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Assessment of Remaining Structural Life based on SCI In and N/S Wheel Paths

Introduction

The assessment of the structural condition using NDT technologies including H/FWD, radar, targeted coring and material testing is relatively common practise today. The structural condition of in-service pavements is deduced from the H/FWD load response which involves the application of a simulated load to model the pavement structure. Based on the strain level of the actual traffic and transfer functions for material fatigue, the pavement's residual life can be obtained. For a sound result, one mechanistic-empirical calibration of the transfer function is necessary and the pavement engineer must have the actual past traffic data. Unfortunately this is not always the case. This flier deals with an methodology to assess the remaining structural life based on the Surface Curvature Index (SCI) as can be directly measured in a H/FWD survey. The SCI defined as the difference between centre deflection and at 60 cm is related to the strain level of the upper bound pavement layers and hence to the pavement's life.

Modelling pavement deterioration

Pavement's deteriorate gradually. Performance curves can be used to describe the pavement probability. The number of load repetitions Np to a certain reliability level P can be described by:

$$log(N_p) = log(N_{50}) - \mu_p S\, log(N) \qquad (1)$$

Where:
Np = Residual pavement life at probability level P (%)
N50 = Number of load applications to failure (-)
μp = standardised normal deviate associated to a probability P (-)
SlogN = Standard deviation of the logarithm of the expected number of load repetitions (N) to failure

Molenaar1 described the deterioration of the structural pavement layers by:

$$S^2\, log\, N = a^2 b^2 S^2\, log\, SCI + S^2 lof_{(log\, N - log\, \varepsilon)} \qquad (2)$$

Where:
S^2logN = Variance of the logarithm of the expected number of load repetitions (N) to failure,
a = constant from the fatigue relation which is $log\, N = c + a\, log(\varepsilon)$,
b = constant from relation between $log(\varepsilon) = b_0 + b_1\, log(h_e)$ with h_e as equivalent thickness,
S^2logSCI=.Variance of the Surface Curvature Index (SCI),
S^2lof = Lack of fit of the equation describing the fatigue relation.

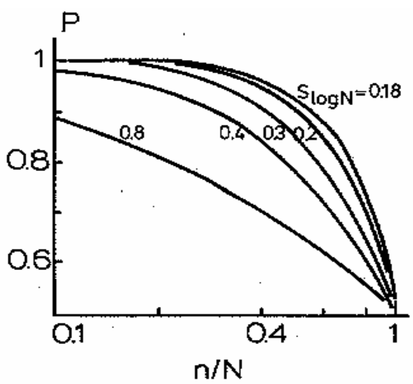

Fig.1 Basic Structural Performance Curves

Relation (1) indicates that the variance of a pavement life, expressed in a number of load applications N, can be derived from deflection measurements. As can be observed from Eq. 2 the value of S^2logN is mainly determined by the variance of material properties and the layer thickness as well as the slope of the fatigue relation an the slope of the log(N)-log(ε) relation. Based on design curves with transfer function between strain and life, probability of survival curves can be derived for several values of n/N and an given value for SlogN. Figure 1 shows the basic form of the structural deterioration of the pavement as a decrease of the probability of survival P in respect of n/N. Structural strengthening is required at p=70%. This model is regarded as the basic structural performance model and can be used for pavement design and evaluation purposes.

[1] "Structural Performance and Design of Flexible Road Constructions and Asphalt Overlays". A.A.A. Molenaar. Phd. Thesis Delft University of Technology, 1983.

Derivation of pavement condition

The actual structural condition can be assessed for a road pavement based on the difference if the SCI measured pair wise in and near side the wheel paths. It can be shown for road pavements with granular bases that the actual performance P is given by:

$$P = \left(\frac{SCI_{n/s}}{SCI_{in}} \right)^{0.53} \qquad (3)$$

Equations (1) and (2) can be used to determine the residual life of the pavement. The first step is to determine the SlogN. Based on the past traffic expressed in equivalent load axles, the transfer function for the pavement under consideration can be assessed. Since major pavement rehabilitation is to be expected at an probability level of 70%, the remaining structural life can easily be determined.

Worked Example

The remaining pavement life can be assessed directly from the H/FWD results and traffic information. Note that outcome of the analysis is not very sensitive to the traffic data. This can be considered advantageous since historic traffic data is not always present an/or reliable. The assessment takes 4 steps.

Step 1. Determination of actual condition.
An FWD survey resulted in a mean value for the SCI in an n/s the wheel path of 225 and 326 μm respectively. The structural indicator P can immediately be calculated at 0,822 (Eq 3). Based on the gradual deterioration in Eq. 1, the standardised normal deviate at this probability P can be determined at μ82.2% = 0,924.

Step 2. Derivation of pavement's deterioration function.
Since the structural condition for the pavement near side the wheel paths is believed to be representative for the unloaded pavement condition, the variation in measured logSCI-values n/s wheel paths is taken to calculate the SlogN (Eq. 2). With common values of 4 for the slope of the asphalt fatigue curve and a value of 1,.0 for the correlation between the strain and structural thickness, the SlogN is equal to 0,488.

Step 3. Derivation of pavement's transfer function (fatigue relationship).
The pavement life depends on the transfer function for pavement fatigue. This function may be determined based on the past traffic data. Suppose that the past traffic is equal to 40.000 Equivalent Axles (log n = 4,602). The mean pavement life can be calculated with the help of equation 1:

$$\log N_{50} = \log N_{past} + u_{82,2\%} S \log N = 4{,}602 + 0{,}924 * 0{,}488 = 5{,}053 .$$

The general form of a transfer function is $\log N_f = c - a \log(\varepsilon)$. With the values presented and a slope of 5,0 for the fatigue curve, the constant c can be determined at 16,03. Therefore, the transfer function of the pavement under consideration is: $\log(Nf) = 16{,}03 - 5{,}0 \log(\varepsilon)$.

Step 4. Assessment of remaining life.
The remaining pavement life is expressed as log Np=70% minus log npast.

$\log N_{70} = \log N_{50} - \mu_{p=70\%} * S \log N = 5{,}053 - 0{,}524 * 0{,}488 = 4{,}797$ i.e. 6,27*104 equivalent axle loads. The present life is 6,27*104 – 4,00*104 = 2,27*104 E.A. Suppose the forecasted traffic is 50.000 E.A. to occur in a design period of 15 years. One can easily determine a remaining life for this pavement of 6 to 7 years time.