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Analysis Of Flexural Strenght Of Concrete Regarding The Addition Of Fly Ash As A Particular Replacement Material For Cement

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ABSTRACT

This study several additional materials to reduce the amount of cement by using fly ash from coal combustion to determine the flexural strength value of concrete. Use of fly ash additives 5%, 10%, 15%. For normal concrete the flexural strength value is 2,66 MPa. For the flexural strength value of concrete with a BFA variation of 5% is 2,67 MPa, For the flexural strength value of concrete with a BFA variation of 10% is 2,71 MPa, and for the flexural strength value of concrete with a BFA variation of 15% is 2,72 MPa. From the results of this study, it can be concluded that the more fly ash mixture, the higher the flexural strength value.

Keywords: BFA variation, material, fly ash, flexural strength.

Introduction

Concrete can be defined as a combination of aggregates, such as sand, gravel, crushed stone, or other materials, combined with a cement and water paste to create a material that resembles aggregate rock. The aggregates can be substituted with granular materials, such as sand, gravel, crushed stone, or other materials, making up 60–75% of the volume of concrete [1].

Fly Ash

In 2019 coal production was 610 million tons, bottom ash and 6.648 million tons *fly ash* [2]. Coal waste is classified as B3 waste that can cause diseases *silicosis* (swelling of the lungs). Therefore, a solution is needed for waste utilization *bottom ash* and *fly ash* has a chemical compound content *SiO2 = 58,75%, AI2yO3 = 25,82%, Fe2O3 = 5,30%, CaO = 4,66%. Alkali = 1,36%, MgO = 3,30%* and nature *Pozzolan* which can be used in the manufacture of cement[3].

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Fly ash as a substitute for part of cement Portland because of the size of the particles is very soft, it can be usde as a cavity filler and as a binder between aggregates and if it react with calcium hydroxide it will produce cement compounds fly ash has a chemical compound content SiO_2 = 58,75%, AI_2O_3 = 25,82% Fe_2O_3 = 5,30%, CaO = 4,66%, Alkali = 1,36%, MgO = 3,30% and nature Pozzollan which can be used in the manufacture of cement [4]

The addition of *fly ash* It can increase the resistance of concrete to sulfate corrosion and minimize the risk of cracking in concrete [5]. *Fly ash* it can be used in dry or wet form and is usually stored in dry conditions. Approximately 30% of water can be added to the *fly ash* it is used, among other things, as a substitute for Portland cement in concrete because it has post-pollane properties [6]. Partial replacement of cement (0%-70%) can increase strength, reduce brittleness and be more resistant to penetration *chloride ions* [2]

The use of waste into something useful is very important in this life so that waste can be used to create something useful and does not cause social environmental problems in society [7]. In the field of civil engineering, many waste products are used as additional materials in concrete mixtures about the use of coal ash (*fly ash*) for *hollow block* that are of high quality and safe for the environment. Utilization of coal waste (*fly ash)* for soil stabilization in reducing environmental pollution [8]

Stretching brought on by outside loads results in bending strength. An increase in the beam's load will cause cracks in the beam span [9]. As such, the concrete bending test has evolved into a requirement for approval of the project's outcomes. The requirement to redo the planning in the mix design and trial mix presents a difficulty for implementers in the task of making concrete, which has been based on compressive strength; therefore, it needs to be analyzed to determine the correlation value. [10]

Methods

This research utilizes an experimental approach to collect the necessary data through testing on the object being tested. The slump value test is used in testing fresh concrete to investigate the workability or ease of the concrete working process [11].

The object used for testing has a cylindrical shape with a diameter of 15 cm and a height of 30 cm. The object under test is left in controlled conditions for a full day, and after this time is completed, the formwork is removed. The next step is to leave the concrete at room temperature until it reaches 28 days. The number of samples used will be shown in table 1 below.

Table 1. Test object mixture composition and test object code

Test Object Code	Age (day)	Amount
BN (Normal Concrete	28	3
BFA 5% (*Fly ash* 5%)	28	3
BFA 10% (*Fly ash* 10%)	28	3
BFA 15% (*Fly Ash* 15%)	28	3
Amount		12

Mix Design

After carrying out basic tests, values are obtained that can be used for planning the desired concrete mix (mix design). Planning of the mixed concrete mix (mix design) is carried out in accordance with the SNI 7656:2012[12] test method. I will display the data in table 2 below:

Table 2. Mix Design Data Table

Data	Units	Value
Concrete quality	MPa	25
Slump	mm	75-100
Maximum aggregate size	mm	19
Oven dry weight of coarse aggregate	Kg/m^2	1514,5
Specific gravity of cement without added air	12,64721	3,15
Fine Aggregate Fineness Modulus		3,8
Specific gravity(SSD) of fine aggregate		2,61
Specific gravity SSD) of coarse aggregate		2,64
Fine aggregate water	%	3,20

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absorption		
Coarse aggregate water absorption	%	1,93

The material requirement for one time mix is 3 x 0.01350 = 0.0405 m^3. So that all the needs of the mixture of ingredients for each variation in 1 time of mixing are as follows:

Tabel 3. Material Requirements for each variation of the mixture

No.	Test Object Code	Cylinder Volume	Material Ingredients				
		m^3	Water	Fine Aggregate	Coarse Aggregate	Cement	Fly Ash
1	BN	0.0405	7,5	13,47858	41,17	13,61	-
2	BFA 5%	0.0405	7,5	13,47858	41,17	12,93	0,68
3	BFA 10%	0.0405	7,5	13,47858	41,17	12,25	1,36
4	BFA 15%	0.0405	7,5	13,47858	41,17	11,57	2,04
Total			30	50,36	164,68	64,6531	4,08

a concrete beam with a square cross section with a total length of the beam four times the width of its cross section.

The test beam was made by referring to SNI 2493: 2011 concerning procedures for making and maintaining concrete test objects in the laboratory, namely with a prismatic test object in the form of a beam as a bending test[14].

According to SNI 4431-2011[13] for the calculation of the bending strength of the concrete, it is reviewed at the position of the cracks that occur in the beams.

- For tests where the fracture plane is located in the central area (area 1/3 of the distance of the central placement point).

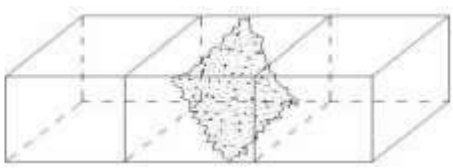

Figure 1. Area 1/3 of the distance of the center placement point (SNI 4431-2011, 2011) the Bending Strength of concrete is calculated according to the following equation:

$$\sigma = \frac{P.L}{b.h^2} \qquad (1)$$

- For tests where the fracture plane is located in the central area (area 1/3 of the distance of the central placement point).

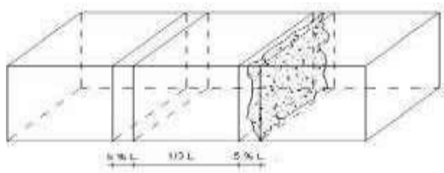

Figure 2. Fracture Area Outside 1/3 of the Central Span and the distance between the loading point and the fracture point < 5 (SNI 03- 4431-2011) the Bending Strength of concrete is calculated according to the following equation [15]:

$$\sigma = \frac{3.P.a}{b.h^2} \qquad (2)$$

- If the fracture site is outside 1/3 of the middle span and the distance between the loading point and the severe point > 5% of the span then the test result is not used.

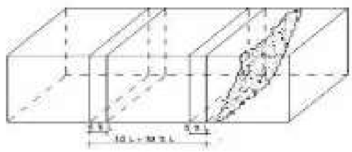

Figure 3. Fracture Area is Beyond 1/3 of the Central Span and the distance between the loading point and the fracture point > 5 (SNI 03- 4431-2011)

Information:

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σ : Flexural strength of the test piece (MPa)

P : Highest load read on the test machine (readings in tons up to 3 digits after the comma)

L : Distance (span) between two placements lines (mm)

b : Horizontal Broken Latitude View Width (mm)

h : Horizontal Broken Latitude View Width (mm)

a : The average distance between the look of the broken latitude and the nearest outer pedestal is measured at 4 places at an angle from the span (mm)

The test is carried out mechanically where the test piece placed on two platforms, is loaded centrally in the middle of the length of the test piece, the loading speed must be carried out continuously without causing a shock effect [16]. This test method can be seen in the following figure:

Figure 4. Laying and Loading Image caption:

A-A : Elongated axis

B : Placement Points

C : Loading Points

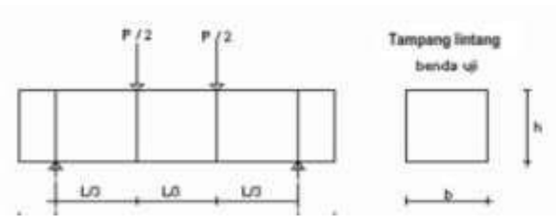

Figure 5. Laying and Loading Lines

Image Description:

b : The apparent width of the latitude of the test object

h : Apparent height of the latitude of the test piece

p : Highest load indicated by the test machine

Results and Research

The data from the research has been completed, it is necessary to carry out an analysis and discussion to get the planned results and goals. In this chapter, I will try to describe the results of research conducted at the Civil Engineering Laboratory of the University of Muhammadiyah North Sumatra. Which begins with the inspection of concrete constituent materials, concrete mix planning, concrete constituent mixing, and concrete testing that has been made [17].

1. Slump test

Slump testing is carried out based on SNI 7656:2012[12] Slump testing is carried out to determine the workability (level of ease of work) of normal fresh concrete mixtures and concrete using fiber additives. Slump will be a parameter for the adequacy of the amount of water provided [18]. Fresh concrete in an Abrams cone; each material intake must be able to accurately depict the mixture up to three layers, each of which makes up roughly 1/3 of the cone's contents and is punctured 25 times total. The piercing stick must reach the bottom of each layer. Once the cone has filled, smooth its top and allow it to sit for ten seconds[9].

After that, lift the cone perpendicular until the concrete mixture is completely detached from the mold and then measure the height of the mix[19]. The difference in the height of the cone with the stir is the slump value, so the results of the slump test are obtained in the table as follows:

Table 4. Slump value for each variation

Types of Concrete	Value (mm)
BN	80
BT + 5% FA	95
BT 10% FA	90
BT 15% FA	85

2. Testing of Concrete Flexural Strenth

The testing of the bending strength of concrete was carried out at the age of 28 days with a total of 3 samples for each variation of the test piece. This test uses a sample in the form of a concrete block with a size of 60 cm in length, 15 cm in width, and 15 cm in height[20]. This test was carried out in accordance with SNI guidance 03- 4431-2011.The results of concrete compressive strength testing in each variation can be seen in the following table:

Table 5. Findings from a test of the concrete fly ash mixture's bending strenth at 15% age 28 days

Condition	MIXED COMPARISON				
	Gross Aggregate Max Size	Slump	Air Rate	Cement Water Ratio	Fine Aggregate Volume
	mm	m^3	%		%
	19	10	0	0,61	0
	Water	Pc	Fine Aggregate	Coarse Aggregate	Mixed Ingredients
	kg/m^3		kg/m^3	kg/m^3	g/kg
	190,59	336,07	548,16	497,75	0
Test Specimen Name			A1	A2	A3
Life of Test Specimen (days)			28	28	28
Length of Test Specimen (mm)			600	600	600
Specimen Width (mm)			150	150	150
Height of Test Specimen (mm)			150	150	150
Test Specimen Weight (kg)			28	27,8	28,2
Test Specimen Volume (mm)			13500000	13500000	13500000
Maximum Load (N)			19580	22125	18075
Span Distance (mm)			450	450	450
Apparent Width Latitude (mm)			150	150	150
Apparent Latitude Height (mm)			150	150	150
Test Flexural Strength (MPa)			2,61	2,95	2,41
Flat Flexural Strength (MPa)				26	

Table 6. Findings from a test of the concrete fly ash mixture's bending strength at 15% age 28 days

Condition	MIXED COMPARISON				
	Gross Aggregate Max Size	Slump	Air Rate	Cement Water Ratio	Slump
	mm	m^3	%	%	m^3
	19	10	0	0,61	0
	Water	Pc	Fine Aggregate	Coarse Aggregate	Mixed Ingredients
	kg/m^3		kg/m^3	kg/m^3	g/kg
	190,59	336,07	548,16	497,75	0
Test Specimen Name			A1	A2	A3
Life of Test Specimen (days)			28	28	28
Length of Test Specimen (mm)			600	600	600
Specimen Width (mm)			150	150	150
Height of Test Specimen (mm)			150	150	150
Test Specimen Weight (kg)			27,8	29	29,8
Test Specimen Volume (mm)			13500000	13500000	13500000

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Maximum Load (N)	15975	23100	20925
Span Distance (mm)	450	450	450
Apparent Width Latitude (mm)	150	150	150
Apparent Latitude Height (mm)	150	150	150
Test Flexural Strength (MPa)	2,13	3,08	2,79
Life of Test Specimen (days)		28	

Table 7. Findings from a test of the concrete fly ash mixture's bending strength at 15% age 28 days

MIXED COMPARISON					
Condition	Gross Aggregate Max Size	Slump	Air Rate	Cement Water Ratio	Slump
	mm	m^3	%	%	m^3
	19	10	0	0,61	0
	Water	Pc	Fine Aggregate	Coarse Aggregate	Mixed Ingredients
	kg/m^3		kg/m^3	kg/m^3	g/kg
	190,59	336,07	548,16	497,75	0
Test Specimen Name			A1	A2	A3
Life of Test Specimen (days)			28	28	28
Length of Test Specimen (mm)			600	600	600
Specimen Width (mm)			150	150	150
Height of Test Specimen (mm)			150	150	150
Test Specimen Weight (kg)			29,4	28,8	29,4
Test Specimen Volume (mm)			13500000	13500000	13500000
Maximum Load (N)			21225	19050	20775
Span Distance (mm)			450	450	450
Apparent Width Latitude (mm)			150	150	150
Apparent Latitude Height (mm)			150	150	150
Test Flexural Strength (MPa)			2,83	2,54	2,77
Life of Test Specimen (days)				2,71	

Table 8. Findings from a test of the concrete fly ash mixture's bending strength at 15% age 28 days

MIXED COMPARISON					
Condition	Gross Aggregate Max Size	Slump	Air Rate	Cement Water Ratio	Slump
	mm	m^3	%	%	m^3
	19	10	0	0,61	0
	Water	Pc	Fine Aggregate	Coarse Aggregate	Mixed Ingredients
	kg/m^3		kg/m^3	kg/m^3	g/kg
	190,59	336,07	548,16	497,75	0
Test Specimen Name			A1	A2	A3
Life of Test Specimen (days)			28	28	28
Length of Test Specimen (mm)			600	600	600
Specimen Width (mm)			150	150	150
Height of Test Specimen (mm)			150	150	150
Test Specimen Weight (kg)			17	19,8	22
Test Specimen Volume (mm)			13500000	13500000	13500000
Maximum Load (N)			16950	24252	19800
Span Distance (mm)			450	450	450
Apparent Width Latitude (mm)			150	150	150

Apparent Latitude Height (mm)	150	150	150
Test Flexural Strength (MPa)	2,26	3,27	2,24
Life of Test Specimen (days)		2,27	

The bending strength test results for standard concrete are shown in the above table; the maximum value for A2 was 2.95 MPa, and the average concrete value for test objects A1, A2, and A3 was 2.66 MPa. The average concrete on test objects A1, A2, and A3 is 2.67 MPa, while the maximum value of A2 is 3.08 MPa for the results of the bending strength test on 5% fly ash concrete. The average concrete on test pieces A1, A2, and A3 is 2.71 MPa, while the maximum value of A1 is 2.83 MPa for the results of the bending strength test on 10% fly ash concrete.

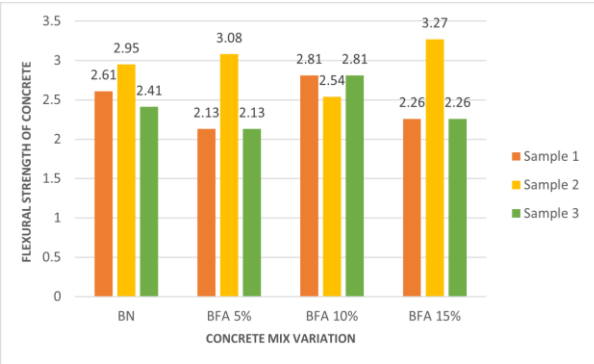

Figure 6. Graph of Flexural Strength Test Results

Additionally, table 9 below displays the average bending strength value for every variation derived from the calculation data:

Table 9. Concrete Flexural Strength Average Chart

Types of Concrete	Value (mm)
BN	2,65
BT + 5% FA	2,66
BT 10% FA	2,71
BT 15% FA	2,72

The maximum value of bending strength was reached with SNI 03-4431-2011[13] in a variation of 15% BFA mixture, which was 2.73, according to table 4.23 in the testing of concrete bending strength. The following graph represents the average results of the concrete flexural strength test:

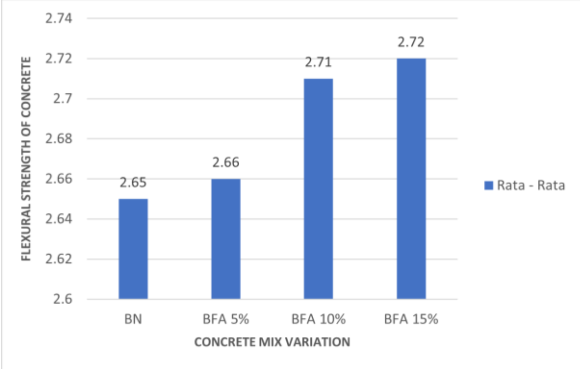

Figure 7. Concrete Flexural Strength Average Chart

Conclusions

From all the data processing experiments, and the discussions that have been carried out in this study, it can be concluded in the following matters:

1. The bending strength value is significantly influenced by the fly ash level during the test. The bending strength value increases with fly ash level. The average flexural strength values for each concrete variation are as follows: BN (Normal Concrete) has a bending strength value of 2.66 MPa with a fly ash variation of 0%; BFA 5% has a fly ash variation of 5% and a flexural strength value of 2.67 MPa; BFA 10% has a fly ash variation and a flexural strength value of 2.71 MPa; and BFA 15% has a fly ash variation of 15% and a flexural strength value of 2.73 MPa.
2. The findings of the computations and experiments indicate that the bending strength value of normal concrete with normal concrete mixed with fly ash 5% is increased in the mixed concrete of fly ash variation, coming in at 99.62%, 98.15%, and 97.79% for normal concrete with normal concrete mixed with fly ash 5%.

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