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Study of High Performance Concrete Using Local Materials (Fly Ash Of PLTU Labuhan Angin, Mount Sinabung Volcanic Ash And Silica Sand) On The Mechanical Properties Of Concrete

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ABSTRACT

Currently in Indonesia a lot of construction work and concrete is one that is widely used. In the development of concrete construction technology, especially in Indonesia, it is necessary to have concrete capable of carrying high loads using available materials. Against the background of future needs, in this study experiments were carried out in a concrete laboratory to obtain high performance concrete mixes with local materials. At the experimental stage, testing of tools and materials, concrete mix, casting, slump test, manufacture of specimens, maintenance, checking of unit weight, There were 11 variations in the compressive strength, split tensile strength and modulus of elasticity tests in this study. Furthermore, the test results were analyzed by the data to draw conclusions. The results show that the compressive strength of concrete at 3 days is very strong, namely 53.8 MPa which could be used for fast precision work. In variation 11 mixture (PCC Cement, Silica Fume, Sand Mesh 35-60, Silica Mesh 325, Water, Viscocrete Superplasticizer 8670 MN, Fly Ash 7% and Polypropylene Fiber 0.2%) tested for 28 days, the compressive strength reached 87.5 MPa, so it can be said as HPC concrete. In this study it was concluded that the use of local materials, Sinabung Volcanic Ash waste and *fly ash* can improve the quality of concrete and reduce environmental pollution.

Keywords: *fly ash, high performance concrete, sinabung volcanic ash*

1. Introduction

Currently in Indonesia a lot do project construction and concrete is a lot of material used . technology mixture material construction concrete going growing. Concrete has been an instrument for providing stable and reliable infrastructure for a long time. In the 20th century, the compressive strength of concrete was in the range of 13.8 MPa, in 1960 it was 41.4 MPa. For achieve efficiency and effectiveness factors in the mix ingredients concrete needed material substitutes and additives, which have strength high and durable in work construction. The Indonesian government requires the development of the latest technology that can be applied, especially in concrete construction technology which is superior in the mechanical behavior of concrete and its use. On development construction Modern concrete requires concrete that is capable of carrying high loads to be used in the construction of tall buildings, special roads for high loads, construction of bridges and other infrastructure. In the development high quality concrete there are 3 levels including *hsc, hpc* and *uhpc.*

Usage HSC has experience development since 1950s, concrete with strong pressure 5000 psi (34 MPa) is considered high strength. In its development HSC concrete can be used in road pavement works, airport runways, bridges, concrete sleepers which receive heavy loads, dam works, etc. The cement to water ratio of 0.26 is used in the HSC design. Strength concrete is maintained in the high strength range of concrete because the compression strength has more than 6000 psi to 9000 psi (62 Mpa) [1].

HPC concrete is made with material proportions that are influenced by many factors, including the performance, of materials available in the area. There are many product technologies available to use concrete to improve concrete quality. In its manufacture, it requires good construction practices and good curing to produce quality HPC concrete [2]. The addition of silica fume and superplasticizer can increase the compressive strength of concrete. The planned f'c concrete quality is 70 MPa, with the addition of increasing the compressive strength of the concrete to 79.68 Mpa [3].

UHPC concrete is a new generation of concrete which has the characteristics of a very dense material with a compression strength of up to 150 MPa – 250 MPa. This new concrete makes it possible to make slender concrete structures with great strength and can save materials. In various developed countries UHPC as a structural material in various buildings, such as bridges, is still very rare. [4]. UHPC designed give density high packaging, produce _ structure optimal pore and strength press outside normal. A promising and effective approach _ For designing sustainable development of UHPC [5].

The eruption of Mount Sinabung from 2010 to 2014 did a lot of damage to crops and agricultural land, with damage varying from light to very heavy, mostly caused by hot clouds sweeping fields and plants, also covered with lava and volcanic ash. The thickness of volcanic ash can be classified as thin 2 cm, medium 2-5 cm and thick 5 – 10 cm. [6]. Using volcanic ash in concrete produces good concrete compressive strength [7]–[9].

Fly Ash is a waste from burning coal which can be found in steam power plants. In the development of fly ash waste technology is widely used in concrete mixtures. Biggest reason use *fly ash* in concrete is increasing age hope life and improvement Power hold related _ with its use. *fly ash* can too lower permeability, because lower ratio of water to cement, so composite become more solid, which can be reduce pore volume capillary (Keskin, Tas and Keskin, 2020). Addition of batbatra fly ash in the concrete mix can increase the compression strength by 26,45% of concrete without fly ash added [10].

Using silica sand resulted in an increase in maximum compressive strength of 2.924 MPa, and split tensile strength of 0.353 MPa. [11] Silica sand increases the compressive strength of concrete by 13% compared to ordinary sand. [12]. Silica sand is a residual material from mineral mining which is widely used as a concrete material. Silica sand was used as a substitute for the mixture, with the resulting compressive strength values obtained being better than standard concrete [13]. Silica sand can increase the compressive strength of concrete. [14]. Silica sand is ground into silica sand powder suspended in sieve number 325 used as a concrete mixture. The finer the silica sand, the greater the compressive strength [15].

Polypropylene Fiber (PF) is a type plastic PF which is special production with high technology. This fiber can be used to improve performance, and produce improvements compared to normal concrete [16]. PF pada beton mutu tinggi meningkatkan sifat mekanik beton, kuat tekan, kuat lentur, kuat tarik beton. [17]. This research uses surrounding waste to improve the quality of concrete. This research aims to determine the compressive strength, split tensile strength and modulus of elasticity in concrete using waste, namely hydroelectric power plant fly ash, volcanic ash from Mount Sinabung. The results of this study are to be useful in the field of construction in Indonesia and the world to use fly ash and volcanic ash waste to obtain concrete quality. Particularly in Indonesia, there has not been much research and use of concrete, so researchers are interested so that in the future it can be useful for future readers and researchers.

2. Method

In this study the research methodology used was an experiment carried out in the structural laboratory and concrete materials and engineering laboratory, Faculty of Civil Engineering, University of North Sumatra. Starting with the problem, then a literature study regarding concrete structures based on journals [18]. And also regarding HSC concrete, HPC concrete and UHPC concrete. The research phase will utilize the waste that is around the researcher to be used as a building block for concrete. The next stage is to provide concrete constituents and tools needed in the research. Furthermore, at the experimental stage, in detail the examination of research tools and materials, planning the composition of the concrete mix, making the concrete mix, examining the slump test, printing the concrete specimen, treating the concrete specimen, checking the volume weight of concrete specimen.

The ingredients used in the composition of the concrete mix are as follows:

1. Flying Ashes of PLTU Labuhan Angin Central Tapanuli.
   Fly Ash The method used in this study was obtained directly from the source of waste disposal at PLTU Labuhan Angin. PLTU Labuhan Angin is one of the electricity suppliers in the Tapian Nauli I area, Tapian Nauli, Central Tapanuli Regency, North Sumatra. Based on the X-Ray Fluorescence (XRF) analysis, fly ash has a SiO2+Al2O3+Fe2O3 content of 81.86% which indicates that the fly ash is in the class F category and meets the quality standards as a concrete mix. Fly ash can improve quality of concrete [19].

2. Volcanic Ash Mount Sinabung
   Abu Sinabung can improve the quality concrete [7]. For this research, volcanic ash was obtained directly from the source, namely in Karo Regency, North Sumatra by using public transportation and then taken to the laboratory for material inspection and manufacture of test objects.

3. Water
   Water is used to trigger a chemical reaction for the binding and hardening process. Almost any natural potable water that is tasteless or odorless can be used as an admixture for making concrete. The water used in this study was sourced from the concrete laboratory.

4. Sand Bangka *Mesh* 35-60
   The sand used does not contain more than 5% mud, because the mud will block the bond between the sand and cement. The sand used is clean sand obtained from Bangka Belitung with a mesh size of 35-60 (500-250 microns) or 0.5–0.25 mm from CV Nagamas, Bangka Belitung, Indonesia.

5. Silica *Mesh* 325
   The fine silica used is silica which can be obtained from Bangka Belitung, Indonesia. With Silica Flour specification mesh size 325 (44 microns) or 0.044 mm.

6. *Polypropylene Fibers*
   Polypropylene Fibers High quality polypropylene monofilament micro fiber material. *Polypropylene Fiber* used _ is SIKA's product is SikaFibre (*Polypropylene Fibers for Concrete*) with diameter of 18 microns and a length of 12 mm . This fiber is resistant to acids and alkalis, and fiber melting point 160 °C. Polypropylene fiber density ~900 kg/m3, tensile strength 700 N/mm2 and modulus E 5000-15000 N/mm2.

7. Cement Type Portland Composite Cement (PCC)
   Cement is a mixed material that is chemically active after contact with water, cement functions as an aggregate adhesive. The cement used in this study was pcc produced by PT. Three Wheels with a pack of 1 sack of 50 kg.

8. *Silica Fumes*
   Silica *Fume* used is the sikafume brand weighing 20 kg/zak from the production of PT Sika Indonesia, Bogor – Indonesia.

9. *Superplasticizer* (SP) *Viscocrete* 8670 MN
   The use of superplasticizers is to reduce water use, but this must be done under the supervision of an engineer in connection with its combination with retarding additives whose main purpose is to produce a strong compressive increase in concrete [20]. The superplasticizer used in this study was Viscocrete 8670 MN, a product of SIKA Indonesia.

The composition of the concrete mixture is presented in table 1.

Table 1 Composition Concrete Mix Variation (V) 1 – Variation 11

Material Concrete	V1 (kg /cm ^{3})	V2 (kg /cm ^{3})	V3 (kg /cm ^{3})	V4 (kg /cm ^{3})	V5 (kg /cm ^{3})	V6 (kg /cm ^{3})	V7 (kg /cm ^{3})	V8 (kg /cm ^{3})	V9 (kg /cm ^{3})	V10 (kg /cm ^{3})	V11 (kg /cm ^{3})
Cement	865	865	865	865	865	865	865	865	865	865	865
Silica Fume	207,6	207,6	207,6	207,6	207,6	207,6	207,6	207,6	207,6	207,6	207,6
Mesh 35-60	994.75	908.77	908.77	994.75	871.92	871.92	822.79	822.79	822.79	822.79	822.79
Mesh 325	190.3	190.3	190.3	190.3	190.3	190.3	190.3	190.3	190.3	190.3	190.3
Water	181.65	181.65	181.65	181.65	181.65	181.65	181.65	181.65	181.65	181.65	181.65
SP	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3	17,3
Volcanic Ash	-	85.98	-	-	171.96	-	85.98	85.98	171.96	-	-
Fly Ash	-	-	85.98	-	-	171.96	85.98	85.98	-	171.96	171.96
pp	-	-	-	2.46	-	-	-	2.46	2.46	2.46	4.91
w/c	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
w/b	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19

For each of the variations in the composition of the concrete mixture, 5 specimens will be made for each test. The test object made is a cube test object with side size of 50 mm for testing compressive strength of concrete.

3. Result And Discussion

3.1 Flowability Tests

A flow ability test is carried out to find out the slump flow and workability values of mixture of Fly Ash, Mount Sinabung Volcanic Ash, Water, Mesh 35-60 Sand, Mesh 325 Silica Sand, Polypropylene Fibers, Pcc Cement, Silica Fume and Viscocrete 8670 MN Superplasticizer [21]. The results flowability test are presented in table 2 and the flowability test graph is presented in Figure 1.

Table 2 Flowability Test Results.

Variation mix	Slump Flow A (cm)	Slump Flow B (cm)	Slump Flow Average (cm)
A	22,7	22,1	22,4
B	21.5	22.5	22
C	20.5	21.5	21
D	18,7	19.5	19,1
E	20.5	21,8	21.15
F	19.5	21.5	20.5
G	19.5	20,8	20,15
H	18,4	19.5	18.95
I	18,8	18.5	18.65
J	17,9	17,8	17.85
K	17.5	17	17,25
K S (28)	17	16,8	16,9
K – M E (28)	17,2	16,7	16.95

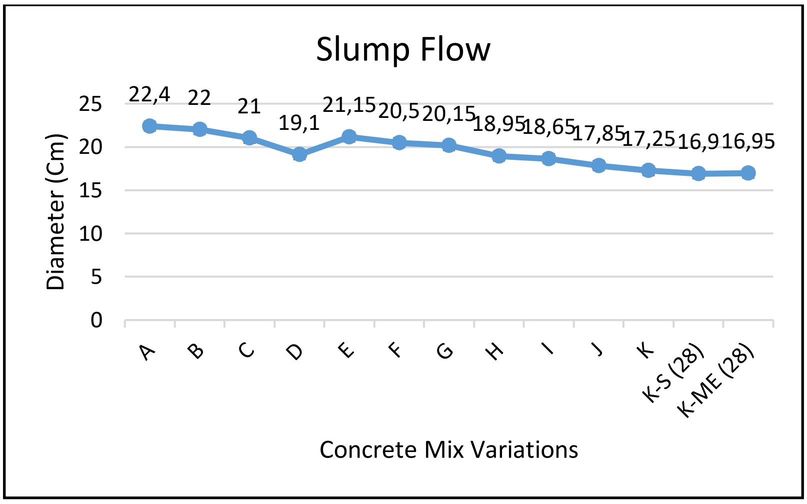

Figure 1 Flowability Test

3.2 Concrete Compressive Strength

Testing the compressive strength of concrete at the ages of 3, 7, 14 and 28 days using cube test specimens. Concrete compressive strength test method[22]. The results of concrete compressive strength for variation 1 are presented in table 3 and the graph for variation 1 is presented in Figure 2.

Table 3 The result of variation 1 concrete compression strength test.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	280	37,2	
3	289	38,9	
3	284	36,9	37,9
3	283	38,6	
3	279	37,9	
7	283	43,7	
7	274	44,3	
7	284	44,7	43,9
7	283	43.0	
7	279	44.0	
14	283	49,8	
14	279	52.5	
14	283	51,1	51,2
14	291	50,1	
14	284	52.5	
28	283	58,9	
28	283	57,9	
28	279	59,2	58,2
28	283	57,2	
28	275	57,9	

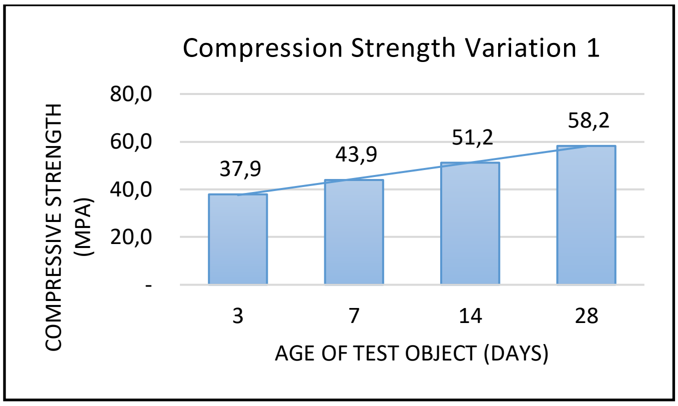

Figure 2 Graph of the compression strength of concrete variation 1

The compressive strength test for concrete variation 2 is presented in table 4 and the compressive strength graph for variation 2 concrete is presented in Figure 3.

Table 4 The results of variation 2 concrete compression strength test.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	289	38,9	
3	291	39,6	
3	291	38,9	39,1
3	272	39,3	
3	292	38,6	
7	287	49,1	
7	293	48,1	
7	291	48,4	48,4
7	293	48,8	
7	291	47,7	
14	291	56,2	
14	278	55.5	
14	292	55.5	56,2
14	290	56.5	
14	291	57,2	
28	291	62,6	
28	290	63.0	
28	292	63.0	62,9
28	290	62,6	
28	278	63,3	

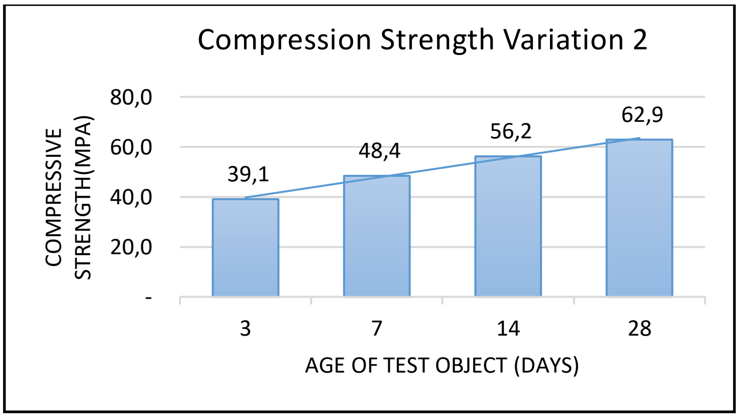

Figure 3 Graph of compressive strength of concrete variation 2

The compressive strength test for concrete variation 3 is presented in table 5 and the compressive strength graph for variation 3 concrete is presented in Figure 4..

Table 5 The results of variation 3 concrete compressive strength test.

Age concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	287	39,6	
3	295	40,6	
3	293	40,3	40,2
3	291	40,3	
3	293	39,9	
7	291	49,8	
7	291	50,1	
7	289	50,1	50,2
7	292	50,4	
7	290	50,8	
14	291	59,9	
14	291	58,6	
14	290	58,9	59,2
14	278	58,9	
14	290	59,6	
28	291	65.0	
28	279	65,3	
28	290	64.0	64,8
28	291	64.0	
28	290	65,7	

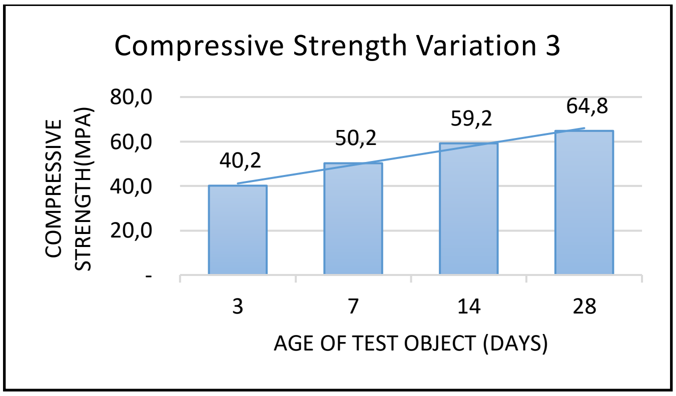

Figure 4 Graph of concrete compressive strength for variation 3

The compressive strength test for concrete variation 4 is presented in table 6 and the compressive strength graph for variation 4 concrete is presented in Figure 5.

Table 6 The results of variation 4 concrete compressive strength test.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	286	39,9	
3	291	39,9	
3	293	39,3	39,7
3	291	39,3	
3	291	39,9	
7	289	49,4	
7	292	49,4	

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
7	290	49,8	49,6
7	291	49,1	
7	291	50,4	
14	277	57,2	
14	279	58,2	
14	290	57,6	57,7
14	291	57,6	
14	291	57,9	
28	290	63,6	
28	289	63,3	
28	291	64,3	63,9
28	291	64,3	
28	287	64.0	

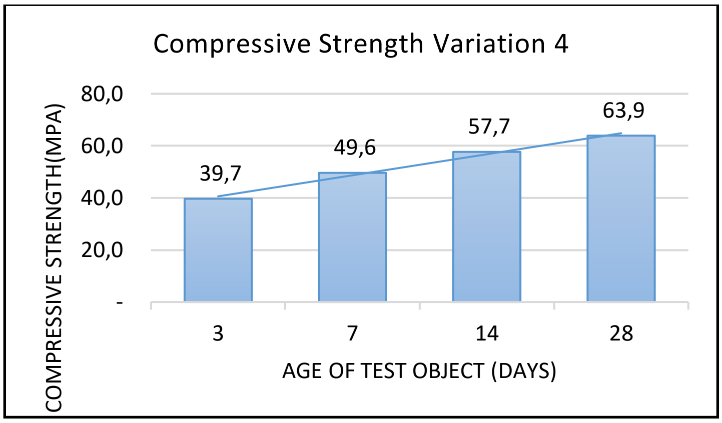

Figure 5 Graph of concrete compressive strength variation 4

The compressive strength test for concrete variation 5 is presented in table 7 and the compressive strength graph for variation 5 concrete is presented in Figure 6.

Table 7 Concrete compressive strength test results for variation 5.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	291	41,3	
3	291	41.0	
3	278	41.0	41,4
3	291	41.6	
3	291	42.0	
7	289	51.5	
7	292	51.5	
7	290	50,8	51,1
7	291	50,4	
7	291	51,1	
14	277	65.0	
14	292	64,3	
14	290	64,3	64,7
14	291	65.0	
14	291	64,7	
28	290	71.4	
28	289	71,1	

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
28	291	72,1	71.5
28	291	72,1	
28	279	70,8	

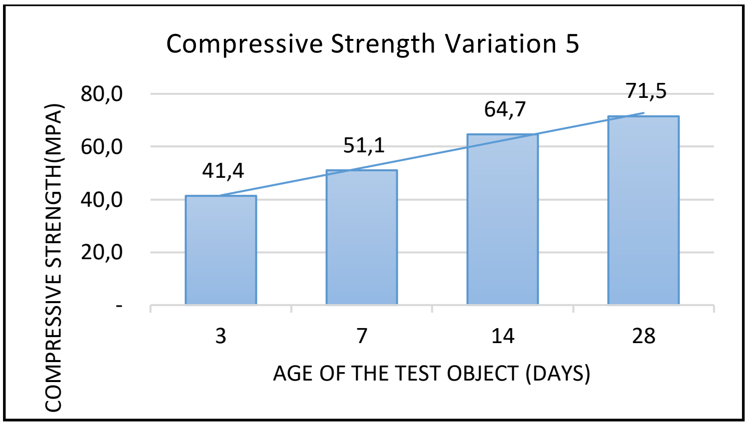

Figure 6 Graph of concrete compressive strength variation 5

The compressive strength test for concrete variation 6 is presented in table 8 and the compressive strength graph for variation 6 concrete is presented in Figure 7.

Table 8 concrete compressive strength test variations 6.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	290	43,3	
3	291	42,3	
3	289	43,3	42,9
3	292	42,7	
3	290	43.0	
7	291	57,2	
7	278	55,9	
7	290	57,6	57,1
7	292	56,9	
7	290	57,9	
14	291	67,4	
14	291	66,7	
14	292	66,4	66,8
14	290	66,4	
14	291	67.0	
28	291	77.5	
28	290	77,2	
28	289	78.2	77,7
28	279	77.5	
28	278	78.2	

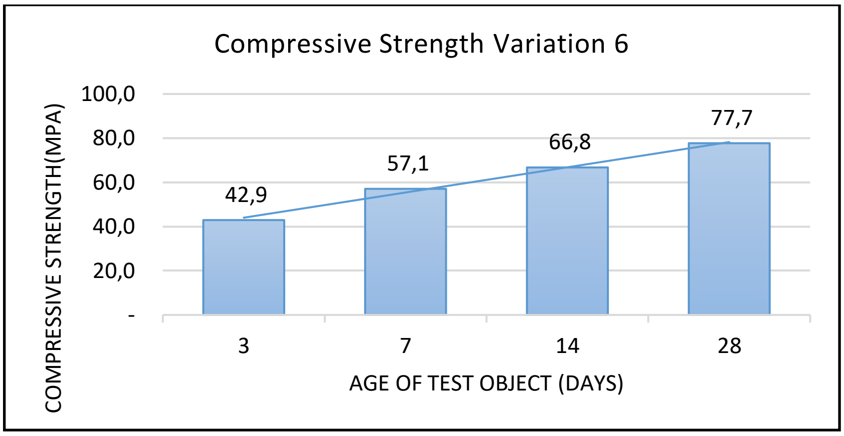

Figure 7 Graph of concrete compressive strength variation 6

The compressive strength test for concrete variation 7 is presented in table 9 and the compressive strength graph for variation 7 concrete is presented in Figure 8.

Table 9 Concrete compressive strength test variations 7.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	290	42,7	
3	291	43.0	
3	291	41,3	42,3
3	290	42,3	
3	292	42,3	
7	290	55,9	
7	278	55,9	
7	291	55,9	56
7	290	55.5	
7	292	56,9	
14	290	65,3	
14	279	64,7	
14	291	65.0	65,3
14	290	65,7	
14	293	65,7	
28	291	76.8	
28	290	76.5	
28	278	76.5	76,6
28	290	77,2	
28	279	75.8	

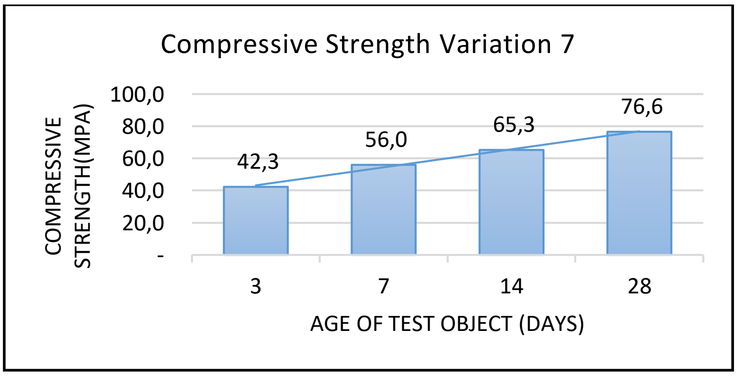

Figure 8 Graph of compressive strength of concrete variations 7.

The compressive strength test for concrete variation 8 is presented in table 10 and the compressive strength graph for variation 8 concrete is presented in Figure 9.

Table 10 concrete compressive strength test variations 8

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	292	44,3	
3	293	43,7	
3	291	44.0	44,1
3	290	44.0	
3	292	44,7	
7	290	60,6	
7	279	59,2	
7	291	60,3	60,3
7	289	60,3	
7	278	60,9	
14	291	71.4	
14	292	71,1	
14	290	71,1	71.6
14	291	72,1	
14	291	72,1	
28	290	80.9	
28	292	79.6	
28	290	80.6	80,1
28	288	80.6	
28	291	78.9	

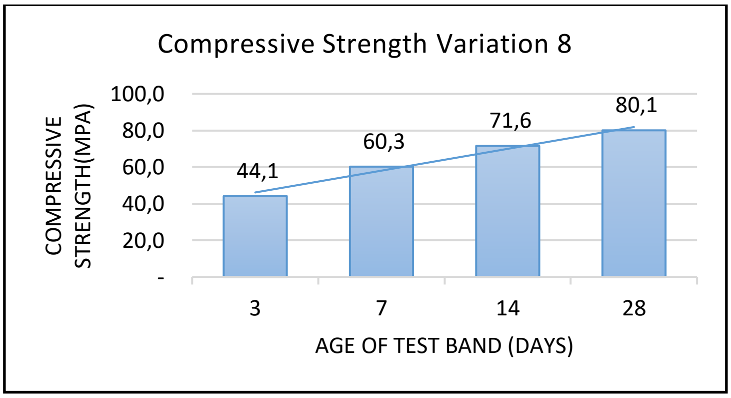

Figure 9 Graph of concrete compressive strength variations 8

The compressive strength test for concrete variation 9 is presented in table 11 and the graphic for compressive strength of concrete variation 9 is presented in Figure 10.

Table 11 Concrete compressive strength test results for variation 9.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	289	47,1	
3	279	46,4	
3	290	46,4	46,7
3	279	47,4	
3	291	46.0	
7	289	62,6	
7	279	60,6	
7	291	61,6	61.5

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
7	292	61.3	
7	290	61,6	
14	291	76,2	
14	278	74.8	
14	291	74.8	75,2
14	290	74.5	
14	279	75.5	
28	287	83.3	
28	293	83.3	
28	293	83.6	83,4
28	291	82.3	
28	290	84.6	

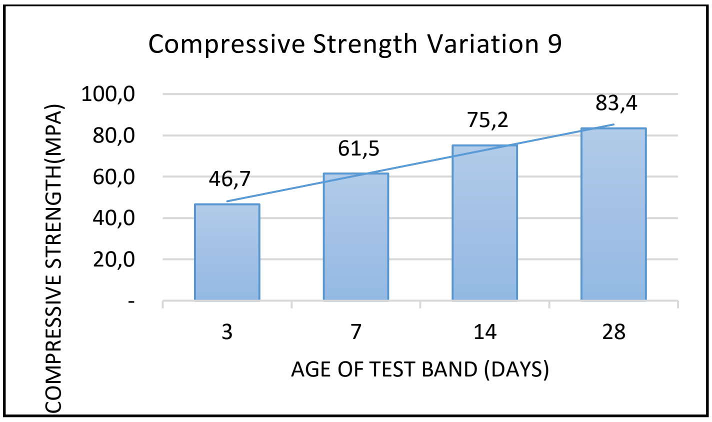

Figure 10 Graph of concrete compressive strength variations 9

The compressive strength test for concrete variation 10 is presented in table 12 and the compressive strength graph for concrete variation 10 is presented in Figure 11.

Table 12 Concrete compressive strength test results of variation 10

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	292	50,1	
3	290	51,1	
3	289	50,1	50,4
3	291	49,8	
3	290	51,1	
7	279	64.0	
7	289	64,3	
7	293	63,3	63,6
7	293	63,3	
7	291	63.0	
14	290	76.8	
14	292	76.8	
14	290	77,2	76.8
14	289	76.5	
14	291	76.8	
28	291	83.6	
28	288	84.0	
28	290	85.0	84,1
28	291	83.6	
28	287	84.3	

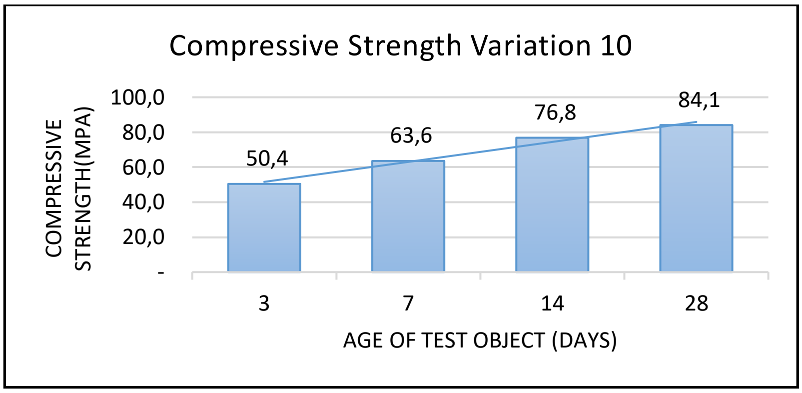

Figure 11 Graph of 10 variations of concrete compressive strength

The compressive strength test for concrete variation 11 is presented in table 13 and the concrete compressive strength graph for variation 11 is presented in Figure 12.

Table 13 concrete compressive strength test variations 11.

Age Concrete (day)	Heavy Test Objects (g)	Strong Press (MPa)	Strong Press Average (MPa)
3	289	53,8	
3	293	53,2	
3	291	53,2	53,8
3	290	54,2	
3	292	54.5	
7	287	66,7	
7	293	66,4	
7	293	65,7	66,3
7	291	66,7	
7	290	66.0	
14	292	78.9	
14	293	78.2	
14	291	77.9	78.4
14	292	78.5	
14	298	78.5	
28	278	87.3	
28	291	88.0	
28	290	86.3	87.5
28	289	89.4	
28	290	86.3	

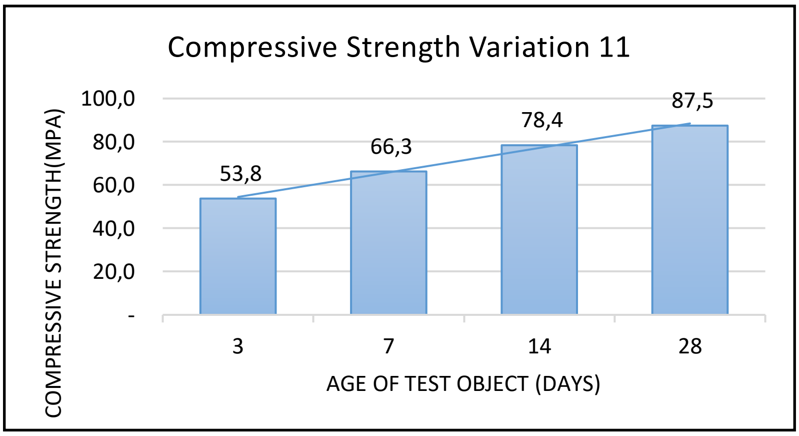

Figure 12 Concrete compressive strength variation graph 11

The compressive strength of concrete aged 3 days is high, reaching a value above 53.8 MPa. so it can be used on construction work and its use requires a fast time, and can be used in new construction buildings and construction reinforcement.

3.3. Split Tensile Strength Concrete

Test the splitting tensile strength of concrete through a splitting process by applying horizontal pressure throughout the test. Concrete Split Tensile Strength Test Method [23].

The split tensile strength test of variation 11 is presented in table 14 and the split tensile strength graph of variation 11 is presented in figure 13.

Table 14 concrete split tensile strength test variations 11

Age Concrete (day)	Heavy Test Objects (g)	Tensile Strength Split (MPa)	Splitting Strength Average (MPa)
28	12656	6,62	
28	12631	6,74	
28	12713	5,77	6,38
28	12622	5.94	
28	12638	6,79	

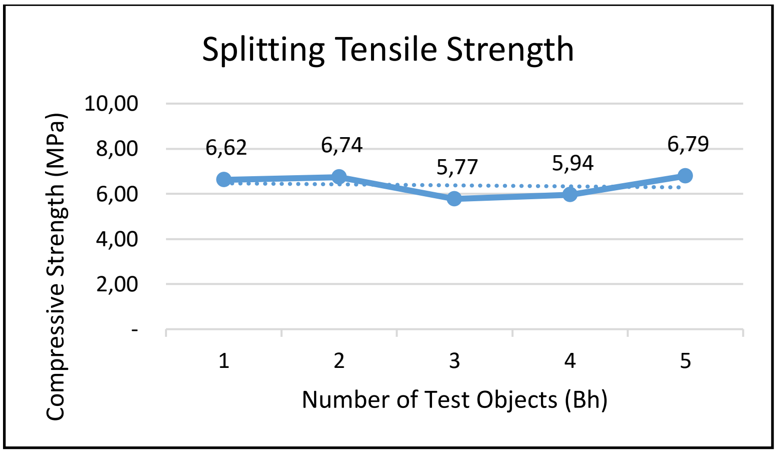

Figure 13 Graph of split tensile strength concrete variation 11

3.4 Modulus Elasticity of Concrete

Modulus elasticity aims to determine relationship between stress and strain in concrete, also any concrete or object that blocks the force will change shape (deformation) [24].

The 11 variation elastic modulus test is presented in table 15 and the 11 variation elastic modulus graph is presented in figure 14.

Table 15 concrete modulus of elasticity test variations 11

Age Concrete (day)	Heavy Test Objects (g)	Modulus Elasticity (MPa)	Modulus Elasticity (GPa)	Elasticity Modulus Average (GPa)
28	12677	58769,4370	58.7694	
28	12586	58812,5745	58.8126	
28	12662	55348,3423	55.3483	57,62
28	12667	54435,8595	54.4359	
28	12594	60719,4913	60.7195	

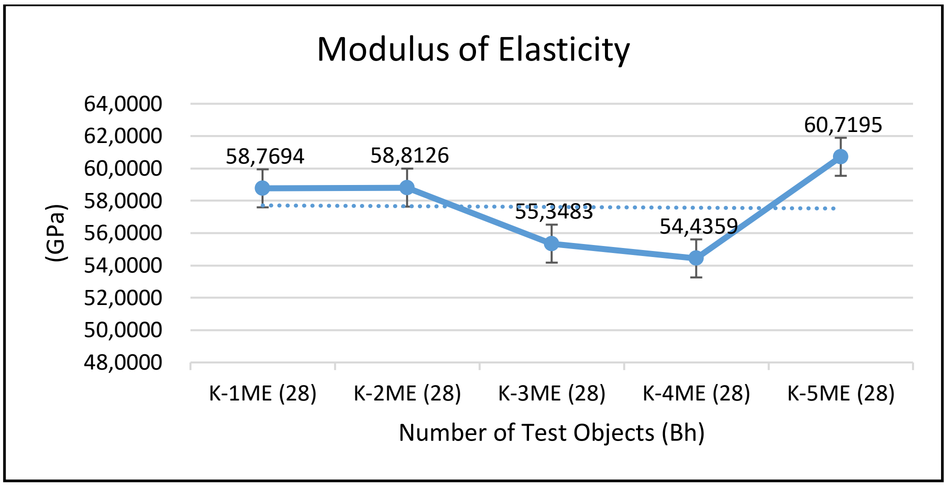

Figure 14 Graph of concrete elastic modulus variation 11

Tests for concrete compressive strength, split tensile strength and modulus of elasticity show that variation 11 concrete has increased compared to other variations..

4. Conclusion

Based on research that has executed, then a number of point conclusion can be delivered as following: 1. Out of the eleven concrete mixtures, the results show that the composition of the mixture 11 is PCC Cement, Silica Fume, Sand Mesh 35-60, Silica Mesh 325, Water, Viscocrete Superplasticizer 8670 MN, Fly Ash 7% and Polypropylene Fibers 0.2% which is a mix maximum. 2. The maximum compression strength value of concrete at 3 days concrete age from the results of this study is 53.76 MPa, so that it is stated as high quality compressive strength (early strength), so that it can be used in construction where work and its use require a fast time. 3. Sinabung Volcanic Ash improves the quality of concrete. 4Fly ash improves the quality of concrete and reduces environmental pollution.

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6. Confliet Of Interest

The authors whose names are listed below declare that this manuscript has no conflict of interest..

Daslin

This statement is signed by the author to indicate agreement that this information is true and correct.

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