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Evaluation of Critical Parameters Causing Premature Failures in Asphalt Pavement

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A B S T R A C T

The current examination focusses on the presentation of adaptable asphalt at an alternate temperature. The examination is done utilizing 2D axisymmetric limited component model for a blend of differing thicknesses of a bituminous layer with base and sub-base. The examination is a lot of valuable to know the conduct of adaptable asphalt under differing climatic conditions alongside stacking and material properties. The basic boundaries are inspected to know the reason for disappointment of the current asphalt structure. The investigation assesses diverse asphalt troubles regarding rutting and weakness life.

Keywords: Watchwords: Rutting, Weariness, Untimely Disappointment, Adaptable Asphalt

1. INTRODUCTION

Ongoing advancement in vehicle area causes passage of substantial multi-hub trucks which were not considered in plan manuals in numerous pieces of the world. Expanded traffic with more number of business vehicles proceeding onward existing asphalt much past its ability. This basic stacking boundary alongside fluctuating climatic conditions like temperature makes it more perplexing to gauge the exhibition of asphalt which requests improvement of a scientific apparatus to oblige all such basic issues which isn't the piece of existing asphalt plan method. Decay of asphalt begins following its opening to traffic, in its initial age the interaction is moderate however shows huge impact later on, what begins with the development of various kinds of breaking which is eventually a consequence of exhaustion or rutting disappointment at basic areas. Non-industrial nation like India where foundation offices are the foundation of advancement in all viewpoint yet because of the disappointment of asphalt before its plan life causes tremendous misfortune for upkeep and development for these disintegrated asphalt structure.This issue examined by changing thicknesses of different layers with shifting material properties for an alternate mix of bituminous layers. The investigation is completed utilizing 2 D hub symmetric limited component model to distinguish the conduct of adaptable asphalt at different temperature conditions. This investigation can be helpful to distinguish potential materials for various temperatures according to IRC 37 (2012) [11].

The malleable strain underneath bituminous layer alongside compressive strain over subgrade layer are basic boundaries while investigating the presentation of the adaptable pavement. The methodology for a disappointment of asphalt begins because of numerous variables like weakness, rutting, temperature, and leakage with their individual and joined impact together. In India the essential control of individuals dependent on farming and unified exercises where around 70 % individuals are living in the rustic piece of the country and they are reliant upon a close by metropolitan territory for any remaining significant exercises and used to travel oftentimes according to their necessities. Despite the fact that there is various progression in the street area because of expanding urbanization the essential street clients are utilizing the vehicles more than its lawful burden conveying limit, even dependent upon 2 to 2.5 occasions than passable stacking condition for moving horticultural based materials. Then again lopsided climatical/natural conditions, erratic precipitation, extreme sweltering and cold environment are prompting be significant reason in the decay of streets through rutting and fatigue.

2. LITERATURE REVIEW

In Over the years number of pavement response models are developed basically which starts from Boussinesq's one-layer model to find stresses, strains, and deflection for homogenous, isotropic, linear elastic theory. The study was more useful for different layers of pavement with same stiffness values. Burmister presented multilayered pavement section which can be examined by finite element model. Huang Y Yang [9] identified various factors like frost infiltration, ground water, freezing index which has to be focused to know their influence on the performance of the pavement. Helwany Sam et al. [8] applied varying loads with different axle load configuration, varying tyre pressure for elastic and non-elastic materials and proposed necessity of finite element model to predict its effect on behaviour of flexible pavement.

Arpan Ghosha et al. [5] studied various factors like pavement temperature, the material characterization in accordance to current design procedure in India, to know their effect on pavement performance using AASHTOWARE software. The study shows that bituminous layer thickness should have more thickness when compared with constructed pavement cross section.

Tapase et al. [25] analyses critical parameters by varying materials and thicknesses of different layers to show the usefulness of finite element model. Increased bituminous layer thickness shows decreasing values of tensile strain and compressive strain. Ranadive M. S. et al. [21] reported that reduced base and sub base thicknesses show more deflection on pavement surfaces.

R. M. Mulungye et al. [17] informed that by variation in wheel configuration, tyre pressure and axle load on soft subgrade and compared with actual field data by recognizing the use of finite element modeling. Such validated model seems to be very useful to forecast the behaviour of the flexible pavement

Rahman M.T, et al. [18] studied different parameters like axle configuration, tyre imprint to find its effect by finite element analysis using ABAQUS software. The study shows that tyre imprint having two semicircles on either side of a rectangle was more accurate than other tyre imprints.

Guangming Wang et al. [7] examines by varying tyre pressure with different axle configuration using finite element and developed pavement interaction model validated with actual field data. The major finding of the study shows that single tyre (super-size) damages more near the surface than wide-based tyres. Yuhong Wang et al [26] suggested that pavement can be designed for heavily trafficked pavement as after its extensive use lacking between bonding and air voids acts separately and together. The main cause of failure of pavement has to be addressed and good maintenance practice should be followed during different phases of construction as per changing climatic condition.

Sanaa Masad et al. [24] reported that bottom side of asphalt layer shows higher tensile stresses for consideration of anisotropic material characterization for different layers of pavement, when evaluated with National Cooperative Highway Research Program (NCHRP) 1-37 [14] models. Andrew Chiasson et al. [2] studied the relation between temperature distribution and thermal stresses by 2-dimensional finite element modeling. Immanuel et al. [10] predicted stresses in base and subgrade by elastic analysis and was compared with field data which shows that this method of analysis is appropriate for dynamic loading under varying environmental and loading conditions.

3. METHODOLOGY

The methodology framed for the current work is based on the consideration of critical parameters identified from rigorous literature survey along with in respect of different procedures described for design of flexible pavement by various institution like Indian Roads Congress (IRC), National Cooperative Highway Research Program and AASHTO standards. The performance of flexible pavement depends upon various factors like material strength, environmental conditions, type of loading, axle configuration along with tyre pressure and many more. It is obvious to calculate fatigue and rutting for forecasting the pavement life. Various types of materials and their combinations has to be used for extending pavement life. So the present study concentrate on to find an economical blend for practical field conditions to have optimum thicknesses of pavement sections for different materials and loading conditions.For this study depending on necessity of the problem the analysis is carried out by considering temperature, freezing and thawing as a one of major phase for variation in temperature.

For this analysis a section consist of two layer of total pavement thickness 560 mm including 110mm of bituminous layer and 450 mm base layer resting over subgrade soil of 900 mm is considered. A mesh consist of 958 nodes and 880 quadrilateral elements are considered for idealization. The horizontal extent for the analysis is about 14760 mm which is around 3 times of pavement width, denoting undefined horizontal extent of soil strata. A four noded quadrilateral elements are considered for the idealization by two dimensional finite element analysis.

It is observed that the boundary condition described by values of initial temperature condition at bottom of subgrade and atmospheric temperature condition. In present analysis the temperature at bottom of subgrade layer is kept constant at 22^{0} C and atmospheric temperature at surface is to 42^{0} C.

Also to calculate the temperature at any point within pavement section due to freezing negative temperature at bottom of subgrade is considered for the analysis. It can be possible to predict the temperature at any

point in multilayer pavement section by doing such type of analysis if initial conditions are defined.Investigation of Critical Parameters Initiating for Premature Failure of flexible pavements in India-

In India, various types of roads like Expressway, National Highway, State Highway, District Roads are designed as flexible pavement by referring Indian Road Congress design manual (IRC 37 - 2012) .Early deterioration of such pavements much earlier than their design life are because of various causes like varying average annual temperature, rainfall intensities, drainage condition, varying ground water depth and their negligence while design of roads.

The climatic condition in India, divides the country into six climatic zones with too much of variation in different parameters such as average annual temperature and rainfall intensities for various parts of country. Also the variation in soil types and their characteristics like CBR values which is one of the most important input parameter to decide pavement thicknesses of different layers of flexible pavement makes it more critical. It is found that design manual referred for design of flexible pavement (IRC 37- 2012) is not addressing these critical parameters in detail which causes early deterioration of flexible pavement much earlier than its design life.

3.1 Pavement Composition:

The analysis was carried out by varying the thicknesses of bituminous layer ranging from 125 to 200 mm with top most Bituminous Concrete (BC) layer keeping constant for 100 mm for all the trails while the variation in Dense Bituminous Macadam (DBM) layers with 25 mm sub layer thickness. Granular layer thickness varied between 450 to 600 mm. with 75 mm. sub layer thickness while subgrade layer kept constant for 900 mm. for all the trails. As the temperature in India varies between 50^0 C in summer in the month of April/May while drastically drops even up to 5 ^{0} C to 10 ^{0} C during winter in the month of December/January. Considering these cycles of variation for a temperature changes annual average temperature of 35 ^{0} C is considered for the given analysis. The different material properties along with modulus of rigidity for different layers with respect to its material types are selected as per design code of practice for flexible pavement IRC 37 (2012).

Finite Element Modelling:

Idealisation, formation, and solution of governing equation for the considered system is done by finite element model for evaluating the design procedures as reported by Tapase and Randive et al. [22]. The current pavement design procedure in India is basically considering important parameters like modulus of elasticity (E) and poison's ratio (μ). There is vast scope available for different type of material which can be encountered for construction of pavement with useful field data with different material properties along with their (E) and (μ) values from the available literature. The considered values of E and μ for the present work are shown in the fig. 1 In present analysis based on Gauss Quadrature

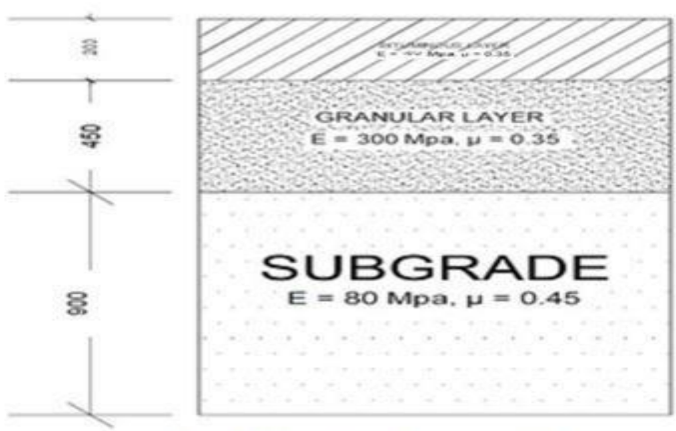

Fig. 1 Pavement Composition

To study the pavement performance, modulus of specific layer is kept constant for designed depth. Different codes like (IRC: 37-2012, AASHTO) suggests the modulus values for different temperature in the range of 22^0C to 42^0C.As per design chart recommended in following chart. Bituminous concrete 50 mm, 125 mm of dense bituminous macadam, 250 mm of granular base and 200 mm of granular subbase while top 50 mm to be used remains same (i.e. value of bituminous concrete suggested by IRC 37-2012). Similarly the value of modulus of remaining layers remains same for their suggested depths. So the design engineer will proposed the thicknesses of different layers of pavement considering that the temperature will remain constant at all depths of pavement which is not correct. But on actual field conditions the temperature at top of pavement, in between layers and bottom layers for varying depths along with respective horizontal locations does not remains constant.

So the proper bitumen grade can be selected by accurately predicting this varying temperature for varying depths together with respective horizontal locations. So the optimum pavement section can only be proposed by considering particular environmental conditions with their effect in variation in intensity of temperature at different levels. The material for various layers can be selected by taking average temperature for that particular depth. Pavement proposed by following this philosophy not only be more stable but economic also, as it is possible to construct pavement section with suitable material for suitable depth

3.2 Interpretation of results for variation of base thickness and material on critical parameters

To know the influence of variation of base thickness and base layer material property, a set of selected nine cases are considered for evaluation. Three base layer thicknesses as 300mm, 450mm and 600mm are compared to observe the effect of thickness variation. Base layers are checked against three material properties for their suitability.

In order to interpret the results, bituminous thickness is kept constant at 175mm and material property (E=1650MPa, μ = 0.35) constant along with subgrade material property as 80MPa. Obtained outcomes are equated with the allowable values of critical parameters as provided in IRC: 37-2012.

From the analysis following observations are derived,

1. The value of $\mathcal{E}$t at bottom of BL for natural gravel (E1=100MPa, μ=0.35) and natural gravel (E2=300MPa, μ=0.35) are exceeding permissible limit at all thickness trials as shown in Figure 3.
2. It is observed that high quality graded crushed rock (E3= 450MPa, μ= 0.35) the values of $\mathcal{E}$t is within the permissible limit for all base thicknesses.
3. From Figure 4, it is observed that the values of cases considered for interpretation are under the allowable limit, for $\mathcal{E}$v on subgrade.
4. When base course material differs from E1=100MPa, μ=0.35 to E2=300MPa, μ=0.35 more than 25 percent decrease in vertical displacement is observed, wherein from E2= 300MPa to E3= 450MPa not even 2 percent decrease in vertical displacement is noticed (Figure 5). Here it is noticed that using stiffer material beyond 300MPa does not reduce vertical displacement, so modulus of the base layer can be restricted at 300MPa.
5. Similarly, it is noticed that increasing thickness of base layer for next trial thickness (i.e. 600mm) gives four times less reduction in vertical displacement value.
6. For all base thickness trails, it is seen that high quality graded crushed rock (E3=450MPa, μ= 0.35) shows the values of $\mathcal{E}$t within the acceptable limit as per IRC: 37-2012. So, it is concluded that the high quality graded crushed rock (E3= 450MPa, μ= 0.35) is the best material for
7. Selected To know the result of variation in thickness of BL and base layer material property, four thicknesses of BL as 125mm, 150mm, 175mm, and 200mm are compared.

Bituminous layers (BL) are checked against three base material properties those are natural gravels (E= 100MPa, μ= 0.35), natural gravel (E= 300MPa, μ = 0.35) and high quality graded crushed rock (E= 450MPa, μ= 0.35) for their suitability. In order to interpret the results, thickness of base layer as 450mm and material property of BL (E=1650MPa, μ = 0.35) are kept constant along with subgrade material property as 80MPa, likewise results reported and compared with allowable values of critical parameters as provided in IRC: 37-2012.

Conclusion:

The results reported by given analysis indicates that the average annual temperature change for upper 0 mm to 110 mm depth is 2.20C. So bituminous mix to be selected should consider this reported average annual temperature, together with the testing to be carried out to find modulus of bituminous mix for average annual temperature of 38.50C.

Also to relate the procedure with practical conditions local appropriate temperature, freezing and thawing records can be produced as boundary conditions for top of surface and bottom of subgrade levels.

The variations in temperature can be predicted by this analysis can be used to select the appropriate materials for different layers of pavement depending on its material characteristics. Even hypothetically designed pavement section can be rearranged to get more stable, economic and ultimately optimum design for particular specific climatic and soil conditions.

The pavement responses including stresses, strains, and deflection which are evaluated from the structural models are used as inputs for distress models. The distress models include fatigue and rutting criteria. In the present investigation, the calibrated fatigue model and a rutting model is used to estimate the fatigue life in terms of a number of the standard axles and the rutting life in terms of a number of cumulative standard axles respectively, both models for 80% reliability level given in IRC: 37-2012 are employed. The computed strains are taken as input and are incorporated in the fatigue and rutting criteria recommended in Indian Road Congress (IRC: 37-2012) to estimate the pavement life for various hypothetical conditions. The fatigue cracking of flexible pavements is based on the horizontal tensile strain at the bottom of BL. On this criterion, the allowable number of load repetitions, (Nf) that causes fatigue cracking is related to the tensile strain ($\mathcal{E}t$) at the bottom of BL. Figure 8 gives a graphical presentation of fatigue life in a number of standard axles on the y-axis versus the thickness of the BL on the x-axis for all trail base material. Figure 9 gives a graphical presentation of a number of cumulative standard axles on the y-axis versus the thickness of the BL on the x-axis for all trail base material.

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