Enhancing the Durability of Bituminous Pavement by the Addition of Polypropylene Fibers

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Abstract - *The flexible pavement is widely preferred in India, due to its advantages over rigid pavement and economy. Flexible pavements are often plagued with problems of cracking and rutting due to repeated traffic loads, steps must be taken to increase the life of the bituminous pavements. At present, addition of fiber is one of the common methods applied for binder modification. Polypropylene fibers were chosen as an additive and were mixed with Hot Mix Asphalt using "wet method".*

In this experiment, the modified bitumen binder was used in Bituminous Concrete (BC) Coarse. The OBC for original mixture was 5.5% and OFC was determined corresponding to maximum stability, minimum flow, mean air voids and mean voids filled with bitumen. Tests like Indirect Tensile Strength (ITS), Indirect Tensile Fatigue test to evaluate the effect of fiber addition on mix performance. It was found that 12mm fiber with 0.2% OFC increased the stability value and Indirect Tensile Strength Ratio and enhanced the fatigue life by increasing the resilient modulus. Therefore, it is concluded that the application of polypropylene fibers alters the characteristics of bituminous concrete mix in a very beneficial way, besides proved to be eco-friendly material.

Key Words: **Flexible pavement, Polypropylene Fibre, Wet method, Bituminous Concrete Coarse, Optimum Binder content, Optimum Fibre content, Indirect Tensile Test, Fatigue Test.**

1.INTRODUCTION

A good roadway infrastructure is an essential component of a strong and stable economy. Bituminous Concrete (BC), a mixture of bitumen and aggregate is a widely employed material for pavement construction. Bituminous concrete roads constitute more than 90% of the paved road network in India. Bituminous concrete roads are typically designed for 20 years. Bituminous concrete shall be used as a wearing course which is laid over DBM or SDBC. The item shall consist of mineral aggregates and appropriate binder mixed in a hot mix plant and laid in accordance with the specifications. As per MORTH specification the thickness varies between 25-50mm. Since Bituminous Concrete is used in the wearing course it is directly exposed to the traffic. Currently bituminous mixes are exposed to greater stress because of increasing magnitude of commercial vehicles and higher tyre pressures. Thus, the performance of the conventional mixes is generally not satisfactory for paving applications. Hence to accommodate ever increasing traffic loadings in varying climatic environments and to resist failures a new emphasis was placed.

However, three major distress types observed on asphalt pavements are rutting, fatigue cracking and low temperature cracking. Fatigue cracking is an important deterioration mechanism of bituminous concrete surfaced pavements. Environmental and climatic factors also play an influential role on the development of fatigue. Fatigue is a major failure criterion for flexible pavements.

At present, Fibers have got much attention for its excellent improvement effect. It is widely believed that the addition of fiber will enhance materials strength and fatigue characteristics. Polypropylene fibers are widely used as reinforcing agents and provide three-dimensional reinforcement of the concrete. In this way, concrete becomes more tough and durable. The emphasis was concentrated mainly on improving the level of performance and service life of roads by modifying conventional bitumen.

This study presents the results of an experimental investigation as how effectively the fiber could be utilized in the bituminous concrete course to improve the performance and service life of flexible pavement.

1.1 Objectives of the study

1. To evaluate the basic strength parameters of the coarse aggregates.

2. To assess the basic strength parameters of the bitumen with and without polypropylene fibers.

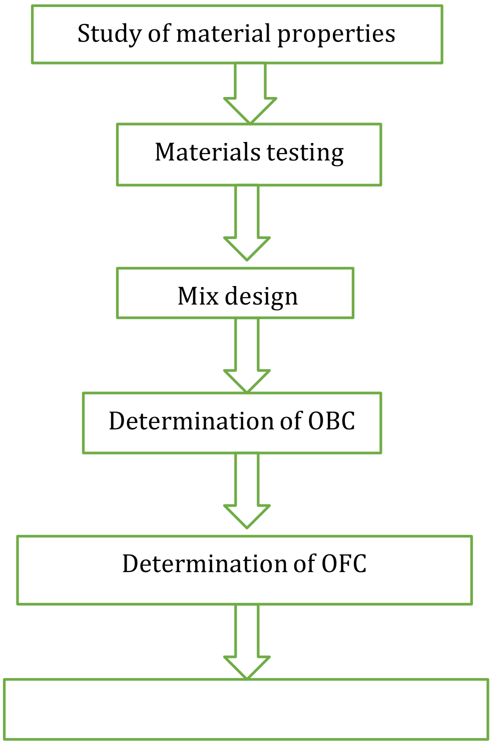
3. To evaluate Marshall properties of bituminous concrete with and without polypropylene fibres.

4. To evaluate the indirect tensile strength value with and without polypropylene fibres.

5. To evaluate the fatigue behavior of neat and fiber reinforced bituminous concrete.

6. To estimate the durability results for different proportions of polypropylene fibers.

2. Methodology



Marshall Method is the widely used procedure for the design of hot mix asphalt (HMA). This is used to determine the optimum binder content (OBC) for the aggregate to be used. This is achieved by preparing the samples of different binder content and then selecting the binder content that provides desirable properties.

1. Sample is prepared for varying percentages of bitumen with 0.5% increase. i.e., 4.5%, 5%, 5.5%, 6%, 6.5%.
2. The sample is analyzed for calculating the Voids in mineral aggregates (VMA), air voids, voids filled with bitumen (VFB).
3. Selecting the optimum binder content (OBC).

b) Indirect Tensile Strength Test

The Indirect tensile test is by applying compressive load on a cylindrical sample in the vertical diametrical direction. This loading develops uniform stress which is perpendicular to the applied load direction and vertically diametric plane, which causes the specimen to fail along vertical dia.

c) Indirect Tensile Fatigue Test

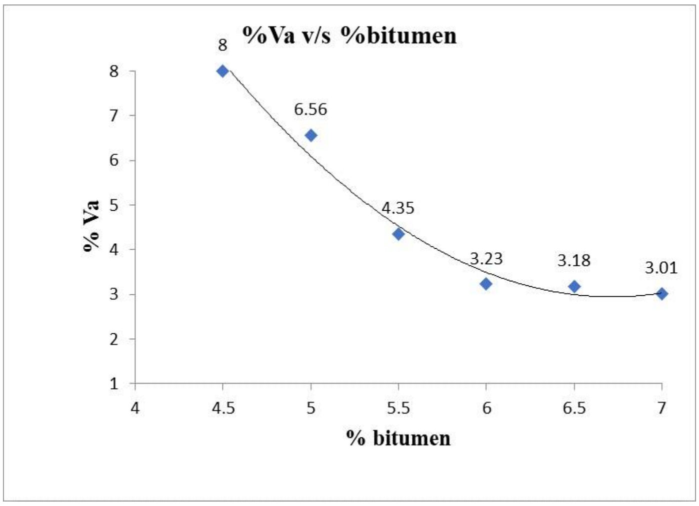
Marshall samples with and without fiber were prepared. Prior to testing, the samples were kept in the water bath for 24hours which is conditioned for test temperature. After this the samples are placed in mould between 2 metal strips and then the bolts are locked. The vertical and horizontal LVDT's are fixed in positions. The holding jack is brought down to apply load on samples. The software reveals the failure of sample when the LVDT's reach specified limit.

The data given by the software is analyzed to determine the resilent modulus, stress applied and initial strain developed in the samples.

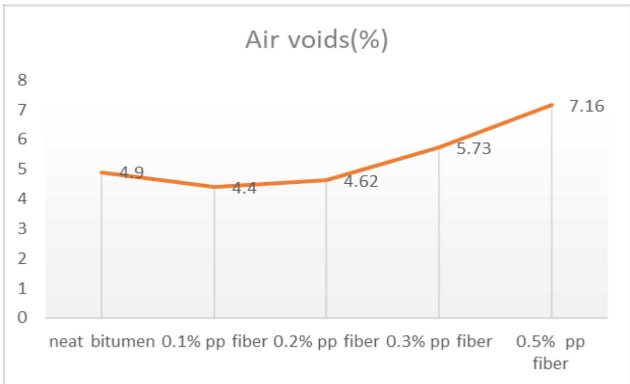
3. Test results

Table 1: Marshall's Test Results

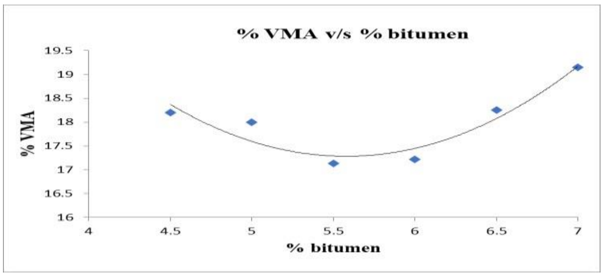
	Stability (kN)	**Flow (mm)**	**Bulk density (g/cc)**	**Air voids (%)**	**VMA (%)**	**VFB (%)**
neat bitumen	12.75	2.33	2.33	4.9	17.93	72.67
0.1% pp fiber	13.95	2.28	2.345	4.4	17.3	73
0.2% pp fiber	14.5	2.25	2.347	4.62	17.15	74.58
0.3% pp fiber	11.33	2.1	2.323	5.73	17.91	68
0.5% pp fiber	10.35	2	2.295	7.16	18.73	61.77



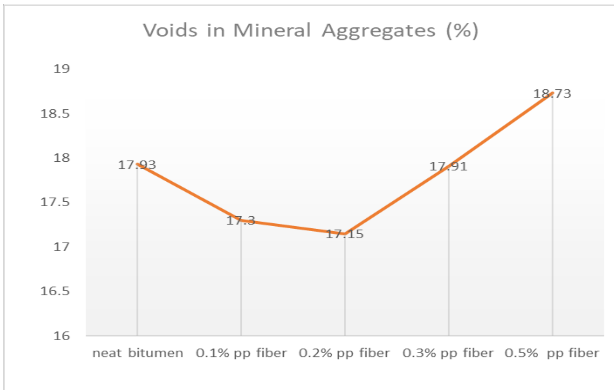
Graph 1: Bitumen (%) vs air voids (%)



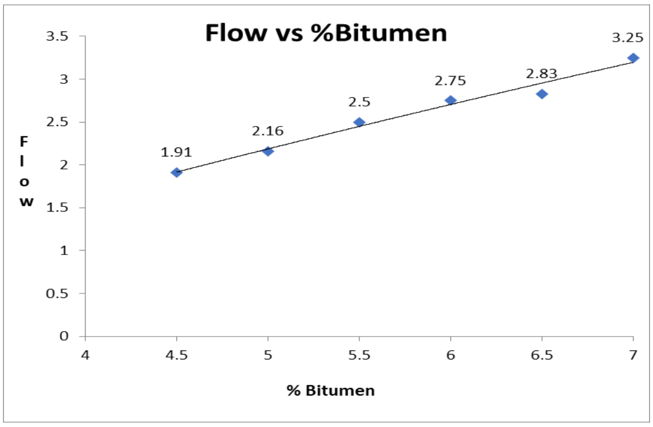
Graph 2: Air voids vs Different percentage of pp fiber



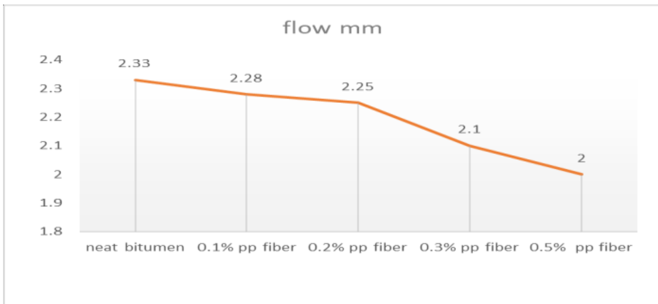
Graph 3: Bitumen (%) vs VMA (%)



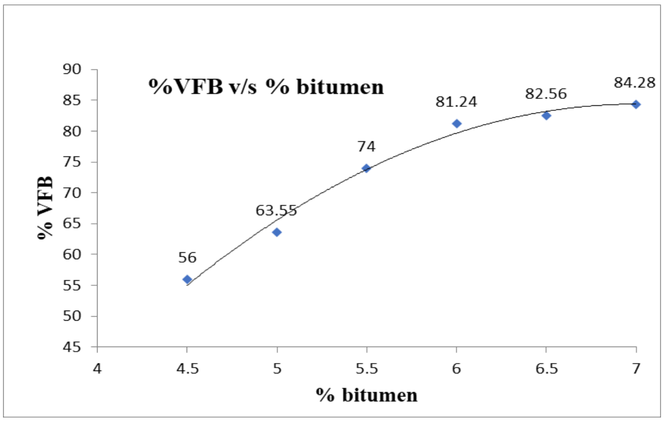
Graph 4: VMA vs Different percentage of pp fiber



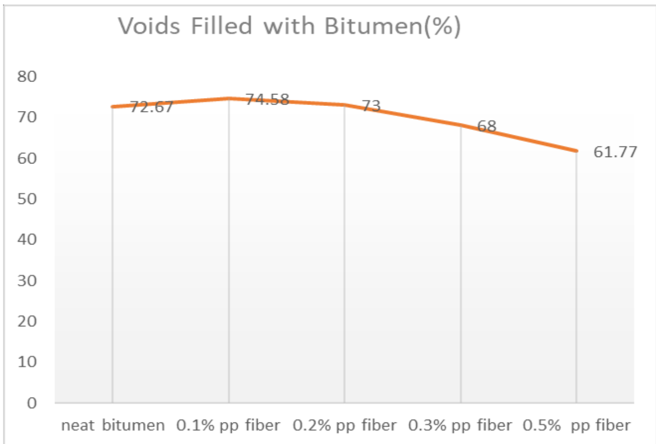
Graph 5: Bitumen (%) vs Flow



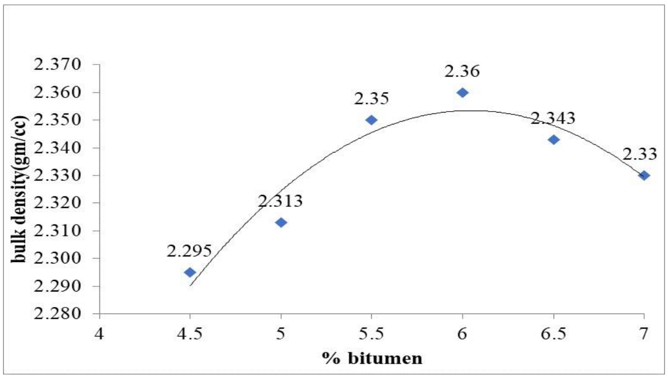
Graph 6: Flow vs Different percentage of pp fiber



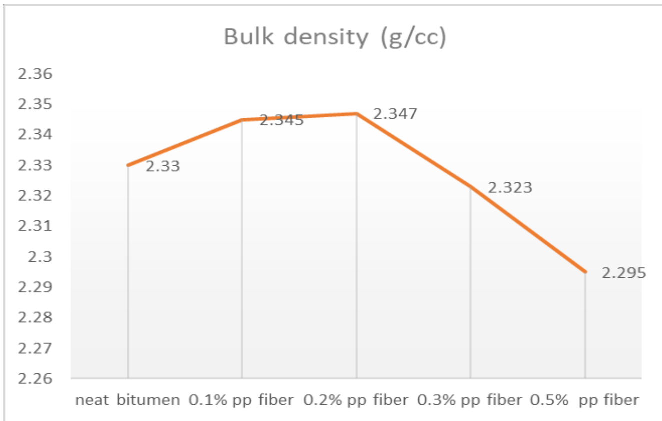
Graph 7: Bitumen (%) vs VFB (%)



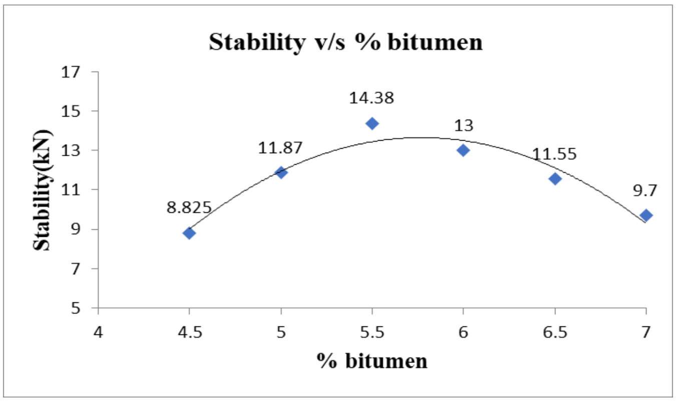
Graph 8: Voids Filled with Bitumen vs Different percentage of pp fiber



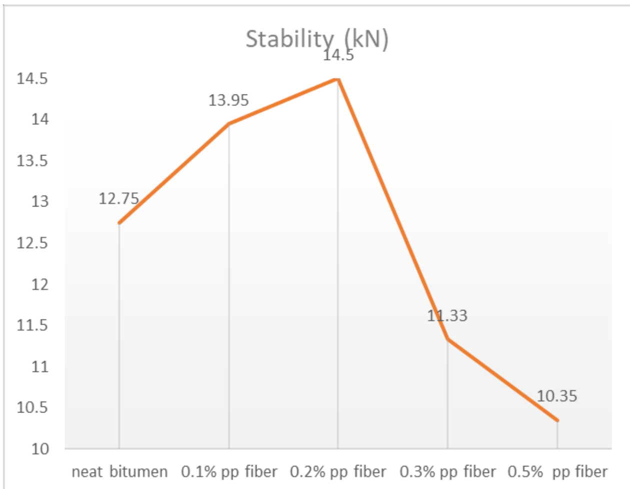
Graph 9: Bitumen (%) vs bulk density (gm/cc)



Graph 10: Bulk density vs Different percentage of pp fiber



Graph 11: Bitumen (%) vs stability (kN)



Graph 12: Stability vs Different percentage of pp fiber

Table 2: OBC results

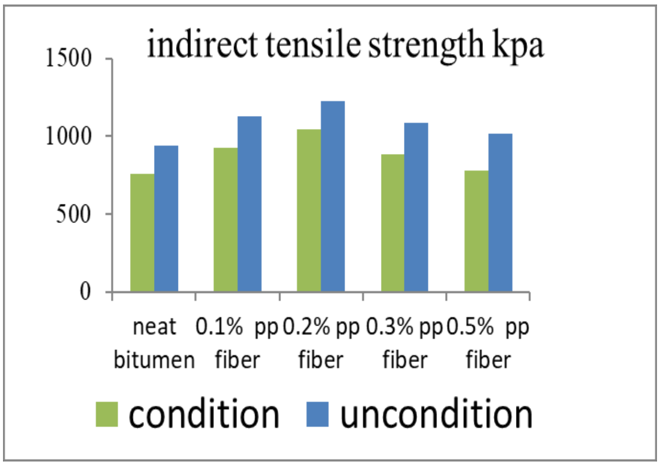
Marshall Properties	Results
OBC	5.5%
VMA	17.9%
VFB	72%
VA	4%
Density	2.335 gm/cc
Stability (KN)	14
Flow (mm)	2.4

Table 3: OFC results

Different parameters	Results
OFC	0.2%
VMA	17.15%
VFB	73%
VA	4.62%
Density	2.347gm/cc
Stability	14.5
Flow	2.25

Table 4: Indirect tensile strength test results

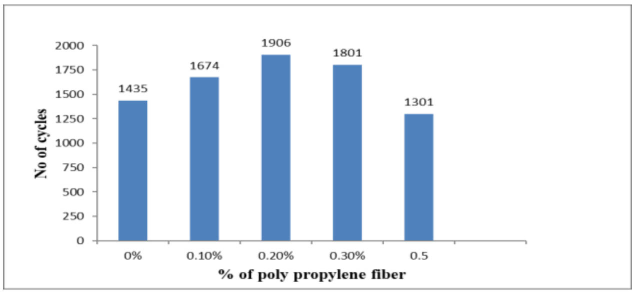
Sl. No	Different % of PP fibres	ITS (kpa) Conditioned specimen	ITS (kpa) Unconditioned specimen	ITS ratio	Retained tensile strength (%)
1	0.0%	939.45	757.29	0.806	80.60
2	0.1%	1131.6	928.77	0.820	82.00
3	0.2%	1227.68	1046.2	0.852	85.20
4	0.3%	1888.9	886.05	0.813	81.30
5	0.5%	1014.2	779.31	0.780	78.00



Graph 13: Indirect tensile strength vs different percentages of pp Fiber

Table 5: Indirect tensile Fatigue strength test results

% of pp fiber	Load in Kg	Height (cm)	Stress (Mpa)	Resilient horizontal deformation (cm)	Resilient modulus (Mpa)	Initial tensile strain	Number Of cycles
0.0 %	152	6.4	1.48	0.0178	827.24	36.68	1435
0.1 %	186	6.4	1.87	0.017	1.56	36.16	1674
0.2 %	210	6.4	2.04	0.0158	1287.6	32.47	1906
0.3 %	180	6.4	1.81	0.0174	1002.15	37	1801
0.5 %	156	6.4	1.57	0.0190	795.39	40.46	1301



Graph 14: Indirect tensile fatigue strength vs different percentages of pp Fiber

4. Conclusions

The tests of mechanical properties, Marshall Stability, flow, indirect tensile test, and indirect tensile fatigue test of both conventional and modified mix were conducted. The following conclusions are drawn based on the laboratory investigation,

1. The basic properties of the aggregates within the limits as per the MORTH SEC.500.
2. The basic properties of the bitumen with and without fibers are within the limits as per MORTH SEC.500.
3. The optimum fiber content of 0.2% was added to the bitumen, this improved the stability, density and flow and also enhanced the fatigue life.
4. The optimum binder content was found to be 5.5% for conventional mix.
5. Marshall stability of bituminous concrete mix prepared using polypropylene fiber increases by 20% when compared to conventional mix.
6. Indirect tensile strength of bituminous concrete mix prepared using polypropylene fiber increases by 35% when compared to conventional mix.
7. Addition of polypropylene fibers improves the behavior of the specimens by increasing the life of samples under fatigue testing. According to the test results, the addition of 0.2 % of polypropylene fibers prolongs the fatigue life by 25 % in terms of number of cycles, in comparison to plain bituminous mix.
8. Proved to be an eco-friendly material, since polypropylene fibers are derived from plastic wastes.

REFERENCES

1. Min-Jae Kim a,Soonho Kim a, Doo-YeolYoo, Hyun-Oh Shin, 'Enhancing Mechanical Properties of Asphalt Concrete using Synthetic Fibres', Department of Architectural Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea.
2. Serkan Tapkın (2009), 'Repeated Creep Behavior of Polypropylene Fibre-Reinforced Bituminous Mixtures', Civil Engineering Department, Faculty of Engineering and Architecture, Anadolu University, 26555 Eskisehir, Turkey.
3. S. Tapkın, Ü. Uşar and Ş. Özcan, 'The Physical and Mechanical Behaviour of Polypropylene Fibre-Reinforced Modified Asphalt Mixtures', Anadolu University, Turkey and A. Çevik, University of Gaziantep, Turkey.
4. Asphalt Institute (1994), Mix Design Methods for Asphalt Concrete and Other Hot-Mix Manual Series No. 2, Sixth edition, Asphalt Institute, Lexington, KY.
5. YUE Hongbo et al., (2007), 'Study on dynamic characteristics of fibre-Reinforced Asphaltic Concrete', Key Laboratory of Silicate materials Science and Engineering of Ministry of Education, Wuhan, 430070, China.
6. Ministry of Road Transport and Highways Section-500.
7. IS: 1202-1978 for Specific gravity of Bitumen.
8. IS: 1203-1978 for Penetration.
9. IS: 1205-1978 for softening point.
10. IS: 1206-1978 for Viscosity.
11. IS: 1208-1978 for Ductility.