Study on VG-30 BC Mix by Partial Replacement of Cashew Nutshell Liquid for Rural Road

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ABSTRACT

A country's advancement for the most part relies upon the advancement of transportation of the nation. As Flexible pavement is significantly used in India, it is significant that means must be taken to expand the life of the bituminous mix. Flexible pavement is frequently exposed to issues like rutting, cracking, and other failures due to repeated traffic loads. In this paper, the main aim of the study is stabilization of bituminous mix with CNSL and comparing the results with the conventional bituminous mix. The material used for the present study is VG-30 grade bitumen, CNSL, Lime and Natural Coarse Aggregate. In this research study, the CNSL as a replacement to bitumen by 2%, 4% and 6% and finally the stability of the bituminous mix and stability of the partial replaced bitumen by CNSL are compared by conducting Marshal Stability test.From the experimental investigation it has been proved that 2% addition of CNSL gave better stability and the flow value was higher for addition of 4% CNSL when compared to conventional mix.

Keywords: Bitumen, Cashew Nutshell Liquid, Stone Dust, Lime.

1 Introduction

Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and industrial wastes product is one such category. If these materials can be suitably utilized in highway construction, the pollution and disposal problems may be partly reduced. Cashew nut shell liquid (CNSL) is a unique natural source for unsaturated long-chain phenols. It is a cheap and renewable material, obtained as a by-product of the cashew industry. CSNL by itself is useful as insecticidal, fungicidal, anti-termite and medicinal applications. It can be used as starting material for organic synthesis and replaces phenol in many instances with equivalent or better results. Resins derived from CNSL are widely employed in the field of friction materials, automobiles, surface coating, adhesives, laminates, rubber compounding, and have several miscellaneous applications. The most attractive consideration for CNSL use as an industrial product can be its low cost, abundant availability, and its chemically reactive nature. Technical CNSL is obtained by roasting shell at 180-200 °C. The anacardic acid is thermally unstable and is easily decarboxylated during the extraction process by heating and then transformed into cardanol. Technical CNSL contains mainly cardanol (60-65%), cardol (15-20%), polymeric material (10%), and traces of 2-methyl cardol. Depending on the conditions of the roasting process, the composition of the technical CNSL can change and reach higher cardanol content (83-84%), less cardol (8-11%) and maintain polymeric material as 10% and 2-methyl cardol content as 2%. Due to the abundance of CNSL in the Southern States of India and its chemical affinity with sodium hydroxide and calcium oxide, it can be used as pavement material [2].

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1.1 Objectives

The objectives of this project are as follows;

- To examine the basic properties of bitumen, aggregate, CNSL & filler material.
- To determine the percentage of Optimum Bitumen Content (OBC) for Bituminous Concrete (BC) based on the marshal test mix.
- To calculate the percentage of the optimum CNSL content for Bituminous Concrete.

2 Experimental Investigations

This research includes the details about the method of casting the specimens and test procedure of the different tests performed during the investigation.

2.1 Materials Used

2.1.1 Bitumen

Bitumen is a common binder used in road construction. It is principally obtained as a residual product in petroleum refineries after higher fractions like gas, petrol, kerosene and diesel, etc are removed. Bitumen of VG-30 grade was used in the study [5].

Table 1: Properties of VG-30 Bitumen compared with requirements

Characteristics	Unit	Value	Requirements as per IS 73-2013
Penetration Value	Mm	62.6	45
Ductility Value	Cm	69.5	>100
Softening Point	°C	55	>47
Flash Point	°C	241.6	>220
Fire Point	°C	241.6	>235
Specific Gravity	-	1.2	0.98-1.02

2.1.2 Cashew Nut Shell Liquid

Cashew nut shell liquid is a by-product of the cashew industry which is collected from the Vittalindustry. CNSL has chemical properties that have special structural features, which transforms the specialty chemicals and high value polymer. The oil thus provides a value addition of chemical features that provides 100% chemically pure products. Therefore, cashew nut shell liquid oil is used in this research work [6].

Figure 1CNSL

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2.1.3 Lime

Lime is a type of dry powder made from limestone. It formed by adding water to quicklime in order to turn oxides into hydroxides. The lime used as filler which was stored in a cool & dry place away from weathering effects.

2.1.4 Natural aggregate

Aggregate of 20mm maximum size and retained in pan 4.75mm sieve had been used for specimen preparation of Marshall Stability test. Locally available Basalt rock was used as coarse aggregate which borrowed from stone crusher plant.

2.1.5 Stone Dust

Stone dust was used as filler in the bituminous mixes for comparison and economical point of view.

2.1.6 Gradation

Table 2: Gradation of Aggregates

IS Sieve sizes (mm)	Cumulative percentage by weight of total aggregate passing	Adopted gradation	Percentage of materials taken for test	Weight of materials (gm)
26.5	100	100	-	-
19	79-100	89.5	10.5	126
13.2	59-79	69	20.5	246
9.5	52-72	62	7	84
4.75	35-55	45	17	204
2.36	28-44	36	10	120
1.18	20-34	27	10	120
0.6	15-27	21	7	84
0.3	10-20	18	7	84
0.15	5-13	9	7	84
0.075	2-8	5	4	48
Total				**1200**

2.2 Methodology

Present experimental investigation consists of Penetration test, Ductility test, Specific gravity test, softening point test, Flash point test, Fire point test and Marshall Stability test on VG30 grade.The tests were carried on with different proportion of bitumen replaced by CNSL. Each parameter demonstrates the various qualities and properties of bitumen and changes that occur when the CNSL is added in various extents. This section covers the laboratory test results of aggregates, bitumen with cashew Nut shell Liquid[4].

2.2.1 Laboratory tests for aggregates

Tests were conducted to determine the specific gravity, water absorption, crushing value, aggregate impact value, Los Angles abrasion value, elongation index and flakiness index of aggregates according to the procedures specified by BIS standards and results are summarized in Table 3[1].

Table 3: Preliminary Test Results of Aggregates

Tests	MORTH Specification	Values obtained
Specific Gravity	2.5-3.2	2.68
Impact Value (%)	<24%	23.71
Crushing Value(%)	<27%	25.84
Water Absorption(%)	<2%	1.9
Flakiness Index(%)	<30%	22.30
Elongation Index(%)	<30%	15.60
Abrasion Test (%)	<30%	9.6

2.2.2 Laboratory tests for bitumen

For this study, Bitumen of VG 30 grade (equivalent to penetration grade 60/70) is used for the study.

i) Penetration Test :Penetration value of bitumen is determined by IS: 1203-1978.The penetration value of bitumen is defined as the amount of standard penetration needle passed is 5sec.

ii) Softening Point Test: The softening point of the various test samples is obtained using the ring and ball test in accordance to IS: 1205-1978.

iii) Ductility Test: Ductility value of bitumen is determined as per IS:1208-1978.

iv) Flash and Fire Point Test: Flash and Fire point of bitumen is determined as per IS: 1209-1978[7].

2.2.3 Mixing of materials and specimen preparation

The compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 145^{o}C. About 1200 gm of sample aggregates were taken and kept in oven until it dried. Heating of aggregates was done up to 140^{o}C before the addition of bitumen. Cashew nut shell liquid was used as replacement of Bitumen. Bitumen was replaced by cashew nut shell liquid in the percentage of 2%, 4% and 6%.The mixture thoroughly mixed by hand mixing with trowel maintains the temperature of mix up to 154^{o}C - 160^{o}C. For each binder content and composites 3 samples were prepared by compacting to 75 blows on both sides of sample in Marshall Compactor. Then the sample was de-molded and the weight of sample in air and in water was noted down to determine the bulk density of mix. Also, the average thickness and diameter of the specimen are noted. For the determination of stability and flow value on Marshall Apparatus, sample was immersed in water bath at 60^{o}C for 40 minutes before testing. The specimens are taken out one by one, placed in the Marshall test head and the Marshall stability and flow values are noted[3].

3 Results and Discussions

3.1 SPECIFIC GRAVITY

The following are the specific gravity of bitumen as replaced by CNSL

Table 4: Variations in specific gravity of CNSL mixed bitumen

Percentage of bitumen	Percentage of CNSL	Specific gravity
100	0	0.99
98	2	1
96	4	1.01
94	6	1.01

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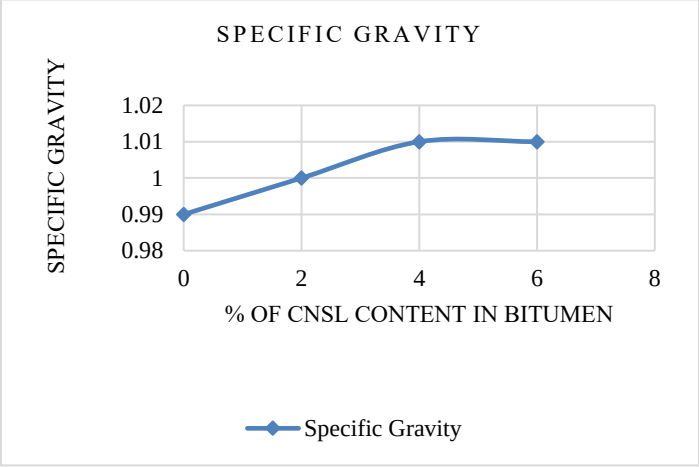

Figure 2 Variation in Specific Gravity Value of CNSL Mixed Bitumen

In the Table 2 and Figure 2, the specific gravity at different percentage of replacement i.e.,2%,4%,6%, of CNSL mixed bitumen are compared with plain bitumen with no replacement i.e., 0% replacement. It is seen that 0% replacement has lower specific gravity and 4% has the highest value of ductility. It is observed by the results that the specific gravity increases with every percentage added. The specific gravity of plastic mixed bitumen with 2%, 4%, and 6% bitumen replacement are 1, 1.01, 1.01 times the specific gravity of plain bitumen. So, the specific gravity of bitumen increased by small amount by the replacement of 4%.

3.2 PENETRATION TEST

The penetration values of bitumen replaced by different percentages of CNSL. The Penetration values are decreasing significantly for 60/70 bitumen mixed with 0% CNSL to 6% of CNSL. It is observed that the penetration value increases as the CNSL increases.

Table 5: Variations in penetration value of CNSL mixed bitumen

Percentage of bitumen	Percentage of CNSL	Penetration value in mm
100	0	62.6
98	2	63
96	4	64
94	6	66

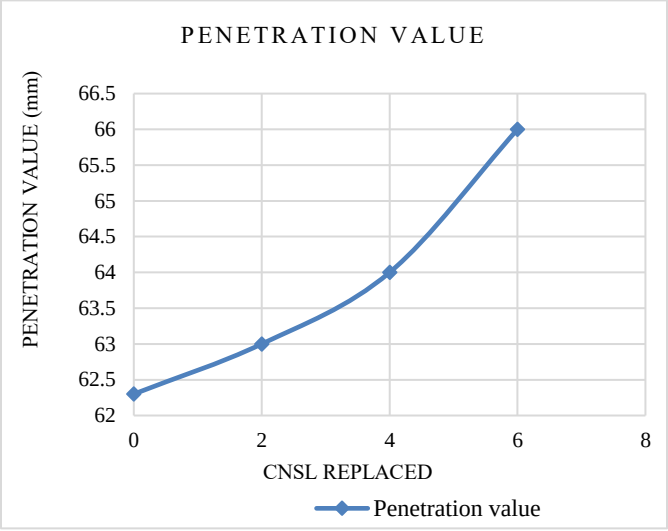

Figure 3: Variation in Penetration Value of CNSL Mixed with Bitumen

The penetration value at different percentage of replacement in the Table 3 and Figure 3 i.e. 2%, 4%, 6% of CNSL mixed bitumen are compared with plain bitumen with no replacement i.e., It is seen that 0% replacement has lower penetration value and 6% has the higher value of penetration.

3.3 DUCTILITY TEST

The following shows variation in ductility value of Plain and CNSL mixed bitumen

Table 6: Variations in ductility value of CNSL mixed bitumen

Percentage of bitumen	**Percentage of CNSL**	**Ductility value (cm)**
100	0	100
98	2	100
96	4	96
94	6	90

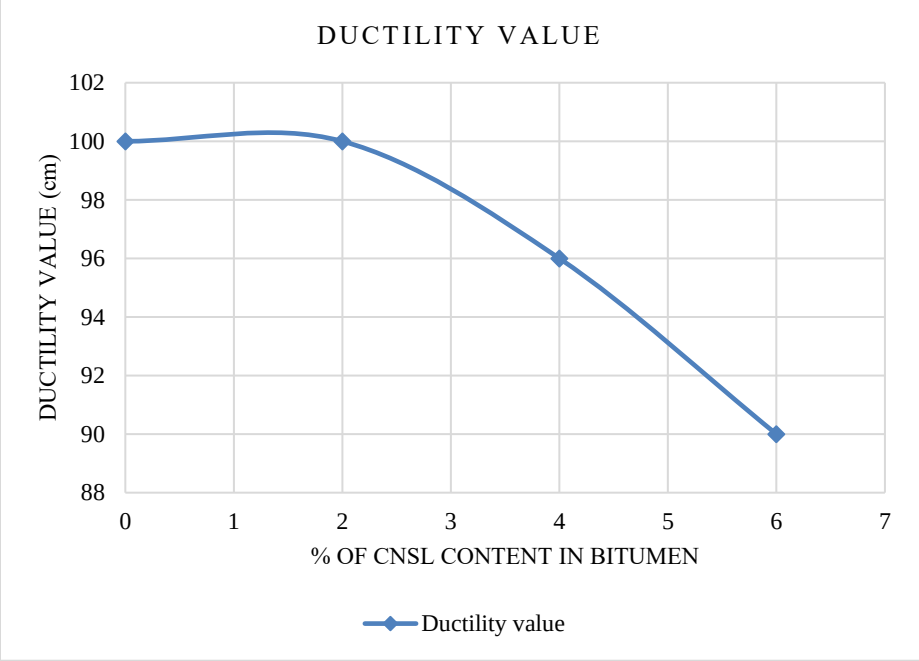

Figure 4 Variation in Ductility Value of CNSL Mixed Bitumen

In the Table 5 and Figure 4, the ductility value at different percentage of replacement i.e., 2%, 4%, 6% of CNSL mixed bitumen are compared with plain bitumen with no replacement i.e.,0% replacement. It is seen that 0% replacement has higher ductility value and 4% has the lowest value of ductility. It is observed by the results that the ductility value decreases with every percentage added. The ductility value of CNSL mixed bitumen with 2% 4% 6% bitumen replacements are 1, 0.96, 0.90 times the ductility value of plain bitumen. So, the ductility value of bitumen by 4% by the replacement of 4%.

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3.4 SOFTENING POINT TEST:

The following shows variation in softening point of Plain and CNSL mixed bitumen

Table 7: Variations softening point value of CNSL mixed bitumen

Percentage of Bitumen	Percentage of CNSL	Softening point (°C)
100	0	55
98	2	55
96	4	54
94	6	52

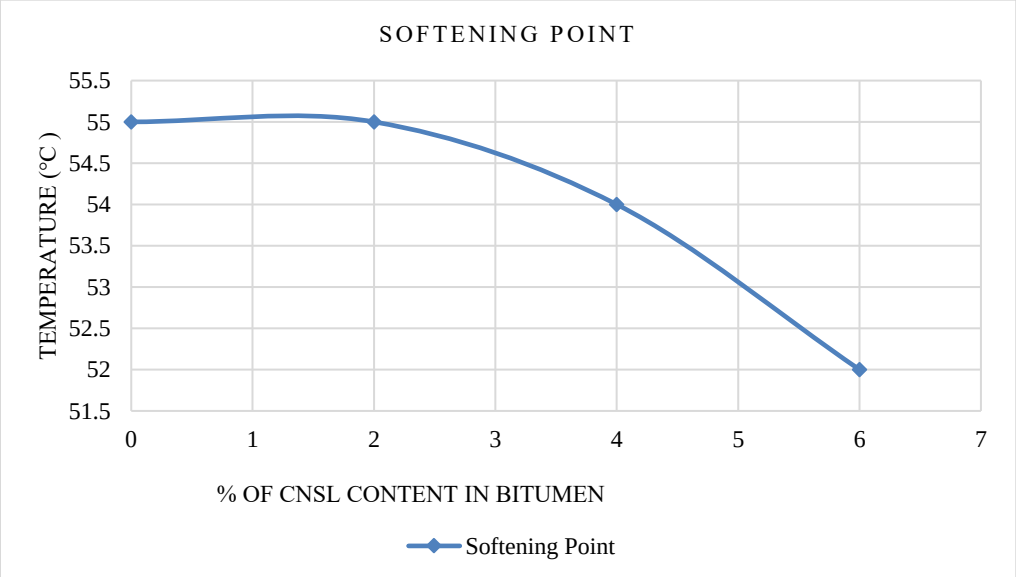

Figure 5 Variation in Value of Softening Point

In the Table 5 and Figure 5, the softening point at different percentage of replacement i.e., 2%, 4%, 6%, of CNSL mixed bitumen are compared with plain bitumen with no replacement i.e., 2% replacement. It is seen that 2% replacement has highest softening point and for 4% replacement the softening point decreases with every percentage added.

3.5 FLASH AND FIRE POINT TEST

The following values shows variations in flash and fire point in CNSL mixed bitumen

Table 8: Variations in flash and fire point value of CNSL mixed bitumen

Percentage of Bitumen	Percentage of CNSL	Flash point (°C	Fire point (°C)
100	0	242	250
98	2	245	255
96	4	247	259
94	6	250	260

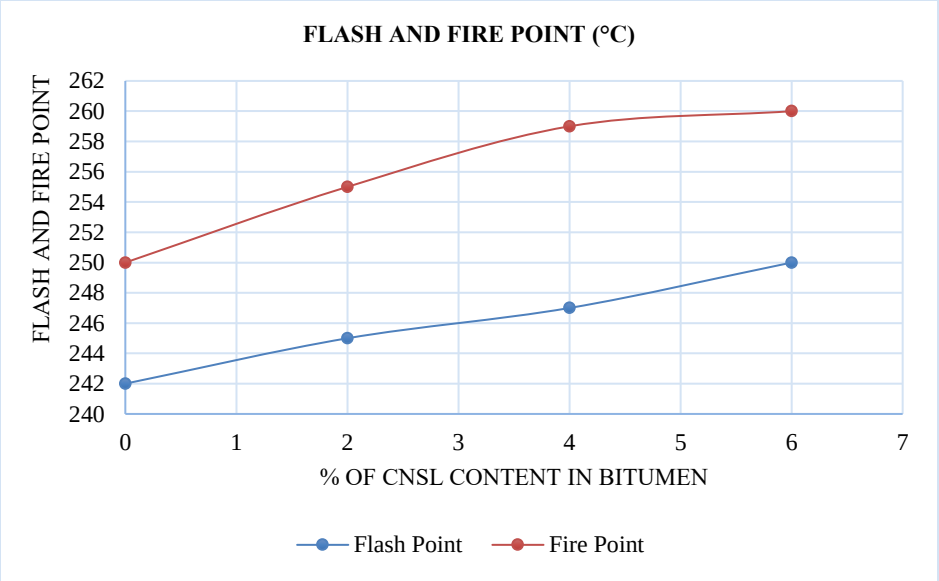

Figure 6 Variation in Value Flash and Fire Point Value of CNSL Mixed Bitumen

The flash and fire point at different percentage of replacement i.e., 2%, 4%, 6%, of CNSL mixed bitumen are compared with plain bitumen with no replacement i.e., 0% replacement. By referring Table 4.5 and Figure 4.5 it is seen that 0% replacement has lower flash and fire point and 4% has the highest flash ad fire point. It is observed by the results that the flash and fire point increases with every percentage added.

3.6 BITUMINOUS CONCRETE MIX FOR VG-30 GRADE

Here the results of Marshall Stability Test Conducted upon VG-30 Bitumen.

Table 9: results of marshal stability test on VG-30 bitumen

Bitumen content (%)	Stability (Kg)	Flow value (mm)	Bulk density (Kg/m³)	% Air voids	VMA (%)	VFB (%)
5	1523	3.6	2.35	4.8	16.1	70.18
5.5	1774	3.8	2.40	2.4	15.03	84.03
6	1685	4.36	2.37	2.8	16.35	82.87

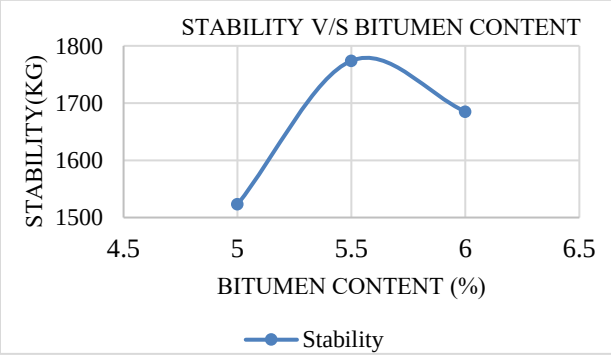

Figure 7 Variations in Stability of Plain Bitumen for VG -30 Grade

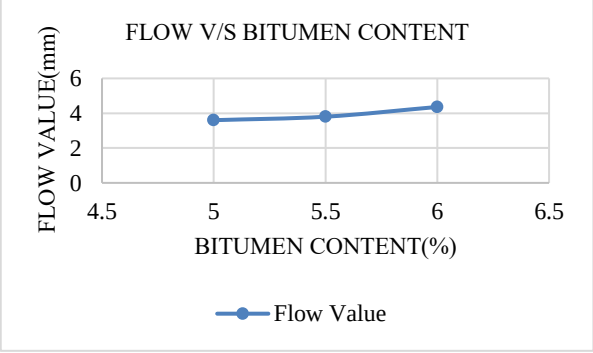

Figure 8 Variations in Flow Value of Plain Bitumen for VG -30 Grade

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From the Figure 7 it is observed that, the maximum stability value 1774 Kg is obtained at 5.5 % of bitumen content.From the Figure 8 it is observed that, the maximum flow value 4.36 mm is obtained at 6% of bitumen content.

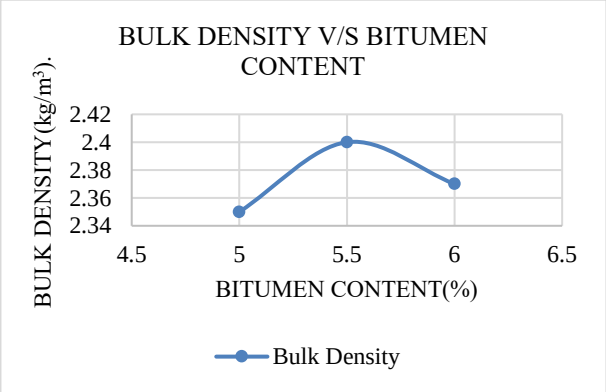

Figure 9 Variation in Bulk Density of Plain Bitumen for VG -30 Grade

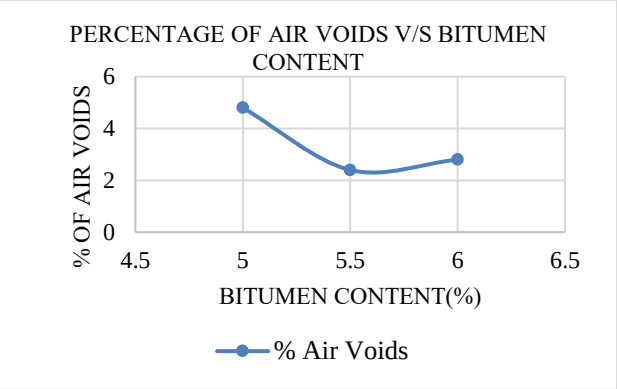

Figure 10 Variation in Air voids of plain bitumen for VG -30 Grade

From the Figure 9 it is observed that, the maximum bulk density 2.40 Kg/m3 are obtained at 5.5% of bitumen content.From the Figure 10 it is observed that, the maximum % air void 4.8 is obtained at 5% of bitumen content.

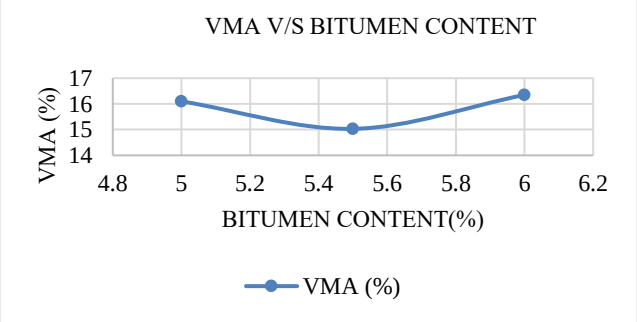

Figure 11 Variation of VMA of bitumen for VG -30 Grade

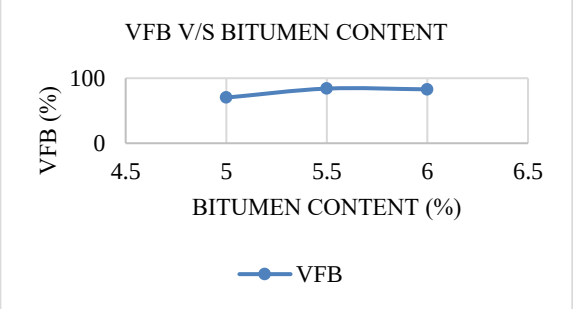

Figure 12 Variations in VFB of Bitumen for VG -30Grade

From the Figure 11 it is observed that, the maximum % VMA 16.35 is obtained at 6% of bitumen content. From the Figure 12 it is observed that, the maximum % VFB 84.03% is obtained at 5.5% of bitumen content [8].

4 Conclusions

- From the previous studies up to 4.5 % bitumen not gave the results as per the MORTH. So that we have selected 5%, 5.5% and 6% of bitumen content.
- From experimental investigation it has been proved that 2% addition of CNSL gave better stability and the flow value was higher for addition of 4% CNSL when compared to conventional mix.
- The maximum marshal stability value for plain bitumen and 2% addition of CNSL is1774 kg and 1620 kg respectively hence by 2% addition of CNSL Marshall Stability value gave relatively better stability.
- CNSL can be replaced for other grades of bitumen, in our research we have used VG-30 and we got better results. Hence CNSL can be partially replaced for conventional material.

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