UTILIZATION OF FLY ASH AS CEMENT SUBSTITUTION OF MATERIAL FOR STRENGTHENING PRECAST CONCRETE

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ABSTRACT : *The abstract should summarize the content of the paper. Try to keep the abstract below 200 words. Do not.The use of precast concrete as a practical solution with shorter implementation time and the increasing need for building materials along with the increasing pace of physical development requires innovation to obtain concrete that has the desired quality and is environmentally friendly, one of which is using Fly Ash as a substitute for cement in the mix. concrete. The method used is experimental and analytical research methods, where the compressive strength test was carried out in an experimental laboratory with 25 cylindrical test objects, with variations using Fly Ash 0%, 5%, 10%, 15% and 20%, concrete mix analysis using Indonesian National Standard (SNI) 7656 Procedure for selecting mixes for normal concrete, heavy concrete and mass concrete, as well as analysis of the relationship between added load and deflection that occurs on the plate using the BOEF (Beam On Elastic Foundation) method, results of compressive strength test without the addition of Fly Ash 31.29 MPa, 5% 33.22 MPa, 10% 36.55 MPa, 15% 35.68 MPa and 20% 35.39 MPa and split tensile strength test results without the addition of fly ash of 2. 80 MPa, 5% of 2.88 MPa, 10% of 3.02 MPa, 15% of 2.99 MPa and 20% of 2.93 MPa, with the optimum relationship between split tensile strength and compressive strength of 8.337% and the results of the analysis deflection with a load of 10 kN of 0.337 mm .20 kN of 0.675 mm, 30 kN of 1.012 mm and 40 kN of 1.350.*

Keywords: *Fly Ash, Precast Concrete, Compressive Strength, Split Tensile Strength, Deflection*

INTRODUCTION

Fly Ash is a waste product of coal combustion which may damage the environment and threaten human health. Fly ash particles are considered to be highly environment-contaminating, due to their enrichment in potentially toxic trace elements [1]. The availability of ash can be reduced if it is used as an additive in concrete mixtures. Previous studies have examined the potential of fly ash as a substitute for cement [2,3]. This is based on the properties of this material which are similar to the properties of cement. High-strength concrete can be produced by increasing the porosity of the concrete. The porosity of concrete is influenced by the gradation of aggregate and the fineness of the cement grains.

The use of infrastructures such as roads using concrete as a pavement layer or rigid pavement is generally carried out by direct casting on the spot, road works that are generally carried out using the direct casting method are difficult to control in terms of controlling the proportion of the mixture and concrete maintenance work which results in the required concrete quality being difficult to achieve. This method also requires road closures during implementation and requires a relatively long time. To overcome this, one of the efforts made by the project manager is by applying precast concrete.

Several previous studies related to this research include the Mechanical properties and durability performance of reinforced concrete containing fly ash [4], the Development of materials for sustainable precast concrete block pavements [5], the Effectiveness of Fly Ash onSelf Compacting Concrete[6], A review of the characteristics of fly ash- Towards the promotion of high volume utilization in developing sustainable concrete[7],Properties of mortar with fly ash as fine aggregate[8], Plate Deflection Calculation Method Using Equivalent Subgrade Reaction Modulus for Flexible Plate Structures[9], Utilization of Fly Ash in High-Performance Concrete for Precast Cheap Houses[10], High-Quality Concrete Experiments Made from Fly Ash as a Partial Substitute for Cement[11], Use of Recycled Concrete Aggregate in Precast/Prestressed Concrete[12], Mechanical properties and durability performance of reinforced concrete containing fly ash[12].The purpose of this study was to determine the optimum percentage of fly ash that provides maximum compressive strength and maximum split tensile strength in precast concrete and also to determine the relationship between load and deflection in precast concrete with the use of fly ash.

MATERIALS AND METHODS

This research was conducted experimentally in the structure and materials laboratory, Faculty of Engineering, Indonesian Muslim University Makassar. The research stages are:

The initial stage is examining the characteristics of the concrete forming materials in order to determine the physical and mechanical properties of the materials that meet the terms and conditions based on material specification standards. The final stage of testing the characteristics of precast concrete is to determine the physical and mechanical properties produced based on the planned quality standards and guidelines for testing implementation for the type of precast concrete.

2.1 Compressive Strength

Compressive strength is the ability of concrete to accept a broad unit of compressive force. Compressive strength is one of the mechanical properties of concrete, concrete compressive strength identifies the quality of a structure. The higher the desired level of structural strength, the higher the quality of the concrete given. The compressive strength value of concrete is obtained through standard testing procedures, using a testing machine by applying a multilevel compressive load to a concrete cylinder test object (diameter 150 mm, height 300 mm) until it crumbles. SNI 2011 is used for compressive strength test standards.

For testing the compressive strength of concrete, the specimen in the form of a concrete cylinder with a diameter of 15 cm and a height of 30 cm is pressed with a load P until it collapses. Because there is a compressive load P, a compressive stress occurs in the concrete (f'c) equal to the load (P) divided by the cross-sectional area of the concrete (A), so that it is formulated:

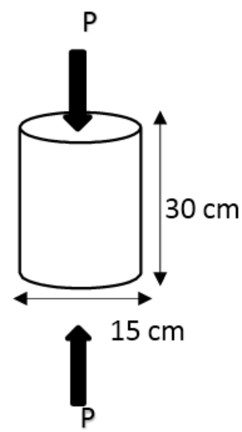

Figure 1: Compressive Strength Testing

$$f'c = \frac{p}{a} \quad \text{...(1)}$$

Where:
f'c = Compressive strength (MPa)
P = Maximum load (N)
A = surface area of the test object (mm2)

2.2 Splitting Tensile Strength

One of the weaknesses of concrete is that it has a very small tensile strength compared to its compressive strength, which is 9% -15% fc. The tensile strength of concrete affects the ability of concrete to overcome the initial crack before being loaded. The tensile strength of concrete is not directly proportional to its ultimate compressive strength. This tensile strength is quite difficult to measure with direct axial tensile loads so to determine the tensile strength of concrete in testing it can only be measured by the modulus of rupture test method and the cylinder split test method.

The splitting tensile strength test used a Tensile Splitting Test (TST). The split tensile test is a test by slitting the cylinder by pressure towards the diameter to obtain the split tensile strength.

The split cylinder test method generally gives better results and better reflects the actual tensile strength. The approximate value obtained from the results of repeated testing of tensile strength T = 0.50 0.60 √f'c. According to article 11.5 of SNI-03-2847 (2002), the value of the tensile strength of concrete when related to the compressive strength is T = 0.7 √f'c Mpa.

The tensile strength of concrete can be measured by carrying out a cylinder splitting test based on ASTM C496/C496M-11, 2011. A cylinder is placed according to its position on the testing machine and then a compressive load is applied evenly throughout the entire length of the cylinder until it is split in half from end to end. which means that at that moment the tensile strength is reached. To determine the tensile strength can be determined by equation 2.

$$T = \frac{2p}{\pi LD} \quad \text{..........} (2)$$

Where T = split tensile strength, P = load at splitting time, L = length of the cylindrical specimen and D =sample diameter

2.3 Deflection test

The structure is made to be able to carry the existing load:

a. Self-weight

b. Other expenses, for example:

Occupants, tools, vehicles, wind, earthquake and shock. The structure will provide a response that can be in the form of support reaction, strain and internal stress, as well as deformation.

The response of the structure depends on:

a. Shape, geometry and structure

b. Materials used

Therefore, an understanding of the properties of materials is needed so that structures can be planned properly, and safely, can function for a predetermined time and are economical. Knowledge of material properties, especially mechanical properties in generalobtained from experiments supported by theories Several basic concepts for a structure must meet the requirements:

a. Strength

b. Stiffness

c. Stability

When a slab is placed on the ground, its strength will depend on the strength of the slab itself, the bearing capacity of the subgrade and the interaction between the slab and the subgrade in supporting the load, which is generally affected by the presence of cavities formed between the two. To evaluate the performance of this system, analytical calculations or a plate load test can be carried out on it to determine the relationship between load and deflection.

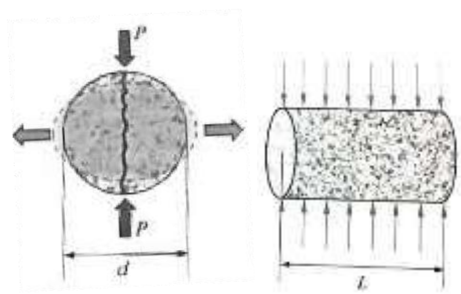

Figure 2: Split test

Analytical calculation of the deflection of the plate above the ground can be calculated using the BoEF (Beams on Elastic Foundation) method with the following equation:

$$\delta = \frac{Q}{2K} \frac{1}{sinh\lambda l + sin\lambda l} \left[\begin{array}{l} cos\lambda(l-x \\ + cos\lambda x cosh\lambda(l-x) \\ -sinh\lambda x sin\lambda(l-x) \\ +sin\lambda x sin\lambda(l-x) \\ +2\ cosh\lambda x cos\lambda x \end{array} \right] \quad \text{..........} (3)$$

with :

$$\lambda = \sqrt[4]{\frac{ks\ x\ B}{4EI}} \quad \text{..........} (4)$$

Where:

Ks: Modulus of subgrade reaction (kN/m3)

B : Slab Width (m)

E : Plate Elasticity kN/m2
I : Plate Inertia (m4)

RESULT AND DISCUSSION

3.1. Fine aggregate characteristics

This study examined the characteristic of fine aggregate. The result showed that all characteristics of the fine aggregate parameters from the sieve analysis for organic content meet the required specifications, so it can be concluded that the fine aggregate that has been tested is suitable for use in the concrete mixing process (Table 1).

Table1. Fine aggregate characteristics

NO	Parameters	Result	Qualification
1	Sieve Analysis	2.99	Meet the requirement
2	Water content	6.56%	Meet the requirement
3	Solid Volume Weight	1.548kg/L	Meet the requirement
	Loose Volume Weight	1.459kg/L	Meet the requirement
4	Specific gravity	2.63	Meet the requirement
	Absorption	0.71%	Meet the requirement
5	Sludge levels	3%	Meet the requirement
6	Organic Content	*Clear yellow*	Meet the requirement

3.2. Coarse aggregate characteristics

It can be seen from table 2 that all the results of examining the coarse aggregate parameters from the sieve analysis for organic content meet the required specifications, so it can be concluded that the fine aggregate that has been tested is suitable for use in the concrete mixing process (Table 2).

Table2. Fine aggregate characteristics

NO	Parameters	Result	Qualification
1	Sieve Analysis	6,786	Meet the requirement
2	Water content	2,25 %	Meet the requirement
3	Solid Volume Weight	1,602 kg/ltr	Meet the requirement
	Loose Volume Weight	1,481 kg/ltr	Meet the requirement
4	Specific gravity	2,62	Meet the requirement
	Absorption	0,56 %	Meet the requirement
5	Sludge levels	0,74 %	Meet the requirement
6	Coarse Aggregate Wear	20,2 %	Meet the requirement

3.3. Cement characteristics

It can be seen from table 3 that all cement inspection results meet the required specifications, so it can be concluded that the cement that has been tested is suitable for use in the concrete mixing process.

Table 3. Cementmeasure results

NO	Parameters	Result	Qualification
1	Specific Gravity of Cement	3.15	Meet the requirement
2	Cement Fineness #100	100%	Meet the requirement
	Cement Fineness #200	91%	Meet the requirement
3	Normal Consistency	23%	Meet the requirement
4	Initial Tie Time	150menit	Meet the requirement
	End Time	225menit	Meet the requirement
5	Solid Cement Volume Weight	1.199kg/L	Meet the requirement
	Loose Cement Volume Weight	1.127kg/L	Meet the requirement

3.4 Fly Ash Analysis

The results of the fly ash test showed that the binding time was longer with increasing fly ash concentration. The initial binding time without fly ash is 3 minutes and the end is 105 minutes; whereas at a concentration of 20% the binding time increased to 65 minutes early and 185 minutes late (Table 4).

Fly ash content (%)	**Time (minutes)**	
	Start	**Finish**
0	30	105
5	35	120
10	45	135
15	60	165
20	65	185

The results of measurements in the laboratory showed that the total content of SiO_2+Al_2O_3+Fe_2O_3 is 65% referring to the chemical requirements for the Fly Ash class, so this Fly Ash is included in class C with a minimum SiO_2+Al_2O_3+Fe_2O_3 content of 50% (Table 5).

Table 5. Chemical content of fly ash

No.	**Parameter**	**Result (%)**
1	Calcium Oxide (CaO)	27.15
2	Magnesium Oxide MgO)	9.04
3	Silica (SiO2)	32.02
4	Aluminum Oxide (Al2O3)	16.70
5	Ferroxide (Fe2O3)	16.28
6	Alkali (Na2O+K2O)	0.19
7	Sulfur (SO3)	0.0186
8	Phosphorus (P2O5)	0.0672

3.5. Result of job mix formula

The results of the job mix formula indicated that the formula required 208.75 kg of water, 577.40 kg of cement, 982.75 kg of fine aggregate and 497.09 kg of coarse aggregate (Table 6).

Table 6. The need for each concrete mix material per m^3

No	Materials	Weight (kg)
1	Water	208.75
2	Cement	577.40
3	Coarse Aggregate	982.75
4	Fine Aggregate	497.09

3.6. Concrete material requirements for trial mix loss

The need for cement and fly ash for concrete materials for the Trial Mix 10% loss factor varies frequently with an increase in fly ash concentration. At a fly ash concentration of 0%, the cement requirement is 12.099 kg; while at a concentration of 20% the need for cement is 9.679 kg and fly ash is 2.420 (Table 7).

Table 7. Concrete material requirements for trial mix loss factor 10%

No	Fly Ash(%)	Materials				
		Cement (Kg)	*FlyAsh* (Kg)	Coarse aggregate(Kg)	Fine aggregate(Kg)	Water (Kg)
1	0	12.099	0	26.879	22.243	5.244
2	5	11.494	0.605	26.879	22.243	5.244
3	10	10.889	1.210	26.879	22.243	5.244
4	15	10.284	1.815	26.879	22.243	5.244
5	20	9.679	2.420	26.879	22.243	5.244

3.7. Compression strength

In this study, the compressed strength test of concrete was carried out with five replicates. Concrete compressive strength testing was carried out at 28 days of age using cylindrical specimens measuring 150 mm x 300 mm, as many as 25 cylinders with variations of mineral supplements 0%, 5%, 10%, 15%, and 20% where each variation was made of 5 objects test. The highest compression strength was obtained at a concentration of 10% fly ash (36.55 Mpa) while the lowest was obtained at a concentration of 0% (31.29 MPa) (Table 8).The graph of the compressive strength test can be seen in Figure 1. The graph of the relationship between the variation of mineral supplements (%) and the compressive strength of concrete (MPa) follows (Figure 1).

Tabel8. Result of compression strength measurements

Sample	**kN**	**Damage burden**	**Compression strength**
		N	**(N/mm^2)**
Concrete of 0%Flyash			
1	562	562,000	31.82
2	568	568,000	32.16
3	550	550,000	31.14
4	549	549,000	31.08
5	534	534,000	30.23
		Average	31.29
Concrete of 5%Flyash			
1	559	559,000	31.65
2	506	506,000	28.65
3	599	599,000	33.91
4	606	606,000	34.31
5	664	664,000	37.59
			33.22
Concrete of10%Flyash			
1	650	650,000	36.80
2	692	692,000	39.18
3	640	640,000	36.23
4	709	709,000	40.14
5	537	537,000	30.40
			36.55
Concrete of15%Flyash			
1	659	659,000	37.31
2	606	606,000	34.31
3	616	616,000	34.88
4	606	606,000	34.31
5	664	664,000	37.59
			35.68
Concrete of20%Flyash			
1	614	614,000	34.76
2	595	595,000	33.69
3	611	611,000	34.59
4	583	583,000	33.01
5	634	634,000	35.90
			34.39

In this study, the compressive strength test of concrete was carried out. Concrete compressive strength testing was carried out at 28 days of age using cylindrical specimens measuring 150 mm x 300 mm, as many as 25 cylinders with variations of mineral supplements 0%, 5%, 10%, 15%, and 20% where each variation was made of 5 objects test. The graph of the compressive strength test can be seen in Figure 1. The graph of the relationship between the variation of mineral (fly ash) supplements (%) and the compression strength of concrete (MPa) follows (Figure 1)

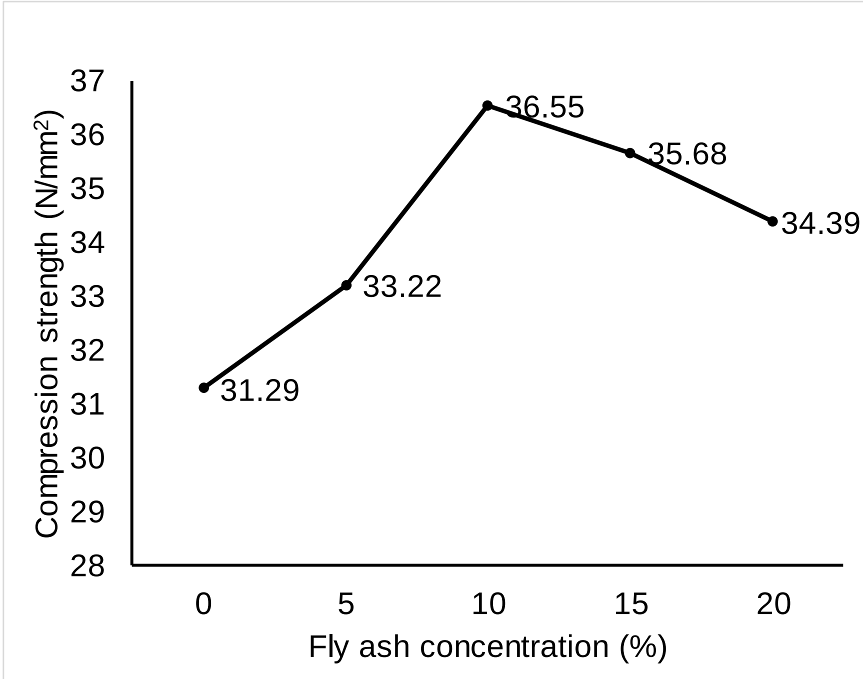

Figure 1. The relationship between the variation of mineral (fly ash) supplements (%) and the compression strength

With an average compressive strength value of 0% of 31.29 MPa, 5% of 33.22 MPa, 10% of36.55 MPa, 15% of 35.68 Mpa, 20% of 34.39 Mpa. Thus the optimum percentage of Fly Ash based on the regression equation is 13.3% with a compressive strengthmaximum of 36.352 MPa with an R2 correlation of 0.9046. The following is a graph of the optimum Fly Ash content from the calculation results above (Figure 2).

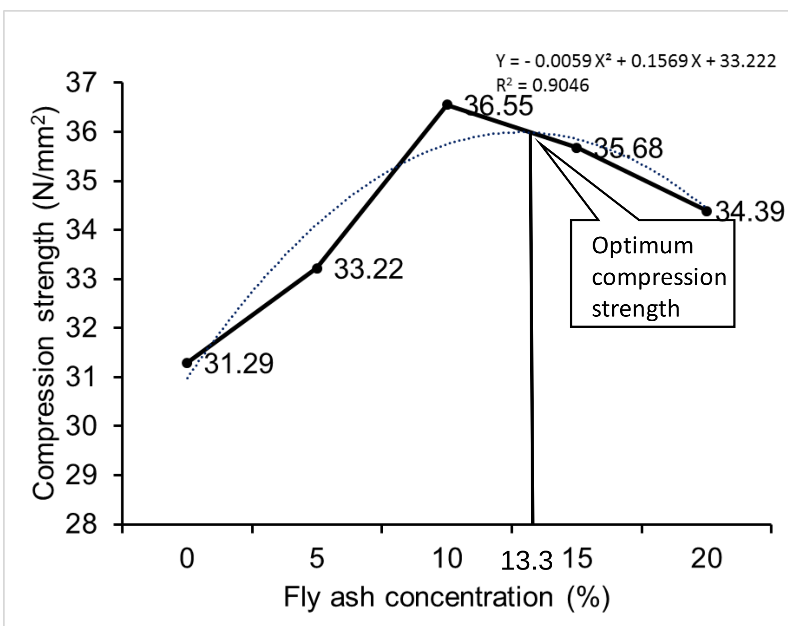

Figure 2. Polynomial regression between variation of mineral (fly ash) supplements (%) and the compression strength

Figure 2 showed that the relationship between the compressive strength and the percentage of fly ash on the compressive strength of concrete tends to show a degree 2 polynomial effect or a parabolic effect. Figure 3 shows the increase in compressive strength from the addition of 0% to 20% Fly Ash which produces an optimum value of 36.352 MPa with a correlation coefficient (R2) of 0.9046 and a decrease in compressive strength after the addition of Fly Ash greater than 13.3% .

3.8. Testing of Split Tensile Strength

In this study, the split tensile strength test of concrete was carried out. The split tensile strength test of concrete was carried out at the age of 28 days using cylindrical specimens measuring 150 mm x 300 mm, totaling 25 cylinders with a variety of mineral supplements of 0%, 5%, 10%, 15%, and 20% where each variation was made 5 test object. The averagesof split tensile strength value were of 0% of 2.80 MPa, 5% of 2.88 MPa, 10% of 3.02 MPa, 15% of 2.99 MPa, 20% of 2.93 Mpa (Table 9).

Table 9: Results of Splitting Tensile Strength Test

Sample	Split Tensile Strength (N/mm2)	Average of Split Tensile Strength(N/mm2)
	Concrete of 0%Flyash	
1	2.90	2.80
2	2.69	
	Concrete of 5%Flyash	
1	2.87	2.88
2	2.89	
	Concrete of10%Flyash	
1	3.10	3.02
2	2.95	
	Concrete of15%Flyash	
1	3.01	2.99
2	2.96	
	Concrete of20%Flyash	
1	3.09	2.93
2	2.77	

The graph of the split tensile strength test can be seen in Figure 3. The graph of the relationship between the variation of mineral supplements (%) and the split tensile strength of concrete (Mpa) is in Figure 3. Thus the optimum percentage of Fly Ash based on the regression equation is 13.17% with a maximum splitting strength of 3.0312 MPa with an R2 correlation of 0.9253.

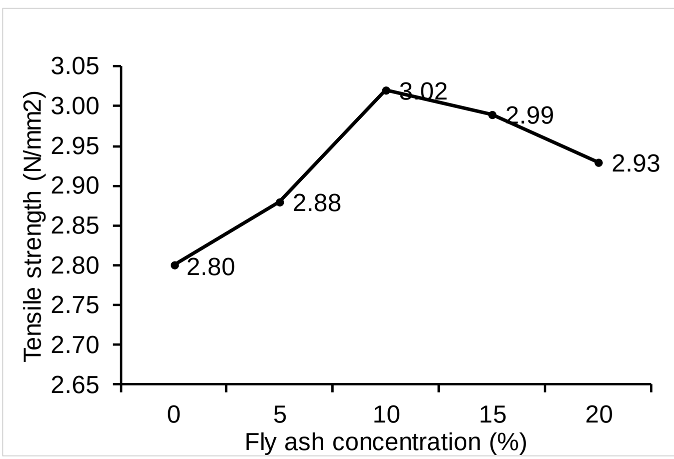

Figure 3. The relationship between the variation of mineral (fly ash) supplements (%) and the split tensile strength

The following is a graph of the optimum Fly Ash content from the calculation results above.Figure 2 shows that the relationship between split tensile strength and the percentage of fly ash on the split tensile strength of concrete tends to show a degree 2 polynomial effect or a parabolic effect. Figure 3 shows the increase in split tensile strength from the addition of 0% to 20% Fly Ash which produces an optimum value of 3.0312 MPa with a correlation coefficient (R2) of 0.9253 and a decrease in split tensile strength after the addition of Fly Ash is greater than 13.17% (Figure 4).

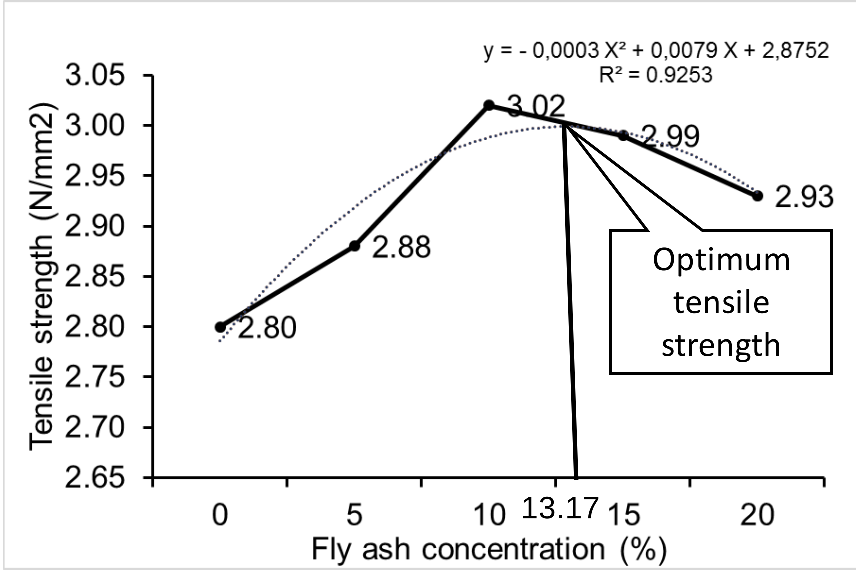

Figure 4. Polynomial regression between variation of mineral (fly ash) supplements (%) and the split tensile strength

3.9. Deflection

The deflection test was done on PLT-01 and PLT-02. Results show that the deflection of PLT-01 ranged from 2.423 mm (10 kN burden) to 5.001 mm (40 kN burden), while those of PLT-02 ranged from 2.410 mm (10 kN burden) to 4.949 mm (40 kN burden) (Table 10).

Table 10 : Results of deflection analysis

No.	Plat code	Burden(kN)	Deflection (mm)
1	PLT-01	10	2.423
		20	3.282
		30	4.142
		40	5.001
2	PLT-02	10	2.410
		20	3.256
		30	4.102
		40	4.949

The relationship between load and deflection can be seen in Figure 4, the graph of the relationship between load and deflection. If we look at the graph formed for the plate using Fly ash with the PLT-02 code, the relationship between load and deflection with concentrated loading, the graph tends to behave linearly, this explains that along with the addition of the load on the plate, the deflection that occurs will also increase, with the location of the maximum deflection that occurs on the plate in the middle of the span (Figure 5).

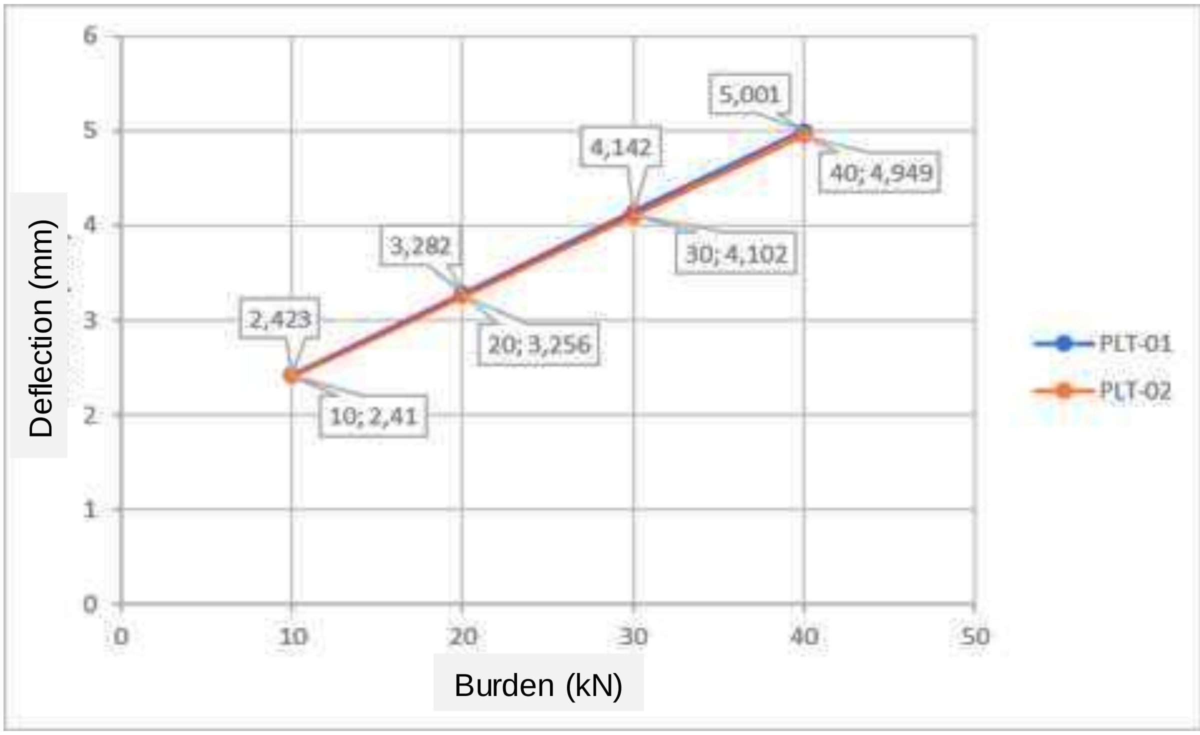

Figure 5. Relationship between burden (load) and deflection

CONCLUSION

1. Based on the compressive strength results obtained, variations in the addition of 10% fly ash produce the greatest compressive strength with a value of 36.55 MPa. From the regression equation, the optimum percentage of fly ash addition is 13.30% with the optimum compressive strength value 36.352 MPa. The percentage of the relationship between split tensile strength and compressive strength is 8.337% (fulfills the requirements of 7-11%).
2. Precast concrete with an optimum percentage of fly ash of 13.30%, meets the requirements as a rigid pavement (fr=1.37fb=4.151 MPa > 3 MPa).
3. Based on the results of the calculation of the deflection, it is obtained that the behavior of the relationship between the load and the deflection of precast concrete using fly ash is linear with the results of the calculation of the deflection using the BoEF method ranging from 0.3 mm – 1.4 mm.

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