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Flexural and Compressive Strength on No-fines Concrete Slab using Variations of Fly Ash and Superplasticizer

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Abstract: Concrete is one of the most used construction materials in the world. The advantages of concrete, which has a cheap and easily obtainable price, make this material popular in the world community. Concrete construction is usually used for building construction, bridges and rigid pavements on roads. This research will make concrete slabs without the use of fine aggregates which are often referred to as no-fines concrete. The reduction of the constituent material in the concrete causes the formation of cavities which aim to accelerate the absorption of water for road construction. The specimens were made in the size of 400 x 100 x 600 mm with three variations using fly ash and three variations using materials added superplasticizer and one variation without using any added material with a total of 21 samples. In addition to flexural testing, compressive strength testing was also carried out by making 63 cylindrical concrete samples measuring 150 mm in diameter and 300 mm in height. The flexural test is done when the concrete slab is 28 days old using a centralized static load in the middle of the span, while the concrete cylinder compressive strength test is carried out at the age of 7, 14 and 28 days.

Keywords: Nofines concrete, slab, compressive strength, flexural strength

1. Introduction

No-fines concrete is a composite building material consisting of a constituent material in the form of coarse aggregate, Portland cement, and water. This concrete has a difference with conventional concrete that is the use of uniform aggregate gradations [1]. In addition to the differences in grain gradations used, no-fines concrete has a compressive strength that is smaller than normal concrete, a fairly high level of permeability and has a smaller weigh t and there are many activities [2]. The application of no-fines concrete so far has been carried out in various countries, some of the research that has been carried out is the application of no-fines concrete for housing in the United Kingdom [3] as a building material [4] as well as pavement material on roads [5] .

The more developed innovations regarding no-fines concrete, there is also a lot of research that has been done regarding the innovation of constituent materials of this type of concrete. Some researchers have made innovations

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using concrete aggregate waste as coarse aggregate [6] and utilization of plastic fiber waste [7]. No-fines Concrete is often applied to road pavement, especially for roads that are not covered by large loads, it aims to facilitate water absorption when rain occurs. As a result of the lack of use of fine aggregates on this concrete, there are many cavities which increase the permeability value of this type of concrete.

In this study testing the flexural strength of concrete no-fines slabs will be carried out measuring 400 x 100 x 600 mm without rein-forcement. The variation in this study is to add the composition of the superplasticizer to the concrete mixture in the hope of increasing the flexural strength of the no-fine concrete slab. In addition, variations of fly ash substitution were carried out into concrete mixes.

Fly ash is a material that has been used very often for added mate-rials in making concrete, several studies have shown that the use of fly ash with certain compositions can increase the strength of the concrete. In addition to flexural strength testing, compressive strength testing was also performed on each variation of the mixture composition. Compressive strength test specimens in the form of concrete cylinders with a height of 300 mm and a diameter of 150 mm were tested respectively at the age of 7, 14 and 28 days.

The purpose of this study was to determine the compressive strength and flexural strength of concrete no -fines slabs using a variety of ingredients added to fly ash and superplasticizer addi-tives. Through this research, it is expected that it will produce an appropriate composition for utilizing fly ash and superplasticizer in the manufacture of no-fines concrete and can be applied to road pavement, especially roads with conditions that do not receive substantial loads.

2. Materials and Test Method

This research was conducted in the structure and construction materials laboratory, Universitas Muhammadiyah Yogyakarta by testing the properties of coarse aggregate, slump flow test, porosity test, flexural test and compressive strength of no-fines concrete.

2.1 Materials

In this study, the ingredients for the no-fines concrete used are cement, water, coarse aggregate, fly ash and superplasticizer. The cement used is Portland Pozzolan Cement which comes from Gresik, East Java Province. This cement has a specific gravity of 3.15. While the water used came from the Construction and Struc-ture Materials Laboratory, Universitas Muhammadiyah Yogyakarta. The aggregate used in this study is coarse aggregate originating from Kulon Progo Regency, Indonesia, this aggregate is good enough to be used as a concrete material [8], whereas the testing of each coarse aggregate property refers to the standard [9].

Table 1 describes the results of coarse aggregate testing. In this test carried out checking specific gravity, water content, water absorption, unit weight, mud content, and roughness values. Spe-cific gravity obtained through the test results is 2.60, this shows that the specific gravity is good enough for the concrete constituent. The water content obtained is 2.72%, it is also quite good for the constituent of concrete and the water absorption value is quite small, which is 1.96%. the roughness value obtained is 26.47%, the maximum limit that is determined that the roughness value is not more than 40%, this shows the coarse aggregate of Kulon Progo is quite feasible to be used as a concrete constituent. Mud content contained in this aggregate is 0.79% which still meets the maximum allowable sludge requirement of 1%. Based on all inspections, this aggregate is quite feasible for concrete constituent materials.

Table 1 - Mechanical properties of coarse aggregate

Test Item	Resu
Specific Gravity	2.
Water Content (%)	2.
Absorption (%)	1.
Unit weight (gr/cm^3)	1.
The Roughness (%)	26.
Mud Content (%)	0.79

In this study also used additional ingredients in the form of fly ash and superplasticizer Viscocrete 1003. Materials added to fly ash are used to reduce the pores that exist but are still in the category for no-fines concrete. Fly ash used in this study is 20%, 40% and 60% of the weight of cement used. Fly ash is taken from the East Java Steam Power Plant. The use of superplasticizer aims to reduce the amount of water. In this study using Sika Viscocrete 1003 where this product reduces water use by 30%. In this study using a variation of 0.5%, 1.0% and 1.5% superplasticizer which was taken by the percentage of the weight of cement used.

2.2 Mix Design

In this study planned to make no-fines concrete slabs with 7 varia-tions. Where each variation has a difference in the composition of the ingredients added to fly ash and superplasticizer. Table 2 explains the differences in each variation used. The composition of cement, water and coarse aggregate in all variations has the same composition, while the composition of fly ash and superplasticizer is taken from the weight of cement depending on the percentage of each variation.

Table 2 - The percentage of fly ash and superplasticizer for each variation

Code	Type of variation
NFC-1	Fly Ash 0% + Superplasticizer 0.5%
NFC-2	Fly Ash 20% + Superplasticizer 0.5%
NFC-3	Fly Ash 40% + Superplasticizer 0.5%
NFC-4	Fly Ash 60% + Superplasticizer 0.5%
NFC-5	Fly Ash 0% + Superplasticizer 0%
NFC-6	Fly Ash 0 % + Superplasticizer 1%
NFC-7	Fly Ash 0% + Superplasticizer 1.5%

Table 3 shows the composition of the mixture in all variations used. In this study using a variety of NFC -5 supporters in the form of concrete that does not use added ingredients at all, which are known as normal no-fines concrete. The cement water factor used in this study also has different values.

The smallest cement water factor used is 0.17 on the NFC-4 variation, this is because the use of fly ash is quite large, namely 60% while the water needs are used constantly, so the cement water factor used is very small, while the biggest cement water factor used that is equal to 0.28. This variation is found in concrete without the use of ingredients added to fly ash.

Other cement water factors used are 0.23 for NFC-2 variations and cement water factor 0.20 for NFC-3 variations. The composition in Table 3 is the use for 1m3 using standard [10]. Where this standard requires a trial of reducing the water used to a maximum reduction that can be done for all variations of 30%. The use of different percentage of added ingredients, the weight of the concrete produced also varies according to Table 3 below. NFC-4 test object has the highest weight because it uses fly ash at most compared to other variations.

Table 3 - Mix design result for 1m^3

Materials	Composition in 1m^3						
	NFC-1	NFC-2	NFC-3	NFC-4	NFC-5	NFC-6	NFC-7
Cement	238.64	238.64	238.64	238.64	238.64	238.64	238.64
Water	66.54	66.54	66.54	66.54	66.54	66.54	66.54
Coarse Aggregate	1152.5	1152.5	1152.5	1152.5	1152.5	1152.5	1152.5
Fly Ash	0	47.73	95.46	143.18	0	0	0
Superplasticizer	1.19	1.19	1.19	1.19	0	2.39	3.58
w/c	0.28	0.23	0.20	0.17	0.28	0.28	0.28

2.3 Test Method

Testing of no-fines concrete slab bending strength refers to the applicable standard [11] where the load position is centered in the center. The slabs used are 400 x 100 x 600 mm without using steel reinforcement [11]. The test object used in this research is a cylinder with a diameter of 150 mm and a height of 300 mm. Each variation in this study consisted of nine samples.

Before testing the compressive strength and flexural strength, a fresh concrete check is carried out in the form of testing the value of the slump and when the hardened concrete has tested the value of porosity. In Fig. 1, it is seen setting up the flexural test of the slab where the deflection value is measured using a dial gauge and the load is centered in the middle of the span.

3. Result and Discussion

3.1 File Naming and Delivery

Slump test results are shown in Fig. 2, from the results of the slump test it was found that the largest slump value was on NFC-7 specimens with 0% fly ash variation and superplasticizer of 1.5%, the resulting slump value was 220 mm. Whereas the smallest slump value is found in NCF-4 specimens with 60% fly ash variation and superplasticizer of 0.5%, The resulting slump value is 28 mm.

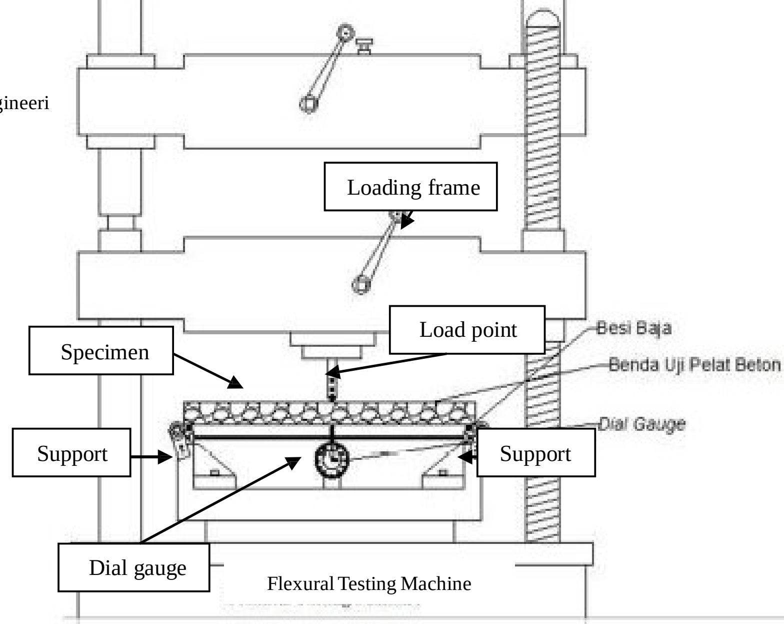


Fig. 1 - Experimental set-up

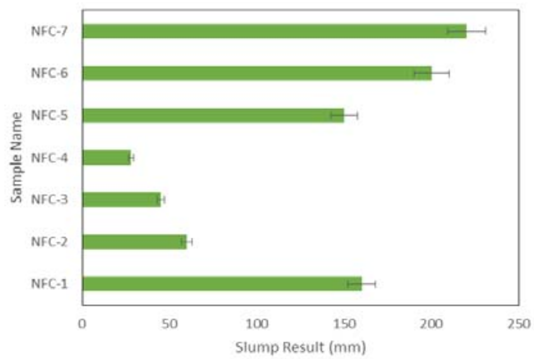
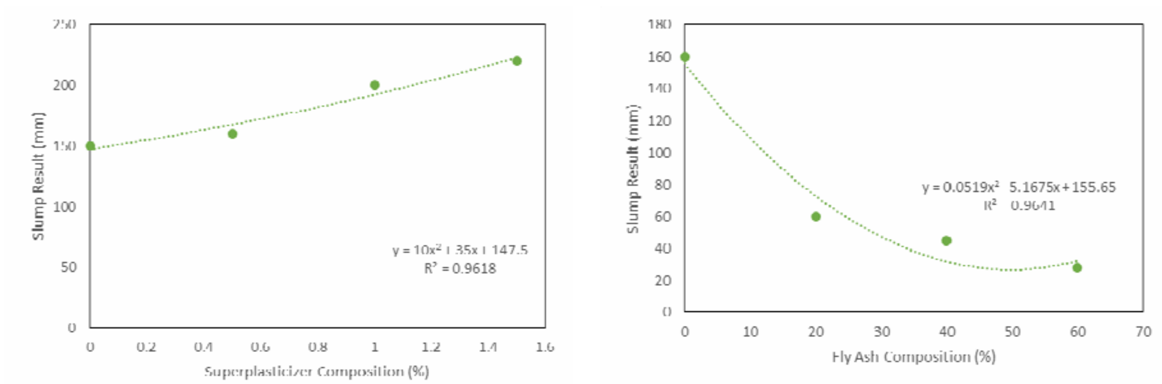


Fig. 2 - Slump result

In Fig. 3(a) describes the relationship of the composition of fly ash with the results of the slump value, from the results that have been tested can be concluded below the more the percentage of material added fly ash that will be very influential in the value of the slump produced which will be smaller, so that the resulting equation can design the proportion of fly ash needed in accordance with the desired slump value. Whereas in Fig. 3(b) shows the relationship between the composition of the use of superplasticizer with slump value produced where the higher the percentage of superplasticizer value used will result in higher slump values as well. In the equation in Fig. 3(b) can be determined the need for superplasticizer desired in accordance with the needs of the slump that you want to achieve.



(a) (b)

Fig. 3 - (a) The relationship between slump results with fly ash composition; (b) The Relationship between slump results with superplasticizer com-position.

Porosity testing is done when the concrete is 28 days old. Porosity testing is done to find out the cavities in the concrete. Fig. 4 describe the highest porosity value is found in specimens with an NFC-1 variation of 26.05% where this variation has the highest slump value and uses the highest proportion of superplasticizer. Test object with the smallest porosity value obtained from NFC-4 variation is equal to 19.88%; this variation uses 60% added to fly ash, the effect of increasing filler used can reduce the cavities in the concrete.

In NFC-2 specimens with variations of material added 20% fly ash obtained porosity value of 24.49%, with the increase of fly ash to 40% making the porosity value also smaller which is equal to 20.85%. Whereas normal concrete without any additional material has a porosity result of 24.86%. From the figure, it can be seen that the use of ingredients added by fly ash or superplasticizer affects the porosity value, although not very significant.

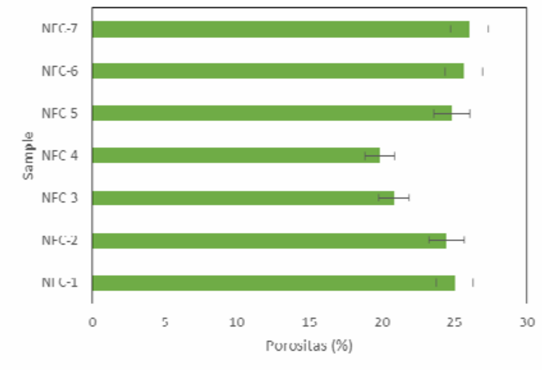


Fig. 4 - Porosity test result

Fig. 5 describes the relationship of fly ash composition with the value of porosity produced. The results of this test are, the greater the percentage of fly ash used will make the porosity value smaller. From the equation, it can also be determined the porosity value desired if it requires certain porosity levels with certain fly ash composition as well.

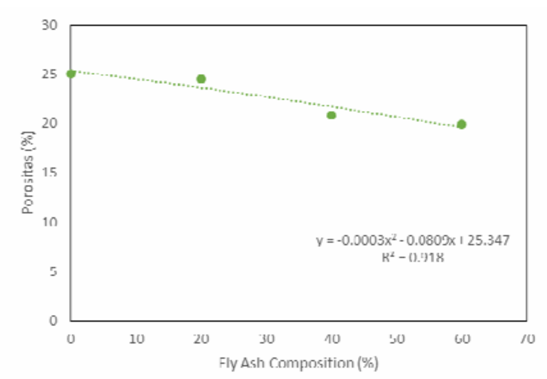


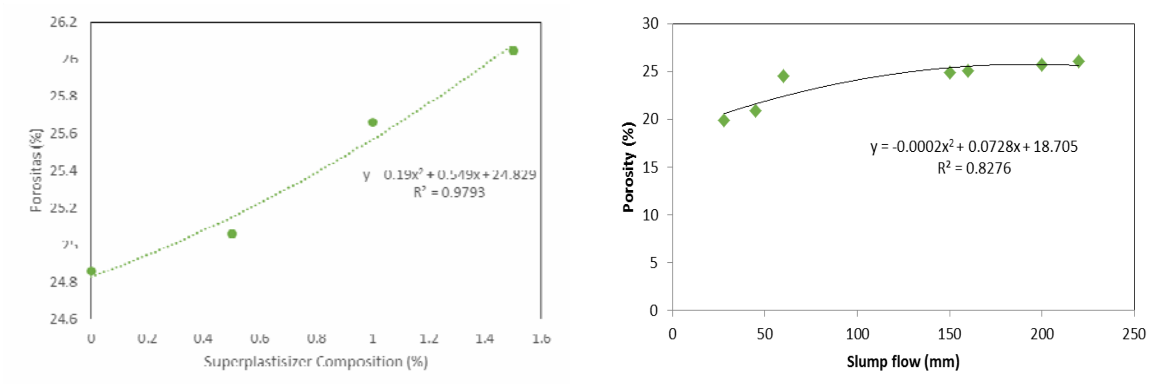
Fig. 5 - The relationship between fly ash compositions with porosity result

Fig. 6(a) describes the relationship between the percentages of the use of superplasticizer Viscocrete 1003 with the value of porosity produced. It can be explained that the higher the superplasticizer composition used will make the porosity value higher as well. This can be seen from the physical form of the specimen where the more superplasticizer used makes the segregation level higher because the concrete becomes very watery and the resulting slump value becomes very high. From the existing equation can be used as reference material for the desired porosity value by using each of the added ingredients needed. Using superplasticizer can help improve workability and using fly ash can reduce porosity. Fig. 6(b) describes the relationship between slump and porosity. From the test results, it was found that the greater the slump value, the greater the value of porosity. The use of a large amount of water makes the slump value increase; if the concrete has hardened, it will increase the cavities due to water that has evaporated, this causes the value of porosity to increase.

3.2 Compressive Strength Result

Testing of compressive strength was carried out at concrete ages 7, 14 and 28 days. The NFC-1 variation obtained a compressive strength of 4.0 MPa at 7 days, 5.15 MPa at 14 days and had a compressive strength of 7.23 MPa at 28 days. For NFC-2 variation, the compressive strength was 5.20 MPa at 7 days, 6.29 MPa at 14 days and 8.89 MPa at 28 days of curing time. In the NFC-3 variation produced concrete compressive strength of 4.20 MPa at the age of 7, while at the age of 14 the results obtained the compressive strength of 6.50 MPa and 28 days of age yielded 9.26 MPa. In the NFC-4 variation, the compressive strength is 4.93 MPa at 7 days, 9.93 when the concrete is 14 days old and 12.25 MPa when the concrete is 28 days old.

In the NFC-5 variation, the compressive strength was 4.00 MPa at 7 days old, 5.19 MPa when the concrete was 14 days old and 6.73 MPa when the concrete was 28 days old. The NFC-6 variation produces 2.24 MPa concrete compressive strength at the age of 7 days, while at 14 days it produces a compressive strength of 3.97 MPa and 5.71 MPa for compressive strength at 28 days. Whereas the last variation resulted in compressive strength of 2.08 MPa at 7 days, 3.24 MPa at 14 days and 5.08 MPa at 28 days. Table 4 explains the results of compressive strength for all specimen.



(a) (b)

Fig. 6 - (a) The relationship between superplasticizer compositions with porosity results; (b) The relationship between slump and porosity

Table 4. Compressive strength

Age	**Compressive Strength (MPa)**						
	NFC-1	**NFC-2**	**NFC-3**	**NFC-4**	**NFC-5**	**NFC-6**	**NFC-7**
7	3.39	4.56	2.55	4.76	3.01	2.16	2.33
7	4.35	5.15	5.20	5.78	4.34	2.09	2.16
7	4.27	5.88	4.86	4.24	4.65	2.48	1.75
Average	**4.00**	**5.20**	**4.20**	**4.93**	**4.00**	**2.24**	**2.08**
14	5.66	6.20	6.08	7.71	4.69	4.24	2.77
14	4.77	6.57	6.61	7.25	5.26	4.34	3.09
14	5.01	6.09	6.81	8.82	5.63	3.33	3.87
Average	**5.15**	**6.29**	**6.50**	**7.93**	**5.19**	**3.97**	**3.24**
28	7.36	8.87	10.65	12.22	6.36	6.56	5.44
28	7.05	8.92	8.63	10.72	6.50	4.77	4.50
28	7.28	8.87	8.49	13.80	7.33	5.81	5.31
Average	**7.23**	**8.89**	**9.26**	**12.25**	**6.73**	**5.71**	**5.08**

In Fig. 7, it can be concluded that concrete with NFC-4 variation has a compressive strength of 12.25 MPa, concrete with this variation is a mixture with ingredients added 0.5% superplasticizer and 60% fly ash. While the compressive strength with normal concrete without added material produces a compressive strength of 6.73 MPa, this shows that with 60% added material, fly ash can increase the compressive strength up to 2 times the normal concrete. While the smallest compressive strength at 28 days concrete age is with an NFC-7 variation of 5.08 MPa, this compressive strength is only 75.48% of normal concrete compressive strength while with the highest concrete compressive strength, this mixture is only able to achieve a performance of 41.47%. NFC-7 variation is a mixture with added superplasticizer 1.5% and without using fly ash.

In Fig. 8, the relationship between the values of the slump with the compressive strength can be concluded that the higher the value of the slump will produce no-fines concrete compressive strength getting smaller. Basically, making a good no-fines concrete is not owned by the slump value, and the compaction process as in roller compacted concrete will produce better concrete compressive strength. From the requirements in Fig. 9, the need for starting slump can be determined according to the required compressive strength.

Fig. 9 describes the relationship of porosity to the value of concrete compressive strength. The value of the compressive strength of the concrete will continue to decrease if the value of porosity increases. This shows that the more cavities in the concrete will reduce the compressive strength of the concrete. In Fig. 10 we can determine the equation for the required percentage of cavities according to the planned compressive strength.

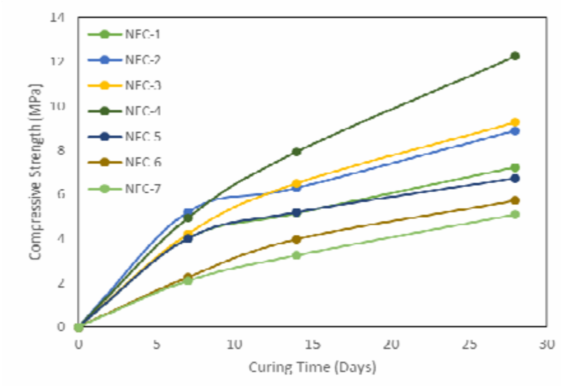


Fig. 7 - Compressive strength result

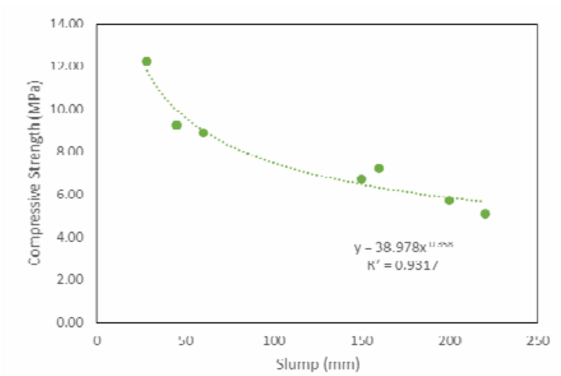


Fig. 8 - The relationship between compressive strength with slump result

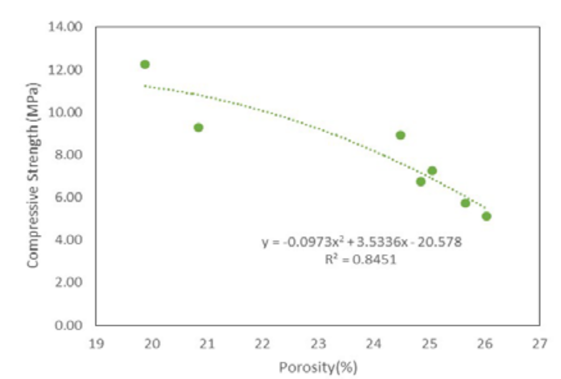


Fig. 9 - The relationship between compressive strength with porosity result

3.3 Flexural Strength Result

The flexural strength of the no-fines concrete slab was tested when the concrete was 28 days old. This test is conducted to determine the flexural strength of the slab and the resulting displacement. Fig. 10 describes the results of the flexural strength obtained in each specimen.

Test object with the smallest flexural strength is NFC-7 with flexural strength at 28 days old concrete that is equal to 1.10 MPa, it is in line with the results of the compressive strength which is the smallest result than the results of other variations. While the NFC-6 variation test object obtained a concrete flexural strength of 1.34 MPa followed by the flexural strength of the NFC-1 variation of 1.73 MPa. The flexural strength of the slab for normal concrete is NFC-5 obtaining a result of 2.17 MPa while the concrete slab with NFC-2 variation obtains the flexural strength of 2.42. Flexural strength for NFC-3 variation when the concrete is 28 days old is 2.89, and the concrete with NFC-4 variation gets the highest yield of 3.23 MPa. Table 5 describes the results of flexural strength testing on the no-fines concrete slab when the concrete is 28 days old. While in Table 6 describes the results of the deflection obtained from the dial gauge through the flexural strength test.

Table 5 - Flexural strength

Age	Flexural Strength (MPa)						
	NFC-1	NFC-2	NFC-3	NFC-4	NFC-5	NFC-6	NFC-7
28	2.22	2.45	3.41	3.61	2.25	1.88	1.45
28	1.32	2.88	2.58	2.84	1.66	1.09	0.88
28	1.65	1.92	2.67	3.25	2.61	1.04	0.98
Average	**1.73**	**2.42**	**2.89**	**3.23**	**2.17**	**1.34**	**1.10**

Table 6 - Deflection result

Age	Deflection (mm)						
	NFC-1	NFC-2	NFC-3	NFC-4	NFC-5	NFC-6	NFC-7
28	0.91	0.95	3.50	2.10	1.37	0.91	1.50
28	4.04	3.60	2.93	4.40	0.81	4.04	1.20
28	3.50	3.00	0.60	1.50	0.14	3.50	3.50
Average	**2.82**	**2.52**	**2.34**	**2.67**	**0.77**	**2.82**	**2.07**

The lowest flexural strength in this study is 1.10 MPa or only 50.69% of flexural strength for normal concrete, while the highest compressive strength is 3.23 MPa, this is 176.47% higher than normal concrete without the use of materials added to fly ash and superplasticizer. With the compressive strength obtained, this type of concrete with NFC-4 variations can be used for applications in road construction that do not receive too large loads. Because the no-fines concrete will be able to apply the drainage system to the base of the road construction.

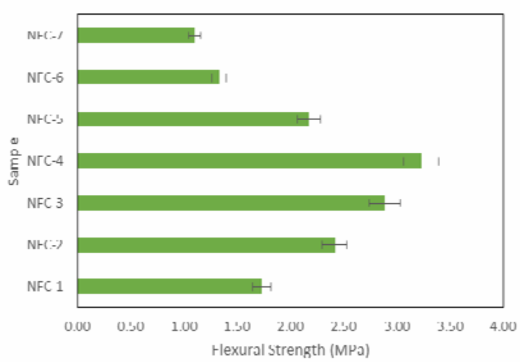


Fig. 10 - Flexural strength result.

In addition to the value of flexural strength, in this test also obtained the maximum deflection value produced. The NFC-1 test object obtained a maximum deflection of 2.82 mm, while the NFC-3 specimen obtained a maximum deflection of 2.52 mm, the NFC-3 test object obtained a maximum defect of 2.34 mm. Deflection generated on NFC-4 test object is 2.67 mm, while NFC-5 gets the lowest deflection of 0.77 mm. Test specimens of NFC-6 and NFC-7 variation respectively obtained maximum deflection of 2.82 mm and 2.07 mm.

In Fig. 12(a) is a relationship between the composition of fly ash and flexural strength testing results. In this study, it was concluded that the higher the amount of fly ash used, it can also increase the flexural strength of no-fines concrete. Whereas in Fig. 12(b) describes the relationship of superplasticizer composition with flexural strength. From this equation, it can be concluded that the use of superplasticizer that is excessive will reduce the compressive strength, so it is not recommended to use superplasticizer more than 1%. In this study, the use of superplasticizer is not good enough to use no-fines concrete, because the strength of concrete with this type is very dependent on little or much of the cavity being produced and the perfect compaction process.

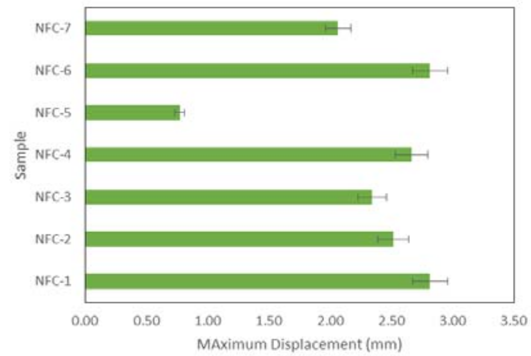
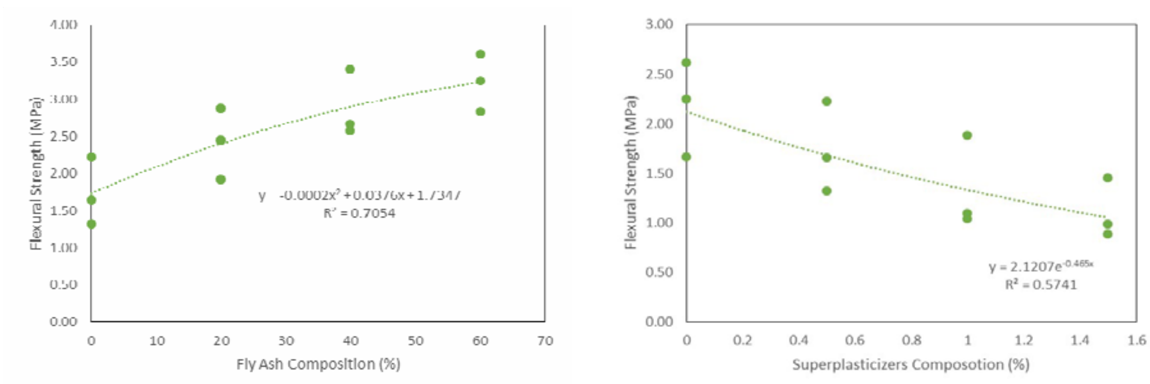


Fig. 11 - Maximum deflection result



(a) (b)

Fig. 12 - (a) The relationship between flexural strength with fly ash composition; (b) The relationship between flexural strength with superplasticizer composition.

Fig. 13 describes the test results for several specimens. From the test results, all specimens were damaged in the 1/3 part in the middle of the span; this was because the exact load position was centered in the middle of the span. It can be concluded that the no-fines concrete stock is very brittle and does not use reinforcement, so its use will be better only for construction that accepts compressive force. Some variations are observed in the segregation process, this is due to the use of fly ash which is quite a lot and not too evenly distributed, so that the entire cement and fly ash are much lower at the base of the concrete slab mold while the coarse aggregate is in place and results in an uneven pore all concrete parts. Compaction method in making concrete no-fines is very important. Limited use of water and cement must be of particular concern during casting until excessive segregation does not occur.

Fig. 13 - Specimen after bending test

4. Conclusion

Based on the results and discussion above, it can be concluded that the highest compressive strength and flexural strength are obtained with NFC-4 variation, namely the variation with an additional mixture of fly ash by 60% and superplasticizer by 0.5% with a cement water factor of 0.17. The use of fly ash which has more and more potential to make compressive strength and flexural strength of no-fines concrete is higher but needs special attention during casting and compaction processes. The use of superplasticizer Viscocrete 1003 can reduce the use of water by up to 30%, but using a high enough composition makes the slump value very high as well and makes concrete with this variation resulting in compressive strength and flexural strength that is not higher than normal no-fines concrete.

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