International Journal of Engineering &Technology, 7 (4) (2018) 6084-6087

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.23127
Research paper

Effect Bottom Ash as Partial Substitute of Sand on Compression Strength of Concrete

Rika Deni Susanti [1] *, Indra Kesuma Hadi [2], Sahat Sitompul [3], Ibnu Shubhan [1]

[1] Department of Civil Engineering, Institut Teknologi Medan, Indonesia
[2] Department of Architecture, Institut Teknologi Medan, Indonesia
[3] Department of Mechanical Engineering, Universitas HKBP Nommensen Pematang Siantar, Indonesia
**Corresponding author E-mail: razzanrikadeni@yahoo.com*

Abstract

This article presents a study on compression strength of concrete with bottom ash as partial substitute of sand. Initial testing was conducted with slump test of normal concrete and bottom ash-concrete. Further tests were performed with compressive strength test with 0%, 10%, 20%, 30%, and 40% of bottom ash each with concrete age of 14, 21, and 28 days. The next test performed on a specimen with 5%, 7.5%, 10%, and 12.5% of bottom ash. From each test variation, it was found that the potential of compressive strength achieved when sand was replaced by bottom ash. The result showed that the concrete mix with 10% bottom ash or smaller can be used as a substitute for sand in concrete mixes.

Keywords: *Bottom Ash; Coal; Strengths; Concrete; Compressive Strength.*

1. Introduction

Concrete is known today is a building material and construction that its properties can be determined by conducting planning and careful monitoring of the materials selected. In the field of construction, the use of concrete is the main option for structure, because concrete is the basic material that is malleable and the price is relatively cheap compared to other construction materials.

Concrete is a mixture of portland cement with coarse aggregate, fine aggregate, water and the added material that will form the fresh concrete. The hardening of concrete is imminent because of the events of the bond between the water and cement, in which the concrete is stronger by higher age. Volcanic ash can used as substitute cement and bottom ash as substitute sand.

In terms of aesthetics, concrete only requires little maintenance, besides that, concrete is resistant to fire attacks. The stress of the properties of concrete is to experience deformation that depends on time and is accompanied by shrinkage due to the drying of concrete and other symptoms associated with it. The effects of environmental conditions, crawling, shrinkage, loading which results in dimensional changes in the concrete structure and its elements must receive sufficient attention at the planning stage to overcome the difficulties that will occur.

Reinforced and non-reinforced concrete is a construction that has a characteristic strength which is when examined with a large number of test objects, the value will spread around a certain average value. The distribution of the results of this examination will be small or large depending on the level of perfection of the implementation. By assuming the values of the examination results are normal, the size of the size of the distribution of the results of the examination becomes a measure of the quality of implementation.

Several studies on the development of concrete materials has been conducted as volcanic ash or cement [7]; the material pozzolanic on self-compacting concrete [3]; pond ash as substitute of sand [15]; pond ash as replacement of cement [16], some artificial pozzolana in concrete production [14]; and recycled concrete [2], alccofine and fine fly ash as partial substitute of cement [9], and volcanic ash as partial substitute of cement [12]. A waste material like pond ash can be effectively material as a substitute of cement and 20% pond ash is effectiveto increase it combination with steel fibres to increase the strength of concrete in long term [16].

The most important properties of an aggregate are crushing strength and impact resistance, which can affect its bond with cement paste, porosity and water-catching characteristics which affect the resistance to a changing season, and resistance to shrinkage. Because it affects the quality of aggregate as a concrete constituent material. The aggregate content in concrete mixes is usually very high. Based on experience, the composition of the aggregate ranges from 60% to 70% of the weight of the concrete mixture. Although its function is only as a filler, but because of its large composition, aggregate becomes very important. Therefore, it is necessary to study the aggregate characteristics that will determine the properties of mortar or concrete produced.

The aggregates used in concrete mixes can be natural aggregates or artificial aggregates. In general, aggregates can be distinguished based on their size, namely coarse aggregates and fine aggregates. Brick between fine aggregates and coarse aggregates differ between disciplines with one another.

Fine aggregate is an aggregate of no more than 5 mm, so that the sand can be either natural sand or in the form of sand from breaking rocks. In the practice of making concrete construction, the selection of fine aggregates is considered important. This is done so that the aggregate used is a good aggregate so that the concrete quality can be achieved.

Bottom ash material has several characteristics in which the nature and composition of the chemical compounds that make up the bottom ash are influenced by the way of preparation of combustion methods and differences in coal quality. The technology that is developing at this time is the processing of industrial waste to be used

as raw materials or building materials. With the discovery of innovations these materials are expected to replace building materials so as to reduce production costs and reduce production waste. One of the innovations is using bottom ash as a substitute for cement in the concrete block mixture. The bottom ash is in the form of fine particles and is pozzolanic. There are three types of combustion methods in the energy production process, namely dry bottom boillers, wet-bottom boillers, and funcane cyclon.

Another development is the use of bottom ash as a mixture of concrete to get the compressive strength comparable normal concrete. Bottom ash from coal waste can replace the function of sand. Sivakumar and Kameshwari [11] stated that to substitute of fine aggregate with bottom ash, fly ash as replacement cement, and expansive clay granules as replacement of fine aggregate, but with the replacement above 10% reduction in compressive strength significantly.

Raju, et al. [8] stated that slump values of concrete with bottom ash decreased with the increase in level of sand substitute by bottom ash. The compressive strength of concrete with bottom ash increase at all the levels of sand substitute with bottom ash.

Compressive strength of concrete with bottom ash increase at the curing age of 28 days, Compressive strength of concrete with 5% of bottom ash more strength than the normal concrete [13].

Ibrahim et al. [4] found that the substitute level of 10-30% of bottom ash is ideal mixture to get good compressive strength. Nadig et al. [6] stated that a replacement of 30-50% of sand with bottom ash at 90 days of concrete produces higher compressive strength than normal concrete.

The compressive strength of concrete is influenced by the material used, the better the quality of cement, gravel or coarse aggregate and sand or fine aggregate. Sand be replaced by bottom ash for concrete mix. Addition of bottom ash is 5% close to the compressive strength of normal concrete and significantly reduced in the addition of bottom ash above 30% [11]. Concrete is said to be eligible if it has a greater compressive strength value of 20 MPa [12].

Normal concrete consisting of cement, sand, and gravel is less favorable if these materials are not eligible due to limited availability, therefore the need to find alternative natural additives in accordance with their respective functions. Singh and Siddique [10] stated that there is bottom ash can be used as replacement of sand.

Structures require no small cost in implementation. It also includes a fairly high concrete weight will affect the design of the reinforcement system is large enough, for the alternatives sought by replacing some concrete materials with lightweight materials.

Low bottom ash weight can reduce the weight of concrete [1]. Uses and applications of bottom ash as fine aggregate can reduce the cost of construction [5].

Concrete mixtures need to be developed with the use of other alternative materials, so that they are not always dependent on this material, if at any time not available due to certain factors and conditions. Alternative materials to be developed are volcanic ash as a substitute for cement and bottom ash as a substitute for fine aggregate which can increase the compressive strength of concrete so that it can optimize concrete mixtures and produce more economical concrete.

A lightweight material such as volcanic ash as a substitute for cement and coal bottom ash in lieu of fine aggregate, so as to reduce the weight of the concrete while maintaining a compressive strength, and can reduce the use of reinforcement systems are more economical. In this study the concrete material that is replaced is just fine aggregate, while other material remains.

The use of volcanic ash has been carried out by several researchers to reduce the use of cement in construction. Likewise, bottom ash as a substitute for fine aggregate in a concrete mixture. Blending of volcanic ash and bottom ash on concrete mixes has never been done. The innovation carried out in the study was how much the addition of volcanic ash as a cement substitute and how much the use of coal base ash as a substitute for fine aggregate, can increase the compressive strength of concrete when compared to normal concrete which only consists of cement, fine aggregate and coarse aggregate.

The purpose of this study is to obtain the percentage of bottom ash as a substitute for the addition of sand to improve the strength of concrete so that it can optimize the concrete mix and produce concrete which is more economical. This study is expected to develop the use of bottom ash as a substitute fine aggregate for concrete.

2. Research methods

The test material used in this study is the result of the formation of coal in the form of bottom ash. The research material was taken from the factory waste storage area in Belawan, Medan, North Sumatra Province. Sand extraction is done by separating bottom ash waste from other wastes.

This research was carried out with an experimental method to determine the compressive strength of concrete on specimens using bot-tom ash, as an enhancer and filling pores in the concrete.

Research conducted:

1) Preparing materials, namely: bottom ash, sand, gravel, portland cement, and clean water.
2) The production of 30 (square) cubes for P = 15 cm, L = 15 cm, T = 15 cm.
3) Immersion at the age of 14 days, 21 days and 28 days.

At the initial stage were conducted the slump test and continued with compressive strength test with 0%, 10%, 20%, 30%, and 40% of bottom ash at the age of concrete of 14, 21 and 28 days.

Based on the value of compressive strength of the mixture on top of an evaluation to get a variation mix produces a better compressive strength. The next test performed on a specimen with 5%, 7.5%, 10%, and 12.5% of bottom ash.

The optimum compressive strength obtained from the addition of bottom ash at a certain amount. A good amount of bottom ash can be seen from the compressive strength of bottom ash-concrete which is higher than normal concrete.

3. Results and discussion

3.1. Slump test of concrete with bottom ash

Slump test was conducted on a concrete slab with a mixture of 10%, 20%, 30%, and 40% of bottom ash. Slump test results are shown in Figure 1. The value addition of 10% slump in bottom ash is less than normal concrete and increasing with increasing bottom ash. Slump value of each addition of bottom ash is approximately equal to the normal concrete.

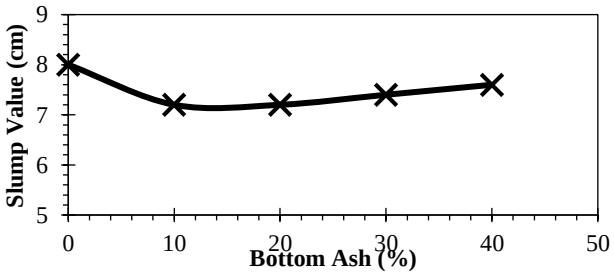

Fig. 1: The Slump Value of Concrete with Bottom Ash.

3.2. Compression strength value of concrete without bottom ash

Concrete compressive strength test on normal concrete and concrete with bottom ash obtained from cube-shaped test specimens with size 15 cm x 15 cm x 15 cm. Number of test specimens of 2 to the age of the concrete respectively 14, 21 and 28 days. Normal concrete test results are shown in Table 1. Values higher compressive strength with age concrete. The increase in compressive strength of concrete is shown in Figure 2.

Table 1: Compression Strength Value of Concrete without Bottom Ash

No.	Compression Strength (MPa)		
	14 days	21 days	28 days
1	17.84	21.84	24.08
2	19.47	22.83	24.92
Average	18.60	22.34	24.50

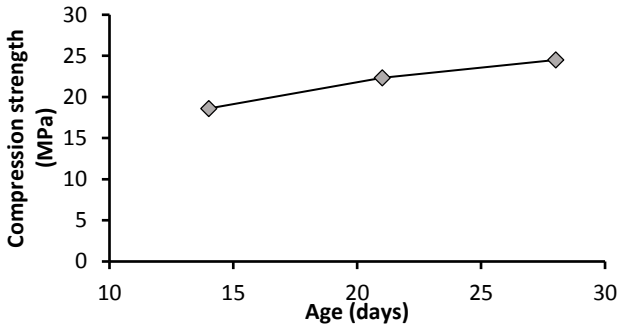

Fig. 2: Compression Strength Value of Concrete without Bottom Ash.

3.3. Compression strength value of concrete with bottom ash

Concrete compressive strength test results on a normal concrete mix (0% bottom ash) and a mixture of concrete with 10-40% bottom ash are shown in Figure 3. Generally, the strength of concrete is increasing along with the increasing age of the concrete. The addition of large quantities of bottom ash in concrete compressive strength showed a smaller than normal concrete. Increasing the concrete showed increased compressive strength of concrete at every variation of bottom ash.

The effect of adding 10-40% bottom ash as a substitute for sand in the concrete mix can be seen in Figure 5. The compressive strength of concrete at 14 days decreased in 30% of bottom ash, while at the age of 21-28 days the concrete compressive strength reduction occurs in 40% bottom ash.

The compressive strength of concrete due to the addition of over 10% bottom looks less significant because it is lower than 20 MPa. Although the compressive strength below 30% bottom ash seemingly constant, but the compressive strength values obtained are still far from the expected requirements. However, the addition of bottom ash is less than 10% were seen approaching the compressive strength of normal concrete, therefore carried out further tests on the concrete mixture with addition of 5%, 7.5%, 10%, and 12.5% bottom ash.

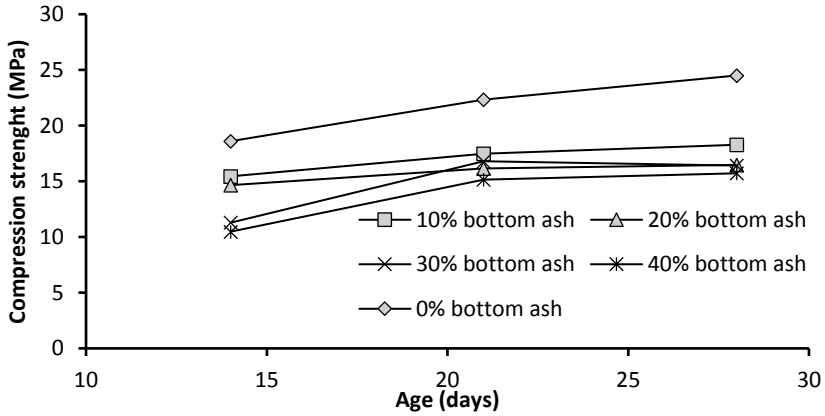

Fig. 3: Compression Strength Value of Concrete with Bottom Ash.

The results of compressive strength test on the concrete mixture with addition of 5%, 7.5%, 10%, 12.5% and bottom ash are shown in Table 2. The relationship percentage of bottom ash with a mean compressive strength of concrete is shown in Figure 5. The compressive strength of concrete with a mixture of bottom ash as looks pretty good substitute for sand in the mix below 10% bottom ash, while a mix of above 10% saw a decrease of concrete compressive strength significantly. The compressive strength with a mixture of bottom equal to or smaller than 10% result in the compressive strength of concrete is eligible.

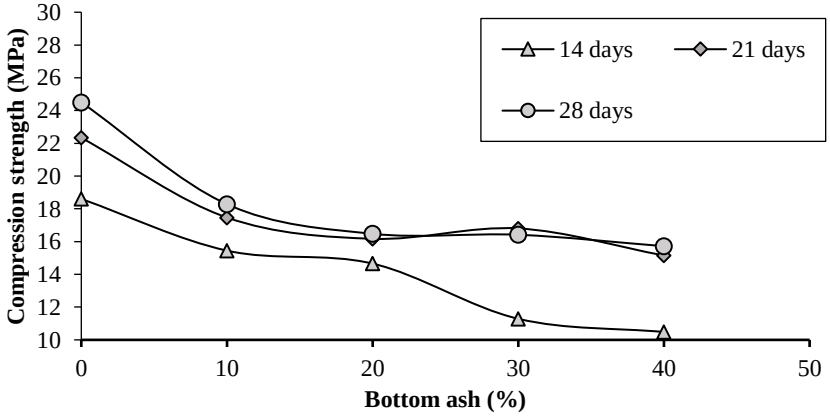

Fig. 4: Relationship of % Bottom Ash and Compression Strength.

Table 2: Compression Strength Value of Concrete with Bottom Ash

Bottom ash (%)	Compression strength (MPa)				> Standard
	1	2	3	Standard	
5	21.333	25.778	22.222	20	Ok
7.5	23.556	22.222	23.556	20	Ok
10	24.889	22.222	23.359	20	Ok
12.5	21.778	20.444	19.407	20	Ok

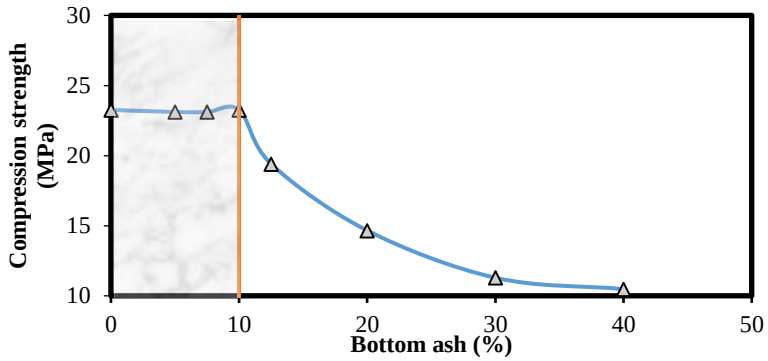

Fig. 5: Optimum Compression Strength of Concrete with Bottom Ash.

4. Conclusion

In this section you should present the conclusion of the paper. Conclusions must focus on the novelty and exceptional results you acquired. Allow a sufficient space in the article for conclusions. Do not repeat the contents of Introduction or the Abstract. Focus on the essential things of your article.

Based on the results of the study some conclusions were obtained:

The slump value in the concrete mix with the addition of bottom ash is approximately equal to the slump value of normal concrete.

Age of concrete above the 21 day compressive strength of concrete which generates nearly constant.

The compressive strength of concrete with a mixture of bottom ash is below 30% obtained constant at 21-28 days of age, but decrease on the concrete mix above 30%.

In general, the compressive strength of concrete with a mixture of bottom ash over 10% experienced a significant decrease, while the bottom ash concrete mixture with equal or less than 10% is obtained approaching normal compressive strength.

Concrete mixture with 10% bottom ash or smaller can be used as a substitute of sand in concrete mixture. Thus the concrete mixture can save the use of sand, thus diminishing construction cost.

Acknowledgement

This research was funded from Ministry of Research, Technology and Higher Education of the Republic of Indonesia. For this reason, the authors would like to thank for the funding that has been given.

References

[1] Aggarwal P, Aggarwal T, & Gupta SM (2007), Effect of bottom ash as replacement of fine aggregates in concrete. *Asian Journal of Civil Engineering (Building and Housing)* 8, 49-62.

[2] Curović N (2017), Recycled concrete - ecology and economic criterias. *Journal of Applied Engineering Science* 15, 271-274. https://doi.org/10.5937/jaes14-10964.

[3] Fathi A, Shafiq N, Nuruddin MF, & Elheber A (2013), Study the effectiveness of the different pozzolanic material on self-compacting concrete. *ARPN Journal of Engineering and Applied Sciences* 8, 299-305.

[4] Ibrahim MHW, Abidin NEA, Jamaluddin N, Kamaruddin K, & Hamzah AF (2016), Bottom ash – potential use in self-compacting concrete as fine aggregate. *ARPN Journal of Engineering and Applied Sciences* 11, 2570-2575.

[5] Kumar D, Gupta A, & Ram S (2014), Uses of bottom ash in the replacement of fine aggregate for making concrete. *International Journal of Current Engineering and Technology* 4, 3891-3895.

[6] Nadig VR, Sanjith J, Ranjith A, & Kiran BM (2015), Bottom ash as partial sand replacement in concrete - a review. *IOSR Journal of Mechanical and Civil Engineering* 12, 148-151.

[7] Olawuyi BJ, & Olusola KO (2010), Compressive strength of volcanic ash/ordinary portland cement laterized concrete. *Civil Engineering Dimension* 12, 23-28. https://doi.org/10.9744/ced.12.1.23-28.

[8] Raju R, Paul MM, & Aboobacker KA (2014), Strength performance of concrete using bottom ash as fine aggregate. *International Journal of Research in Engineering & Technology* 2, 111-112.

[9] Reddy MVS, Ashalatha K, & Surendra K (2016), Studies on eco-friendly concrete by partial replacement of cement with alccofine and fine fly ash. *ARPN Journal of Engineering and Applied Sciences* 11, 3445-3448.

[10] Singh M, & Siddique R (2013), Effect of coal bottom ash as partial replacement of sand on properties of concrete. *Resources, conservation and recycling* 72, 20-32. https://doi.org/10.1016/j.resconrec.2012.12.006.

[11] Sivakumar S, & Kameshwari B (2015), Influence of fly ash, bottom ash, and light expanded clay aggregate on concrete. *Advances in Materials Science and Engineering*, 2015. https://doi.org/10.1155/2015/849274.

[12] Susanti RD, Tambunan R, Waruwu A, & Syamsuddin M (2018), Studies on concrete by partial replacement of cement with volcanic ash. *Journal of Applied Engineering Science* 16, 161-165. https://doi.org/10.5937/jaes16-16494.

[13] Thirumalai R, Anantharaja V, Kaleeswaran M, Lakshmanakumar R, Logeswaran VG (2016), Study on performance of bottom ash in concrete. International Journal of Innovative Research in Science, Engineering and Technology, 5(4), 5648-5653.

[14] Tsado TY, Yewa M, Yaman S, & Yewa F (2014), Comparative analysis of properties of some artificial pozzolana in concrete production. International Journal of Engineering and Technology, 4(5), 251-255.

[15] Tumingan M, Tjaronge W, Djamaluddin R, & Sampebulu V. (2014), Compression strength of concrete with pond ash as replacement of fine aggregate. *ARPN Journal of Engineering and Applied Sciences* 9, 2923-2928.

[16] Phanikumar BR, & Sofi A (2016), Effect of pond ash and steel fibre on engineering properties of concrete. *Ain Shams Engineering Journal* 7, 89-99. https://doi.org/10.1016/j.asej.2015.03.009.