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Pavement Construction by Using Synthetic Fiber

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Abstract— This project investigates the influence of fibers on improving properties of soil sub grade and bituminous mixes for the construction of flexible pavement. Conventional practices in design and construction of pavements require material of higher quality to satisfy the required standards. Soil to be used as sub grade does not satisfy this in many parts, making it mandatory to seek alternative solutions for the use of weaker sub grade. To achieve stronger sub grade, an attempt has been made to use polypropylene fiber with soil at various percentages 0.25%, 0.5%, 0.75% 1%. Nylon fiber is used as an additive for bituminous mixtures to obtain an enhanced behavior concerning resistance to fatigue cracking and aging. The percentages of nylon fiber added are 0.25%, 0.5%, 0.75%. Detailed laboratory investigations are carried out.

Key words: Pavement, Synthetic Fiber

I. INTRODUCTION

Roads are the major channel of transportation for carrying goods and passengers which forms the basic infrastructure for the development and economic growth of the country. Construction of such pavements has to be planned and executed carefully and a pavement which is not designed properly deteriorates fast. In India, flexible pavements have been widely constructed. In flexible pavement, design of various pavement layers is much dependent on the strength of sub grade over which above layers are to be laid. Soil is highly complex, heterogeneous and unpredictable material which has been subjected to vagaries of nature without any control. The properties of soil change not only from place to place but at place with different depth, loading condition. Sometimes, need arises to construct pavement on the selected site other than soil conditions. If unsuitable soil conditions are encountered at the site, soil in place can be treated with polypropylene fiber to attain good strength for construction work.
Bitumen has been widely used in the construction of flexible pavements for long time. This is the most simple and convenient type of construction but performance is not considerably satisfactory as roads are subjected to many harsh environmental conditions such as traffic loading, ingress of water, chemical attack and widely fluctuating temperatures. It leads to significant maintenance requirements which can only be met at a very high cost. Conventional bitumen cannot overcome these conditions so modification of the bitumen properties with fibers becomes necessary. The properties of fiber modified bitumen are dependent on the fiber characteristics and bitumen nature as well as bendingprocess.
The primary motive of this study is to investigate the benefits of using synthetic fibers with pavement materials at different proportions to achieve greater strength of sub grade and to overcome the draw backs of bitumen used.

II. LITERATUREREVIEW

Shivrajsarjeraopatil (2015), studied the Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient.
Ayininuola G.M, Oladeji O.S (2013), The research investigated the use of nylon solution to enhance the California bearing ratio (CBR) of soil. The nylon solution was used to stabilize poorly graded sandy soil. In addition, on hot mixed with soil sample. The study focused on the use of nylon solution obtained from hot

mixed nylon in DPK solution as soil stabilizer.
DondetiSukanya, SiddiRaju.S.Dr (2013), studied If properly designed, constructed and maintained, reinforced structures are generally very durable. They conclude that the concrete with polypropylene fiber is the best fiber for pavement Quality concrete when compared to plain concrete and polyester fiber reinforcedconcrete.
Debashishishkar(2012), studied the effect of use of a naturally and locally available fiber called SISAL fiber is used as stabilizer in SMA and as an additive in BC. Binder content has been varied regularly from 4% to 7% and fiber content varied from 0% to maximum 0.5% of total mix. Fly ash has been found to result satisfactory Marshall Procedure and has been used for mixes of subsequent works. it is observed that SMA is better than BC in respect of indirect tensile strength and creep characteristics.
SrinivasRao, B. Jayalekshmi, S(2010), Studied the strengthening of soil sub grade with polymeric reinforcements. For flexible pavement, the initial cost of SC soil reinforced with polyester fiber is approximately 21.5% more than the unreinforced SC soil. This is due to the high cost of the fiber used.
KameshwarRaoTallapragada, Anuj Kumar Sharma, TarulataMeshram (2009), the present work is undertaken to evaluate the benefits of fiber reinforced sub grade soil in flexible pavements. From UCS test it was found that Maximum Stress value of soil increases with increasing aspect ratio and fiber content. Swelling pressure of soil also decreases with addition some percentage of fibers insoil.
BhagabanAcharyaet al (2007)(Tribhuvan University), proved through experimental studies that geogrid reinforced flexible pavements increased pavement life by approximately 2-4 times with respect to unreinforced pavement. They help to distribute vertical load over a wider area of the sub grade and reduces lateral movement of soil particles there by increasing the bearing capacity.
Rajagopalet al (2005)(IIT Madras), studied about the role of geocell layers in improving the quality of pavement. It was observed that the reinforced section maintained a good level surface whereas the unreinforced section had surface depressions. Pressure (150kN) and settlement (10.47mm) of the soil was obtained. The sub- base layer compacted over the geogrid layer achieved higher drydensity.

III. MATERIALS

The pavement materials used in this project are local available soil, Aggregate and Bitumen. The fiber additives added with the pavement materials are polypropylene fiber and nylon fiber respectively.

A. Natural Sub Grade

The soil investigated in this project is collected from our college campus in kariapatti village, virudhunagar. The sample is taken for conducting soil tests. The properties of soil were found from the soil test according to IS 2720. Sieve analysis is done for grain size analysis of the sub grade. Further, uniformly co-efficient and co-efficient of curvature are found. By conducting the pycnometer test, the specific gravity of the soil is determined. Swell index is the increase in volume of a soil, without any external constraints, on submerge inwater.
The Atterberg's limits are a basic measure of the critical water contents of a fine grained soil, such as its shrinkage limit, plastic limit and liquid limit. The objective of finding Atterberg's limits is to determine the shrinkage and settlement characteristics of soil. Swell index is the increase in volume of a soil, without any external constraint on submerge in water. The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, sub grades and base course beneath new carriagewayconstruction.

B. Aggregates

The properties of the soil tested are listed in table.I

Table 1: Properties Of Soil

Soil characteristics	Values
Specific gravity	2.45
Particle size distribution Gravel (%) Sand (%) Silt (%) Clay (%)	 4 31 52 13
Liquid limit (%)	48.5
Plastic limit (%)	28.8
Plasticity index	19.7
Optimum moisture content (%)	13.65
Maximum dry density (g/cc)	2.08
Unconfined compressive strength	15.5
California bearing ratio	2.6

abrasion test (IS 2386-Part 5). Specific gravity test and Water absorption test (IS 2386-Part 3) to determine specific gravity and porosity of aggregate. Properties are listed in table.II.

Tests on Aggregate	Value
Crushing test	35%
Impact test	50%
Los Angeles abrasion test	60%
Water absorption test	0.4%

Table 2: Properties Of Aggregates

C. Bitumen

Bitumen of 60/70 grade is used here. Tests to assess various properties of bituminous materials are carried out. Penetration test (IS 1203-1978) at 25°C was carried out..Softening test (IS 1205-1978) to determine the softening temperature of bitumen. To determine the deformation of bitumen, Ductility test (IS 1208-1978) was carried out. Bitumen properties are given in table.III.

Tests on Bitumen	Value
Penetration Test	65
Softening Point Test	45.5
Ductility Test	83
Specific Gravity Test	1.01

Table 3: Properties Of Bitumen

D. PolypropyleneFiber

The most commonly used synthetic material, polypropylene is used in this project. The fiber is obtained from market. This material has been chosen due to its low cost and chemically inert nature which does not absorb or react with soil moisture or leachate. Properties of fiber are listed in table IV.

Table 4: Properties Of Polypropylene Fiber

Color	White
Density	1.14 gm/cc
Elongation at break	15-45%
Elasticity	Very good
Moisture regain	3.5-5%
Melting point	215°c

E. Nylon 6 Fiber

Nylon is the usual fiber in the carpet production. These fibers can be used as the additive in the bituminous mixtures. Nylon fibers are widely used because of their good cost to performance ratio. The properties are given in tableV.

Aggregates influence the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction. The sample is taken and the properties of sample are observed according to IS 2386. Crushing test of aggregate (IS 2386-Part 4) determines the strength due to loading and the sample is subjected to a compressive load of 40 tonnes gradually.

Toughness can be determined by the Impact test (IS 2386-part 4) measured as percentage of aggregates. To determine the Hardness property of aggregate, Los Angeles

Table 5: Properties Of Nylon Fiber

Color	White
Specific gravity	0.91
Melting point	160^{o}c
Average diameter	0.06mm
Length	20mm
Chemical resistance	Generally excellent
Dispersibility	Excellent

IV. SAMPLEPREPARATION

A. Soil + Polypropylenefiber

Reinforced soil samples are prepared by adding different proportions of polypropylene fiber of 0.25%, 0.5%, 0.75%, 1% to the soil. The prescribed contents of fiber are mixed well the samples to achieve homogenous mixture at each stage of mixing.

B. Bitumen + Nylonfiber

Fiber modified bitumen sample is prepared by melt blending technique. The bitumen about 400gm was heated in oven till fluid condition and fiber was slowly added, while the speed of the mixer was maintained at 400 rpm and temperature was kept between 180ºc and 200ºc. the concentration of nylon fiber used were 0.5%, 1%, 1.0%, 2% by weight of blend. Mixing was continued for 1hour to produce homogeneous mixtures. The modified bitumen was sealed and stored for furthertesting.

V. EXPERIMENTALINVESTIGATIONS

A. soil + polypropylenefiber

1) Standard Proctor Test (CompactionTest)

For the determination of optimum moisture content and maximum dry density, the standard proctor test was conducted. The test used here to determine the optimum moisture content of different combinations of soil samples. A curve was obtained between the dry density and the water content.

2) Unconfined CompressionTest

The unconfined compressive strength tests were carried out to determine the unconfined compressive strength of the soil sample which in turn is used to calculate unconsolidated, undrained shear strength of unconfined soil. The test was specimen were prepared by compacting samples at the maximum dry unit weight and optimum moisture content determined by conducting standard proctor test.

3) California Bearing RatioTest

California bearing ratio test was conducted in laboratory. The test was used for the evaluation of sub grade strength of roads and pavements. The CBR value obtained by this test was used with the empirical curves to determine the thickness of pavements and its component layer. This is the most widely used method for the design of flexible pavement.

B. Bitumen + Nylon fiber

1) Marshall test

Marshall Test was basically an unconfined compression test where load is applied to a cylindrical specimen of a bituminous mix and the sample was monitored till its failure. The resistance to plastic deformation of the specimen of bituminous mixture was measured when loaded at the periphery at 5cm/min. stability and flow, togetherwith density, voids and percentage of voids filled with binder were determined at varying binder contents to obtain an optimum bitumen content for stability, durability, flexibility, fatigue resistance,etc.

VI. RESULTS AND DISCUSSIONS

A. Soil + PolypropyleneFiber

The results obtained from the standard proctor tests, unconfined compression tests and California bearing

ratio tests have analyzed to study the effect of polypropylene fibers on the soils.

1) Standard Proctor Test (CompactionTest)

During the compaction tests, it was observed that the strength of the reinforced soil increased with increase in fiber content up to 0.75% and further addition decreases the strength. The Significant effects on optimum moisture content and maximum dry density by addition of fiber are shown inFig.1.

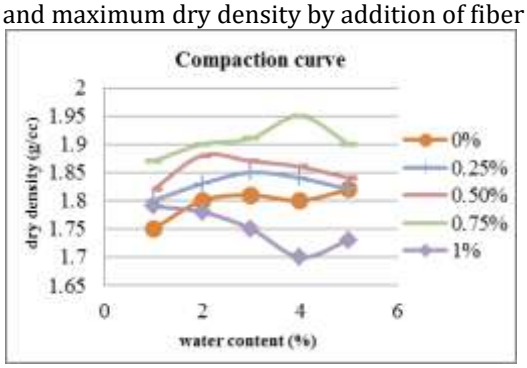

Fig. 1: Compaction curve

2) Unconfined CompressionTest

From UCC tests, it was observed that the value of treated soil increased than the untreated soil up to fiber content of 0.75%. Variation of values with the addition of polypropylene fiber is shown in table.VI andfig.2.

PPF (%)	0	0.25%	0.5%	0.75%	1%
UCC	15.1	78.2	105.2	129	92.67

Table 6: Variation of UCC strength

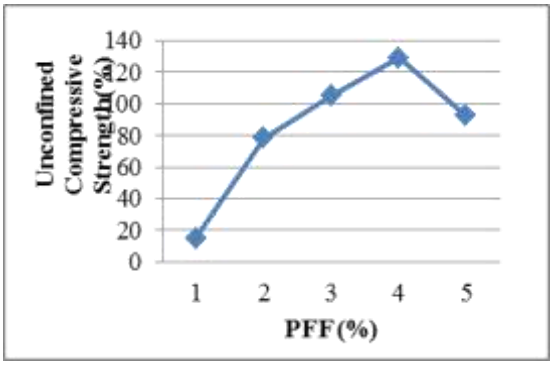

Fig. 2: variation of UCC strength

3) California Bearing RatioTest

During the tests, it was observed that the CBR values increase with increase in the addition of fiber up to 0.75% and by further addition of fiber the values decreases. Variation in CBR values with the addition of fiber are shown infig.2.

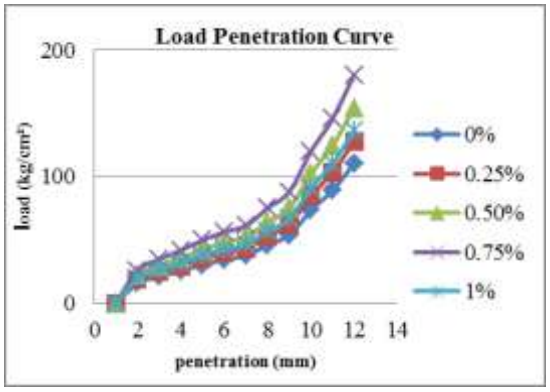

Fig. 3: Load Penetration Curve

B. Bitumen + NylonFiber

1) Marshall Test

Stability value increases with increase in binder content up to certain binder content and. Also stability value increases with increase in fiber content and further addition of fiber decreases the stability. The stability curve and flow range for the bituminous mixtures is given in Fig.4 andFig.5.

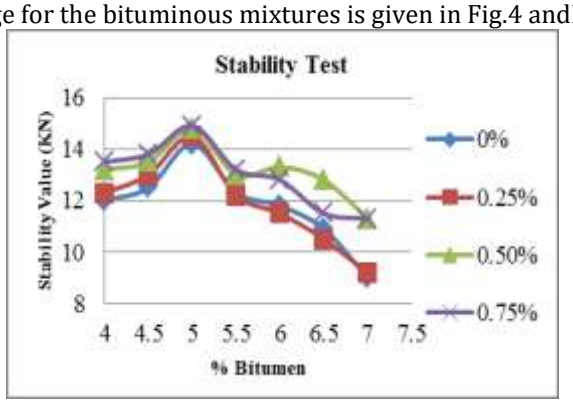

Fig. 4: stability curve

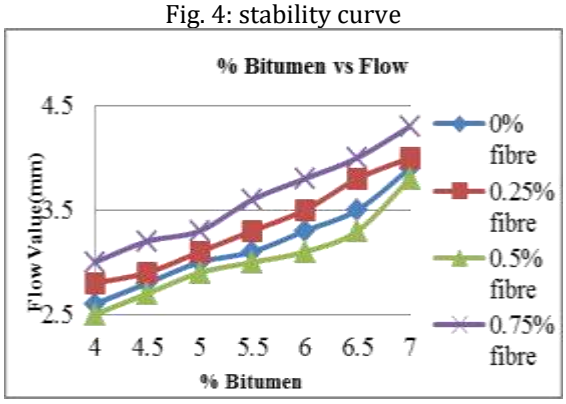

Fig. 5: Flow vale of Bitumen

VII. CONCLUSION

A series of tests were conducted to study the effects of synthetic fiber on soil and bitumen and soil for the construction of pavement. The effects of fiber on soil were investigated with compaction test, unconfined compressive strength and California bearing ratio test. As well as for bitumen, Marshal Test is used to determine the effects of fiber in bitumen. The following are the conclusions from these tests.

A. From SoilTests

– The optimum moisture content does not show a significant change by addition of polypropylene fiber whereas maximum dry density reduces as fiber content increases in compactiontests.

– Unconfined compressive strength seems to be increased for the treated soil than the untreated clayeysoil.

– California bearing ratio, a most widely used test for sub grade also shows the increased value with the addition of polypropylenefiber.

– As a result of this investigation, polypropylene proved a good addition with clayey soil for stabilization making it attain good strength for pavements.

B. From Bitumen Tests

– Nylon modified bitumen increases the fatigue life of a pavement than the mixtures without fibers.

– Flow value of the modified bitumen also seems to give better result than unmodifiedmixtures.

– The modified bitumen mixture shows the increased value in stability test hence it enhances betterperformance.

– The road can withstand heavy traffic and show better durability as fiber improves the fatigue cracking resistance.

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