Lecture 8

Nondestructive Structural Evaluation of Flexible Pavement

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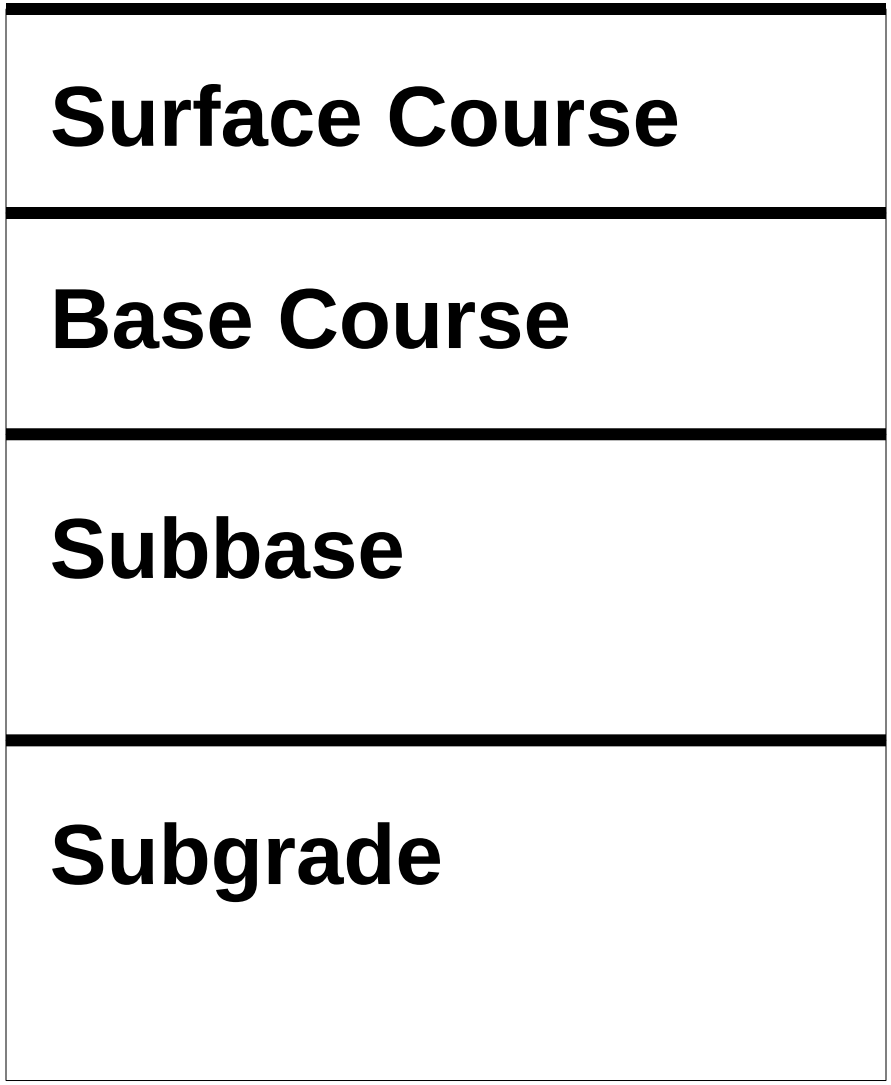
Backcalculation of Flexible-Pavement Properties



- Elastic multilayer system
- Linear vs. nonlinear systems
- Static vs. dynamic loading

Steps in Backcalculation

1. Assume E_1 , E_2 , E_3 , μ_1 , μ_2 , μ_2
2. Compute surface deflections
3. Compare computed and measured deflections
4. Check errors of computed deflections with respect to measured deflections
5. Repeat step 1 until errors are sufficiently low

Matching of Deflection Basins

Error to be Minimized	
♦ Sum of absolute differences of deflections	$Min. \sum_{i=1}^{N} w_i \left(D_i - d_i\right)$
♦ Sum of squared differences of deflections	$Min. \sum_{i=1}^{N} w_i \left(D_i - d_i\right)^2$
♦ Sum of squared relative errors of deflections	$Min. \sum_{i=1}^{N} w_i \left(\frac{D_i - d_i}{D_i}\right)^2$
♦ Maximum percent error of deflection	$Min \left\langle Max \left(\frac{D_i - d_i}{D_i}\right), \; i = 1,2,...N \right\rangle$
♦ Maximum percent error of computed layer modulus in successive iterations	$Min \left\langle Max \left(\frac{E_j^{(k)} - E_j^{(k-1)}}{E_j}\right), \; j = 1,2,..m \right\rangle$

Backcalculation Software

- **MODULUS** (microcomputer linear elastic backcalculation program) -- Texas Transportation Institute
- **WESDEF** – U.S. Army Corps of Engineers Waterways Experiment Station (WES)
- **EVERCALC** (microcomputer backcalculation program based on CHEVRON n-layer elastic solution scheme) – University of Washington for WSDOT
- **MICHBACK** (microcomputer linear elastic backcalculation program) – University of Michigan

Choice of Seed Moduli

- Most backcalculation software requires input of seed moduli
- Issues with user-input seed moduli
- Choice of seed-moduli affects performance of backcalculation software, and final results of the backcalculated elastic moduli

Methods of selecting seed moduli:

- Engineering judgment
- Regression equations
- Default values by software
- Estimated values from books
- Empirical rules

Computer Software for Generating Seed Moduli

- To minimize or eliminate subjectivity and user-dependency in seed moduli selection

- To develop a mechanistically based procedure for estimation of seed moduli

Concept of Approach

- Closed-form elastic 2-layer backcalculation program (2L-BACK)
- Seed moduli for top and bottom layers of multi-layer flexible pavement generated by 2L-BACK.

2L-BACK -- Closed-Form Backcalculation Program

Based on Burmister elastic 2-layer solution

$$w_i \, r_i \, E_1 = \frac{3P}{4\pi} F_i \quad \text{where } F_i = f\,[r, h, \theta=(E_2/E_1)]$$

➔ $w_i F_k - w_k F_i = 0$ and solve for θ

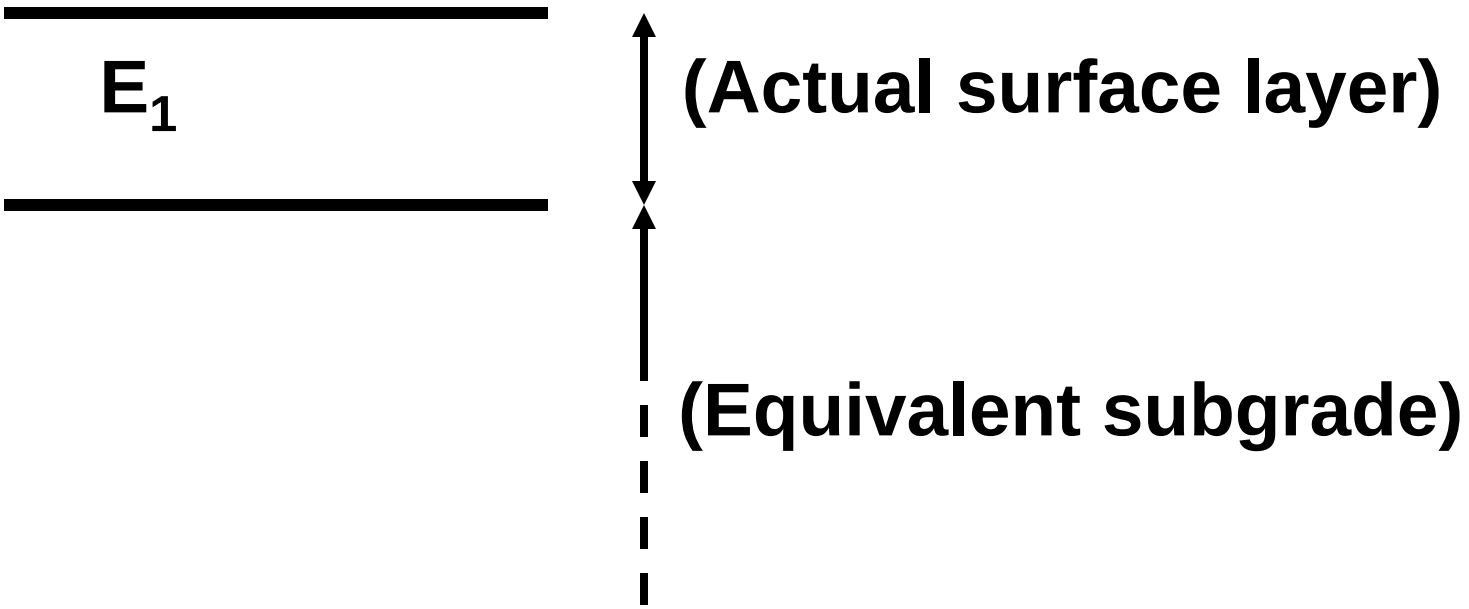
➔ Deflection equations to obtain E_2 and E_1

2L-BACK Closed-Form Backcalculation

- Input : h_1 , ν_1 , ν_2 , & deflection data
- Output : E_2 , E_1
- Pentium 4 PC 2.66 GHz execution time < 1 sec

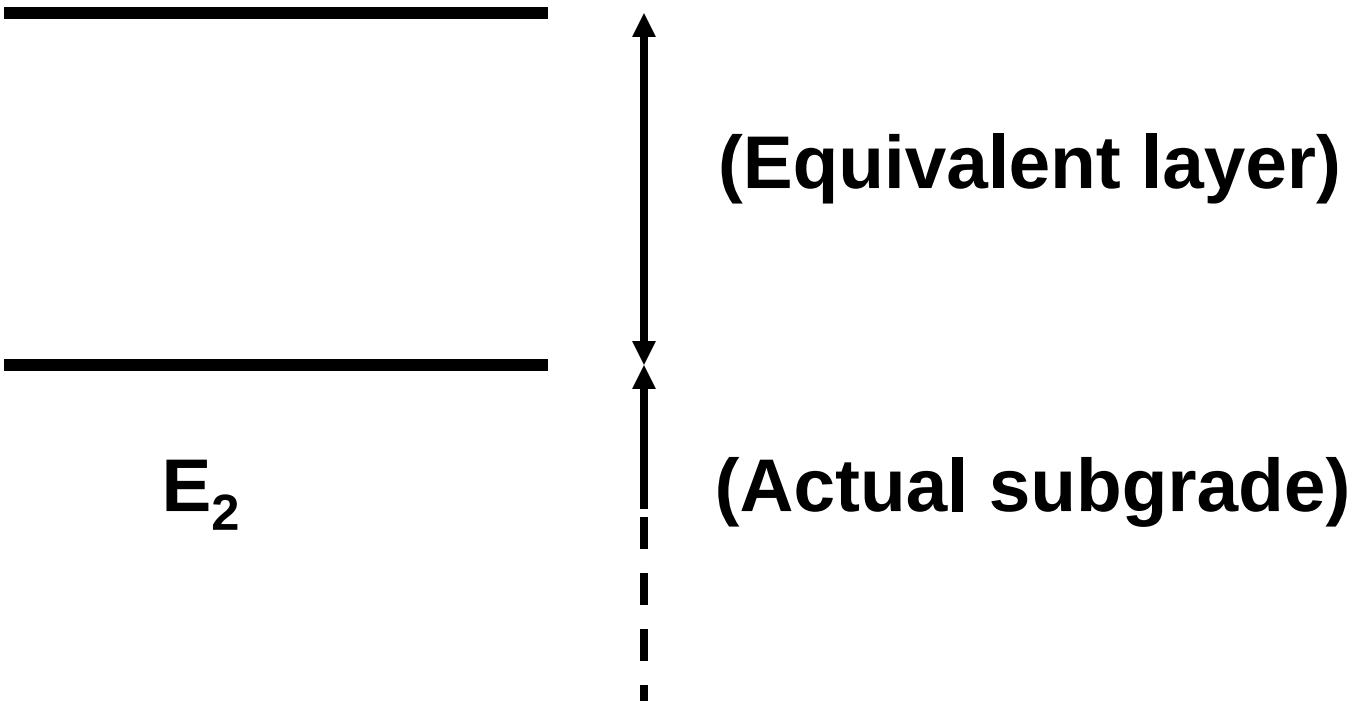
Seed Moduli by 2L-BACK

E_1 of Multi-Layer Flexible Pavement



Seed Moduli by 2L-BACK

E_2 of Multi-Layer Flexible Pavement



Seed Moduli by 2L-BACK

Moduli of Intermediate Layer(s)

Corps of Engineers Method:

$$E_2 = (1+0.17h_2)\,E_4$$

$$E_3 = (1+0.075h_3)\,E_4$$

References

- Chapter 20 “Structural Evaluation of Highway Pavements” in The Handbook of Highway Engineering, edited by T. F. Fwa. (2006)
- Fwa T. F. and Rani T. S. (2005) Seeds-Generation Algorithm for Moduli Backcalculation of Flexible Pavement Properties. Transportation Research Record, No. 1905, pp. 117-127.