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# AN EXPERIMENTAL STUDY OF BITUMINOUS CONCRETE MIXES WITH NATURAL FIBRE

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**ABSTRACT**
The goal of this laboratory study was to determine the aids of use of naturally available fibre such as SISAL fibre used as additive in Bituminous concrete. A bituminous mixture is a mixture of coarse and fine aggregate with filler and binder material. A Hot Mix Asphalt (HMA) is a bituminous mixture where all ingredients are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes such as Bituminous Concrete (BC). In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibre called SISAL fibre is used as an additive in BC. SISAL fibre was used in bituminous mixtures to know about the benefits of use of natural fibre and its environmentally sustainable design. Pavements are defenceless to cracks, potholes, distresses and permanent deformation. Aggregate gradation has been taken as per MORTH specification for the preparation of bituminous mix, and binder content has been varied regularly from 4% to 6% and fibre content varied from 0% to maximum 0.8% of the total mix. Standard Marshall Mix design test and Drain Down test were performed for this experimental study. Using Marshall test Procedure, the optimum value of bitumen content was found to be 5.2% and 5.5% for BC-1 and BC-2 mixes respectively. Similarly, Fibre content for Bituminous Concrete (BC) was found to be 0.4% for both the bituminous mixes. Bituminous Concrete (BC) mix designs were made to find out their Optimum Binder Content (OBC) and Optimum Fibre Content (OFC), then performed with tests like Marshall Stability and Drain down test to measure the results of addition of fibre in bituminous mix. The test results show that the modification of bitumen with sisal fibre used as additive in the bituminous mixture help in increasing in its stability, durability and decreasing air void and flow value. At the end it is found that using fibre as an additive enhance the properties like Stability, Strength, and material orientation and reduce the Drain down of Bituminous Concrete (BC).

Keywords:

## 1. Introduction

Development of transportation plays an important role in the development of society. Construction of highway involves huge outlay of investment. With a specific and detailed engineering design may save considerable investment and it will also enhance the performance of the in-service highway. As flexible pavement is commonly used in India and due to more benefits over rigid pavement. Flexible pavement requires a detailed engineering design which minimize its cost and give good dependable performances of in-service highway. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design of pavement layers are the two most major aspects of consideration. This study is related to the mix design considerations. A bituminous mix is expected to result in a mix which is satisfactorily strong, durable, resistive to fatigue and permanent deformation, environment friendly and economical and so on. Fibre is one of the major focus of research for scientists and researchers. SISAL fibre is naturally and locally available fibre in India which has been economically beneficial as well as shows its good characteristic. SISAL fibre is obtained from leaf skin after removing the pulp. A researcher attempts to attain these essential

and fulfil by preparing number of samples on the bituminous mix with varied proportions and test them to find out the optimum from it.

## 2. Literature review

SISAL fibre neither attract dust particles nor absorb water and moisture [1]. The use of SISAL fibre gives better strength, durability and prevent from drain down of the mix [2]. The size of SISAL fibre used in the sample preparation was taken to be length 6mm to 18mm with diameter 0.2mm to 0. 6mm. The aggregate gradation was taken according to the of IS: 107-2386 Grade1 and as per specification of Ministry of road transportation and highway (MORTH, 2013) [3]. The calculation of the optimum value of bitumen and optimum fibre content are found with the help of Marshall Test. To determine the values of Marshall test parameters were stability, flow value and voids in mineral aggregates VMA, voids filled with bitumen (VFB) and air content (VA) [4]. The drain down determines the part of mixture which separates itself from the sample and flow down [5].

| IS Sieve Size | Passing % for BC-1 | Passing % for BC-2 | % Quantity of aggregate | % Quantity of aggregate |
|---|---|---|---|---|
| 26.5 | 100 | | | |
| 19 | 90-100 | 100 | 9 | |
| 13.2 | 59-79 | 90-100 | 12 | 15 |
| 9.5 | 52-72 | 70-88 | 17 | 22 |
| 4.75 | 35-55 | 53-71 | 8 | 9 |
| 2.36 | 28-44 | 42-58 | 10 | 11 |
| 1.18 | 20-34 | 34-48 | 10 | 10 |
| 0.6 | 15-27 | 26-38 | 10 | 10 |
| 0.3 | 10-20 | 18-28 | 10 | 8 |
| 0.15 | 5-13 | 12-20 | 5 | 5 |
| 0.075 | 2-8 | 4-10 | 4 | 5 |
| Filler | 5 | 5 | 5 | 5 |

## 3. Materials and methods

### *3.1 Natural Aggregates (NA)*

For the preparation of bituminous mixes Natural aggregates were used which comprising of Stone dust (SD), Coarse aggregate (CA) and Fine aggregates (FA). The materials used for the preparation of BC should be of proper gradation, clean, and should not be rounded to resist heavy traffic loads. The aggregate gradation was taken as per the specification of Ministry of Road Transportation and Highway (MORTH) described in Table. 1. As per the Indian standards physical properties of virgin aggregates were tested. Generally coarse aggregates consisted of stone chips size ranges up to 4.75 mm IS sieve size.

Its specific gravity was found as 2.70. Fine aggregates, consisting of stone crusher dusts with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found as 2.6. Aggregate passing through 0.075 mm IS sieve is called as filler. Stone dust are used as filler whose specific gravity was found as 2.65. The physical properties of natural aggregates summarized in Table. 2.

Table. 1. Gradation of aggregate as per MORTH specifications

Table. 2. Physical properties of aggregate as per MORTH specifications

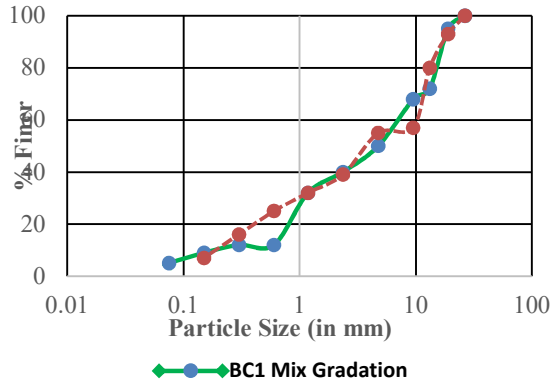



Fig.1. Natural Aggregate Mix Gradation For BC-1 and BC-2


| Property | Test Method | Test Result | MORTH specifications |
|---|---|---|---|
| Aggregate Impact Value (%) | IS: 2386 (Part IV) | 17.3 | Max 24% |
| Aggregate Crushing Value (%) | IS: 2386 (Part IV) | 13.02 | |
| Los Angels Abrasion Value (%) | IS: 2386 (Part IV) | 18 | Max 30% |
| Flakiness Index (%) | IS: 2386 (Part I) | 20.83 | Max 30% |
| Elongation Index (%) | IS: 2386 (Part I) | 21.5 | Max 30% |
| Water Absorption (%) | IS: 2386 (Part III) | 0.2 | Max 2% |
| Combined Elongation and Flakiness Test (%) | IS: 2386 (Part IV) | 28.45 | Max 35% |

Fig. 2. Materials used in the study (A) aggregates as Per specific quantity, (B) SISAL fibre (C)Coated with Emulsion (D) Small cut pieces SISAL fibre.

*3.2 Binder*

In this laboratory study VG-40 grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.01. It's important property is given in Table.3.

Table.3 Physical properties of bitumen (VG-40)

| Property | Test Method | Test Result | Specifications as per IS 73: 2013 |
|---|---|---|---|
| Penetration at 25°C 0.1mm,100gm, 5sec | IS: 1203-1978 | 44 | 35 Min. |
| Ductility at 25°C, (cm) | IS: 1208-1978 | 50 | 25cm Min. |
| Softening Point (R&B) (°C) | IS: 1205-1978 | 55 | 50 Min. |
| Specific gravity | IS: 1202-1978 | 1.02 | …….. |

*3.3 Natural Fibre*

In this study sisal fibre is used as natural additive whose length is about 900 mm. and diameter of the material varied from 0.2mm to 0.6 mm. The sisal fibres were cleaned and cut in to small pieces of 6-18 mm in length to ensure proper mixing with the aggregates and binder during the process of mixing. The emulsion SS-1 was used to coated the SISAL fibre and then it was stored in a hot air furnace at 110 °C for 24 hours.

*3.4 Methodology*

Bituminous concrete (BC-1 and BC-2) Mix design samples were prepared as per the proportion of aggregates shown in Table. 1 and at varying binder content from 4%-6%. The optimum binder content was found out by Marshall Test. Stability, Flow value and Air Voids of the bituminous mixes were determined by Marshall mix design method. Various percentages of fibre content (0% - 0.8%) and fibre length(6mm-18mm) were taken. 1200 gm of fresh aggregate with 5% filler as a stone dust by weight of aggregate to determine the OFC. Optimum binder quantity of bitumen to prepare a strong pavement and good working to allow easy layer settlement without segregation or separating. The aim is to oppose shear buckling under heavy traffic condition at higher temperature. Researcher experience had shown that SISAL fibre performs better than other fibre and polymer in case of reduction of the drain down of mix.

*3.5 Preparation of Mix*

The Marshall test procedure describe in ASTM D1559 and MORTH specification followed for this experimentation. The Bituminous Concrete composed of fine, coarse aggregates and Stone dust were mixed as per adopted gradation. Bitumen is heated at temperature of 150°C. The mix was heated up to 180°C in an Air oven for continuous 2 hours so that it can mix well with heated binder. The process was performed according to (IRC-MORTH). SS-1 emulsion coated the fibre and kept for 24 hours in an air-hot furnace at 110°C. Then the emulsion coated Sisal fibre was cut into small pieces by length asper the requirement and weight, then after added directly to the mixture as per the required quantity. The total aggregate was kept up at a temperature of 20°C higher than the temperature of the bitumen. Required amount of bitumen was add on aggregate and fibre heating mixture. The mix preparation was performed manually with hands until the colour and constancy of the mixture to show constant and homogenous. The mixing time maintained 2 to 5 minutes. The prepared mix was transferred in to pre-heated Marshall Moulds and the samples were compacted by 75 blows on both sides with heavy rammer as per the procedure. For Room temperature cooling, the samples had been kept overnight. Then, a standard testing procedure

was using extract and test samples with a temperature of 60°C.

The following steps are followed to carry out in the laboratory for preparation and testing of bituminous mixtures:

i. The first step was to determine the Optimum Binder Content (OBC) of the bituminous mixes with the help of Marshall stability Test, this was achieved by preparing the marshal sample at varying bitumen percentages ranges from 4% to 6%.
ii. The Marshall Stability parameters was used to determine that 5.2% bitumen content was found to be an Optimum value for Bituminous Concrete Grade-1 and for Bituminous Concrete Grade -2 it was found a 5.5%.
iii. Then by keeping the bitumen content constant with their respective bituminous mixes (5.2% and 5.5%), SISAL fibre varying from 0% to 0.8% and different Fibre length up to 6mm-18mm will help in determining the Optimum Fibre content which was 0.4%.
iv. At the end samples of with sisal fibre 0.4% and without fibre content with their respective bitumen content of bituminous mix tested with drain down test.

## 4. Results and discussions

### *4.1. Marshall Stability Test*

Marshall Mix design is a commonly used laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. For this experimental study Marshall properties like Stability, Flow value, Air voids, VMA and VFB with various fibre content were investigated with the optimal binder contents (OBC) with respect to grade of bituminous mixture to find optimal fibre contents (OFC). The Marshall properties of bituminous mix with addition of sisal fibre are present in Fig.3 and Fig.4 for BC-1 and BC-2 respectively.

The modified bituminous mix (BC Grade-1,2) with addition of sisal fibre is tested by Marshall method and the Marshall properties are present in Fig.3 and Fig.4. Optimal binder content was found to be 5.2% for BC-Grade 1 and for BC-Grade 2 it is 5.5%. The graph shows the Fibre content varying percentage were 0.2%,0.4%,0.6% and 0.8% and Fibre length varying from length 6mm,10mm,14mm and 18mm.

The Marshall Stability graphs show an increase in stability till a certain percentage then it starts decreasing. As the graph shows adding up to fibre length 10mm and Fibre content 0.4% it increases, but when adding more than 0.4% fibre content stability start decreases. It is also observed that with increase in fibre content and fibre length up to a certain level, Air void and flow value also decreases. Thus, the consistency of bitumen changes and becomes harder and adding up to o.4% fibre shows good characteristic and strength.

Void in Mineral Aggregates with addition of fibre content up to 0.4% shows good result. whereas adding further i.e. greater than 0.4% and more than 10mm, it starts gradually increases and decreases. Void Filled with Bitumen till addition of 0.4% shows stable and good binding character.

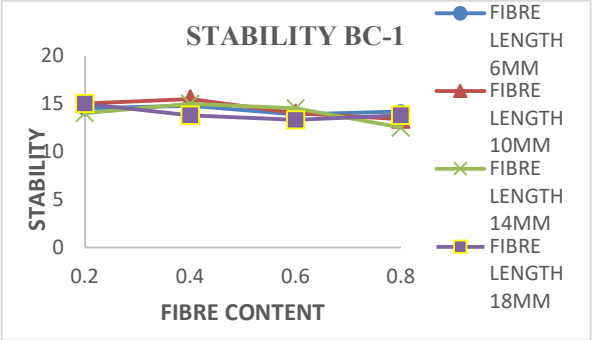



FIGURE3. A

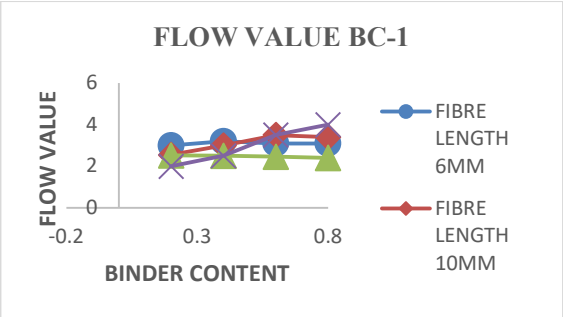



FIGURE 3.B

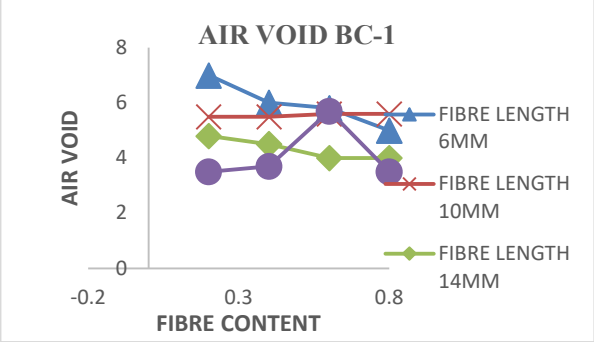



FIGURE 3.C

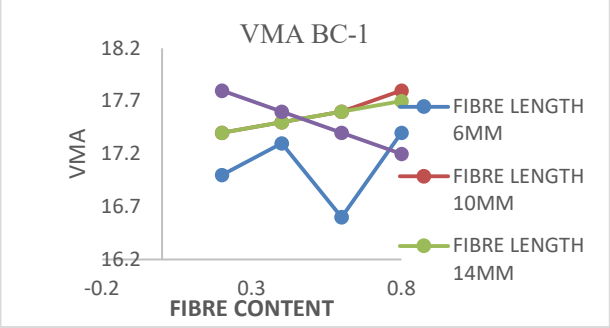



FIGURE 3.D

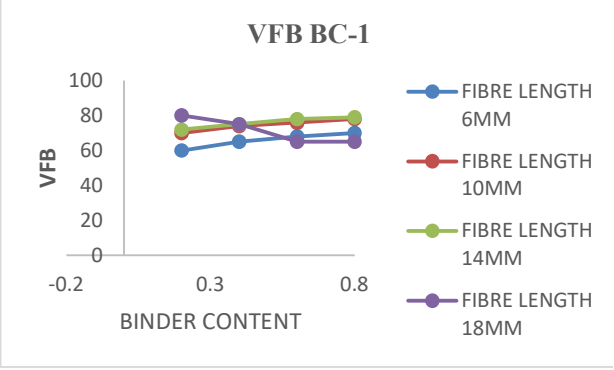



FIGURE 3.E

Fig. 3. The Marshall Properties with varying Fibre length and Fibre content at OBC-5.2% for BC grade-1 (A) Stability (B) flow value. (C) Air voids. (D) Variation in voids in mineral aggregate. (E) Variation in VFB.

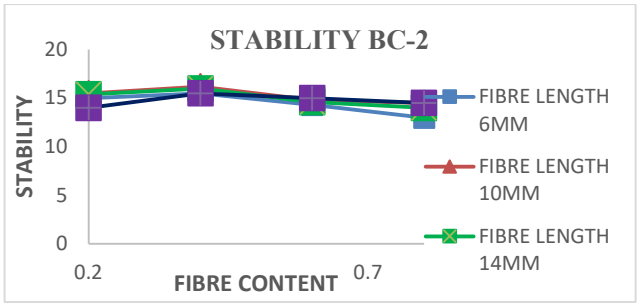
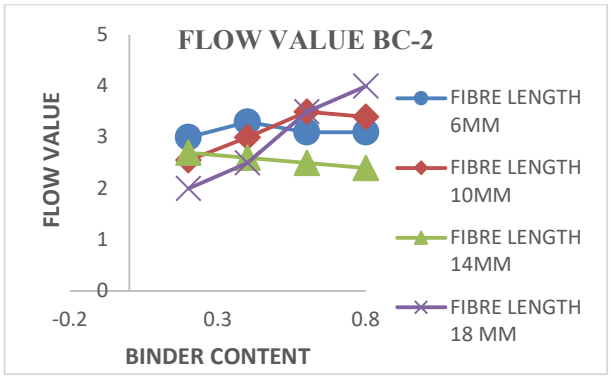



FIGURE 4.A



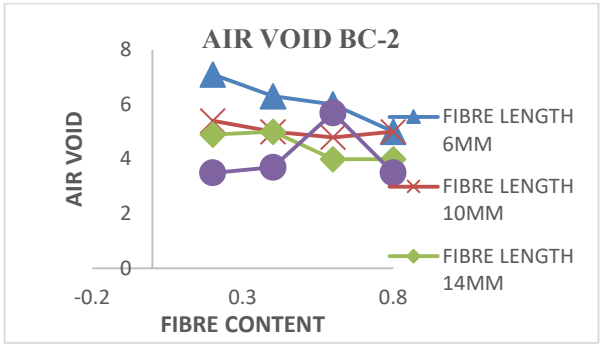




FIGURE 4.C

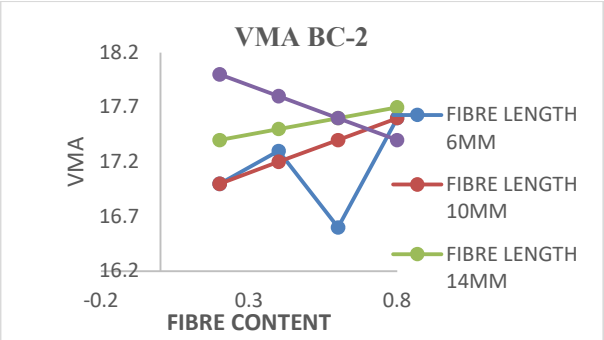



FIGURE 4.D

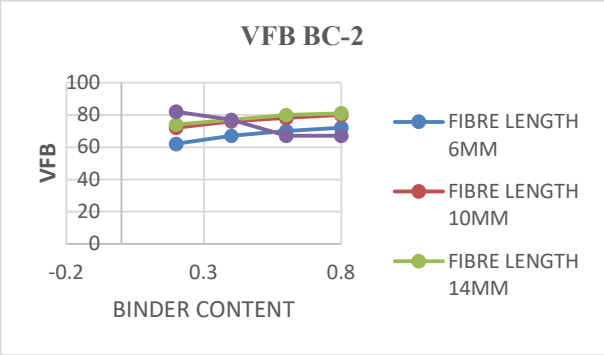



FIGURE 4.E

Fig. 4. The Marshall Properties with varying Fibre length and Fibre content at OBC-5.5% for BC grade-2 (A) Stability (B) flow value. (C) Air voids. (D) Variation in voids in mineral aggregate. (E) Variation in VFB.

*4.2. Drain down Test*

Drain Down test in which part of mix separate from sample of bituminous mix and flows downward and drain down. The test process and determine the amount of Drain Down in an uncompacted bituminous concrete [5]. In this Present study bituminous concrete was obtained at Optimum bitumen content and Optimum fibre content. Drain down test of samples with fibre and without fibre were determined through drain down method. The drain down method suggested by MORTH (2001) was adopted in this study. The drainage baskets fabricated locally according to the specifications given by MORTH (2001) is shown in Figure. 5. The loose un-compacted mixes were then transferred to the drainage baskets and kept in a pre-heated oven maintained at 150°C for three hours. Pre weighed plates were kept below the drainage baskets to collect the drained-out binder drippings.

It is observed that drain down value of Bituminous concrete with fibre decreases as compare to without fibre which means it reduces and prevent drain down of bituminous concrete. The observed Drain down value for both BC-1 and BC-2 with and without OFC are summarized in Table.4

Fig.1. Drain Down Test For BC-1 and BC-2

**Table.4 Drain Down Values of Bitumen Mixtures**

| Drain Down (in %) Value of Bitumen Mixtures | | |
|---|---|---|
| Grade of mixtures | Without Fibre Content | With Fibre Content |
| BC-1 | 0.04% | 0.02% |
| BC-2 | 0.06% | 0.02% |

## 5. Conclusion

In the current Experimental work, a natural fibre that is Sisal fibre was used as additive in the mix design of Bituminous Concrete. For this study both BC-grade 1 as well as BC-grade 2 mix design was performed and OBC and OFC was found out. Marshall tests were performed to

evaluate its characteristic Marshall quotient with strength characteristics and drain down was performed to evaluating the stoppage of drain down of bituminous mix.

I. The Optimum Binder Content (OBC) for Bituminous Concrete – Grade 1 and for Bituminous Concrete – Grade 2 was found out to be 5.2% and 5.5% respectively.
II. From the above experiment it was observed that after adding Sisal fibre up to 0.4% and the length of fibre up to 10mm with keeping bitumen content constant with the OBC value the stability of the mix increases, but when adding more than 0.4% fibre content stability start decreases for both BC-1 and BC-2.
III. It was identified that with increase in fibre content and fibre length up to a certain level, Air void and flow value decreases Thus the consistency of asphalt changes and becomes harder.
IV. Use of emulsion coated fibre increases resistance to moisture induced damages.
V. Drain down of binder decreases which show good characteristics of bitumen.

## 6. References


[1] P Teja Abhilash. A Study on bituminous mix with sisal fibre. International Journal of Civil engineering and Concrete Structures (Int. J. Civil Engg. Conc.Structs). October 2016, ISSN 2455-7714 www.trpubonline.com Vol. 1, No. 3.

[2] Garnepudi Sandeep. Experimental study of bituminous mixture mixes with natural fibre International Journal of Advance Engineering and Research Development (IJAERD). 2017 February ISSN: 2348-4470, Vol.4 Issue 02.

[3] Ministry of Road Transport & Highways. Specifications for road and bridge works. 5thedn. IRC: Delhi, 2013.

[4] Rajkumar JSS, Vijayalakshmi MM. Evaluating the Performance of Super pave Graded Bituminous Mix. Indian Journal of Science and Technology. 2016 September; 9(35):1 7.

[5] Naveen Kumar. Drain down Analysis of Bituminous Mix Modified with Natural Fibre. International Journal of Innovations in Engineering and Technology (IJIET), December-2016, ISSN 2319-1058 Volume Issue 4.

[6] Bureau of Indian Standards. Methods of testing for aggregate for concrete. 2002 March; IS: 2386.

[7] IRC 94. Specification for Dense Bituminous Macadam. Indian Road Congress. New Delhi, India. 1986

[8] L.R Kadiyali. Principles and Practices of Highway Engineering. Khanna Publications: 2005.

[9] IRC: SP: 107. Guideline for Gap Graded Wearing Courses with Rubberized Bitumen (Bitumen - Rubber). Indian Road Congress. New Delhi, India. 2015; p. 1-28

[10] IRC SP 53. Guidelines on use of modified bitumen in road construction. Indian Road Congress. New Delhi, India.2010.

[11] Chakraborty, P., & Das, A. “Principles of Transportation Engineering”, Prentice Hall of India, New Delhi, (2010), pp 294-299.

[12] T Subramani. Experimental investigations on coir fibre Reinforced Bituminous Mixes. International Journal of Engineering Research and Applications (IJERA). May 2012 ISSN: 2248-9622 Vol. 2, Issue 3.

[13] Anuj Narwhal. Analysis of results on bituminous mixes using natural fibers. International Journal of All Research Education and Scientific Methods (IJARESM). June-2016, ISSN: 2455-6211, Volume 4, Issue 6.