Evaluation And Strengthening Of Existing Hma Pavements And Newly Introduced Wma Pavements. (In Cold Regions Of India)

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Abstract: Pavements are used for vehicular movement in a smooth and comfortable manner. Pavements are usually designed to support increased wheel load replication and therefore undergo perturbation. In order to overcome the distress caused due to wheel load, prevailing climatic conditions and soil subgrade conditions, maintenance of pavements is important. Maintenance can be achieved through evaluation and strengthening. This study involves intercity roads of Srinagar J&K. Two Stretches, one paved using Hot Mix Asphalt (HMA) and other using Warm Mix Asphalt (WMA) were evaluated in this study for their Present condition, Traffic density, and Soil type. BBD test was performed above 20˚C and below 20˚C on these stretches for determining their characteristic deflection. These parameters were used to design the overlay thickness and Pavement thickness for strengthening. A co-relation between the parameters thus obtained was found in order to widen the boundaries of temperature within which the code operates in colder region.

Index Terms: BBD test, evaluation, HMA pavements, overlay thickness, pavement thickness, strengthening, WMA pavements.

1 INTRODUCTION

Srinagar City being a part of Kashmir valley and capital of J&K, Union Territory of India lies along the banks of Jehlum River. The average winter temperature of 3.2˚C and average summer temperature of 23˚C.During winters the temperature dips below 0˚C and during summers it goes up to 35˚C. Roads being the backbone of any emerging nation undergo distress due to application of vehicle loads and impact of weather conditions. Roads of Kashmir valley in addition to degradation due to vehicle loads also get degraded due to constant weather conditions of Summer and winter season for a period of 6 months each. This constant increase and decrease in Temperature every year causes the roads to deteriorate even before their design life is over i, e. before 10 years. In order to maintain the standard of design life Warm Mix Asphalt (WMA) with Evotherm used as an additive was introduced and two stretches one in Srinagar city, Central Kashmir and other in Pulwama district, South Kashmir were used for Test coat having length of 2km each. This study includes evaluation and strengthening of existing Hot mix asphalt (HMA) pavements and newly introduced Warm Mix Asphalt (WMA) pavements. In this study HMA stretch S1, (From Temple Path, Munshi Bagh Srinagar towards Dal Gate of length 4km) and WMA stretch S2, (Temple Path, Munshi Bagh towards Old Zero Bridge (Residency Road) (2 kms) were evaluated for pavement condition survey, traffic data, soil type, soil tests, and strengthened by performing BBD test for characteristic deflection, and designing of overlay thickness, new pavement design using all the parameters.

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When the construction of the pavement gets completed its maintenance is required, and thus strengthening can be used as a pavement maintenance measure as it is the most common method adopted. Hence, for the purpose of the fulfilment of above factors and for comfortable movement of traffic I am designing an overlay (extra thickness) on existing pavement at temperature above 20ºC (based on IRC: 81-1997 recommendations) and I am also designing an overlay below 20ºC (which IRC: 81-1997 does not recommend) and ultimately comparing the results.

2 OBJECTIVES

The ultimate objective of the study is to find a correlation between the two results and to widen the boundaries of temperature within which code operates in the cold region. Thus I will try to incorporate the factor of temperature in the overlay design for the temperature below 20 degree Celsius. In addition I have designed a new flexible pavement for the selected road stretches using a CBR method of design.

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3 BENKELMAN'S BEAM DEFLECTION TECHNIQUE

BBD test can be described as a method to evaluate the rebound deflection of the pavement using regular truck's rear axle which is under static load. A check point is selected and the truck's dual wheels are positioned around the check point. As per IRC 81-1997 the rear axle of the truck should be carrying a load of 8170 kg or 8 Ton. Processing of all the data is done to obtain proper deflections. For the determination of calculation parameters IRC-81, 1997 is extensively used. These results guide the design of the thickness of the overlay.

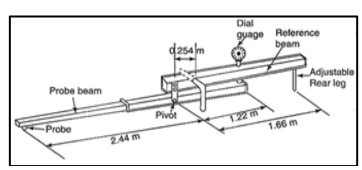


Fig.1 *BBD Equipment*

4 METHODOLOGY

The flowchart below represents the overall methodology used for this study. The first step is the site selection, which are the two stretches S1 and S2 that have been selected as mentioned in the introduction of this paper. Site selection is followed by site survey which involves the pavement condition survey, pavement structural survey, and traffic density survey and soil tests. The PCS determines whether the pavement is good, fair, poor depending upon the rut depth, cracks measurements. The pavement structural survey is the determination of thickness of the existing layers and the type of pavement. Traffic density is determined for calculating the million standard axles which is further used for designing of pavements. Soil Tests are performed to determine various physical properties of the sub grade soil and the designing of pavements with respect to overlay thickness or new flexible pavements depends upon CBR value. The third step was performing BBD test at temperatures above 20˚C and below 20˚C for determining Characteristic deflection of both the stretches. The results obtained were recorded and calculation was done for designing overlay thickness and new pavements. Further the results were analyzed to find a co-relation between the two results obtained for two stretches.

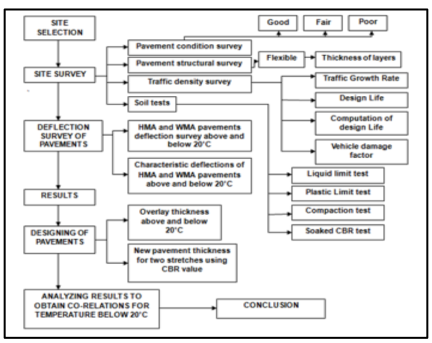


Fig.2 *Flowchart representing overall methodology followed in the study.*

Fig. 3 *Axle wheel load and Pavement Temperature Measurement.*

Fig .4 *Setting up BBD test apparatus and taking deflection measurements.*

5 RESULTS AND DISCUSSION

5.1 Pavement Condition Survey for stretch S1 & S2

Sr. No.	Chainage km. (HMA)	Avg. Area of Cracks in m2 (C)	Avg. Area of Patching in m2 (P)	Average Rut depth in mm. (RD)	Pavement Classification section
1	0 To 1	152.90	300.59	17.288	Fair
2	1 To 2	140.90	132.90	14.24	Fair
3	2 To 3	137.85	125.40	19.066	Poor
4	3 To 4	53.01	63.76	4.98	Good

Table 1: *Pavement condition of S1 (HMA) divided into chainage each of length 1km.*

Sr. No.	Chainage km. (WMA)	Avg. Area of Cracks in m2 (C)	Avg. Area of Patching in m2 (P)	Average Rut depth in mm. (RD)	Pavement Classification section
1	0 To 1	68.41	65.45	6.25	Good
2	1 To 2	71.11	80.26	7.864	Good

Table 2: *Pavement condition of S2 (WMA) divided into chainage each of length 1km.*

Both the stretches S1 and S2 are classified as fair from PCS point of view.

5.2 Traffic density for stretches S1 & S2.

Day	Cars	Two Wheelers	Three Wheelers	Buses (>3 T)	Trucks			Total
					Mini	Carriage (>3 T)	Army (>3T)	
Mon	8376	5691	3124	234	334	240	6	18005
Tue	7864	5166	2903	214	311	224	6	16688
Wed	7581	4967	2792	227	289	229	6	16091
Thur	7298	4765	2678	239	265	233	3	15481
Fri	7492	4901	2889	256	284	243	3	16068
Sat	7680	5043	3092	265	300	248	3	16631
Sun	6133	3785	2281	174	210	172	-	12755
Total =111719								

***Table 3:** Traffic volume for seven days of all vehicle type for stretch S1.*

Day	*Vehicles >3 T*
Monday	*814*
Tuesday	*755*
Wednesday	*752*
Thursday	*740*
Friday	*788*
Saturday	*816*
Sunday	*577*
Avg. Traffic Volume = 816cvpd	

***Table 4:** Average volume of vehicles >3T for stretch S1.*

Day	Cars	Two wheelers	Three wheelers	Buses (>3 T)	Trucks			Total
					Mini	Carriage (>3 T)	Army (>3T)	
Mon	8350	5600	3127	230	330	245	5	17887
Tue	7000	5100	2998	218	313	226	5	15860
Wed	7550	5000	2798	230	290	230	5	16103
Thur	7150	4767	2643	235	267	235	4	15301
Fri	7394	4900	2856	260	289	240	4	15943
Sat	7234	5050	3090	265	306	249	4	16198
Sun	6250	3795	2200	176	215	17	-	12653
Total =109945								

***Table 5:** Traffic volume for seven days of all vehicle type for stretch S2.*

Day	Vehicles >3 T
Monday	812
Tuesday	750
Wednesday	749
Thursday	744
Friday	780
Saturday	820
Sunday	578
Avg. Traffic Volume = 748cvpd	

***Table 6:** Average volume of vehicles >3T for stretch S2.*

Using the following equation mentioned below the required calculation can be made:

$$N_s = 365 \times A[(1+r)^n - 1]/r \times F \times D$$

On solving the results obtained are:

	Stretch S1 (msa)	Stretch S2 (msa)
Ns	16.42	15.06

***Table 7:** Million Standard axles for stretch S1 &S2 (msa)*

5.3 Soil Tests for stretch S1 & S2.

	Stretch S1	*Stretch S2*
Liquid Limit	*32.42%*	*41.15%*
Plastic Limit	*18.33%*	*22.50%*
Plasticity Index	*14.09%*	*18.65%*

***Table 8:** Liquid limit, plastic limit, plasticity index values obtained for soil samples collected from S1 & S2*

Compaction Test	Stretch S1	Stretch s2
OMC of Sample	16%	14%
MDD of Sample	16.87 kN/m^3	17 kN/m^3

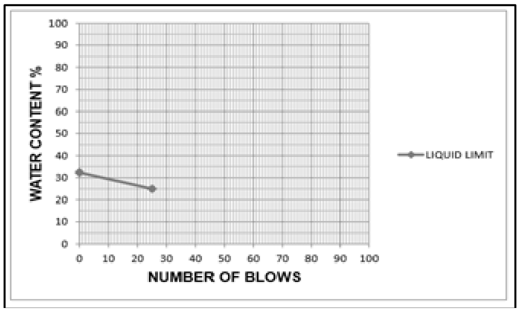
***Table 9:** OMC and MDD of soil samples collected from S1 & S2 by performing Compaction test.*

Using following equation CBR values for both stretches were calculated:

CBR %= $P_T/P_S \times 100$

Penetration (mm)	*CBR Value for stretch S1*	*CBR Value for stretch S1*
2.5	*1.433211679*	*1.45985401*
5	*1.824087591*	*1.94403893*

***Table 10:** CBR Value of soil samples collected from S1 & S2*



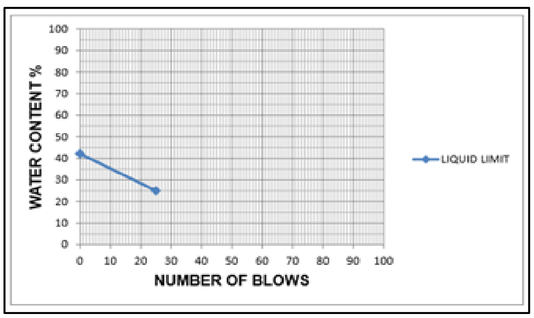
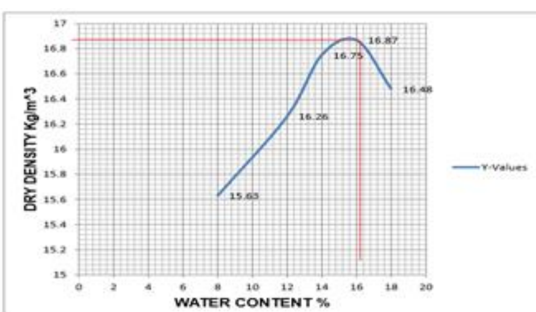


***Fig. 5** Liquid Limit plot for soil samples at 25 no of blows for S1 & S2*



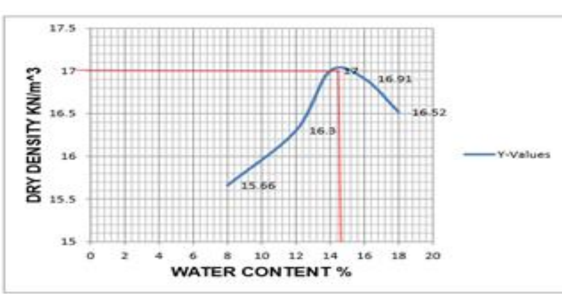


***Fig. 6** MDD of soil samples plot using compaction test for S1 & S2*

5.4 Deflection pavement survey for stretch S1 & S2

Average Pavement Temp (°C)	8.30	12.7	10.50	18.37	29.26
Average Moisture Content %	21.48	20.35	20.91	19.14	16.98
Mean of Rebound Deflection, mm	.5979	.7193	.6108	.8304	1.0416
Standard Deviation	.1980	.1936	.2165	.2417	.4213
Characteristic Pavement Rebound Deflection, mm	.80	.9129	.8274	1.0722	1.4629
Temp correction, mm	NA	NA	NA	NA	NA
Moisture correction factor	1.09	1.1	1.1	1.12	1.15
Corrected Characteristic pavement deflection, mm	.87	1	.91	1.20	1.75
Design Traffic Intensity>3 tonnes per day	942.99	942.99	942.99	942.99	942.99
Cumulative No of standard axels for design	16433004.86	16433004.86	16433004.86	16433004.86	16433004.86
Design overlay thickness, mm (BM)	20	60	40	100	165
Design Overlay thickness, mm (WMM)					85mm (WBM) 55mm (WBM)
Design overlay thickness, mm (BM/DBM and BC)					52mm (BM)+ 40 mm (BC) 50 mm (DBM)+ 40mm (BC)

Average Pavement Temp (°C)	8.06	12.95	10.55	18.39	29.39
Average Moisture Content %	21.50	20.42	20.00	19.25	17.00
Mean of Rebound Deflection, mm	.5980	.7185	.6110	.8309	1.0420
Standard Deviation	.1982	.1939	.2168	.2419	.4215
Characteristic Pavement Rebound Deflection, mm	.83	.9131	.8277	1.0726	1.4632
Temp correction, mm	NA	NA	NA	NA	NA
Moisture correction factor	1.09	1.1	1.1	1.12	1.15
Corrected Characteristic pavement deflection, mm	.89	1	.91	1.21	1.78
Design Traffic Intensity>3 tonnes per day	865.99	865.99	865.99	865.99	865.99
Cumulative No of standard axels for design	15069070.52	15069070.52	15069070.52	15069070.52	15069070.52
Design overlay thickness, mm (BM)	25	65	45	105	170
Design Overlay thickness, mm (WMM)					85mm (WBM) 55mm (WBM)
Design overlay thickness, mm (BM/DBM and BC)					52mm (BM)+ 40 mm (BC) 50 mm (DBM)+ 40mm (BC)

***Fig. 7** Summary table of different parameters of deflection obtained during performing BBD Test on S1 & S2.*

The above figures represent the summary of the results obtained on mean rebound deflection, standard deviation, characteristic pavement rebound deflection, corrected characteristic pavement deflection and the design of overlay thickness for temperatures above 20˚C and below 20˚C of stretches S1 &S2.

5.5 Co-relations

IRC-81 (1997) recommends performing this test at or above 20 degree Celsius and at the weakest condition of the sub-grade soil. As far as Kashmir is concerned both recommendations cannot be achieved at the same time, as the weakest sub-grade condition here is during winters with temperature usually tending to zero degree Celsius. On conducting BBD on series of temperatures below 20ºC and above 20ºC to determine the deflection for HMA and WMA we arrived at thickness of overlays the HMA stretch S1, and WMA stretch S2, pavement requires corresponding to these temperatures. By comparing the results at two series of temperatures for HMA and WMA pavements it is possible to arrive at various co-relations (equation) and plots that can be obtained between various parameters and can be applied for design in cold regions which the code related standards doesn't permit. The various graphs are plotted. In the below

plots deflection correction has been applied on the actual characteristic deflection to arrive at its correct value. These corrections are applied on the actual characteristic deflection for temperatures less than 20° Celsius for stretch S1 & S2
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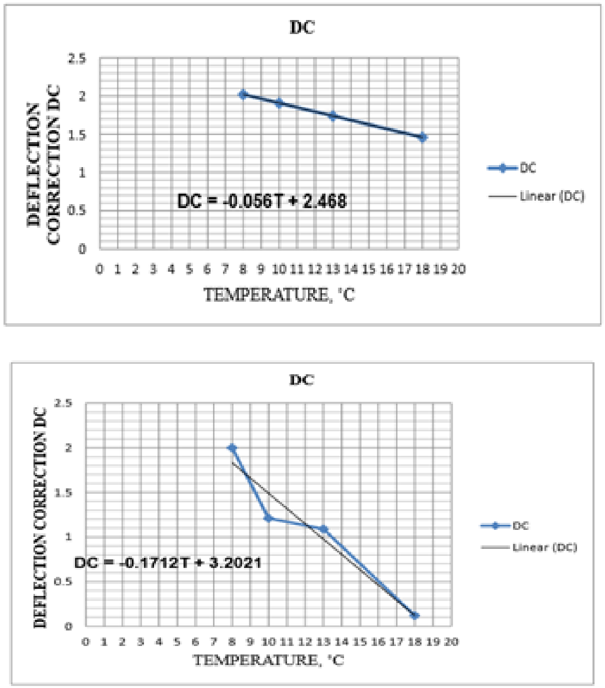
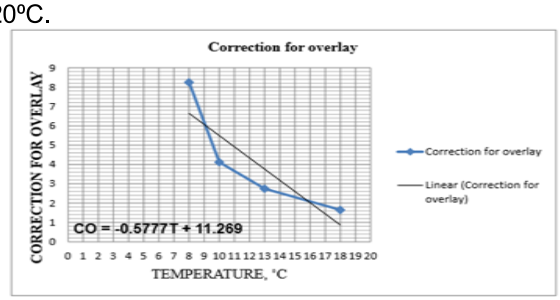


Fig. 8 *Temperature vs Deflection correction plot for S1 &S2.*

The deflection correction has been applied on the actual characteristic rebound deflection to arrive at a correct characteristic deflection for temperatures less than 20º Celsius. The deflection correction is obtained as follows: e.g., HMA Pavement Characteristic deflection for 8ºC = 0.87mm and that for 29ºC = 1.75mm, WMA Pavement Characteristic deflection for 8ºC = 0.89mm and that for 29ºC = 1.78mm So, for HMA Pavement the deflection correction = 1.75/0.87 = 2.01 and further calculations continue in the same manner. Similarly, for WMA Pavement the deflection correction = 1.78/0.89 = 2.00 and further calculations continue in the same manner. The graph between deflection correction and temperature varies linearly. In the plots the equations to obtain appropriate deflection corrections have been introduced. DC = -0.056T + 2.468 DC = -0.1708T + 3.1982 By applying these equations we can arrive at the deflection correction which needs to be applied for a varying range of temperature less than 20ºC.



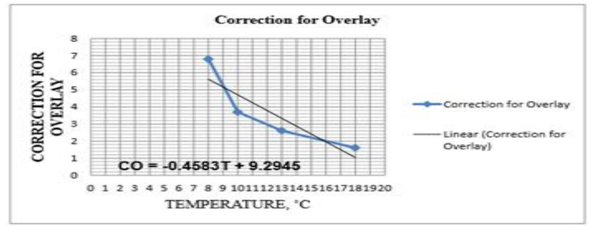


Fig. 9 *Temperature vs Correction overlay plot for S1 & S2.*

In this plot the correction factor has been applied on the overlay thickness which will yield its correct value for temperatures less than 20º C. To further arrive at correct overlay thickness for varying temperatures extrapolation of the plot can be done. For, HMA Pavements Overlay correction can be obtained as, Overlay thickness for 8ºC = 20mm Overlay thickness for 29ºC = 165 mm. Therefore overlay correction factor =165/20 =8.25 similarly for 10ºC overlay correction factor = 165/40 =4.13 and further calculations continue in the same manner, also the equation obtained is CO = -0.5777T + 11.269 similarly for, WMA Pavements Overlay correction can be obtained as, Overlay thickness for 8ºC = 25mm .Overlay thickness for 29ºC = 170 mm. Therefore overlay correction factor =170/25 = 6.8, similarly for 10ºC overlay correction factor = 170/45 = 3.7 and further calculations continue in the same manner, also the equation obtained is CO = -0.5777T + 11.269

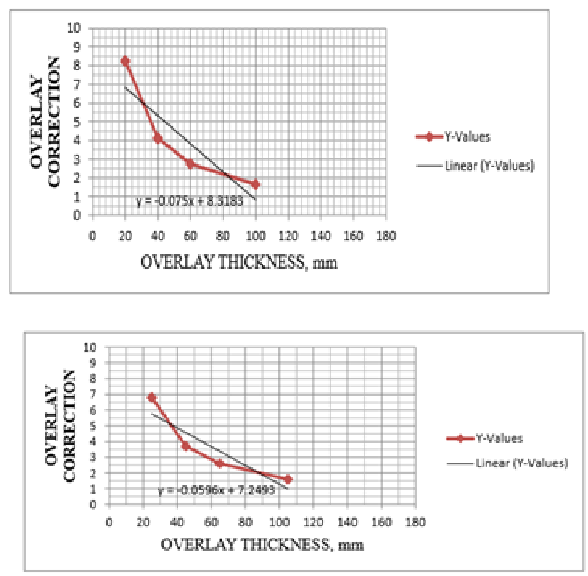
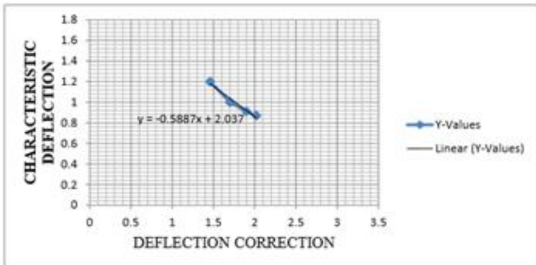


Fig. 10 *Overlay Thickness vs Overlay Correction plot for S1 & S2.*

In these graphs above the overlay correction for its respective thickness has been obtained. These corrections are applied on the actual overlay thickness for temperature less than 20ºC to arrive at its correct value for both the stretches. OC = -0.075x + 8.3183 OC = -0.0596x + 7.2493



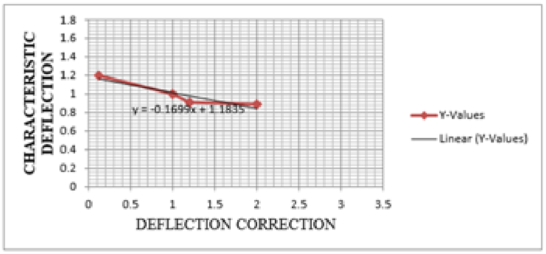


Fig. 11 *Deflection Correction vs characteristic deflection plot for S1 & S2.*

In these graphs above the overlay correction for its respective thickness has been obtained. These corrections are applied on the actual overlay thickness for temperature less than 20ºC to arrive at its correct value for both the stretches. CD = -0.5887x + 2.037 CD = -0.1699x + 1.183

6 CONCLUSIONS AND FUTURE SCOPE

After evaluating the selected sites i.e., S1 and S2 we came to the following conclusion:

1. The condition of the road stretch S1 is good but it may require strengthening and road stretch S2 is also good but due to the presence of flood channel in the vicinity which may weaken the sub grade and due to unanticipated traffic that runs on the stretch due to diversion of vehicles as results of flyover construction 2 may also require strengthening.
2. The stiffness of bitumen varies with temperature and hence the deflections showed at low temperatures are inaccurate which produce incorrect values of overlay thickness.
3. The thickness of bituminous overlay was determined on the basis of characteristic deflections and design traffic as per guidelines laid by IRC: 81. The guidelines give the thickness of overlay required in terms of BM and the thickness of each layer shall not be less than 50mm.
4. Taking into consideration the msa, of the two stretches and their subgrade soil conditions the overlay thickness design attained for each layer should have been 75mm as per the previous design of the authorities or at least 50mm specified by IRC: 81.
5. By designing overlay thickness for stretch S1, as per Characteristic deflections and Design Traffic data obtained during field tests, different levels of BM thickness (20mm, 40mm, 60mm,100mm) were obtained for respective temperature variations (8˚C, 10˚C, 13˚C, 18˚C) and were found inappropriate as per IRC : 81 Guidelines.
6. Similarly the overlay thickness design for stretch S2, as per Characteristic deflections and Design Traffic data obtained during field tests, different levels of BM thickness (25mm, 45mm, 65mm,105mm) were obtained for respective temperature variations (8˚C, 10˚C, 13˚C, 18˚C) and were found inappropriate as per IRC : 81 Guidelines.
7. This is the reason why code restricts strengthening of pavements at temperatures below 20ºC. With the use of various plots and equations provided in this report the overlays can be correctly designed at low temperatures by extrapolating the graphs.
8. The existing HMA pavement thickness was 450 mm and the newly introduced WMA pavement was 525 mm on providing an additional overlay of 150 mm for both the overall thickness comes out to be 600 mm and 675 mm respectively which is relatively much lower than the thickness we get, when it is designed by CBR which comes out to be 869mm and 865 mm.
9. The wearing course provided for both HMA and WMA Pavement as per overlay designed comes out to be 40 mm in terms of BC which is as calculated from CBR method

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FUTURE SCOPE

1. By comparing the results at two series of temperatures it was possible to arrive at various co-relations (equation) and plots that can be obtained between various parameters and can be applied for design in cold regions.
2. These co-relations can be used in future to design overlay thickness for Hot Mix Asphalt pavements and Warm Mix Asphalt Pavements below 20˚C in Cold regions of India. (If code permits).
3. Structural evaluation of the pavement can be done by using falling weight deflectometer (FWD) and/or light weight deflectometer (LWD).
4. Alternate material can be used in the pavement designing.

7 REFRENCES

[1] Ambika Behl, “Evaluation of Field Performance of Warm Mix Asphalt Pavements in India," (2013).
[2] Bexabith A G and Chandra S (2009), 'Comparative Study of Flexible and Rigid pavements for Different Soil and Traffic Conditions.
[3] Crovette J A (2005), 'Development of Rational Overlay Design procedures for flexible pavements',
[4] Dr. Ashwin and Gulzar Mohammad, “A study on City road widening project based on prediction of level of service (los)- a case study in Siliguri West Bengal”(2015)
[5] G .R Singh, “Structural evaluation using Benkelman beam deflection technique and rehabilitation of flexible pavement for state highway 188.(2017).
[6] Hoffman M S (2000), ‘A direct method for evaluating the structural needs of Flexible pavements based on FWD Deflections',
[7] Mohit R.K, “Warm Mix asphalt a boom to pavement structure. (2016)
[8] IRC: 81-1997 “Strengthening Of Flexible Road Pavements Using Benkelman Beam Deflection Technique”, Indian Road Congress, Specifications, Nehru Place, New Delhi, 110019.
[9] IRC: 37-2001 “Guidelines For The Design Of Flexible Pavements”, Indian Road Congress, Specifications, Nehru Place, New Delhi, 110019.
[10] K.R Arora. (2009) “Soil Mechanics and Foundation Engineering”, Published By Standard Publishers, New Delhi, 110006.
[11] Khaled A and Anaza P E, 'Performance based models for flexible pavement structural overlay design', (2005)
[12] MORTH: Development Of Methods: Benkelman Beam Method For Evaluation Of Structural Capacity Of Existing Flexible Pavements And Also For Estimation And Design

Of Overlays For Strengthening Of Weak Pavements, Research Scheme R-6 Of Ministry Of Surface Transport (Roads Wing), Final Report Submitted By Central Road Research Institute, 1995, New Delhi.
[13] Ram A , 'Maintenance Cost Study on flexible pavements in India', Highway Research (1999)
[14] Sunil S., "Study on performance of flexible highway pavements",(2018).
[15] Saji G, Sreelatha T, Sreedevi B G (2013), 'A Case Study on Overlay Design using HDM-4'