Characterization and Testing of Foamed Modified Bitumen for Quality Assurance and Feasibility for Indian Condition and Standards

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Abstract

For many decades, bitumen has been successfully used in asphalt concrete to pave roads. Despite continuous improvements to bitumen production processes, mix design and pavement design, there are limits to the extent that bitumen can surmount the challenge. Accelerating wear and tear caused by heavy traffic and harsh climates are taking a toll. In addition there are increasing demands for quieter and safer roads. In India about 90% of roads are bitumen paved. Pavement industry has developed rapidly all over the world during the last few decades, especially in developing countries. Following the rapid development, increased traffic load, higher traffic volume, and insufficient maintenance led to many severe distresses (e.g. rutting and cracking) of road surfaces. The harsh reality was demanding more on bitumen quality. Considering all these problems it is seen that using plain bitumen is not sufficient now a days due to increase in distress therefore considering the need of modification of bitumen, foaming of bitumen is also a step towards modification of bitumen.

Keywords : Foamed Bitumen, Modified Bitumen, Rehabilitation Of Road, Characteristics, Test Results.

I. INTRODUCTION

A. Foamed Modified Bitumen

Foamed asphalt is a mixture of aggregates (stone and soil) and foamed bitumen. The bitumen is foamed by an innovative process, harnessing the usually undesirable reaction which occurs when hot bitumen is contaminated with water.

Foamed asphalt mix refers to mixture of pavement construction aggregates and foamed bitumen. Foamed bitumen is produced by a process in which water is injected into the hot bitumen resulting in spontaneous foaming. Water on contact with hot bitumen is turned into vapor, which is trapped in thousands of tiny bitumen bubbles. Incorporating foamed bitumen into the aggregates produces foamed asphalt mix.

In order to mix bitumen with road-building aggregates, first it is needed to considerably reduce the viscosity of the cold hard binder bitumen. Traditionally this was done by heating the bitumen and mixing it with heated aggregates to produce hot mix asphalt. Other methods of reducing the bitumen viscosity include dissolving the bitumen in solvents and emulsification. In the foam state the bitumen has a very large surface area and extremely low viscosity making it ideal for mixing with aggregates.

The very basic concept behind the foaming of the bitumen by adding cold water in hot bitumen is shown diagramticaly in the following figure.

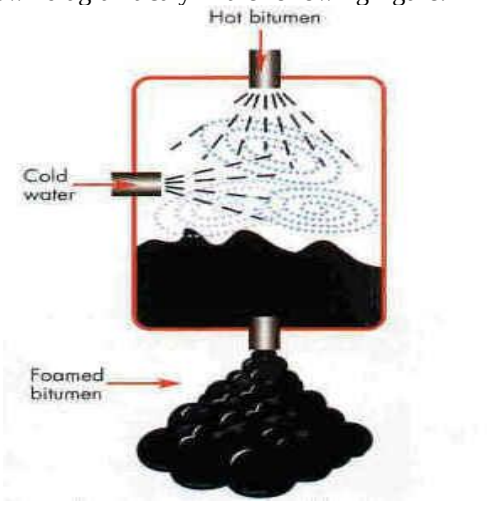


Fig. 1: Concept of Foamed Bitumen

In foamed state, the bitumen is ideal for mixing with fine aggregates. Increases the workability. In foamed state, bitumen has a very large surface area and an extremely low viscosity. Increases the surface tension which reduces water percolation. Also increases fatigue and rut resistance.

B. Foamed Bitumen Apparatus

A device for producing small-scale batches foamed bitumen. The device has a first pressurized, holding chamber for heating bitumen to a selected temperature, a second pressurized, holding chamber for heating bitumen additive (e.g., a foaming agent or chemical additive) to a selected temperature, and various conduits and valves as needed for delivering heated and pressurized bitumen with heated and pressurized additive to a mixing chamber having a selected volume to produce foamed bitumen. A method of producing foamed bitumen, the method comprising the steps of:

1. Heating bitumen to a selected temperature in a first holding chamber,
2. Heating additive to a selected temperature in a second holding chamber,
3. Pressurizing the bitumen to a selected air pressure in said first holding chamber,
4. Pressurizing the additive to a selected air pressure in said second holding chamber,
5. Mixing the heated and pressurized bitumen with the heated and pressurized additive in a mixing chamber having a selected volume to form a foamed bitumen, and collecting the foamed bitumen in a container.

Due half-life period of foamed bitumen it has to mix and laid fast and in continuation so therefore the setup consist of mixer, foam layer in continuation.

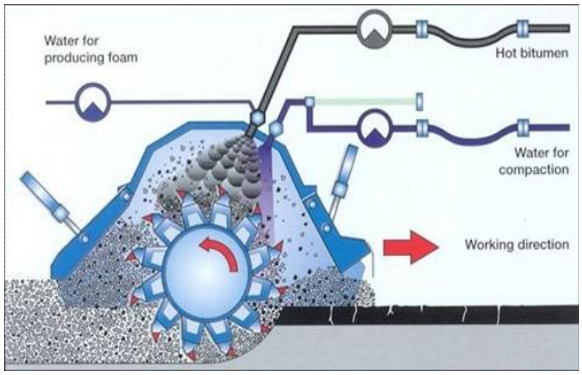


Fig. 2: Site Foaming and Pavement Construction Setup

C. Rehabilitation of Roads by using Foam Modified Bitumen –

This specialist process delivers a fast, effective and long term rehabilitation to un-bound and semi-bound pavements that have exceeded their useful economic life. The process involves the mixing of foamed bitumen with existing pavement materials to produce a durable, high performance pavement with excellent flexibility. In its expanded state the bitumen offers good dispersion properties and result in visco-elastic pavement performance with some characteristics similar to asphalt.

II. METHODOLOGY

As in foreign countries cement and lime are used as filler materials but in India the most common filler material used is stone dust, so the same stone dust as an filler material along with foamed bitumen and road construction aggregates as per IRC grading for surface course layer is been used.

All the tests has been conducted according to IRC specifications so that the result will be feasible in India and Indian condition. The IRC : 37-2012 has been used for conforming the specification given for the flexible pavement construction in India.

As this foamed bitumen asphalt method is being practiced in foreign countries for pavement construction and also for soil stabilization, we wanted to check whether it is feasible in India since the boundary conditions are different and method of construction is also different.

A. Materials

1. Aggregates
2. Stonedust
3. Bitumen (60-70 grade)
4. Water
5. Foaming agent (diesel)

Aggregates used were according to the IRC grading for surface course as follows

Table 1: Grading of Aggregates for Surface Coarse

Size	% lesser than	Wt lesser than (for 10 kg sample)	Weight
12.5mm	100	10kg	1kg
10mm	90	9kg	2.5kg
4.75mm	65	6.5kg	2.25kg
2.36mm	42.5	4.25kg	1.0kg
600µ	23.5	2.35kg	0.55kg
300µ	18	1.8kg	0.6kg
150µ	12	1.2kg	0.5kg
75µ	7	0.7kg	0.7kg

B. Preparation of Samples

The foamed bitumen has been prepared by traditonal method by heating bitumen on electric coil heater upto temperature 150ºC to 180ºC and spraying water (2.5% by weight of bitumen) on it along with diesel as foaming agent.
Bitumen grade – 60-70
Heating apparatus – Electric coil heater
Foaming agent – Diesel
Water – Sprayed using spray bottle

Got foamed bitumen, this foamed bitumen is used for further experimental purpose. This prepared foam of bitumen is to be handeled carefully and to be mixed with the aggregates in its foamed state because in the foamed state the viscosity of the bitumen in very less and due to expansion it becomes very easy to mix with less quantity and and also good coating of the aggregates is achieved

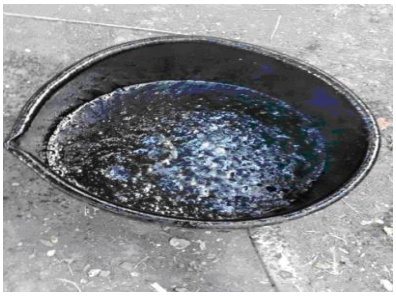


Fig. 3: Foam Modified Bitumen

C. *Material Properties-*

The foaming properties are characterized by two terms: Expansion ratio and Half life Expansion Ratio- The ratio of the maximum volume of foamed bitumen compared to the volume of unfoamed or conventional bitumen.

Half Life- The time taken for the volume of foamed bitumen to settle to half of the maximum volume achived due to foaming.

It is important that sufficient expansion ratio and half life characteristics are present to ensure adequate coating of the fine particles by bitumen.
Only the foaming water can be changed readily to improve the foaming characteristics. Testing indicates the best foaming properties are usually achived with water content of 2.5%.

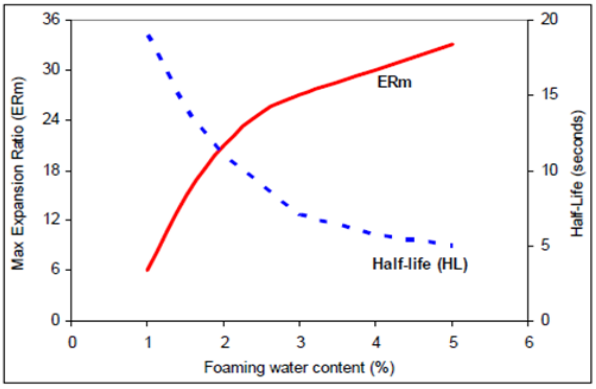


Fig. 4: Curve Showing Foaming Properties Of Bitumen

III. TESTS PERFORMED

A. *Test on Bitumen -*

1. Penetration test
2. Ductility test
3. Softening point test
4. Stripping value test

B. *Tests on Bituminous Concrete -*

1. Marshall stability test

By these tests characteristics of plain bitumen and foam bitumen have been compared.

IV. RESULTS AND DISCUSSIONS

A. *Tests on Bitumen*

1) *Penetration Test*

Table 2: Penetration Value Test Results

Reading No.	Pure Bitumen	Foam Bitumen
1	71	59
2	66	61
3	62	61
4	65	57
5	64	60
Avg.	65.6	59.6

Penetration indicates consistency of bitumen. From penetration test on pure bitumen and foam bitumen, it is found that the penetration value is reduced since foam bitumen has higher stiffness and it gets harder. Higher values of penetration indicate softer consistency. Due to foaming of bitumen, as the penetration value decreases the consistency increases. In warmer region lower penetration grades are preferred to avoid softening of bitumen. Therefore foaming the can be considered beneficial.

2) *Ductility Test*

Table 3: Ductility Test Results

Parameter	Pure Bitumen	Foam Bitumen
Ductility Value (cm)	92	112

In flexible pavement design, it is necessary that binder should form a thin ductile film around aggregates so that physical interlocking of aggregate is improved. From the test results, it is found that ductility or the stretching ability of the bitumen is increased due to foaming. Therefore it is beneficial to avoid cracking of flexible pavement due to repeated traffic load and it provides impervious pavement surface.

3) *Softening Point Test*

Table 4: Softening Point Test Result

Parameter	Pure Bitumen	Foam Bitumen
Softening Point(°C)	47	52

Softening point indicates the temperature at which binder possess the same viscosity. Bituminous material do not have a melting point. Rather, the change of state from solid to liquid is gradual over a wide range of temperature. Softening point has a particular significance for materials to be used as joint and crack fillers. Higher softening point ensures that they will not flow during service. Higher the softening point, lesser the temperature susceptibility. Bitumen with higher softening point is preferred in warmer places.

4) *Stripping Test*

Table 5: Stripping Value Test Result

Parameter	Pure Bitumen	Foam Bitumen
Stripping Valve (%)	30	0

Stripping valve shows the adhesion property of bitumen with aggregates which is affected by water susceptibility of bitumen. From the test it can be stated that, after foaming of bitumen there is better adhesion in between bitumen and aggregates, thereby reducing water susceptibility.

B. *Test on Bituminous Concrete –*

Marshall Stability Test was performed for studying the stability (strength) and flow (deflection) of the bituminous concrete.

1) *Combination 1 (Pure Bitumen and Fresh Aggregates) –*

Table 6: Marshall Stability And Flow Results For Combination 1

Sample No.	Stability (KN)	Flow (mm)
1	13.90	4.2
2	13.87	3.36
3	14.21	3.69

2) *Combination 2 (Foam Bitumen and Fresh Aggregates) –*

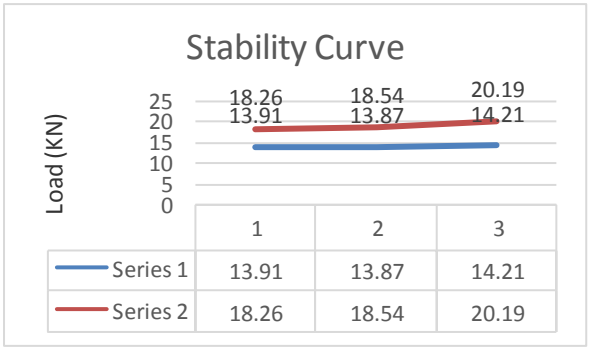
Table 7: Marshall Stability And Flow Results For Combination 2

Sample No.	Stability (KN)	Flow (mm)
1	18.26	3.9
2	18.54	3.6
3	20.19	2.4

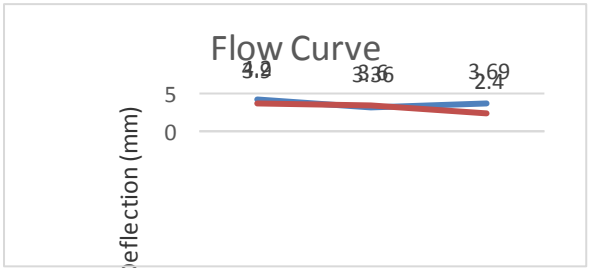
Strength is measured in terms of stability, which is the resistance to the plastic deformation of bituminous concrete. After foaming of the bitumen the mixture becomes stiffer as it can be seen by a decreased penetration value and high softening point, resulting into higher stability values. As the stability of the bituminous concrete increases, its strength increases.

Flexibility is measured in terms of flow value, which is the measure of the deflection of the cylindrical specimen of bituminous concrete. Ideally the flow value should be as minimum as possible. The deflection is an important criteria while judging pavement performance. After foaming of the bitumen as the mixture becomes stiffer, the flow valve decreases indicating more resistance to deflection.

For an ideal sample, the stability value should be higher and the flow value should be lower. Both the values, stability and flow were as required showing a positive result after foaming of the bitumen.



Graph 1: Stability Curve For Combination 1 And Combination 2



Graph 2: Flow Curve For Combination 1 And Combination 2

3) *Combination 3 (Pure Bitumen and Recycled Aggregates) –*

Table 8: Marshall Stability And Flow Results For Combination 3

Sample No.	Stability (KN)	Flow (mm)
1	17.99	4
2	18.32	4.4
3	19.03	4

Stability and flow values were found for bituminous concrete made with pure bitumen and recycled aggregates. Since the aggregates were recycled it previously had certain bitumen content. The recycled aggregates showed higher stability values and lower flow values as compared to Combination 1 (Pure Bitumen and Fresh Aggregates). From the test results it can be stated that, in general use of recycled aggregates is a good option helping to save use of fresh aggregates and reducing the binder content.

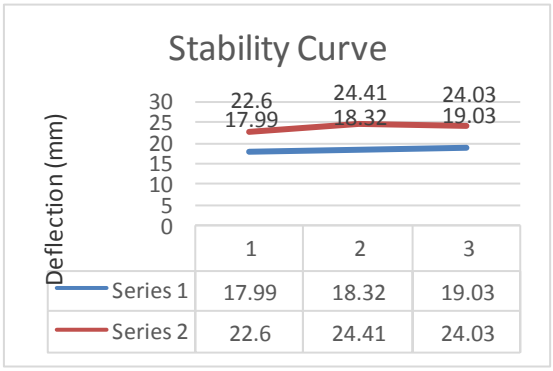
4) *Combination 4 (Foam Bitumen and Recycled Aggregates) –*

Table 9: Marshall Stability And Flow Results For Combination 4

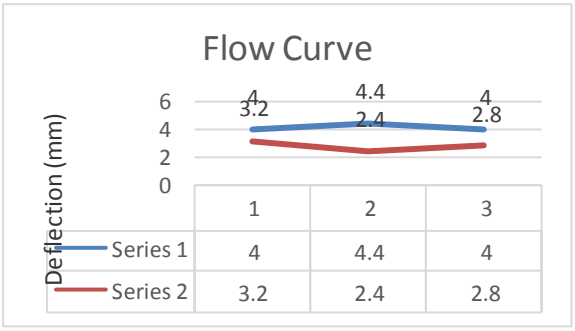
Sample No.	Stability (KN)	Flow (mm)
1	22.6	3.2
2	24.41	2.4
3	24.03	2.8

Stability and flow values were found for bituminous concrete made with foam bitumen and recycled

aggregates. Since the aggregates were recycled it previously had certain bitumen content. The recycled aggregates showed higher stability values and lower flow values as compared to Combination 1 (Pure Bitumen and Fresh Aggregates), Combination 2 (Foam Bitumen and Fresh Aggregates)and Combination 3 (Pure Bitumen and Recycled Aggregates). From the test results it can be stated that, use of foam bitumen along with recycled aggregates gives best result. It is a good option helping to save use of fresh aggregates and reducing the binder content while enhancing the performance depending properties.



Graph 3: Stability Curve For Combination 3 And Combination 4



Graph 4: Flow Curve For Combination 3 And Combination 4

V. CONCLUSIONS

On the basis of the study performed and test results on foamed bitumen, we can conclude the following points,

1. Based upon the laboratory foaming experiment, 2.5% water content was selected as the optimum foaming water content, along with 170ºC 60-70 grade bitumen, to produce the foam bitumen whose expansion ratio was 2.5-3 times that of the original and half-life was around 10 seconds.
2. The addition of foamed bitumen significantly improved the performance of the pavements.
3. From penetration test on foam bitumen, it is found that the penetration value is reduced since foam bitumen has higher stiffness and it gets harder. Due to foaming of bitumen, as the penetration value decreases the consistency increases. In warmer region lower penetration grades are preferred to avoid softening of bitumen.
4. Ductility or the stretching ability of the bitumen is increased due to foaming.
5. Foam bitumen had a higher softening point. It can be successfully used as joint and crack fillers. Higher softening point ensures that they will not flow during service. Bitumen with higher softening point is preferred in warmer places.
6. After foaming of bitumen there is better adhesion in between bitumen and aggregates, thereby reducing water susceptibility.
7. Pavement behaves in a ductile manner and shows good performance even in presence of water.
8. The foamed bituminous concrete showed higher stability (strength) values and lower flow (deflection) values which is very desirable as compared to conventional bituminous concrete.
9. The foamed bituminous concrete made using recycled aggregates showed highest stability values and low flow values as compared to all combinations.
10. Recycled aggregates can be successfully used and foam bitumen can be used as a technique of full depth reclamation (FDR).
11. The technique of foamed bitumen can be successfully used where there is hot climate, road failure due to water susceptibility. It can be used in India since there are similar exposure conditions.

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