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Research Article

GLASS FIBRE REINFORCED CONCRETE FOR RIGID PAVEMENT

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ABSTRACT

Concrete is brittle under tensile loading and the mechanical properties of concrete may be improved by randomly oriented short discrete fibres which prevent or control initiation and propagation or coalescence of micro cracks. Ductility of concrete is provided with fibre reinforced cementations composites, because fibres bridge crack surfaces and delay the onset of the extension of localised crack. This paper presents experimental investigations mainly on mechanical properties of M30 grade of concrete considering water cement ratio 0.47. Glass fibre was added in green concrete by volume of concrete at variegated percentages from 0% to 0.4% with increment of 0.1%. Mechanical properties like compressive strength, flexural strength, indirect split tensile strength and modulus of elasticity along with ultrasonic pulse velocity were carried out. Slump is decreasing with the addition of glass fibres. The maximum increase in compressive strength is 32% and 13% at 7days and 28 days respectively. The flexural strength and split tensile strength increased up to 35% and 32% respectively over the range of glass fibre dosages. Modulus of elasticity increases significantly and higher value of it indicates the controlling factor of sudden failure. Ultrasonic pulse velocity result represents the quality of concrete. Concrete slab for rigid pavement was designed and found safe and economic thickness.

INTRODUCTION

India´s road system is the second largest road network in the world. Only 2% of the total length of the road is made up of concrete and the rest are made up of aggregates surfaced with bitumen. The main reason behind that, the initial cost of rigid pavement is much more than the flexible pavement. The cost is not the single parameter that is responsible for such less construction. But, other factors are also responsible to cause failures like development of cracks, mud pumping, sagging of slabs due to less flexural strength and brittleness of concrete etc. However, the concrete road construction is said to be better as compared to flexible pavement in long term maintenance, design life, riding quality etc. As the concrete is brittle in nature it needs some supporting agents like steel bars. But the conventional steel reinforcement boosts more thickness which in turn becomes uneconomical. The tensile strength of concrete was increased so that it can bear high tension at increased strain. Glass fibre was added to enhance the flexural and tensile strength of concrete. After the addition of fibre, a complex material was formed which showed different properties from non-reinforced concrete. The strength so achieved will vary with respect to type and amount of fibre used.

The addition of fibre in brittle concrete will help in mitigating the propagation of micro cracks as well as improving in other mechanical properties. Development of fast rate construction of road and other infrastructures, glass fibre reinforced concrete are being used in practice. Different varieties of fibres are available in the market such as steel fibres, glass, acrylic, aramid, polyester and some natural fibres such as sisal, jute, cellulose etc. are also used. From the above stated fibres, glass fibre is gaining additional popularity day by day. Glass fibre is a lightweight, very strong, and robust material. Glass fibre reinforced concrete (GFRC) does not fail immediately under load but yields gradually nevertheless in cement and concrete tensile failure begins with micro cracks. Cracks propagate quickly and cause destruction. The key of this accepted behaviour of GFRC is due to randomly distribution of tiny glass fibres in it whereas uniformed distributed fibres expand the loads in a wide range and let the matrix to behave cohesive. The existence of glass fibres provides crack arresting system. The aim of this paper is (i) to explore the utilization of glass fibre in concrete pavement construction, (ii) to view the effect of glass fibre reinforced concrete on physical, mechanical and performance behaviour and (iii) to collate the design thickness with and without using fibres reinforced concrete so that suggest for the saving in materials.

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LITERATURE REVIEW

Barros J.A.O. *et al* (1994) had examined the tensile strength of glass fibre reinforced concrete. Tensile test on specimen of dimension 150 x 60 x 50 mm was performed and found improvement in it. Chandramouli *et al* (2010) carried out the effect of glass fibre on strength of glass fibre reinforced concrete. Glass fibre of 0.3% by volume of concrete was used in different grades of concrete like M20, M30, M40 and M50. It was found that compressive strength increased by 20 to 25% whereas the flexural and split tensile strength increased by 15 to 20%. Ghorpade Vaishali G. (2010) had made laboratory investigations on high performance concrete by using glass fibre along with silica flume as an admixture. Concrete mix was prepared with varying percentage of glass fibre viz. 0%, 0.5%, 1% etc. by volume of concrete fraction. Result reveals that by mixing 1% glass fibre and 10% silica fume, the compressive and flexural strength of concrete improved significantly. Gornale *et al* (2012) examined the compressive and flexural characteristics of glass fibre reinforced concrete. The slump value of concrete decreased after adding of 0.3% glass fibre by volume of concrete. Compressive strength after 28 days for M20, M30 and M40 grade concrete were increased around 30%, 21% and 24% respectively whereas the flexural strength was increased around 30%. Lv Yan *et al* (2012) had conducted the flexural strength as well as fatigue test of concrete with addition of glass fibre. The fatigue behaviour of glass fibre reinforced concrete was better than plain concrete. Ghorpade Vaishali G. (2010) had made laboratory investigations on high performance concrete by using glass fibre along with silica flume as an admixture. Concrete mix was prepared with varying percentage of glass fibre viz. 0%, 0.5%, 1% etc. by volume of concrete fraction. Result reveals that by mixing 1% glass fibre and 10% silica fume, the compressive and flexural strength of concrete improved significantly. Patel *et al* (2013) had performed different test such as flexural strength, tensile strength etc. on M20 grade of concrete by addition of 0.03%, 0.06 % & 0.1% of glass fibres. It was found that tensile strength was improved 42.34% but no significant change in flexural strength was noticed. Kumar C. *et al* (2013) observed that 0.5 % glass fibre in concrete contributes efficiently in concrete as the strength and fire resisting properties of concrete. Swami B.L.P *et al* (2010) had studied the strength parameter and their behaviour of glass fibre reinforced concrete. Significant result was obtained at 1%.

EXPERIMENTAL INVESTIGATIONS

Materials

The concrete consists of cement, coarse aggregate, fine aggregate and water. All constituent materials for making concrete were collected from local market. Cement used was Ordinary Portland cement of 43 Grade have brand name JP Cement. The source of the fine sand was Sone River in Bihar whereas the source of coarse aggregate was Pakur quarry in Jharkhand. Properties of aggregates and cement are presented in Table 1 and Table 2 respectively.

Table 1 Properties of coarse and fine aggregate

Properties	Coarse aggregate		Fine aggregate		Reference
	Result	Permissible limit	Result	Permissible limit	
Nominal size (mm)/Zone	20		III		IS:383-1970
Aggregate impact value (%)	12.33	20-30%			IS:2386(part 4)-1963
Los Angeles abrasion value (%)	28.44	<35%			IS:2386-1963
Aggregate crushing value (%)	23.30	<30%			IS:2386(part 4)-1963
Water absorption (%)	0.685	<2%	1.3	<2%	IS:2386(part 3)-1963
Specific Gravity	2.73	2.5-3	2.44	2-3	IS:2386(part 3)-1963
Flakiness Index (FI)%	9.3	<25%			IS:2386(part 1)-1963
Elongation Index (EI)%	12.53	FI+EI<30%			IS:2386(part 1)-1963

Table 2 Properties of Cement

Properties	Result	Permissible limit	Reference
Fineness (%)	3	<10%	IS:4031 (part 1)-1996
Initial setting time (min)	30	>30min	IS:4031 (part 5)-1996
Final setting time (min)	578	<600min	IS:4031 (part 5)-1996
Consistency (%)	31	Near30%	IS:4031 (part 4)-1996
Density	2.85	Near3.15	IS:4031 (part 11)-1988
Compressive strength (28 days in MPa)	44.7	>43MPa	IS:4031 (part 6)-1996

Glass fibre and its properties

Glass fibre is also famous with name of Glass wool or Fibre Glass. It was invented by Russell Games Slayterof Owen-Corning. It is not durable and rigid as carbon fibre but it is economical than carbon fibre. It was primarily invented for thermal insulation but now it is used in different areas. Glass fibre is made when thin strands of silica based glass are extruded from suitable opening. Different types of Glass fibre are manufactured in market such A-glass, E-glass etc. (source: Wikipedia). Different mechanical and physical properties of glass fibre are reported in the Table 3 and sample of glass fibre is shown in Figure 1.

Table 3 Physical and mechanical properties of glass fibre

Cost (Rs./ kg)	200
Length (mm)	12
Appearance	White monofilament
Density(gm/cm^3)	0.91
Melting point (^{o}C)	1200
Acid & Alkali resistance	Strong
Tensile strength(Mpa)	More than 600
Elastic Modulus(Mpa)	More than 3500
Crack elongation (%)	10
Water Absorbency	No
Electrical Conduction	Low
Fire reaction	Incombustible
Heat Conduction	Low

Figure 1 Glass fibre used in this study

(Source: Manufacturer Lalit Mistry)

Concrete mixing and testing

This study is carried out basically pro to concrete pavement therefore concrete mix proportioning has been made as per guidelines of IRC: 44-2008. M30 concrete was adopted for this study. Design mix proportion for 1m^3 is given in Table 4 for non-fibrous concrete (NFC) and Fibre reinforced concrete (FRC). Slump values were observed for each mixes. Six cube (150 mm x150 mm x150 mm) specimens were prepared for compressive strength test as per IS: 519-1959, three beam (100 mm x100 mm x 500 mm) were prepared for flexural strength test as per IS: 519-1959, and six cylindrical specimens (dia. 150mm and height 300mm) were casted for split tensile strength test as per IS: 5816-1999 at various mixes. Ultrasonic Pulse velocity test was performed as per IS 13311-1992 for getting homogeneity in concrete. Glass fibre added in the design mix from 0.1 to 0.5% by volume of concrete with increment of 0.1%.

Table 4 Concrete Mix proportioning and fibre contents

Water cement ratio	Cement	Fine aggregate	Coarse aggregate	Percentage of glass fibre
0.47	1	1.486	3	0, 0.1, 0.2, 0.3, 0.4, 0.5

RESULT AND DISCUSSION

Workability

Workability of concrete mixes was assessed through Slump test. It was found that the slump value decreases with increases of the percentage of glass fibre as shown in Figure 2. The addition of glass fibres to the mix changes the slump out of proportion to the workability change. The composite forms a relatively stable system due to the interlocking of fibres which resists the flow of fresh concrete. But, observed slump value lies between the ranges (25-50) as desired for the pavement construction. The unsuitability of conventional workability tests for fibre concrete is essentially because of the fact that internal structure and flow characteristics of fibre reinforced concrete are distinctly different from those of conventional concrete due to the presence of fibres.

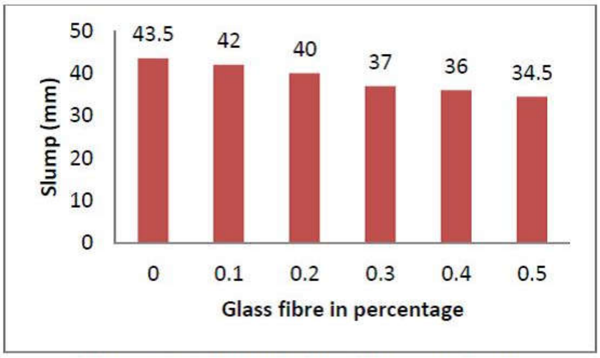

Figure 2 Effect of glass fibre on slump

Compressive Strength

Result of compressive strength after 7 days and 28 days curing is shown in Figure 3. Compressive strength increases gradually with the increase of the per cent of glass fibre in concrete mix. The improvement in strength may be due to the voids filled by randomly distributed glass fibre in concrete. Glass fibre hold the concrete mix, when compressive load is acted on the face of cube then at the adjacent side tension force acted and glass fibre made bond with concrete. So it was found that the propagation of crack in adjacent side of cube is not occurs, this phenomena may be the responsible for increasing the compressive strength. It was observed that the compressive strength at 7days increases from 24.77 MPa at 0% glass fibre to 32.79 MPa at 0.5 % glass fibre which is about 32% increment whereas the compressive strength at 28 days increases from 39.28 MPa at 0% glass fibre to 44.65 MPa at 0.5 % glass fibre which is about 13.67% increment as indicated in Figure 4.

Indirect Split Tensile Strength

The split tensile strength was obtained by applying the transverse load on cylindrical sample after 28days curing by using the compression testing machine. It was found that the split tensile strength increases gradually with the increase of glass fibre in concrete mix as shown in Figure 5. The reason behind it may the glass fibre having small diameter and strong in tension, which hold the concrete mix strongly. The split tensile strength value at 0% and 0.5% addition of glass fibre in concrete is 3.24MPa and 4.3MPab respectively. This increment of split tensile strength is 32.72% as indicated in Figure 6. Split tensile test use to check edge of pavement is strong or not.

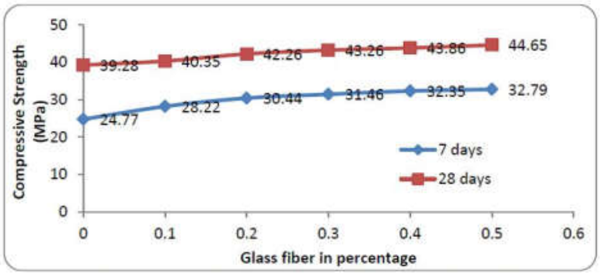

Figure 3 Effect on compressive strength

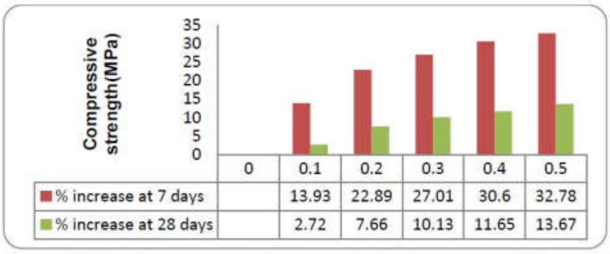

Figure 4 Change in compressive strength

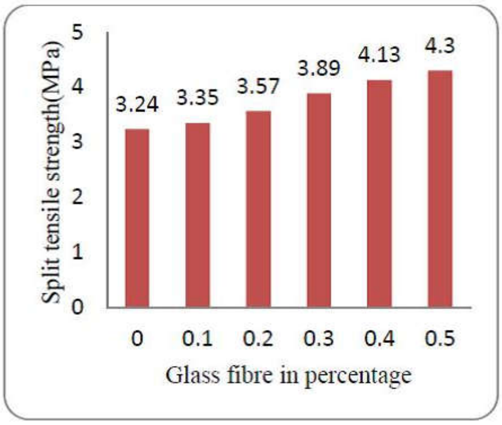

Figure 5 Effect of glass fibre on split tensile

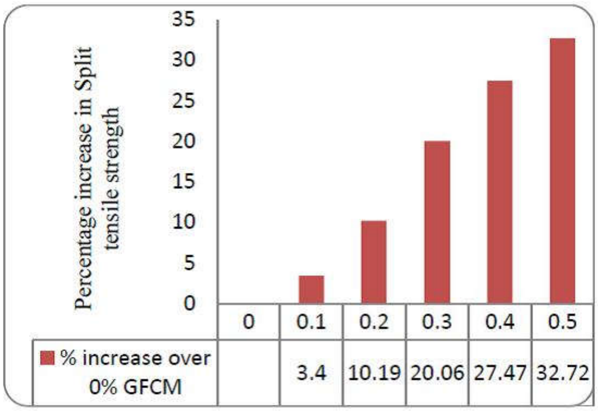

Figure 6 Change in split tensile strength strength

Flexural Strength

The flexural strength was obtained from the two point loading system and the result of test for various percentage of glass fibre by volume of concrete fraction is shown in Figure 7.

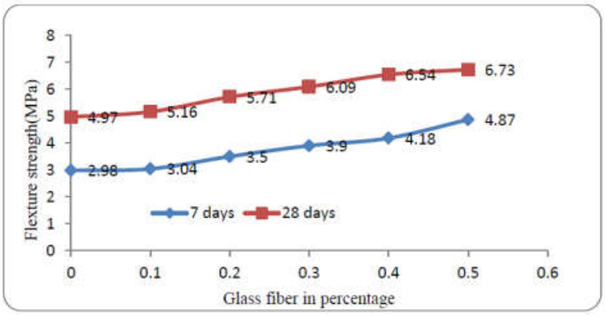

Figure 7 Effect of glass fibre on flexural strength

It was seen that at 0 % glass fibre the flexural strength is 4.97 MPa and at 0.5 % glass fibre the flexural strength becomes 6.73 MPa which is more than 1.35 times of strength at 0% glass fibre. Percentage increase of flexural strength with respect to zero per cent of fibre content are 3.82, 18.91, 22.54, 31.59 and 35.41MPa at 0.1, 0.2, 0.3, 0.4 and 0.5% of glass fibre dosage in concrete respectively as shown in Figure 8.

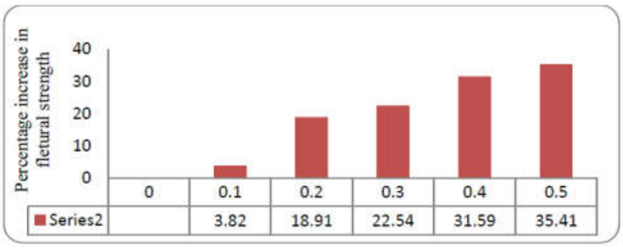

Figure 8 Change in flexural strength

Modulus of rupture is determined by using theoretical model according to IS: 456 code and actual experimental data as indicated in the Figure 9. It was reported that the differences found in both methods varies almost from 29% to 75%. The improvement in flexural strength may be due to the formation of convincing matrix when glass fibres randomly distributed in the concrete mix. It has been also noticed that flexural strength is greater than the tensile strength.

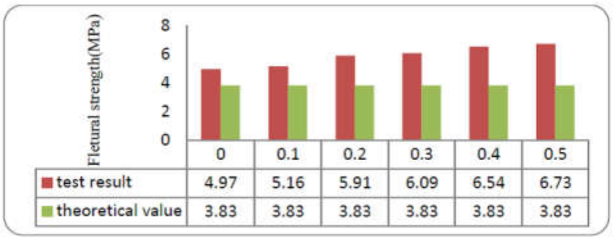

Figure 9 Comparison between observed

Water Absorption

Water absorption was estimated after gone through the process mention ahead. Hardened concrete initially immerge in water at 27 ºC for 24 hour then removed from water and left it for surface dry in room temperature, weigh the specimen(w_2) further specimen was kept for oven dry at 110 ºC for 24 hour and weigh(w_1). The observed result of test for various percentages of glass fibre by volume of concrete fraction is shown in Figure 10.

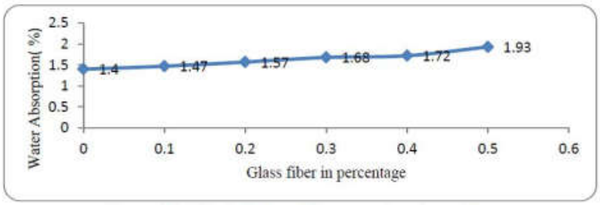

Figure 10 Effect of glass fibre on water absorption and theoretical flexural strength

It was seen that the water absorption at 28 days increases with increase in per cent of glass fibre**.** It is found that at 0 % glass fibre the water absorption is 1.40% and at 0.5 % glass fibre the water absorption becomes 1.93%. This may be due to the increase of pores with increases of glass fibre content which is harmful for rigid pavement by the action of freezing and thawing. Percentage increase in water absorption varies from 5% to 37.85% as indicated in Figure 11.

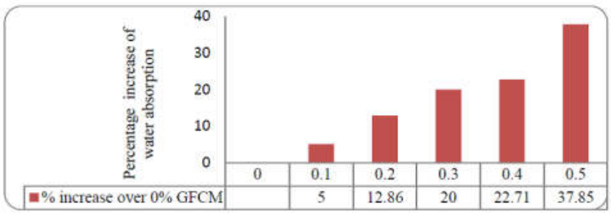

Figure 11 Change in water absorption

Ultrasonic pulse velocity

Pulse velocity technique is an important test for finding out the quality of concrete for various mix proportion of concrete. The ultrasonic pulse velocity value for all concrete containing glass fibre with respect to 28 days of curing is given in Figure 12.

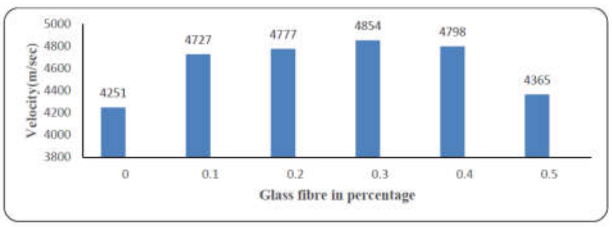

Figure 12 UPV result

The test results showed that better hardening properties of the concrete for optimized glass fibre. The ultrasonic pulse velocity value presented a growing trend for various concrete mixes with the pulse velocity values in between 4100 to 4900 m/s. If the value increase which show the voids are more, that means the glass fibre made the bond with concrete but not fill the voids. Due to this reason quality of concrete mix decreases. However, higher UPV values(4854m/s) as obtained for 0.3% of glass fibre at 28 days until values exhibited suitable results as per IS:13311-1989(Part-1).

Modulus of Elasticity

The Modulus of Elasticity values of concrete increases with an increase of glass fibre content. Figure 13 shows the plot of stress v/s strain in which various trend are shown at different dosages of fibre content. Secant modulus of concrete is estimated and found maximum modulus of elasticity at 0.5% of glass fibre and corresponding value is 3.4×10^5 kg/cm^2. Minimum value found at 0% of glass fibre content and the corresponding value is 2.9×10^5 kg/cm^2.

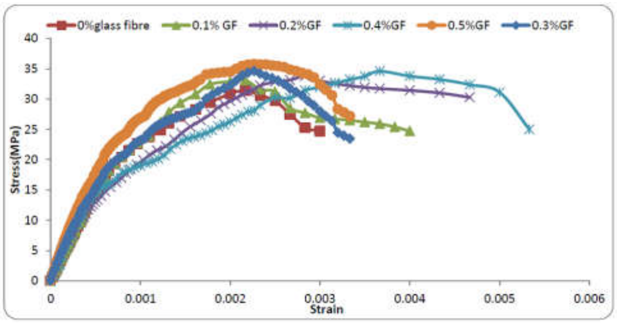

Figure13 Stress v/s strain curves at various glass fibre contents

Dynamic Modulus of Elasticity

The value of dynamic modulus depends upon dry density of concrete and velocity value which is found from ultrasonic pulse velocity test.

$E_{d=}$ (1)

Where $E_{d=}$ Dynamic modulus of elasticity,μ = Poisson's ratio, v = velocity (m/s), ρ = Dry density. Dynamic value increases with glass fibre content from 0% to 0.4% but from 0.4% to 0.5% of glass fibre content, its value decreases because voids increases in mix as mentioned in Figure 14.

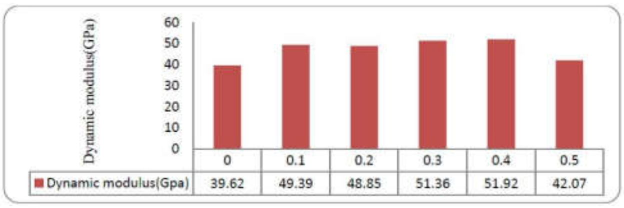

Figure 14 Effect of glass fibre on dynamic modulus of elasticity

Pavement Slab Thickness

Thickness of the slab was determined by using traffic 47msa and modulus of subgrade reaction is 8kg/cm^2 as per IRC: 58 guidelines. Design showed decrement in pavement thickness for all fibrous concrete due to increment in flexural strength. Slab thickness at 0% glass fibre content was 30 cm but at 0.4% and 0.5% glass fibre content it was 25 cm. It was found that thickness was reduced to 25cm with adding the glass fibre.

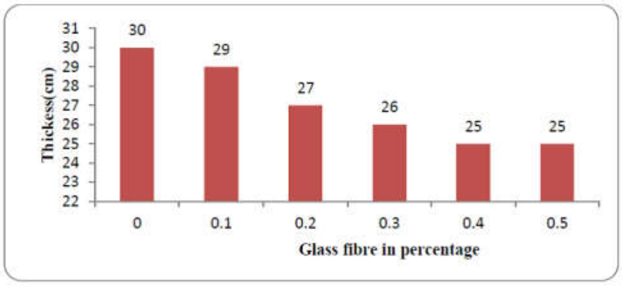

Figure 15 Effect of glass fibre on Slab thickness

CONCLUSIONS

- Slump is decreasing with the addition of glass fibres. However, the observed values lie between as specified (25-50) by the code for the pavement construction. Super plasticizer can be used if required more workable concrete.
- The addition of glass fibres improved compressive strength. The maximum increase in compressive strength is 32% and 13% at 7days and 28 days respectively. Addition of 0.5% of glass fibres in M30 grade concrete reached compressive strength equivalent to the M40 grade concrete.
- The flexural strength increased up to 35% over the range of glass fibre dosages. Higher value of modulus of rupture can be capacitating to inhibit cracks formation.
- Split tensile strength increased from 3.24 to 4.30MPa when added glass fibre varies from 0% to 0.5%. Split tensile strength is lower than the modulus of rupture because of the assumption of the linear behaviour of material up to failure.
- Water absorption increases with increase of fibre content and maximum water absorption found at 0.5% of glass fibre content. This is the drawbacks of glass fibre reinforced concrete because it will increase permeability and hence reduce durability.
- Modulus of elasticity increases with increase in glass fibre. The value of modulus of elasticity of concrete mix at 0% glass fibre is 3.04*10^5 kg/cm^2 and 0.5% glass fibre concrete mix is 3.40*10^5, which is nearly equal to 0.4% of GFCM. Higher value of modulus of elasticity indicates more ductile material and it control sudden failure.
- Ultrasonic pulse velocity test for 0% and 0.5% glass fibre concrete gives good and medium quality of concrete respectively and 0.1% , 0.2%, 0.3%,0.4% glass fibre concrete have excellent quality.
- On the basis of UPV test, modulus of elasticity test and water absorption test it may be suggested to use 0.4% of glass fibre concrete for construction. There is reduction in slab thickness of rigid pavement from 30 cm at 0% glass fibre to 24 cm at 0.5% glass fibre and 0.4% glass fibre concrete have 25 cm thickness. Reduction in thickness implies save material and to become economical.

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