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Research Article

Preservation of Indian National Highways Using Asphalt Recycling Techniques

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ABSTRACT

Pavement preservation using reclaimed asphalting techniques is a new field of research which has not yet been explored in India to a great length and valid guidelines and specification are still not established with available road maintenance norms. A rigorous literature review has been made in this regards 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 mix design philosophy. In the present study an attempt has been made to strengthening Chennai-Tada Road, N.H-5, by milling of the damaged bituminous layer through cold planning and cold in- place recycling technique using foamed Bitumen in chainage from 22+000 to 54+300. Various distressed stretches with first stage failure were selected. Cores were taken from distressed chainages. Reclaimed asphalt pavement (RAP) material was collected using miller machine from the longest stretch in the job to enable the mix to be designed based on 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 guideline for bitumen stabilized materials, TG2 Second revision, May 2009 and IRC- 37: 2012. 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 specimen prepared with Rap material for the road base, with different percentage of foamed bitumen content which varies from 1.5% to 2.5%. Using suggested guidelines, Bituminous stabilized material (BSM) was successfully produced with composition of 82% RAP material, 17% Dust, 1% Cement, Bitumen VG-10, 2% and 6.53% water for optimum control. The Test results obtained classifies the mix as BSM1which can be used for the heavily traffic in the road base as an alternative option to Dense bituminous macadam (DBM) layer.

KEYWORDS : Rehabilitation, Reclaimed asphalting technique, Cold in-place Recycling, Bitumen Stabilized material, RAP, reconstruction, maintenance, road network, cost effectiveness, BSM, milling, cold planning .

Introduction

It is high time to understand the thin gap which exists between 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 huge cost. The survey indicates this as a topic of great interest. Under 12th plan, the Government of India has decided to rehabilitate and upgrade, 15000 Km road length to multi lane standard. Under scarce funds availability for maintenance of existing road network of India the timely action for rehabilitation with economical approach is a need of the time. It is highly important to recognize asphalt recycling technique as a power full and cost-effective tool for rehabilitation of Indian road network in the present time specially when increasing of road network is in high demand due to population growth and economic development. Asphalt recycling provides an additional and economical rehabilitation method for maintaining existing road work. The benefit of reclaimed asphalt pavement (RAP) includes reuse of non renewable natural recourses; highly cost saving in comparison to traditional rehabilitation methodology, helps in elimination of existing road surface cracks with no disturbance to the existing sub grade and road base, helps in profile correction, energy conservation and improves highway performance. USA and Japan are among the top countries that are presently recycling the asphalting material. There are major five categories classified by Asphalt Recycling and Reclaiming Association (ARRA) to describe the various methods of asphalt recycling: Cold planning (CP), Hot recycling, Hot in place recycling (HIR), Cold Recycling, Full depth reclamation (FDR). Under Wirtgen Cold Recycling Technology guidelines for strengthening of existing old roads, an upper portion of an existing roadway has to be removed via cold planning (CP) and the resultant Reclaimed Asphalt Pavement (RAP) has to be stockpiled at the asphalt plant. The cold planed surface has to be prepared and overlaying is to be done with hot mix asphalt (HMA) containing the RAP from the milled off layer which results in low construction cost in comparison to surface mixes when used with virgin asphalt and aggregate. The philosophy of asphalt recycling should be recognized for various rehabilitation and reconstruction programs especially surface renewal programs provided to Indian National Highways to achieve low maintenance and construction cost .

Objectives of the study

Following are the objectives of the study:

To check the properties of reclaimed asphalting pavement material (RAP) using foam bitumen through lab analysis.

To produce an economical design for Bituminous stabilized material (BSM) for base/binder course.

To check the viability of reuse of reclaimed asphalting pavement material in rehabilitation projects.

Data Collection

Under present study Chennai-Tada Road, N.H-5 has been selected for study purpose. The Pavement was recommended for major strengthening under rehabilitation and up-gradation program from four lane to six lane. The existing pavement surface composition was found 40 mm Bituminous Concrete (BC) and 160 mm Dense Bituminous Macadam (DBM) laid in two layers of 80 mm each. Based on agency's investigation reports, visual inspection, deflection studies and from severity of distress (PCI) of the pavement, the Chennai Tada road (km 11+000 to 54+365) was found perfect candidate for the use of Cold in-place asphalt recycling technique and it was recommended that the existing bituminous pavement to be milled till the depth of 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 structural and functional failure, traffic characteristics and adjoin land use details. Two cores each taken from chainages km 32.3, 36.3, 45.3, and 53.The visual inspection of the cores were done. The cores revealed top down cracking which was restricted to the HMA layer. The depth of the cracks varies from 60 mm to 200 mm from top. RAP material was collected using miller machine from the longest stretch in the job to enable the mix to be designed based on representative of the site condition. Exact location of stretches for milling at site is reproduced below along with photographs showing typical distresses of some locations.

3.1 Location of stretches identified for milling on NH-5 Chennai-Tada road

Various distressed stretches with first stage failure were selected from chainage 22+000 to 54+300. Table1 Shows Location of stretches identified for milling on NH-5 Chennai-Tada road.

Table 1. Location of stretches identified for milling on NH-5 Chennai-Tada 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			

3.2 Pictures of various surface failures of Chennai-Tada road N.H.

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, pot holes, patches, rutting, spalling. Fig .1 shows rutting and cracking along wheel path at Km 53.00. Fig 2 shows Alligator map cracking at Km 45.30. Fig. 3 shows 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 core from Km 45.300 and Km 32.350 of Chennai-Tada road, N.H.5

Fig. 1 rutting and cracking along wheel path at Km 53.00 Chennai-Tada road, N.H.5

Fig. 2 Alligator map cracking at Km 45.30 Chennai-Tada road, N.H.5

Fig. 3 Severe map and block cracking at Km 32.350 Chennai-Tada road, N.H.5

Fig. 4 Longitudinal cracks at Km 36 Chennai-Tada road, N.H.5

Fig. 5 Core cutting in progress Km 32.350 Chennai-Tada road, N.H.5

Fig. 6 Core from Km 45.300 32.350 Chennai-Tada road, N.H.5

3.3 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 guide line suggested in TG2 to enable the mix to be designed based on material representative of the site conditions. Table 2 shows location from which RAP material was collected for BSM mix design. Fig.8 and 9 show RAP sample collected from various chainages of Chennai –Tada road NH-5.

Table 2. RAP material collected from various Chainages Chennai –Tada road NH-5

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

Fig.7 RAP sample collected from Chennai –Tada road NH-5

Fig.8 RAP sample collected from Chennai –Tada road NH-5

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 required BSM mix as a base material for Chennai-Tada road: that is wet sieve analysis to determine the grading for RAP material (ASTM D422), 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 obtained 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 condition. Active filler (Cement) was added to the mix to enhance the dispersion of the bitumen.

4.1 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) needs 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 wet sieve analysis of RAP material. Fig.10 shows Gradation curve of RAP samples collected from Chennai-Tada Road. Table 4 Shows combine grading of blended material.Fig.11 shows gradation curve for blended Material.

Table 3. Wet Sieve Analysis of RAP material

Grading of RAP material (% cumulative passing)				
Seive size (mm)	KM 32.50	KM 36.3	KM 45.3	KM 53
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

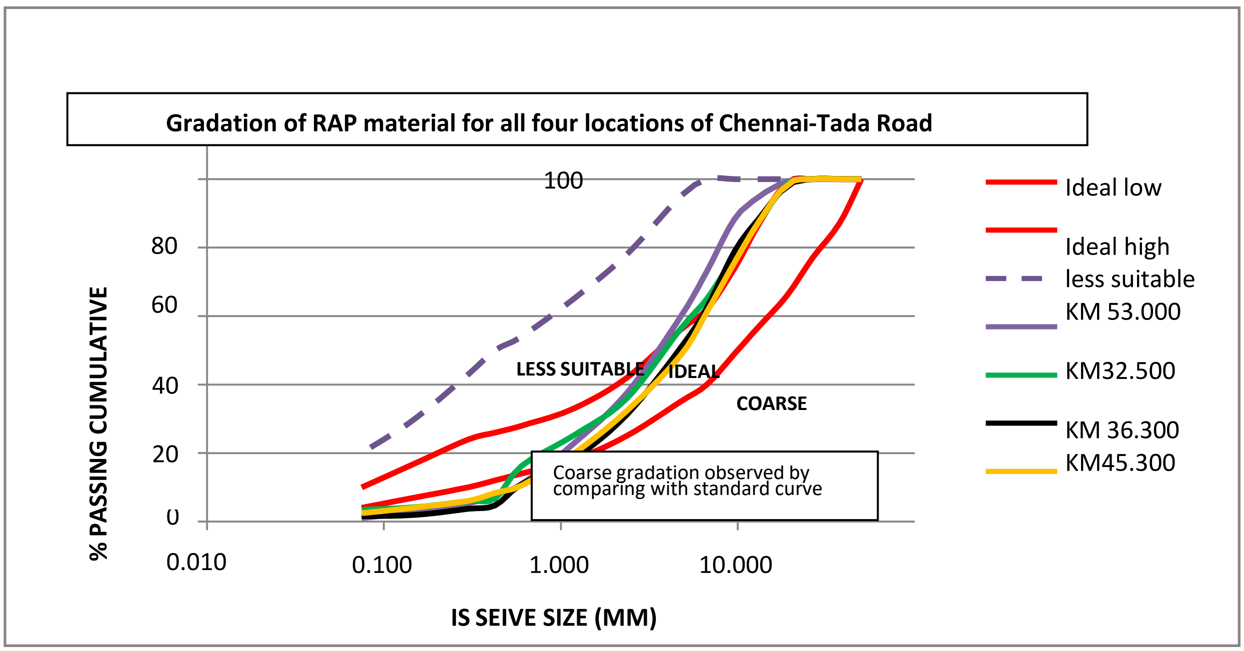


Fig.9 Gradation curve of RAP samples collected from Chennai-Tada Road

Table 4. Combine grading of Blended Material

Cold Mix BLENDING										
IS SIEVE (mm)	**Passing To Retained**			**Percentage for blending**			**Total % of Passing**	**MID LIMIT**		
				RAP	**C /Dust**	**Cement**				
	RAP	**C /Dust**	**Cement**	**80%**	**19%**	**01%**			**Lower Limit**	**Upper limit**
50.00	100.00	100.00	100.00	80.00	19.00	1.00	**100.00**	100.00	100	100
37.50	100.00	100.00	100.00	80.00	19.00	1.00	**100.00**	93.50	87	100
26.50	100.00	100.00	100.00	80.00	19.00	1.00	**100.00**	88.50	77	100
19.00	98.06	100.00	100.00	78.45	19.00	1.00	**98.45**	82.50	66	99
13.20	88.51	100.00	100.00	70.80	19.00	1.00	**90.80**	72.00	57	87
9.50	78.89	100.00	100.00	63.11	19.00	1.00	**83.11**	61.50	49	74
6.70	62.44	100.00	100.00	49.95	19.00	1.00	**69.95**	51.00	40	62
4.75	50.66	91.56	100.00	40.53	17.40	1.00	**58.93**	45.50	35	56
2.36	31.20	74.78	100.00	24.96	14.21	1.00	**40.17**	33.50	25	42
1.18	18.32	60.21	100.00	14.66	11.44	1.00	**27.10**	25.50	18	33
0.600	10.89	45.93	100.00	8.72	8.73	1.00	**18.44**	21.00	14	28
0.425	4.72	40.65	100.00	3.77	7.72	1.00	**12.50**	19.00	12	26
0.300	3.72	35.00	100.00	2.98	6.65	1.00	**10.63**	17.00	10	24
0.150	1.94	24.64	98.95	1.55	4.68	0.99	**7.22**	12.00	7	17
0.075	1.56	13.33	91.96	1.25	2.53	0.92	**4.70**	7.00	4	10

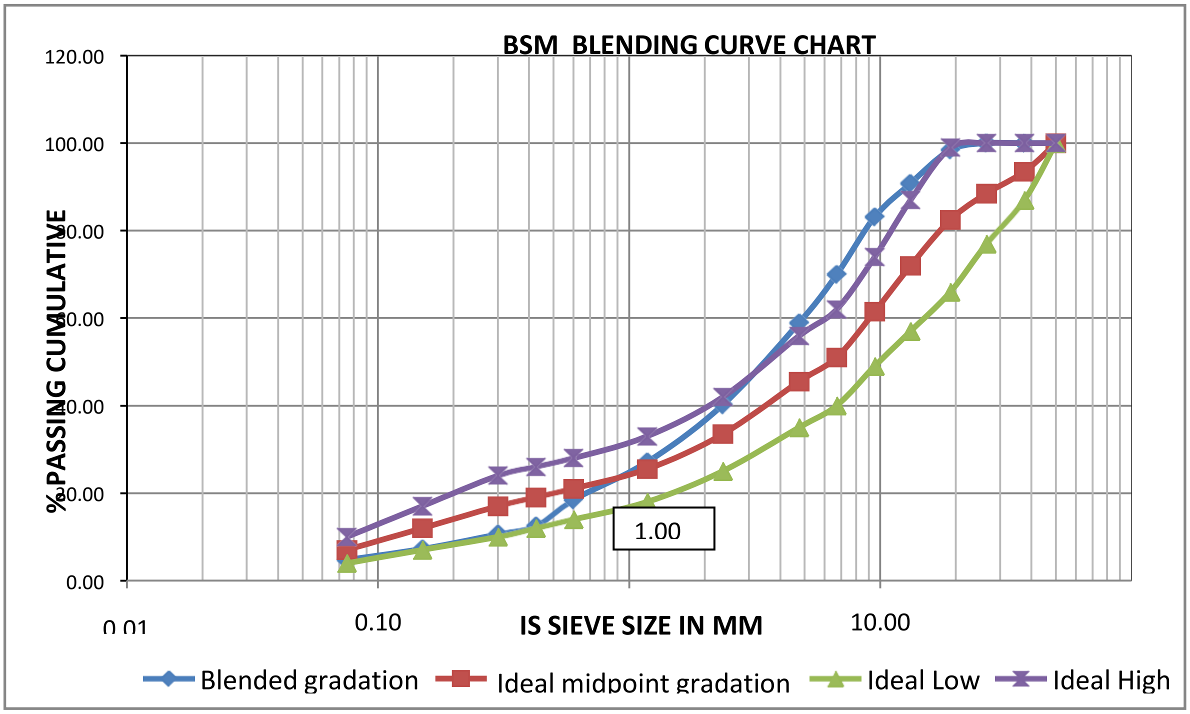


Fig.10 Gradation curve for blended Material curve

4.2 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 non plastic. 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.

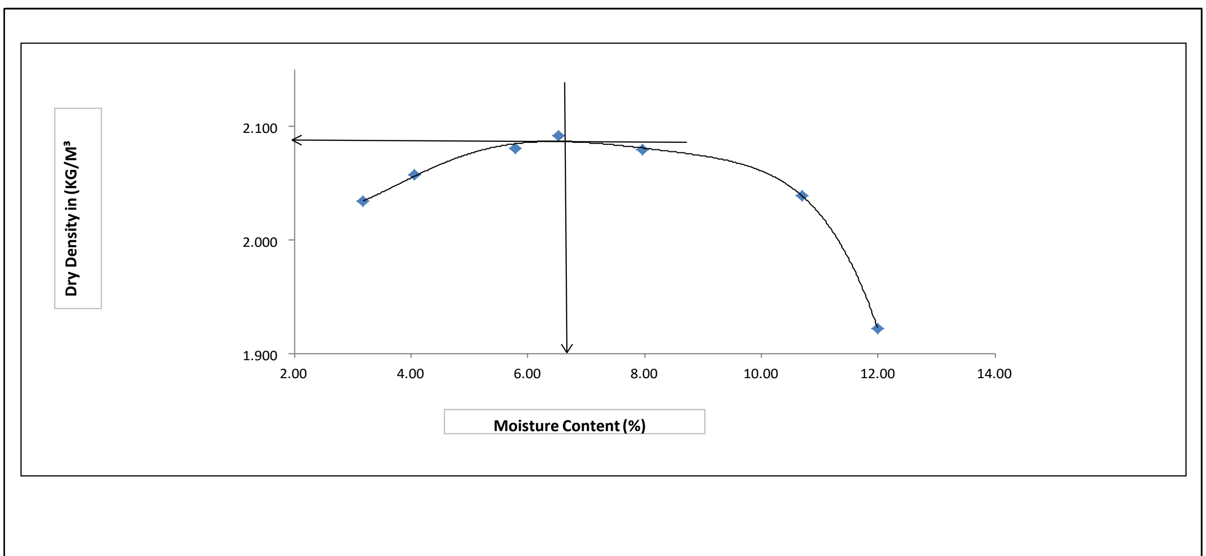
4.3 Moisture density relationship

The Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of the untreated blended material (RAP + Crusher Dust) was 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 maximum compaction of the specimens in the mix design stage. Table 5 shows Result of modified proctor test for determination of OMC and MDD of blended material. Fig.12 shows 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 Procter Test of Blended Material			
Mould No. 1	Date Sampled	24-08-2012	
Location / Source : NH-5 Chennai-Tada Road	Sampled by	L&T IDPL	
Type of material : RAP & Crusher dust blend	Date Tested	24-08-2012	

Wt. of sample	: 6000 Gram		Tested at		Pavement Lab, IIT Madras			
Volume of Mould (cm^3) :	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. of Compacted Soil (gm)	4722	4818	4952	5014	5052	5078	4844
4	Wet Density gm/cc	2.099	2.141	2.201	2.228	2.245	2.257	2.153
5	Container No.	1	2	3	4	5	6	7
6	Wt.of Container (gm)	136	136	140	164	132	134	144
7	Wt. of wet Soil + Container (gm)	720.00	750.00	506.00	718.00	782.00	982.00	966.00
8	Wt. of dry Soil +Container (gm)	702.00	726.00	486.00	684.00	734.00	900.00	878.00
9	wt of Dry Soil (gm)	566.00	590.00	346.00	520.00	602.00	766.00	734.00
10	Wt. of Water (gm)	18.00	24.00	20.00	34.00	48.00	82.00	88.00
11	Moisture Content (%)	3.18	4.07	5.78	6.54	7.97	10.70	11.99
12	Dry Density (gm/cc)	2.034	2.058	2.081	2.092	2.080	2.039	1.922



Max Dry Density :	2.092 gm/cc	OMC :	6.53 %

Fig.11 Plot of moisture content Vs dry density for determination of OMC & MDD

4.4 Laboratory studies for foamed Bitumen mix design

4.4.1 Representative proportioning

The sample of blended material (RAP+ Crusher dust) from Km 36 was separated into the four fractions: retained on 19 mm sieve, passes the 19.0mm sieve and retained on the 13.2mm sieve. Passing 13.2mm and retained on 4.75mm and passing from 4.75mm. The sample was reconstituted for the portion passing the 19.0mm sieve in accordance with the grading determined above (for the blended sample). The percentage portion material retained on 19.0mm sieve was discarded but substituted by the same percentage to the material that passes the 19.0mm sieve and retained on the 13.2mm sieve. The processed is reproduced below. The material obtained from the representative proportioning was used for preparation of 100 mm specimens for ITS (Indirect Tensile Strength) dry and wet testing. Table 6 shows representative proportioning of blended material.

Table 6.Representative proportioning of blended material

Sieve analysis		Quantity of material to be included for every 10 Kg of sample		
Sieve size (mm)	Percentage passing (from sieveanalysis on blended sample)	Passing 4.75 mm	Passing 13.2 mm and retained on 4.75mm	Passing 19 mm and retained on 13.2 mm
19.0	98.43	58.12/100 x 10000=5812 gm	((90.69-58.12)/100 x 10000)=3257 gm	((100-90.69)/100 x10000)=931 gm
13.2	90.69			
4.75	58.12			

4.4.2 Hygroscopic moisture Content

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.

4.4.3 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 PI of the material less than 10; hence 1% OPC 53 grade has been added as per recommended procedure. Maximum 1% of cement should be added as addition in excess of more than 1% will make the mix stiff and it will lose its flexibility.

4.4.4 Determination of foaming characteristics of Bitumen

Bitumen VG 10, 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 have been used for the laboratory foam production. An expansion ratio of 15 and 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.

4.4.5 Test Results

All prepared specimen were cured and tested for Indirect Tensile Strength (ITS) for dry and wet condition in order to ascertain the optimum foaming bitumen content. The procedure followed for sample preparation, fabrication of 100 mm diameter specimen, curing procedure, determination of bulk density and indirect tensile strength (ITS) in order to ascertain the optimum foaming bitumen content. BSM design was produced with optimum binder content of 2% obtained from graph, with foment 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. Table7 shows combine summary of specimens with different foaming binder content. Table 8 shows ITS results for Dry and wet Condition. Fig 13 shows % of foamed bitumen Vs ITS dry and wet condition.

Table7. Foamed Bitumen stabilized specimen test results with different foaming binder content

FOAMED BITUMEN MIX DESIGN (Dry Curing)				
Project	NH-5Chennai-Tada Road			
Sample/Mix No	1			
Material Description	RAP & Crusher Dust	**Optimum moisture content**		6.53%
Maximum Dry Density	2.09	**Grading:**	**Medium**	**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	

Table 8 ITS result for dry and wet condition

ITS DRY	**(KPA)**	256.15	265.448	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**	
ITSWET	**(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	

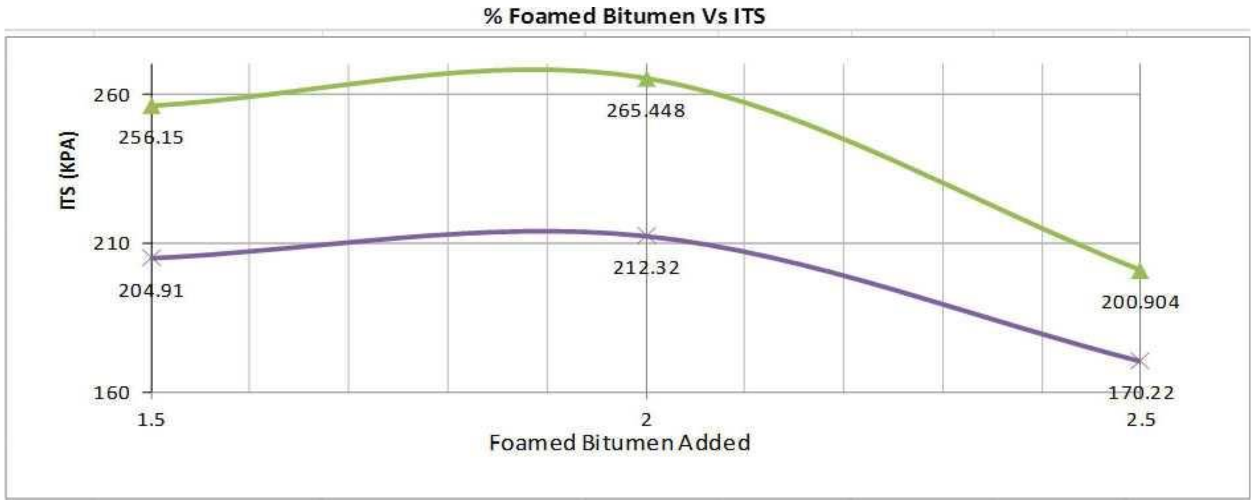


Fig 12 percentage of Foamed Bitumen Vs Indirect Tensile strength for Dry and wet condition

Conclusions

Lab analysis indicates that average value of ITS dry for 1.5% and 2.0% foamed bitumen content was255.79 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 property of the mix.

The test result obtained for Bitumen stabilized material by conducting above experiments classifies the mix as BSM 1 which can be used for 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 rehabilitation and strengthening of existing Indian National Highways.

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