Mechanistic Empirical Design Exercise

AC thickness optimization against top down cracking

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Road Construction and Maintenance (AF 2903)

Deadline of submission (25/04/2013)

1. The following four layer pavement system has to be checked against top down fatigue cracking. The pavement is subjected to a single-axle dual-wheel load of magnitude 22480pound (100KN) and a tyre pressure of 166psi (800KPa). The spacing between the dual wheels is 12inch (30.5cm) center-to-center. The expected traffic during the design period is 10 million ESALs and it is designed with a reliability of 95%. The design period is 20 years and the pavement is located in an area with a mean annual air temperature (maat) of 75°F. A reference temperature of 50^{o}F should be used to predict aging condition).
   The tensile stress at the bottom of the AC layer for the trial pavement system should be calculated based on the following structure. **Use English units in the Matlab calculation (inch, psi…)**

AC layer:	thickness 4.5 inch, AC stiffness, from AC stiffness predictive model
Base layer:	thickness 12 inch, modulus 63600 psi
Subbase layer:	thickness 12 inch, modulus 51000 psi
Subgrade:	semi-infinite layer 999 inch, modulus 361000 psi

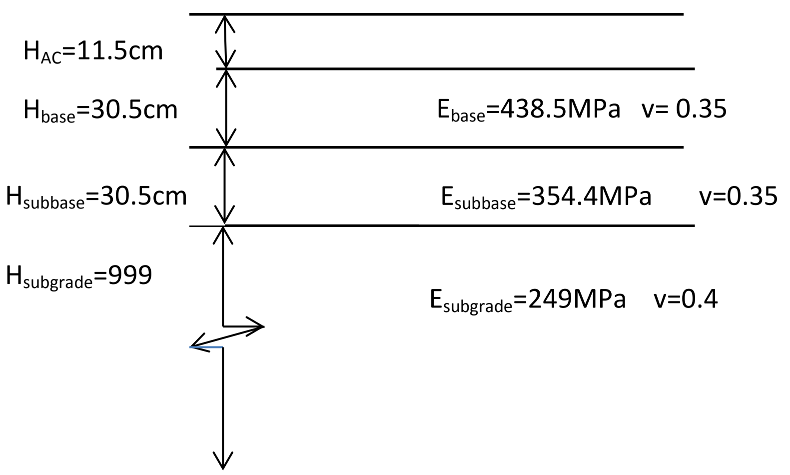

Figure 1 Pavement system

The aging effect on the AC stiffness is considered by dividing the AC layer into sub-layers and since aging is most pronounced close to the surface, the Ac stiffness can be obtained at $1/8H_{AC}$ and $1/2H_{AC}$.

A predictive equation is provided to calculate the AC stiffness, tensile strength and creep parameters at different depths in the AC layer. Use time of loading t=0.1 sec for the AC stiffness prediction and t=1800 sec for tensile strength prediction.

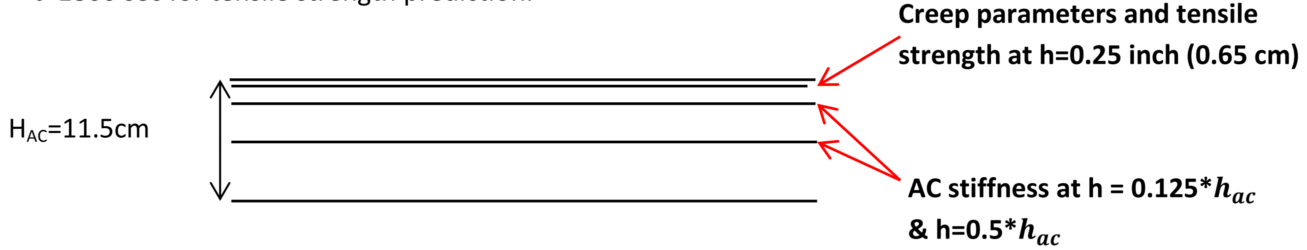

Figure 2 AC layer

Use the following mix gradation, volumetrics and rheological properties of the AC layer as input in the predictive equations.

Gradation (Percent passing by weight)				*Volumetric*		*Rheological properties*	
$\rho_{\frac{3}{4}}(19\,mm)$	$\rho_{\frac{3}{8}}(9.5\,mm)$	$\rho_{4}(4.75\,mm)$	$\rho_{200}(0.075\,mm$	$V_a(\%)$	$V_{beff}(\%)$	*A*	*VTS*
100	*93.7*	*74.6*	*5.6*	*3.2*	*10.7*	*10.6316*	*-3.548*

Tasks

1. Estimate the energy ratio optimum, $\boldsymbol{ER_{opt}}$

    - Uncomment line 13 to 21 in the file ***eropt.m*** and write the necessary expression for energy ratio optimum for the given reliability

Reliability (%)	$ER_{opt} = f(x$: ESALs in 10 millions)		
	$x<0.14$	$0.14\leq x<0.8$	$x\geq 0.8$
95	$ER_{opt} = 0.329\,x + 0.65$	$ER_{opt} = 0.640\,x + 0.61$	$ER_{opt} = 0.256\,x + 0.92$

    - Use traffic, reliability and the file ***fcm.m*** to determine $\boldsymbol{ER_{opt}}$

2. Estimate the tensile strength $\boldsymbol{S_t}$

    - Uncomment line 19 and 20 in the file ***tensile_strength.m*** and write the necessary expression for the curve fitting parameters (delta and alpha)

$$\delta = 2.718879 + 0.079524\times p_{200} - 0.007294\times(p_{200})^2 + 0.002085\times\rho_4 - 0.01293\times V_a + 0.08541\frac{V_{be}}{V_{be}+V_a}$$

$$\alpha = 3.559267 - 0.005451\times\rho_4 + 0.020711\times\rho_{3/8} - 0.000351\times(\rho_{3/8})^2 + 0.00532\times\rho_{3/4}$$

$\boldsymbol{\rho_{3/4}, \rho_{3/8}, \rho_4}$ **: percent weight retained on 19mm, 9.5mm and 4.75mm sieve respectively**

$\boldsymbol{\rho_{200}}$ **: percent passing on 0.075 mm sieve**

$\boldsymbol{V_a}$**: Air void** $\boldsymbol{V_{be}(V_{beff})}$**: effective asphalt content**

- To determine the tensile strength uncomment line 40 in the same file and write the tensile strength predictive equation, use the regression constants at line 7 & 8 and tensile dynamic modulus at line 39

$$S_t = \sum_{n=0}^{5} a_n \cdot (\log S_f)^n$$

- Use the required inputs and the file ***fcm.m*** to determine the tensile strength

3. Estimate creep parameters $\boldsymbol{D_1 and\ m}$

- Uncomment line 16 and 17 in the file ***creep_parameters.m*** and write the necessary expression for the curve fitting parameters (delta and alpha**).**
- To determine $\boldsymbol{D_1 and\ m}$ uncomment lines 29 and 31 and write the necessary description for D0 and temp

$$\log(D_0) = -\delta - \alpha - \log \lambda_r, \quad \log(D_0 + D_1) = -\delta - \frac{\alpha}{1 + e^{\beta}} - \log \lambda_r$$

$$m_0 = \alpha \gamma \times \frac{\exp(\beta + 3\gamma)}{[\,1 + \exp(\beta + 3\gamma)\,]^2} \qquad m = m_0 + \frac{\kappa}{\log \log \eta}$$

- Use the required inputs and the file ***fcm.m*** to determine $\boldsymbol{D_1 and\ m}$

4. Determine the AC thickness $\boldsymbol{H_{tot}}$

- Uncomment line 12 and 13 in the file ***AC_modulus.m*** and write the necessary expression for the curve fitting parameters (delta and alpha)
- Uncomment line 21 and specify depth levels at which the AC Stiffness has to be calculated.
- Open and run the file ***fcm.m*** after you have inputted all the necessary inputs to get optimized thickness