mixture composition of Portland cement concrete production.

Composition	Portland Cement (kg)	Sand (Kg)	Crushed gravel stone (kg)	Nickel slag aggregate (kg)	Water (Litre)
BSP 0%	1.50	2.20	3.30	0	0.72
BSP 20%	1.50	2.20	2.70	0.67	0.72
BSP 40%	1.50	2.20	2.02	1.34	0.72
BSP 60%	1.50	2.20	1.34	2.02	0.72
BSP 80%	1.50	2.20	0.67	2.70	0.72
BSP 100%	1.50	2.20	0	3.30	0.72

3. Results and Discussion

3.1 The Surface Structure of Portland Cement Concrete Fracture

The bond between Portland cement matrix and nickel slag coarse aggregate is observed through the sample fracture after compressive testing. Compressive strength test is done by giving compressive force, or load with a compressive force on the surface of a sample until a fracture crack has observed.

Figure 1 shows the macroscopic structure of Portland Cement bonded with coarse aggregate for all variations of the addition of nickel slag aggregate and crushed stone. The figure of the morphological surface structure shows that the bond between Portland cement matrix and nickel slag aggregate has been strongly formed.

Figure 1 A is the concrete surface without nickel slag aggregate with material composition BSP 0% as shown in table 1. The fracture pattern on this material surface follows the pattern of crushed stone aggregate which spreads in all part of the sample. It is caused by the bonding pattern between Portland cement composite with crushed stone aggregate is not strong enough to withstand the compressive force was given, so this material has the lowest mechanical properties.

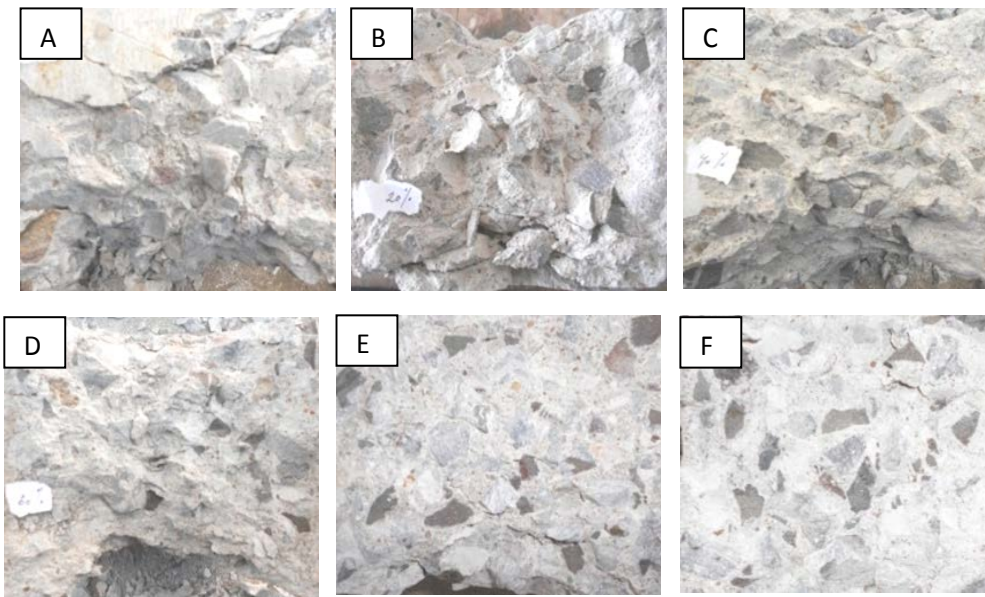


FIGURE 1. The surface structure of Portland Cement Concrete after compressive testing (a) BSP 0%; (b) BSP 20%; (c) BSP 40%; (d) BSP 60% ; (e) BSP 80% dan (f) BSP 100%, respectively.

Furthermore, in figure 1B, 1C, 1D, 1E, and 1F is a concrete surface with the varied percentage of nickel slag aggregate. The strong bond between nickel slag aggregate and Portland cement matrix makes this material able to maintain fracture until to the maximum limits before nickel slag aggregate crushed. This result will improve compressive strength. The bigger of the percentage of nickel slag aggregate, be affect samples with the biggest value of compressive strength.

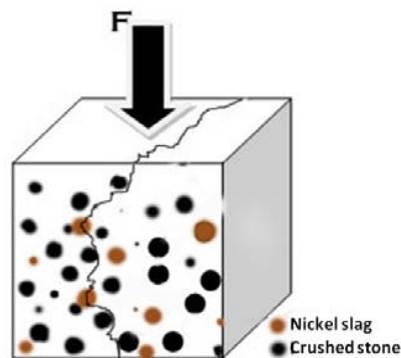


FIGURE 2. Illustration of the fracture on Portland cement concrete sample with the substitution of nickel slag and crushed stone aggregate.

Figure 2 shown the illustration of the occurrence of cracks during the load process of a concrete sample. This illustrates the forming pattern of cracks in load process; the cracks follow the shape of usual stone aggregate. Meanwhile, because the bond between cement matrix and nickel slag is very strong, the fracture occur in the nickel slag aggregate. In contrast to the usual stone aggregate does not bind quite well with Portland cement, therefore if the compressive force is given, the crack will turn to follow the shape of the usual stone aggregate, these results be caused by the lower compressive strength.

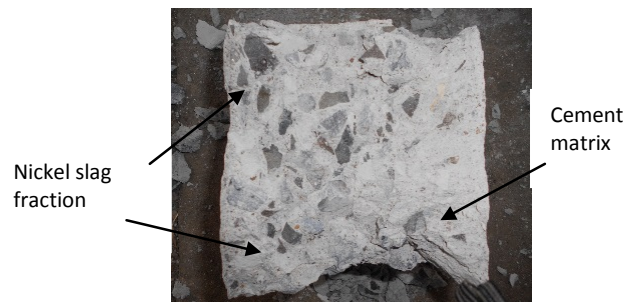


FIGURE 3. Portland Cement Concrete Surface with Nickel Slag Aggregate after the compressive test.

Figure 3 shows the crushed nickel slag aggregate due to the withstand of compressive force in the compressive strength test. The strong bond between nickel slag aggregate and Portland cement matrix is formed by the silica contents in the nickel slag surface [5,6,7]. The bigger and more contact between nickel slag surface and cement matrix, make the bond between Portland cement paste and aggregate will also be stronger.

4. Conclusion

The addition of nickel slag aggregate in Portland cement concrete affects the bond between the matrix of aggregate and cement paste matrix, becomes increasingly more strength and compact. These results indicate that the value of concrete compressive strength is better than used of usual stone aggregate. In this study, it is revealed that the mechanical strength of concrete material obtained is higher than the Indonesian nationalize standard for the concrete industry.

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