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The Effect of Fly Ash Substitution in 3 Brands of PCC Cement on The Compressive Strength f Concrete

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ABSTRACT

Fly ash, a by-product of coal combustion in thermal power plants is utilized as a substitute for Portland Cement in concrete due to its pozzolanic properties. Mainly, class F fly ash—produced from the combustion of anthracite coal at approximately 1560˚C (according to SK SNI S15-1990-F)—contains less than 10% lime (CaO) and exhibits significant pozzolanic or filler properties. This research investigates the impact of varying fly ash proportions (0%, 10%, 15%, and 20%) on the compressive strength of concrete. The experimental setup included 108 cylindrical test specimens (10 cm in diameter and 20 cm in height), representing different brands of cement and fly ash mixtures, tested at 7, 14, and 28 days. The study was conducted at PT. Waskita Beton Precast Plant in Sadang, Purwakarta, West Java, targeting a concrete compressive strength of 40 MPa. Results indicate that at 0% fly ash, the compressive strength using Garuda Cement reached 76.66 MPa after 28 days. However, this strength decreased with increasing fly ash content, measuring 72.35 MPa, 69.07 MPa, and 68.13 MPa for 10%, 15%, and 20% fly ash, respectively. These findings highlight the influence of fly ash content on the structural integrity of concrete, suggesting a potential trade-off between sustainability and mechanical performance.

Keyword: Fly Ash, Compressive Strength of Concrete, Portland Cement

Introduction

The development of technological engineering is increasingly advanced in all fields, one of which is in the construction sector. Concrete is the most often used construction material. It is in demand because it is a basic material that is easy to shape and relatively cheap compared to other construction materials. Concrete is a mixture of cement, fine aggregate, coarse aggregate, and water, which then hardens to form a solid object[1]–[5].

The choice of materials in making concrete is very important to obtain the desired quality according to the use of the concrete itself and, of course, at the most economical cost possible. One of the materials that can be used to mix concrete is coal dregs, which have a high buildup, namely fly ash. Fly ash is industrial waste produced from burning coal and consists of fine particles[2], [4], [6]–[10]. Using coal as an energy source will produce ash, namely fly ash and bottom ash. The fly ash content is 84% of the total coal ash. World coal fly ash production is estimated to be no less than 500 million tons per year, which is expected to increase. Only 15% of fly ash production is used. The remaining fly ash tends to be reclamation.

This amount is quite large, so it requires further processing. Taking into account the potential for fly ash produced by coal-using power plants in Indonesia, which is more than 1 million tons per year and the difficulties in storing fly ash, it is necessary to research the possibility of using coal ash from PLTU waste for example for industrial purposes [11]–[13]. Cement production generally uses the primary raw materials, namely limestone and clay, which contain silica compounds (SiO2)[1], [6], [10], [12], [14]–[17]. If we look at the composition of the number of compounds, the chemicals in fly ash are silica compounds; this potential can be used as a cement mixture.

Fly ash is used as a substitute for Portland Cement in concrete because it has pozzolanic properties. As a pozzolan, its effect is very large in increasing the strength of concrete. The use of fly ash can be said to be a critical factor in concrete maintenance. Its function is to replace part of the weight of cement in general. This is limited to class F fly ash, produced from burning anthracite coal at a temperature of approximately 1560oC (SK SNI S15-1990 -F). This fly ash is pozzolanic and contains less than 10% lime (CaO). Fly ash is a by-product of the Steam Power Plant (PLTU) industry, which uses coal as fuel in the form of light, round, non-porous fine granules that have pozzolanic or filler properties[18][3], [16], [19]–[21].

The variation in adding 15% fly ash is the most optimum level for testing compressive strength, modulus of elasticity and split tensile strength. This research used fly ash variations of 0%, 10%, 15% and 20%. This test uses 3 (three) test objects for each brand of cement and variations in adding fly ash. The test object used is cylindrical with a diameter of 10 cm and a height of 20 cm. The result of the targeted concrete compressive strength is fc' 40 Mpa.

Research Method

This research uses literature methods and experimental methods, namely research methods to conduct experimental activities to obtain results[2], [22]–[24][25]. These results show cause-and-effect relationships between one variable and another. This research was conducted at PT. Waskita Beton Precast Plant Sadang Purwakarta, West Java. The test objects used for concrete compressive strength research were cylindrical, with 108 test objects, lasting 7, 14, and 28 days. The test objects used for concrete compressive strength research were cylindrical, with 108 test objects, lasting 7, 14, and 28 days.

Results and Discussion

1. Compressive test results for concrete aged 7 days

Table 1. 7 Day Concrete Compression Test Results for Roda Tiga Cement

Test Objects	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-STR100%-FA0%	June 22, 2023	3,79	233,0	29,59	29,37
		3,8	229,2	29,17	
		3,77	230,9	29,34	
B-STR90%-FA10%	June 22, 2023	3,77	229,4	29,05	28,72
		3,76	220,9	28,14	
		3,78	227,5	28,98	
B-STR85%-FA15%	June 22, 2023	3,81	219,5	27,80	27,34
		3,71	208,3	26,54	
		3,78	218,8	27,67	
B-STR80%-FA20%	June 22, 2023	3,84	205.12	26.13	26,43
		3,76	209.91	26.74	
		3,80	207.32	26.41	

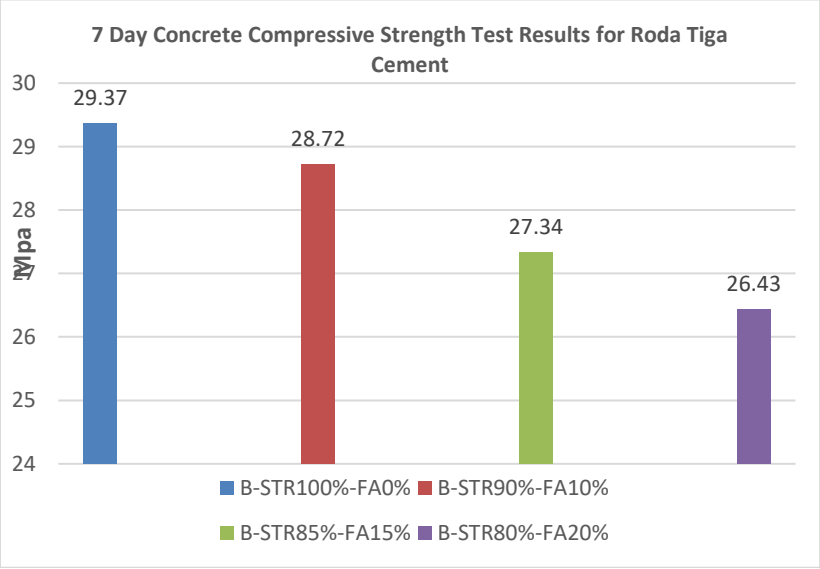

Figure 1. Compressive Strength Test Results of 7 Day Old Concrete for Tiga Roda Cement

From graph 1, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 7 days the highest compressive strength was obtained from Normal Concrete at 29.37 Mpa.

Table 2. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	Selisih kuat tekan beton normalterhadap beton campuran
1	10%	-0,65
2	15%	-2,03
3	20%	-2,94

From table 2, above, you can see the difference in compressive strength values between normal concrete and concrete mixed with fly ash at the age of 7 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 3. 7 Day Concrete Compression Test Results Padang Cement

Test Objects	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SP100%-FA0%	June 22, 2023	3,80	294.6	34,71	34,39
		3,78	286.1	34,46	
		3,91	291.2	34,01	
B-SP90%-FA10%	June 22, 2023	3,68	272.5	37.39	36,95
		3,78	241.9	36.37	
		3,91	270.5	37.09	
B-SP85%-FA15%	June 22, 2023	3,81	241,9	33,98	33,03
		3,8	270,7	32,09	
		3,76	269,0	33,01	
B-SP80%-FA20%	June 22, 2023	3,91	267,7	32,97	32,94
		3,68	262,8	32,88	
		3,78	278,0	32,98	

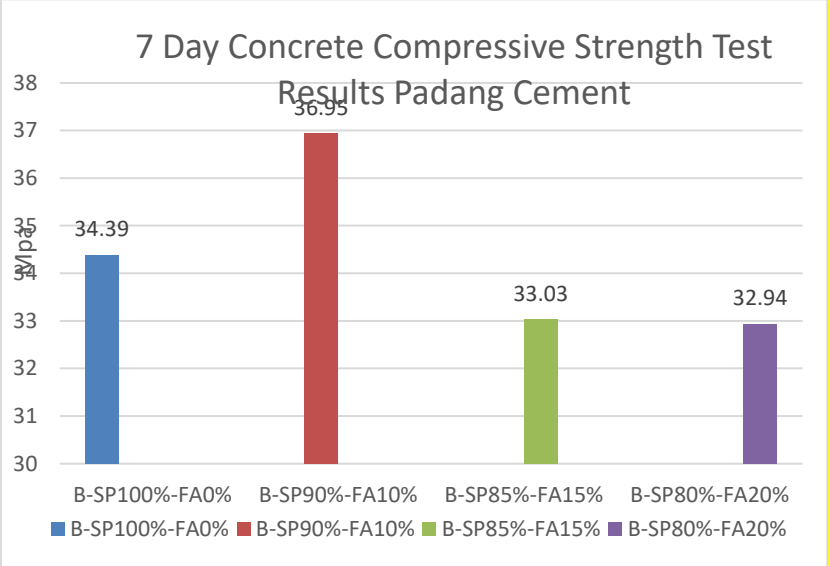

Figure 2. Histogram of Compressive Strength Results of Test Objects Aged 7 Days Padang Cement

From graph 2, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 7 days, the highest compressive strength was obtained from concrete with 10% Flyash of 36.95 Mpa.

Table 4. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	2,56

2	15%	-1,36
3	20%	-1,45

From table 4 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at the age of 7 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 5. 7 Day Cement Aged Concrete Compression Test Results Garuda Cement

Test Objects	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SG100%-FA0%	June 22, 2023	3,83	338,8	43,08	44,02
		3,75	351,5	44,78	
		3,70	347,0	44,20	
B-SG90%-FA10%	June 22, 2023	3,76	381,8	48,64	49,20
		3,77	391,2	49,83	
		3,79	385,6	49,12	
B-SG85%-FA15%	June 22, 2023	3,83	386,4	49,20	48,83
		3,87	353,2	48,99	
		3,80	379,2	48,31	
B-Sg80%-Fa20%	June 22, 2023	3,80	274,9	35,02	35,98
		3,71	289,2	36,77	
		3,78	283,7	36,14	

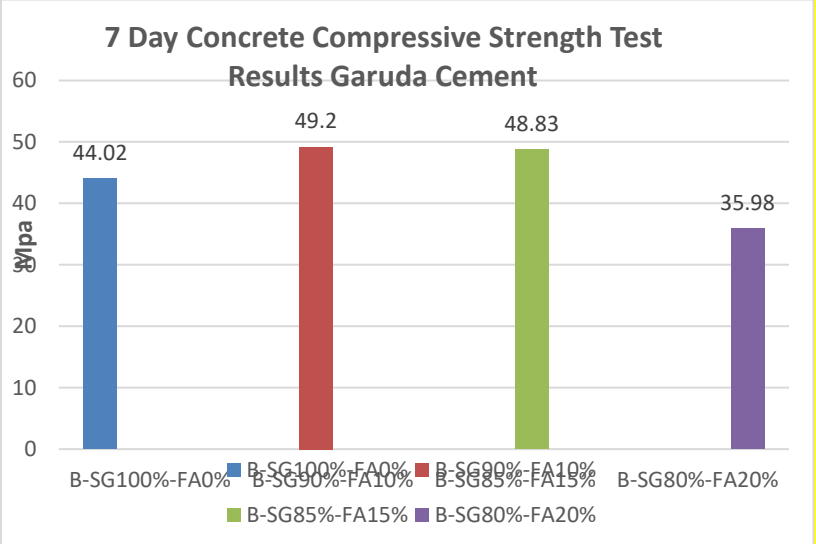

Figure 3. Histogram of Compressive Strength Results of Test Objects Aged 7 Days Garuda Cement

From graph 3, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 7 days the highest compressive strength was obtained from Normal Concrete at 49.34 Mpa.

Table 6. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	5,18
2	15%	4,81

3	20%	-8,04

From table 6 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at 7 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

2. Compressive test results for concrete aged 14 days

The results of the concrete compressive strength test at 14 days can be seen in the table below and can be described as follows:

Table 7. 14 Day Concrete Compression Test Results for Tiga Roda Cement

Test Objects	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-STR100%-FA0%	July 7, 2023	3,80	314,5	40,1	39,92
		3,78	310,0	39,5	
		3,91	315,6	40,2	
B-STR90%-FA10%	July 7, 2023	3,68	308,7	39,3	38,81
		3,78	299,1	38,1	
		3,91	306,2	39,0	
B-STR85%-FA15%	July 7, 2023	3,81	295,4	37,6	37.01
		3,8	282,1	35,9	
		3,76	294,1	37,5	
B-STR80%-FA20%	July 7, 2023	3,91	277,7	35,4	35,78
		3,68	284,2	36,2	
		3,78	280,7	35,8	

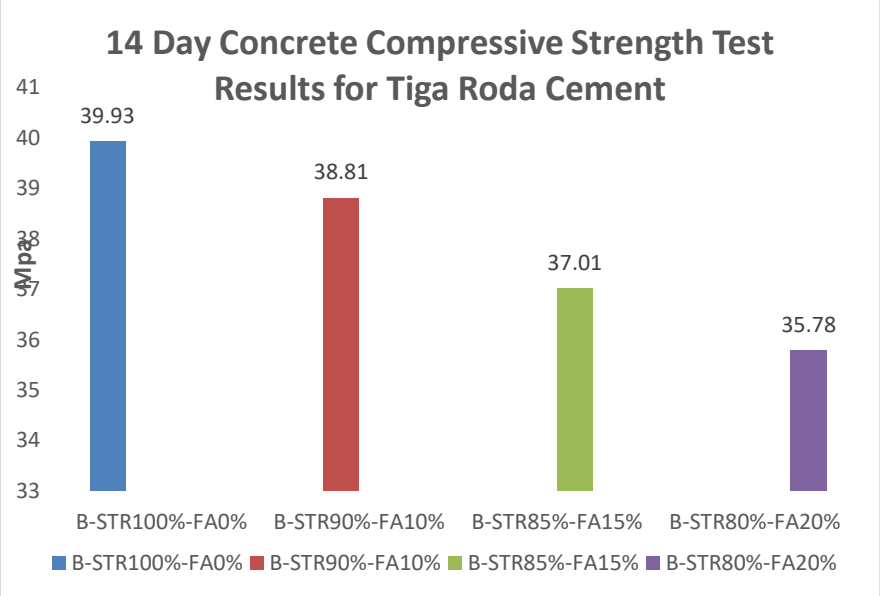

Figure 4. Histogram of Compressive Strength Results of 14 Day Old Test Objects for Tiga Roda Cement

From graph 4, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 14 days the highest compressive strength was obtained from Normal Concrete at 39.93 Mpa.

Table 8. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	-1,11
2	15%	-2,91
3	20%	-4,14

From table 8 above, it can be seen the difference in compressive strength values between normal concrete and fly ash mixed concrete at the age of 14 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete. From table 8 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at the age of 14 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 9. 14 Day Concrete Compression Test Results for Padang Cement

Test Objects	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SP100%-FA0%	July 7, 2023	3,79	368,9	47,0	46,56
		3,8	361,4	46,0	
		3,77	366,2	46,7	
B-SP90%-FA10%	July 7, 2023	3,77	397,4	50,6	50,02
		3,76	386,5	49,2	
		3,78	394,2	50,2	
B-SP85%-FA15%	July 7, 2023	3,81	368,2	46,7	46,48
		3,71	366,2	46,9	
		3,78	360,3	45,9	
B-SP80%-FA20%	July 7, 2023	3,84	346.2	44,1	44,3
		3,76	352.5	44,9	
		3,80	344.6	43,9	

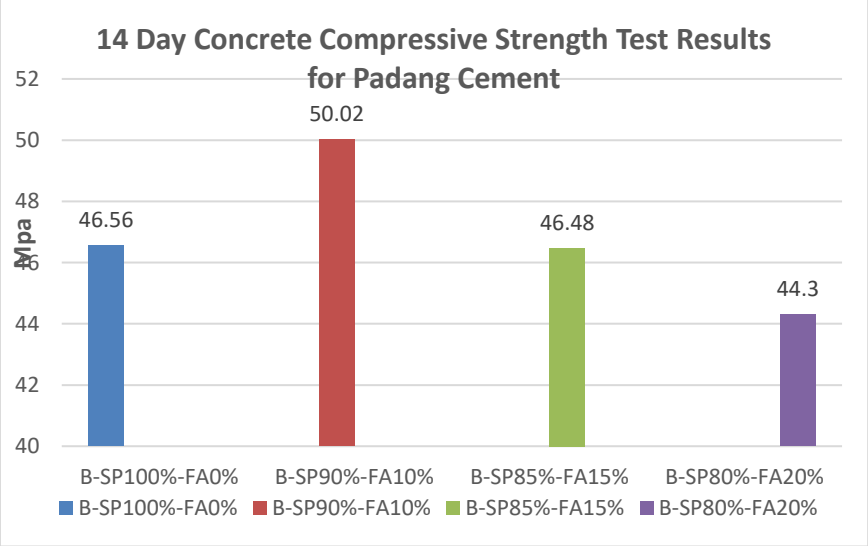

Figure 5. Histogram of Compressive Strength Results of 14 Day Old Test Objects for Padang Cement

From graph 5, in variations of concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 14 days the highest compressive strength was obtained from Normal Concrete at 49.33 Mpa.

Table 10. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	3,46
2	15%	-0,08
3	20%	-2,26

From table 10 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at 14 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 11. 14 Day Concrete Compression Test Results for Garuda Cement

Test Object	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SG100%-FA0%	July 7, 2023	3,83	457,8	58,3	59,60
		3,75	475,9	60,6	
		3,70	469,7	59,8	
B-SG90%-FA10%	July 7, 2023	3,76	516,9	65,9	66,60
		3,77	529,6	67,5	
		3,79	522,0	66,5	
B-SG85%-FA15%	July 7, 2023	3,83	522,9	66,6	66,11
		3,87	520,7	66,3	
		3,80	513,4	65,4	
B-SG80%-FA20%	July 7, 2023	3,80	372,2	47,4	48,71
		3,71	390,8	49,8	
		3,78	384,1	48,9	

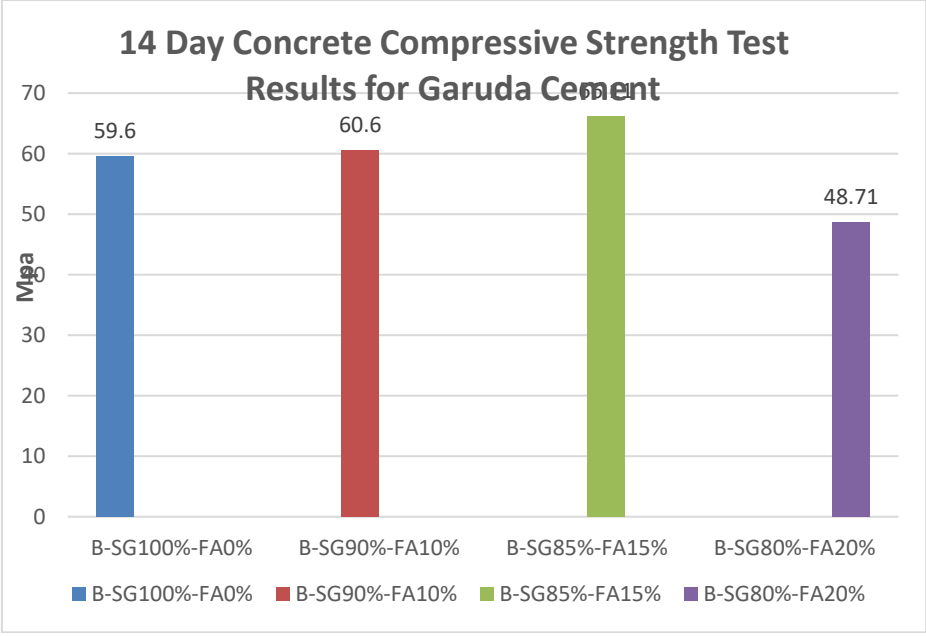

Figure 6. Histogram of Compressive Strength Results of 14 Day Old Test Objects for Garuda Cement

From graph 6, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 14 days the highest compressive strength was obtained from Normal Concrete at 66.57 Mpa.

Table 12. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	7

2	15%	6.51
3	20%	-10,6

From table 12 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at 14 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

3. Compression test results for concrete aged 28 days

The results of the concrete compressive strength test at 28 days can be seen in the table below and can be described as follows:

Table 13. 28 Day Concrete Compression Test Results for Tiga Roda Cement

Test Object	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SG100%-FA0%	July 22, 2023	3,83	357,8	45,52	44,84
		3,75	352,7	44,88	
		3,70	346,4	44,13	
B-SG90%-FA10%	July 22, 2023	3,76	351,3	44,69	43,99
		3,77	340,3	43,29	
		3,79	345,2	43,98	
B-SG85%-FA15%	July 22, 2023	3,83	336,2	42,77	42,06
		3,87	320,9	40,83	
		3,80	334,2	42,57	
B-SG80%-FA20%	July 22, 2023	3,80	346,6	40,20	40,66
		3,71	227,6	41,14	
		3,78	319,0	40,63	

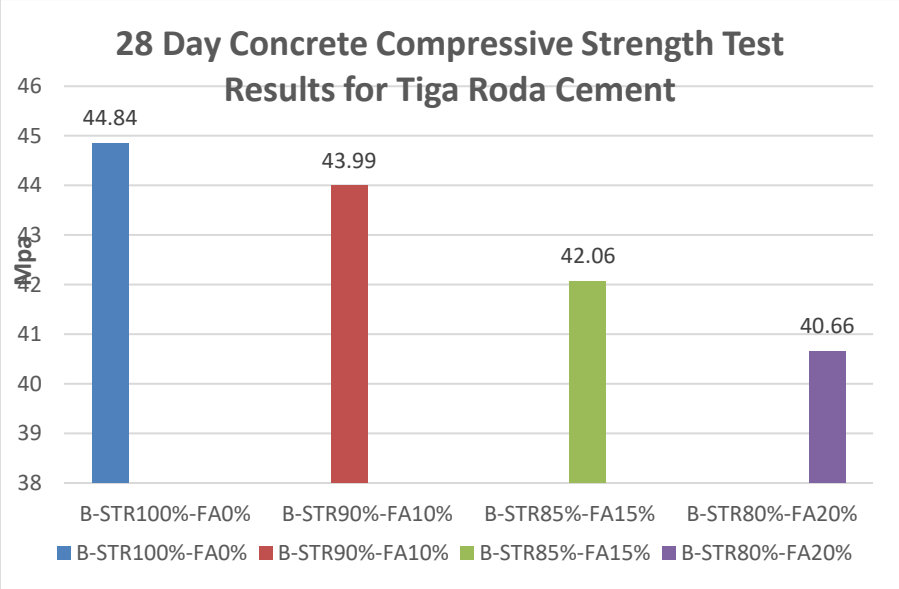

Figure 7. Histogram of Compressive Strength Results of 28 Day Old Test Objects for Tiga Roda Cement

From graph 7, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 28 days the highest compressive strength was obtained from Normal Concrete at 44.64 Mpa.

Table 14. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	-0,85
2	15%	-2,78
3	20%	-4,18

From table 14 above, it can be seen the difference in compressive strength values between normal concrete and fly ash mixed concrete at the age of 28 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 15. 28 Day Concrete Compression Test Results for Padang Cement

Test Object	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SG100%-FA0%	July 22, 2023	3,87	419,7	53,40	52,91
		3,8	371,5	52,32	
		3,77	416,2	53,02	
B-SG90%-FA10%	July 22, 2023	3,77	452,1	57,52	56,94
		3,76	441,5	56,24	
		3,78	447,9	57,06	
B-SG85%-FA15%	July 22, 2023	3,81	434,5	55,35	55,69
		3,71	437,7	55,76	
		3,78	439,2	55,95	
B-SG80%-FA20%	July 22, 2023	3,84	419,2	53,40	53,01
		3,76	410,7	52,32	
		3,80	418,6	53,32	

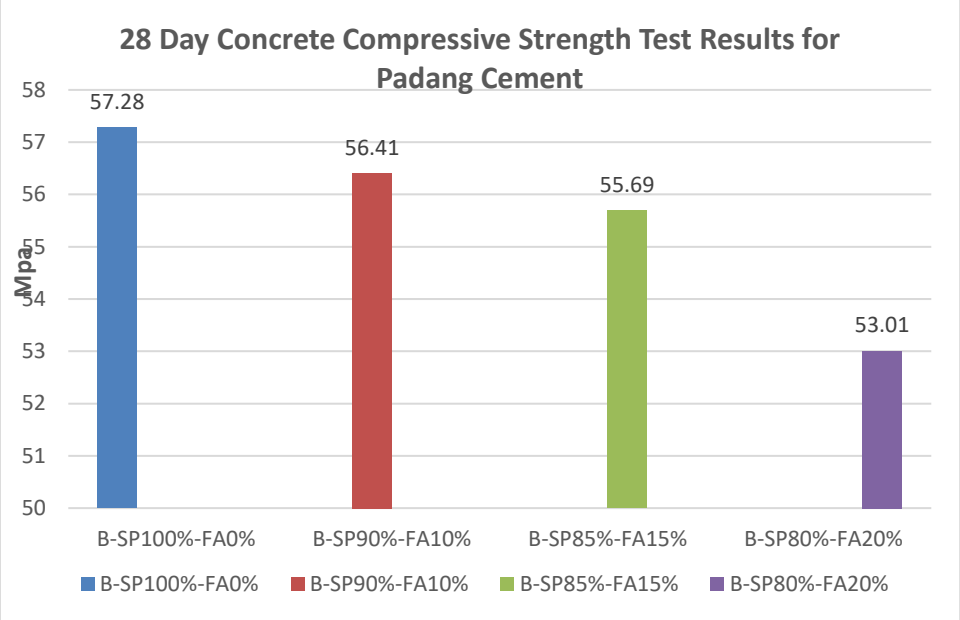

Figure 8. Histogram of Compressive Strength Results of 28 Day Old Test Objects for Padang Cement

From graph 8, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 28 days the highest compressive strength was obtained from Normal Concrete at 57.28 Mpa.

Table 16. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	4,03
2	15%	2,78
3	20%	0,1

From table 16 above, you can see the difference in compressive strength values between normal concrete and concrete mixed with fly ash at the age of 28 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Table 17. 28 Day Concrete Compression Test Results for Garuda Cement

Test Object	Compressive Strength Date	Weight (Kg)	Load (Kn)	Compressive Strength (Mpa)	Average (Mpa)
B-SG100%-FA0%	July 22, 2023	3,79	520,9	66,28	67,72
		3,8	541,5	68,89	
		3,77	533,8	68,00	
B-SG90%-FA10%	July 22, 2023	3,77	539,8	74,83	75,69
		3,76	602,5	76,66	
		3,78	593,2	75,57	
B-SG85%-FA15%	July 22, 2023	3,81	594,9	75,69	75,13
		3,71	544,0	75,37	
		3,78	583,4	74,32	
B-SG80%-FA20%	July 22, 2023	3,84	350,9	53,88	55,35
		3,76	444,6	56,57	
		3,80	436,5	55,60	

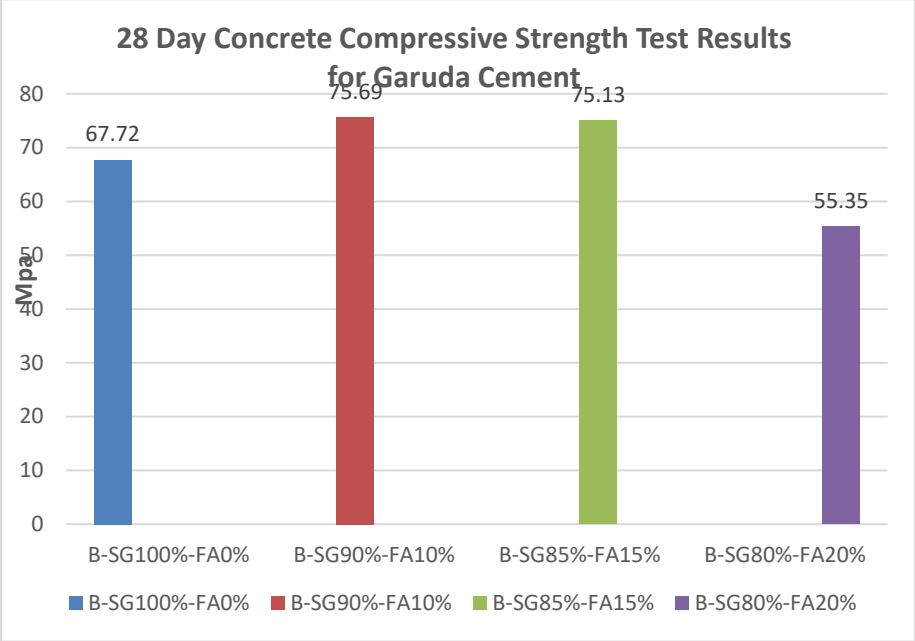

Figure 9. Histogram of Compressive Strength Results of 28 Day Old Test Objects for Garuda Cement

From graph 9, in variations in concrete mixtures with added ingredients of 10%, 15% and 20% fly ash, there was a decrease in compressive strength. This shows that the added fly ash material has an effect on the compressive strength of the concrete. At the age of 28 days the highest compressive strength was obtained from Normal Concrete at 75.98 Mpa.

Table 18. Difference in Compressive Strength of Normal Concrete to Mixed Concrete

No	Fly Ash	The difference in compressive strength of normal concrete compared to mixed concrete
1	10%	7,97
2	15%	7,41
3	20%	-12,37

From table 18 above, you can see the difference in compressive strength values between normal concrete and fly ash mixed concrete at the age of 28 days. The greater the use of the fly ash mixture, the greater the difference in value with normal concrete.

Conclusion

Based on the research carried out, the following conclusions can be drawn. From the research results, the optimum compressive strength value of concrete with the addition of fly ash as a cement substitute varies with normal concrete: At 0% variation in 28 days compressive strength using Garuda Cement has a strong value. pressure of 76.66 Mpa. With a 10% variation in compressive strength, 28 days using Garuda Cement has a compressive strength value of 72.35 Mpa. With a 15% variation in compressive strength for 28 days using Garuda Cement, the compressive strength value is 69.07 Mpa. With a 20% variation in compressive strength, 28 days using Garuda Cement has a compressive strength value of 68.13 Mpa. This research shows that each brand of cement affects the compressive strength of concrete with results increasing with each addition of fly ash. From the graph it can also be seen that there is an increase in the compressive strength of concrete in the Semen Garuda brand along with the increase in fly ash from 0% to 20%.

Based on the research results, the author can provide suggestions for further research: When mixing and casting, attention needs to be paid to the balance of filling and compacting the aggregate in the mold. Because this will affect the quality of the resulting concrete mixture. Paying attention to the concrete maintenance process according to the predetermined day plan is necessary. During the test, test the cement vicat and concrete setting time. Researching the compressive strength of concrete substituted with fly ash is recommended, testing with concrete ages of more than 28 days, 56 days or more.

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