International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June-2018 www.irjet.net p-ISSN: 2395-0072

Experimental Study on Strength of Fiber Reinforced Concrete for Rigid Pavements

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Abstract - *Concrete is one of the most widely used material in construction industry. Nowadays the behaviour the rigid pavement is on the expansion and need more analysis in improvement the properties of concrete. The lack of tensile strength under the severe conditions is one of the orientation or target in this paper. The improvement of the concrete in rigid pavement will be focused on using the fibres. The aim of study is to check the various characteristic of M- 40 concrete mix design by using steel fibers and polypropylene fibers individually as well as in hybrid form with normal mix design by varying the fiber percentages, to check the effects of hybrid fibres on behaviour of pavement quality concrete.*

***Key Words*: Fibre Reinforced Concrete, Cement, Polypropylene Fibres**

1. Introduction

India's good road network has an important bearing on the economic growth of the country. It has a road network of over 4,689,842 kilometers (2,914,133 mi) in 2013,the second largest road network in the world which forms the arteries of the nation. Rural connectivity is perceived as one of the major component in increasing the agricultural output and earning capacity of the rural population.

A pavement is the layered structure on which the vehicle travels which serves two purposes, namely, to provide a comfortable and durable surface for vehicles and to reduce stresses on underlying soils. Traditionally the bituminous pavements are widely used in India. Bitumen is the byproduct of distillation of imported petroleum crude but locally available cement is a better substitute for the construction of rigid pavements rather than flexible ones. It is a bitter truth that petroleum and its byproducts are getting designated day by day. In India whenever there is a need for road construction it is taken for granted that it would be a bituminous pavement and chances are rare for the thought of an alternative like concrete pavements. Within two to three decades bituminous pavements would be a history and thus the need for an alternative is critically important.

A new trend of using wide range of fibers in concrete has revolutionized the concepts of concrete technology. Inclusion of fraction quantity of fibers in cement concrete has shown remarkable appreciation in its static and dynamic properties. The inclusion of fibers in concrete generally improves material properties like ductility, flexural strength, toughness, impact resistance, fatigue strength and little improvement in compressive strength. The type and amount of improvement is dependent upon the fiber type, size, strength and configuration and amount of fiber. Hybridization of steel fibers and polypropylene fibers can result in enhancement of properties of concrete by fulfilling each other's drawbacks and lacking when used separately.

One of the most important aspects of project design is effective pavement design. The pavement is the portion of the highway which is most obvious to the motorist. The condition and adequacy of the highway is often judged by the smoothness or roughness of the pavement. Deficient pavement condition can result in increased user costs and travel delays, braking and fuel consumption, vehicle maintenance repairs and probability of increased crashes. The pavement life is substantially affected by the number of heavy load repetitions applied, such as single, tandem, tridem and quad axle; trucks, buses, tractor, trailers and equipments.

1.1 Rigid Pavements

Rigid pavements are so named because the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. A rigid pavement structure is typically composed of a pcc surface course built on top of either (1) the sub grade or (2) an underlying base course. Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one, or at most two, structural layers.

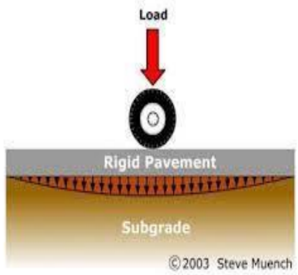

Figure 1.1: Rigid pavement load distribution

2 Literature Review

K. Vamshikrishna, j. Venkateswara Rao (2014) – in his study "experimental study on behavior of fiber reinforced concrete for rigid pavements" emphasis is given to experimental investigation on mechanical properties of m20 grade concrete by incorporating polyester fibers in the mix. Polyester fibers of 0.1%, 0.2%, 0.3%, 0.4% by weight of cement are added to the mix. A comparative analysis has been carried out for conventional concrete to that of the fiber reinforced in relation to compressive, split tensile, flexural strengths. As the fiber content increases compressive, split tensile and flexural strengths are proportionally increasing. It is observed that 0.3% fibers by weight of cement is the optimum dosage. It is found that with 0.3% fiber content results in 20% reduction of pavement thickness. Dr. Deepa sinha, prof. C.b.mishra, ravindra k. Solanki (2014) explained in their study on "comparison of normal concrete pavement with steel fiber reinforced concrete pavement" that in india, owing to rapid engines of growth in infrastructure and tremendous rise in highly laden vehicles on limited road space demands road to withstand high stresses with minimum maintenance. Pavements made of concrete provide durable service life and has remarkable application under heavy traffic loading. They have made an attempt is made to evaluate the compressive strength and flexural strength with and without steel fibers. Also the stresses are worked out. The test results shows that steel fiber reinforced concrete is an excellent new type of composite material compared with ordinary concrete as thickness of road is reduced without affecting the load carrying capacity and is a cost effective technology. The inclusion of steel fiber shows a constant increase in radius of relative stiffness increases also increase of flexural strength is noted with increase in % of steel fibers, especially economical at a dosage of 1 % of steel fibers. Considerable changes in temperature stress values are noted too.

3. Materials and its Properties

3.1 Cement

While using cement in important and major works it is very essential on the part of the user to test the cement in the laboratory to confirm the requirements of the Indian standard specifications with respect to its physical and chemical properties.

Table 3.1

Weight Of Sample In Grams	Weight Of Remaining In Grams	Result %
100	1.96	1.96

Table 3.2: Normal Consistency of cement

Water Added In % By Weight Of Cement	Penetration From Top
25	39
28	37
29	36
30	35+
31	**34**

Table 3.3: Initial setting and Final setting of cement

Compressive Strength N/Mm²			
	3days	7days	28days
Required	27	37	53
Obtained	33.1	43.97	59.69

Table 3.4 Compressive strength of cement

Setting Time	Obtained
Initial	35 Mins
Final	135 Mins

Table 3.5: Specific gravity of Aggregates

Sl.No.	Size Of Aggregate (Mm)	Specific Gravity [A/(AD)]%
1.	20(C.A.)	2.94
2.	10(C.A)	2.84
3.	2.36(F.A.)	2.57

Table 3.6: Water absorption of aggregates

Sl. No.	Size of Aggregate in mm	Water Absorption
1	Coarse Aggregate (20 Mm)	0.85%
2	Coarse Aggregate (10 Mm)	1.30%
3	Fine Aggregate (4.75 Mm)	1.40%

3.2 Fibre Reinforced Concrete

Fibre Reinforced Concrete (FRC) can be defined as a composite material consisting of concrete and discontinuous, discrete, uniformly dispersed fine fibres. The continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

The inclusion of fibres in concrete generally improves material properties like ductility, flexural strength, toughness, impact resistance, fatigue strength and little improvement in compressive strength. The type and amount of improvement is dependent upon the fibre type, size, strength and configuration and amount of fibre.

3.3 Steel Fibres

Steel fibre is one of the most commonly used fibre. They are generally round. The diameter may vary from 0.25mm To 0.75mm. The steel fibre is likely to get rusted and loose some of its strength. Use of steel fibre makes significant improvements in flexural impact and fatigue strength of concrete.

Steel fibres have been extensively used in overlays or roads, pavements, air fields, bridge decks, thin shells and flooring subjected to wear and tear and chemical attack.

Figure 3.1: Hooked End Steel Fibres

Figure 3.2: Straight Steel Fibres

Physical Properties
- Type: Hook End
- Length: 30mm
- Diameter: 0.50mm
- Ultimate tensile strength: 128.21 kg/mm^2
- Aspect ratio : length/diameter = 30mm/0.50mm = 60

Chemical properties
- Carbon: 0.08%max
- Manganese: 0.35%max
- Silicon: 0.15% max
- Sulphur: 0.05%max
- Phosphorous: 0.035%max

3.4 Plastic Fibres

Fibers such as polypropylene, nylon, acrylic, aramid and polyethylene have high tensile strength but low young's modulus thus inhibiting reinforcing effect.

Polypropylene and nylon fibres are found to be suitable to increase the impact strength. Their addition to concrete has shown better distribute cracking and reduced crack size. They have low modulus of elasticity. The amount of plastic fibres added to concrete is about 0.25 to 1 percent by volume. The polypropylene fibres are available in two forms: mono filaments and film fibres. The film fibres are commonly used.

Figure 4: Polypropylene Fibre

Physical Properties
- Appearance: White Fibers
- Specific Gravity: 0.91
- Melting Point: 165°C
- Length: 12mm
- Absorbency: <0.1%

4. Results and Discussions

Table 4.1 Result of Slump of SFRC

Duration	Initial Slump	
Slump	50 Mm	Conventional Concrete
Temp:	$34^{0}C$	
2 % Steel Fibre	68 Mm	
2.5 % Steel Fibre	70 Mm	
3 % Steel Fibre	71 Mm	

Table 4.2 Result of Slump of PFRC

Duration	Initial Slump	
Slump	45 Mm	Conventional Concrete
Temp:	$36^{0}C$	
0.5% PP Fibre	55 Mm	
0.75% PP Fibre	59 Mm	
1% PP Fibre	60 Mm	

30 +/- 15 Mm Morth 602.3.4.2

Table 4.3 Compressive Strength of M-40 Grade SFRC (Straight) With 2%, 2.5% And 3% Fibres

Age In Days	For SFRC With 2% Fibres				For SFRC With 2.5% Fibres				For SFRC With 3% Fibres			
	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)
3	8.63	950	42.22	**42.37**	8.58	980	43.56	**43.56**	8.64	1000	44.44	**44.44**
	8.68	970	43.11		8.70	990	44.00		8.69	1010	44.89	
	8.74	940	41.78		8.63	970	43.11		8.58	990	44.00	
7	8.74	1000	44.44	**44.30**	8.64	1100	48.89	**49.93**	8.70	990	44.00	**49.63**
	8.65	1010	44.89		8.65	1130	50.22		8.82	1200	53.33	
	8.82	980	43.56		8.82	1140	50.67		8.49	1160	51.56	
28	8.72	1380	61.33	**60.59**	8.76	1420	63.11	**62.07**	8.68	1440	64.00	**63.56**
	8.68	1310	58.22		8.83	1390	61.78		8.75	1430	63.56	
	8.75	1400	62.22		8.43	1380	61.33		8.63	1420	63.11	

Table 4.4 - Compressive Strength Of M-40 Grade PFRC With .5%, .75% And 1% Fibres

Age In Days	For PFRC With .5% Fibres				For PFRC With .75% Fibres				For PFRC With 1.0% Fibres			
	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)	Wt Of Cube (Kg)	Load (Kn)	Strength (N/Mm²)	Avg Strength (N/Mm²)
3	8.71	880	39.11	**40.59**	8.68	910	40.44	**40.74**	8.79	950	42.22	**43.70**
	8.69	910	40.44		8.75	940	41.78		8.63	970	43.11	
	8.57	950	42.22		8.81	900	40.00		8.74	1030	45.78	
7	8.89	980	43.56	**44.30**	8.90	1020	45.33	**44.59**	8.80	990	44.00	**45.78**
	8.67	1000	44.44		8.74	980	43.56		8.68	1040	46.22	
	8.52	1010	44.89		8.64	1010	44.89		9.00	1060	47.11	
28	8.71	1200	53.33	**54.07**	8.90	1210	53.78	**57.48**	8.87	1310	58.22	**59.26**
	8.76	1190	52.89		8.80	1360	60.44		8.52	1290	57.33	
	8.69	1260	56.00		8.61	1310	58.22		8.69	1400	62.22	

5. Pavement Design

Example of design of slab thickness for pavement as per IRC:58-2011

TYPE OF PAVEMENT CONSIDERED	
Carriageway	4-Lane Divided
Tied concrete shoulder	Yes
Transverse joint spacing(m)	4.5
Lane width (m)	3.5
Transverse joint have dowel bars?	Yes

DESIGN TRAFFIC ESTIMATION	
Design period (years)	30
Total two-way commercial traffic (cvpd) in the year of completion of Construction	6000
Average annual rate of growth of commercial traffic	0.075
Cumulative no of commercial vehicles during design period (two-way), **A**	226444692
Average no of axles per commercial vehicle,**b**(each tandem axle set is Counted as one axle unit. Similarly, each tridem axle set is counted as oneAxle)	2.35
Cumulative no of commercial axles (steering, single, tandem, tridem) During design period (two-way),**c = a*b**	532145025
Proportion of traffic in predominant direction ,d	0.50
Design traffic factor (0.25 for 2-lane 2-way. For multilane highways the Value is 0.25 x d),e	0.125
Traffic factor for buc analysis (for six-hour period during day),f	0.2
Traffic factor for tdc analysis (for six-hour period during night),g	0.3
Design axle repetitions for buc analysis (for 6 hour day time traffic), H = c*e*f	13303626
Proportion of vehicles with spacing between front and the first rear axle Less than the spacing of transverse joints,i	0.55
Design axle repetitions for tdc analysis (for 6-hour night time traffic),j = c*e*g*i	10975491
Proportion of front single (steering) axles,k1	0.450
Proportion of rear single axles,k2	0.150
Proportion of tandem axles,k3	0.250
Proportion of tridem axles,k4= (1-k1-k2-k3)	0.150

PAVEMENT STRUCTURAL DETAILS	
Modulus of subgrade reaction of subgrade, mpa/m	50.3
Thickness of granular subbase, mm	12
Thickness of dry lean concrete subbase, mm	150
Effective modulus of subgrade reaction of foundation, mpa/m	285
Unit weight of concrete, kn/m3	24
28-day flexural strength of cement concrete, mpa	4.5
Max. Day-time temperature differential in slab, °c (for bottom-up Cracking)	16.8
Night-time temperature differential in slab, °c (for topdown cracking) = Day-time diff/2 + 5	13.4
Trial thickness of concrete slab, m	0.28
Load transfer efficiency factor for tdc analysis, beta =	0.66
Elastic modulus of concrete, ec (mpa)	30000
Poisson's ratio of concrete, mu	0.15
Radius of relative stiffness, m	0.66621
Note: Beta Value Will Be 0.66 For Dowelled Transverse Joint And 0.90 For Without Dowels	

DESIGN AXLE LOAD REPETITIONS FOR FATIGUE ANALYSIS	
For Bottom-Up Cracking Analysis	
Front single (steering) axles = h * k1	5986632
Rear single axles = h * k2	1995544
Tandem axles = h * k3	3325906
Tridem axles = h * k4	1995544
For top-down cracking analysis	
Front single (steering) axles = j * k1	4938971
Rear single axles = j * k2	1646324
Tandem axles = j * k3	2743873
Tridem axles = j * k4	1646324

6. CONCLUSIONS

1. All cement tests and aggregate tests confirms their respective acceptance ranges and gradation of course and fine aggregate satisfies the limited standards and hence can be utilized further for design purpose.
2. Slump values for frc mix with steel fibres as well as polypropylene is found slight decreasing with respect to normal concrete mix of pqc m-40 grade. So to counter
3. Balance the slump and to maintain the workability dosage of 1% super plasticizer Rheobuild 1126 is achieved by different trials and accordingly up to 30% of water Reduction is possible.
4. It is observed that compressive strength and flexural strength are on higher side for 3% Steel and 1% polypropylene fibres content as compared to that produced from 2% steel and 0.5% polypropylene fibres
5. From The Present Study It Can Be Concluded That, Hybridization May Allow Us To Reduce the thickness of The Rigid Pavements Upto 30% On Achieving The Remarkable Compression and Flexural Strengths.
6. Compared To Other Traditional Solutions For The Problem Of Reducing Thickness Of Hybridization Marks The Suitability And Ultimately Cost Benefits.

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