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Comparison for Design of Flexible Pavement Using Empirical Approach and Mechanistic Empirical Approach

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Abstract: Among the various modes of transport, road transport plays a vital role in the economic, social and industrial development of the country. Like the arteries in human beings, roads play an important role in the transport of people and goods from one place to another. While considering road transportation, the type of pavement plays a very important role in deciding the cost of construction and its operation fee. Considering flexible pavements, observations have been made regarding issues related to softening of bitumen resulting in rutting, bleeding, and segregation of the bitumen leading to failure of pavements. And those that were constructed using concrete i.e. Rigid pavements are not satisfactory in performance in accordance with the amount invested.

This paper focuses the design of flexible pavement as per the guidelines of IRC:37-2012 with an appropriate and productive combination of maintenance and designed life. The paper aims at providing steps to be followed for proposing a design of perpetual pavements with the use of IIT PAVE and IRC 37, 2012 for a stretch of road having dense traffic as high as 500 msa. After many iterations, the pavement is designed for calculated msa and with the obtained values of horizontal and vertical strains the actual designed msa would be calculated and checked for the fatigue and rutting type of failure when the pavement is designed for a design life of 40 years or more. Thus the aim of the paper is to put forward the comparison of design of Perpetual pavements and flexible pavements with granular Base and Sub-Base with the use of IIT Pave and IRC:37-2012 guidelines thus using mechanistic empirical approach which is more scientific and reliable as compared to conventional empirical approach.

Keyword: Rutting, Fatigue , CBR , msa(million standard axles) , Perpetual Pavements, Hot Mix Asphalt (HMA), Stone Mastic Asphalt (SMA).

I. INTRODUCTION

Perpetual pavement are flexible but strong asphaltic pavement that do not undergo structural damage even when there is high volume of traffic flowing over a long period of time .These pavements are made up of multiple layers of durable asphalt .The idea is to combine a rut resistant, impermeable and wear resistant top structural layer with a rut resistant and durable intermediate layer and a fatigue resistant and durable base layer as shown in the figure .These pavements are generally designed for high volumes of traffic but they can be justified for medium or low volume of traffic by taking higher design life .One of the major advantages of these pavements is that their overall thickness is thinner as compared to those with thick granular base.

Mechanistic Empirical method is used for its design .The reaction to loads are determined using principles of Physics. Knowing the critical points in the pavement one can design against certain kind of distress by choosing material type and thickness of layer. Depending on which layer is considered, the stiffness of each layer is optimized in order to resist fatigue or rutting whereas durability is primary concern for all the layers.

II. LITERATURE REVIEW

Various research papers were studied for the purpose of this work to be carried out. The research papers studied were mostly based on the mechanistic empirical approach of pavement design. Study was also done on the concept of Perpetual Pavements, improving CBR and use of mechanistic empirical approach in different countries.

Lande et al. (2004) carried out their work and described the experience of Perpetual Asphalt Pavement (PAP) in Afghanistan. The study was carried out on Kandahar Herat highway which was earlier built by Russia in 1960s. After around 40 years the road is totally impassable and is severely deteriorated for its major length. Resulting from the analysis the pavement design recommended was rubblization of PCC followed by overlay of HMA layers.

Sunghwan et al. (2005) stated that Mechanistic Empirical Pavement Design Guide (MEPDG) requires many more parameters than the current AASHTO guide based on empirical methods which are connected to each other in the software. Thus, the general design approach which includes increasing the layer thickness in AASHTO is not the only option in MEPDG. Volumetric properties of bitumen, Climate, AADTT, and type of base generally influenced most of the predicted performance measures. The predicted longitudinal cracking performance measure was influenced by most input parameters. Alligator cracking was not a critical distress in the relatively thick pavement structures used in this study.

Mallick et al. (2006) carried out collection of data for the pavement structures and materials, setting up models, and simulating the effect of different materials and structures with the newly available Mechanistic Empirical Pavement Design Software. It was concluded that fatigue failure within the design life is expected in typical high traffic volume pavements. Further it was stated that rutting failure is expected in high volumes pavements in warmer states. To increase the resistance against rutting significantly, enhancement of the base is done by using foamed asphalt and by using higher temperature grade asphalt binder. Thermal cracking can be reduced by using thick HMA layer.

Carvalho & Schwartz (2007) stated that locations with higher average temperatures exhibited worse performance (as per mechanistic empirical approach) than those in locations with mild to low average temperatures. NCHRP 1-37A predicted performance, the 1993 AASHTO guide overestimates performance (i.e., underestimates distress) for pavements in warm locations.

Mandapaka et al. (2012) stated that Mechanistic Empirical analysis proves to be a very effective tool in analyzing the effect of complex interactions of traffic ,climate and material deterioration on pavement performance. With the help of M-E analysis the engineer can compare the cost of application of cost of preservation treatments. Extended pavement preservation with HMA was found to be most effective Maintenance and Rehabilitation Strategy in particular region. However this finding may not hold for different project in different climatic and traffic conditions.

Nagrale & Patil (2012) carried out an experimental program to study effect of hydrated lime and polypropylene fiber on Clay type of subgrade .Earlier investigation indicated that strength properties of fiber reinforced soils are the function of fiber content, fiber - surface friction along the soil mass and fiber strength characteristics .Polypropylene fiber was chosen due to its low cost and hydrophobic and chemically inert nature which does not absorb or react with soil moisture .The lime content was varied from 1.5% to 6 % at the step of 1.5 % by dry weight of soil whereas fiber content was varied from 0.25 to 1 % at the step of 0.25% by dry weight of soil. The CBR value of unstabilized subgrade soil is 1.45 % . This value increases to 7.7% and 4.23 % due to 4.5 % lime, and 0.5 % fiber content respectively by dry weight of subgrade soil. Also it is observed that beyond 4.5% lime content and 0.5 % fiber content the CBR value of stabilized soil decreases. It indicates that these percentages can be considered as an optimum percentage of stabilizers for maximum benefits .In this study the thickness of subgrade is assumed to be 500mm. IRC recommends a capping layer should be provided if CBR less than 2 %. In present study the CBR value of subgrade is 1.45% hence a capping layer of 150mm has been provided in addition to subbase thickness. Vertical compressive strain developed at the top of unstabilized and stabilized subgrade was captured for varying thicknesses of subbase, base and DBM. Lime stabilized and fibre stabilized subgrade showed a reduction of about 33.80 % and 22.96 % respectively in vertical compressive strain at the top of subgrade. The mechanistic design approach provides different alternatives to designer to quantify the subgrade stabilization.

Basu et al. (2013) carried out research to step the conventional pavement design and to look for pavement type selection removing alternative design and pavement materials. A full depth asphalt pavement is proposed as a sustainable solution to heavy traffic and the best economic interest. Life cycle cost is considered to include direct cost of construction, the cost of reconstruction and the cost of potential maintenance. A total of seven types of payment including conventional, semi-rigid, recycled white top and rigid pavement section with a perpetual counterpart followed by respective life cycle cost analysis. This paper also focused on the need for an extensive study on Perpetual Pavements by designing trial sections and subjecting them to real life loads for a period of three to four years so that pavement can be physically measured.

Singh & Bagra (2013) carried out an experimental study on soil locally available (Doimukh, Itanagar, Arunachal Pradesh, India) and reinforced it with Jute fiber. In this study soil sample were prepared at maximum dry density corresponding to optimum moisture content in the CBR mould with and without reinforcement. The percentage of Jute fiber by dry weight of soil was varied from 0.25 % to 1 % at the step of 0.25 %. The length of the fibre and the diameter were varied. Different length of fibre such as 30 mm, 60 mm and 90 mm where used. And for each fibre length, two different values of diameter 1 mm and 2 mm were used. The laboratory CBR value for soil and soil reinforced with jute fibre were determined. Effect of diameter and length of jute fibre on the laboratory value of CBR was studied. Test results indicated an increase in CBR value with increase in fibre content. It was also observed that

CBR value increased with an increase in length and diameter of fibre. Finally it was concluded that there is a significant increase in CBR value oil of soil reinforced with jute fibre and this increase in CBR value will further reduce the thickness of pavement subgrade.

Kulkarni et al. (2016) carried out research on various drawbacks existing roads have , Roads that were constructed using bitumen resulted in bleeding, segregation and rutting which lead to the failure of flexible pavements .And the performance of rigid pavements as compared to the amount invested was not satisfactory. Generally the type of road determines the cost of construction and operating fee. Due to increasing cost of construction there was a need to step beyond the conventional design approach and look for an alternative design which is efficient in both cost and reliability. The paper studies the major drawback of existing pavements in terms of design life and proposes a design of perpetual pavement with the use of IRC: 37-2012 guidelines and IIT PAVE software for three major roads in Mumbai where there is dense traffic as much as 500 msa. As suggested in the guidelines of IRC: 37-2012 the vertical

compressive and horizontal tensile strains were calculated at critical locations which were later input in the fatigue and rutting model to calculate actual designed msa for a period of 40 years. Thus Perpetual pavements designed were easy to maintain as they eliminate reconstruction costs and reduce life cycle cost of pavement network.

Shinde et al. (2016) focused on the sustainable development of road construction and discussed the concept of Perpetual Pavements which are designed for a design life of 50 years. Perpetual pavements are linked to higher construction costs as compared to conventional flexible pavements, but they require less maintenance and less rehabilitation if designed and constructed for a design life of 50 years .

These pavements can save on materials ,emissions and energy .The Perpetual Pavement Concept derived on mechanistic principle discussed various layers such as Wearing Course, Intermediate Binder layer and Bottom Binder layer in terms of their design ,properties and functions. The various advantages of Perpetual Pavement is discussed .The study also states the use of Perpetual Pavement in developing countries like China and is recommended for India as they need not to be completely removed and replaced as in case of conventional flexible pavement. It also helps in reduction of user cost associated with construction delays as routine maintenance can be done quickly in off-peak hours unlike the replace and remove option which leads to 24 hr closure in case of conventional flexible pavements.

Dilip et al. (2016) implemented the concept of perpetual pavement in order to compare these long lasting payments with conventional flexible pavements and evaluate economic feasibility in Indian conditions. The design was based on the Mechanistic Empirical approach where limiting the pavement responses are used for the design. The pavement design software KENPAVE was used. For Fatigue cracking horizontal tensile strain of 70 micro strains at the bottom of bituminous layer and for rutting vertical compressive strain of 200 micro strains at top of subgrade, are taken as endurance limits. The software LCCA Express was used to carry out life cycle cost analysis. It was concluded that at the end of 50 years, Perpetual Pavements are a viable option as they provide long-lasting roads with minimum maintenance.

III. METHODOLOGY

The steps in this research work are as follows:

A. Selection of Site

The traffic and soil conditions vary from site to site. Different sites will have different traffic and soil conditions. Utility of road determines the amount of traffic it will have to accommodate. Some Roads may be classified as Low volume or High volume roads depending upon the usage and its importance. Along with traffic soil conditions may vary significantly. Therefore, a particular stretch in Panchkula is selected for this study.

B. Data Collection

Data is required as inputs for both the empirical as well as mechanistic approach for selected stretch of road .Traffic Data is collected in the form of traffic counts either manually or by using videography. Only vehicles having laden weight more than 3 tonnes are considered for the count as the vehicle damage factor for vehicle whose weight is less than 3 tonnes is almost negligible .Thus commercial vehicles per day (CVPD) is calculated which is further used to calculate million standard axles (msa) for which a particular stretch is designed. The behaviour of soil is studied by calculating laboratory value of CBR which determines the subgrade strength of the soil. In areas of heavy rainfall CBR value of soil is calculated for soil sample which is soaked for four days.

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C. Data Analysis

The data collected in terms of million standard axles (msa) and CBR of soil is further used to calculate total pavement thickness along with the thicknesses of various layers with the help of design charts and tables showing thickness of pavement as a function of CBR and million standard axles (msa). The charts vary from 2 % to 10 % in terms of CBR and 10 msa to 150 msa in terms of design traffic. The charts also depend upon the pavement composition. Different pavement composition such as use of granular base and subbase or cemented base and subbase have different set of tables .Generally a three layered system is considered that is subgrade, granular base and subbase and bituminous layers along with the thickness.

D. Design

The design of flexible pavement will be done by mechanistic empirical approach. Mechanistic Empirical approach uses horizontal tensile strain at the bottom of bituminous layer and vertical compressive strain at top of subgrade to calculate actual msa for fatigue and rutting failure respectively using fatigue and rutting failure models. The methodology adopted depends on the type of method that is used for design purpose .For empirical approach a different set of guidelines have to be followed. Mechanistic empirical Approach also demands a different set of methods to be used.

E. Flow Diagram for Empirical Approach

The flow chart for empirical approach is shown below in Figure. 1.

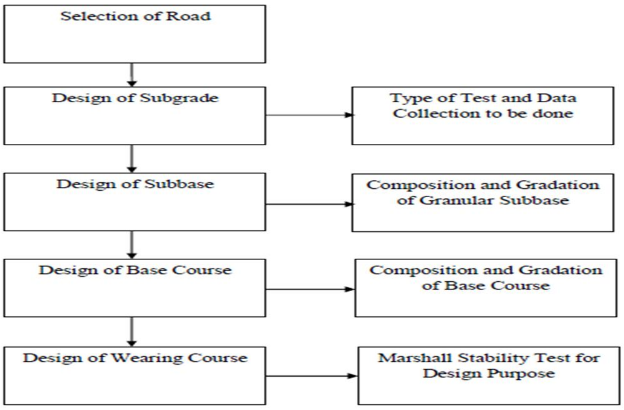

Figure-1 Flow Chart for Empirical Approach

F. Flow Chart for Mechanistic Empirical Method

Figure 2, shows the flow chart for the mechanistic empirical approach.

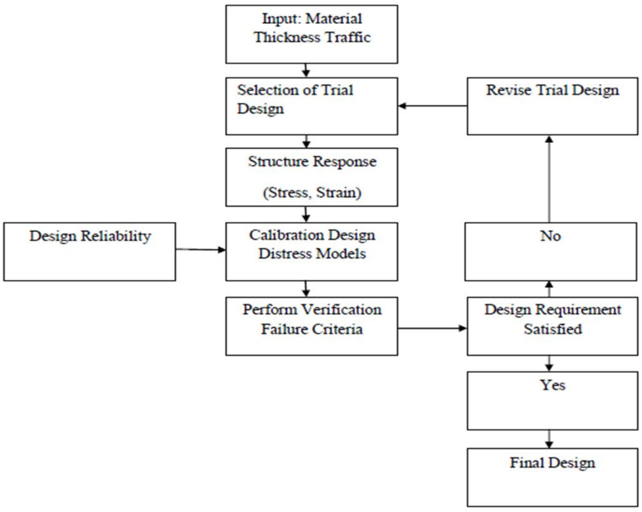

Figure-2 Flow Chart for Mechanistic Empirical Method

IV. CONCLUSIONS

This study discusses the Mechanistic Empirical method of pavement design for flexible pavements. The Conclusion drawn on the basis of this study are stated below:

A. As compared to Empirical Method, the Mechanistic Empirical method is preferred as in this method the thickness of pavement is increased on the basis of stresses, strains and deflections rather than on experimental or experiences basis.
B. The use of soft bitumen in areas of high temperature and heavy axle loads indicated rutting in bituminous layers than in granular layers. This problem was solved by selection of high viscosity binder.
C. With increase in the thickness of granular layers, there is little effect on the horizontal tensile strain at the bottom of bituminous layers.
D. With increase in the thickness of granular layers, there is a decrease in the vertical compressive strain at the top of the subgrade.
E. An increase in Poisson's Ratio decreases the vertical compressive strain at the top of subgrade, whereas there is no considerable effect on the horizontal tensile strain at the bottom of bituminous layers.
F. Cost comparison for both conventional flexible pavements and perpetual pavement are done for a period of 50 years. The total cost of flexible pavement comes out to significantly more than that calculated for perpetual pavement.
G. Although the initial cost of the perpetual pavement is quite high but its benefits like reduced user cost, less inconvenience to user further increases the cost of conventional flexible pavements.

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