EVALUTION OF BOND BETWEEN BITUMINIOUS PAVEMENT LAYERS

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ABSTRACT: The current work emphases to improve the procedure for analysis and design of flexible pavement by consideration of variety of materials to be used in different layers of pavement together with the environmental conditions on actual field. By using 2 D axis symmetric finite element method performance parameters are studied for varying loading condition, varying material properties for varying soils available in the study areas. Initially, proposed pavement sections from available codes are assumed and validated and horizontal and vertical extents of the mesh are fixed. Field investigation and laboratory analysis was carried out to classify the subgrade soil based on their strength parameter. In the present study, the effect of waste materials individually and in combination on physical properties, rutting, and fatigue behavior of pavement by laboratory and the analytical investigation is evaluated. The various important input parameters like traffic characteristics, moduli of paving materials etc. are used in structural models. The output of structural models in the form of strains, stresses and deflection are used in distress models while the output of this distress models are examined against fatigue and rutting criteria recommended by design manual of flexible pavement (IRC37-2012). The computed strains at the critical locations are compared with allowable limits to decide the thicknesses of hypothetical conditions formed under different combinations of varying materials and varying thicknesses. It is observed that most of the flexible pavement in India are getting deteriorated earlier than its design life. Analytical investigation carried out for overloading and inflated pressure illustrates that overloading seems to be one of the important parameter responsible for early deterioration of pavement. The reduction in pavement life due to overloading is more predominant for the pavements constructed on poor subgrade soils and hence the issue has to be addressed at pavement design stage only. Temperature analysis suggest that design of pavement with back calculated elastic moduli bituminous mixes will be more optimum in depth which ultimately makes it more economical. The design charts proposed by consideration of multiple factors of varying nature is giving more realistic and optimum design charts which can be considered to replace existing pavement section with an ecofriendly and economic approach.

Key words: Flexible pavement, Performance evaluation, Finite element method.

I INTRODUCTION

The development of any country depends on the strength of its road network. Accordingly, several development mega projects are in progress in developing nations like India. Construction of new roads along with under repair or deteriorated condition of roads in terms of cracking, potholes and uneven surface due to rutting is the major cause of road accidents. The World Health Organization (WHO) has already termed the ongoing decade as the decade of action for road safety, as millions of people around the globe are losing their lives or getting permanently injured in road accidents. According to [1] the provisional data released by the government of India, the total number of road fatalities is 1,51,417 in 2018 with 4,69,418 accidents and the country ranks first for the number of deaths due to road accidents amongst 199 countries as per the report submitted to WHO for the issue of global road safety. The Ministry of Road Transport and Highways (MORT&H) [1] has already brought the Road Transport and Safety Bill to strengthen road safety as well as improve ease of transport across the country.

To meet the growth of industrial development and to reduce the traffic density on existing transportation facilities expansion of infrastructure is a must which ultimately helps to reduce the different causes of accidents in many developing countries like India. These increased infrastructure facilities have to cater to traffic on these roads for their changing static and dynamic characteristics of the vehicle, overloaded vehicles. These factors together are responsible for the early deterioration of pavement in terms of potholing, cracking, undulation, raveling, rutting, etc. in the bituminous layer. The instrumented pavement is one of the techniques that can be used to overcome this problem by knowing the effect of these overloaded vehicles, but these locations are widely spaced throughout the country making this process tedious and time-consuming. So this issue can be addressed by preparing proper design charts supported with the proper design procedure to fulfill the present-day requirements .

The present design guidelines are based on the skills, experience, and engineering judgments of the experts from the field for selecting the pavement composition. In an actual sense, the experiences are based on particular local conditions irrespective of regions and different climatic conditions which is the major drawback of the Indian Road Congress

(IRC) and American Association of State Highway Officials (AASHTO) [3] codes. For designing a new flexible there is a necessity to have a tailor-made tool that will predict the performance before its construction for different combinations of material and thicknesses. To achieve a more durable and stronger composition along with a cost-effective approach with bituminous surfacing different compositions with variation in base and sub-base layer along with crack relief layer of aggregate interlayer below the bituminous surfacing, reclaimed asphalt pavement (RAP) base treated with foamed bitumen/ bitumen emulsion, cementitious subbase having Wet Mix Macadam (WMM), base and bituminous surfacing, availability of conventional and alternative materials for road construction can be obtained.

The increasing traffic along with overloaded trucks and significant variations in daily and seasonal temperature of pavements have been responsible for the early development of distress symptoms like raveling, undulations, rutting, cracking, bleeding, and potholing of bituminous surfacing. A good pavement design is one that provides the expected performance with appropriate economic consideration, so, here the need arises to find an economical alternative in the form of an analytical tool that can accommodate the details of the complex pavement system. To reduce the number of road accidents caused due to deteriorated conditions of the road there is an urgent need to prepare a proper blend of design procedure/charts which are practically useful for any combination of material and environmental condition. The application of such an enhanced analytical tool can prove to be beneficial to predict the performance of pavement without actual construction or even surpassing the expensive and time-consuming laboratory or in situ tests. In this connection, the application of the versatile finite element method (FEM) towards the design of flexible pavement holds a perfect assurance. The present work describes the use of two-dimensional finite element analysis (FEA) for exploring the parametric study of flexible pavement..

II LITERATURE REVIEW

The gap investigation for the present work is done after doing a rigorous literature review. The analysis and assessment of findings of different design procedures and methodologies regarding flexible pavement from various parts of the world have been reported as and when as it is essential to prerequisite the problem. The list of literature referred to is attached at the end of the thesis.

III MODEL FORMULATON

Developing countries like India where infrastructure facilities are the backbone of development in all aspects but due to the failure of pavement before its design life causes a huge loss for maintenance and construction for this deteriorated pavement structure. In many parts of the world, the design of flexible pavement is based on considering only empirical approach which leads to either the early failure of pavement or uneconomical pavement section, to avoid this situation the current design procedure has to be updated with experimentation result for a different set of environmental condition with different material properties. (AASHTO) .The current design procedure has to be updated to give a more economical section considering all such critical parameters and their influence on the flexible pavement. To decide such a design procedure an analytical tool has to be developed which will avoid the costly and time-consuming process of the actual construction of pavement and their experimentation . In this regard application of the finite element model for 2 D, the axis-symmetric condition seems to be a sound solution to overcome this hurdle. Rutting and fatigue are two different significant modes of distresses and have to be analyzed differently at two different positions i.e. Tensile strain (Horizontally) at bottom of a bituminous layer and compressive strain (Vertically) above the subgrade layer. Beyond its acceptable limit for fatigue and rutting lives gives rise to different types of failures in the form of various types of cracking.

By varying thicknesses of pavement layer with different materials to calculate rutting and fatigue values of the pavement for a particular environmental condition. Such a validated model seems to be very much useful to revise the design charts and procedures to surpass the mechanistic-empirical design approach. Different thicknesses and material properties for the analysis were considered concerning the design manual of flexible pavement i.e. IRC 37 (2012) .

It is learned that researchers have reported the complex characteristics of flexible pavement throughout the world which needs to be extended to study the effect of different parameters and performance of pavement by estimating pavement life in terms of fatigue and rutting cycles based on Indian conditions and to develop analytical based useful design charts/procedure.

TWO-DIMENSIONAL FINITE ELEMENT MODELING:

The use of versatile software ANSYS allows to perform laborious analysis by two dimensional finite element analysis for the parametric study of pavement. The analysis is done by discretizing the arena into finer elements and leading equations and material properties are implemented to the corners of elements. Equations are formulated by applying constraints of the problem and the solution of these equations shows the response of the continuum under applied constraints or situation . The general methodology followed for design of flexible pavement is shown in Figure 3.1. The poison’s ratio and moduli of pavement materials in different layers of pavement section are the important input parameters for structural models. The output of structural model i.e. values of critical parameters at critical locations were used in distress model. The output from distress model were compared against the failure criteria’s. If the output from distress model is beyond the safe limits the pavement section is not safe and has to be refined by changing the thicknesses and material of pavement section. The outputs from structural model i.e. strains, stresses and deflection when used as input in distress model gives the output in the form of number of repetitions in terms of cumulative standard axles. The above mentioned analysis was carried out for various waste materials after its assessment by laboratory investigation. Further the work is continued for overloading, inflated tyre pressure for all shortlisted trials and the conclusion is drawn based on the analysis carried out for the same.

FIELD AND LABORATORY INVESTIGATION

To get the appropriate results from analytical investigation it is very essential to get the exact values of material properties from experimental work which has to be put as an important input parameters for the analytical investigation. The properties of subgrade soil in terms of strength seems to be the most important input parameter to decide the optimum thickness of any pavement section as the load coming from pavement surface ultimately transfers to the soil underneath the subgrade layer. For this purpose the soil near the vicinity of study area is divided in to number of zones based on type of soils and geology of the area. The soil samples from different zones were collected to perform California Bearing Ratio (CBR) test and accordingly the soils are classified based on their CBR values in terms of percentage. The soil samples from the field were collected and 3 tests were performed for each location and average value is considered as its CBR value to classify the soil based on its strength parameter.

The strength of soil for collected samples from different zones of the study area was determined based on the test results obtained from CBR test method. The locations for soil to be tested are selected amongst near different taluka places of Guntur district, tourist places and towns along NH- 4 as these places are of administrative importance and connected to each other by major district roads or state highways and under revision to upgrade their status due to increase in traffic intensity. The soils from different selected locations were collected after one month of monsoon season to get the appropriate soil strength values. The test results obtained for various locations shows a very wide range of values in terms of variation in strength parameter dividing the soil as poor subgrade soil having CBR values lying in between 1% to 2%, medium soil with CBR values near to 5% and good strength soil having CBR value above 8%. The results obtained from the test can be interrelated to find modulus of elasticity of locally available soil based on the equation stated in design manual IRC 37- 2012. For analytical investigation the modulus of elasticity value of these subgrade soils are considered as an input parameter to propose design chart for the local soil conditions. The present study considers various types of subgrade soils (good and poor) available in different parts of the Guntur district which shows the extreme variation in modulus values ranging between 10 MPa to 120 MPa. Considering these vast variations in the types of subgrade soil's, it is categorized into five types silt (5 MPa), silty sand (25 MPa), sandy clay (45 MPa), clay (80Mpa), and gravel (100 MPa).

Collection of conventional and waste materials from the field

The work carried out in different parts of the world showcased the advantageous for use of waste materials as an alternative to aggregates and bitumen or a combination of both by replacement of conventional materials partially by weight or by volume. The reuse of aggregates and bitumen from reclaimed asphalt pavement (RAP) is a sustainable eco- friendly technical approach towards waste management, which not only proves to be an alternative for conventional material but also helps in maintaining a check on the cost of new pavement . Restoration of pavements is the most appealing rehabilitation technique which is taking shape day by day from the laboratory and field assessments. Various studies have already suggested that the use of reclaimed asphalt pavement (RAP) and warm mix asphalt (WMA) utilizes the minimum amount of conventional material giving a complete coat of binder to the aggregates at lower temperature resulting in a reduction in CO2 emissions and similar properties to that of hot mix asphalt (HMA) .

The crumb rubber used for the pavement construction is considered as a sustainable construction technique . The advantageous of using crumb rubber in bituminous mixes is reported by numerous researcher across the world. Different physical properties of mixes can be enhanced by addition of crumb rubber by finding its optimum percentage, which depends upon the type of bitumen and other local factors like the source from where it is extracted. In the present work crumb rubber, CRMB60 is used as a partial replacement to bitumen by wet method which allows the ingredients of mix to react with each other.

The bitumen binder used for the present work is of VG30 grade having a 60/70 penetration grade which is widely used for paving applications in the Guntur district. Frequently natural aggregates are obtained from parent rock basalt throughout the Guntur district which is the important constituent of road construction. Tests are conducted to check on aggregate to check their suitability for strength, hardness, toughness, durability, adhesion with bitumen, and shape before their use as a pavement construction material.

The use of crumb rubber, which is then reprocessed tyre rubber, based on the type D classification of IS 15462-2004 [60], CRMB 50, CRMB55, and CRMB60 are the crumb rubber modified binders. The construction of flexible pavements is more usually done by CRMB60 in India. Recycled reclaimed asphalt pavement (RAP) aggregates were obtained from the demolished pavement, and extreme care was taken while collecting the RAP materials to keep it free from any contamination. RAP material was collected from Bengaluru-Pune National Highway 4 from three to four locations and the corresponding data were collected from the records of respective government and available codes published by Indian road congress. After following the procedure on collected RAP sample i.e. of crushing followed by screening, and separating in the same size as that of conventional aggregates, it is used as partial replacement to aggregates in varying proportions like 20%, 40%, and 60% for each sample.

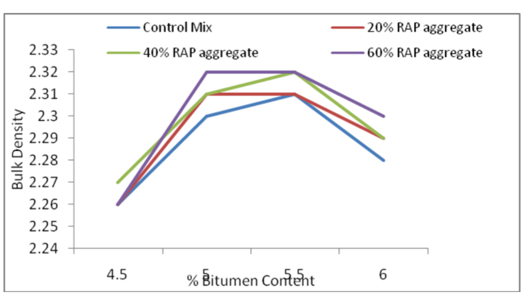

Figure 1 Bulk Density Vs. Percentage bitumen content for RAP aggregate

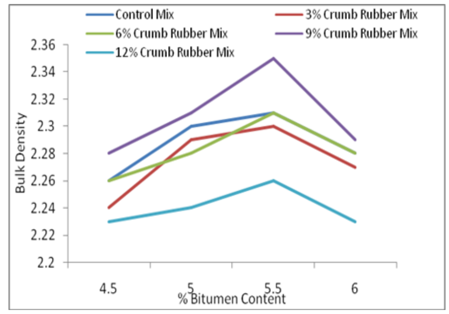

Figure 2 Bulk Density Vs. Percentage bitumen content for crumb rubber mix

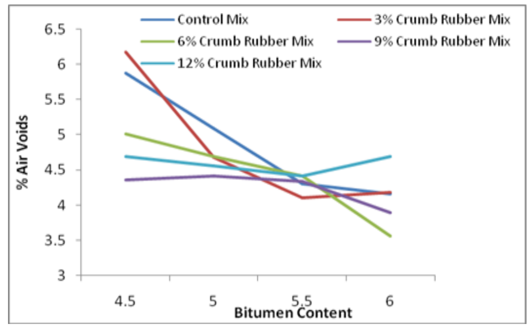

Figure 3 % Air voids Vs. Percentage bitumen content for crumb rubber mix

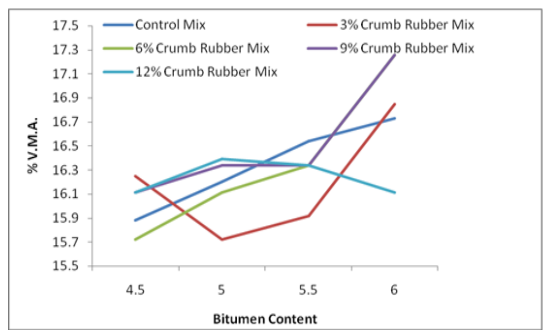

Figure 4 % V.M.A. Vs. Percentage bitumen content for crumb rubber mix

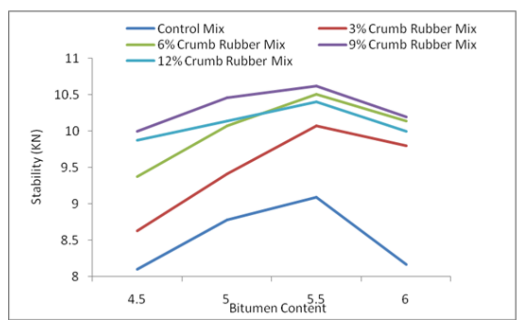

Figure 5 Marshall Stability (kN) Vs. Percentage bitumen content for crumb rubber mix

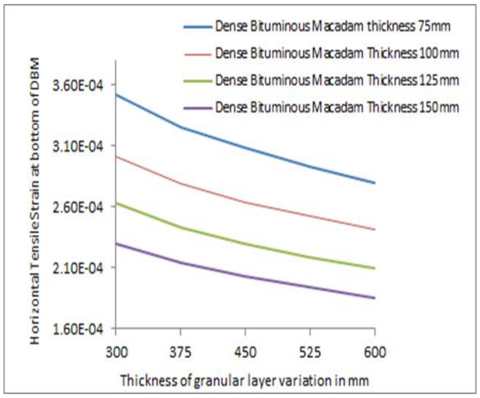

Figure 6 The thickness of granular layer variation Vs. Horizontal tensile strain at bottom of DBM layer

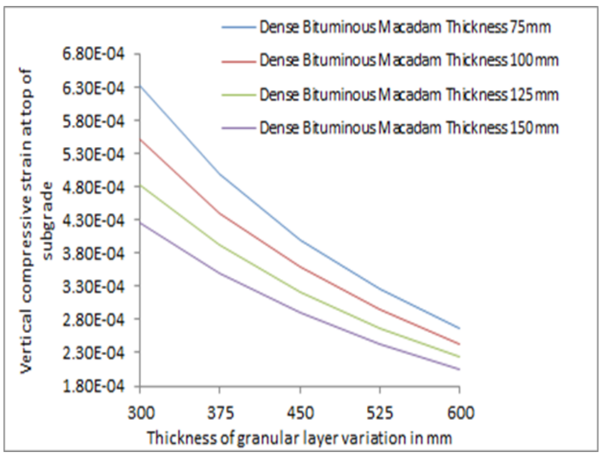

Figure 7 Thickness of granular layer variation Vs. Vertical compressive strain at top of the subgrade

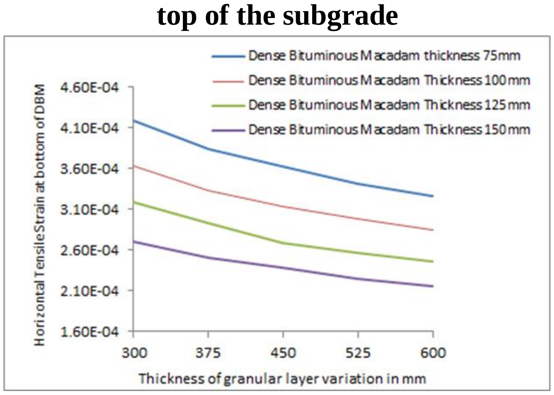

Figure 8 Thickness of granular layer variation Vs. Horizontal tensile strain at bottom of DBM layer

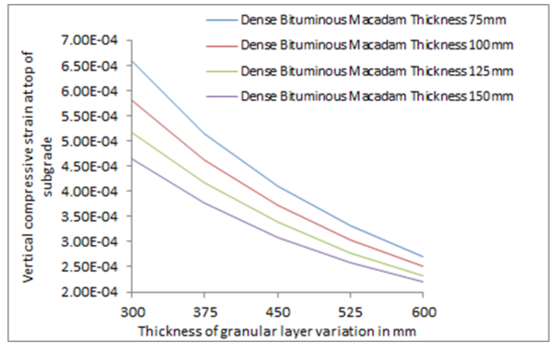

Figure 9 Thickness of granular layer variation Vs. Vertical compressive strain at top of the subgrade

Based on the findings of the study for using the RAP aggregates with CB, it is proposed to provide an additional 500mm modified subgrade layer for sandy soil to make it safe against critical parameters like fatigue and rutting . For good strength subgrade soils like clay and gravel minimum DBM layer thickness of 100mm with a minimum base layer thickness of 525mm satisfies the criteria (Fatigue and Rutting). For weak strength subgrade soils like silt and silty sand, it is not possible to propose a design chart amongst any trailed combination without doing any soil stabilization or soil improvement technique.

The analytical investigation carried out for CRMB and RAP aggregates together proposes the design chart for all types of subgrade soils . The modified subgrade layer of 500mm is proposed for silt, silty sand, and sandy clay with a maximum base layer thickness of 600mm together with 150mm thickness of DBM layer. For the soils like clay and gravel, no need to provide a modified subgrade layer but the maximum layer thicknesses of 300mm and 100mm for the base and DBM layer satisfies the criteria's (fatigue and rutting).

CONCLUSIONS:

A brief conversation of consequences attained from finite element analysis (FEA) along with its explanation and valuable interpretations are presented in Chapter 5 for numerous cases informed in Chapter 3. Based on the findings of the study undertaken subsequent significant conclusions, which can be used as the guidelines for the design of flexible pavement in India are listed below

- To create the design procedure more accurate alignment of in situ parameters with analytical methodology seems very important. The important in situ parameters like the CBR values for various types of soil existing in the study area exposed conflicting results. As the subgrade soil available in the study area shows very wide range based on different parameters like elasticity modulus and strength.
- For the design of flexible pavement on weak subgrade soils like silt and silty sand more attention has to be taken compare to strong subgrade soils like clay and gravel.
- For poor subgrade soil subjected to overloading should be proposed with enhanced design procedure compared to the soil having good strength in terms of CBR values.
- One of the important aspect of this parametric study for design of flexible pavement is use of waste material in different layers of pavement as an alternative to conventional material. The use of plastic and crumb rubber in bituminous mixes to test its suitability for different physical and strength parameters followed by determining the optimum percentage, which gives the current design procedure of pavement more sustainable approach.
- It is perceived that the use of WMM and RAP materials in base layer results in significant reduction in the values of critical parameters and is well within the allowable limits. Hence it is proposed to use WMM and RAP in base layer for different layer combinations.

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