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EFFECTS OF LOW FREQUENCY ON POLYMER MIXED CONCRETE

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Abstract

In recent years, it has been found that some concrete structures, even for some high performance concrete and ready mixed concrete under good quality control, start to deteriorate long before reaching their designed service life. In this paper, the main objective of this research is to study the effect of fiber on to the fatigue strength of the polymer-mixed concrete. The polymer concrete that has been used in this study is a series formulation with ratio of 60:30:10 of sand, polyester resin and talcum powder. For a fiber-reinforced polymer concrete, chopped strand mat glass fiber is added 0.25% by weight of mixture and reducing the sand by 59.75% from above ratio. Polymer-mixed concrete with and without fiber were tested with tensile and fatigue. In fatigue test, three points bend specimen with and without notch were employed. The tests were conducted at constant R- ratio = 0.1 and low frequency at 5 Hz.

Keywords: Polymer concrete, fiber-reinforced polymer concrete, fatigue strength, notch

1.0 INTRODUCTION

Centuries ago, human discovered that composite materials should have the combined advantages with superior performance in comparison with the individual material. The idea of combining two different materials to make single superior composite materials is not new. Some of the earliest building materials were composite materials. In composites, a second material is added to obtain specific performance that is not available in the unmodified material.

A Composite material is a complex material such as wood or fiberglass, in which two or more distinct materials or phases, structurally complementary substances, especially metals, ceramics, glasses and polymer, are combined to produce structural or functional properties that are not present in any individual component. Simply state that, a composite is a combination of the materials joined into a whole to create an end product for a specific purpose. Composite materials are becoming more popular in the construction industry nowadays. They exhibit a behaviour with properties that are not easily found in any simple material. Many of these desirable features are obtained more efficiently and often at lower cost. Traditionally, the use of the composite materials in structural engineering applications has been limited to two very common materials, namely steel and concrete.

The effects of fiber for reinforcement in polymer laminates are well-known and have led researchers to the idea of using fiber reinforcement in polymer concrete. Polymer concrete displays brittle characteristics

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which is limited in its usefulness for load-bearing applications although it is stronger about 3–5 times in flexure than conventional Portland cement concrete. Polymer–mixed concrete and fiber-reinforced concrete material are new construction materials that may be used in the construction industries of building structures, pipelines and railway slippers. Depending on the composition, polymer-mixed concretes may possess high strength, density and chemical resistance to most industrial aggressive media, and high decorative and finishing futures.

2.0 BACKGROUND/LITERATURE REVIEW

Polymers concrete has been used in construction a long time ago in the fourth millennium B.C when the clay brick walls of Babylonia were built using the natural polymer asphalt in the mortar. Polymer concrete is a composite material that is formed from polymerization of a monomer or aggregate mixture. It has properties of high compressive strength, fast curing, high specific strength and resistance to chemical attack. A number of researches has been conducted regarding the effect of various parameters like resin type, fiber reinforcement, curing conditions, aggregate type and silane coupling agents on the properties polymer concrete.

Application of Polymer-mixed concrete can be seen in repairing existing structure and fabrication of precast product (Yeon et al., 2014). Addition of sulphur by controlling crystallization during manufacturing process increases the water absorption character and shows the improvement of hydro-mechanical behaviour of the polymer-mixed concrete (Mohamed & Gamal, 2009). The result indicates that this type of polymer-mixed concrete has high compressive strength and high resistance to permeation of water which is suitable for application in waste management system.

The usage of recycled fiber and aggregates in polymer-mixed concrete (Ahmadi et al., 2017) reduce the required concrete thickness in pavement construction because it can replace the natural aggregates in certain ratio. This lead the enhancement of materials usage especially recycled materials in the construction industry. (Dehghan et al., 2017) suggest the addition of recycled glass fiber reinforced polymer to the Portland cement which reported improvement in splitting tensile strength in most cases. However, compressive strength decreases because water contained in the recycled glass fiber reinforced polymer may have been released during concrete mixing.

Most existing pavements and bridge decks repair are done using unsaturated polyester (UP) concrete. Using Unsaturated Polyester-methyl methacrylate polymer (UP-MMA) which has better workability, it can be apply in both precast and cast-in polymer-mixed concrete (Hyun & Yeon, 2012). The flexural fatique performance was analysed using the two-parameter Weibull distributions and reported to have strong statistical validity for fatigue life analysis (Yeon et al., 2017).

Based on (Raman et al., 2013), between two types of resins which are epoxy and polyester, epoxy polymer concrete has far superior mechanical properties and durability. From (Golestaneh et al., 2010) studies show that conventional concretes on furan resin using aggregate mint concrete resulting many favourable advantages. The advantages are low proportion of fine fillers with minimum content and the mechanical strength is much better. Moreover, the experiment measures the effect of polymer fiber on properties of concrete (Tomas U. Ganiron, 2013) shows that polymer fiber as admixture gave efficient characteristic on the performance of the concrete to its properties such as better strength, durability, elasticity and shrinkage.

Furthermore, different concretes require different degrees of durability depending on the exposure environment and the properties desires. According to (Minu Miriam & Ravikumar, 2016) life and ultimate durability of concrete can be based on their concrete ingredients, their proportioning and service environment.

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3.0 METHODOLOGY

In order to have a good achievement in this research, suitable methodology or good work processes must be applied. Please refer to Figure 1 for the Flow Chart of Methodology.

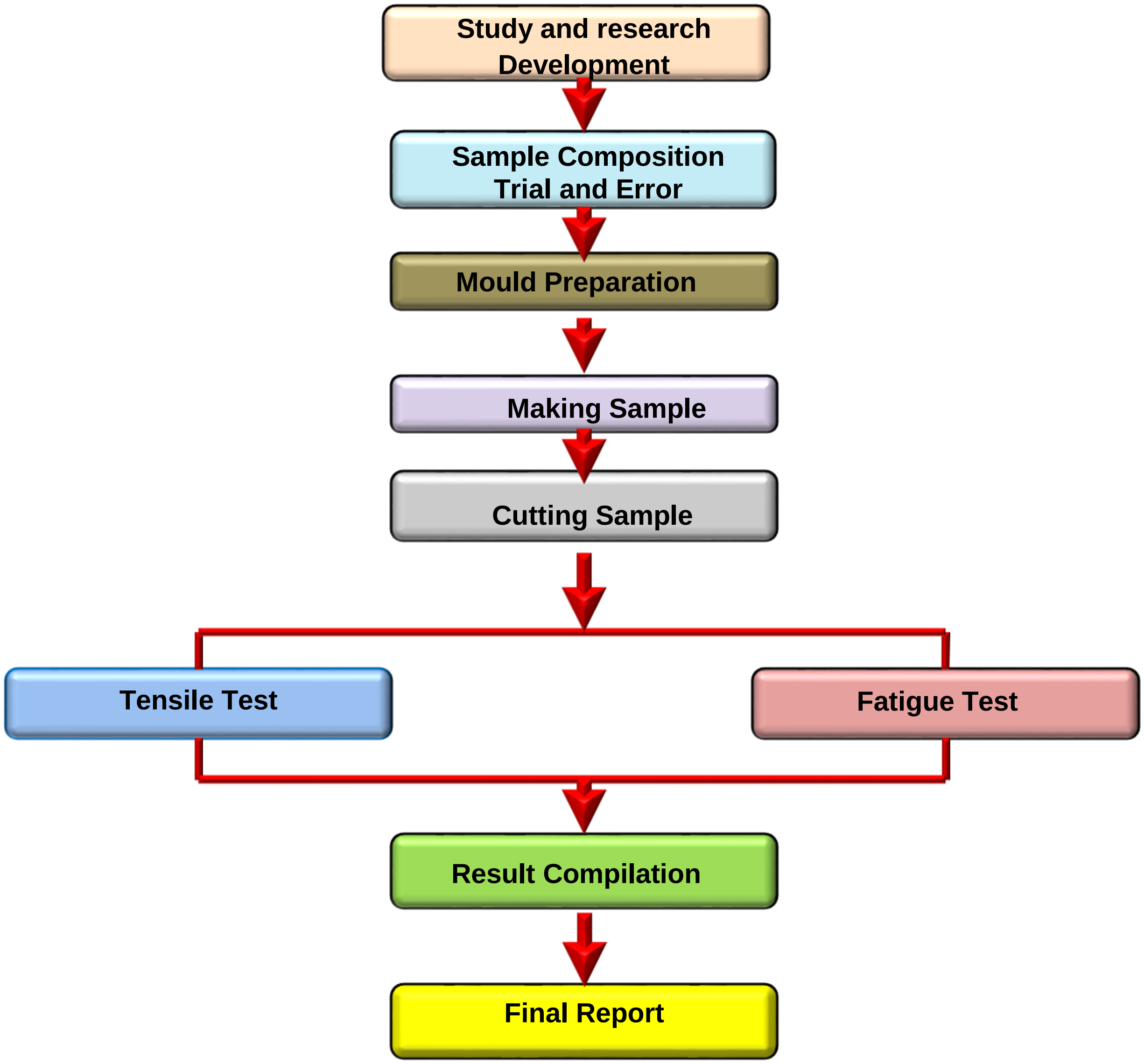

Figure 1 Flow Chart of Methodology

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3.1 Raw Material

The materials used in the mixture of polymer mixed concrete:

1. Polyester Resin (Polymer 820 -I- WPT (A)).
2. Aggregate (Silica sand/ river sand ≥ 600µm).
3. Talcum Powder (Lioxing Talc Powder)
4. Hardener (Metyl Ethyl Ketone Peroxide (MEKP)
5. Wax and Multi-Purpose Lubricant(MP10)
6. Chopped Strand Mat Fiber

See below Figure 2 for the materials to make the polymer mixed concrete.

a) Polyester Resin.

b) Aggregate.(Silica sand)

c) Talcum (Lioxing Talc Powder)

d) Chopped Strand Mat Fiber

e) Hardener (Metyl Ethyl Ketone Peroxide (MEKP)

Figure 2 The Materials To Make The Polymer Mixed Concrete

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3.2 Preparing Sample of Polymer Concrete

In this research preparing sample of Polymer Concrete is the most important thing to be prepared firstly before the experiment and testing can be done. Two types of sample of polymer mixed concrete with and without fiber need to be prepared. In order to get exact composition for mould polymer mixed concrete with and without fiber, trial samples must be made by using the ratio (sand: polyester: talcum powder).

In doing trial samples, varies of silica aggregate sizes were used in order to get suitable sizes for a good sample. The composition of silica in this project such as river sand was used because it can produce fine surface and better quality of sample. Polyester resin, talcum and hardener were mixed together at first until it gets balance mixture which is not too wet or too hard. The percentage or composition of resin was due to it.

The composition of hardener is important to be measured, because the quality of hardener can affect the hardened of the mixture, either it will harden so fast or the mixture will not be completely hardened. In doing a trial sample for polymer concrete with fiber, the amount of fiber needs to be determined and measured. Besides that, the way on how to mix it also becomes very important so that the fibers can properly distribute with the mixture. This explains why trial samples need to be made. The flow chart of making the sample and process of polymer mixed concrete preparation can be referred to Figure 3 and Figure 4 respectively.

3.3 Specimen Preparation

The Sample was divided into two parts for experimental tensile and fatigue strength tests and it was cut into two sizes. As for the tensile test, the samples with and without fiber were cut into size of 20mm width x l4mm thick x 200mm long. For fatigue strength test, the samples were cut into size of 12mm thick x 25mm width x 110mm long. The length dimension for the specimens fatigue strength test must be greater than the length of distance between two spans (80mm) in order to be located for three point bend test.

3.4 Tensile Test For The Materials

Tensile test machine UTM 1000 Universal Testing Machine Digital Servo Control is used with crosshead speed of 2.5 mm/min and at full scale load range of 100.00 kN. All tests were done in air at 24°C and 73% of humidity. A same procedure for tensile test was conducted for both samples, polymer concrete with and without fiber reinforcement to determine the maximum stress of the materials. The configuration of the testing is shown in Figure 5.

3.5 Fatigue Strength Test

For fatigue strength test, the specimen of polymer concrete with and without fiber will be testing on three point bend. All the specimens with and without fiber will be tested without notch and with notch. The configuration of fatigue strength test for both samples is shown in Figure 6. The machine used for fatigue strength test was also UTM 1000 Universal Testing Machine Digital Servo Control.

In this fatigue strength test, constant parameters were implemented for the stress amplitude loading and the frequency of the test. The low frequency of 5 Hz was used and the stress amplitude loading 0.5mm/sec was maintained at a constant R- ratio = 0.1. The load test will be repeated to fluctuate until the fatigue damage occurs and causes the specimen to break. The machine or the experiment must be stopped immediately when the specimen breaks, so that the number of cycles of the fluctuating load can be noted down. All tests were done with air temperature of 24°C and 73% of humidity.

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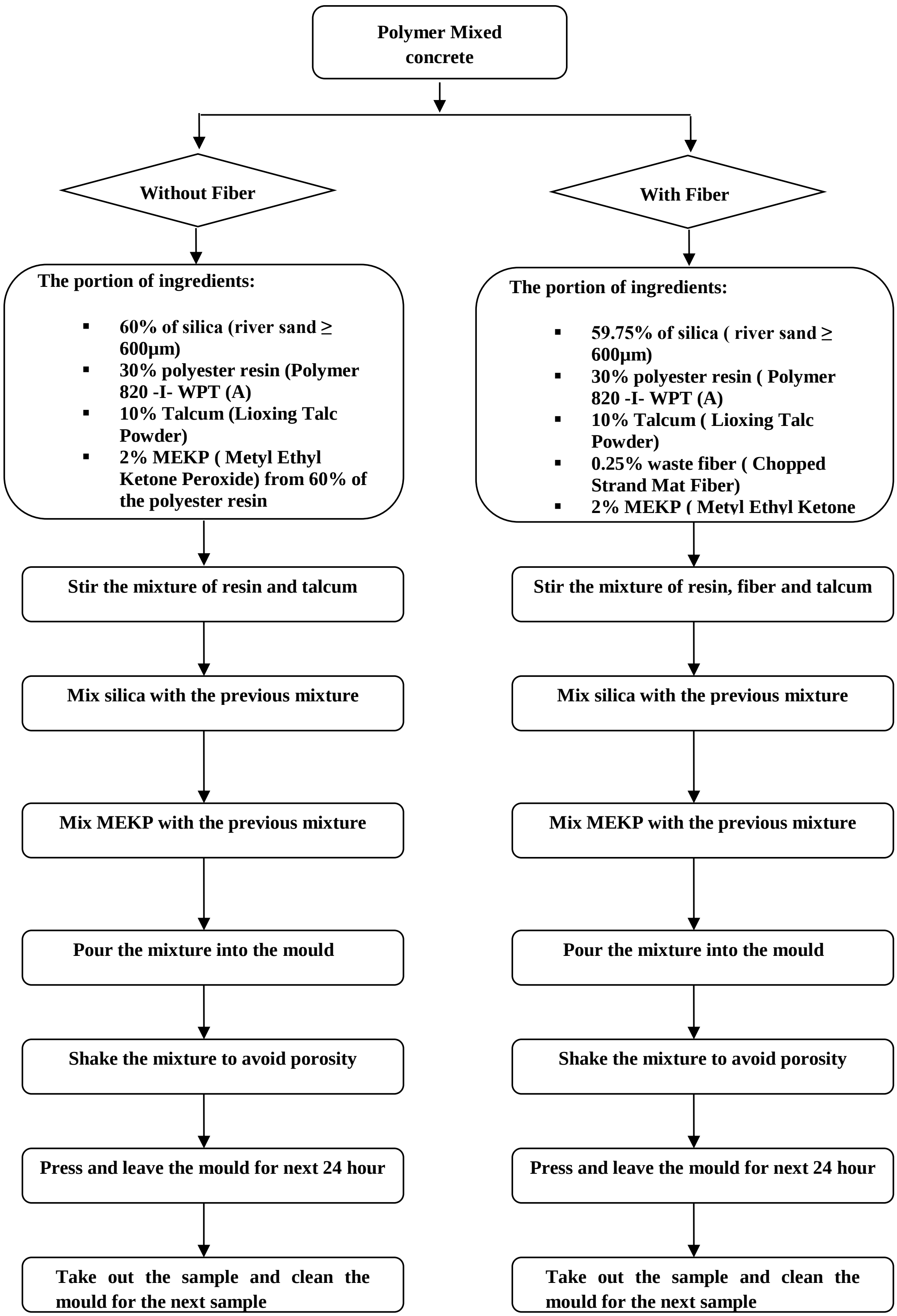

Figure 3 **Flow Chart of Making Sample.**

Figure 4 The Process of Polymer Mixed Concrete Preparation

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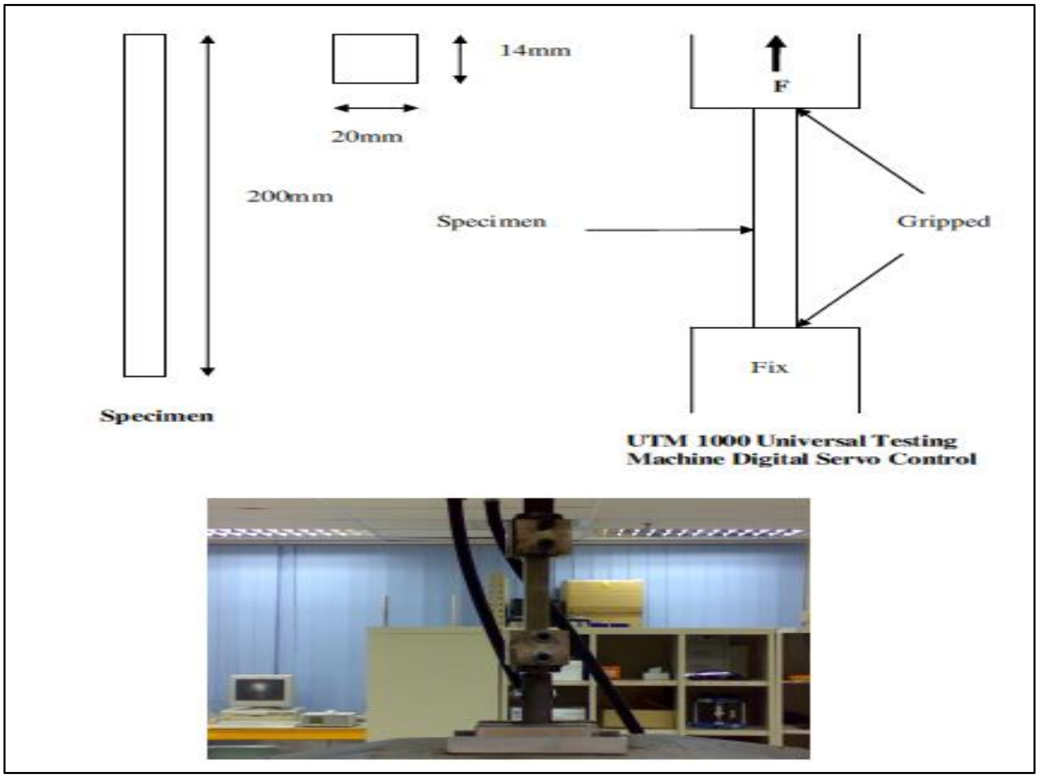

Figure 5 Tensile Test Configurations

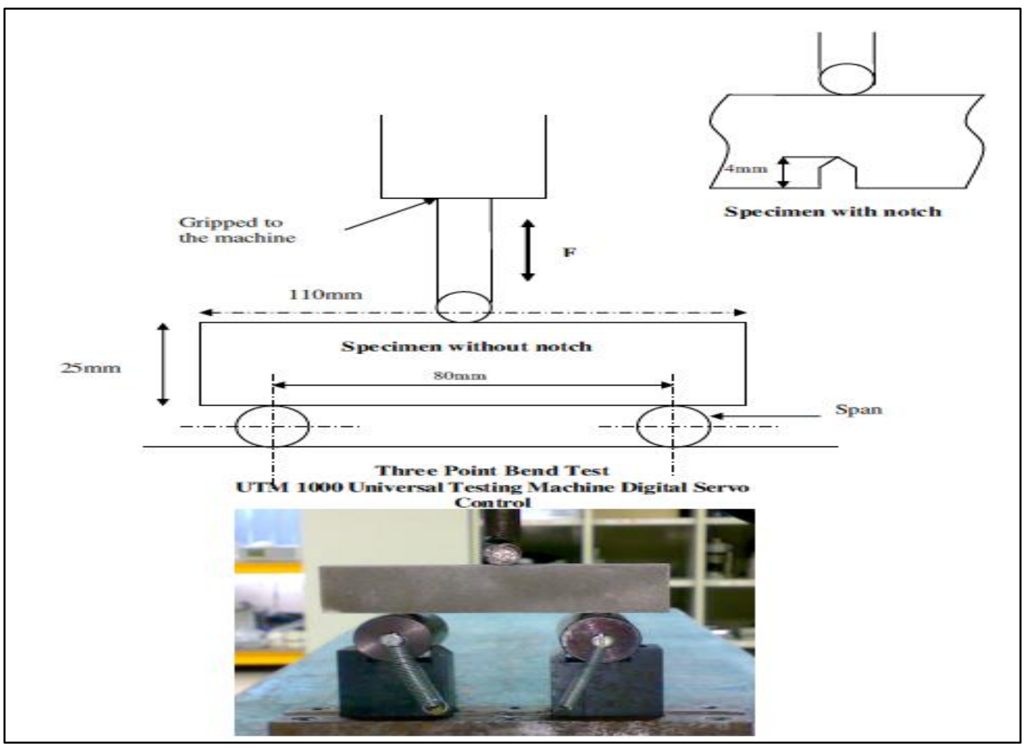

Figure 6 Fatigue Strength Test Configurations

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4.0 RESULTS AND DISCUSSION

4.1 Density Of Composite Materials

The density measurements have been taken for tensile and fatigue specimen with two different types of specimen which is polymer-mixed concrete with fiber (PCF) and polymer-mixed concrete without fiber (PC). Table 1 shows the results of tensile average density for specimens PC and PCF (Size 20mm width x l4mm thick x 200mm long).

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Table 1 Tensile Average Density for Specimens PC and PCF (Size 20mm width x l4mm thick x 200mm long).

Specimen	No	mass(kg)	Volume(mm^3)	Density(kg/mm^3)	Average Density
PC	1	0.09596	56000	1.71357E-06	**1.72142E-06**
	2	0.09309	56102	1.6593E-06	
	3	0.09708	54302	1.78778E-06	
	4	0.09452	55492	1.70331E-06	
	5	0.09784	55981	1.74774E-06	
	6	0.09495	55306	1.71681E-06	
PCF	1	0.09452	56000	1.68786E-06	**1.68727E-06**
	2	0.09484	55988	1.69393E-06	
	3	0.09408	54461	1.72747E-06	
	4	0.09303	55457	1.67752E-06	
	5	0.09398	55988	1.67857E-06	
	6	0.09251	55787	1.65827E-06	

For fatigue test it has been divided into two groups which are without notch and with notch. Table 2 and Table 3 show the results of fatigue average density at different specimens prepared without notch and with notch for polymer-mixed concrete with fiber (PCF) and polymer-mixed concrete without fiber (PC) (Size of 12mm thick x 25mm width x 110mm long).

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Table 2 Fatigue Average Density for Specimens PC and PCF Without Notch
(Size of 12mm thick x 25mm width x 110mm long)

Specimen	No	mass(kg)	Volume(mm^3)	Density(kg/mm^3)	Average Density
PC	1	0.06582	33000	1.99455E-06	**2.02482E-06**
	2	0.06844	32910	2.07961E-06	
	3	0.0657	32988	1.99163E-06	
	4	0.06513	32987	1.97441E-06	
	5	0.06425	32975	1.94845E-06	
	6	0.06736	33018	2.0401E-06	
	7	0.06275	32310	1.94212E-06	
	8	0.071	32989	2.15223E-06	
	9	0.06931	33000	2.1003E-06	
PCF	1	0.06631	32975	2.01092E-06	**2.00529E-06**
	2	0.06498	32987	1.96987E-06	
	3	0.06969	33000	2.11182E-06	
	4	0.06336	33000	0.00000192	
	5	0.06829	32910	2.07505E-06	
	6	0.06292	32998	1.90678E-06	
	7	0.06696	33018	2.02798E-06	
	8	0.06312	32989	1.91337E-06	
	9	0.06969	33000	2.11182E-06	

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Table 3 Fatigue Average Density for Specimens PC and PCF With Notch
(Size of 12mm thick x 25mm width x 110mm long)

Specimen	No	mass(kg)	Volume(mm^3)	Density(kg/mm^3)	Average Density
PC	1	0.06482	33018	1.96317E-06	**1.99485E-06**
	2	0.06744	32310	2.08728E-06	
	3	0.0647	32989	1.96126E-06	
	4	0.06413	33000	1.94333E-06	
	5	0.06325	33000	1.91667E-06	
	6	0.06636	32910	2.01641E-06	
	7	0.06175	32988	1.87189E-06	
	8	0.07	32987	2.12205E-06	
	9	0.06831	32975	2.07157E-06	
PCF	1	0.06531	32910	1.9845E-06	**1.97495E-06**
	2	0.06398	32998	1.93891E-06	
	3	0.06869	33018	2.08038E-06	
	4	0.06236	32989	1.89033E-06	
	5	0.06729	33000	2.03909E-06	
	6	0.06192	32975	1.87779E-06	
	7	0.06596	32987	1.99958E-06	
	8	0.06212	33000	1.88242E-06	
	9	0.06869	33000	2.08152E-06	

The average density for fatigue specimens without notch PC and PCF are 2.02482E-06 kg/mm^3 and 2.00529E-06 kg/mm^3. While for the average density for fatigue specimens with notch PC and PCF are 1.99485E-06 kg/mm^3 and 1.97495E-06 kg/mm^3. From the results obtained, it shows clearly that the specimen without fiber has greater density than the fiber composition. The polymer concrete with fiber (PCF) has lower density because of the fiber properties itself which can trap air inside. For the polymer concrete without fiber (PC) has the highest density due to the shaking and mixing process which make it becomes more solid sample and denser.

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4.2 Tensile Test Results

The Polymer concrete displays brittle characteristics which in brittle materials the fracture strength is equivalent to the Ultimate Tensile Strength (UTS) = the maximum load for the specimen to break. The results of tensile test are shown in Table 4 and Table 5. For the specimen polymer concrete without fiber (Table 4), the maximum load for the specimen to break was more than 2 kN. From the data, the average maximum stress for the polymer without fiber was 18.89 Mpa.

As for the polymer concrete with fiber, the data from Table 5 clearly shows that the maximum load for the material to break was increased. The maximum load for the specimen to break can reach until 3.88 kN. The polymer concrete with fibers (PCF) increased the strengthening in tension compared with polymer concrete (PC). Therefore the average maximum stress also increases from 18.89672 Mpa for polymer concrete (PC) to 32.21988 Mpa for polymer concrete with fibers (PCF). The existence of fiber in the polymer-mixed improves tensile PC by about 70%.

Table 4 The Result Tensile Test Specimen Polymer Concrete Without Fiber (PC)

NO	WIDTH	THICKNESS	LOAD MAX	STRESS	STRESS
	mm	mm	kN	kN/mm^2	Mpa (N/mm^2)
1	20	14	2.12	0.0201819	20.18189
2	20	14	2.103	0.0173802	17.38016
3	20	14	2.158	0.0190992	19.09915
4	20	14	2.091	0.0197852	19.78519
5	20	14	2.093	0.0177108	17.71077
6	20	14	2.165	0.0192231	19.22314
		Average	**2.12166667**	**0.0188967**	**18.89672**

Table 5 The Result Tensile Test Specimen Polymer Concrete With Fiber (PCF)

NO	WIDTH	THICKNESS	LOAD MAX	STRESS	STRESS
	mm	mm	kN	kN/mm^2	Mpa (N/mm^2)
1	20	14	3.854	0.0323074	32.30736
2	20	14	3.859	0.0321148	32.11482
3	20	14	3.875	0.0320248	32.02475
4	20	14	3.984	0.0329256	32.9256
5	20	14	3.873	0.0320083	32.00827
6	20	14	3.864	0.0319385	31.9385
		Average	**3.88483333**	**0.0322199**	**32.21988**

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4.3 Fatigue Strength Test Results

Figure 7 shows all the trend lines which were plotted together to get the clear features of fatigue strength of the specimen polymer concrete with and without fiber, without notch and with notch at low frequency 5Hz.

From the graph, the trend lines for the polymer concrete with fiber shows that it can stand more cyclic repeated loading than the one without fiber when the same stress load applied. As for the specimen with notch and without notch, the trend lines show that the specimen without notch is able to stand fatigue failure at high stress load.

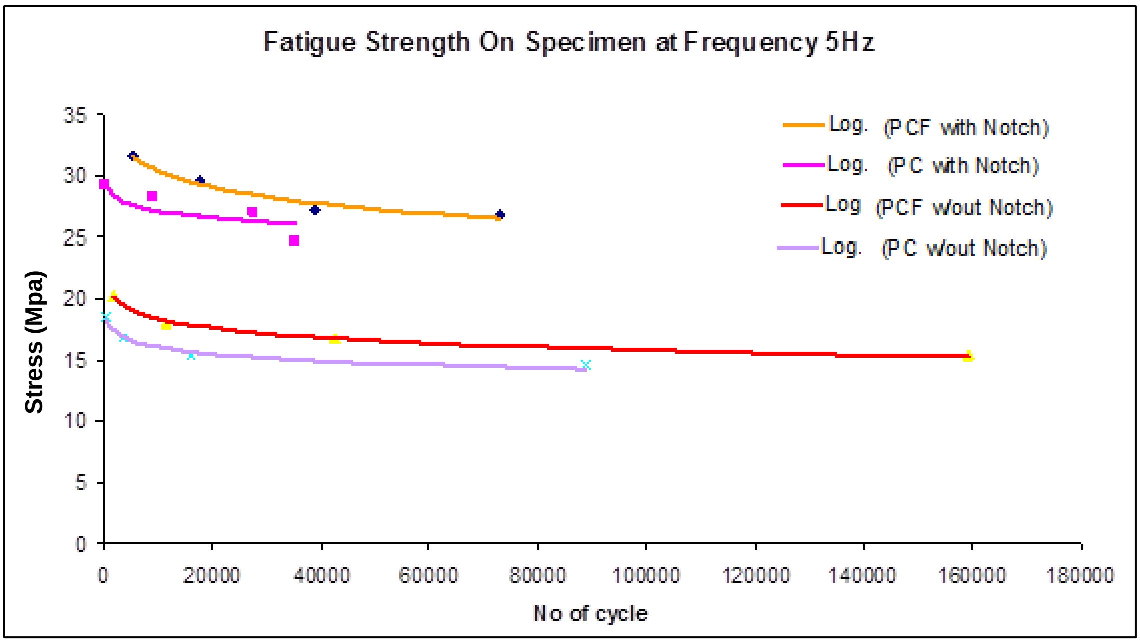

Figure 7 Fatigue Strength of The Specimen Polymer Concrete With and Without Fiber, Without Notch and With Notch At 5Hz.

5.0 CONCLUSION

From tensile test conducted on both polymer concrete with and without fiber, the results show high tensile strength for both. It is noticed that the fiber reinforcement gives increment in strength about 41.35% and stiffness 45.38 %, whereas stiffness for polymer concrete without fiber is 2.12kN and with fiber is 3.88kN.

In fatigue strength test at low frequency 5Hz and amplitude loading maintaining at a constant R- ratio = 0.1, the presence of notch for examining crack propagation on polymer mixed concrete can decrease the fatigue strength compared with the one without notch or plain specimen. The notch decreased the fatigue life about 60%-90%.

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The existence and the reinforcement of fiber in polymer concrete can prolong the fatigue life and postpone the fatigue failure. The fiber reinforcement will increase the fatigue strength, stiffness and tensile strength of polymer concrete composite by extending or blunting crack propagation.

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