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STUDY OF COMPRESSIVE STRENGTH OF CONCRETE MODIFIED WITH BUKHO STONE FRACTIONS

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ABSTRACT: Innovation in concrete materials persists, offering alternatives in situations where the primary material becomes scarce. Alternative materials need to be considered for quality and availability at the location of the construction work. The bukho stone material is easily available on one of the islands in Indonesia, whereas the main material for concrete is very limited. This study used bukho stone fractions as a partial replacement material for sand and partly for gravel. The amount of mixture used was 5%, 10%, and 15%, respectively. The concrete constituent materials were mixed in such a way as to mold cubical specimens measuring 15 cm x 15 cm x 15 cm. Concrete compressive strength tests were conducted at 7 days, 14 days, and 28 days of concrete age. The results showed that the potential of bukho stone fractions with a size < 4.75 mm as a partial replacement of sand provided significant compressive strength values at the maximum use of 10% bukho stone. Fragments of bukho stone with a size > 4.75 mm as a partial replacement of gravel showed an increasing trend in compressive strength for the use of more than 10% bukho stone. Longer concrete ages showed an increase in compressive strength in each of the concrete mixtures used, this could be due to the pozzolanic reaction in the mixture continuing to occur at longer concrete ages.

Keywords: Concrete, Bukho Stone, Sand, Gravel, Compressive Strength

1. INTRODUCTION

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without additives, that forms a solid mass. Concrete mixtures have standard specification requirements that must be met in order to achieve the desired compressive strength. Unmet properties of constituent materials require additives to improve concrete performance.

Additives can be chemicals, mineral materials, or waste products in the form of fine powders as pore filling materials in concrete mixtures. Mineral additives can include fly ash, pozzolan, and silica fume. Volcanic ash can potentially replace cementitious materials [1]. Minerals containing silica and aluminum that react chemically with calcium hydroxide at ordinary temperatures form cementitious compounds. The use of 12–17% rice husk ash produces the best compressive strength of concrete compared to other mixes [2]. Even the strength can be higher than ordinary concrete [3]. This indicates that these materials have potential as concrete mixes.

Cold lava sand can be used as a substitute for fine aggregate materials in concrete mixes. This material is the result of a volcanic eruption. The combination of both volcanic waste materials, cold lava sand and volcanic ash, gives good results in increasing the compressive strength of concrete with the use of up to 10% volcanic ash [4]. However, the compressive strength value is still smaller than the compressive strength of normal concrete. Coal-bottom ash can be used as a partial replacement for sand material [5]. In addition to being a sand replacement material, coal bed ash also has the potential to be a cement replacement for concrete in normal and aggressive environments [6]. The performance of concrete made using fly ash and plastic mixtures can increase compressive strength compared to conventional concrete [7].

The compressive strength of concrete made from these materials is still less than that of normal concrete consisting of cement, sand, and gravel. This could be due to the small amount of mix, some materials requiring a combination of different materials, and the shape of the aggregate also affecting the performance of the concrete. More coarse-grained aggregates were found to be helpful in increasing the compressive strength of concrete [8]. In some places, marine sand is the preferred material to be used as fine aggregate in concrete mixes. Concrete is very sensitive to the effects of seawater mixed with marine sand. Concrete structures are severely damaged by the sulfate and chloride salts in the sea sand [9]. The use of marine sand commonly used in Nias islands can be minimized through the use of bukho stone fractions as a replacement material. Fractured bukho stone gives good results when used as pavement material for road structures [10]. This research shows good potential to be used as an alternative material for

concrete mixes. However, a combination of finely crushed bukho stone as fine aggregate and coarsely crushed bukho stone as coarse aggregate is required. River sand is difficult to obtain in certain areas. As on Nias Island, the use of sand for construction is mostly taken from mountain sand and sea sand. Fractured bukho stone material is easily found in this area. Generally used as road paving. If processed, it is necessary to find out its potential when used as a fine aggregate to replace sand and as a coarse aggregate to replace gravel. However, the composition that can produce adequate concrete compressive strength needs to be investigated further and in detail through this research. This type of stone, when broken, can consist of three parts: the fine-size part passing sieve no. 200 can resemble cement, the medium-size part resembles the size of sand, and the hard, unbreakable part can resemble the size of gravel.

The use of alternative materials for concrete mixtures prioritizes the use of local materials such as volcanic ash as a partial replacement for cement and cold lava sand as a substitute for sand [4]. The amount of volcanic ash used was limited to 10% to provide compressive strength values close to those of normal concrete without the use of volcanic ash. Partial replacement of sand for concrete mixtures can use coal bed ash, but the results obtained are still much smaller than the compressive strength value of normal concrete without coal bed ash [5]. This may be due to the small amount of additional material. A higher amount of fly ash shows a better increase in the compressive strength of the mix [11]. This is proven by the results of research using 30% coal fly ash with a combination of nickel slag, which gives a higher compressive strength value than 100% sand [12]. Aggregate replacement of up to 50% has an effect on increasing the compressive strength of concrete [13].

In addition to the mix combination, it is important to consider the curing period of the concrete. The geopolymer concrete from the fly ash combination gave successful results at a concrete curing age of 28 days [14]. The addition of 0.6% glass fiber material can increase the compressive strength of 28-day concrete from 57 MPa to 66 MPa [15]. The best compressive strength performance of concrete is obtained at 7 days, 14 days, and 28 days [16].

Based on the above description, it is necessary to innovate local materials to be used as concrete materials by paying attention to grain size, the amount of replacement material, and the combination of fine aggregate material with coarse aggregate. The added material used in the research is bukho stone fractions as a partial replacement for fine aggregate and coarse aggregate.

2. RESEARCH SIGNIFICANCE

This research plays an important role in raising the potential of materials that have the potential to be used as concrete materials. Materials from bukho stone are crushed until it forms fine grains and coarse grains. This material is developed to be used as a substitute for some of the sand and some of the gravel used as part of the concrete material. This has an impact on the development of alternative materials in concrete mixtures.

3. MATERIALS AND METHODOLOGIES

3.1 Materials and Preparation

The main material of the study was bukho stone fragments taken from Nias Island, North Sumatra (Fig. 1). These bukho stone fragments were separated based on grain size, with sizes < 4.75 mm as fine aggregate and > 4.75 mm as coarse aggregate [17] (Fig. 2).

Fig. 1 Bukho stone

(a) (b)

Fig. 2 Fractured bukho stone: (a) Fine aggregate; (b) Coarse aggregate

The bukho stone fragments were fed into an abrasion tool to obtain fine and coarse grains, which were separated on a no. 4 (4.75 mm) sieve. The fine (S) < 4.75 mm and coarse (G) > 4.75 mm bukho stone fragments were separated, respectively, to be used as partial sand replacement (BS-S) and partial gravel replacement (BS-G). The fine aggregate and coarse aggregate compositions in the concrete compressive strength test mix were 5%, 10%, and 15% bukho stone fragments (BS), respectively.

3.2 Testing Methodologies

The concrete mixture consisted of cement, fine aggregate in the form of fine bukho stone and/or sand, coarse aggregate in the form of coarse bukho stone and/or gravel, and sufficient water to be mixed to make a test specimen (Fig. 3). The test specimens for compressive strength used cubes measuring 15 cm x 15 cm x 15 cm [18] (Fig. 4).

Each mixture was made into three test speciments and soaked for 28 days before the concrete compressive strength test; this refers to the best compressive strength value from the research results [11]. The concrete strength test of this cube-shaped test specimen produces an average concrete compressive strength value of 3 test specimens of each mixture with a crack pattern in the vertical direction (Fig. 5).

Fig. 3 Concrete mix

The expected result of this research is that fine bukho stone can replace most or all of the sand composition as fine aggregate in concrete mixes, while coarse bukho stone can replace part or all of the gravel composition in concrete mixes. The compressive strength of concrete using bukho stone fractions is expected to compensate for concrete using sand and gravel. The results of this study are expected to be the basis for mixing concrete using bukho stone fractions.

Fig. 4 Concrete cube mold

Fig. 5 Concrete compressive strength test specimen

4. RESULTS AND DISCUSSIONS

The results of this study are presented with the results of compressive strength tests on cube specimens, both using bukho stone fractions as a partial replacement of sand and gravel. The compressive strength values influenced by bukho stone fraction content and concrete age are discussed to get the trend of changes caused by the amount of mixture and age.

4.1 Bukho Stone Characteristics

The bukho stone material used in this study is one type of stone in general. Physically, this rock is brownish white with a rough texture. The fragments

of this bukho stone can consist of fine, medium, and coarse grains. Coarse grains are difficult to break so they can be equated with coarse aggregate. Fine and medium grains are the result of fragments of this bukho stone, these grains can be equated with fine aggregate. The chemical composition of the fragments of bukho stone is presented in Table 1. The main components consist of Calcium carbonate with $CaCO_3$ is 76.78% and Aluminum oxide with $Al2O_3$ is 14.3%. Based on the results of the chemical composition test of bukho stone, it can be said that this material is close to the same as lime. According to research [19], lime has a main content of $CaCO_3$ is 84.85%, SiO_2 is 7.06%, and $Al2O_3$ is 2.38%.

Table 1. Chemical characteristics of bukho stone

Chemical characteristics	Unit	Value
Calcium carbonate ($CaCO_3$)	%	76.78
Magnesium oxide (MgO)	%	0.58
Silicon dioxide (SiO_2)	%	1.28
Aluminium oxide (Al_2O_3)	%	14.3

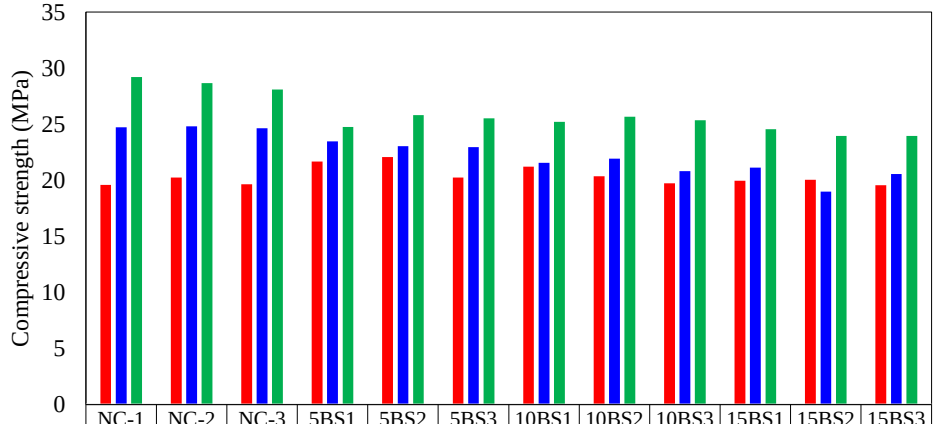
4.2 The Results of the Compressive Strength Test

The compressive strength test results on concrete cubes are divided into two categories. The first is concrete cubes made from a mixture of bukho stone fractions as a substitute for the resultant aggregate or sand. The second is concrete cubes made from a mixture of bukho stone fractions to substitute coarse aggregate or gravel. Each specimens is made of as many as 3 (three) with an age of 7 days, 14 days, and 28 days.

The results of the compressive strength test on concrete cubes with a mixture of bukho stone fractions as a partial replacement for sand are shown in Fig. 6. The results show that the results are not much different from one test specimen to another at the same mixture and age. The effect of concrete age on the mixture of bukho stone fragments shows a high increase from 14 days to 28 days compared to 7 days to 14 days.

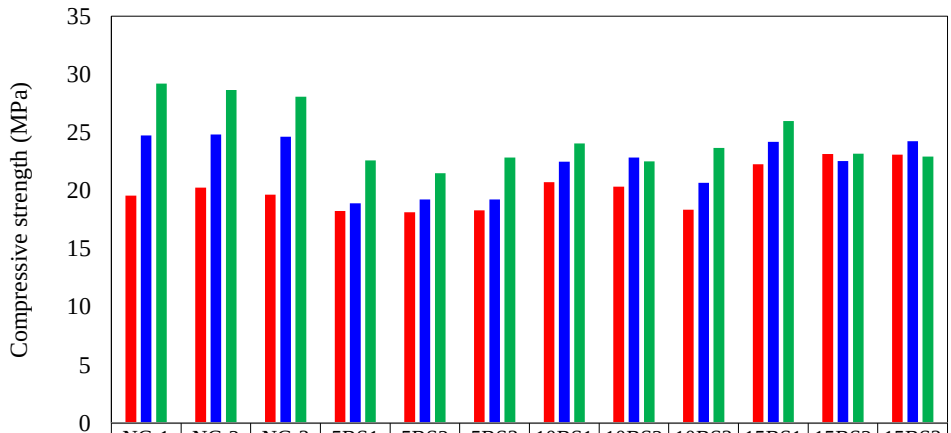
The results of the compressive strength test on concrete cubes with a mixture of bukho stone fractions as a partial replacement for gravel are shown in Fig. 7. The effect of concrete age is clearly visible in the mixture of 5% and 10% bukho stone fractions, while the 15% mixture does not show significant differences. The results show a tendency to increase the compressive strength value along with adding bukho stone fractions as a substitute for gravel.

The effect of age on normal concrete without bukho stone admixture shows a significant effect at the ages of 14 and 28. This is different from concrete with bukho stone admixture. The 28-day concrete age of bukho stone mixture as a partial replacement of sand shows a higher effect than the 14-day concrete age, while bukho stone mixture as a partial replacement of gravel has not shown significant changes at 14 days and 28 days of concrete. This means that the pozzolanic reaction in concrete using bukho stone fractions takes a long time.



	NC-1	NC-2	NC-3	5BS1	5BS2	5BS3	10BS1	10BS2	10BS3	15BS1	15BS2	15BS3
7 days	19.577	20.251	19.649	21.666	22.073	20.23	21.221	20.365	19.717	19.951	20.031	19.557
14 days	24.729	24.824	24.634	23.473	23.037	22.953	21.554	21.925	20.82	21.136	18.996	20.565
28 days	29.207	28.651	28.084	24.738	25.808	25.511	25.216	25.664	25.337	24.552	23.948	23.961

Fig. 6 The result of the test on the cube with a bukho stone fractions as a sand substitute



	NC-1	NC-2	NC-3	5BS1	5BS2	5BS3	10BS1	10BS2	10BS3	15BS1	15BS2	15BS3
7 days	19.577	20.251	19.649	18.234	18.125	18.308	20.716	20.331	18.368	22.27	23.156	23.1
14 days	24.729	24.824	24.634	18.9	19.248	19.248	22.494	22.835	20.668	24.195	22.544	24.242
28 days	29.207	28.651	28.084	22.602	21.493	22.856	24.063	22.502	23.679	25.994	23.173	22.925

Fig. 7 The result of the test on the cube with a bukho stone fractions as a gravel substitute

4.3 Effect of Concrete Age on Compressive Strength

The effect of concrete age is shown for both types of mixes for concrete, with bukho stone as a partial sand replacement and bukho stone as a partial gravel replacement. The effect of concrete age on the compressive strength of cubes with bukho stone fractions as partial sand replacement is shown in Fig. 8.

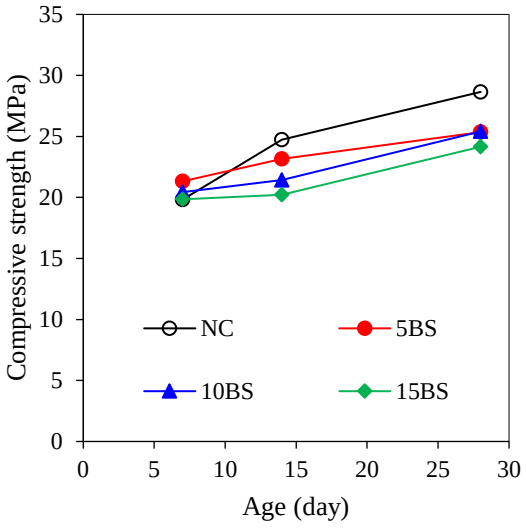


Fig. 8 Effect of concrete age on sand replacement specimens

The age of the concrete showed a significant effect on all the specimens, both using bukho stone fractions and conventional concrete. There is a possibility that the compressive strength of concrete will still increase for concrete aged above 28 days, especially for 10BS and 15BS mixes. This can be due to the pozzolanic reaction that still takes place at the age of concrete above 28 days [6].

The effect of concrete age on the compressive strength of cubes with a mixture of bukho stone fragments as a partial replacement for gravel is shown in Fig. 9. The age of concrete was seen to have a significant effect on each specimen, but conventional concrete showed better improvement compared to concrete with bukho stone fractions. The concrete ages for 5–15% bukho stone (5BS, 10BS, and 15BS) produced similar values.

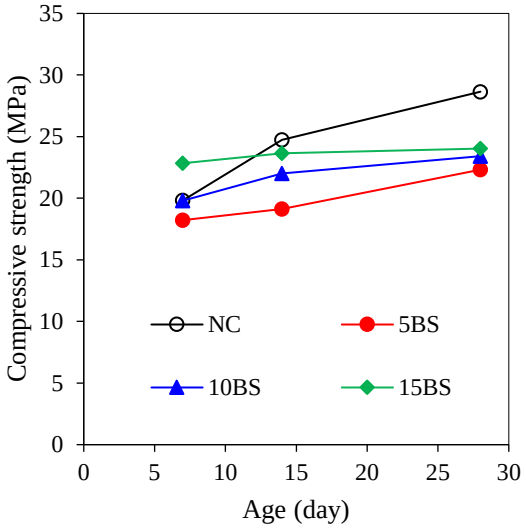


Fig. 9 Effect of concrete age on gravel replacement specimens

4.4 Effect of Bukho Stone Content on Compressive Strength

The effect of the amount of bukho stone fractions added as a partial replacement of sand and gravel explains the compressive strength values for each mixture used. The compressive strength values shown are the average values of the three test specimens used.

The effect of mix content on the compressive strength values of cubes with bukho stone as partial sand replacement is shown in Fig. 10. Increasing the amount of bukho stone fractions as partial sand replacement shows a decreasing trend in compressive strength as the amount of admixture increases, especially for 15% bukho stone admixture (15BS). This implies that using bukho stone fractions as partial sand replacement should be limited to 10% (10BS).

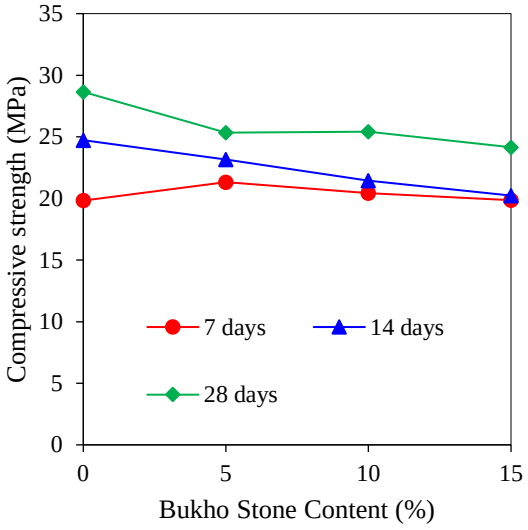


Fig. 10 Effect of bukho stone content on sand replacement specimens

The effect of mix content on the compressive strength values of cubes with bukho stone as partial gravel replacement is shown in Fig. 11. Although there is a decrease in the compressive strength of concrete with the use of 5% bukho stone (5BS), the use of 10% and 15% bukho stone as partial replacements for gravel shows an increase with the addition of bukho stone fractions. This implies that there is still a possibility of increasing the compressive strength of concrete with the use of bukho stone above 15%.

4.5 Comparison of Bukho Stone Usage

The utilization of bukho stone fractions is divided into two categories, each as a partial replacement of sand for grain size < 4.75 mm and a replacement of gravel for size > 4.75 mm. A comparison of the two is shown in the compressive strength value due to the influence of the amount of bukho stone fractions and the age of the concrete used.

A comparison of compressive strength and utilization of bukho stone as a partial replacement of sand with partial gravel in terms of concrete age is shown in Fig. 12. Concrete age has a significant effect on increasing its compressive strength, both for the bukho stone mixture as a substitute for sand and the bukho stone mixture as a substitute for gravel.

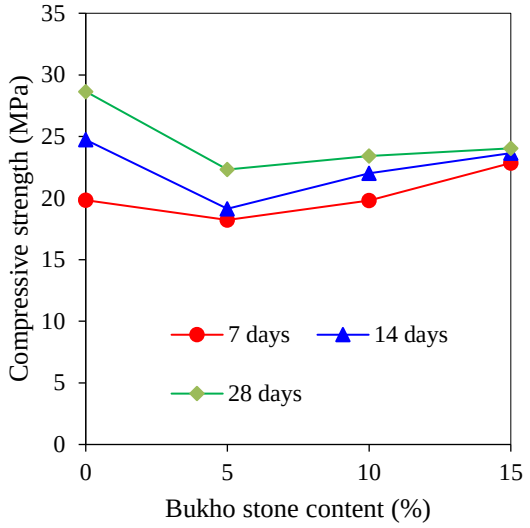


Fig. 11 Effect of bukho stone content on gravel replacement specimens

A comparison of compressive strength and utilization of bukho stone as a partial replacement of sand with partial gravel in terms of mix content is shown in Fig. 13. The results show that as a sand substitute, it is more suitable to use with a small amount of bukho stone at a maximum of 10%, and as a gravel substitute, it is better to use with a minimum amount of bukho stone at 10%. This is shown in the fact that the concrete compressive strength value tends to decrease in the bukho stone mixture as a sand substitute and tends to increase in the bukho stone mixture as a gravel substitute. The compressive strength value of concrete is seen to be relatively decreased in the coarse aggregate mixture of 5% bukho stone, this can occur due to the amount of bukho stone material being too little so that it is not distributed throughout the concrete cube. However, along with the addition of bukho stone, it was found that the compressive strength value increased at 10-15% bukho stone.

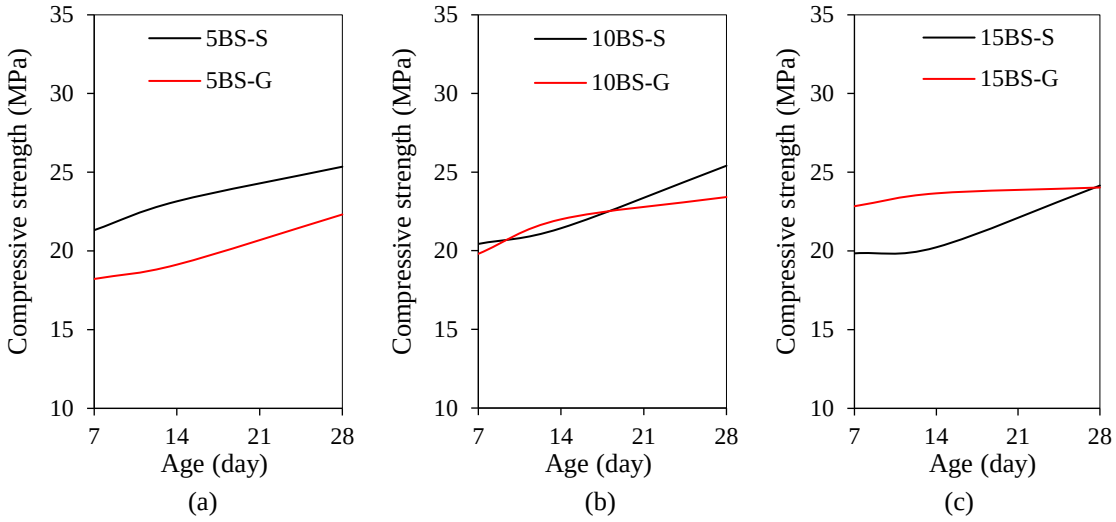


Fig. 12 Effect of concrete age: (a) 5% bukho stone; (b) 10% bukho stone; and (c) 15% bukho stone

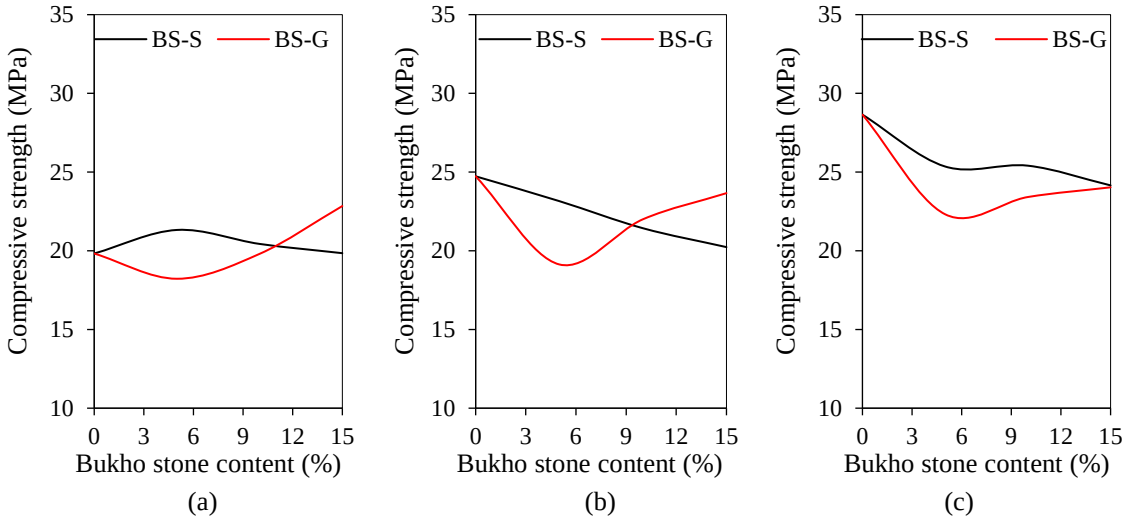


Fig. 13 Effect of bukho stone fraction content: (a) 7 days; (b) 14 days; and (c) 28 days

5. CONCLUSION

The conclusion of this study are:

1. The compressive strength of concrete increases with the age of the concrete for both bukho stone mixtures as a partial replacement of sand and bukho stone mixtures as a partial replacement of gravel. Thus, there is a possibility of increasing the compressive strength of concrete at ages above 28 days.
2. The addition of bukho stone mixture as a partial replacement of sand gives positive results for the maximum use of 10% bukho stone fractions, while for the use of bukho stone as a partial replacement of gravel, there is a potential increase for levels above 15% bukho stone fractions.
3. Good results are recommended at a maximum of 10% for the use of crushed bukho stone < 4.75 mm as sand replacement and a minimum of 10% for the use of crushed bukho stone > 4.75 mm as gravel replacement.
4. Based on the results of the study, further research is needed to increase the amount of bukho stone as a substitute for gravel with a longer concrete age, the same for bukho stone fractions as a partial replacement of sand but for a maximum mixture amount of 10%.

6. ACKNOWLEDGMENTS

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022/LL1/AL.04.03/2024, number 010/LPPM-Unham/VI/2024 dated June 20, 2024, June 21, 2024.

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