

Low-Cost Maintenance of old Existing Indian Highways Using Asphalt Recycling Techniques

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Abstract: In the present study, an experimental attempt has been made to design and produce Bituminous Stabilized Material (BSM) and to use it as a road base material for the strengthening of Dewas- Bhopal 4 lane Road, S.H-18, through cold in-place recycling technique using foamed Bitumen. A complete survey was carried out for structural and functional failures. The results from the field and laboratory investigation indicate that the road is structurally sound but functionally failed in maximum stretches. It was decided to replace the damaged top asphalt layer completely with a bituminous stabilized material (BSM) as an alternative to the DBM course. Various distressed stretches with first-stage failure were selected for milling purposes. Cores were taken from distressed chainages. Reclaimed asphalt pavement (RAP) material was collected using a miller machine from the longest stretch in the job to enable the mix to be designed based on the representative of the site condition. Proper evaluation of the RAP and mix design was undertaken based on the guidelines of Wirtgen Cold Recycling Technology, Technical guidelines for bitumen stabilized materials, TG2 Second revision, May 2009, and IRC- 37: 2012. The blending of aggregate was done as per the specified grading requirement for Bituminous stabilized material (BSM). Under strict laboratory control, all required tests were performed on the Rap material: Atterberg limits, Procter test for MDD and OMC, and Determination of Hygroscopic moisture content. Properties of foamed bitumen and its half-life were found in the lab, Bituminous Stabilized Material was produced with different percentages of foamed bitumen content which varies from 1.5% to 2.5%. By using the suggested guidelines, Bituminous stabilized material (BSM) was tested for Indirect Tensile Strength under wet and dry conditions and BSM was produced with the composition of 82% RAP material, 17% Dust, 1% Cement, Bitumen VG-10, 2%, and 6.53% water for optimum control successfully. The Test results obtained classify the mix as BSM1 which can be used for the heavy traffic in the road base as an alternative option to the Dense bituminous macadam (DBM) layer.

Keywords:

Rehabilitation, reclaimed asphalt technique, Cold in-place Recycling, Bitumen Stabilized material (BSM), Recycled asphalt product (RAP), reconstruction, maintenance, road network, cost-effectiveness, BSM, milling, cold planning.

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1. Introduction

Pavement maintenance using reclaimed asphalt Pavement techniques is a new field of research, that has not yet been explored in India to a great length. The present road maintenance manuals and Codes do not provide any specific norms and guidelines to the agencies responsible for road maintenance work. A rigorous literature review has been made in this regard to explore an additional method of rehabilitation for maintaining a great Indian road network through asphalt recycling techniques and to understand its cost-effectiveness and Reclaimed Asphalt Product (RAP) design philosophy. S.H.18 Dewas -Bhopal Road was selected from the State of Madhya Pradesh for study purposes. The total length of the road is 142.64 Km. The First major rehabilitation and up-gradation work on this road was carried out during the year 2008 on a BOT basis with a maintenance bond of 25 years under the supervision of the Madhya Pradesh Road Development Corporation (MPRDC) and road construction work was completed in 2010. The road was initially designed for 15 years of life. Recently since 2018, the top surface of the road developed various types of first-stage surface failures. It is high time to understand the thin gap which exists between the rehabilitation and reconstruction stage of any old existing road and deferring timely rehabilitation may result in costly reconstruction and loss of National assets constructed at a huge cost. Asphalt recycling provides an additional and economical rehabilitation method for maintaining existing road work. The benefit of reclaimed asphalt pavement (RAP) includes the reuse of nonrenewable natural resources; highly cost-saving in comparison to traditional rehabilitation methodology, helps in the elimination of existing road surface cracks with no disturbance to the existing subgrade and road base, helps in profile correction, energy conservation and improves highway performance.

Objectives of the study

The following are the objectives of the study:

- To check the properties of reclaimed asphalt pavement material (RAP) using foam bitumen through lab analysis.
- To produce an economical mix design for the base/binder course.
- To check the viability of the reuse of reclaimed asphalt pavement material in rehabilitation projects.

2. Data Collection

Under the present study Dewas- Bhopal 4 lane Road, S.H-18 has been selected for study purposes. The Pavement was recommended for major strengthening under the rehabilitation and up-gradation program from two-lane to four-lane. The existing pavement surface composition was found 50 mm Bituminous Concrete (BC) and 120 mm Dense Bituminous Macadam (DBM) laid in two separate layers. Based on the agency's investigation reports, visual inspection, deflection studies, and from the severity of distress (PCI) of the pavement, the Dewas- Bhopal (km 11+000 to 54+365) Bairagadh towards Sehore was found perfect candidate for the use of Cold in-place asphalt recycling technique and it was recommended that the existing bituminous pavement be milled till the depth of the damage and replaced with

suitable material. Various distressed stretches with first-stage failure were selected from chainage 22+000 to 54+300. Visual investigations were carried out which broadly covered the assessment of various functional failures, traffic characteristics, and adjoining land use details. Two cores each taken from chainages km 32.3, 36.3, 45.3, and 53. The visual inspection of the cores was done. The cores revealed top-down cracking which was restricted to the HMA layer. The depth of the cracks varies from 60 mm to 120 mm from the top. RAP material was collected using a miller machine from the longest stretch in the job to enable the mix to be designed based on the representative of the site condition. The exact location of stretches for milling at the site is reproduced below along with photographs showing typical distresses of some locations.

2.1 Location of stretches identified for milling on SH-18 Dewas- Bhopal road

Various distressed stretches with first-stage failure were selected from chainage 22+000 to 54+300. Table 1 Shows the Location of stretches identified for milling on SH-18 Dewas-Bhopal Road

Table 1. Location of stretches identified for milling on SH-18 Dewas- Bhopal Road

LHS			RHS		
From	To	Length	From	To	Length
22970	23430	460	24000	23590	410
23740	23940	200	23390	23000	390
24400	24850	450	25400	25650	250
25050	25250	200	28000	28200	200
26200	26400	200	32350	33425	1075
28100	28350	250	34000	34250	250
29050	30200	1150	36650	36975	325
31550	32500	950	38100	38600	500
33000	33370	370	39300	39800	500
33900	34100	200	40480	40950	470
36300	37500	1200	42700	43250	500
37950	38200	250	45300	46300	1000
38400	38600	200	46650	47200	550
40450	40650	200	50100	50350	250
42950	43150	200	52350	52850	500
47950	48200	250	53360	53850	490
49800	50150	350			
50750	50950	200			
52400	53000	600			
53670	54180	510			

2.2 Pictures of various surface failures of SH-18 Dewas- Bhopal Road

A functional evaluation survey of selected pavement sections was done through digital photography. Photographs were taken for all defective and damaged portions showing various types of surface failures: cracking, potholes, patches, rutting, and spalling. Fig .1 shows rutting and cracking along the wheel path at Km 53.00. Fig 2 shows Alligator map cracking at Km 45.30. Fig. 3 shows a severe map and block cracking at Km 32.350. Fig. 4 shows longitudinal cracks at Km 36. Fig. 5 shows core cutting is in progress in Km 32.350. Fig.6 shows the core from Km 45.300 and Km 32.350 of Dewas- Bhopal Road, S.H.18.



Figure 1: Rutting and cracking along wheel path at Km 53.00 Dewas-Bhopal road, S.H.18



Figure 2: Alligator map cracking at Km 45.30 Dewas-Bhopal road, S.H.18



Figure 3: Severe map and block cracking at Km 32.350 Dewas-Bhopal road, S.H.18



Figure 4: Longitudinal cracks at Km 36 Dewas- Bhopal road, S.H.18



Figure 5: Core cutting in progress Km 32.350 Dewas-Bhopal road, S.H. 18



Figure 6: Core from Km 45.300 and Km32.350 Dewas-Bhopal road, S.H.18

2.3 Sample collection of RAP material

RAP material was collected using milling machines from the longest homogeneous stretch in the job with uniform pavement composition as per the guideline suggested in TG2 to enable the mix to be designed based on the material representative of the site conditions. Table 2

shows the location from which RAP material was collected for the BSM mix design. Fig.7 and 8 show RAP samples collected from various chainages of Bhopal-Dewas Road S.H. 18.

Table 2: RAP material collected from various sections of Bhopal-Dewas Road S.H. 18.

Chainage	Side	Qty (kg)
32.350	RHS	200
36.300	LHS	200
45.300	RHS	200
53.000	LHS	200



Figure 7: RAP sample collected from Bhopal-Dewas Road S.H. 18.



Figure 8: RAP sample collected from Bhopal-Dewas Road S.H. 18.

3. Methodology and Analysis of Data

Complete lab investigation was done on RAP material in accordance with guidelines of Wirtgen Cold Recycling Technology, TG2 Second revision, May 2009 and IRC- 37: 2012 to produce the required BSM mix as a base material for Chennai-Tada road: that is wet sieve

analysis to determine the grading for RAP material (ASTMD422), Atterberg's limits to determine the plasticity index (ASTMD4318), Moisture density relationship (AASHTO-T180), Modified Proctor test for determination of MDD and OMC for blended material, Hygroscopic moisture content test was conducted for the blended material (ASTMD 2216) to know the existing moisture content present in the material and subtract it from OMC at the time of adding water to the mix. In order to obtain optimum binder content for the BSM mix the foaming characteristic of Bitumen was examined by making 100mm diameter samples which were cured and tested for Indirect Tensile Strength (ITS) for dry and wet conditions. Active filler (Cement) was added to the mix to enhance the dispersion of the bitumen.

3.1 Sieve analysis

The wet sieve analysis was done for the RAP material collected from chainages km 32.350, 36.300, 45.300, 53.000. Results are plotted with the specified grading limits for BSM as prescribed. The curves indicate that the gradation of the four material samples is homogeneous and hence a common mix design using any of the material samples can be followed for the complete job. The RAP extracted from km 36.3 has been utilized for laboratory testing conducted. The gradation lacks the minimum requirement of 4% material passing 0.075mm sieve and hence fresh aggregates in the form of material passing 4.75mm (hereinafter referred to as Crusher Dust) need to be added with the sample to achieve the required gradation both for laboratory testing and job execution in the field. Wet sieve analysis of Crusher dust and dry sieve analysis of cement was carried out. A blend of 80% RAP material, 19% Crusher Dust and 1% Filler (OPC 53 Grade) met the grading requirements for Bitumen Stabilized Material. Table 3 shows a wet sieve analysis of RAP material. Fig.9 shows the Gradation curve of RAP samples collected from Bhopal Dewas Road S.H-18. Table 4 shows the combined grading of blended material. Fig.10 shows the gradation curve for blended Material.

Table 3: Wet Sieve Analysis of RAP material

Grading of RAP material (% cumulative passing)				
Seive size(mm)	KM32.50	KM36.3	KM45.3	KM53
50.000	100.00	100.00	100.00	100.00
37.500	100.00	100.00	100.00	100.00
26.500	100.00	100.00	100.00	100.00
19.000	98.44	98.06	98.49	99.45
13.200	87.53	88.51	87.65	94.93
9.600	77.35	78.89	75.71	88.40
6.700	65.04	62.44	61.25	73.18
4.750	56.21	50.66	48.51	59.82
2.360	35.90	31.20	32.35	37.57
1.180	25.09	18.32	19.85	22.80

0.600	16.21	10.89	10.56	10.95
0.425	6.70	4.72	8.41	7.94
0.300	5.92	3.72	6.10	5.37
0.150	4.16	1.94	4.14	2.96
0.075	3.43	1.56	2.48	1.05

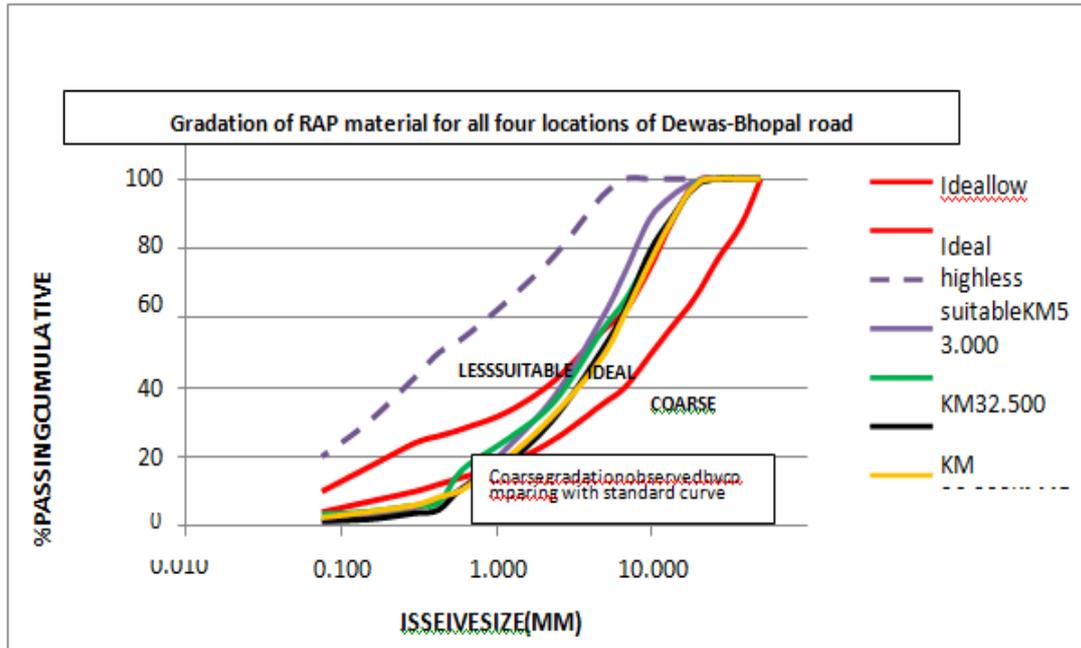


Figure 9: Gradation curve of RAP samples collected from Dewas-Bhopal Road

Table 4: Combine grading of Blended Material

Cold Mix Blending										
ISSIEVE (mm)	Passing To Retained			Percentage for blending			Total % of Passing	MIDLIMIT		
				RAP	C/Dust	Cement				
	80%	19%	01%	Lower Limit	Upper Limit					
50.00	100.00	00.00	100.00	0.00	19.00	1.00	100.00	100.00	100	100
37.50	100.00	00.00	100.00	0.00	19.00	1.00	100.00	93.50	87	100
26.50	100.00	00.00	100.00	0.00	19.00	1.00	100.00	88.50	77	100

19.00	98.06	00.00	100.00	3.45	19.00	1.00	98.45	82.50	66	99
13.20	88.51	00.00	100.00	0.80	19.00	1.00	90.80	72.00	57	87
9.50	78.89	00.00	100.00	3.11	19.00	1.00	83.11	61.50	49	74
6.70	62.44	00.00	100.00	9.95	19.00	1.00	69.95	51.00	40	62
4.75	50.66	01.56	100.00	0.53	17.40	1.00	58.93	45.50	35	56
2.36	31.20	04.78	100.00	4.96	14.21	1.00	40.17	33.50	25	42
1.18	18.32	00.21	100.00	4.66	11.44	1.00	27.10	25.50	18	33
0.600	10.89	05.93	100.00	72	8.73	1.00	18.44	21.00	14	28
0.425	4.72	00.65	100.00	77	7.72	1.00	12.50	19.00	12	26
0.300	3.72	05.00	100.00	98	6.65	1.00	10.63	17.00	10	24
0.150	1.94	04.64	98.95	55	4.68	0.99	7.22	12.00	7	17
0.075	1.56	03.33	91.96	25	2.53	0.92	4.70	7.00	4	10

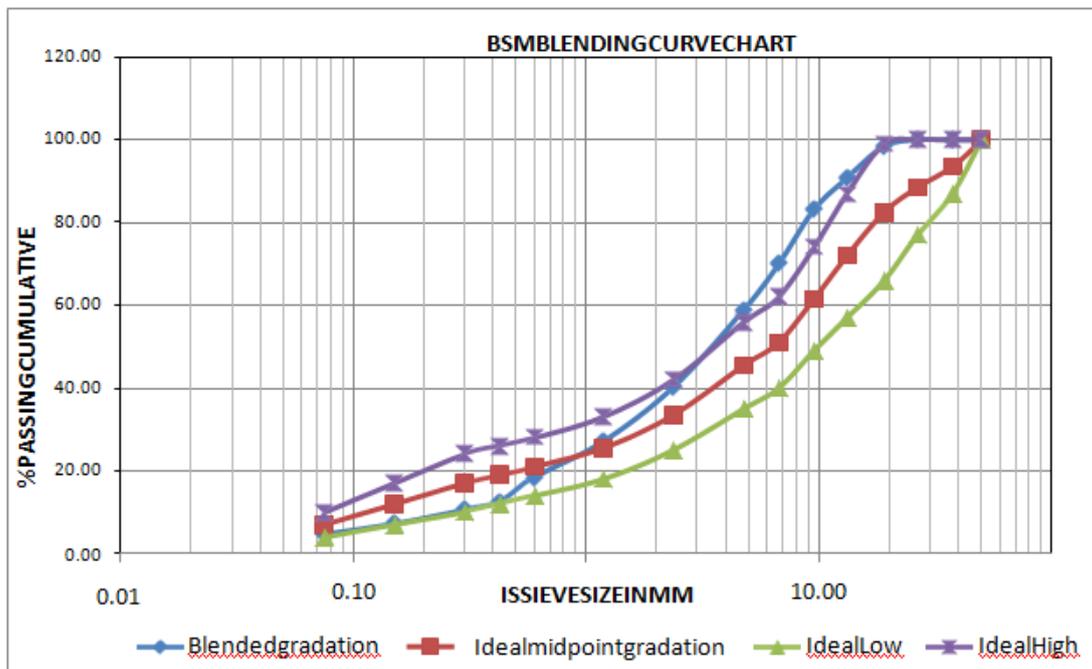


Figure 10: Gradation curve for blended Material curve

3.2 Atterberg limits

Atterberg limit test was conducted on fines passing 0.425 mm sieve for the blended material (RAP + Crusher Dust). The material was found to be nonplastic. This implies that no pre-

treatment of the material with lime is required. If the Plasticity Index (PI) of the material is greater than 10, then 1% lime should be added to reduce the plasticity of the material.

3.3 Moisture density relationship

The Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of the untreated blended material (RAP + Crusher Dust) were determined by establishing the moisture density relationship of the material when prepared and compacted with modified AASHTO compaction procedure at different moisture contents. The OMC and MDD were found to be 6.53% and 2092 kg/m³. These values were used for the maximum compaction of the specimens in the mix design stage. Table 5 shows the result of the modified proctor test for the determination of OMC and MDD of blended material. Fig.11 shows a plot of moisture content Vs dry density for determination of OMC & MDD

Table 5. Result of Modified Proctor test for determination of OMC & MDD of blended material

Modified Proctor Test of Blended Material								
MouldNo.1		DateSampled	24-08-2018					
Location/Source:SH -18 Bhopal-Dewas Road		Sampledby	PWD lab					
Typeof material:RAP&Crusher dustblend		DateTested	24-08-2018					
Wt.ofsample :6000Gram		Test edat	Pwd Site lab					
VolumeofMould(cm3):	2250							
Sr.No.	Description	Observation						
		1	2	3	4	5	6	7
1	Wt.of Mould(gm)	7128	7128	7128	7128	7128	7128	7128
2	Wt.of Mould+Compacted Soil(gm)	11850	11946	12080	12142	12180	12206	11972
3	Wt.ofCompactedSoil(gm)	4722	4818	4952	5014	5052	5078	4844
4	WetDensitygm/cc	2.099	2.141	2.201	2.228	2.245	2.257	2.153
5	ContainerNo.	1	2	3	4	5	6	7
6	Wt.ofContainer(gm)	136	136	140	164	132	134	144
7	Wt.ofwetSoil+Container (gm)	720.00	750.00	506.00	718.00	782.00	982.00	966.00

Table 6: Representative proportioning of blended material

Sieve analysis		Quantity of material to be included for every 10K g of sample		
Sieve size (mm)	Percentage passing (from sieve analysis on blended sample)	Passing 4.75mm	Passing 13.2mm and retained on 4.75mm	Passing 19mm and retained on 13.2mm
19.0	98.43	58.12/100 x 10000=5812gm	((90.69-58.12)/100 x 10000)=3257gm	((100-90.69)/100 x 10000)=931gm
13.2	90.69			
4.75	58.12			

3.4.2 Hygroscopic moisture Content

The hygroscopic moisture Content of the blended aggregate was determined as per ASTM D 2216. One kg blended sample was taken and oven dried for 24 hrs at 105- 110°C till constant mass was achieved and the dry mass compared with the initial mass to determine the hygroscopic water content. This test was repeated before mixing each time for different bitumen content. The hygroscopic moisture content was found to be in the range of 0.18-0.2%. This test is carried out to know the existing moisture content present in the material and subtract it from OMC at the time of adding water to the mix.

3.4.3 Filler

Active filler (Cement 1%) is added to the mix to enhance the dispersion of the bitumen. The RAP has been found to be non-plastic with a PI of the material less than 10; hence 1% OPC 53 grade has been added as per the recommended procedure. A maximum of 1% of cement should be added as an addition in excess of more than 1% will make the mix stiff and it will lose its flexibility.

3.4.4 Determination of foaming characteristics of Bitumen

Bitumen VG 10, the grade was tested due to its superior foaming properties. Experiments to obtain the largest expansion ratio and longest half-life of the bitumen yielded an optimum value of 6% water content at 180 degrees Celsius which has been used for laboratory foam production. An expansion ratio of 15 and a half-life of 15 seconds have been obtained against a minimum requirement of 8 and 6 seconds. After the preparation of representative samples and determination of hygroscopic moisture content, percentage of active filler to be added and selection of the binder for foaming, the sample is prepared with different foaming binder content for fabrication of 100 mm diameter specimen.

3.4.5 Test Results

All prepared specimens were cured and tested for Indirect Tensile Strength (ITS) for the dry and wet conditions in order to ascertain the optimum foaming bitumen content. The procedure followed for sample preparation, fabrication of 100 mm diameter specimen, curing procedure, and determination of bulk density and indirect tensile strength (ITS) in order to ascertain the optimum foaming bitumen content. BSM design was produced with an optimum binder content of 2% obtained from the graph, with foaming water content of 6% at 180C, active filler cement OPC 53 grade 1%, 19% addition of crusher dust and OMC, and MDD of 6.53% and 2092kg/m³. Table 7 shows a combined summary of specimens with different foaming binder content AND ITS results for Dry and wet Conditions. Fig 12 shows % of foamed bitumen Vs ITS dry and wet conditions.

Table 7: Foamed Bitumen stabilized specimen test results with different foaming binder content

FOAMED BITUMEN MIX DESIGN (Dry Curing)					
Project	SH-18 Dewas- Bhopal Road				
Sample/Mix No	1				
Material Description	RAP & Crusher Dust		Optimum moisture content	6.53%	
Maximum Dry Density	2.09		Grading:	Mediu	Fine
Percentage <0.075mm	4.7				
Plasticity Index	Non Plastic Material				
Bitumen Source	IOCL		Bitumen Type	VG ₁₀	
Active Filler Type	Cement 1%		Filler Source	OPC 53	
FOAMED BITUMEN STABILISED MATERIAL SPECIMENS					
Comapctive Effort	Marshall			100mm Diameter	
Foamed Bitumen Mix Design with		1.5%	2%	2.5%	
Foamed Bitumen Added	(%)	1.5	2	2.5	
Active Filler Added	(%)	1	1	1	
Moulding Moisture Content	(%)	4.93	5.1	5.25	

ITS DRY	(KPA)	256.15	265.44	200.904	
Moisture Content at break	(%)	0.82	0.88	0.95	
Dry Density	(Kg/m ³)	2083	2054	2048	
Average Deformation	(mm)	-	-	-	
Temperature at break	(°C)	25	25	26	
		1.5	2	2.5	
ITS_{WET}	(KPA)	204.91	212.32	170.22	
Moisture Content at break	(%)	6.1	5.03	4.13	
Dry Density	(Kg/m ³)	2101	2057	2054	
Average Deformation	(mm)	-	-	-	
Temperature at break	(°C)	25	25	25	
Tensile Strength Retained	(%)	80	80	85	
Material Classification		BSM-1	BSM-1	BSM-1	

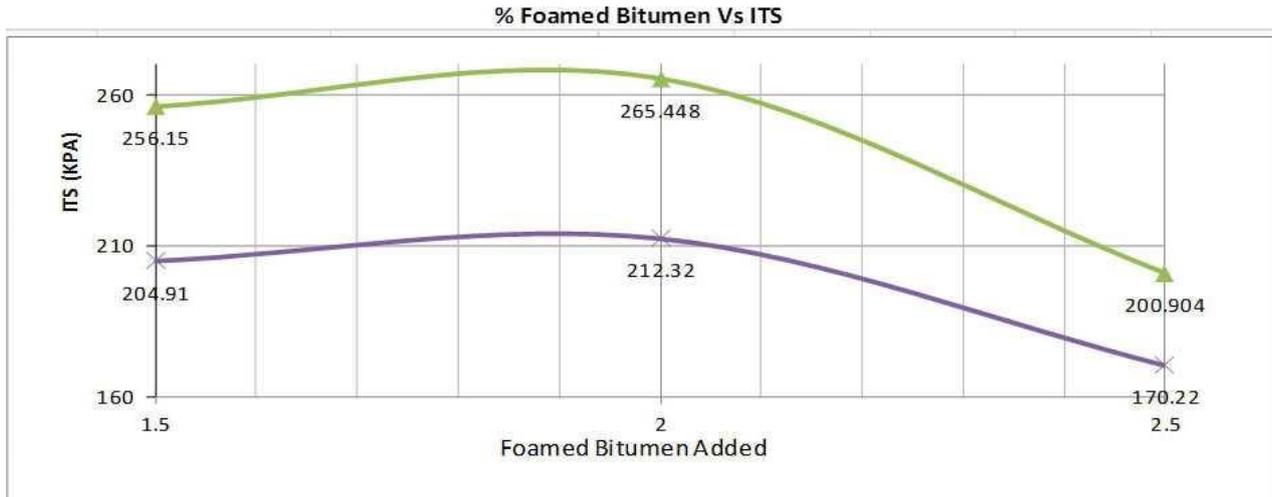


Figure 12: Percentage of Foamed Bitumen Vs Indirect Tensile strength for Dry and wet condition

4. Conclusions

- Lab analysis indicates that average value of ITS dry for 1.5% and 2.0% foamed bitumen content was 255.79 kPa and 265.45 kPa respectively which is well above the minimum recommended value as per TG2 and IRC 37:2012 (draft) of 225 kPa for BSM 1 class material used for heavily trafficked roads. The ITS wet value at foamed bitumen content of 1.5%, 2.0% and 2.5% was 204.06 KPa, 212.32 KPa and 170.22 KPa which are well above 100 KPa as recommended by IRC 377:2012 and TG 2. TSR (Tensile strength ratio) at foamed bitumen content of 1.5%, 2.0%, and 2.5% was 80%, 80%, and 85% respectively which indicates good moisture resistance properties of the mix.
- The test result obtained for Bitumen stabilized material by conducting the above experiments classifies the mix as BSM1 which can be used for the heavily trafficked road as an alternative to base binder course.
- The Result shows that pavement can be successfully rehabilitated using cold in-place recycling with foamed bitumen as per the design mix produced and it can be used as an economical and additional method for the rehabilitation and strengthening of existing Indian Highways.

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