LAYER COEFFICIENTS AND RESILIENT MODULUS

PAVEMENT DESIGN METHODS AND BACKGROUND

Methods of flexible pavement design can be classified into five categories:

- empirical method with or without soil strength testing,
- limiting shear failure method,
- limiting deflection method,
- regression method based on pavement performance or road test, and
- mechanistic-empirical method.

Dynamic Cone Penetrometer

The 1973, 1986, and 1993 AASHTO Design Methods are based on the regression method and the original road tests that were performed in the late 1950's and 1960's. NHDOT currently follows the 1973 AASHTO Design Guide. The pavement design process relies on the combined strength/stiffness properties of the hot mix asphalt (HMA) and each of the base course layers and subgrade that support it. In the AASHTO 1973 Design Guide, the strength/stiffness of each of these layers is represented by soil support values and by layer coefficients (a_i) whereby the layer coefficients are multiplied by the individual layer thicknesses and summed to compute the Structural Number (SN). NHDOT currently uses a Soil Support Value of 4.5 to represent ALL subgrade types and has developed a series of layer coefficients (a_i) to represent our more common HMA and base course materials.

Heavy Weight Deflectometer

CRREL SPECIAL REPORT 94-30

In 1993, the US Army Corps. Cold Regions Research and Engineering Laboratory (CRREL) and the NHDOT constructed ten roadway test sections in Bow to determine the layer coefficients of reclaimed stabilized base (RSB) and re-evaluate the layer coefficients of other commonly used base and subbase materials, including:

- Gravel (Item 304.2)
- Crushed Gravel (Item 304.3)
- Crushed Stone—fine (Item 304.4)
- Crushed Stone—coarse (Item 304.5)
- Reclaimed Stabilized Base (Item 306)
- Asphalt Concrete
- Pavement Millings

California Bearing Ratio

Clegg Hammer

Tests were conducted with the heavy weight deflectometer (HWD), dynamic cone penetrometer (DCP), and the Clegg hammer. California bearing ratio (CBR) tests were also conducted. The aim was to use the test data to back-calculate the layer modulus and relate it back to the layer coefficients.

CRREL SPECIAL REPORT 99-14

In the late 1990's, CRREL was contracted to develop a laboratory testing program to evaluate the strength properties of subgrade soils commonly found in New Hampshire. To accomplish this task, resilient modulus tests were conducted on five different subgrade soils which reflected most, but not all of the possible soils that would be encountered during construction (see Table 1).

Tests were conducted on samples prepared at optimum density and moisture content, using a kneading compactor. A series of trials were conducted to determine the correct kneading pressure and the number of tamps necessary to provide a uniform density (as a function of depth) for the sample at the optimum moisture content. To determine the effective resilient modulus, tests were conducted at room temperature and at freezing temperatures. The computer program FROST was used to determine the temperature at the top of the subgrade layer for typical interstate and rural pavements. Temperatures for both the Concord and Lebanon, N.H. areas were used in the analysis.

CRREL Designation	Classifications: New Hampshire	AASHTO	USCS	Optimum Moisture ω (%)	Density γ_d (pcf)
NH1	Silt, some fine sand. Some coarse to fine gravel, trace coarse to medium sand (glacial till).	A-4	SM	9.0	128
NH2	Fine sand, some silt.	A-2-4	SM	14.5	107
NH3	Coarse to fine gravelly, coarse to medium sand, trace fine sand.	A-1-a	SP	9.5	108
NH4	Coarse to medium sand, little fine sand.	A-1-b	SP	13.6	102.5
NH5	Clayey silt (marine deposit).	A-7-5	ML	23.5	101

Table 1: Common NH subgrades tested under CRREL 99-14

BENEFITS AND IMPLEMENTATION

Some of the direct benefits of this research are as follows:

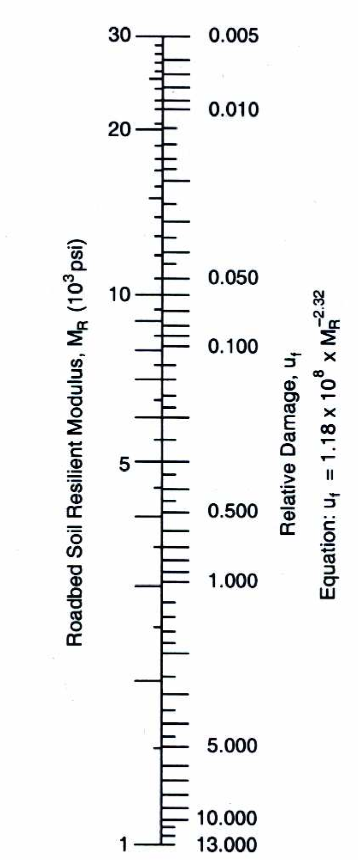
1. The layer coefficients provided by the CRREL 94-30 study provide a check against the NHDOT layer coefficients that are used in design practice today. Although revised layer coefficients were suggested by CRREL, it was recommended that a follow-up study be conducted to determine the seasonal structural performance of the pavement structure whereby test sections using the old and new layer coefficients would be constructed and the performance monitored over time to validate the newer values.

2. The modulus values that were obtained from the CRREL 94-30 study may be utilized in implementation of the upcoming AASHTO Mechanistic-Empirical Design Guide and may also be used in the Asphalt Institute Perpetual Pavement Design method. However, further research studies to evaluate the fluctuation of the modulus values through the different seasons are recommended.

3. The CRREL 99-14 study provides a useful evaluation of five typical subgrades that are commonly encountered during construction. The study provides insight into how the modulus varies between the seasons (see the chart, Figs. 1 & 2), especially during the spring thaw, and provides guidance to the designer regarding the effective resilient modulus concept that is incorporated in the 1993 AASHTO Design Guide. The effective resilient modulus concept represents a significant advancement from the 1973 Design Guide and the "one value fits all" approach. This information may also be used with the newer Mechanistic Empirical and Perpetual Pavement Design methods.

Month	Roadbed Soil Modulus (psi) M_R	Relative Damage u_f
Jan	20,000	0.01
Feb	20,000	0.01
Mar	2,500	1.51
Apr	4,000	0.51
May	4,000	0.51
Jun	7,000	0.13
Jul	7,000	0.13
Aug	7,000	0.13
Sep	7,000	0.13
Oct	7,000	0.13
Nov	4,000	0.51
Dec	20,000	0.01
Summation: Σu_f		3.72

Average: $\bar{u}_f = \frac{\Sigma u_f}{n} = \frac{3.72}{12} = 0.31$



Effective Roadbed Soil Resilient Modulus, M_R (psi) = 5,000 (Corresponds to $\bar{u}_f$)

Figure 1. Chart for estimating effective roadbed soil resilient modulus for flexible pavement designed using the serviceability criteria (after AASHTO 1996).

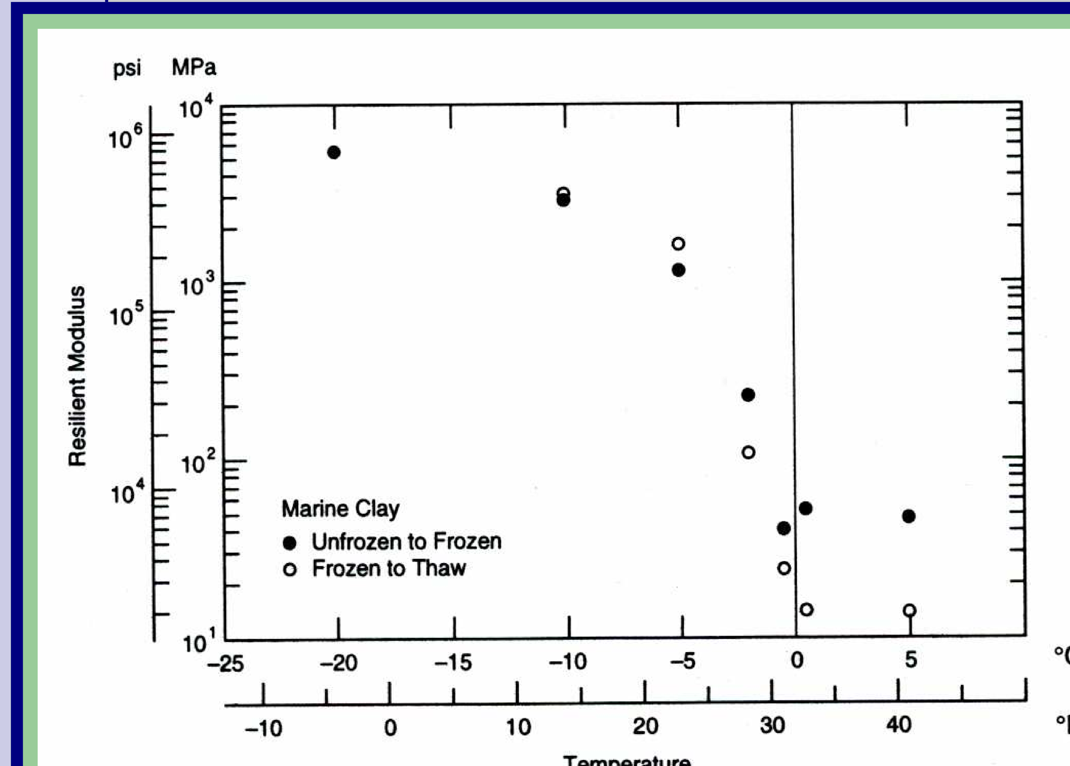


Figure 2. Effect of freezing and thawing on the resilient modulus of marine clay.

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FOR MORE INFORMATION

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