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A STUDY ON THE UTILITY OF PAVEMENT METHOD

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Abstract

Performance of pavement can be generally defined as to the change in their condition or function with respect to age. It can also be indicative of the ability of a pavement to carry the intended traffic and satisfy the environment during the design life, both functionally and structurally. With the increased economic and development activities in India, the traffic has increased multi fold during the last 3 decades resulting in the overstressing of road network.

The development of higher stresses leads to performance failure of the pavements. If the pavements fail to carry the design loads satisfactorily, then the failure is of structural type. It is of functional type, if the pavement does not provide a smooth riding surface. The uneven surface not only causes discomfort, but also increases the Vehicle Operating Cost (VOC), thus influencing the overall transportation cost. This paper gives a broad outline of the importance of pavement performance evaluation, type of models, applications of performance models in other countries for their Pavement Management System and the research studies carried out so far.

Keywords: *Pavement, Performance, Evaluation*

INTRODUCTION

The structural and functional conditions of flexible pavements changes with time due to continued effects of its structural adequacy, volume, composition and loading characteristics of traffic, environment, surrounding conditions and the maintenance inputs provided. The failure of the pavement occurs due to internal damage caused by traffic loads within an operational environment, over a period of time; and is not an abrupt phenomenon. Deterioration can also be defined as the process of accumulation of damage and the failure of the pavement is said to have reached at the limiting stage of serviceability level. Studies conducted all over the world have established that even though design and construction techniques vary from country to country, the deterioration pattern of pavements shows the same trend.

The various factors which cause deterioration of flexible pavements can be represented as shown in Fig. 1.

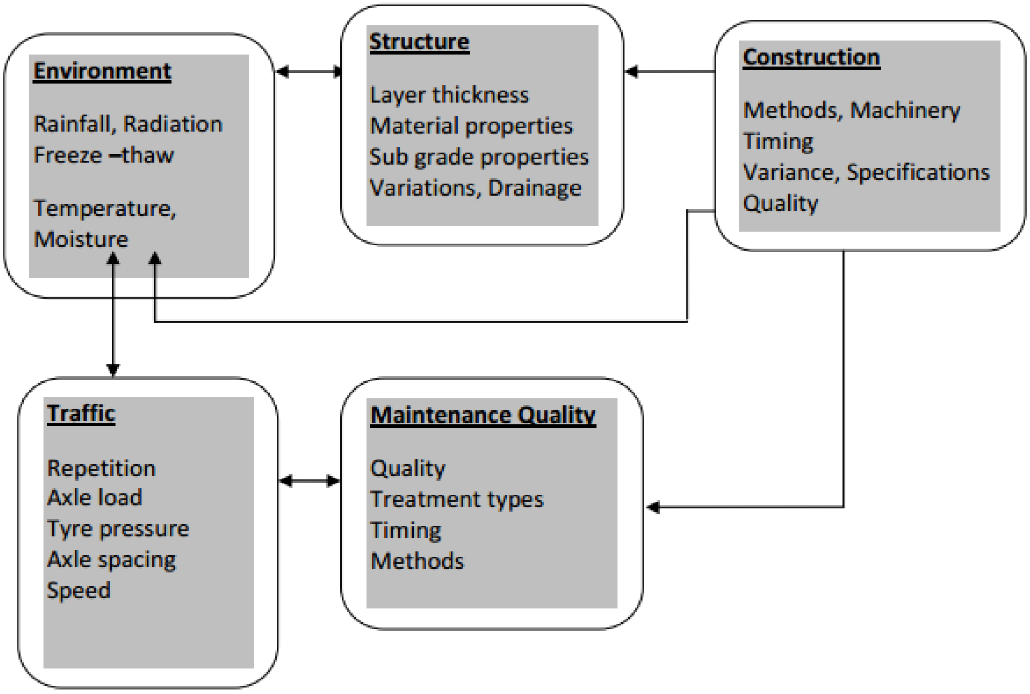

Fig. 1 Factors influencing pavement performance

The main deteriorations include cracking, potholes, rutting along wheel path and roughness of road surface. The physical manifestation of the internal damage (cracking, rutting, potholes etc.) is known as distress. Percentage of distress gives an indication of the pavement condition. Different modes of distress occur either independently or simultaneously with mutual interaction. For planning purpose, the distress can be based on distress type and the most important are those, which trigger decisions.

PERFORMANCE EVALUATION OF PAVEMENTS

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 show 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 (i) Structural evaluation and (ii) Functional evaluation. Pavement evaluation process is normally represented using four criteria, namely, Pavement Roughness (Reliability), Pavement distress (Surface condition), Pavement deflection (Structural failure) and Skid resistance (Safety). Certain terms are defined by researchers and are mentioned here before looking upon the models developed. They are:

• Present Serviceability. This is the term used to represent the ability of a specific section of pavement to serve high-speed, high-volume, mixed traffic within the existing conditions.

• Individual Present Serviceability Rating (PSR). This denotes an independent rating by an individual on the present serviceability of a specific section of roadway. The ratings usually range from 0 to 5. The individuals may also be asked to indicate whether or not the pavement is acceptable as a primary highway.

• Present Serviceability Index (PSI). PSI is a mathematical combination of values obtained from certain physical measurements formulated to predict the PSR for those pavements within prescribed limits.

• Performance Index (PI). This denotes the summary of PSI over a period of time, which can be represented by the area under the PSI versus time curve. There are many possible ways in which the summary value can be computed. The simplest summary consists of the mean ordinate of the curve of PSI against time.

PERFORMANCE PREDICTION MODELS (PPM)

According to the World Road Association, a PPM is a mathematical representation that can be used to predict the future state of pavements, based on current state, deterioration factors (traffic and climate) and effects resulting from maintenance and rehabilitation actions (or simply M&R actions).

The projection of the present condition of the performance of the pavement is done within user-defined scenarios of future loading and maintenance using accurate and realistic models. But the outcome of the applied models will be acceptable only if they conform to a reasonable set of generic criteria. Road deterioration modeling is considered as an important parameter in Road Infrastructure Management and Road Maintenance Management Systems. (RMMS). Good RD models should be able to suggest efficient and economically viable treatment options, which could be converted into realistic work programs and strategies for planning. They assume importance in a PMS due to many reasons as given below:

• The type of the deterioration indicated by the model, its severity, intensity and extent with time of occurrences are used to decide upon the nature of the proposed treatment.

• The severity of deterioration of pavement has influence on surface unevenness, which will be used to determine the RUE costs modeling. If the RD modeling is not perfect and realistic, RUE modeling will be influenced, even if RUE models are correctly formulated.

• Modeled maintenance effects can be realistic only if the RD models produce accurate predictions.

• The Work Effect (WE) modeling and parameter resets are used for determining the treatment. Then the RD models perform the modeling of the performance of the pavement until the next set of WE is applied. The RD models are most important for predicting the performance of pavements, and they are to be very accurate to get, both technically and financially realistic WE applications.

Techniques of Pavement Performance Models (PPM)

PPM's can be developed using different techniques such as Regression analysis, Bayesian methodology, Homogeneous Markov Process, Non Homogeneous Markov Process, Semi-Markov process etc. Bayesian methodology can be used in both relative and absolute models. ANN, Fuzzy systems and hybrid computing systems also can be used. KENLAYER is a Computer Program that can be used to find out the damage ratio using distress models. Cracking and rutting are the distress models in KENLAYER and they are considered as the most critical elements for bituminous pavements. The horizontal tensile strain (Et) at the bottom of the bituminous layer which causes fatigue cracking and the vertical compressive strain (Ec) on the surface of the subgrade which causes permanent deformation or rutting are the critical elements. The performance of the pavement can be predicted using pavement deterioration models in HDM -4.

METHODS OF FLEXIBLE PAVEMENT DESIGN

There exist a number of methods for the design of flexible pavements. These are empirical method with or without a soil strength test, limiting shear failure method, limiting deflection method, regression method based on pavement performance, mechanistic-empirical method and design based on theoretical studies. The use of empirical method without a strength test dates back to the development of Public Roads (PR) soil classification system, in which the subgrade was classified as uniform from A-l to A-8 and non-uniform from B-l to B-3. This System was later modified by the Highway Research Board; in which soil were grouped from A-l to A-7 and a group Index was added to differentiate the soil within each group.

A good example of the use of regression equations for pavement designs is the AASHTO method based on the result of the road tests. The disadvantage of the method is that the design equation can be applied only to the conditions at the road test site. The mechanistic-empirical methods of design are based on the mechanics of materials that relate an input, such as a wheel load, to an output or pavement response such as stress and strain. The response values are used to predict distress based on laboratory test and field performance data.

Dependence on observed performance is necessary because theory alone has not proven sufficient to design pavements realistically.

The horizontal tensile strain at the bottom of the bituminous layer and the vertical compressive strain on the subgrade are identified as the critical parameters for fatigue and rutting failures respectively. The mechanistic-empirical method is more theoretical in approach, through it needs calibration based upon the performance of in-service pavements. This approach is increasingly popular amongst various countries.

In India too, the Pavement Design Guidelines IRC: have been updated in 2001 where the design methodology has changed from empiricism to mechanistic pavement design principles. The mechanistic-empirical approach is being successfully used in the design of reinforced sections also, as it tries to relate the stress-strain parameters with the expected life of the pavement.

Design of flexible pavements as per guidelines of IRC: 37-2001

These guidelines are applied to design flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/MOST standards. These guidelines apply to new pavements.

The flexible pavements has been modeled as a three layer structure and stresses and strains at critical locations have been computed using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered:

1. Vertical compressive strain at the top of the subgrade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.

2. Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.

3. Pavement deformation within the bituminous layer.

While the permanent deformation within the bituminous layer can be controlled by meeting the mix design requirements, thickness of granular and bituminous layers are selected using the analytical design approach so that strains at the critical points are within the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the stiffness of dense bituminous macadam (DBM) layer with 60/70 bitumen has been used in the analysis.

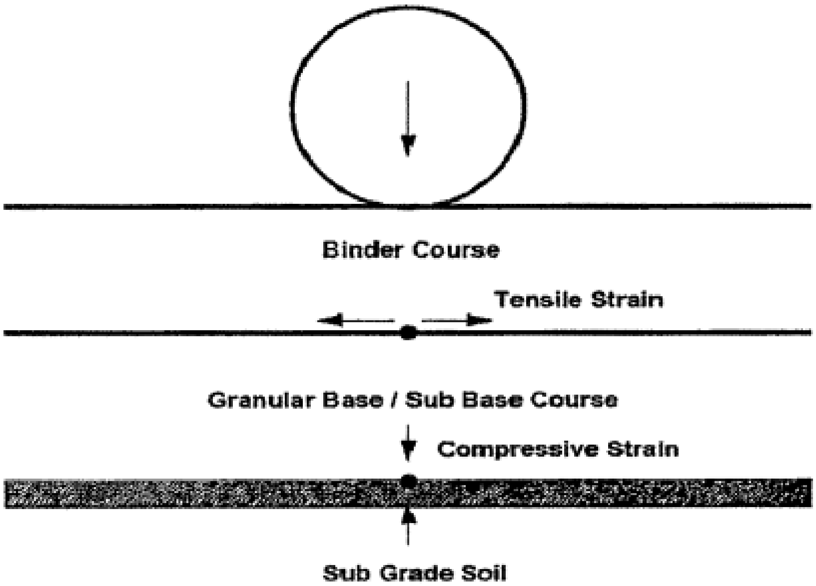

Figure 2: Critical Locations in pavement

Fatigue Criteria:

Bituminous surfacings of pavements display flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. The relation between the fatigue life of the pavement and the tensile strain in the bottom of the bituminous layer was obtained as

$$N_f = 2.21 \times 10^{-4} \times \left(\frac{1}{\epsilon_t}\right)^{3.89} \times \left(\frac{1}{E}\right)^{0.854}$$

in which, Nf is the allowable number of load repetitions to control fatigue cracking, e(is the tensile strain and E is the Elastic modulus of bituminous layer. The use of the above equation would result in fatigue cracking of 20% of the total area.

Rutting Criteria:

The contribution of rutting from various layers could be different . It is reported that, 46% of rutting take place from bituminous surface and granular base course, while the subbase and sub grade contribute 54% of the total rutting. The vertical strain at subgrade is assumed as the index of rutting to occur in a pavement.

The allowable number of load repetitions to control permanent deformation can be expressed as

$$N_r = 4.1656 \times 10^{-8} \times \left(\frac{1}{\epsilon_z}\right)^{4.5337}$$

Nr is the number of cumulative standard axles to produce rutting of 20 mm and is the subgrade strain.

Design Procedure:

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the guidelene. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35° C.

The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength: - Design traffic in terms of cumulative number of standard axles; and - CBR of subgrade.

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