Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, July, 2021: 7769-7783

Research Article

Rehabilitation of Existing Indian National Highways with Cold in-place Recycling Technique using Foamed Bitumen "A Cost-Effective Tool."

Naveen Shankar[1], Dr. Basant Kumar[2]

ABSTRACT

Timely rehabilitation of existing old BT roads using asphalt recycling techniques to regain the structural capacity and the functional serviceability up to a desirable level would be a cost-effective and eco-friendly option. In the present study, an attempt has been made to produce an economical design for the rehabilitation of Chennai-Tada Road, N.H-5, by recycling the existing pavement material through a cold in-place recycling technique using foamed bitumen. Also, to work out a mix design for the base binder course and find out its cost-effectiveness. A complete assessment was carried out for the functional and structural failure from km 22.000 to 54.365. Main parameters considered rutting, cracking and shoving and severity pavement condition indicators were assigned as low, medium and high, and the Benkelman Beam deflection method was used to determine structural inadequacy. Cores were taken from distressed chainages. Reclaimed asphalt pavement (RAP) material was collected using a miller machine. The mix design was undertaken based on the guidelines of Wirtgen Cold Recycling Technology, TG2 Second revision and IRC- 37: 2012. The blending of aggregate was done as per the specified grading requirement. The sample was prepared with different foaming binder content varies from 1.5% to 2.5% and successfully produced BSM mix with 82% RAP material. Test results obtained classifies the mix as BSM1, which can be used for heavy traffic. The pavement was designed with the composition of BSM in 240mm thickness as an alternative option to the Dense bituminous macadam (DBM) layer along with the fresh bituminous concrete layer of 40 mm thickness.

KEYWORDS : Rehabilitation, Cold in-place Recycling Technique, Bitumen Stabilized material, Foamed (BSM), Strengthening, milling, cold planning, aggregate grading.

1. Introduction

Flexible pavement is usually designed for 20 years. After the expiry of the designed period, the pavement is likely to deteriorate structurally and functionally and therefore would require major

[1]PhD. Scholar, Department of Civil Engineering, SIRT, SAGE University Indore (MP) India, naveenshankar69@rediffmail.com

[2]Professor, Department of Civil Engineering, SIRT, SAGE University Indore (MP) India, basantkumarochani@gmail.com

rehabilitation to extend its life further. Avoiding timely restoration will result in costly reconstruction and loss of National assets constructed at a considerable cost. The rate of deterioration of the pavements depends on the structural adequacy of the pavement, traffic, climate and environmental factors, and large-scale rehabilitation demands have seen the adoption of cold in place recycling as the preferred procedure that is technically and financially viable. Presently India has the largest road network after the USA, which consists of 6.5 million kilometres, and timely maintenance of such an extensive existing road network with dedicated funds is highly difficult under growing demands of more road network due to population and economic growth and constant Shrinkage in funds made available by the government for maintenance work. With the advancement of technology, recycling existing pavements for rehabilitation of roads has gained considerable importance due to the depletion of aggregates in the region and the high cost of transportation of road construction material. The advantages of recycling pavements are reduced construction cost, conservation of aggregates and binder, preservation of the existing pavement geometry, protection of the environment, conservation of energy and minor user delay. The use of this technology in India will pave the way for green highways, which will go a long way in building sustainable infrastructure for national development.

2. Objectives of the study

Following are the objectives of the study:

- To evaluate the structural inadequacy and functional failures of the road on systematic criteria.
- To find out the optimum percentage of reclaimed asphalt pavement material to be used in rehabilitation works as a base binder course.
- To produce an economical design for base binder course for road rehabilitation projects with bituminous stabilized material (RAP) and determine its cost-effectiveness.
- To produce an economical design for rehabilitation works by considering existing pavement structure and reclaimed asphalt product (RAP).

3. Data Collection

The various Data pertain to functional and structural characteristics, and soil subgrade values were collected from Chennai-Tada National Highway-5, in chainage between km 22+000 to 54+365, where the pavement shows distress.

3.1 Site investigation and pavement condition assessment

The site was investigated to assess the pavement condition for functional and structural failure and fix the maintenance strategies for the existing four lanes of the project road.

3.1.1 Existing pavement composition and functional failure assessment

The assessment was made for the functional failure for the selected distressed stretches with first stage failure in chainage between km 22+000 to 54+365 for Chennai-Tada road NH.5. The pavement composition was found 40 mm Bituminous Concrete (BC) and 160 mm Dense Bituminous Macadam (DBM) laid in two layers of 80 mm each. The following essential distress parameters were considered in the present study for functional failure: Cracking, Rutting and Shoving. Cracking and rutting areas were classified into three groups based on severity and density of cracking and rutting, respectively as light (L), medium (M) and heavy (H). To verify the nature of the cracking, two cores, each taken from selected stretches 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 the top, and This establishes that rehabilitation by Cold in-place recycling up to 200 mm depth is a viable option. Table 1 shows the existing pavement composition. Tables 2&3 show pavement cracking conditions on the left and right-hand sides of the road, respectively. Fig.1 shows the existing crust. Fig. 2 shows various types of surface failure: Severe wheel path fatigues cracking, rutting, shoving, and inadequate cross slope in selected distressed stretches. Fig. 3 shows core cutting in process. Figs. 4 and 5 show core taken from Km 45.30 and 32.350 respectively.Fig.6 shows the cracking pattern identified during coring.

Table 1: Existing pavement composition

Layer	**Thickness(mm)**
BC	40
DBM 1	80
DBM 2	80
WMM	250
GSB	200
Prepared Sub-grade	500

Table 2: Pavement condition in the LHS direction

Chainage	**Cracking**			**Cracki ng**	
	Severity	**Density**		**Severity**	**Density**
22-23	M	L	39-40	L	L
23-24	L	L	40-41	L	L
24- 25	L	L	41-42	L	L
25-26	**M**	**M**	42-43	L	L
27-28	L	L	43-44	L	L
28-29	**M**	**M**	44-45	L	L
29-30	**H**	**H**	45-46	L	L
30-31	L	L	46-47	L	L
31-32	L	L	47-48	L	L
32-33	L	L	48-49	L	L
33-34	L	L	49-50	L	L
34-35	L	L	50-51	L	L
35-36	L	L	51-52	L	L
36-37	L	L	52-53	L	L
37-38	L	L	53-54	L	L
38-39	L	L	54-55	L	L

Table 3: Pavement condition in the RHS direction

Chainage	Cracking		Chainage	Cracking	
	Severity	Density		Severity	Density
55-54	L	L	36-35	M	L
54-53	**M**	**H**	35-34	L	L
53-52	**M**	**M**	34-33	L	L
52-51	L	L	**33-32**	M	L
51-50	**M**	**M**	32-31	L	L
50-49	**M**	**H**	31-30	L	L
49-48	M	L	30-29	L	L
48-47	**M**	**M**	29-28	L	L
47-46	M	L	28-27	L	L
46-45	M	L	26-25	L	L
45-44	**M**	**H**	**25-24**	**M**	**H**
44-43	M	L	24-23	L	L
43-42	L	L	**23-22**	**M**	**H**
42-41	**M**	**H**	39-38	L	L
41-40	M	L	**38-37**	**M**	**H**
40-39	L	L	**37-36**	**H**	**H**
39-38	L	L	36-35	M	L
38-37	**M**	**H**	35-34	L	L
37-36	**H**	**H**	34-33	L	L

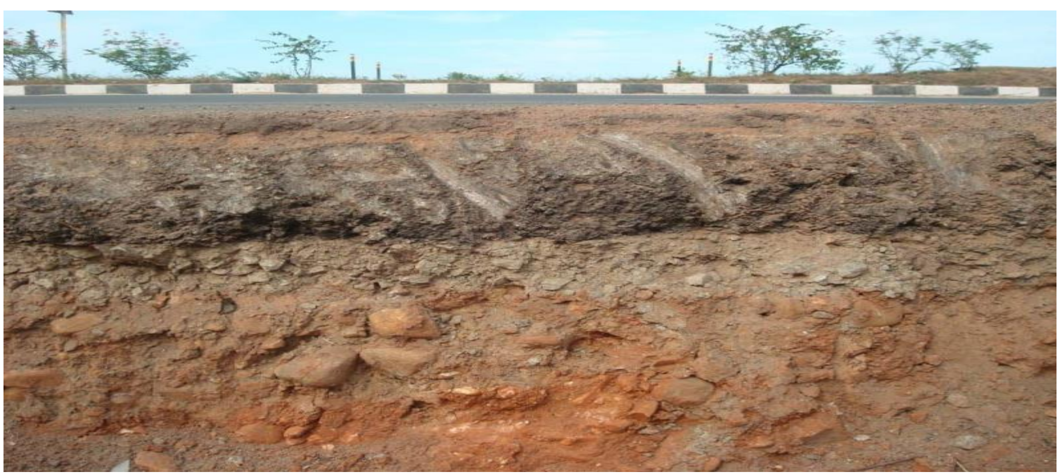

Figure 1: Existing crust details

Figure 2: Severe wheel path fatigues cracking, rutting, shoving, and inadequate cross slope Chennai-Tada Road NH-5.

Fig. 3 core cutting in progress Km 32.350

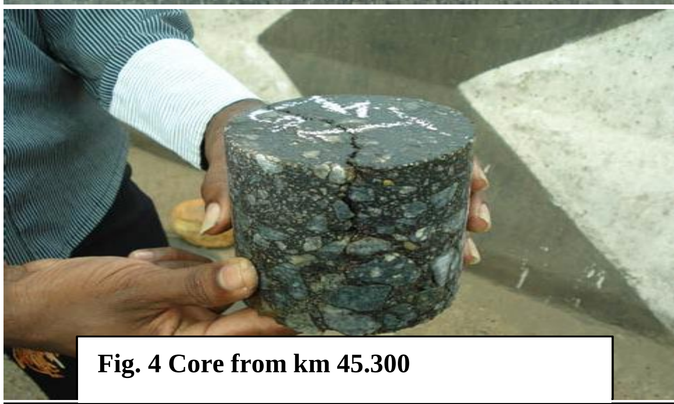

Fig. 4 Core from km 45.300

Fig. 5 Core from km 32.350

Fig.6 Cracking pattern identified during coring

3.1.2 Structural Failure assessment

Benkelman Beam deflection studies were carried out on the Chennai-Tada section of NH-5 from km 22 to 54.400 for both LHS and RHS Carriageway. The evaluation of structural strength of existing flexible pavement was carried out using a Benkelman Beam in accordance with the procedure given in IRC 81-1997.Fig.7 and 8 show characteristic deflections of Km 22 to 55 RHS and LHS.

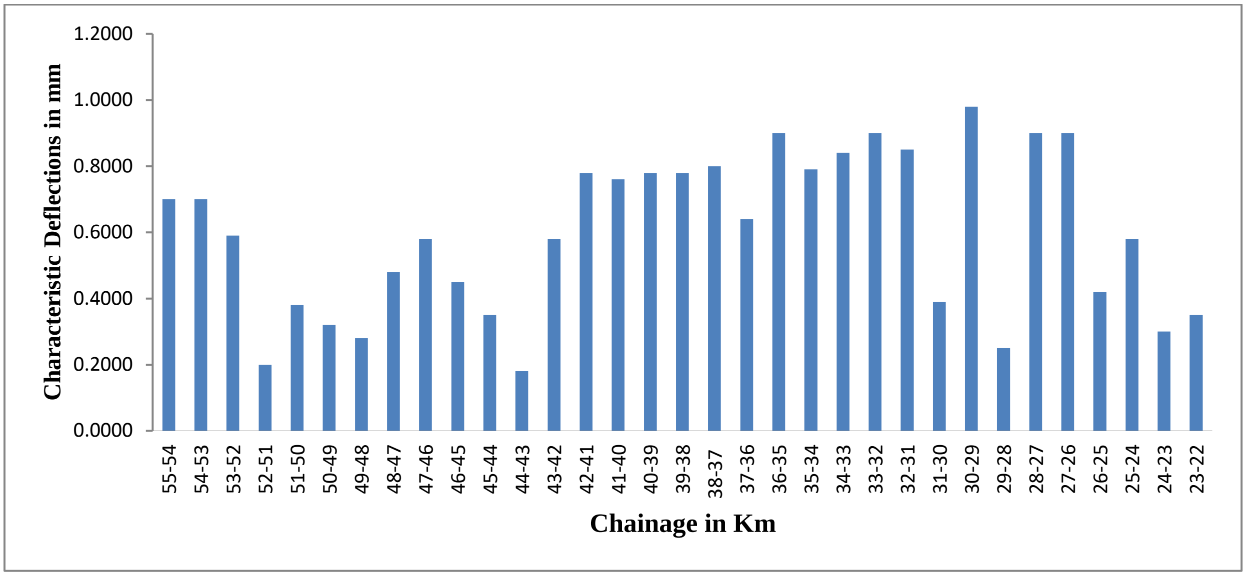

Figure 7: Characteristic Deflection Values in the RHS Direction

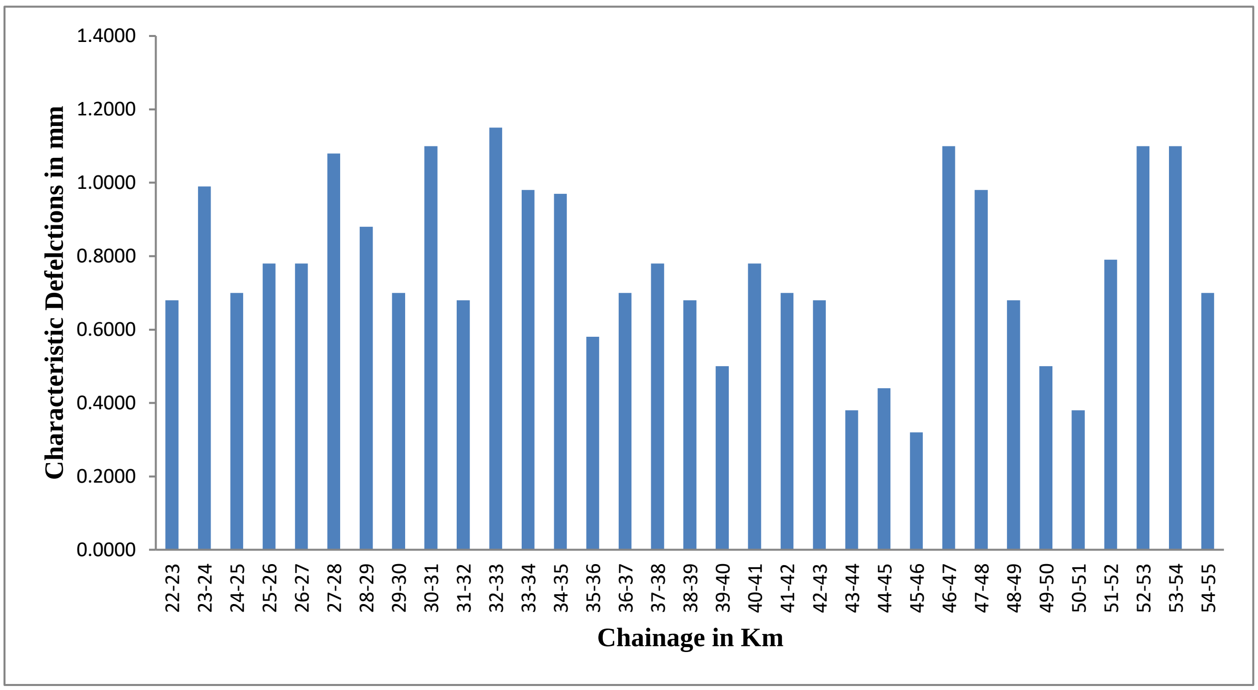

Figure 8: Characteristic Deflection Values in the LHS Direction

3.2 Sample collection and properties of RAP material

RAP material was collected using milling machines from the homogeneous distressed stretches with uniform pavement composition. Characterization of RAP was carried out by conducting the Wet Sieve analysis to determine the grading (ASTM D422), Atterberg limits to determine the plasticity index (ASTM D4318) and Modified Procter test to determine the moisture/ density relationship (AASHTO T-180).

4 Methodologies and Analysis of Data

Based on the visual inspection, analysis of the cores, deflection studies and severity of distress (PCI) of the pavement, which show the pavement is still in sound condition; hence it was recommended that the existing bituminous pavement should be milled till the depth of the damage and replaced with suitable material.

4.1 Laboratory tests performed on RAP Material

Sieve analysis was performed on pulverized, air-dried reclaimed asphalt product (RAP) collected from four different locations to determine the grading. The blending of aggregate was done with additional dust taken from the stockpiles to achieve the specified grading limits for BSM as prescribed. Atterberg's limits test was performed to determine the plasticity index, showing that the material is non-plastic. A hygroscopic test was performed to know the existing moisture content present in the material. Modified Proctor test for determination of OMC and MDD for blended material was performed and were found to be 6.53% and 2092 kg/m3 respectively. It was found that the blend of 80% RAP material, 19% Crusher Dust and 1% Filler (OPC 53 Grade) met the grading requirements for Bitumen Stabilized Material. Hygroscopic moisture content was found to be in the range of 0.18-0.2%, subtracted from OMC when adding water to the mix Fig.8 shows the Gradation curve of RAP samples collected from Chennai-Tada Road. Fig.9 shows the gradation curve for blended material. Fig.10 shows the plot of moisture content Vs dry density for the determination of Dry density and MDD.

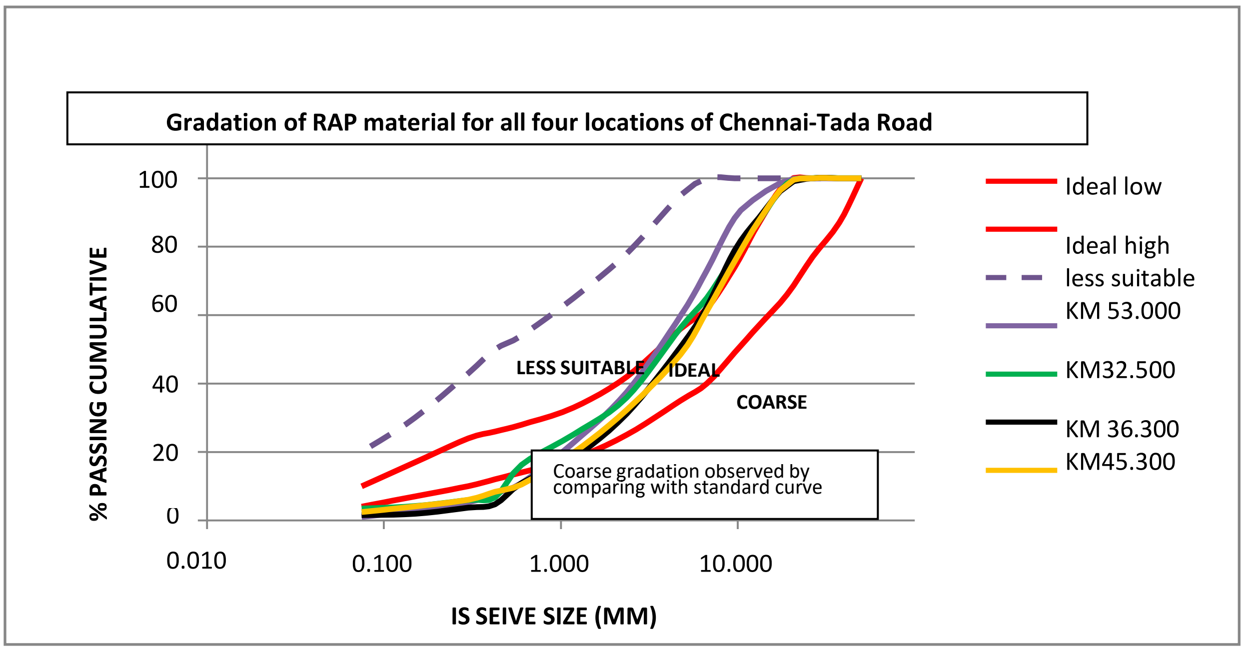

Fig.8 Gradation curve of RAP samples collected from Chennai-Tada Road

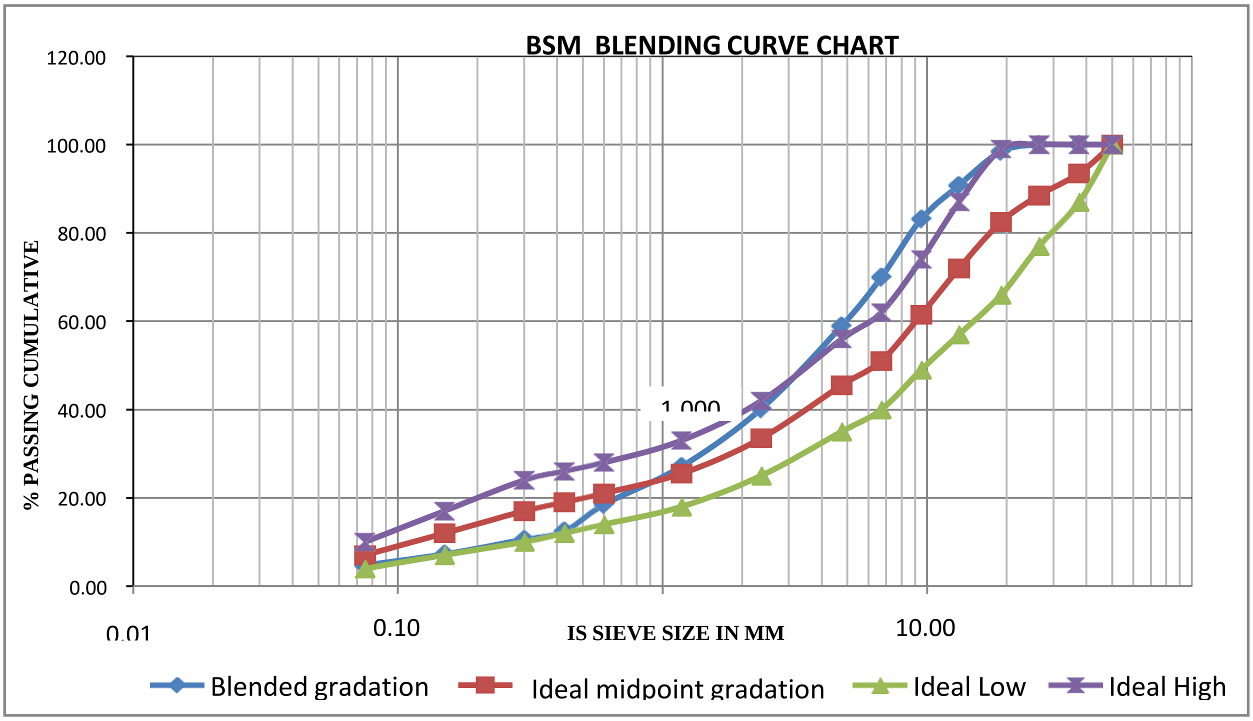

Fig.9 Gradation curve for blended Material curve

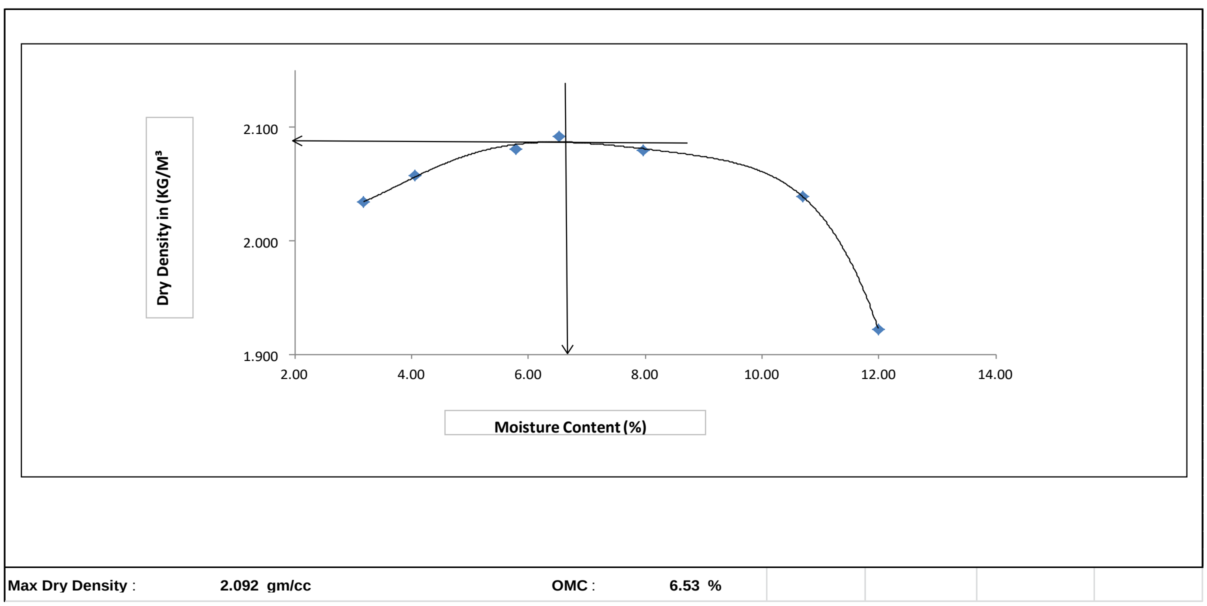

Fig.10 Plot of moisture content Vs dry density for determination of OMC & MDD

4.2 Laboratory test for foaming characteristics of Bitumen.

For the present study, Bitumen VG 10 grade was selected. The optimum value of 6% water content at 180 degrees Celsius was used for the laboratory foam production to obtain the most significant expansion ratio and longest half-life of the bitumen yielded. An expansion ratio of 15 and a half-life of 15 seconds have been brought against a minimum requirement of 8 and 6 seconds.

4.3 Preparation of foam mix, specimen costing and test results.

After the selection of the binder, representative blended samples is prepared with 1.5, 2 and 2.5% foaming binder content for fabrication of marshal specimens of 100 mm diameter, which were cured and tested for bulk density, Indirect Tensile Strength (ITS) for the dry and wet condition to ascertain the optimum foaming bitumen content. BSM design was produced with an optimum binder content of 2% obtained from the graph shown below, with fomenting 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. The average value of ITS dry for 1.5%, 2.0%, and 2.5% foamed bitumen content was found at 255.79 kPa and 265.456 KPa and 200.904 KPa. The ITS wet value at foamed bitumen content of 1.5%, 2.0% and 2.5% were found 204.06 KPa, 212.32 KPa and 170.22 KPa, respectively and classified the mix as BSM-I, which can be used for heavy traffic as per the TG2 guidelines.Table3 shows a combined summary of specimens with different foaming binder content. Table 8 shows ITS results for Dry and Wet Conditions. Fig 11 shows % of foamed bitumen Vs ITS in dry and wet conditions. Fig.12 shows the relationship between ITS and ITSM values.

Table4. 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:**	**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 STABILIZED 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)**	255.79	265.44	200.904	
Moisture Content at break	**(%)**	0.82	0.88	0.95	
Dry Density	**(Kg/m³)**	2083	2054	2048	
Average Deformation	**(mm)**	-	-	-	
Temperature at break	**(°C)**	25	25	26	

		1.5	2	2.5	
ITS$_{WET}$	**(KPA)**	204.06	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 Ratio	**(%)**	80	80	85	
Material Classification		BSM-1	BSM-1	BSM-1	

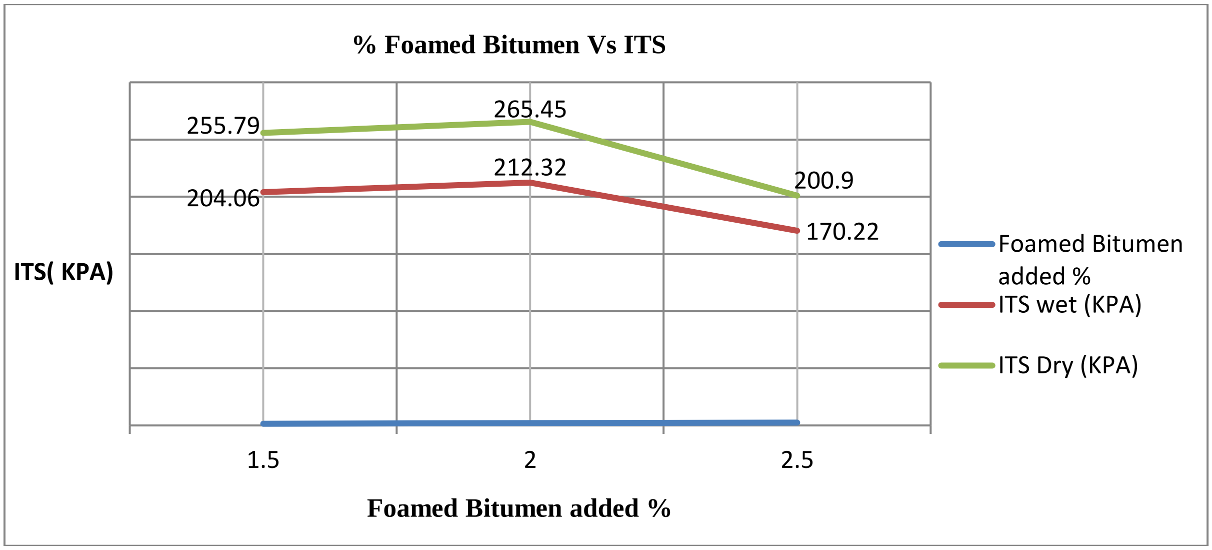

Fig. 11 % of foamed bitumen Vs ITS dry and wet condition

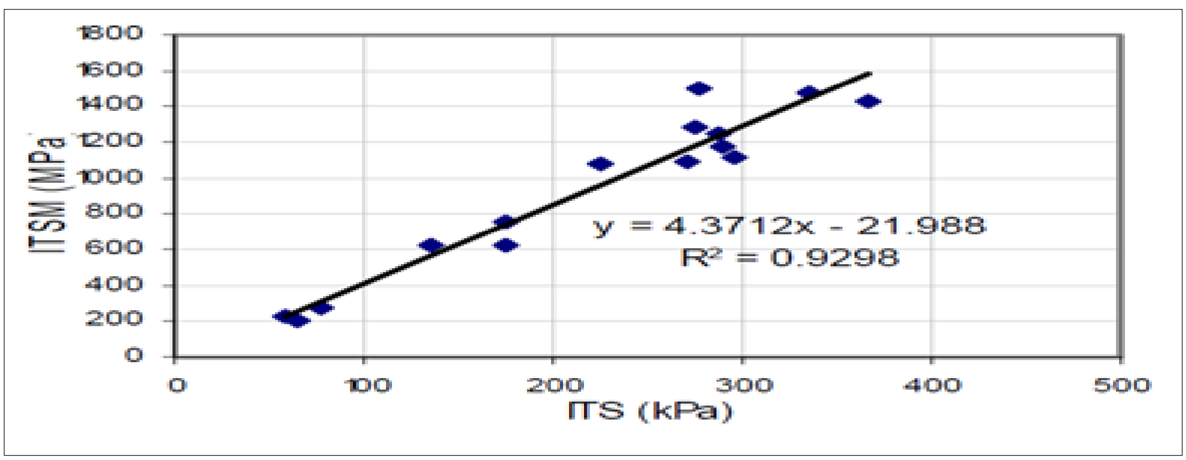

Fig.12 Relationship between ITS and ITSM values (Source: Sri Sunaryano)

4.4 Pavement Structural Design

By considering a design life of 20 years, design traffic of 84 msa and 10% CBR, the Chennai-Tada Six lane pavement's final design after recycling was obtained using Circly software. The value of resilient modulus of BSM ranges from 600-1200 MPa as per Sec 7.3.3 IRC- 37:2012

(Draft), and it is recommended to use the value of 800 MPa for structural design purposes. It also states that the value of resilient modulus is much higher in the lab compared to 600 Mpa. As BSM is sensitive to moisture, a safer value of 600 MPa is adopted for structural design as per IRC-37:2012 (Draft). The values of TSR (tensile strength ratio) of more than 80% obtained from test results indicate a suitable moisture resistance property of the BSM mix. Considering an average ITS value of 260 KPa, the stiffness modulus for the BSM was found 1115 Mpa obtained from the above relationship shown in Fig.12. A mid-value of resilient 800 MPa is assumed for the BSM layer for structural design purposes. The other elastic parameters used for BC, WMM, GSB and Sub-grade layer is as per IRC-37:2012. The design thicknesses adopted are found to be adequate for the design traffic of 84 msa. Table 4 shows the final Pavement composition after recycling.

Table5 final Pavement composition after recycling

Layer	Thickness(mm)	Properties	Resilient Modulus (MPa)	Poisson's Ratio	Reference for elastic parameters
BC(fresh overlay onBSM layer)	40		1700	0..35	IRC: 37 -2012 (Draft) , Sec. 7.4.2, Table 7.1, BC with VG30 grade bitumen, Temperature 35ºC
BSM(recycled layer)	240		800	0.35	IRC:37-2012 (draft), Sec. 7.3.3 & ANNEX-IX, Table- IX-3, Pg. 82 ; Foamed asphalt mixes-Mix design procedure, KM Muthen. Report CR-98/077
WMM	250		240	0.35	IRC: 37 -2012, Sec. 7.3.1, Eq. 7.3. Sub-base and base are both unbound granular layers, Hence same Resilient modulus, M_R
GSB	200		240	0.35	

	Density	Material			
BSM	2200	Kg.	Unit	Rate	Amount
Bitumen VG10	2.00%	44.0	Kg	32.45	1428

Prepar	500	CBR –10%	76.82	0.35	IRC: 37 -2012, Sec 5.3, Eq. 5.2

4.5 Comparative Cost analysis for DBM and **BSM**

Cost analysis was done separately for DBM and BSM mix by considering the latest market rates of aggregate, labour, machinery, and bitumen. A cost comparison was made to find out the net saving per Km. Table 6 shows the cost comparison of BSM Vs DBM. Table 7 shows the overall cost of DBM and BSM for the six-lane road for 31.365 km in length. Tables 8 & 9 show seperate cost analysis for DBM and BSM mix.Fig.13 shows a cost comparison between BSM and DBM mix. Fig 14 shows the cost of DBM and BSM for 31.365 Km road length and net saving.

Table 6 Cost comparison between DBM and BSM

Sr.No	Cost of DBM per Cubic Meter(A) INR	Cost of BSM per Cubic Meter (B) INR	Net saving Difference A-B INR	Cost-effectiveness
1	5762.00	2012.00	3750.00	65.081%

and BSM for the six-lane road for 31.365 km road length

Sr.No	Cost of DBM for six-lane road per Km (A) INR	Cost of BSM for six-lane per Km (B) INR	Net saving per km length (A-B) INR
1	2x1000x10x0.18=3600M3 3600x5762.00=**2,07,42200.00 (INR)**	2x1000x10x0.24=4800M3x 4800x2012=**9657600.00**	**11084600.00** **53.44%**
2	**Total cost for DBM on the project length of 31.365 km** **31.365X 2.0742200= 65.0579103 (Cr)**	**Total cost for BSM on the project length of 31.365 km** **31.365X 0.966= 30.30 (Cr)**	**Total net saving on the project length of 31.365 km** **=34.767 Cr**.

Table 8 Cost analysis of DBM per cubic meter

	Density	Material			
DBM	**2200**	**Kg.**	**Unit**	**Rate**	**Amount**
Bitumen VG30	4.50%	99.0	Kg	31.95	3163
Fine Agg.	39%	858.0	Kg	0.60	515
Course Agg.	60%	1320.0	Kg	0.60	792
Filler/Cement	1%	22.0	Kg	5.00	110
Paver		1.0	Cum	200.0	200
Plant		1.0	Cum	350.0	350
Roller/other		1.0	Cum		0
Transportation	10	1.0	Cum	10.0	100
DG	52	1.0	Cum	52.3	52
LDO	12	1.0	Cum	40.0	480
Total Cost (INR) per Cubic Meter					**5762.00**

Fine Agg.	17%	374.0	Kg	0.60	224
Course Agg.(RAP)	82%	1804.0	Kg	0.00	0
Filler/Cement	1%	22.0	Kg	5.00	110
paver		0.0	Cum	0.0	0
Cold Mixing plant		1.0	Cum	100.0	100
Roller/other		1.0	Cum	50.0	50
Transportation	10	1.0	Cum	10.0	100
DG	0	1.0	Cum	0.0	0
LDO	0	1.0	Cum	0.0	0
Total Cost (INR) per Cubic Meter					**2012.00**

Table 9 Cost analysis of BSM per cubic meter

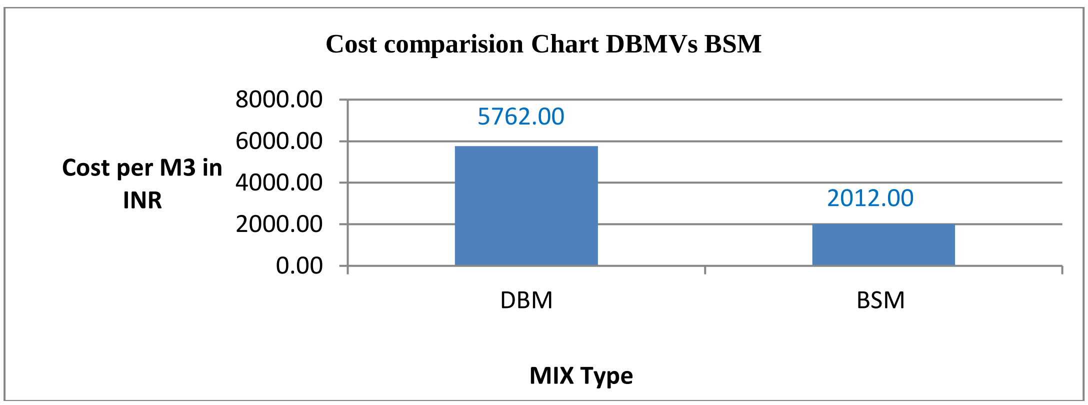

Fig.13 cost comparison between BSM and DBM mix

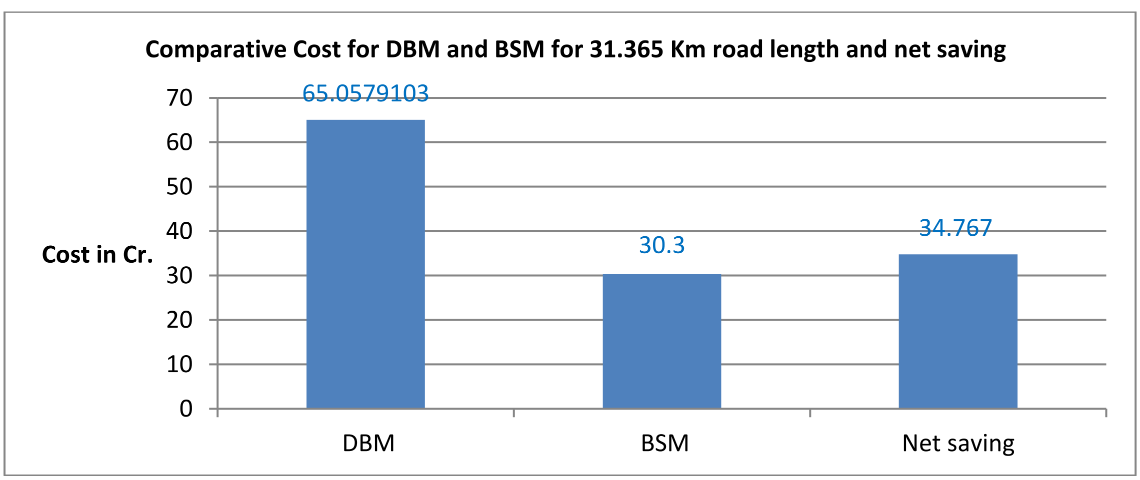

Fig.14 Cost comparison between BSM and DBM for 31.365 Km road length and net saving

5 Conclusions

- The study shows that structural and functional evaluation based on systematic, measurable criteria by conducting appropriate field and lab investigations as suggested helps to fix proper maintenance strategies as per the actual road requirement for rehabilitation works.
- The study shows that 80% RAP material was successfully utilized to produce Bituminous stabilized mix (BSM) as a base binder course in the road project considered for rehabilitation.
- Bituminous stabilized mix (BSM) produced classifies the Mix as BSM-I as per the TG-2 guidelines, which can be used for heavy traffic as a base binder course and cost-effective by 65.081% compared to DBM mix.
- The economic road designed with BSM for overall road length of 31.365 Km resulted in a net saving of 34.767 Cr.

6 References

1- Anil Kumar Yadava "Characterization of Indian reclaimed asphalt pavement (rap) based on sources of rap and gradation characteristics of rap aggregates." International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN 2278-3075, Volume 08, Issue 07, May 2019, pp. 2402-2408.

2- AbhishekVerma, Rachita Sharma ."Evaluation of Reclaimed Asphalt Pavement (RAP) In Flexible Pavement Layers" World Journal of Engineering Research and Technology (WJERT). Vol. 3, Issue 2, March 2017.pp. 91-104.

3- Technical guideline for bitumen stabilized materials. A guideline for the design and construction of Bitumen Emulsion and Foamed Bitumen stabilized materials, TG2 Second revision, May 2009, Pretoria, South Africa.

4- Wirtgen "Wirtgen Cold Recycling Technology Manual", 2010, 3rd edition.

5- Dr.Soosan George T, Susan P.Rajan , "Pavements Using Reclaimed Aggregates". Civil Engineering and Urban Planning: An International Journal (CiVEJ), Vol. 3, NO. 2, June 2016.pp. 145-153

6- Jashanjot Singh And AK Duggal "An Experimental Study On Reclaimed Asphalt Pavement In Bituminous Concrete" IOP Conference Series: Earth and Environmental Science 498 (2020) 012025, 2019, pp.01-08.

7- IRC-37_2012 - Guidelines for the design of flexible pavements (third revision), Indian Road Congress July 2012.

8- Muthen, K.M.(1999). "Foamed Asphalt Mixes: Mix Design Procedure", Contract Report CR-98/077, SABITA Ltd & CSIR Transportek, South Africa.