Scientific Journal of Impact Factor (SJIF): 4.14
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 9, September -2016

EXPERIMENTAL INVESTIGATION ON PROPERTIES OF SYNTHETIC FIBRE REINFORCED CONCRETE PAVEMENTS

Athira Das[1] & Priya Grace IttiEipe[2]

[1]PG Scholar, Dept. of Civil Engineering, SVNCE
[2]Professor and Head, Dept. of Civil Engineering,SVNCE

Abstract-*Rigid pavements which are mad of concrete is broadly used in construction world due to its compressive strength, extended service life and economy. There are several advantages of cement concrete pavement over bituminous pavements. Synthetic fibre reinforced concrete pavement proves to be more efficient than conventional concrete pavement in several aspects. They consists of added fibres in concrete which increases the structural integrity of pavement. This work presents a preliminary study on the fundamental material properties of synthetic fibre reinforced concrete used in pavements for M25 grade concrete mix and the fibres used were polypropylene, polyester and nylon. Synthetic fibres of 0.25%, 0.5%, 0.75% and 1% by volume fraction were added to the mix. A comparative analysis had been carried out for conventional concrete to that of the fiber reinforced in relation to various material test conducted. The optimum dosage of each fibre and their durability properties was also examined.Synthetic fibre reinforced concrete proved to be used advantageously over normal concrete pavement. Each type of fibre has its characteristics properties and limitations.*

Keywords: *Rigid pavements, polypropylene, polyester,nylon, conventional concrete*

I. INTRODUCTION

Cement concrete pavement offers long term service life and excellent applicability to heavy traffic. It is easier to purchase and more durable than bituminous pavement. A pavement is a layered structure on which vehicles travel. In India, the traditional system of bituminous pavements are widely used. The traditional bituminous pavements and their needs for continuous maintenance and rehabilitation operations points towards the scope for cement concrete pavements. Locally available cement concrete is a better substitute to bitumen which is the by-product in distillation of imported petroleum crude. However, concrete is a well-known brittle material when subjected to normal stress and impact loading, especially, with its tensile strength being just one tenth of its compressive strength. As a result the formation of crack is the main reason for the failure of concrete. To increase the tensile strength of concrete many attempts have been made. However fibre reinforcement gives the solution to this problem.

Fibres act as crack arresters and prevent the propagation of the cracks. These fibres are uniformly distributed and randomly arranged. The main reason for adding fibres to concrete matrix is to improve the post cracking response of the concrete, to improve its energy absorption and apparent ductility and to provide crack resistance and crack control. Use of synthetic fibre is an environment friendly approach in the field of pavement construction as almost all sorts of synthetic waste can be recycled and used as a reinforcing admixture in the concrete pavements. The Bureau of Indian Standards (BIS) and Indian Road Congress (IRC) have recognized the use of polymer fibres with concrete. This study includes the concept of synthetic fibre reinforced concrete (SNFRC) used in pavements and the fibres used were polypropylene, polyester and nylon fibre. Monofilament fibres were used and they were having specific aspect ratio. In order to study the load transfer efficiency of different joint conditions, an experimental program was undertaken in terms of the load-deflection behavior of beams in the Universal Testing Machine.

II. EXPERIMENTAL DETAILS

2.1 Materials

The materials used in this investigation were: Ordinary Portland cement, coarse aggregate, fine aggregate and potable water as well as locally available synthetic fibres such as polypropylene, nylon and polyester. The properties of each material in concrete mix were studied at this stage.Ordinary Portland cement of 53 grade conforming to IS 12269 was usedand its properties are shown in Table 1. Crushed stone sand was used as fine aggregate. Laboratory tests were conducted on fine aggregate to determine the different physical properties and it is shown in Table 2. Crushed granite stones obtained from local quarries were used as coarse aggregate. The maximum size of coarse aggregate was 20 mm with fineness modulus 7.079 and its properties are shown in Table 3. The fibres used were polypropylene fibre,obtained from BSS Pvt Ltd, Ernakulam, nylon fibre from Meher International, Surat and polyester fibre used in this study was Recron 3S and was obtained from Reliance India Ltd. The properties of fibres are shown in Table 4. Potable water was used as mixing water.

Table-1 Properties of cement

PARTICULARS	VALUES
Fineness of cement	6%
Specific gravity of cement	3.13
Consistency of standard cement paste	30.75%
Initial setting time	92minutes
Final setting time	267minutes
3rd day compressive strength (N/mm^2)	28
7th day compressive strength (N/mm^2)	32

Table-2 Properties of fine aggregate

PARTICULARS	VALUES
Specific gravity	2.6
Sand type	Medium
Grade	Zone II

Table-3 Properties of coarse aggregate

PARTICULARS	VALUES
Specific gravity	2.65
Void ratio	0.771
Bulk density(Kg/m^3)	1.571
Porosity	0.435

Table-4 Properties of syntheticfibre

Properties of Fibres	Polypropylene	Nylon	Polyester
Type	Monofilament	Monofilament	Monofilament
Diameter (mm)	0.44	0.030	0.036
Aspect ratio	113.6	633.33	333.33
Specific gravity	0.91	1.14	1.4
Water absorption, %	30.21	66.66	44.72
Density, kg/m^3	763	657	1380

2.2 Mix proportioning

As per IRC 44-2008, a mix design was suitably designed for M25 grade concrete based on the material properties. The same mix proportion was used for SNFRC and conventional concrete, in order to compare the properties of both. The concrete mix proportion of 1:2.16:3.75 (1 part of cement, 2.16 parts of fine aggregate, 3.75 parts of coarse aggregate) with water cement ratio 0.45. Table 5 shows the details of the mix.

Table-5 Details of the mix

Water	Cement	Coarse aggregate	Fine aggregate	Super plasticizer	W/C ratio
148.8ltrs	331 kg	1243 kg	716.08 kg	0.3%	0.45

In this study synthetic fibre mixes at different dosages were adopted. One control mix and the remaining mixes were prepared by adding synthetic fibres polypropylene, nylon and polyester to concrete at 0.25%, 0.50%, 0.75% and 1% by volume fraction (V_f). Table 6 shows the mix designation of different mixes. The weight of synthetic fibres used in the mix depends on the required volume fraction, the dimensions of the mould and on the specific gravity of each fibre itself. Volume fraction of fibre is the ratio of volume of fibre to gross volume of compacted concrete, expressed in percentage.

Table-6 Mix designation

Vol. Fraction	Polypropylene	Nylon	Polyester
0.25 %	PP 0.25	NY 0.25	PY 0.25
0.5%	PP 0.5	NY 0.5	PY 0.5
0.75%	PP 0.75	NY 0.75	PY 0.75
1%	PP 1	NY 1	PY 1

2.3 Specimen preparation and curing

Specimens of fibre reinforced concrete and conventional concrete were prepared. Mixing was done in a laboratory type pan mixer as shown in Fig 1. While preparation of concrete specimens, aggregates, cement and fibres were mixed in the revolving pan. After proper mixing, mixture of water and plasticizer were added. The mixing was continued until uniform mix was obtained. Thoroughly mixed concrete is filled into the mould in 3 layers of equal heights followed by tamping. After casting the moulded specimens were stored in the laboratory at room temperature for 24 hrs from the time of addition of water to dry ingredients. After this period the specimens were removed from the moulds, immediately submerged in clean and fresh water as shown in Fig 2. 7, 28, 56 and 90 days curing were done for different specimens.

Figure-1 Mixing of concrete

Figure-2 Curing of specimens

Cube specimen of dimensions 15x15x15cm and 10x10x10cm, 15cm diameter and 30cm height cylinder specimens, 10cm diameter and 20cm height cylinder specimens, 15 cm diameter and 5 cm height disc specimens and 50 x 10 x 10 cm beams specimens were cast. A total of 366 specimens were cast.

2.4 Workability of fresh concrete

Slump test is the most commonly used method for measuring workability of concrete, which can be employed either in laboratory or at site of work. It was observed that the workability reduced as the synthetic fibre content increased. The reduction in the slump with the increase in the fibre will be attributed to presence of fibres which causes obstruction to the free flow of concrete. Super plasticizer was added to reduce the slump loss in FRC. Due to higher surface area and water absorption capability, polypropylene fibres possessed les workability in increased fibre dosage.

Compaction factor is one of the most efficient test for measuring the workability of concrete. It was observed that compaction factor decreases with addition of fibre in concrete with respect to the normal mix. Minimum loss in workability was observed for nylon fibre. Due to less content and small surface area of nylon fibre, it absorb less cement paste to wrap around on comparing to polypropylene and polyester.

2.5 Strength study on hardened concrete

Compressive strength of concrete is a measure of its ability to resist static load, which tends to crush it. Cube specimen of size 15x15x15x cm were casted and tested in compressive testing machine for each fibre mixture as shown in Fig 3 and 4 and 7,28 and 56 days strength was calculated. Specimens were placed on the bearing surface of the machine of capacity 2000kN without eccentricity and a uniform rate of loading of 14 N/mm^2 per minute was applied till the failure of the cube. Four volume fractions were considered for three synthetic fibres. It was observed that, compressive strength of PP0.75 was obtained as maximum strength for polypropylene fibre and NY0.25 and PYo.5 was observed as the optimum dosages for nylon and polyester fibre mixes respectively and later with increase in fibrecontent strengths were falling down. Table 7 shows compressive strength test for different mixes.

Figure-3 Compressive testing machine

Figure-4 Compression test on cube

Table-7 Compressive strength test for different mixes

V_f (%)	Polypropylene Fibre (MPa)			Nylon Fibre (MPa)			Polyester Fibre (MPa)		
	7 day	28 day	56 day	7 day	28 day	56 day	7 day	28 day	56 day
0	22.77	31.11	35.55	22.77	31.11	35.55	22.77	31.11	35.55
0.25	26.22	32.34	36.22	31.44	38.33	40.44	26.33	34.67	39.11
0.5	27.53	35.56	39.56	27.22	35.56	36.89	31.11	42.44	45.33
0.75	28.68	38.89	42.44	22.99	27.55	32.67	27.12	36.22	37.77
1	23.55	30.22	33.56	20.34	24.23	30.44	25.33	29.33	32.44

For split tensile strength test, cylinder specimens of size 15 cm (diameter)x 30 cm (height) were casted for all dosages of fibre mixes and tested in compressive testing machine. It was done after 28 days of water curing. In this test a cylindrical specimen was horizontally placed between the loading surface of the machine and the load was applied until the failure of the cylinder, along the vertical diameter as shown in Fig 5. Increase in split tensile strength with respect to the control mix was observed for all mixes. Maximum increase in split tensile strength was by 47.27% for PP0.75 mix and an increment of 42.41% for NY0.25 and 44.98% for PY 0.5 mixes were observed. Table 8 shows split tensile strength test for different mixes.

Figure-5 Split tensile strength on cylinder

Table-8 Split tensile strength test for different mixes

Volume Fraction of Fibre (%)	Polypropylene (MPa)	Nylon (MPa)	Polyester Fibre (MPa)
0	3.49	3.49	3.49
0.25	4.58	4.97	4.88
0.5	4.82	4.86	5.06
0.75	5.17	4.59	4.93
1	4.77	4.23	4.76

Fordetermining flexural strength of mixes, beam specimens of size 50x10x10 cm were casted and tested in flexural strength testing machine as shown in Fig 6, for all dosages of fibre mixes. Testing was done after 28 days of water curing. The specimen was simply supported on the two rollers of the machine. The load shall be applied on the beam from the rollers which were placed above the beam. The load was increased till the beam fails as shown in Fig 7. Flexural strength assessment demonstrated that having fibre in concrete showed better results due to crack bridging action of fibre. Maximum increment of strength was observed by 44.75% for NY0.25 mix with respect to normal mix. Similarly, increment of 42.79% and 40.17% for PP0.75 and PY 0.5 mixes respectively were observed on comparing with normal mix. Table 9 shows flexural tensile strength for various mixes.

Figure-6 flexural strength testing machine

Figure-7 Bean specimen subjected to flexuralloading

Table-9 Flexural strength test for different mixes

Volume Fraction of Fibre (%)	Polypropylene (MPa)	Nylon (MPa)	Polyester Fibre (MPa)
0	4.58	4.58	4.58
0.25	5.94	6.63	6.05
0.5	6.23	6.38	6.42
0.75	6.54	6.14	6.26
1	6.04	5.98	6.05

Modulus of elasticityof concrete was experimentally determined as per IS 516-1959 from the slope of a stress-strain curve plotted based on uniaxial compression test conducted on concrete cylinder specimen 15 cm (diameter) x 30 cm(height) in compression testing machine as shown in Fig 8. The axial deformation of the cylinder was measured using a dial gauge of accuracy 0.002mm fitted to a longitudinal compressometer of gauge length 200mm. A series of reading were within the elastic limit and the stress-strain graphs were plotted. The test was conducted at 28 days curing.It was observed that modulus of elasticity decreased with fibre dosage. For nylon fibre elasticity was almost same as that of normal mix but for polypropylene and polyester fibre mixes elasticity reduced for about 10.34% and 3.34% respectively on comparing to normal mix. Reduction in modulus of elasticity was due to the less workability of fibre mixes. Table 10 shows modulus of elasticity for different mixes

Figure 8 Test for modulus of elasticity

Table-10 Modulus of elasticity for different mixes

Mix	Modulus of elasticity (GPa)
CC	29.567
PP 0.75	26.328
NY 0.25	29.285
PY 0.5	28.958

Impact resistance is the dynamic energy absorption or strength and is one of the major attributes of concrete. Cylinder specimen of size 15cm (diameter) x 5cm (height) were casted for mixes of optimum dosages that is, for PP0.75, NY0.25 and PY0.5 mixes. It was determined as per the impact test recommended by ACI Committee 544. The test was carried out by dropping a hammer weighing 4.5 kg from a height of 460mm repeatedly by a 64 mm diameter hardened steel ball, which will be centrally placed on the top of the cylinder specimen as shown in Fig 9. The hammer was dropped repeatedly and the number of blows required to cause the first visible crack and to cause ultimate failure were both recorded as shown in Fig 10. The mode of failure was extremely ductile for all fibre dosages, instead of a conventional brittle and sudden failure. This advantage of enhanced ductility and unique failure mode is a very valuable feature to SNFRC. Impact ductility index is defined as the ratio of failure impact number to initial impact number, which can be used to present the flexural impact ductility. For plain concrete impact ductility index is 1. Table 11 shows impact resistance test for different mixes.

Figure-9 Impact resistance test set up

Figure-10 Impact resistance on disc specimen

Table-11 Impact strength test for different mixes

Mix	No. of blows for first crack	No. of blows for ultimate crack	Impact ductility index
CC	10	11	1.1
PP 0.75	7	18	2.57
NY 0.25	12	20	1.67
PY 0.5	10	17	1.7

2.6 Durability study on hardened concrete Durability properties of concrete can be determined by carbonation test, sulphate resistance test and bulk diffusion test.Carbonation of concrete is a process by which carbon dioxide from the air penetrates and reacts with calcium hydroxide in concrete to form calcium carbonates. Cylinder specimens of size 10 cm (diameter) x 20 cm (height) were casted for mixes of optimum dosages of fibre that is, for PP0.75, NY0.25, and PY0.5 mixes. All specimens were kept outside and exposed to the same environment.The specimen was split into 2 halves in the longitudinal direction using compression testing machine and freshly broken surface of concrete is sprayed with a solution of phenolphthalein diluted in alcohol. On the area of concrete face, where the calcium hydroxide in concrete was affected by CO_2, the colour turned purple and the area where carbonation occurred remained uncoloured as shown in Fig 11. Table 12 shows carbonation depth for different mixes. It was observed that carbonation effect was more for normal mix on comparing to the fibre mixes. Addition of fibre reduces carbonation in concrete and it was observed that durability is more for nylon fibre on comparing to others.

Figure-11 Carbonation effect on cylinder specimen

Table-12 Carbonation depth for different mixes

Mix	Carbonation depth (mm)	
	56 days	90 days
CC	5	8
PP 0.75	3	4
NY 0.25	2	2
PY 0.5	2	3

Sulphate resistance test is used to check the durability of concrete due to chemical attack. This test proposes to assess the sulphate attack on concrete by determining the deterioration of compressive strength of 100mm concrete cube. This test was done as per ASTM C 452 test method. Cube specimens of optimum fibre mixes were casted and the concrete specimens were water cured for 3 days and the was introduced into magnesium sulphate solution as shown in Fig 12 and cured for another 56 and 90 days. The weight loss and changes in strength were compared with that of specimens were water cured.It is observed that when concrete specimen is immersed in magnesium sulphate solution, the compressive strength and mass of specimen get reduced slightly as the duration of sulphate exposure increases. Fig 13 shows specimen subjected to compression loading. Table 13 shows compressive strength variation for different mixes and Table 14 shows mass variation for different mixes

Figure-12 Specimens exposed to $MgSO_4$ solution

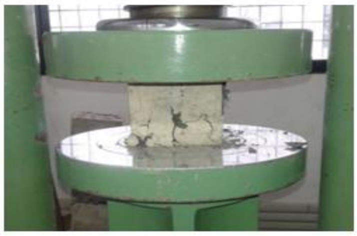

Figure-13 Specimens subjected to compression load

Table 13 Compressive strength variation for different mixes

Mix	Compressive strength (N/mm^2)			
	56 days water curing	90 days water curing	7 days water curing	
			56 days sulphate exposure	90 days sulphate exposure
CC	36	40	32	34.5
PP 0.75	42	45.5	39.5	42.5
NY 0.25	40.5	44	38	41
PY 0.5	45.5	48.5	43.5	46

Table 14 Mass variation for different mixes

Mix	Initial Mass (Kg)	56 day sulphate exposure mass (Kg)	90 day sulphate exposure mass (Kg)
CC	2.562	2.448	2.416
PP 0.75	2.664	2.605	2.513
NY 0.25	2.629	2.567	2.546
PY 0.5	2.642	2.591	2.571

Bulk diffusion test was carried out to determine the depth of penetration of chloride ions. Cylinder specimens of size 10cm (diameter) x 20 cm (height) were casted for mixes of optimum dosages of fibre. After 7 days of water curing, the concrete specimens were exposed to NaCl solution for 56 and 90 days as shown in Fig 14. Depth of penetration of chloride ions was found out by spraying 0.1M $AgNO_3$solution to the split surface of the cylinder, which was exposed to 1.8M NaCl solution. A white precipitate was formed to the penetrated depth of chloride ion as shown in Fig 15. By measuring the depth of penetration of chloride ion we can determine the resistance of concrete to chloride attack. The fibre distribution in concrete creates an easy path for the chloride ion for penetration, so the chloride ion penetration increased with the amount of fibre added, and it is maximum for PP0.75 mix.Table 15 showsdepth of penetrationof chloride ion

Figure-14 Specimen exposed to NaCl solution

Figure-15 Chloride attack on specimen

Table-15 Depth of penetration of chloride ion

Mix	Depth of Penetration of chloride ions(mm)	
	7 days water curing	
	56 days	90 days
CC	7	9
PP 0.75	10	12
NY 0.25	8	10
PY 0.5	9	11

III CONCLUSION

From the present experimental investigation the following conclusions are arrived at.

1. Workability of SNFRC decreases with the increment of fibres. In all mixes slump value and compacting factor value were found to be less than that of control mix. Polypropylenefibres possessed the least workability with increased fibre dosage.

2. Compressive strength, flexural strength, split tensile strength, gets improved due to the addition of fibres, on comparing with normal mix.

3. Optimum dosage of each fibre was determined and highest compressive strength was observed for PP 0.75, NY0.25 and PY 0.5 mixes.

4. It was seen that the addition of nylon fibre imparts better flexural strength compared to other fibres and maximum increment was observed by 44.75% for NY 0.25 mix.

5. Maximum increase in split tensile strength is by 47.27% for PP 0.75 mix due to the fact that fibres suppress the localization of micro cracks and consequently the apparent tensile strength of the matrix increases.

6. Tests revealed that modulus of elasticity decreased with fibre dosage due to the less workability of FRC mixes. Nylon fibre has almost same elasticity as that of normal mix on comparing to other mixes.

7. On comparing with normal mix, higher impact resistance was obtained for fibre mixes due to bonding of fibres in concrete mix. The mode of failure was ductile for all fibre mixes.

8. Carbonation effect was more for normal mix when compared to fibre mixes. Addition of fibre reduces carbonation in concrete.

9. For sulphate test the reduction in compressive strength was found to be minimum for PY 0.5 mix compared to normal mix and other fibre mixes.

10. The depth of penetration of chloride ions under 56 and 90 days exposure was more for fibre mixes than normal mix. Because fibre distribution in concrete creates an easy path for the chloride ion for penetration and it was maximum for PP 0.75 mix.

REFERENCES

1. Banthia, N.and Gupta, R, "Hybrid Fibre Reinforced Concrete: Fibre Synergy in High Strength Matrices," Materials and Structures, 37, 707–716, 2004.

2. Bentur, A., Mindess, S, "Fibre Reinforced Cementitious Composites," Second Edition, Taylor and Francis, London, 2007.

3. Kanalli, S. A., Palankar, R., Kumar, B., Kumar, P., & Prakash, S. K,"Comparative Study of Polymer Fibre Reinforced Concrete with Conventional Concrete Pavement," International Journal of Research in Engineering and Technology, 3(01), 2014.

4. Krishna, V., & Rao, V, "Experimental study on behavior of fibre reinforced concrete for rigid pavements," IOSR Journal of Mechanical and Civil Engineering, 11(4), 49-53, 2014

5. Kumar, R., Goel, P., &Mathur, R,"Suitability of Concrete Reinforced with Synthetic Fibre for the Construction of Pavements," Third International Conference on Sustainable Construction Material and Technologies, 2013.

6. Patel, H., Patel, C., Patel K., Balya, M. I., Patel, V. A,"Performance Evaluation of Polymer Fibre "RECRON-3S" in Pavement Quality Concrete," International Journal for Scientific Research & Development, 2(11), 2015.

7. Rai, A., & Joshi,"Applications and Properties of Fibre Reinforced Concrete," International Journal of Engineering Research and Applications, 4(5), 2014.

8. Song, P.S., and Hwang, S,"Strength Properties Of Nylon And Polypropylene- Fibre – Reinforced Concretes," Cement and Concrete Research 35(8), 1546-1550, 2005.

