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APPLICATION OF THE DISSIPATED ENERGY CONCEPTTO THE FATIGUECRACKING IN ASPHALT PAVEMENTS

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ABSTRACT: Highway pavements, when constructed will not last forever. After a time, signs of wear will appear. These signs include cracking, rutting and polishing of the road pavement. Loss of skidding resistance and loss of texture are forms of pavement maintenance. The structural purpose of the pavement is the support of vehicle wheel loads applied to the carriageway and the distribution of them to the subgrade immediately underneath. One of the principal mechanisms causing failure in Flexible Pavements is the development of fatigue cracking on a bituminous surface due to repeated cycles of tensile stresses generated by vehicle loading. The long life of pavements can also be achieved by the removal of any cracked or severely rutted material, before the defects has progressed too deeply, and its replacement with the new material. A constant load is applied to a flexible pavement material, the strain of the material is proportional to the applied stress and when the load is withdrawn, thus there is a complete regain to the original position. The behaviour of flexible pavement material in which a constant stress increases the strain over a long time and when the applied stress is removed, the material fails to attain its original position leading to permanent deformation. Fatigue can be minimized by controlling the dissipated energy. In the present study, various types of bitumen available for the flexible pavement purposes are being compared and discussed in respect of bitumen content, strain level, and testing temperature on dissipated energy on NH-1A and testing the material properties like softening point, penetration, bitumen concrete extraction gradation, flakiness and elongation index test, Bump integrator Test, flexural beam fatigue.

I. INTRODUCTION

For this present study regarding application of the dissipated energy concept to fatigue cracking in bituminous pavement, a section is falling between Srinagar (J&K) and Jammu (J&K) measuring a length of 267.40 Kms with a four lane highway arrangement on National Highway 44 (NH-1A). The site under consideration is due to the reasons that it is connects the Kashmir Valley with the rest of the India. The highway starts from Lal Chowk, Srinagar and passes through pulwama district, Anantnag district, Kulgam District, Ramban district, and Udhampur District, and ends in Jammu City. The highway lies in the Kashmir valley for the first 68 km (uptoQazigund), then passes through a series of mountains up to Jammu. The Government of Jammu and Kashmir maintains and improves the highway. Notably, the tunnels, such as the Chenani-Nashri Tunnel and the BanihalQazigund Road Tunnel have reduced the distance between Jammu and Srinagar. A railway line runs from Baramulla at the western end of the Kashmir Valley, to the south end of the Srinagar and finally concludes at the Banihal south of the PirPanjal Range via Banihal Railway tunnel (6.969 mi) .

II. OBJECTIVES

The objective of this work is to evaluate and develop the concept of dissipated energy to explain the fatigue process in bituminous materials.

The visco-elastic properties of pavement is calculated for the energy that gets dissipated due to fatigue cracking.

The main objective of the present study shall be carrying out a survey on pavement cracking present in the section of National Highway of India.

The specific objectives of this study are:

1. To identify the different locations of pavement failure & cracking's in the highway.
2. The frequency of pavement cracking present on this highway stretch.
3. To study possible causes of these distresses and at meantime suggesting remedies and solutions for these distress.
4. To assess the performance of the Highway.

III. LITERATURE

The ability of a material to withstand repeated application of stress generally at a level below the tensile strength of a material without fracture. The importance of testing asphalt mixtures for fatigue performance was first recognized in the 1950's (Hveem.1955) due to increasing concern with the pavement cracking. Since that time, significant process has been made with regard to the understanding of fatigue behaviour of asphaltic mixtures. Fatigue cracking can be generally considered as occurring in two stages.

1. The formation of crack (crack initiation)
2. The growth of crack (crack propagation)

In order to build more durable roads for tomorrow, it is imperative to find out how pavements and materials will perform under repeated heavy loads. The deterioration of the pavements shows slow progress during the initial years after construction, but very fast progress during later years. Performance evaluation involves a thorough study of various factors such as subgrade support, pavement composition & its thickness, traffic loading and environmental conditions. The evaluation is broadly classified into Structural evaluation and Functional evaluation. Pavement evaluation process is normally represented using four criteria's namely, Pavement Roughness (Reliability), Pavement distress (Surface condition), Pavement deflection (Structural failure) and Skid resistance (Safety).

IV. METHODOLOGY

In Hot Mix bituminous pavements, fatigue cracking occurs when repeated traffic loads ultimately cause sufficient damage in a flexible pavement to result in fatigue cracking. A number of factors can influence a pavement's ability to withstand fatigue, including pavement structure (thin pavements or those that do not have strong underlying layers are more likely to show fatigue cracking than thicker pavements or those with a strong support structure), age of the pavement, and the materials used in construction. The flexural fatigue test is used to investigate fatigue as it relates to Hot Mix bituminous construction materials.

FATIGUE LIFE CONCEPT:

The concept of a fatigue life centres on the universal idea that most materials undergo a gradual deterioration under repeated loads that are much smaller than the ultimate strength of the material. A paper clip can be broken by repeatedly bending it just as a large pressure vessel can fail after being subject to many thousands of pressure cycles. Hot Mix bituminous pavements are similar.

Asphalt Mixture Characterization:

For the laboratory study, aggregate of sizes 20 mm, 10 mm, stone dust and lime must be used and tested as per IS Standards. Bitumen of Viscosity CRMB 60 as well as conventional bitumen of various grades must be considered for the test purposes to obtain the results and many other types of bitumen such as Conventional Bitumen CB (80/100), CB (60/70) and so on are available. CRMB 60 and CB (60/70) must be used and tested as per Bureau of Indian Standards (BIS).

Bump Integrator:

The roughness of pavement surface is commonly designated as unevenness index value and is expressed in surface roughness measured by a Bump Integrator. Roughness index is represented as the ratio of the cumulative vertical displacement to the distance travelled and is expressed in mm/Km.

Marshall stability:

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method.

Other tests include:
Specimen preparation
Flexural Fatigue Test Principles
Preparation of Bitumen Concrete Mixture
Flexural Fatigue Test.

V. DATA COLLECTION AND ANALYSIS

1. Penetration of Bituminous Material

(Bitumen Grade: CRMB 60)			
Trial No.	Readings		Penetration in 1/10th mm
	Initial	Final	
1	0	37	37
2	0	40	40
3	0	39	39

2. Softening Point Test

Specific Gravity of Bitumen: 1.024		Grade of	Bitumen : CRMB60
Rate of Heating 5^{0}C /min :15			
Time (min)	Temp. Of water bath ^{0}C	Time (min)	Temp. Of water bath ^{0}C
0	5.0	0	5.0
1	9.8	1	9.8
2	14.9	2	14.9
3	19.5	3	19.5
4	24.1	4	24.1
5	29.6	5	29.6
6	34.7	6	34.7
7	38.2	7	38.2
8	43.9	8	43.9
9	48.0	9	48.0
10	53.3	10	53.3
11	56.4	11	56.4
12	60.2	12	60.2
13	64.2 ^{0}C Touch	13	64.2 ^{0}C Touch

3.Gradation Test Results

Sieve Size (mm)	Weight Retained (gm)	Cum. Weight Retained (gm)	Cumulative % Retained	% of Passing	Specified Limits MOST (500-18) Gr-2	Specified Limits JMF	JMF Variation
19.0	0	0	0	100	100	100	
13.2	103.4	103.4	8.6	91.4	76-100	83.8-95.8	±6%
9.5	135.8	239.3	19.80	80.2	71-89	73-85	±6%
4.75	243.5	482.7	39.2	60.8	54-72	54-64	±5%
2.36	153.6	636.2	52.5	47.5	42-58	42.4-50.4	±4%
1.18	103.8	740.1	61.23	38.77	34-48	34.5-42.5	±4%
0.600	95.3	835.4	69.0	31.0	25-37	29-37	±4%
0.300	101.3	936.4	77.3	22.7	19-29	19.6-25.6	±3
0.150	88.5	1025.0	84.7	15.3	11-19	11-17	±3
0.075	102.4	1127.5	93.4	6.6	5-11	5.6-8	±1.5

Gradation of the bituminous concrete

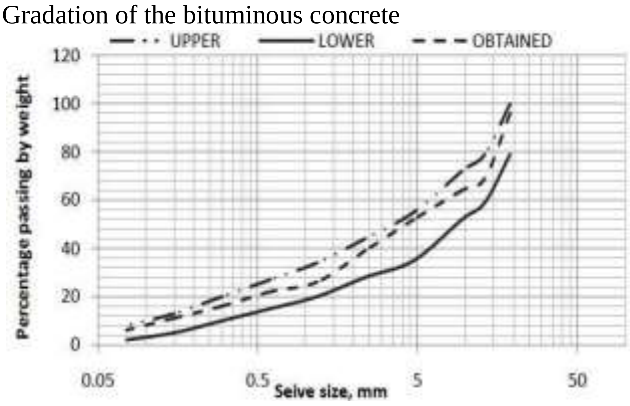
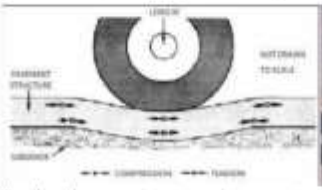


Table 4.27 Effect of temperature on fatigue life & dissipated energy

Mix	Fatigue life (No. Of load cycles)			Dissipated Energy (MJ/m^3)		
	250 Micro strain	400 Micro strain	750 Micro strain	250 Micro strain	400 Micro Strain	750 Micro strain
30°C	7706	9207	10870	0.0562	0.0432	0.0110
20°C	6596	6190	10275	0.0465	0.0371	0.0030
5°C	5383	4795	9681	0.0051	0.0156	0.0091


Tensile and compressive stresses in pavement


Fatigue Cracking

4. FLANKINESS AND ELONGATION TEST RESULTS

Sieve Size (mm)		Total Wt. Of agg. Retained on sieve (A) (gm)	Wt. agg Passing From thickness gauge (B) (gm)	Wt. agg Retained on thickness gauge (C) (gm)	Wt. agg. Ret on Length gauge After ret On Thickness gauge (D) (gm)
20.0	16.0	2114	270	1845	238
16.0	12.5	1145	148	998	140
12.5	10.0	699	98	604	90
10.0	6.3	288	38	221	34
Total		4246	554	3668	502

Flakiness index= $\frac{\sum B}{\sum A}$ *100 =13.04 Elongation index= $\frac{\sum D}{\sum C}$ *100 =13.68

Combined Index = 26.72

VI. CONCLUSION

In this present work, evaluation and development of the concept of dissipated energy to explain the fatigue process in bituminous pavement materials has been conducted. The CRMB 60 (Crumb Rubber Modified Bitumen) improves the viscoelastic behavior of the bitumen and changes its rheological properties. The penetration value of paving bitumen is affected more by temperature changes i.e. temperature susceptibility. Viscosity Grading (VG) i.e. degree of fluidity, higher the grade, stiffer the bitumen. At lower strain levels, mixes prepared with crumb rubber modified bitumen had higher fatigue life as compared to mixes prepared with conventional bitumen. The Marshall Stability Test results indicated higher stability for dense graded mixtures prepared with CRMB 60 bitumen than CB (60/70). The elastic recovery in conventional binder is much less than that of CRMB 60. So, the conventional binder does not recover its original shape when tension is released but CRMB 60 recovers to its original when load is withdrawn at a faster rate. This degree of elastic recovery was used as an indicator of permanent deformation in pavement materials.

The Flexural Fatigue Test is routinely used to determine the fatigue life of bituminous materials. The flexural fatigue test result showed that the addition of CRMB increased the fatigue life of the bituminous mix; it could sustain higher number of load cycles in comparison to conventional bituminous mix.

VII. FUTURE SCOPE

Based upon this work, further application of the dissipated energy concept to the cracks in bituminous pavements under traffic load conditions using Finite Element Method (FEM) can be evaluated. Several different polymer types with same base bitumen, for example by blending base bitumen with thermoplastic polymer, thermo elastic polymer and high boiling point petroleum oil in order to improve rutting and fatigue resistances as well as low temperature cracking shall be studied. Conduct more experiments for fatigue damage, including more mix variables and different rubber size to evaluate the effect of the particle size and texture of rubber. A life cycle cost analysis of pavement constructed using various polymer-modified bituminous binder in comparison to those constructed using conventional binder needs to be performed.

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