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REVIEW PAPER ON APPLICATION OF THE DISSIPATED ENERGY CONCEPT TO FATIGUE CRACKING IN FLEXIBLE PAVEMENT 187.020 TO 205.070 AMBALA-MOHRA SECTION OF CHANDIGARH NEW DELHI NATIONAL HIGHWAY 1

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Abstract:- Bituminous surfacing of pavements exhibit flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. Commonly bituminous concrete used as surface course mixes produced with conventional bitumen a viscoelastic material and temperature susceptible. It is also prone to permanent deformation under repeated axle loads. The flexural stiffness, phase angle, energy dissipation were calculated from the load-displacement data and fatigue life was calculated using all the aforementioned approaches. The fatigue life of asphalt concrete pavements depends on stiffness of the mix, bitumen content, softening point of bitumen, viscosity of bitumen, grading of aggregate, construction practice, traffic, and climate. Aggregate shape also indirectly influences fatigue performance by its effect on applied strain. Pavement Maintenance validated using pavement condition survey data from NH 1 from Ambala to Mohra.

Keywords: Fatigue cracking, flexible pavement, maintenance, fatigue life, dissipated energy

INTRODUCTION

Fatigue cracking occurs when materials are subjected to repeated application of loads at a level, which induces stresses generally below the tensile strength. In road pavements, traffic induces stresses and a strain at the underside of then bound bituminous layer has been linked in this form of cracking. The cracking can result in moisture penetration and this in turn can cause weakening of the soil foundation, accelerating the failure of pavement structures. The need to protect the considerable value invested in road pavement prompts the need to understand the fatigue mechanism in relation to road pavement performance. The engineering properties of bituminous paving materials and analysis of the pavement structure are both so complex that, for many years detailed structural analysis was not attempted. When pavements for road vehicles consisted essentially of unbound materials such as, gravels, crushed stones etc covered with thin bituminous treatments such as surface dressing or a thin bituminous mixture, the choice of materials and the thickness required to carry traffic are based on experience. This experience has been originally that of individual pavement engineers but gradually it has rationalised and presented in the form of tables or charts. Many such systems are developed for particular locations by making appropriate allowances for factors such as climate, soil type, drainage and effects of frost.

Various types of cracks such as longitudinal, and transverse or alligator cracks are formed due to temperature changes in the pavement layer and repetitive vehicle loads on the pavement surface. The pavement material fails due to various types of stresses and deflections occurring at the cracks. The cracks start widening forming more crack area, which leads to forming of potholes. Each type of cracking undergoes loading effect in the form of deformation, breaking of pavements, and bending stress development.

- Longitudinal cracking occurs due to shrinkage.
- Transverse or alligator cracks are caused due to decrease in relative bearing capacity of subgrade.

Some of the recent issues

1. Integrated mix design – structural design approach.
2. Damage considerations in pavement design.
3. Design of pavement with recycled/ marginal material.

To study the dissipated energy concept to fatigue cracking in flexible pavement from Ambala to Mohra lies in the Haryana state and the distance between the two stations is 18 Km. In this section of National Highway 1, I have to thoroughly study the fatigue cracking and the energy dissipated through these cracks when a number of vehicles passes on it. This section of pavement which lies between these two stations and the material used has also been observed. The visco-elastic properties of bituminous materials and their relationships for fatigue performance are also taken into consideration.

Flexible pavement

Flexible pavement is that which are having low or negligible flexural strength and are flexible under the loads. When the vehicle moves on the pavement surface, a load is applied on the pavement layers & these pavement layers reflect the deformation of the lower layer on to the surface of the layer. Flexible Pavement is the pavement surface which reflects the total deflection of all subsequent layers due to the traffic load action. The design of flexible pavement is based on the load distributing characteristics of a layered system. It transmits load to the subgrade through a combination of layers. Flexible pavement distributes load to a smaller area of the subgrade beneath relative to the surface course. The initial installation cost of a flexible pavement is quite low that is why this type of pavement is more commonly seen everywhere. However, the flexible pavement requires maintenance and routine repairs every few years. In addition, flexible pavement deteriorates rapidly; cracks and potholes are likely to appear due to poor drainage and heavy vehicular traffic.

Material used

Flexible pavements support loads through bearing rather than flexural action. It is comprised of several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath. The design of flexible pavements is ensured that the load transmitted to it, does not exceed the layer’s load-bearing capacity. A typical flexible pavement section is shown in Figure 1

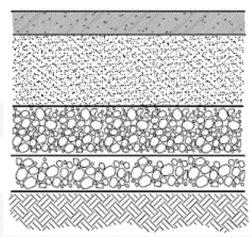

Figure 1

Figure 2 depicts the wheel load moving over may cause high tensile strains at the bottom of the bituminous layer.

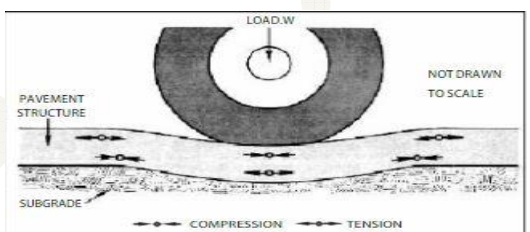

Figure 2

The various layers composing a flexible pavement and the functions they perform are described below

a) Bituminous Surface (Wearing Course); the bituminous surface or wearing course, is made up of a mixture of various selected aggregates bound together with bituminous binder. This layer prevents the penetration of surface water to the base course and provides a smooth well-bonded surface free from loose particles which might helps to resist the stresses caused by wheel loads and supplies a skid-resistant.

b) Base Course; The base course acts one of the main structural component of the flexible pavement. It distributes the imposed wheel load to the pavement surface, the subbase, also on the subgrade. The quality and thickness of base course must be sufficient to prevent failure in the subgrade and/or subbase. It also could withstand the stresses produced in the base itself and resist the vertical pressures that tend to produce consolidation and which lead to distortion of the surface course and resist volume changes caused by fluctuations in its moisture content. The material used for the base course should be hard and durable aggregates.

c) Subbase; this layer is used in areas where frost action is severe or the subgrade soil is extremely weak. The subbase course functions like the base course. The material requirements for the subbase are not as strict as those for the base course since the subbase is subjected to lower load stresses. The subbase consists of stabilized or properly compacted granular material.

d) Subgrade; the subgrade is the compacted soil layer that forms the foundation of the pavement system. Subgrade soils are subjected to lower stresses than the surface, base, and subbase courses. Since load stresses decrease with depth. The controlling subgrade stress usually lies at the top of the subgrade. The combined thickness of subbase, base, and wearing surface must be great enough to reduce the stresses occurring in the subgrade to values that will not cause excessive distortion or displacement of the subgrade soil layer.

FLEXIBLE PAVEMENT FAILURE

Defects in flexible pavements can be placed into one of five classes. These classes are cracking, distortion, disintegration, slippery surfaces, and surface treatment problems**.**

Cracking

Cracking can be defined as the slight breakage of the pavement surface. To make the proper repairs, first you should determine the type of crack and the cause. The most common types of cracks are alligator, edge, edge joint, lane joint, reflection, shrinkage, and slippage.

ALLIGATOR CRACKS; Alligator cracks are interconnected cracks, forming a series of small blocks resembling an alligator's skin as shown in figure 3. In most cases, excessive movement of the surface causes alligator cracking over unstable subgrade or base courses. The unstable support is the result of saturated granular bases or subgrade. Normally, the affected area is not large. When it does occur on a large scale, the cracking is most likely due to repeated loads above the designed strength of the pavement.

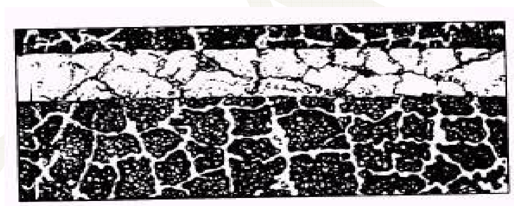

Figure 3 Alligator cracks

EDGE CRACKS.- Edge cracks are longitudinal cracks approximately 1 foot from the edge of the Pavement as shown in figure 4.

Figure 4 Edge cracks**.**

Edge cracks can have transverse cracks, branching in towards the shoulder. Normally edge crack are caused by a lack of side or shoulder support. They also may be caused by settlement or yielding of the base material underlying the cracked area. These cracks may be developed by the result of poor drainage, frost heave, or shrinkage from the drying out of the surrounding earth.

EDGE JOINT CRACKS; Edge joint cracks occur between the pavement and the shoulder as shown in figure 5.

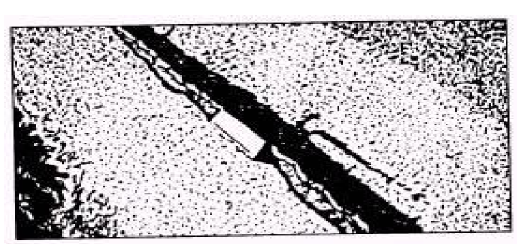

Figure 5 Edge joint cracks

They are normally caused by alternate wetting and drying beneath the shoulder surface. This can result from poor drainage from a shoulder that is too high, or it can result from depressions along the pavement edge.
The uneven pavement traps water on top, allowing it to seep into the base. Another cause could be heavy trucks, straddling the joint.

LANE JOINT CRACKS.- Lane joint cracks are longitudinal separations along the seam between two paving lanes (fig. 6).

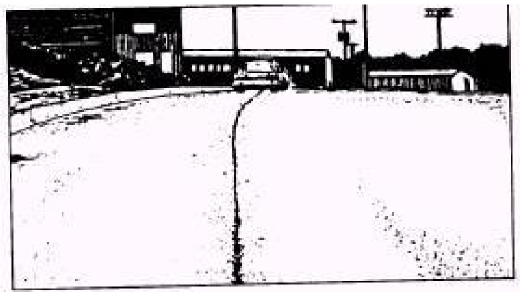

Figure 6 Lane joint cracks.

This type of crack is usually caused by a poor bond between adjoining spreads in the pavement.

REFLECTION CRACKS; Reflection cracks normally occur in asphalt overlays. These cracks reflect the crack pattern in the pavement structure underneath. They are most frequently found in asphalt overlays over Portland concrete and cement-treated bases. Reflection cracks are normally caused by vertical or horizontal movements in the pavement beneath the overlay, resulting from traffic loads, temperature, and earth movements.

REMEDIAL MEASURES TO PREVENT CRACKING

Preventing fatigue cracking can be as simple as preventing the common causes. For example, reducing overloading on an asphalt pavement or improving drainage can prevent fatigue cracking in many cases. Prevention primarily depends on designing and constructing the pavement and subbase to support the expected traffic loads, and providing good drainage to keep water out of the subbase.

A good strategy to prevent overloading, which is a main cause of fatigue cracking, is to increase the depth of the asphalt layer. According to certain researchers, pavements that exceed a certain minimum strength or thickness can hypothetically handle infinitely many loads without showing structural defects, including fatigue cracking. These pavements are called perpetual pavements or long-term performance pavements (LTPP).

When repairing pavement affected by fatigue cracking, the main cause of the distress should be determined. However, often the specific cause is fairly difficult to determine, and prevention is therefore correspondingly difficult. Any investigation should involve digging a pit or coring the pavement and subbase to determine the pavement's structural makeup as well as determining whether subsurface moisture is a contributing factor. The repair needed also differs based on the severity and extent of the cracking.

In the early stages, sealing cracks with crack sealant limits further deterioration of the subgrade due to moisture penetration. Small areas may be repaired by removal of the affected area, and replacement with new base and asphalt surface. Once the damage has progressed or the affected area is large and extensive, structural asphalt overlay or complete reconstruction is necessary to ensure structural integrity. Proper repair may include first sealing cracks with crack sealant, installing paving fabric over a tack coat, or milling the damaged asphalt. An overlay of hot mix asphalt is then placed over the completed repair.

The objective of the 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 & crackings 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

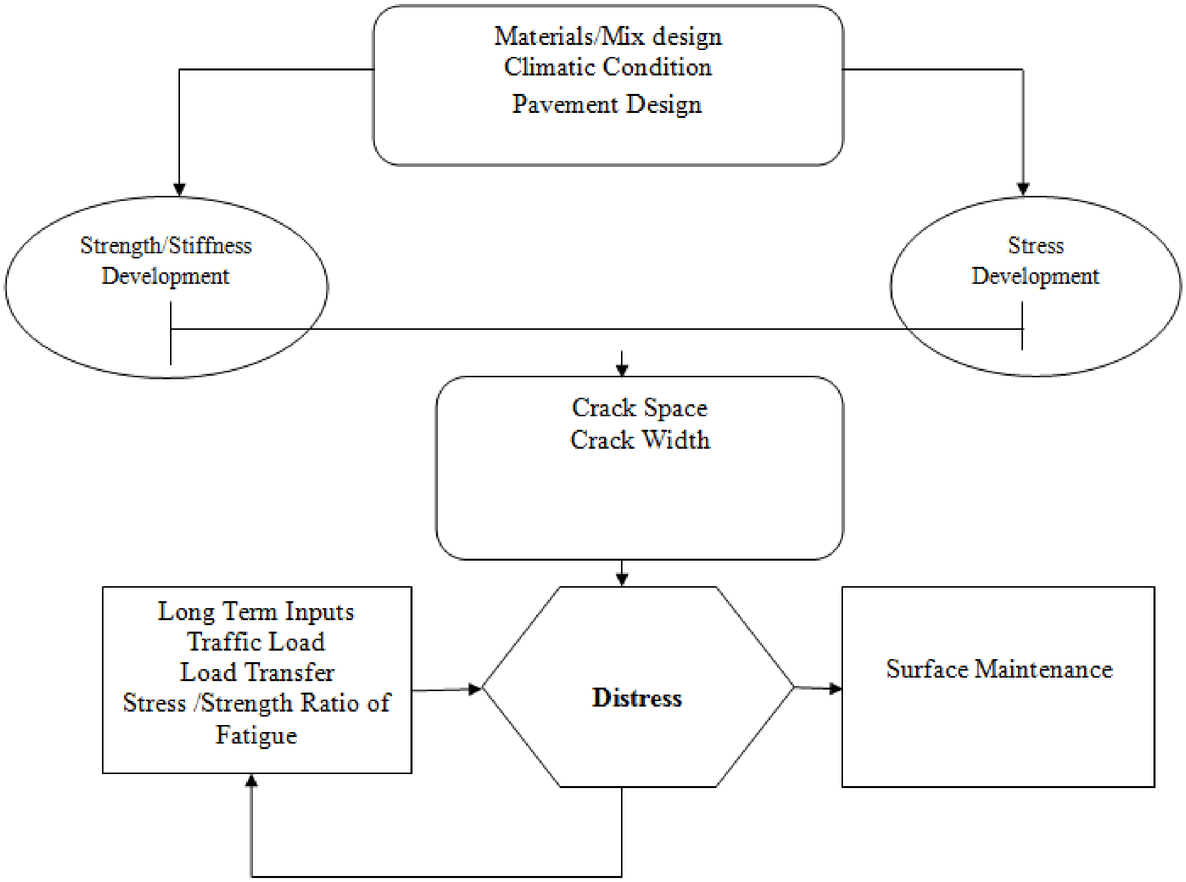

Fig: 7 Flow Chart Diagram Highway Pavement Evaluation

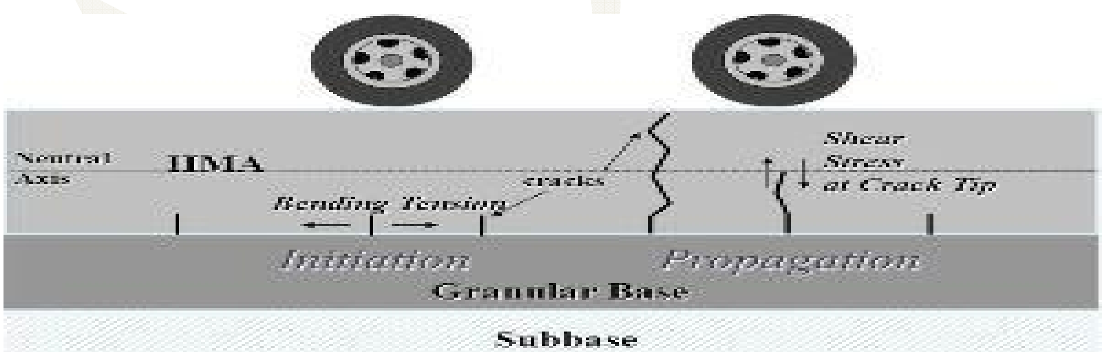

Fig: 8 cracks due to wheel load on pavement surface

Literature Review

Abo-Qudais, S., and Shatnawi, I., (2007) examined the number of cycles occurring until failure can be easily predicted based on the fact that the variation of the slope of the accumulated strain keeps decreasing until the number of loading cycles approaches 44% of cycles that cause fracture occurrence. The effect of different asphalt types and aggregate gradations on fatigue behavior and cycles at which the slope of accumulated strain differs from a decreasing mode to an increasing one. Fatigue and stiffness modulus properties of asphalt concrete mixture need to be considered in the mix design.

Liang and Zhou, 1997 shows Propagation of fatigue cracks, namely, crack initiation, stable and unstable fatigue crackgrowth Fatigue cracks usually initiated in the form of microcracks and proceed to macrocracks, these cracks grow due to shear and tensile stresses in road pavement. Fatigue life of pavement is affected by different properties of the mixture including type and amount of binder used in the mixture, temperature and air voids.

M. Coni & S.Portas et.al, 2011 analysed the Indirect Tensile Fatigue Test (ITFT) is routinely used to determine the fatigue life of bituminous materials. However, the test does not represent the actual flexure of a pavement layer, under a moving wheel. Therefore, a four-point bending apparatus have been developed, as presented in this paper, in order to carry out a comprehensive study on its fundamental characteristics (i.e., geometry, material, asymmetric condition in loads and constraints, etc.) and conseguence on estimated fatigue life.

Mohammad Abojaradeh 2013 concludes that a single failure criterion depending on dissipated energy was presented for fatigue characterization that is independent on the mode of loading. The method shows a well-defined failure condition during the test, strengthening the arbitrary 50 percent reduction in the specimen stiffness. The developed fatigue failure criterion is preferred over other energy-based criteria because of its rationality and accuracy of fit of data. Although the new failure criterion developed in this study has not been calibrated in the field, it has the potential to closely simulate field performance to be used for pavement distribution.

Lee and Kim 2000 have used afore mentioned viscoelastic linear constitutive model to develop a prediction model for fatigue. For the development of this fatigue prediction model, they assume that the test is conducted under controlled strain and consider as failure criterion the loss of half the pseudostiffness. Pseudostrain-based models need additional tests, for example, the creep test, to determine material parameters used by these models.

Qazi Aurangzeb1 , Imad L Al Qadi2 , Hasan Ozer3 2012 shows the use of recycled products in pavements is one approach to build environmental friendly pavements. However, the performance of asphalts with the addition of recycled products can be compromised. Laboratory mix preparation has also been a challenge; especially those with high RAP contents due to variability in RAP stockpiles. This study evaluated the fatigue performance of asphalt mixes with RAP. The fatigue behaviour of the asphalts was studied using classical beam fatigue and push-pull fatigue tests. In case of beam fatigue test, two approaches to predict the fatigue behaviour of the asphalts were compared i.e. conventional fatigue curve approach and PV approach. It was observed that the two methods gave contradictory results; the fatigue curve approach showed an improvement in fatigue behavior with RAP addition; whereas, the PV method showed that the addition of RAP might potentially reduce the asphalt fatigue life.

CONCLUSION

The average depth of potholes found in NH-1 for the section Ambala to Mohra is 20-40 mm deep, and the deepest pothole found being 150 mm. The bleeding distress has been found along this particular section of a road. The interval of the pavement failure due to cracking is too frequent and well exceeded the standard. The fatigue life increases with the increase in large size aggregate in the mix. The optimum binder content is reduced and shear strength (stability) of the mix is increased. However, the effect of aggregate gradation on fatigue behaviour is more prominent than the effect of asphalt content.

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