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Compressive strength of concrete mixtures of phosphorus powder and glass powder in concrete of grade FC'20 MPA

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ABSTRACT

The research objective in this study is to analyze the effect of substitution of phosphorus powder and glass powder which has an impact on the compressive strength of 20 Mpa fc concrete and to find out the results of testing the compressive strength of concrete with added phosphorus and glass powder at ages 7 days, 14 days, 21 days and 28 days. From the research results, it was found that the compressive strength value of concrete aged 7 days in variations of 3% Glass concrete and 0.35% Phosphorus decreased compared to normal concrete with a ratio of 43%, in variations of Glass concrete 5% and 0.35% Phosphorus decreased compared to normal concrete with a ratio 53% and in the Glass concrete variation 7% & 0.35% Phosphorus decreased to 45.5%. At the age of 14 days in the Glass concrete variation of 3% and 0.35% Phosphorus decreased compared to normal concrete with a ratio of 26%, in the Glass concrete variation of 5% and 0.35% Phosphorus decreased compared to normal concrete with a ratio of 21% and in the Glass concrete variation 7% & 0.35% Phosphorus decreases up to 20%. At 21 days, the Glass concrete variation of 3% and 0.35% Phosphorus increased compared to normal concrete with a ratio of 6.5%, the Glass concrete variation of 5% and 0.35% Phosphorus decreased compared to normal concrete with a ratio of 6% and the Glass concrete variation 7% & 0.35% Phosphorus decreases up to 11%. At 28 days in the Glass concrete variation of 3% and 0.35% Phosphorus increased compared to normal concrete with a ratio of 1.10%, in the Glass concrete variation of 5% and 0.35% Phosphorus decreased compared to normal concrete with a ratio of 0.95% and in the Glass concrete variation 7 % & 0.35% Phosphorus decreased to 18.02%.

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1. INTRODUCTION

Concrete is a very significant and dominant factor as a material in building structures. Concrete is usually composed of cement, fine aggregate, aggressive aggregate and water. However, with the growth of time, the use of concrete materials continues to be diverse. Many efforts are made to obtain concrete with greater quality than ordinary conventional concrete which is also certainly at a cheaper cost (Li et al., 2022).

In terms of cheap one of the most expensive parts of concrete is cement. With various efforts cement is tried to be exchanged or reduced usage. Some substitute materials can efficiently improve the performance of concrete, after passing tests at various levels or types and judged to meet the

standards formalized listed economic considerations let alone social, has been made in bulk (Hamdi et al., 2022). These materials come from various sources including steel industry waste and other industrial waste.

The author notices the existence of glass waste both from industry or building demolition and from households in large quantities, which is likely to be utilized as well as an alternative solution to environmental problems caused by glass waste. The use of industrial waste such as glass is a good alternative, because there will be a utilization process so that waste can be reduced (Andreola et al., 2016; Jani & Hogland, 2014). Some glass waste from the remaining production is reprocessed into new glass, and the rest is just thrown away without being utilized properly, there are also glass bottles that are produced for one-time use only, so that used bottles become a pile of waste, plus the remaining glass waste processed by glass craftsmen who are thrown away carelessly because they cannot be utilized (Ps, 2008).

Glass is an amorphous material made by dry silica with basic oxides. Glass powder (split) has a grain size of 0.075 mm - 0.15 mm (passes sieve no 200), is not porous and is pozzolanic. Glass powder has advantages over other materials (Lolo et al., 2019), namely: zero water absorption, the hardness of the glass makes the concrete resistant to abrasion which can only be achieved by a few natural aggregates, glass powder improves the content of fresh concrete so that high strength can be achieved without the use of superplasticizers, and glass powder has pozzoland properties so that it can function as a substitute for cement and filler. The substance content in glass powder has some of the same constituents as cement. Glass powder contains SiO2 (61.72%), Al2O3 (3.45%), Fe2O3 (0.18%) and CaO (2.59%) (Coulson et al., 1999; Purnomo & Hisyam, 2014) while cement contains CaO (60-67%) , SiO2 (17-25%), Al2O3 (0.3-0.8%), MgO (0.3-0.8%) and SO3 (0.3-0.8%) (Amin & User, 2017), so glass powder is likely to be used as a cement mixture. In addition, the content in glass powder also has the same constituent elements as silica fume, namely: SiO2 (92%), Al2O3 (0.30%), Fe2O3 (0.10%) and CaO (0.15%) (Christiansen, 2013; Jamaaluddin, 2022). Where the use of silica fume in concrete mixes aims to produce concrete with higher strength, glass powder is also likely to increase the compressive strength of concrete. However, the ratio of the content contained in cement and glass powder is certainly not balanced, so mixing the two materials certainly has a limited mixing rate and has a mixing ratio to produce stronger and more effective concrete.

Noting from previous research (Karwur et al., 2013) which uses glass powder as a mixture for making concrete, mixing glass powder is varied (0%, 6%, 8%, 10%, 12% and 15%) of the weight of cement, the value of the compressive strength of concrete at the age of 28 days for 6%, 8% and 10% glass has increased against 0% glass but the value of the compressive strength of concrete in the next variation of 12% and 15% glass variation has decreased. The optimum compressive strength value is obtained at 10% glass variation which is 31.1 MPa. Utilization of glass powder as a powder in self-compacting concrete, obtained the optimum level of partial substitution of glass powder is 10% (Younis Khudair et al., 2020). The composition produces an average compressive strength and split tensile strength of 49.08MPa and 4.08 MPa, which shows an increase in strength of +0.33% and +4.88%. Glass powder content up to 20% still produced concrete above the planned compressive strength of 40 MPa. At up to 30% glass powder content, structural concrete can still be produced with a compressive strength of 32.23 MPa.

This research uses glass powder and Phosphorus Powder as filler to increase the density of concrete. The composition of glass powder and Phosphorus Powder varies, so that the optimum levels of glass powder and Phosphorus Powder will be known to produce concrete mixes of FC'20 Mpa quality. The silica content contained in glass powder will affect the cement in the concrete mixture, so that the quality of concrete will also be affected. Samples will be made as many as 3 pieces for each variation of glass powder content of 3%, 5% and 7% and Phosphorus Powder of 0.35% by weight of cement.

Each sample will be tested at 7 days, 14 days, 21 days and 28 days with compressive test, split tensile test, and modulus of elasticity. The planned concrete quality is Concrete fc'20 MPa. The quality of this concrete plan already includes the requirements of the high quality concrete group. High quality concrete is concrete that has a compressive strength of 41.4 Mpa (Mohamad et al., 2020). In this research, type I portland cement from Semen Gresik brand, fine aggregate from Sungai Progo, and coarse aggregate from Celereng were used to make the high quality concrete mix. The

high-grade concrete mix used silica fume and superplasticizer. Then, based on the composition of the high-grade concrete mix, a concrete variation with glass powder as filler was made. The composition of glass powder varies as mentioned. Based on the use of glass powder as a filler in the concrete variation, the effect of using glass powder in high-grade concrete mixtures with silica fume and superplasticizer will be known.

In this study, the authors were interested in conducting a research with the title "Compressive Strength of Concrete Mixed with Phosphorus Powder and Glass Powder in Concrete of Quality FC'20 Mpa". Through this research, it is expected to produce more effective and economical concrete quality.

2. RESEARCH METHOD

The type of research used is qualitative research (Starman, 2013). Qualitative research is research on research that is descriptive and tends to use analysis. This research was conducted from May to July 2023 in the testing process at UPTD. Construction Materials Laboratory of the Public Works and Spatial Planning Office of North Sumatra Province located at Jln.Sakti Lubis No.7R Medan. Data collection techniques are carried out by experimental methods on several test objects from various treatment conditions tested in the laboratory. Data collection techniques are divided into two namely primary and secondary data. The process of making test objects can be done after the job mix desaign has been obtained from the data data. Test objects are made from fresh concrete. The materials that need to be prepared in the manufacture of test objects must be in accordance with the job mix design that has been determined. The materials used include fine aggregate, coarse aggregate, cement and water. In preparation for this manufacture each material must be weighed according to its respective proportions.

3. RESULTS AND DISCUSSIONS

3.1 Betok Compressive Strength Testing

The test results for compressive strength of concrete and split tensile strength of normal and varied concrete in this study are shown in the following table:

Table 1. Test results for concrete compressive strength

Test Objects	Age (Days)	Mass (kg)	Percentage		Compressive Strength
1	7	3.84	3%	0.35%	11.6
2		3.78			16.3
1	7	3.9	5%	0.35%	9.4
2		3.86			7.6
1	7	3.9	7%	0.35%	10.9
2		3.9			8
1	14	3.84	3%	0.35%	14.8
2		3.96			17.1
1	14	3.92	5%	0.35%	15.8
2		3.9			15.9
1	14	3.88	7%	0.35%	16
2		3.94			13.8
1	21	3.84	3%	0.35%	21.3
2		3.92			18.6
1	21	3.94	5%	0.35%	18.8
2		3.88			15.8
1	21	3.88	7%	0.35%	17.8
2		3.92			16.7
1	28	3.43	3%	0.35%	22.01
2		3.50			21.77
1	28	3.41	5%	0.35%	19.0
2		3.39			19.2
1	28	3.38	7%	0.35%	18.02
2		3.38			18.57

From table 1 above, it shows that the compressive strength of concrete increases with increasing concrete age in each variation. This is because the hydration process in the cement paste mixture is increasing and strengthening the bond of the concrete material. However, increasing the volume of the mixture of phosphorus powder and glass powder can cause a significant decrease in

the quality of the concrete which is caused by the adhesive contained in phosphorus powder and glass powder not being as good as that of type 1 portland cement, thereby reducing the adhesion power which results in a decrease in the quality of the concrete test results.

Characteristics of Normal Benton and Concrete Mixed with Phosphorus Powder and Glass Powder Aged 7 Days.

Table 2. *Test Results for Compressive Strength of Concrete Aged 7 Days*

Parameter		3% Glass & 0.35% Phosphorus	Reduction	5% Glass & 0.35% Phosphorus	Reduction	7% Glass & 0.35% Phosphorus	Reduction
Compressive Strength	Test Object 1	11.6	42 %	9.4	53 %	10.9	45.5 %
	Test Object 2	16.3	18.5 %	7.6	62 %	8	60 %

From table 2 above, it can be seen that the greater the percentage of concrete additives mixed, the more the compressive strength value will decrease by 42% compared to normal concrete in mixed concrete types.3% Glass and 0.35% Phosphorusin test specimen 1 and there was a decrease in the compressive strength value of concrete by 18.5% compared to normal concrete in this type of concrete mixture3% and 0.35% glass in test specimen 2, in test object 1 the concrete compressive strength value decreased by 53% and in test object 2 the concrete compressive strength value decreased by 62% in the type of 5% and 0 glass powder mixture, 35% Phosphorus. In test object 1, the concrete compressive strength value decreased by 45.5% and in test object 2, the concrete compressive strength value decreased by 60% in the type of mixture of 7% glass powder and 0.35% phosphorus.

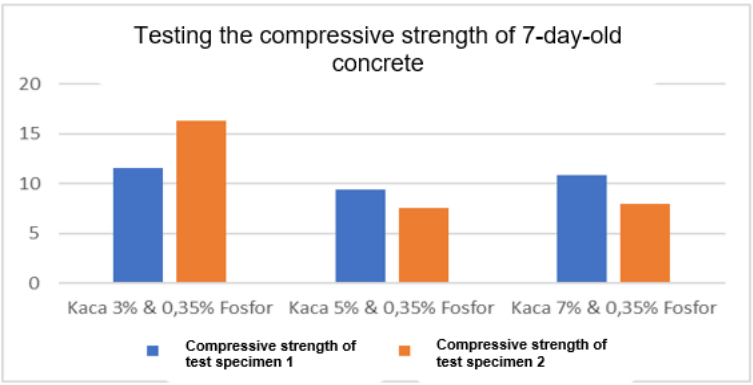

Figure 1. Graph of Compressive Strength Test Results for 7 Day Concrete

Characteristics of Normal Benton and Concrete Mixed with Phosphorus Powder and Glass Powder Aged 14 Days

Table 3. Test Results for Compressive Strength of Concrete Age 14 *Day*

Parameter		3% Glass & 0.35% Phosphorus	Reduction	5% Glass & 0.35% Phosphorus	Reduction	7% Glass & 0.35% Phosphorus	Reduction
Compressive Strength	Test Object 1	14.8	26 %	15.8	21 %	16	20 %
	Test Object 2	17.1	14.5 %	15.9	20.5 %	13.8	31 %

From table 3 above, it can be seen that the greater the percentage of concrete additives mixed, the more the compressive strength value will decrease by 26% compared to normal concrete in mixed concrete types.3% Glass and 0.35% Phosphorusin test specimen 1 and there was a decrease in the compressive strength value of concrete by 14.5% compared to normal concrete in this type of concrete mixtureGlass 3% and 0.35% in test object 2, test object 1 experienced a decrease in the compressive strength value of concrete by 21% and test object 2 experienced a decrease in the compressive strength value of concrete by 20.5% in the type of mixture of 5% glass powder and 0.35% Phosphorus. Test object 1 experienced a decrease in the compressive strength value of the

concrete by 20% and test object 2 experienced a decrease in the compressive strength value of the concrete by 31% in the type of mixture of 7% glass powder and 0.35% phosphorus.

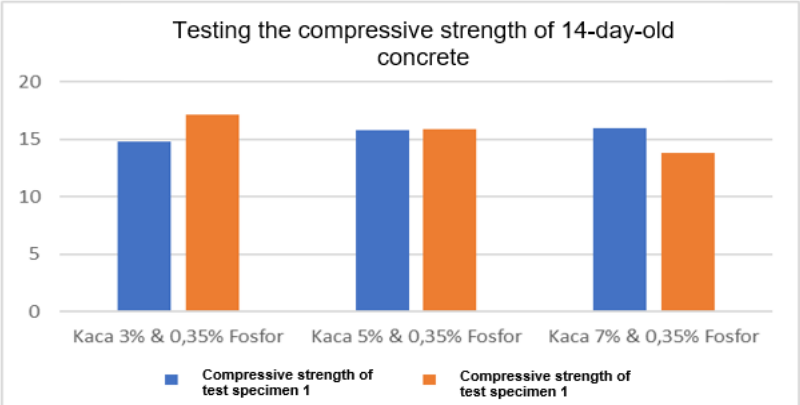

Figure 2. Graph of Compressive Strength Test Results for 14 Day Concrete

Characteristics of Normal Benton and Concrete Mixed with Phosphorus Powder and Glass Powder Aged 21 Days

Table 4. Compressive Strength Test Results for Concrete Age 21 *Day*

Parameter		3% Glass & 0.35% Phosphorus	Reduction	5% Glass & 0.35% Phosphorus	Reduction	7% Glass & 0.35% Phosphorus	Reduction
Compressive Strength	Test Object 1	21.3		18.8	6%	17.8	11%
	Test Object 2	18.6	7%	15.8	21%	16.7	16.5%

From table 4 above, it can be seen that the greater the percentage of mixed concrete additives, the more the compressive strength value will decrease by 0% compared to normal concrete in mixed concrete types.3% Glass and 0.35% Phosphorusin test specimen 1 and there was a decrease in the compressive strength value of the concrete by 7% compared to normal concrete in this type of concrete mixture3% and 0.35% glass in test specimen 2, in test object 1 the concrete compressive strength value decreased by 6% and in test object 2 the concrete compressive strength value decreased by 21% in the type of 5% and 0 glass powder mixture, 35% Phosphorus. Test object 1 experienced a decrease in the compressive strength value of the concrete by 11% and test object 2 experienced a decrease in the compressive strength value of the concrete by 16.5% in the type of mixture of 7% glass powder and 0.35% phosphorus.

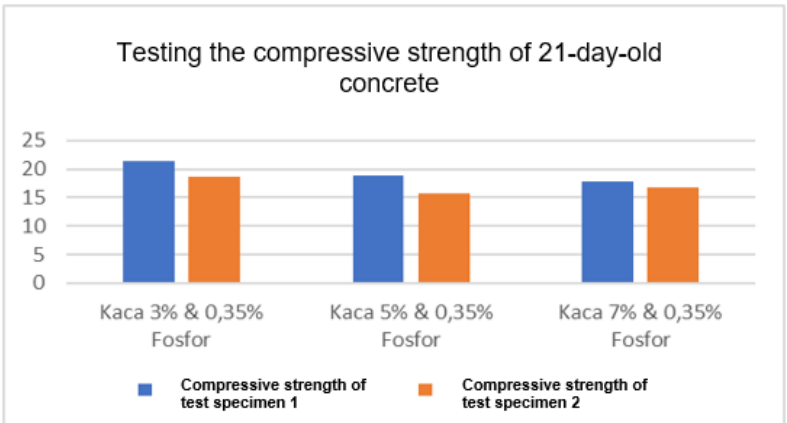

Figure 3. Graph of Compressive Strength Test Results for 21 Day Concrete

Characteristics of Normal Benton and Concrete Mixed with Phosphorus Powder and Glass Powder Aged 28 Days

Table 5. Compressive Strength Test Results for Concrete Age 28 *Day*

Parameter		3% Glass & 0.35% Phosphorus	Reduction	5% Glass & 0.35% Phosphorus	Reduction	7% Glass & 0.35% Phosphorus	Reduction
Compressive Strength	Test Object 1	22.01	+1.10	19	0.95	18.02	0.90
	Test Object 2	21.77	+1.08	19.2	0.96	18.54	0.92

From table 5 above, it can be seen that the greater the percentage of mixed concrete additives, the more the compressive strength value will increase by 1.10% compared to normal concrete in mixed concrete types.3% Glass and 0.35% Phosphorusin test specimen 1 and there was an increase in the compressive strength value of concrete by 1.08% compared to normal concrete in this type of concrete mixture3% and 0.35% glass in test object 2, test object 1 experienced a decrease in the concrete compressive strength value of 0.95% and test object 2 experienced a decrease in concrete compressive strength value of 0.96% in the 5% and 0 glass powder mixture. 35% Phosphorus. Test object 1 experienced a decrease in the compressive strength value of the concrete by 0.90% and test object 2 experienced a decrease in the compressive strength value of the concrete by 0.92% in the type of mixture of 7% glass powder and 0.35% phosphorus.

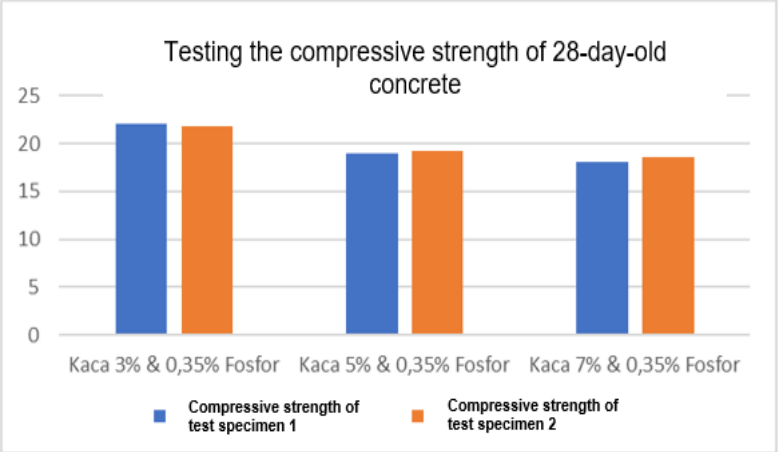

Figure 4. Graph of Compressive Strength Test Results for 28 Day Concrete

Comparison of Normal Concrete and Concrete Mixed with Phosphorus Powder and Glass Powder

Table 6. Comparison of Normal Concrete and Mixed Concrete*Phosphor Powder and Glass Powder*

Parameter			Normal Concrete	3% Glass & 0.35% Phosphorus	%	5% Glass & 0.35% Phosphorus	%	7% Glass & 0.35% Phosphorus	%
Compressive Strength	7 days	Test Object 1	20 Mpa	11.6	42	9.4	53	10.9	45.5
		Test Object 2	20 Mpa	16.3	18.5	7.6	62	8	60
	14 days	Test Object 1	20 Mpa	14.8	26	15.8	21	16	20
		Test Object 2	20 Mpa	17.1	14.5	15.9	20.5	13.8	31
	21 Days	Test Object 1	20 Mpa	21.3	+ 6.5	18.8	6	17.8	11
		Test Object 2	20 Mpa	18.6	7	15.8	21	16.7	16.5
	28 Days	Test Object 1	20 Mpa	22.01	+1.10	19	0.95	18.02	0.90

Parameter		Normal Concrete	3% Glass & 0.35% Phosphorus	%	5% Glass & 0.35% Phosphorus	%	7% Glass & 0.35% Phosphorus	%
	Test Object 2	20 Mpa	21.77	+1.08	19.2	0.96	18.54	0.92

From table 6 above, we can see the compressive strength value of concrete aged 7 days for various concrete variations3% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 43%, in concrete variations5% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 53% and to variations in concreteGlass 7% & 0.35% Phosphorus decreases to 45.5%. Compressive strength value of concrete aged 14 days for various concrete variations3% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 26%, in concrete variations5% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 21% and to variations in concreteGlass 7% & 0.35% Phosphorus decreases up to 20%. Compressive strength value of concrete aged 21 days for various concrete variations3% Glass and 0.35% Phosphorusincreases compared to normal concrete with a ratio of 6.5%, in concrete variations5% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 6% and to variations in concreteGlass 7% & 0.35% Phosphorus decreases up to 11%. Compressive strength value of concrete aged 28 days for various concrete variations3% Glass and 0.35% Phosphorusincreases compared to normal concrete with a ratio of 1.10%, in concrete variations5% Glass and 0.35% Phosphorusdecreased compared to normal concrete with a ratio of 0.95% and to variations in concreteGlass 7% & 0.35% Phosphorus decreases to 18.02%.

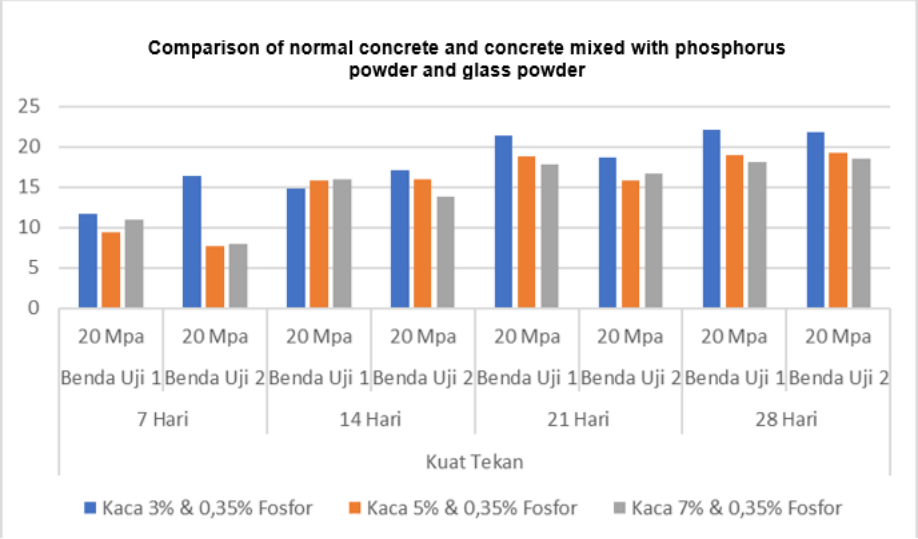

Figure 5. Comparison graph of compressive strength of normal concrete and concrete mixed with phosphorus powder and glass powder

3.2 Relationship between Concrete Compressive Strength and Concrete Age

In terms of the development of compressive strength, based on SNI 03-6805-2002 it is stated that the ratio of concrete age to concrete compressive strength is directly proportional. Where the longer the age of the concrete, the compressive strength of the concrete will increase and conversely, the shorter the age of the concrete, the smaller the compressive strength.

Table 7. Relationships between Concrete Compressive Strength and Concrete Age

No.	Age (days)	*fcm*	Unit
1	7	25.90	MPa
2	14	31.20	MPa
3	21	37.58	MPa
4	28	42.38	MPa

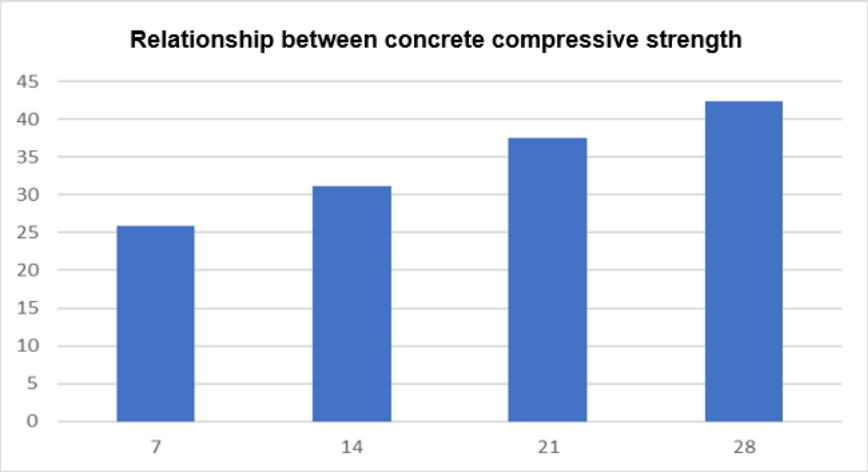

Figure 6. Relationship between concrete compressive strength and concrete age.

4. CONCLUSION

The compressive strength value of 28 days old concrete in 3% Glass and 0.35% Phosphorus concrete variation increased against normal concrete with a ratio of 1.10%, in 5% Glass and 0.35% Phosphorus concrete variation decreased against normal concrete with a ratio of 0.95% and in 7% Glass & 0.35% Phosphorus concrete variation decreased to 18.02%.

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