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Use of glass fiber in pavement quality concrete slab

Vishal Jamwal
vishaljamwal1130@gmail.com
Lovely Professional University, Phagwara, Punjab

Paramveer Singh
param.1989@yahoo.com
Lovely Professional University, Phagwara, Punjab

ABSTRACT

The construction pavements have high strength, better durability and have moderate economy for a long period of time. The pressure nowadays is to make light and green pavements of better serviceability, which can resist the loads of high intensity. The main objective of this study is to design the slab thickness of pavement quality concrete (PQC) using achieved flexural strength of concrete mixture. In this study glass fiber is added to concrete at different percentages like 0.05%, 0.1%, 0.2%, and 0.4% and then these results are compared to the normal concrete mix. The flexural and split tensile strength are increasing as the fiber content is increasing. The study shows that having the high values of flexural strength and split tensile strength helps in higher load carrying capacity and higher life expectancy. The addition of glass fiber to concrete help in reducing the slab thickness and the least thickness of pavement slab is found for the addition of 0.4% glass fiber to concrete. As for pavement slab thickness is also reduced for M4-GF (0.05%) mix by 110 mm as compared with control mix result as per IRC 58:2002. The study helps in decreasing the cost of the project, thus by saving the cost of the material without even decreasing the strength of concrete.

Keywords: *Pavement quality concrete, Flexural Strength, Glass Fiber.*

1. INTRODUCTION

Concrete is widely used in construction industry because of its desirable properties like good compressive strength, high stiffness and high durability under good environmental conditions. But concrete on the other hand has low tensile strength and is brittle by nature. A high strength material should be used to make a good quality concrete pavement. The thickness of PQC is primarily dependent on the flexural strength of the concrete and on wheel axle.

In present era the main aim is to reduce the cost of construction due to concrete. To overcome the cost of concrete are either there will be replacement by waste materials or some addition is done to reduce the cost of concrete. In present study, glass fiber is used in addition to concrete to investigate the flexural properties and reduce the cost of the concrete. Glass fiber is a material made up of numerous extremely small fibers of glass. In present time there is boost to use some additional material to concrete to reduce the overall cost of project. Similarly glass fiber is used at various places to reduce the overall cost of construction.

Glass Fiber

Glass fiber is a material made up of numerous extremely small fibers of glass. The inclusion of any fiber (steel, glass, synthetic and natural) into concrete matrix is known as Fiber Reinforced Concrete (FRC). The fibers are dispersed into the concrete in random fashion thus by increasing the properties in all directions. . The fibers help in transferring the load to internal micro crack. Fibers help in fatigue strength, impact strength, pre-crack tensile strength, post peak ductility and prevent temperature and shrinking cracks. The fiber interlock and entangle around aggregates and significantly reduces the workability, while the mix becomes more cohesive and less prone to segregation. The present study uses Alkali Resistant glass fiber which prevents corrosion and helps improve concrete properties like tensile, impact, shear, and better water resisting properties. Glass fiber weight is much lighter in weight when compared to steel used in concrete.

Table 1: Physical Properties of Glass Fiber

PHYSICAL PROPERTIES	VALUES GIVEN BY SUPPLIER
Specific Gravity	2.68
Elastic modulus (GPa)	72

Tensile Strength (MPa)	1700
Length (mm)	12

2. LITERATURE REVIEW

Geeta V, Jose Ravindera Raj B. studied the effect of glass fiber in M40 grade of concrete by adding fiber at 0%, 0.1%, 0.2%, and 0.3% and found that strength are maximum at 0.3% addition of glass fiber; and 0.2% addition gives more strength than control concrete. **K.I.M.Ibrahim** observed that on addition of fiber as 0%, 0.1%, 0.3%, 0.5% by volume of concrete there is an significantly increase in the overall strength of the matrix**. Paramveer Singh** shows the optimum design of pavement quality concrete using RHA and he examined the flexural strength for different percentages of RHA with replacement of cement (by weight) i.e. for 5%, 10%, 15% and 20%.Maximum flexure strength of pavement quality concrete is achieved for 5% RHA replacement but at 10 % RHA replacement strength decrease slightly from control mix strength. **K Srinivas Rao, S.Rakesh kumar et al.** compared the results of standard concrete (SC) and Fiber reinforced concrete (FRC) at elevated temperature**,** which shows that fiber reinforced concrete shows high strength at all temperatures than standard concrete. **Chandermouli K, Srinivas Rao et al** studied the strength properties of fiber reinforced concrete. In this study 0.03% of glass fiber is added to M20, M30, M40, M50 grade of concrete and then compressive, flexural and split tensile strength of these concrete is carried out. He observed that the increase in compressive strength of various grade after 28 days was found to be 20 to 25%. The flexural and split tensile strength for these mixes was also found to increase by 15 to 20% with addition of glass fiber. **Komal Chawla and Bharti Tekwani** studied the composites of glass fiber reinforced concrete where he added glass fiber in ratio of 0, 0.33%, 0.67%, 1% by weight of concrete and he observed that the toughness of concrete is increased by 1157% compared to conventional concrete and the maximum toughness is attained at 0.67% and 1.25% steel reinforcement. Modulus of elasticity is increased by 4.14% compared to normal concrete. An increase in compressive is observed by adding glass fiber and the increase in compressive strength is 37% after 28 days. The increase in flexural strength is 5.19% after 28 days.

3. MATERIALS AND METHODS

Cement

In this study OPC 43 grade cement for design mix as per IS 269-2015. The various properties of cement are found out i.e. compressive strength after 3, 7 and 28 days, specific gravity, consistency and initial and final setting of cement as shown in Table 2

Table 2: Properties of OPC 43 grade Cement

S .no.	Characteristics	Value obtained Experimentally
1.	Specific Gravity	3.15
2.	Standard Consistency	30.5%
3.	Initial Setting Time	150 minutes
4.	Final Setting Time	255minutes
5.	Compressive Strength	
	3 days	32.9 N/mm^2
	7 days	42.6 N/mm^2
	28 days	47.5N/ mm^2

3.1.2 Coarse Aggregate

Coarse aggregate used in the experiment are mainly obtained from crashed stone with 20 mm and 10 mm size in 50:50 fraction respectively.

Fine Aggregate

Fine aggregate used for experimental work is of Zone II. The specific gravity examined is 2.68.

Glass Fiber

In the present study Alkali Resistant glass fiber is used having a length of 12mm and specific gravity of 2.68.

Mix Design for Concrete

The main aim of experimental work is to investigate flexural strength of concrete. M40 grade of concrete is used to investigate the mechanical properties of concrete. The mix design was prepared to investigate the properties of concrete using IS 10262-1982. The mix proportion of concrete is given in Table 3.

Table 3: Mix Proportion of concrete per cubic meter

S No.	Mix	Mix Proportion (C:F.A:C.A) (1:2.17:3.5)						
		Glass fiber %	Glass fiber (kg/m^3)	Cement (kg/m^3)	W/C ratio	F.A (kg/m^3)	C.A (kg/m^3)	S.P %
1	CM	0	0	350	0.4	761	1228	0.5
2	M1	0.05	1.169	350	0.4	761	1228	0.50.5
3	M2	0.1	2.339	350	0.4	761	1228	0.5
4	M3	0.2	4.678	350	0.4	761	1228	0.5
5	M4	0.4	9.356	350	0.	761	1228	0.5

C: Cement, F.A.: Fine Aggregate, C.A: Coarse Aggregates, S.P: Super plasticizer
G.F: Glass fiber, CM: Control Mix, M1: Mix one, M2: Mix two, M3: Mix three, M4: Mix four

4. TEST RESULTS AND DISCUSSION

Flexural Strength

The most common concrete structure subjected to flexure is a highway or airway pavement and strength of concrete for pavements is commonly evaluated by means of bending tests. The flexure strength in this study is increasing as the content of glass fiber increases. The beam specimens 100mm x 100mm x 500mm were used for testing the flexural strength after 7 days and 28 days as per IS: 516-1959 . Specimens has been made for control mix and compared with different percentages replacement of cement with RHA i.e. for 5%, 10%, 15 % and 20 %. The flexural strength after 7 days and 28 days discussed in given figure 1.

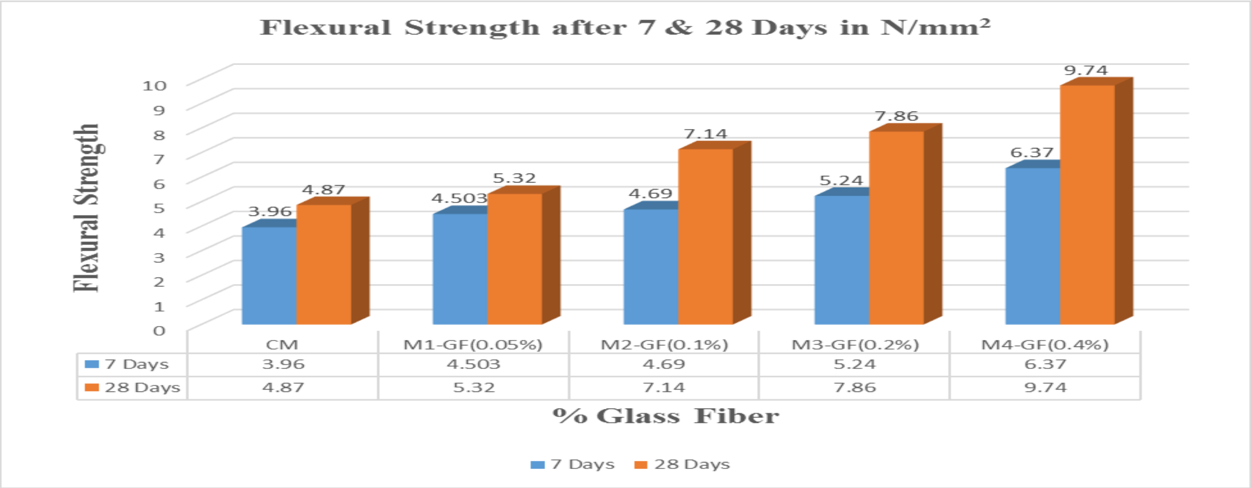


Fig 1: Flexural Strength after 7 and 28 days

In Pavement Quality Concrete the mean target strength for control mix for m40 after 28 days is 4.5 N/mm^2, and in our case its 4.87 N/mm^2 which is greater than the target strength. We can see that as the percentage of fiber is increasing the flexural strength is increasing. The target strength at every percentage addition of glass fiber is more than the target strength. So for M40 grade of concrete we are getting optimize results at every single variation of glass fiber.

3 Split Tensile Strength

The split tensile strength is calculated at 7 and 28 days for M40 grade of concrete with addition of glass fiber at different percentages. The split tensile strength in this study is increasing as the content of glass fiber is increased. The results of split tensile strength are shown in given table below and same are shown on the chart below.

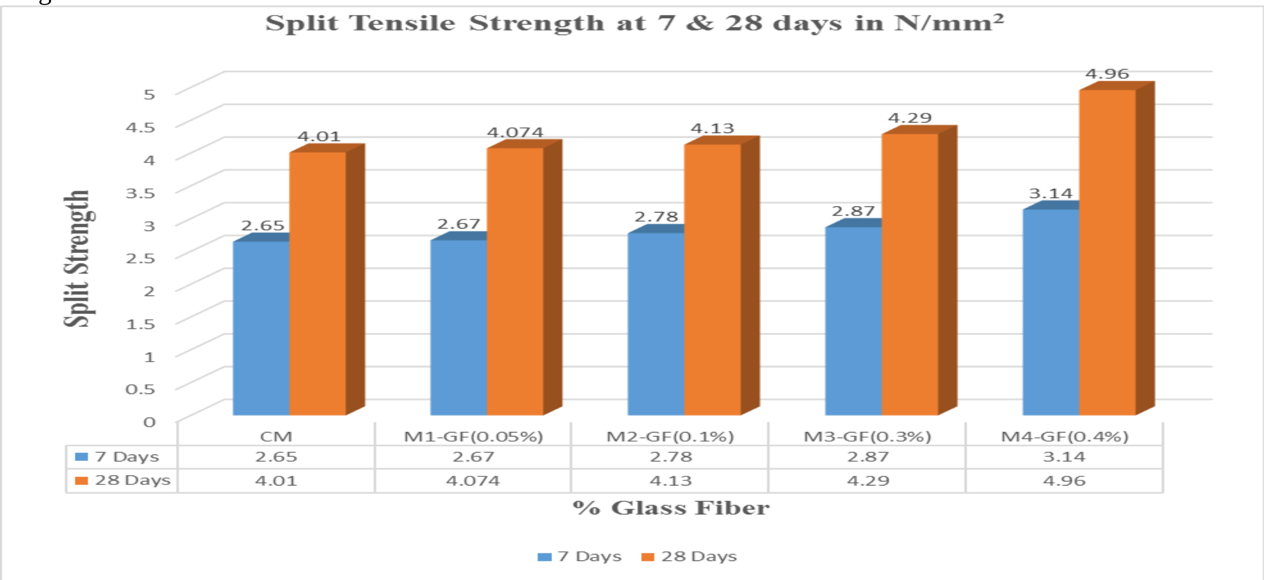


Fig 2: Split Tensile Strength after 7 and 28 days

Design of Slab Thickness

The slab design process as per IRC 58-2002 for the pavement quality concrete tested in the laboratory is presented in figure 1. The Table 3 contains results according to the input traffic data in terms of the expected repetitions for the single and tandem axles, for which the slab thicknesses have been calculated. The other input parameters are as below:

Road category: Four lane National Highway Cement Concrete Pavement

Modulus of sub-grade reaction with 150mm,

DLC: 8kg/cm^3

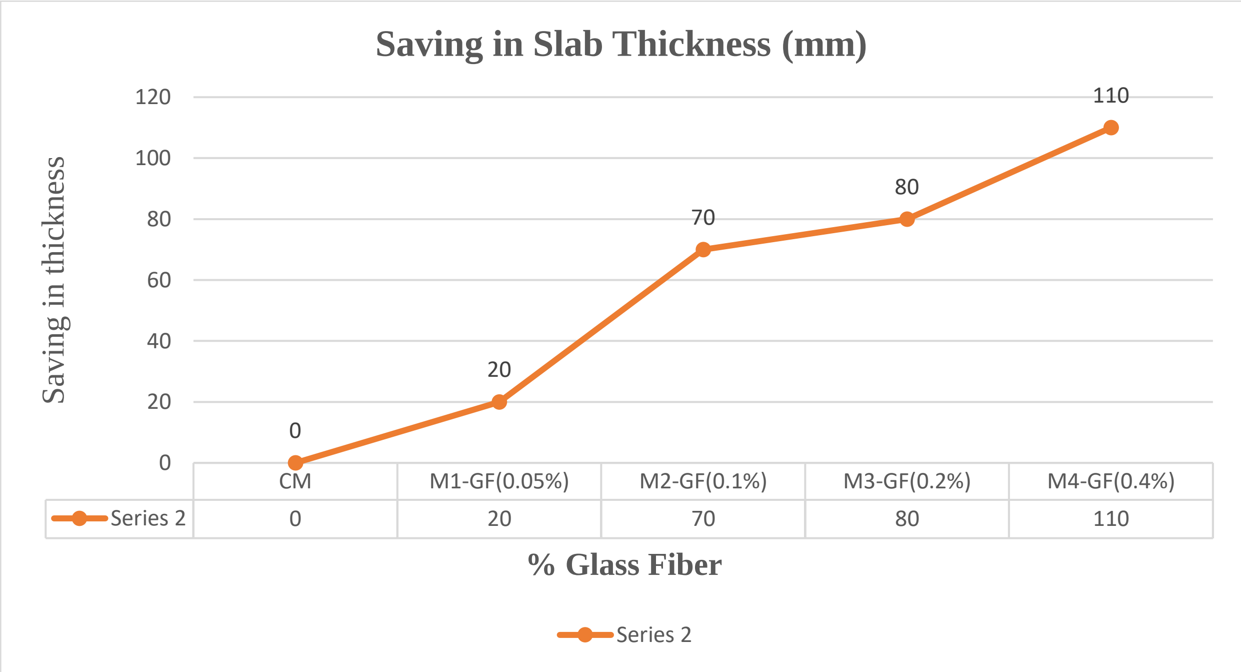
Elastic Modulus of Concrete: 3 x 10^5 kg/cm^2

Tyre Pressure: 8 kg/cm^2

Rate of increase of traffic: 7.5%

Table 4: Thickness of slab corresponding to observed flexural strength as per IRC 58:2011

S. No.	**Mix**	**Flexural Strength after 28 days in N/mm^2**	**Thickness of slab (mm)**	**Fatigue value**
1	CM	4.87	280	0.44
2	M1-GF (0.05%)	5.32	260	0.69
3	M2-GF (0.1%)	7.14	210	0.84
4	M3-GF (0.2%)	7.86	200	0.55
5	M4-GF (0.4%)	9.74	170	0.81



Saving of Materials in Design of Slab Thickness Pavement

According to the results of the study, compiled for different mixes incorporating RHA in the Table 5 below, other than nominal mix, there is a noticeable change (i.e. decrease in material usage or saving of materials on economical basis) of following materials:

- Concrete Pavement Thickness
- Volume of concrete (m3) used for 1 km Two Lane Highway
- Cement content (kg)
- Fine Aggregate (kg)
- Coarse Aggregate 10mm (kg)

Table 5: Saving in Concrete Ingredients by using glass fiber

Mix	**Slab Pavement thickness (mm)**	**Saving in PQC slab thickness (mm)**	**Saving in m^3 of Concrete for 1 km Four lane Highway**	**Saving in Cement Content ((Kg)**	**Saving in Fine aggregate (Kg)**	**Saving in Coarse aggregate (Kg)**
CM(Min)	330	-				
CM	280	50	700	151124.5	382595.9	67586.3
M1-GF (0.05%)	260	70	980	211574.3	535634.6	946207.2

M2-GF (0.1%)	210	120	1680	362698.7	918231.3	1622069
M3-GF (0.2%)	200	130	1820	392923.6	994750.6	1757242
M4-GF (0.4%)	170	160	2240	483598.2	1224309	2162759

From this table we can conclude that M4-GF (0.4%) is optimum for design of pavement slab. It will save 2240m3 of concrete as compared to CM as per IRC58:2011. So this mix should be used for economical aspect as per construction requirement.

5. CONCLUSION

From this study we are able to conclude these following results:

- The flexural strength is increasing as the fiber content is increasing and the maximum flexural strength is attained at 0.4% addition of glass fiber to concrete. The maximum flexural strength is 6.37N/mm^2 and 9.74N/mm^2 after 7 and 28 days of curing.
- The split tensile strength is also increasing as the fiber content is increased and the maximum results are found at 0.4% addition of glass fiber. The maximum split tensile strength is 3.14 N/mm^2 and 4.96 N/mm^2 after 7 and 28 days.
- The maximum flexural strength is attained at 0.4% addition of glass fiber so we had designed the PQC at 0.4% because it had attained least thickness of slab which had automatically decreased the overall cost of project.

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