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Strength of Concrete Containing Combination of Macro Straight Glass and Polypropylene Fibre

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Abstract: Concrete is an essential material that is needed in the construction industry. However, concrete has high compressive strength but low in tensile strength making them exposed to cracking and causing defects as well as failure of shrinkage. The aim of this study is to investigate the compressive strength and tensile strength of concrete containing macro straight glass (MSG) and polypropylene (PP) fibre. Different mix design ratio of fibre are used in this study. Compressive strength test and split tensile test were conducted with the design addition of fibre which is 0%, 0.5%, 1.0%, and 1.5% for both type of fibre. It was found that design mix of 1.0% PP fibre with 0.5% MSG had significant increase in compressive strength with 18.01% compared to normal concrete. 1.5% PP fibre with 1.0% MSG also produced highest tensile strength with 36.42% compared to normal concrete. The addition of the fibres improved the compressive strength and tensile strength of concrete.

Keywords: Concrete, Polypropylene, Macro Straight Glass, Compressive Strength, Tensile Strength.

1. Introduction

Concrete is a product and a mass made by combination of cementing medium where the medium is the product of reaction of hydraulic cement and water. Concrete can be made up of several types of cement and other substances such as pozzolan, fly ash, blast furnace slag, microsilica, recycled concrete aggregate, admixtures, polymers, fibres, and more [1]. According to Zollo [2], fibre reinforcement has been frequently used method in cementing materials in order to minimize micro-cracking as well as to escalate the strength and energy absorption capacity. Fibre reinforced concrete also have been proved to be effective in enhancing the failure mode and escalate the concrete's resistance. Plain concrete has weak tension and low resistance in cracking due to their brittle material which will results in defects and failure of the concrete. However these problems can be overcome by adding fibres as helps to

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decrease the crack of mechanical bond between fibre and cement paste [3]. In a statement by Bentur and Mindess [4], concrete containing fibre is advantageous in hindering cracks from happening and distribute micro cracks and macro cracks level. In addition, fibres such as Polypropylene (PP) fibres can reduce the compressive strength as well as increased tensile and flexural strengths [5], thus adding PP in plain concrete may improve the mechanical properties of the concrete [6]. Malhotra et al. [7] has mentioned that Polypropylene (PP) fibres are widely used in concreting technology as they have great advantages including high durability of FRC. Other than that, they also increase the percentage of reducing the concrete's shrinkage [8-9]. In addition, they diminish the spalling effect in high-strength concrete exposed to high temperature [10-11].

According to Pakravan and Ozbakkaloglu [12], concrete is a porous material with poor tensile strength and strain capacity compared to its compressive strength, making it susceptible to cracking. Cracks in concrete structures minimize the structure's serviceability and reliability over its lifetime. Problems of concrete regarding brittleness and low resistance to crack initiation and growth in cement-based materials have been successfully solved by the addition of short fibres of various types and shapes [12]. This problem can be solved by conducting research and study as well as more improvement can be made to concrete's consistency. Concrete takes a long time to harden and build strength, but it does have its own strength limit. A research on enhancing the resilience of concrete by combining it with other materials is extremely beneficial.

Comparable to glass fibre, like some other fibres, has the potential to bridge cracks, and it is frequently used as a fibre reinforcing material to improve the mechanical properties of cementitious composites [13]. Glass fibres are the reinforced materials that are top frequently used for structural construction purposes due their specific strength properties. This also improves stiffness, toughness, hardness, heat distortion, temperature, and mold shrinkage. In fact it also reduce the manufacturing cost significantly [14]. According to Tian et al. [15], glass fibre could be an excellent option as a fibre reinforcement in structural concrete for high compressive strength, higher elastic modulus, better corrosion resistance efficiency, and excellent adhesion with cement hydration products.

This research study the performance of concrete containing the combination of macro straight glass and polypropylene fibre. The objective of the study is to determine the compressive strength and tensile strength of the designd concrete containing MSG and PP fibre.

2. Materials and Methods

The laboratory testings are compressive strength test and split tensile strength test. The tests conducted is to determine the mechanical properties of the concrete containing macro straight glass and polypropylene fibres. The data obtained from test are analyzed and compared to the normal concrete.

2.1 Materials

The materials used in this cement were Ordinary Portland Cement (OPC), coarse aggregates, fine aggregates, polypropylene fibre, macro straight glass and tap water. The PP fibre has 45mm length over diameter and 10mm length of straight glass fibres.

2.2 Methods

In this study, the volume was measured for each concrete component in order to fill up 1m3 of the concrete. Water cement ratio of 0.5 is used in this mix design study. There were two type of concrete sample that were used for the test, a concrete cube with dimension of 100mm x 100mm x 100mm (length x width x height) and cylinder concrete with the dimension of 100mm x 150mm (diameter x height). The concrete cube samples is used for compressive strength test and the concrete cylinder sample is used for split tensile test. The tests are conducted based on BS EN 12390-3:2000(2000) [22]. There were a total of 60 sample for compression test cured at 7 and 28 days. The tensile strength test used 30 sample cured at 28 days.

2.3 Equations

The aim of the compressive strength is to assess that the concrete mixture has meet the requirement for specified strength. After the concrete has reach the maximum compressive strength, the average of three test result for each concrete batch were taken and recorded. The cubes concrete are taken and tested using hydraulic compression machine with 2000kN capacity. The compressive strength will be determined by using the formula shown in Equation 1.

$$\sigma = \frac{F}{A} \; Eq.1$$

where,

σ = Compressive strength

F = Force Applied (N)

A= Area of the specimen (mm^2)

The split tensile strength of the concrete is acquired from applied compressive force along the length of the concrete cylinder. This is because the concrete is highly prone to tensile crack compared to when under different type of compression and applied load. As mentioned before, hydraulic compression machine is used to apply load on the concrete cylinder. In order to make sure the loading is straight, bearing strips are placed at the top and bottom of the specimens. By using Equation 2, the splitting tensile ultimate strength is calculated at the ultimate load capacity.

$$\sigma_t = \frac{2P_t}{\pi DL} \; Eq.2$$

where,

σ t = Resultant split tensile strength (MPa)

Pt = Tensile force exerted when the sample fails (N)

D = Diameter of Cylinder (mm)

L = Length of cylinder (mm)

3. Results and Discussion

The data of compressive strength is shown in Table 2. Figure 1 shows the compressive strength of the fibre reinforced concrete. The compressive strength of concrete containing MSG and PP fibre showed increased strength compared to normal concrete. It can be seen that all the mix design ratio increased in compressive strength with more than 10% percentage compared to normal concrete. From the figure, combination of 1.0% PP with 0.5% MSG produced the highest compressive strength, 37.29 MPa with 18.01% compared to normal concrete. Thus, the mechanical properties of concrete can improve significantly by adding fibres to the mixtures [16-19].

Table 2: Compressive strength of concrete containing polypropylene and macro straight glass

Type of samples		7 days			28 days		
		Per cube (MPa)	Average compressive strength (MPa)	Percentage difference compared to normal (%)	Per cube (MPa)	Average compressive strength (MPa)	Percentage difference compared to normal (%)
Normal concrete		25.91 22.94 25.78	24.88	0	33.17 32.13 28.08	31.13	0
PP fiber 0.5%	Glass Fiber 0.5 %	20.03 23.21 24.59	22.61	9.56	36.68 36.11 34.49	35.76	13.84
	Glass Fiber 1.0 %	22.4 23.99 25.31	23.90	4.02	36.9 35.99 36.13	36.34	15.44
	Glass Fiber 1.5 %	22.18 22.37 21.77	22.11	11.79	35.01 35.29 34.87	35.06	11.87
PP fiber 1.0%	Glass Fiber 0.5 %	19.33 22.11 24.0	21.81	13.15	38.0 37.19 36.69	37.29	18.01
	Glass Fiber 1.0 %	21.37 24.21 23.38	22.99	7.90	37.22 36.31 36.63	36.72	16.48
	Glass Fiber 1.5 %	23.08 23.01 21.19	22.43	10.36	34.81 35.9 35.07	35.26	12.44
PP fiber 1.5%	Glass Fiber 0.5 %	19.3 20.01 19.99	19.77	22.89	35.08 36.77 33.31	35.05	11.85
		21.71 20.13	21.02	16.82	35.32 35.01	35.12	12.05

Glass Fiber 1.0 %	21.21			35.02		
Glass Fiber 1.5 %	21.28 22.3 22.1	21.89	12.79	35.19 34.23 34.17	34.53	10.36

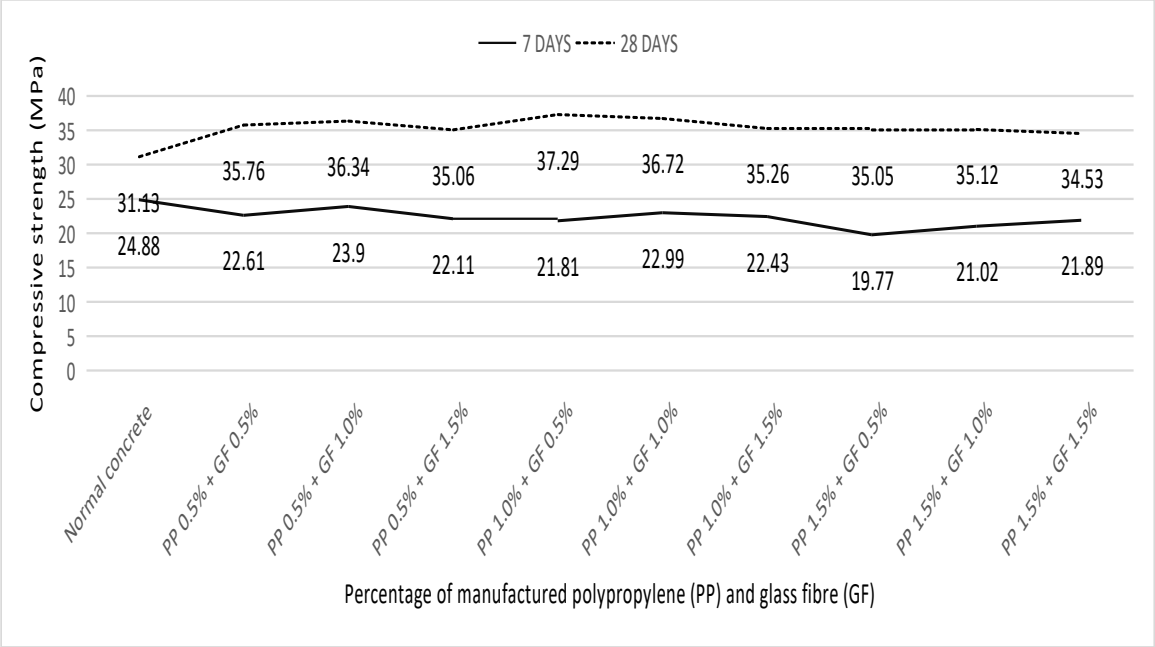

Figure 1: Compressive strength of concrete containing polypropylene and macro straight glass at 7 and 28 days

Consequently, the split tensile strength were also recorded. Table 3 and Figure 2 shows the results of split tensile strength test conducted. From the data, the tensile strength of the fibre reinforced concrete (FRC) has increased more than 20% compared to normal concrete. FRC with ratio of 1.5% PP and 1.0% MSG produced the highest split tensile strength, 3.7 MPa with percentage difference of 36.42% than normal concrete which is 2.56 MPa. This can be supported by Khalid et al. [20], tensile strength of concrete can be improve with adding fibres, manufactured synthetic fibres showed a significant improvement up to 1.5% fibre content. One of the fibre that can solve this problem are glass fibre [21].

Table 3: Split tensile strength between normal concrete and concrete containing polypropylene and macro straight glass

Type of samples		Splitting Tensile 28 days		
		Per cube (MPa)	Average compressive strength (MPa)	Percentage difference compared to normal (%)
Normal concrete		2.56	2.56	0
PP fiber 0.5%	Glass Fiber 0.5 %	3.33 3.31 3.41	3.35	26.73
	Glass Fiber 1.0 %	3.31 3.59 3.67	3.52	31.58
	Glass Fiber 1.5 %	3.11 3.27 3.34	3.24	23.45
PP fiber 1.0%	Glass Fiber 0.5 %	3.30 3.29 3.36	3.32	25.85
	`Glass Fiber 1.0 %	3.33 3.61 3.69	3.54	32.13
	Glass Fiber 1.5 %	3.23 3.35 3.43	3.34	26.44
PP fiber 1.5%	Glass Fiber 0.5 %	3.51 3.45 3.49	3.48	30.46
	Glass Fiber 1.0 %	3.69 3.63 3.79	3.70	36.42
	Glass Fiber 1.5 %	3.48 3.59 3.54	3.54	32.13

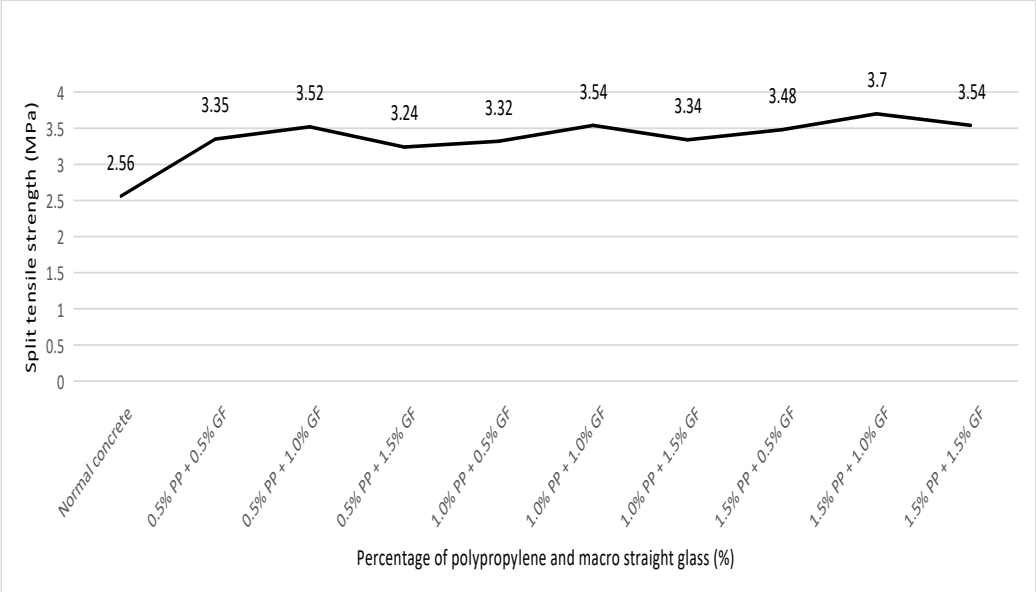

Figure 2: Split tensile strength of concrete containing polypropylene and macro straight glass at 28 days

4. Conclusion

It can concluded that the presence of macro straight glass and polypropylene produce significant improvement on the compressive strength and tensile strength. It can be proven from Figure 1 and 2 where the increasement are being compared to the normal concrete. The design ratio of 1.0% of PP and 0.5% MSG had the greatest improvement in compressive strength, 37.29 MPa with percentage difference of 18.01%. The highest tensile strength were produced, 3.70 MPa with the presence of 1.5% PP and 1.0% MSG. The percentage difference recorded were 36.42% than normal. Other than that, more tests such as workability test, density test, and flexural strength test are recommended in this study in order to obtain the properties and performance of the concrete.

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