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MECHANICAL PROPERTIES OF FIBER REINFORCED POLYMER COMPOSITE – A REVIEW

Ali Salim Ali Minnah*[1], Abdelrahman Miftah Akoush[1]

[1]Engr.&Department of Civil Engineering, Cyprus International University, Mersin 10, Turkish Republic of Northern Cyprus
Corresponding author/ E-mail address: alisalemsalem55@gmail.com

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ABSTRACT. *Fiber reinforced plastic composites or as called fiber-reinforced polymer, consists many rewards such as its ultimate strength, its low density, and easier processing procedures. Thus, the fiber-Reinforced polymer is used in many fields for instance: in automotive, constructions, as well as in aerospace. Merging two or more fibers into one mixture polymer matrix guides to develop the hybrid composite. The mechanical properties of single fiber-reinforced polymer composite can be improved by the process of Hybridization. The resin and aggregates can be seen as a polymer concrete composite material signs. The (FRPs) are used instead of the steel in both rehabilitation and construction projects because of their non-corrosive and their light weight Thus they are non-magnetic, inert from the prospective of the chemical composition, also they can be applied easily. In addition, they are suitable economically for strengthening, rehabilitating and seismic retrofit of columns, beams, joints, and many more other uses in structures. In this paper, the mechanical properties of the Fiber-Reinforced Polymer (FRP) is presented in this paper.*

Keywords*:* Composite, Mechanical Properties, Fiber, Resin, Polymers, Fibres

1. INTRODUCTION

The usage and importance of the polymer is in demand more and more in these days. It can be used in (PMC), when are employed beside cement, (PIC) polymer impregnated concrete, which is used in polymerized and soaked cement concrete is used. (PC), polymer concrete, where the cement paste is replaced by polymer. ACI, 1999, (2007) [1]. These composites have some main concerns as to the usual cement concrete, for instance: it is rapid in hardening, its large mechanical strain, its practical chemical resistance, etc. on the other hand it is not cheap material. The utilization domain of polymer concrete always interchangeable: PMC is used in making floors and bridge overlays; PC was used in 1958 in the United States of America for building; nowadays, it is used for marbles and, labs and I repairing overlays for bridges. Aggarwal L.K., Thapliyal P.C., Karada S.R., 2007 [2]. The ordinary Cement resembles the polymer concrete in terms of its ingredients unless the hydraulic binder is replaced by polymer material. The performance of polymer concrete accounts for the polymer properties Abdel-Fattah H, (1999) [3], (Banthia, N., and Macdonald, 1996) [4].

The composite empolyed in dry state could be silicates, quartz, crushed stone, limestone, calcareous, granite, clay, etc. In general, can be employed as filler. Several types of finer substance are employed such as: fly ash, silica fume, cinder, etc. Cheng-Hsin C., Huang R., (2006) [5] and Erhard,Gunter, (2006) [6]. Filler, specifically fly ash, will increase the characteristics of polymer concrete Ehsani, M.R, 1994. Fiber reinforced polymers revealed many positive actions over steel including its significant resistance for corrosion, it resists the fatigue, low coefficient of thermal expansion, also, it is light in weight. F.R.P. has higher specific stiffness and an equally high specific strength in the direction of fiber alignment. Utilizing of F.R.P. provides a high structural effectiveness, and their density is low which makes physical utilization which is sample. unluckily, F.R.P. are also not cheap, high costs of F.R.P substance are of`ten offset by savings in reduction in usual maintenance, higher life period and of reduction in costs of labour ACI, 1999 [1].

2. WORKABILITY

All fiber reinforcement's success is specifically based on the finishing of the spreading of homogenous mixtures, in the concrete, the spraying and casting and the interface with the cement. There would be a deteriorating effect on workability of the concrete if more percentage of fiber is added particularly which have small diameters. This is because there is a bigger combined surface area in small diameters of fibers. Additional water and cement or admixtures are on extra demand, in which the outcome there would be a spectacular effect on the concretes workability. Peng Zhang and Qing-fu Li (2013) [18] stated that the concretes workability includes silica fumes and fly ash, in which additional polypropylene fibers decreases. Moreover, fresh concretes fluidity decreases, and the fresh concretes cohesiveness amplifies with also the increase of the fiber volumes fractions.

The workability of the mix lessens with the increase in fiber content s observed by Atis C.D.and Karahan O., (2009) [19]. When the dosage of the circular PET fibers weight goes beyond 1%, the concrete mix is hardly workable. Despite the fact that there is use of plasticizer, fibers in high amounts are not recommended due to the fact that concrete is not workable any more.

Several properties that were investigated by Mohammadi Y. et al., (2008) [20] which included aspect ratios that was different and then evaluated with concrete. It could be argued that in the end that here is a decrease in the workability and there is an increase in the fiber content. It is observed by Antonio Domingueset a., (2015) [16] that the movement of the aggregate is hindered by the fibers, resultant there is a loss in the portability and the strength, which is course reduction in the ratio of the fibers is shortened. However, there is a loss in the post crack strength of the tough fiber reinforced concrete. It could be argued in the conclusion that the maximum size of aggregate to be reduced or the content of mortar in the concrete to be increased. If there is an increase in the content of fiber from 0 to 2% the outcome in the slump value would decrease from 230mm (for 0%) to 20mm (for 2%) as studied by Faisal Fouad wafa (1990) [21]. It could be analyzed that the fibers that are hooked are performing better when they are being compared fibers that are straight due to the fact that during the mixing balling was prevented. As concluded by Libre N.A., et al., (2011) [25] there is a lesser effect on the workability of the fresh mix in the PP fibers when they are being compared to steel fibers. It has been analyzed that the dangers of separation in the lightweight concretes is reduced because of the effects of blocking by the polypropylene and fiber steels. The fibers that are different like steel and polypropylene have a lasting effect that reduces the aggregates sedimentation, the surface bleeding and increased in uniformity in the light weight concrete (LWC). It is analyzed that there was decrease in the slump by 54.2%, which was because of the adding of steel in the LWC.

3. COMPRESSIVE STRENGTH

The definitive resistance which was given by the block of concrete right before the yielding the exerted compressive loads could be defined by the concretes strength. Even though the plain concrete disastrously failed during the compression tests, the plastic fiber reinforced concrete failed due to the happening of the many minor cracks that were on the surface. It was inspected by Spadea S.et al., (2015) [22] that the very shortly incorporations nylon recycling fibers reductionpower pressure of investigated (up to -37.0%). Kim S.B.et al., (2009) [27] observes that the power pressure decreases in around 1.0 to 9.0% and of about 1.0 to 10.0% in the polyethylene terephthelates recycling PET, and reinforced specimen of polypropylene when comparing to the normal sample. Inspected by the Atis C. D, and Karahan O., (2009) [19] that the strength which was at 7.0, 28.0, and a time of 1 year. The rise that was inspected was up to 10% and the fall was up to 6% of the specimen of the concrete which was reinforced with steel fibers. In the end it is argued that the variations are because of the complications in giving a spreading of homogenous fibers which are in the specimen.

It is concluded that circular PET fibers contained in the concrete do not show any noteworthy increase in the compressive strength. It is analyzed by silva D. A., et al., (2005) [28] that adding extra PETF fibers has no major influence mortars compressive strength. The FRCs might increase when the volume of the fiber increased. The compressive strength was increased by 14.2% when the outcome was compared to the plain concrete. It was analyzed by Y. Mohammadi et al (2008) [20] that the compressive strength was 2% fiber volume fraction of steel fibers in a maximum of 26% increase. The finest volume fractions were reported by this percentage of fiber. Experimental investigation on the light weight concrete which is reinforced with the volume fractions (0.0%, 0.5%, 1.0%, 1.5% and 2.0%) as conducted by H.T Wang and L.C Wang, (2013) [23]. In the end it is concluded that improve in the compressive strength in some limit.

Faisal Fouad Wafa (1990) [21] stated that there was no important blow on the concrete compressive strength because of the fiber volumes fractions percentage. It was analyzed by Patil Shweta and Rupali Kavilkar, (2014) that with the incorporations of steel fibers the compressive strength was lessened by 31.10%. During the observation the maximum decline was 1.50% fiber breakage. N.A. Libre et al., (2011) [25] studied the effects of steel fibers compressive power.It was analyzed that when the steel fibers were added the compressive strength of concrete was reduced by half.

As analyzed by C.SelinRavikumar and T.S. Thandavamoorthy, (2013) [26] the concretes compressive strength with glass fiber was directly proportional to the fiber content. The experimental inspection was done by D.A. silva et al., (2005) [28] the different fiber content on the concrete. The increase in the content of the fiber was directly proportional to the compressive strength. Comparative experimental inspection was done by P. S. Spadea et al (2015) [22] about the NFRC and PFRC. Nylon fiber improved the concretes unified strength by 6.3% as observed and then they were compared with PP reinforced concrete. The increase was because of the better distribution and the nylon fibers superior tensile strength. As investigated by Banthia, N., and Macdonald, R. (1996) [4] the PP fiber content (0%, 0.050%, 0.10%, 0.20% and 0.30%) had the effect on the plain concretes compressive strength. There was no major impact observed on the normal concrete, and while the concrete together with silica fumes verified a rise in strength by 23.0%.

4. FLEXURAL STRENGTH

The resistance that is offered by the block of concrete right before the application of bending stresses persuaded by necessary loading. It was reported by S.B. Kim et al., 2009) [27] that there was a rise of 25.0%, 31.0% and 32.0% in flexural strength that was reused by P.E.T reinforced sampie at 0.5%, 0.75% and 1.0% of fiber size sequentially. However, there was no major effect analyzed on the steel fibers flexural strength at low volume fractions as reported by C.D. Atis and O. Karahan, (2009) [19]. But the volume fraction at 1%, the flexural strength had risen by 15% and there was improvement shown.

It was concluded by D. Foti, (2013) that the PET fibers in the concrete are not showing any major rise in the flexural strength. It was examined by D.A. silva et al., (2005) [28] that there was no major impact on the mortar's tensile strength when they added PET fibers. It is because that plain mortar causes the first crack in that close relationship. As examined by H.T Wang and L.C Wang (2013) [23] the adding of steel fibers improved the flexural strength greatly.

As examined by Y. Mohammadi et al., (2008) [20] the final rise with resulted in 100 percent in unvarying flexural energytheamount of the solid fiber of 2.0% with 100% longthy steel fibers in concrete. It was studied b yFaisal fouadwafa (1990 [21] that the finest rise in the flexural strength was 67% and was examined by adding 1.5% of hooked fibers. There was a 2% straight incorporation of straight fibers, which raised 40% of flexural strength compared to plain concrete. The hooked fibers fraction at 2% volume fractions, the flexural strength dropped because of the complications in the consolidations and achievement of the uniform distribution.

It was studied by Patil Shweta and Rupali Kavilkar, (2014) [24] that the SRFC is keeping volume fractions fiber volume at 1.50% and raising the aspect ratio by 70.0% which rose by 58.650% in flexural strength. Moreover, by making the aspect ratio constant at 70.0% and then raise the size fraction of fibers by 2.50%, the increase of flexural strength was by 116.69%.

It was studied by N.A. Libre et al., (2011) [25] that a rise in flexural strength by 200% was observed by adding steel fibers. Moreover, there were some improvements when 0.4% of polypropylene fibers were added. As studied by C. Selin Ravi kumar and T.S. Thandavamoorthy, (2013) [26] that there was 0.5% glass fiber added in the volume fractions, the flexural strength was enhanced by 42% and when adding 1% volume fraction the flexural strength was increased by 75%. It was observed by H.T Wang and L.C Wang, (2013) [23] tht at 3% volume fractions flexural strength was more and adding fibers which compared to 0.0%, 1.0% and 2.0% fibers. In addition, there was 49% amplification in the flexural strength when the steel fibers were added. It was investigated by Patil Shweta and Rupali Kavilkar, (2014) [24] that effects in different P.P fiber amount (0%, 0.05%, 0.1%, 0.2% and 0.3%) in plain concretes strength and with the concrete existence different binding. The confidence stage of 99%, it was examined that the strength was raised by 387% with 0.3% fiber content added.

5. TENSILE STRENGTH

The materials that offer the resistance opposing the longitudinal stresses are calculated in relation to the longitudinal stress which is required to break the materials that usually what is called tensile strength. It was reported by S. Spadea et al., (2015) [22] that there as improvement of 35% in tensile strength and the fracture properties of the cement properties were enhanced by adding R-Nylon Fibers.

It was observed by C.D. Atis et al. (2009) [19] that the incision strength is amplified by 3.0%, 5.0%, 32.0% and 71.0% concrete with and without the fiber volume fractions which are 0.25%, 0.5%, 1% and 1.5%. It was observed by Nanni, A., M.S. Norris and N.M. 1993 [12] that the volume fiber of steel fiber is straight proportional to the tensile strength of concrete. It is studied by H.T Wang and L.C Wang, (2013) [23] that the incision tensile strength significantly improves by adding steel fibers, and different variations were observed in tensile strength from 3.990 MPa to 7.680 MPa. This credit of increase is to the cracking arrests by the steel fibers. It was studied by Y. Mohammadi et al., (2008) [20] that the rise in the tensile strength was 27.0%, 51.0% and 59.0% for volume fractions when adding 1%, 1.5% and 2% of steel fibers to the concrete shuffle. There is a 2% mix ratio of volume fractions which consists of short fibers which are 35% and long fibers which are 65% and in accumulative increase of tensile strength by 59%. The studies of Faisal fouadwafa, (1990) [21] that 57% was the maximum of enhancing the strength of concrete when added 1.5% volume fractions of steel fibers. It is reported by N.A. Libre et al., (2011) [25] that including both steel and polypropylene fibers would augment the tensile strength by 116%.

It was studied by C. Selin Ravi kumar and T.S. Thandavamoorthy, (2013) [26] when adding 0.5%-part size of glass fiber., the tensile strength would be enhanced by 20%, and while the tensile strength was amplified by 37% when 1% glass fiber was added. It was observed by S.B. Kim et al., (2009) [27] that there is more tensile strength when 3% of volume fraction is added than 0%, 1% and 2%. In addition, there was 49% enhancement in the tensile strength when steel fibers were added as shown in table 1. It was examined by D. A. Silva et al., [28] that nylon FRC spitting tensile strength was augmented by 6.7%. The better diffusion of nylon fibers that are mixing in the water is the reason why there is a slight increase. Nearly all carbon fibre is obtained from a standard industrial fibre is known polyacrylonitrile fibre, also called as PAN. Most PAN fibre is utilized to produce acrylic fibre. It is further used to obtain carbon fibre with a pyrolyzing process, which implies it is burned to ultra-high temperatures to eliminate all components excluding the carbon. Most carbon fibre is sold at this position and it has a tensile modulus of 33 million pounds per square inch (MSI) shown in table 1. Carbon fibre is often time created utilizing two principal schemes: by the practice of Polyacrylonitrile (PAN) and from the pitch. Pitch is a viscoelastic material that is comprised of aromatic hydrocarbons. Pitch is fabricated via the distillation of carbon-based materials. Table 1 reviews the impact mechanical agents of fibre such as, Carbon (PAN and Pitch), ARAMID (Kevlar 29, 49, 129, 149 and Twaron, Technora respectively) and GLASS (E- Glass and S- Glas) S.B. Kim et al (2009) [27].

Table- 1: Typical Mechanical Properties of Fibers

FIBER TYPE		**Tensile Strength [MPa]**	**Modulus of Elasticity [GPa]**	**Elongation [%]**	**Coefficient of Thermal Expansion [x10^{-6}]**	**Poisson's Ratio**
CARBON						
PAN	High Strength	3500	200-240	1.3-1.8	(-1.2) to (-0.1) 7 to 12	-0.2
	High Modulus	2500-4000	350-650	0.4-0.8		
Pitch	Ordinary	780-1000	38-40	2.1-2.5	(-1.6) to (-0.9)	N/A
	High Modulus	3000-3500	400-800	0.4-1.5		
ARAMID						
Kevlar 29		3620	82.7	4.4	N/A	0.35
Kevlar 49		2800	130	2.3	(-2.0) to(59)	
Kevlar 129		4210 (est.)	110 (est.)	--	N/A	
Kevlar 149		3450	172-179	1.9	N/A	
Twaron		2800	130	2.3	(-2.0) to(59)	
Technora		3500	74	4.6	N/A	
GLASS						
E-Glass		3500-3600	74-75	4.8	5.0	0.2
S-Glass		4900	87	5.6	2.9	0.22
Alkali Resistance Glass		1800-3500	70-76	2.0-3.0	N/A	N/A

6. MODULUS OF ELASTICITY

The concretes stress strain curve of slope, the materials relative limit is contained by the effectiveness which is defined by the concretes elasticity. For the low-levelstresses, the value is constant however it is reduced when high level stresses and concrete cracks are developed. It is studied by "C.D. Atis and O. Karahan (2009)[19] that steel fiber in concrete contains 0.25% of volume fractions and 0.5% slightly greater value of elastic modulus compared to fiber less concrete. Usually with a growing in the fiber content the modulus of elasticity is reduces. It is studied by D.A. silva et al., (2005) [28] that the elasticity modulus of mortar in flexural test had nearly no major effect. It is examined by S.B. Kim et al (2009) [27] that PET and PP concrete which are recycled had value depress in the elastic modulus in contrast to plain concrete. It is also shown in Table 2 that with the increase in fiber content the modulus of elasticity is decreased.

Table -2: Properties of Composites and Comparison with Steel

Property	Steel	Aramid Fibre Reinforcement Polymer	Carbon Fibre Reinforcement Polymer	Glass Fibre Reinforcement Polymer
Tensile Strength, Mpa	300-450	1720-2540	600-3690	480-1600
Elastic modulus, Gpa	200	41-125	120-580	35-51
Rupture strain, %	7-13	1.9-4.4	0.5-1.7	1.2-3.1
Limiting strain, E	.0035	.002	0.01	0.02
Performance factor,Φ	.75	.9	0.8	0.4

Fibre-reinforced plastic (FRP) (similarly described as a fibre-reinforced polymer, or fibre reinforced synthetic) is a composite substance manufactured from a polymer matrix augmented with fibres. The fibres are normally carbon, glass, aramid. Figure 1 shows the Classification of reinforced Polymer. Monomers formed polymers and polymers are classified into synthetic and natural. The synthetic further categorized into thermosetting and thermoplastic respectively. Thermoplastics can be remelted back into a liquid, whereas thermoset plastics always remain in a stable solid state. While natural is further classified as organic and inorganic S.B. Kim et al (2009) [27].

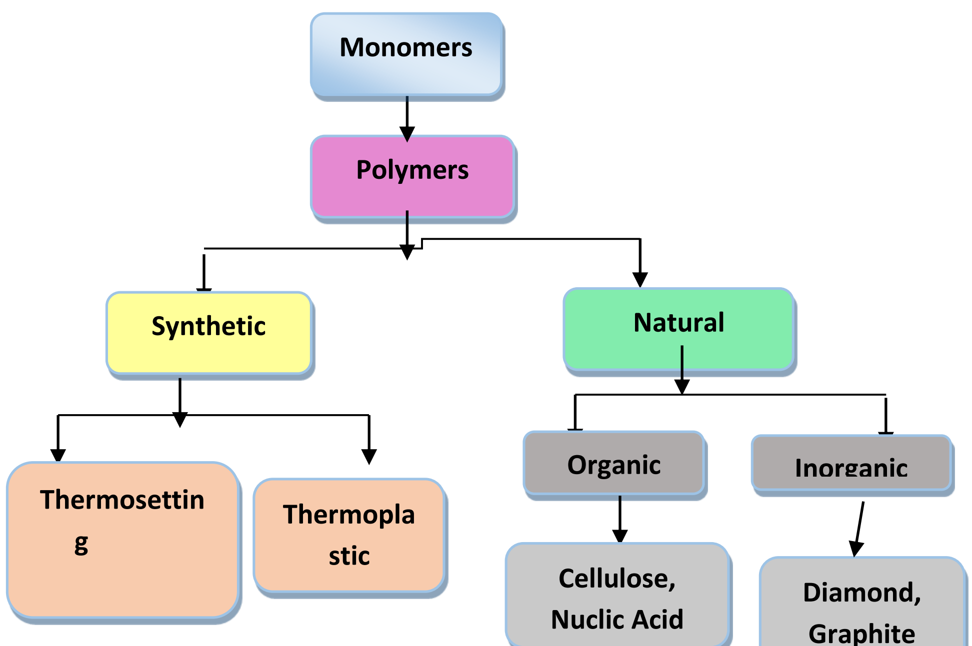

Fig -1: Classification of reinforced Polymer

7. DURABILITY

Significant issues remain unresolved with respect to the long-term durability of composites in concrete construction. There are two major concerns: one relates to the longevity of the composite itself in a deleterious environment, and the other relates to the durability of the bond between the FRP and concrete. A synopsis of our understanding with respect to the durability of the composites is presented in Tables 3 and 4 Harja M., Barbut 2009 [9], Harja M., Barbut (2008) [8] .A compendium of papers related specifically to the durability of the bond is given in APPINDEX A. A detailed treatment of bond durability appears elsewhere (Karbhari V. M 1996) [10]. Table 3 and 4 (Part A and Part B) described the durability of composite of fibre based on their types, with regard to water absorptions taken within the duration of 1 day, thermal expansion, heat, and ultra-violate radiation respectively. In Table 3 and 4 it can be seen that Aramid is attacked when heated while E -Glass and S-Glass have a strong affinity under heat.

Table -3: Durability of Composites (Part A)

MATERIAL	Water Absorption(%/24 hr)	Thermal Expansion ($*10^{-6}\,^0C$)	Heat	UV radiation
Fiber Phase				
Glass E-Glass	-	5.4	GR	GR
S-2 Glass	-	1.6	GR	GR
AR-Glass	-	6.5	GR	GR
Carbon PAN-type	-	-	GR	GR
Pitch-based			GR	GR
Aramid	0.05	-5.2	A	A
Concrete Steel		10-13	-	-
Matrix Phase				
Polyester resin	0.15-0.60	-		A
Vinyl ester resin	0.1-0.2	-	A	A
Epoxy resin	0.0	-	A	GR

(Legend—GR: Generally Resistant; A: Attacked; SA: Slightly Attacked)

Table- 4: Durability of Composites (Part B)

MATERIAL	Weak Acids	Strong Acids	Weak Alkalis	Strong Alkalis	Organic solvents	Oxygen/Ozone
Fiber Phase						
Glass E-Glass	SA	A	SA	A		GR
S-2 Glass	GR					GR
AR-Glass	GR					GR
Carbon PAN-type	GR	GR	GR	GR	GR	GR
Pitch-based	GR	GR	GR	GR	GR	GR
Aramid	GR	SA	A	SA	A	A
Matrix Phase						
Polyester resin	SA	A	A	A	SA	A
Vinyl ester resin	GR	GR	GR	GR	GR	SA
Epoxy resin	GR	SA	GR	GR	GR	GR

(Legend—GR: Generally Resistant; A: Attacked; SA: Slightly Attacked)

7.1 Effect of Alkaline Environment

The structure weakness is due to the high alkaline environment and dissolves the fiber happens because of the deteriorations of the natural fibers mixed with the Portland cement. Studies. Peng Zhang and Qing-fu Li, (2013) [18] examined he fiber reinforced concrete (FRC) that mixed with the coir and sisal fibers. when the samples were revealed to alkaline suspension, the fibers were degraded and varied in tensile strength were found after measuring.

Ca^{+2} ions were reported to have negative effect on fibers. The durability of coconut and sisal fibers after conditioning them with alkaline solutions. Coconut and sisal fibers were immersed in a sodium hydroxide (NaOH) solution for a period of time of 420 days the results showed that the coconut and sisal maintained respectively 60.9%

and 72.7% of their original strength. While the fiber immersed in the Ca (OH)2 solution, the researcher pointed out that the original strength was lost totally because of the crystallization of fiber pores after a period of 300 days.

7.2 Freeze-Thaw Resistance

A specimen such as concrete may break in case water seeps into the cracks of the specimen and freezes. However, the specimen offers resistance to the periodic freezing and fusion which is labeled as freeze-thaw resistance. Peng Zhang and Qing-fu Li, (2013) [18] studied the effects of varying in size fraction of fiber on FRC in an experiment. The experimental results showed that freeze-thaw resistance increased until fiber volume fraction rose to .08%, but then decreased when it was further increased from 0.8% to 0.12%. The results from the experiment suggest that increasing fiber volume decreases the space between the fibers. This essentially means that the number of weak interfaces and the overlapping interfaces of adjacent fibers rises with increasing volume making the micro structure very loose, and thus reducing the freeze-thaw durability of concrete. According to studies made by C.D. Atis and O. Karahan, (2009)[19] , a concrete sample with sword fiber has a little higher freeze-thawing resistance when compared with plain concrete. Other studies made have proposed the steel fiber amount fraction has a great impact in first-resisting ability of steel fiber. Frost damage is significantly reduced when steel fiber volume is 1.5%. Be that as it may, the ice opposing property of concrete is largely lowered with the presence of 2% steel fiber content.

7.3 Permeability

The application of pressure or other forms of duress such as thermal, mechanical and chemical may lead to the creation of cracks in a concrete specimen thereby enhancing its permeability. This permeability may lead to the deterioration in concrete specimen (Peng et al., 2013)[16] investigated the effect of the presence of polypropylene (P.P) fibers on the permeability of a concrete specimen. Findings suggested that the permeability of concrete containing silica fume and fly ash was reduced in the presence of polypropylene (PP) fibers. Results also showed that the permeability of mix decreases with increasing fiber volume fraction. Studies by Mutukumar M., Mohan D.J., (2014) [11] also reveal that permeability decreased considerably following a rise in fiber content and increasing curing age. Water permeability of steel fiber reinforced concrete is not majorly affected by a change in aspect ratio.

7.4 Carbonation Depth

The carbonation depth of a specimen helps to identify the carbonation resistance of concrete under the action CO2 pressure. The process is facilitated by the act of diffusion where C02 moves from the surface of the sample to the inside. As the depth of diffusion rises, carbonation intensity also reis. (Peng et al. 2013) [16] watched in carbonation protection climbed consistently with rising volumes of polypropylene fiber fractions. The reinforced the above view and explained that the capillary channels in the mortar are blocked by the fibers making the pores smaller, and hence inhibit the diffusion of CO2 by reducing micro cracks in the concrete specimen.

8. CONCLUSION

The findings from the studies above can be summarized as follows: -

The addition of fibers negatively impacts the permeability of a fresh mix and is further reduced with increasing fiber volume fraction.

Since individual fibers have varying responses to the strength of the specimen, there is no correlation observed between the compressive strength of specimen due to addition of fibers.

The presence of fibers usually facilitates properties like ductility, flexibility, tensile strength, drying shrinkage and toughness in materials.

Freeze-thaw resistance, permeability, carbonation depth and fire resistance are tests that help to establish the increase in durability of cement-based products with the addition of fibers.

It has been established that fiber reinforcement polymers can be used for the development of high and ultra-high-performance concrete with high quality designs and utilization, the performance of fiber reinforced cement-based material can be maintained.

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