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Analytical Study of Pavement Structure Considerations

Sanjiv Kumar[1], **K. B. Singh**[2], **A. K. Rai**[3]
[1]Research Scholar, Department of Civil Engineering, B. R. A. Bihar University, Muzaffarpur, Bihar, India
[2]Department of Physics, L. S. College, B. R. A. Bihar University, Muzaffarpur, Bihar, India
[3]Department of Civil Engineering, M. I. T., B. R. A. Bihar University, Muzaffarpur, Bihar, India

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ABSTRACT

In this paper, we using geotextiles in secondary roads to stabilize weak subgrades. However, from an economical point of view, a complete life cycle cost analysis, which includes not only costs to agencies but also costs to users, is urgently needed to assess the benefits of using geotextile in secondary road flexible pavement.

Keywords: Geotextiles, Pavement, TBR.

I. INTRODUCTION

Life Cycle Cost Analysis can be used to determine the relationship between performance and cost when geotextiles are incorporated in pavements. The AASHTO 1993 Pavement Design Guidelines were used in this study. Pavement reliability is considered as 70%, and the standard deviation is considered as 0.49 (secondary road).

HMA Thickness (mm)	Base Thickness (mm)	Subgrade Strength (*CBR %)			
		0.5	2	4	6
50	100				1
	150			2	3
	200		4	5	6
	250		7	8	9
75	100			10	11
	150		12	13!	14
	200		15	16	
	250		17		
100	100		18	19	
	150		20		
	200		21		
	250		22		
125	100				
	150		23		
	200	24			
	250	25			

*Bihar Bearing Ratio ;!(ref) represents the reference design

Table 1 shows the matrix of possible secondary road pavement design combinations based on four different HMA thickness (50, 75, 100, and 125mm), four different granular base thicknesses (100, 150, 200, and 250 mm), and four different subgrade strengths (CBR=0.5, 2, 6 and 8%). The design layer coefficient was considered as 0.44 for the HMA layer and the drainage coefficient as 1.0. Using a combination of the aforementioned pavement composition and characteristics, there are 64 design combinations; however, only a fraction of these combinations are considered to be realistic and somewhat representative of secondary road traffic conditions. According to the traffic count data in 2004, the annual average daily traffic (AADT) of a secondary road varies from several hundred to several thousand. Therefore, 25 design combinations based on the Bihar traffic features of the secondary roads in the state of Bihar were selected on which to conduct the cost-effectiveness analysis comparison in this study. The 25 representative designs are designated 1 through 25 in Table 1.

II. PAVEMENT PERFORMANCE PREDICTION

The evaluation of pavement performance is a crucial step in the life cycle cost framework. The ability to predict the remaining life or the distress levels of a pavement section allows engineers, planners, and highway agencies to plan ahead for maintenance and rehabilitation activities, budget for future expenditures, and makes decisions about the timing of those rehabilitation activities. With ample time to plan, state transportation agencies can minimize their costs as well as minimize the impact of their construction activities on the traveling public and others affected by such construction.

Therefore, the first step in the life cycle cost framework is to evaluate a pavement design and the conditions under which it is expected to operate throughout its design life or its analysis period. The framework presented in Figure 1 shows the steps required to prepare an analysis for the life cycle cost procedure. The general inputs relating to the project as a whole, independent of pavement type must be defined prior to idetifying pavement design alternatives. These inputs include such conditions as predicted traffic patterns, pavement loading, and economic variables. Once the general and specific conditions are defined, the life cycle cost framework simulates the predicted traffic loading and environmental conditions for each year of the analysis period. At the end of each year, the performance models predict the level of distress or damage to the pavement based on that year’s current traffic conditions.

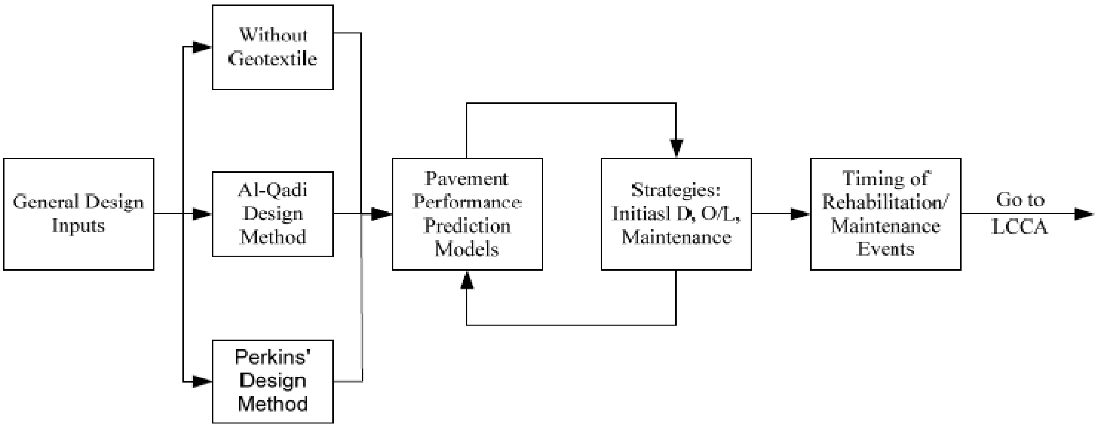

Figure 1: Life Cycle Cost Framework- Pavement Performance

III. PAVEMENT LOADING

Often, vehicular loading of the pavement is the parameter that has the greatest effect on the performance of pavements. Although other factors, such as environmental conditions, affect the performance of pavements, they only help to modify and calibrate performance models to local conditions. The effects of vehicular loading, however, are universal and affect all pavements in any locale. This section will address the method by which the amount of vehicular loading is determined and predicted for the entire analysis period.

In the method that will be discussed, the engineer obtains, or predicts, the equivalent single axle loads (ESALs) for the first year and an estimated annual growth rate. Another method uses the average daily traffic (ADT) for the first year, predicts the ADT for the final year of the analysis period, the percentage of trucks throughout the analysis period, and then designs an ESAL value for the entire analysis period. In order to determine the appropriate ESAL value for each year, the traffic evaluation module begins with the initial year ESAL and increases this value annually by the growth rate. This is represented by equation 1 below, which shows the calculation for the current year's ESAL value:

$$ESAL_{current} = ESAL_{initial} \cdot (1 + g)^{i} \qquad (1)$$

Where;
g = annual ESAL growth rate, and
i = current year, between 0 and analysis period

In the study, the user cost model not only requires the current annual ESAL value, it also requires the cumulative value to predict the level of serviceability. The algorithm used to determine the annual cumulative values is as described below. Given the first and last year ADT values, an annual growth rate can be derived by the following formula:

$$ADT_{final} = ADT_{initial} \cdot (1 + g)^{n} \qquad (2)$$

Where;
g = annual growth rate, and
n = analysis period.

Then, solving for g,

$$g = \left(\frac{ADT_{final}}{ADT_{initial}}\right)^{1/n} - 1 \qquad (3)$$

The annual cumulative ESAL value, then, is calculated by deriving the first yearESAL value from the growth rate and the total ESALs:

$$ESAL_{cumulative} = ESAL_{initial} \cdot \frac{(1+g)n-1}{g} \qquad (4)$$

$$ESAL_{cumulative} = ESAL_{initial} \cdot \frac{g}{(1+g)n-1} \qquad (5)$$

From this point, the cumulative ESAL values for each year are determined by:

$$ESAL_{annual,\ cumulative} = ESAL_{initial} \cdot \frac{(1+g)i-1}{g} \qquad (6)$$

where,
i = current year.

IV. PAVEMENT SERVICE ABILITY PREDICTION MODEL

The AASHTO design guide equation for flexible pavements, which is the major model in use today for predicting the pavement serviceability ratings, is used in predicting the remaining serviceable life of a pavement in the study. The equation is used to determine the design thickness of a flexible pavement, or the allowable loads for a specific thickness. This equation can also be used to determine the decrease in PSI for given inputs and traffic loading. The AASHTO design equation is shown below:

$$\log W_{80} = Z_R S_O + 9.36 \log(SN+1) - 0.2 + \frac{[\log(\Delta PSI)/(4.2-2.5)]}{0.4+1094/(SN+1)^{5.19}} + 2.32 \log M_R - 8.07 \qquad (7)$$

where,

W_{80}= number of 80kN equivalent single axle load applications estimated for a selected design period and design lane;

R = reliability;

Z_R= the normal deviate for a given reliability R;

S_0= standard deviation;

ΔPSI= Present Serviceability Index difference between initial value (Pi) and the terminal value (Pt);

SN= design structure number indicative of total required pavement layer thickness and their corresponding moduli; and

M_R= subgrade resilient modulus.

Each year the current level of traffic is updated in the AASHTO equation and the equation is solved for the PSI value, which provides an estimate of the structural condition of the pavement. This equation can be used with a known or predicted value of ESALs to predict the PSI of a pavement, given other design parameters that will be readily available to the pavement design engineer. Using the PSI prediction, rehabilitation requirements will be evaluated.

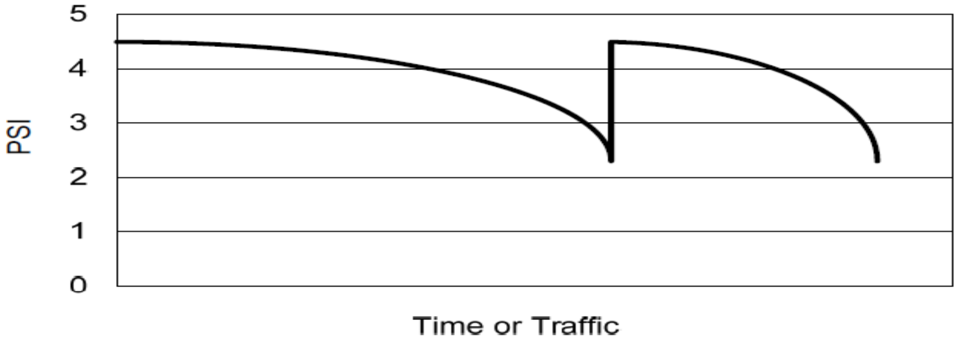

Figure 2: Typical Time or Traffic Versus PSI Curve with One Rehabilitation

The AASHTO model is used for consistency, since it is the same model that will be used for pavement thickness design. NCHRP Report 277 (Darter et. al, 1985) suggested that it was an effective approach as pavement thickness affects the rate of loss of pavement serviceability. Figure 4.2 shows a typical PSI curve with respect to time or traffic. This example shows a major rehabilitation toward the end of the predicted service life, and no action was taken after that.

V. PAVEMENT SERVICE LIFE PREDICTION OF GEOTEXTILE INCORPORATED PAVEMENT

The pavement service life for the design alternative which incorporates geotextiles needs to be quantified. The method to account for the service life benefit due to the utilization of geotextiles in pavement is presented as follows. The AASHTO pavement design equation 4.7 can be rewritten into the following form:

$$\Delta \mathrm{PSI} = 2.7\mathrm{x}\ 10\hat{}\left[\left(0.4 + \frac{1094}{(\mathrm{SN}+1)^{5.19}}\right)[\log \mathrm{W}_{80} - \mathrm{Z}_{\mathrm{R}}\mathrm{S}_{0} - 9.361\log(\mathrm{SN}+1) + 0.20 - 2.32\log \mathrm{M}_{\mathrm{R}} + 8.07]\right] \qquad (8)$$

Changing Present Serviceability Index (ΔPSI) is altered with increases in the applied ESAL: as the applied ESAL increases, ΔPSI increases. The terminal PSI value (Pt) is equal to initial PSI (Pi) value minus ΔPSI. Therefore, Pt decreases as applied ESAL increases. When the Pt reaches 2.0, a major rehabilitation may need to be applied. Hence, the service life of the pavement can be determined. The applied cumulative ESAL up to the year of rehabilitation is cESAL. Using the calculated cumulative ESAL (cESAL) and the TBR, corresponding to the model used, the allowable ESAL for the pavement incorporating geotextiles can be determined:

$$ESAL_G = cESAL \times TBR \quad (9)$$

Utilizing ESALG and ΔPSI at rehabilitation in equation 1 will give SNG (structure number for pavement with geotextiles).

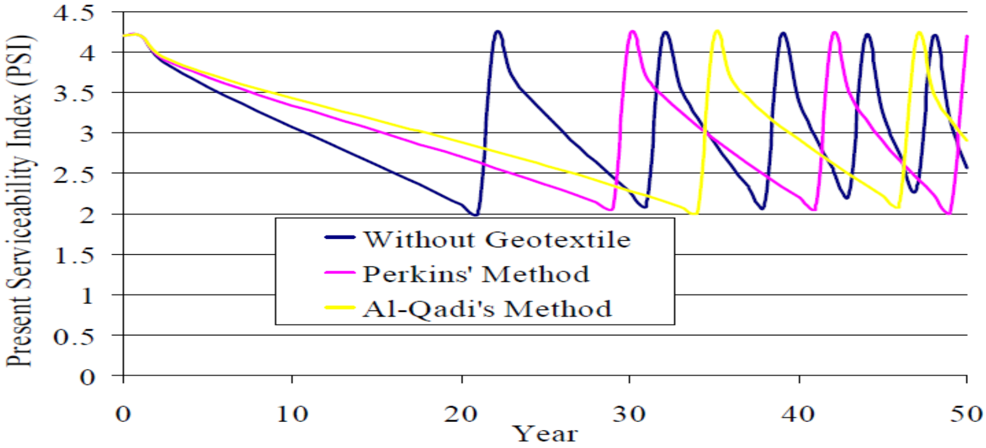

Figure 3: Service Life Comparison between Three Alternative Flexible Pavement Design Approaches

The latter can be used to calculate the ΔPSIG. ΔPSIG represents the change in PSI when geotextiles are used between Pi and the corresponding Pt to the ESAL equivalent to that of Pt without geotextiles. An example of predicted service life of a pavement among these three design alternatives is shown in Figure 3. In this example, the pavement has an HMA layer of 100mm, a base layer of 375mm, and a subgrade of CBR 0.5%. For this low CBR, the TBR value is 2.45 (Al-Qadi's method) and 1.86 (Perkin's method), respectively.

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