

# Performance of Black Stone Waste as Coarse Aggregate in Concrete Production

I Made Alit Karyawan Salain<sup>1\*</sup>, Yenni Ciawi<sup>1</sup>, Mayun Nadiasa<sup>1</sup>, Anak Agung Gede Sutapa<sup>1</sup>

<sup>1</sup>Civil Engineering Department, Udayana University, Bali, Indonesia

\* imaksalain@unud.ac.id

**Abstract**—Performance of black stone waste (BSW) as a substitute for natural coarse aggregate in concrete production has been studied concerning the unit weight, compressive strength and splitting tensile strength. The concrete mixtures were designed using a weight ratio of 1 Portland Pozzolan cement: 2 fine aggregate: 3 coarse aggregate and water cement ratio of 0.5. Five concrete mixtures were made by replacing natural coarse aggregate in concrete mixtures with BSW of 0%, 25%, 50%, 75%, and 100%. For each mixture 10 specimens were made: 5 cube specimens measuring 150x150x150 mm for compressive strength test and 5 cylindrical specimens with a diameter of 150 mm and 300 mm high for splitting tensile strength test. For measurement of unit weight, the two types of specimens were used. The result shows that the unit weight of concrete made with BSW is about 3%-7% lighter than that of concrete made with natural coarse aggregate. Concrete made with certain quantity of BSW can produce both compressive strength and splitting tensile strength higher than concrete made with natural coarse aggregate. The compressive strength and splitting tensile strength of concrete made with 100% BSW can respectively reach about 88% and 104% of that of concrete made with natural coarse aggregate.

**Keyword** - Black Stone Waste, Unit Weight, Compressive Strength, Splitting Tensile Strength

## I. INTRODUCTION

Concrete is a very popular construction material used in the construction industry. This is because concrete is easy to make, strong withstand compressive loads, durable and the price is relatively cheaper than competing construction materials, such as steel. The performance of concrete is much influenced by the forming material: water, cement and aggregate, so that the selection of the material must be considered carefully in order to obtain the quality of the concrete as designed. The use of aggregates, fine aggregate and coarse aggregate, in concrete production can reach about 75% of the total material needed [1]. Thus the selection of the type of aggregates used must be well controlled, particularly with regard to their properties.

Black stones are basalt stones which origin from volcanic lava having frozen. This type of stone is blackish in color, sharp and rough. In the Province of Bali, black stones are usually processed by carving craftsmen to be used as traditional building ornaments. Approximately 30% of black stones processed by craftsmen becomes waste, in the form of granules or powder. At present, this waste has not been managed properly and is usually left to accumulate around the working area and/or drainage channels, so that it has the potential to cause environmental disruption. Figure 1 shows the waste around the craftsmen working area.



Fig. 1. Black stone waste around the craftsmen working area

Visually, the waste in the form of granules has a similar size and shape to aggregates commonly used for concrete. Black stone waste (BSW) in the form of powder has been studied to be used as a basic material to produce artificial stone [2]. Other study shows that BSW powder can be used to replace about 5%-10% of Portland cement type I [3]. However, it is not known to what extent this waste can be used as aggregate in concrete production.

In this study, the possibility of utilizing BSW, in the form of granules, as coarse aggregate for concrete production was examined. The effectiveness of the use of BSW was measured from the performance of concrete at 28 days regarding the unit weight, compressive strength and splitting tensile strength. The results of the study are expected to increase the economic value of BSW as well as to reduce environmental problem due to BSW.

## II. MATERIALS AND EXPERIMENTAL METHOD

This research was carried out using concrete-forming material consisting of water, hydraulic binder, fine aggregate and coarse aggregate. The water used to mix concrete was tap water in the Structure and Material Laboratory of the Civil Engineering Department, Faculty of Engineering, Udayana University. For hydraulic binder, it was used the type of Portland Pozzolan cement (PPC).

Fine aggregate used in the form of natural sand was purchased from building material supplier. For coarse aggregate, it was used 2 types: coarse aggregate in the form of natural stones (NCA) which was purchased from supplier and coarse aggregate that was prepared from BSW. BSW in the form of granules was first pounded with a hammer and then sieved in such a way so that the maximum grain size was of 40 mm.

The grain distribution of fine aggregate was designed to meet the gradation of zone 2 in accordance with SNI 03-2834-2000 whereas that for coarse aggregates was designed for a maximum grain size of 40 mm. Table 1 shows some physical properties of fine aggregate and coarse aggregates.

TABLE I. PHYSICAL PROPERTIES OF FINE AGGREGATE AND COARSE AGGREGATES

Physical Properties	Natural Fine Aggregate	Natural Coarse Aggregate	Black Stone Waste Coarse Aggregate
Unit weight (g/cm <sup>3</sup> )	1.54	1.40	1.12
Specific gravity SSD	2.66	2.43	2.09
Absorption (%)	1.96	1.79	5.88
Abrasion (%)	-	17.48	22.55

The concrete mixture was made in a weight ratio of 1 PPC: 2 Fine Aggregate: 3 Coarse Aggregate, with water cement ratio of 0.5. Five concrete mixtures were made each by replacing coarse aggregates in concrete mixtures with BSW of 0%, 25%, 50%, 75%, and 100%. A mixture with 0% BSW coarse aggregate was a control concrete. For each mixture 10 specimens were made: 5 cubical specimens measuring 150x150x150 mm for compressive strength test and 5 cylindrical specimens with a diameter of 150 mm and 300 mm high for splitting tensile strength test. For measurement of unit weight, the two types of specimens were used. Concrete mixing was realized using a mixing machine. After mixing, the concrete is put into the mold and then compacted. The compacted specimens were left in the mold for 24 hours, then demolded and cured by immersing the specimens in a water bath until the time of testing.

Determination of unit weight was done by weighing and measuring the volume of each specimen before the compressive strength test and splitting tensile strength test were carried out. Testing of compressive strength and splitting tensile strength were realized using a compressive strength test machine with a capacity of 2000 KN referring respectively to SNI 03-1974-1990 [4] and SNI 03-2491-2002 [5]. Those tests were realized at the specimen's age of 28 days.

## III. RESULTS AND DISCUSSION

### A. Results

1) *Unit Weight*: The results of unit weight measurement of concrete for each variation of mixture is presented in Figure 2. From that figure, it can be seen that the use of BSW coarse aggregates to replace that of natural ones reduces slightly the unit weight of concrete.

The more BSW coarse aggregates content in concrete mixes, the lower the weight of the unit weight of concrete. In fact, it is noted that, the use of 25%-100% BSW to replace NCA reduces the unit weight of concrete about 3%-7%.

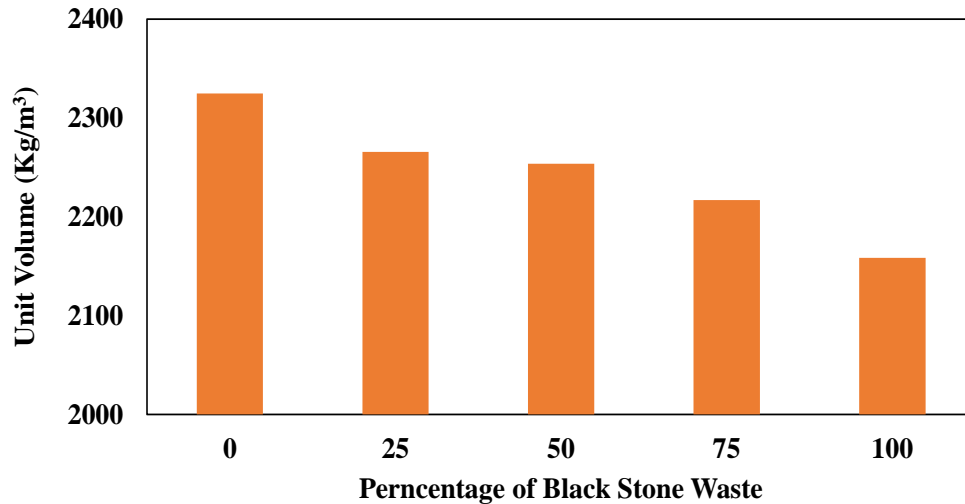


Fig. 1. Concrete unit weight with proportion variation of black stone waste coarse aggregate

2) *Compressive Strength*: The results of concrete compressive strength test for each variation of mixture are illustrated in Figure 3. It can be observed, from that figure, that compressive strength of concrete increases with the replacement of NCA with BSW, until the replacement of 25%, and then tends to decrease subsequently.

However, it is noted that the use of up to 75% BSW in the mixture could still produce higher compressive strength than control concrete does. Compared to control concrete, the compressive strength of concrete with 25%, 50%, 75% and 100% BSW are about 122%, 104%, 106%, and 88% respectively.

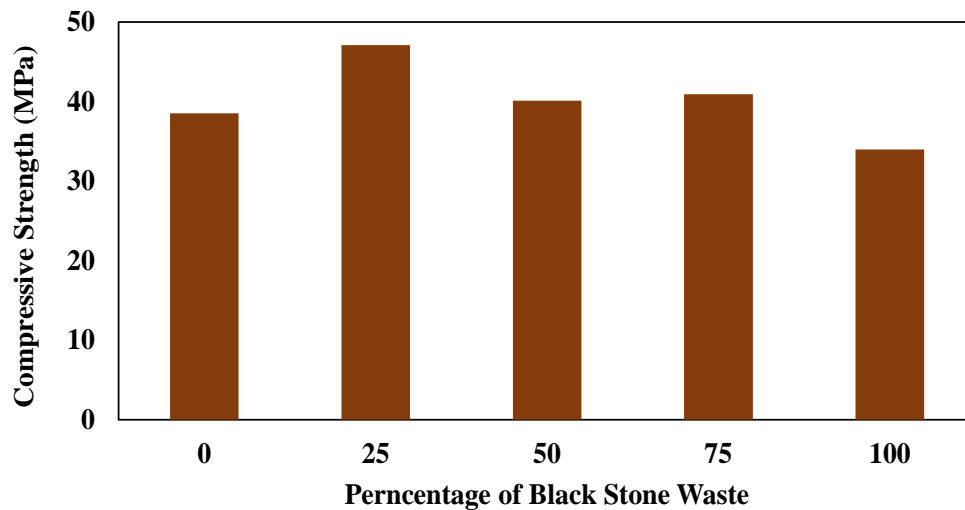


Fig. 3. Concrete compressive strength with proportion variation of black stone waste coarse aggregate

3) *Splitting Tensile Strength*: The results of concrete splitting tensile strength test for each variation of the mixture are presented in Figure 4. From that figure, it can be observed that splitting tensile strength of concrete increases regularly with the replacement of NCA with BSW, until the replacement of 75%, and then tends to decrease subsequently.

Nevertheless, it is noted that the use of up to 100% BSW in the mixture could still produce slightly higher splitting tensile strength than control concrete does. In fact, compared to control concrete, the splitting tensile strength of concrete with 25%, 50%, 75% and 100% BSW are about 108%, 111%, 125%, and 104% respectively.

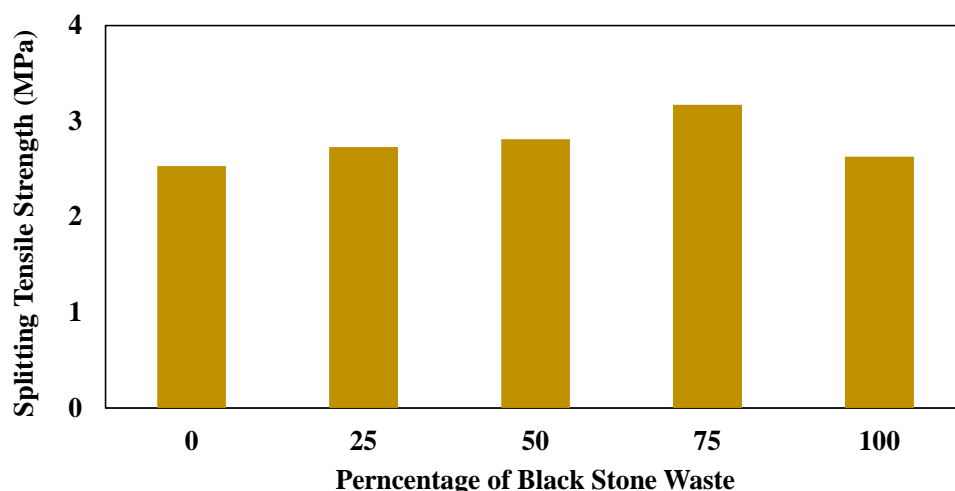


Fig. 4. Concrete splitting tensile strength with proportion variation of black stone waste coarse aggregate

### B. Discussion

The result shows that the more BSW used in the mixture to replace NCA the lighter the concrete produced. With the replacement of 100% NCA with 100% BSW, it is observed that concrete unit weight reduces about 7% compared to that of control concrete. This effect is due to the relatively lower unit weight of BSW than that of NCA which affects the unit weight of concrete produced.

The combination of the use of NCA with BSW in concrete mixtures produces relatively better strength than using only one of these ingredients as coarse aggregate. By replacing the NCA with BSW, the strength of concrete increases to the use of certain NCA and then tends to decrease gradually. It should be noted that in concrete with 100% use of BSW, the compressive strength and tensile strength of concrete produced were around 88% and 104% respectively compared to those of control concrete.

The strength increase observed in concrete with coarse aggregate combinations used can be attributed to the surface roughness of BSW. It is known that aggregate surface roughness is one of the factors that can contribute to the strength of concrete [6-7]. The more rough the aggregate surface, the better the bond that occurs between paste and aggregate [1, 8]. In this case the dominant factor between the increase in aggregate volume due to the aggregate unit weight and the aggregate surface roughness that determines the final strength produced by the concrete. These two conflicting factors ultimately provide different optimum use of BSW to produce both the highest compressive strength and splitting tensile strength. In fact, the optimum use of BSW for compressive strength and splitting tensile strength is about 25% and 75% respectively. By combining 25% BSW with 75% NCA and 75% BSW with 25% NCA, the compressive strength and tensile strength of concrete can reach about 122% and 125% respectively compared to those of control concrete.

### IV. CONCLUSION

Based on the result and discussion of this study, the following conclusions are drawn.

- The unit weight of concrete made with BSW coarse aggregate is 3%-7% lighter than that of control concrete.
- Concrete made with certain quantity of BSW can produce compressive strength as well as splitting tensile strength higher than those of control concrete.
- The optimum use of BSW for compressive strength and splitting tensile strength is about 25% and 75% respectively.
- In these optimum use, the compressive strength and tensile strength of concrete can reach about 122% and 125% respectively compared to those of control concrete.

### ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Leaders of Udayana University through the Udayana University LPPM who provided financial support for this research grant as well as to colleagues, laboratory technicians and students of the Civil Engineering Study Program, Faculty of Engineering, Udayana University who have assisted in the implementation and completion of this research.

### REFERENCES

- [1] I M. A. K. Salain., I K. Sudarsana, W. Mustika, "Mechanical Properties of Concrete Using Nickel Slag as Coarse Aggregate", in The 5th Environmental Technology and Management Conference, Bandung, Indonesia November 23rd-24<sup>th</sup>, 2015.
- [2] G. Sunaryo, "Rancangan Campuran Batu Padas Buatan Jenis Kelating Dengan Memanfaatkan Limbah Batu Tabas", M. Eng. thesis, Udayana University, 2007.
- [3] I W. Intara, I M. A. K. Salain, N. M. A., 'Penggunaan Serbuk Batu Tabas Sebagai Pengganti Sebagian Semen Dalam Pembuatan Beton', Jurnal Spektran, Vol. 1 No. 1, ISSN: 2302-2590, pp. 1-7, Jan. 2013.
- [4] Test method for compressive strength of concrete, SNI 03-1974-1990, Badan Standardisasi Nasional, Jakarta, 1990.
- [5] Test method for splitting tensile strength of concrete, SNI 03-2491-2002, Badan Standardisasi Nasional, Jakarta, 2002.
- [6] P. K. Mehta, Concrete Structure Properties, and Materials, Englewood Cliffs, New Jersey, 1986.
- [7] M. Neville and J. J. Brooks, Concrete Technology, Longman, Singapore, 1998.
- [8] I M. A. K. Salain, "Pengaruh Jenis Semen dan Jenis Agregat Kasar Terhadap Kuat Tekan Beton", Teknologi dan Kejuruan, Vol. 32, No. 1, ISSN: 0852-0062, pp. 63-70, 2009.

### AUTHOR PROFILE

I Made Alit Karyawan Salain is a lecturer at Civil Engineering Department of Udayana University in Bali, Indonesia. He is a Civil Engineer from Bandung Institute of Technology in Bandung, Indonesia, DEA and DR in Civil Engineering from INSA de Lyon in France. His research focused on concrete technology and valorization of industrial wastes in the field of Civil Engineering.

Yenni Ciawi is a lecturer at Civil Engineering Department of Udayana University in Bali, Indonesia. She is a Chemical Engineer from Bandung Institute of Technology in Bandung, Indonesia, PhD in Biotechnology from University of Kent at Canterbury, England. Her research focused on wastewater treatment and concrete technology.

Mayun Nadiasa is a lecturer at Civil Engineering Department of Udayana University in Bali, Indonesia. He is a Civil Engineer and a M.Eng. from Udayana University in Denpasar, Indonesia. His research focused on concrete technology.

Anak Agung Gede Sutapa is a lecturer at Civil Engineering Department of Udayana University in Bali, Indonesia. He is a Civil Engineer from Udayana University in Denpasar, Indonesia and a M.Eng. from Sepuluh November Institute of Technology in Surabaya, Indonesia. His research focused on concrete technology.