Lecture 7

Nondestructive Structural Evaluation of Rigid Pavement

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Structural Evaluation of Pavements

- Structural capacity
- Remaining-life
- Overlay design
- Maintenance/Rehab planning

Surface Deflection Approach

- Deflection bowl indices
- Empirical correlation
- Analytical backcalculation

EVALUATION OF STRUCTURAL CONDITION

Non-destructive evaluation based on pavement surface deflections measurements have been the standard practice.

Backcalculation Analysis is performed to derive material properties of pavement layers.

Methods of surface deflections measurement

(A) Static-Load Deflection Methods
- Plate loading test
- Benkelman Beam Method

(B) Moving-Load Deflection Methods
- Vehicle- or wheel-mounted sensors to measure dynamic deflections
- Curviameter (French) measures vertical acceleration
- Sensors embedded in pavement

Evaluation of Structural Condition

Methods of surface deflections measurement *(cont'd)*

(C) Steady-State Vibratory Deflection Methods

- Dynaflect
- Road Rater
- WES Vibrator (Waterways Experiment Station, US Army Corps of Engineers)

(D) Impact/Impulse Deflection Methods

Falling Weight Deflectometer (FWD) is the most common.

Mass of falling weight, height of fall, and spring damping system can be designed to produce loading impulse closely resembling those produced by moving traffic.

Note: Applicable system parameters of FWD are different for tests on highways and airfields.

ISSUES IN BACKCALCULATION

An Inverse Problem

- Poorly conditioned
- Non-unique solutions
- Seed value dependent

Solutions sensitive to:

- Layer thickness input
- Deflection readings errors
- Initial seed values
- Methods of solution

Advantages of Closed-Form Solutions

- Unique answers
- Quick computation
- Trial values not needed

CLOSED-FORM BACKCALCULATION OF RIGID PAVEMENT

- 2-Layer Rigid Pavement
- 3-Layer Rigid Pavement
- 2-Slab Pavement Systems

2-Layer Rigid Pavement

(Slab) Ec	(Slab) Ec
(Liquid) k	(Solid) Es

ILLI-BACK for 2-Layer System

$$\text{AREA} = 6\left(1 + 2\frac{D_1}{D_0} + 2\frac{D_2}{D_0} + \frac{D_3}{D_0}\right)$$

$$\sum W_i D_i = 6D_0 + 12D_1 + 12D_2 + 6D_3$$

$$\sum W_j D_j = D_0$$

NUS - BACK

- General closed-form solution
- PC-based program
- Any 2 deflection input
- Seed values not needed

2-Layer Rigid Pavement

$D_i = f_1$ (Ec, Es or k)

$D_J = f_2$ (Ec, Es or k)

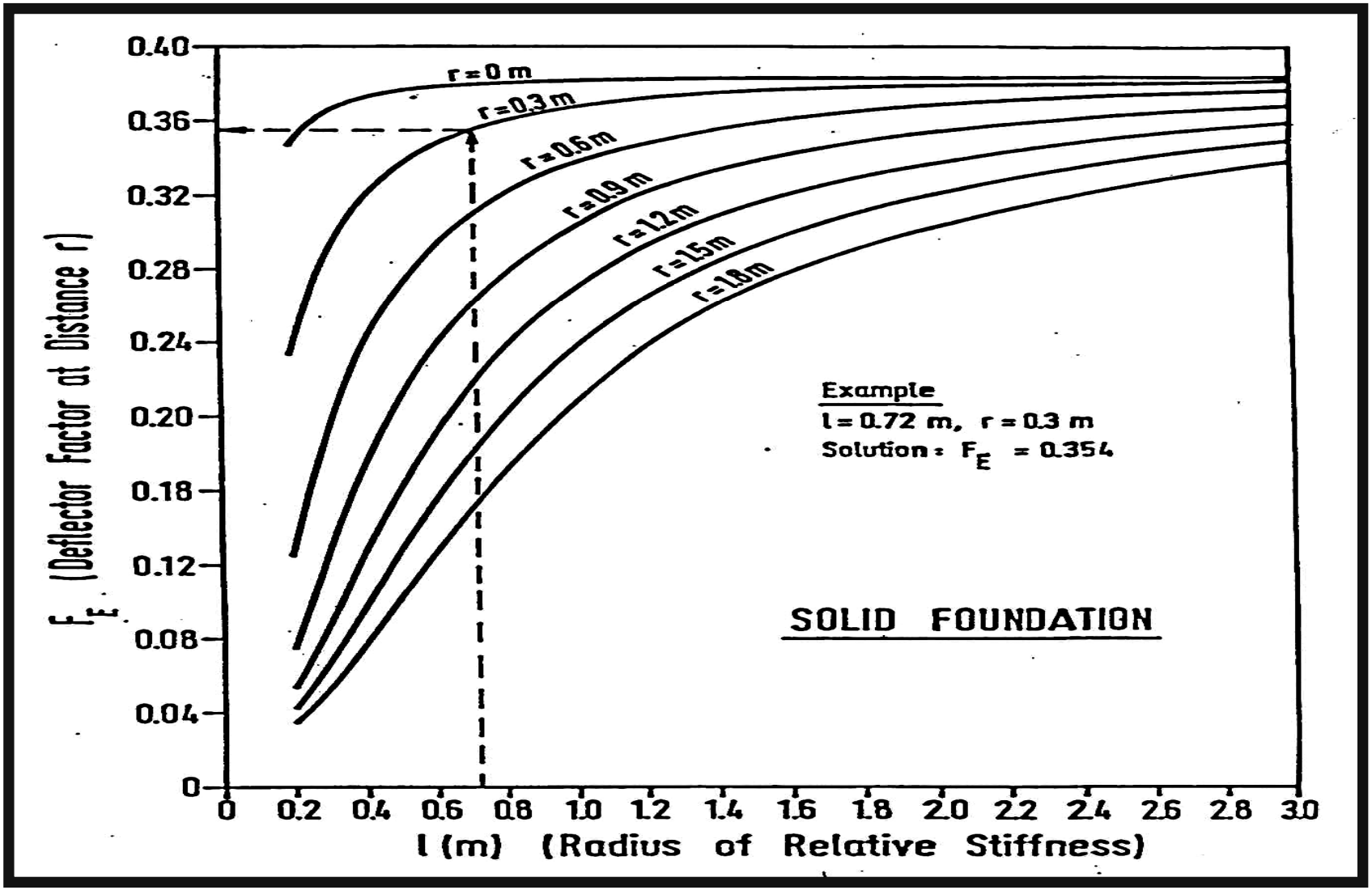
NUS - BACK

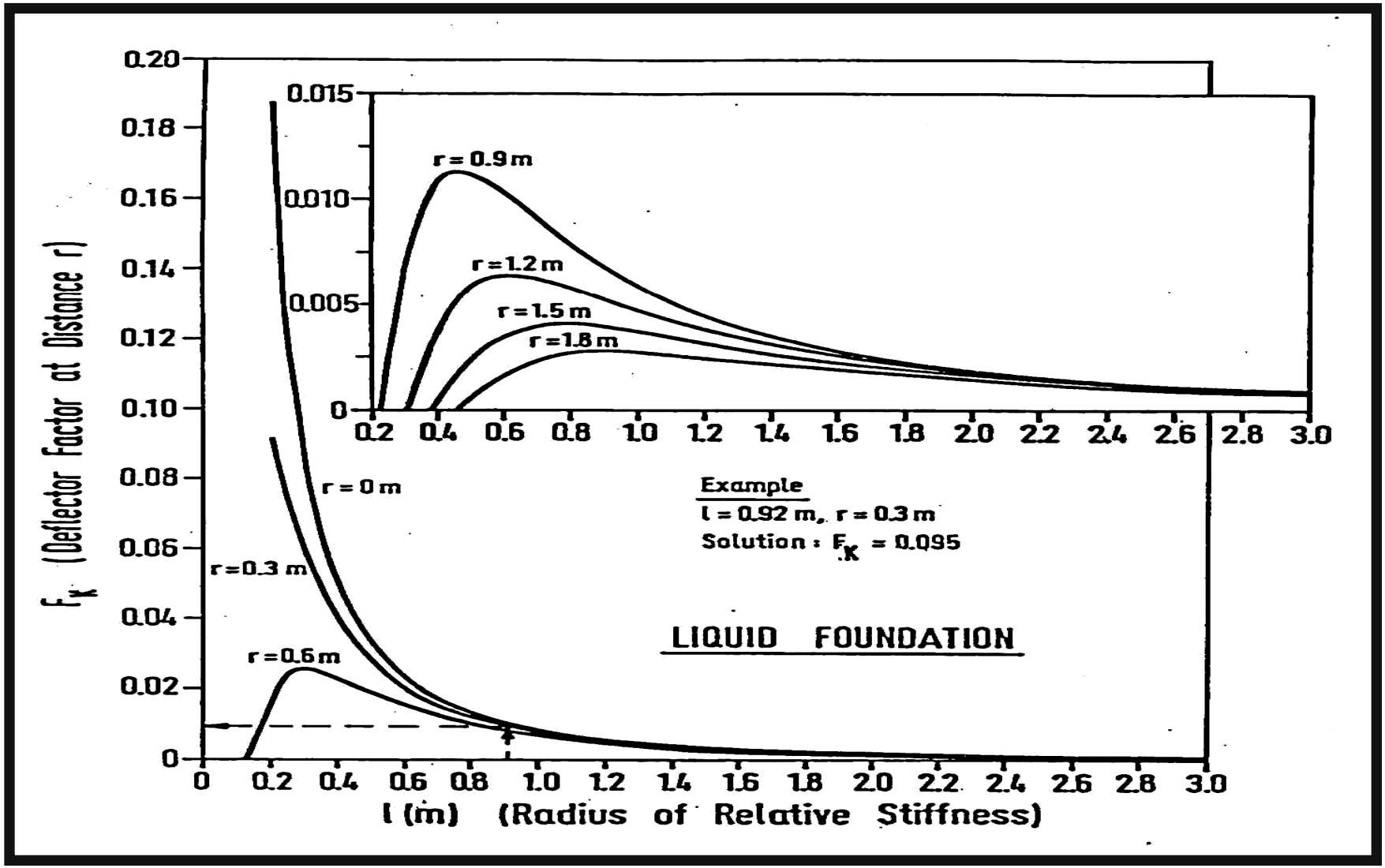
$$D_i = \frac{P}{k\pi a^2} F(\ell, r_i)$$

$$D_j = \frac{P}{k\pi a^2} F(\ell, r_j)$$

NUS - BACK

- PC Program
- Graphical solutions

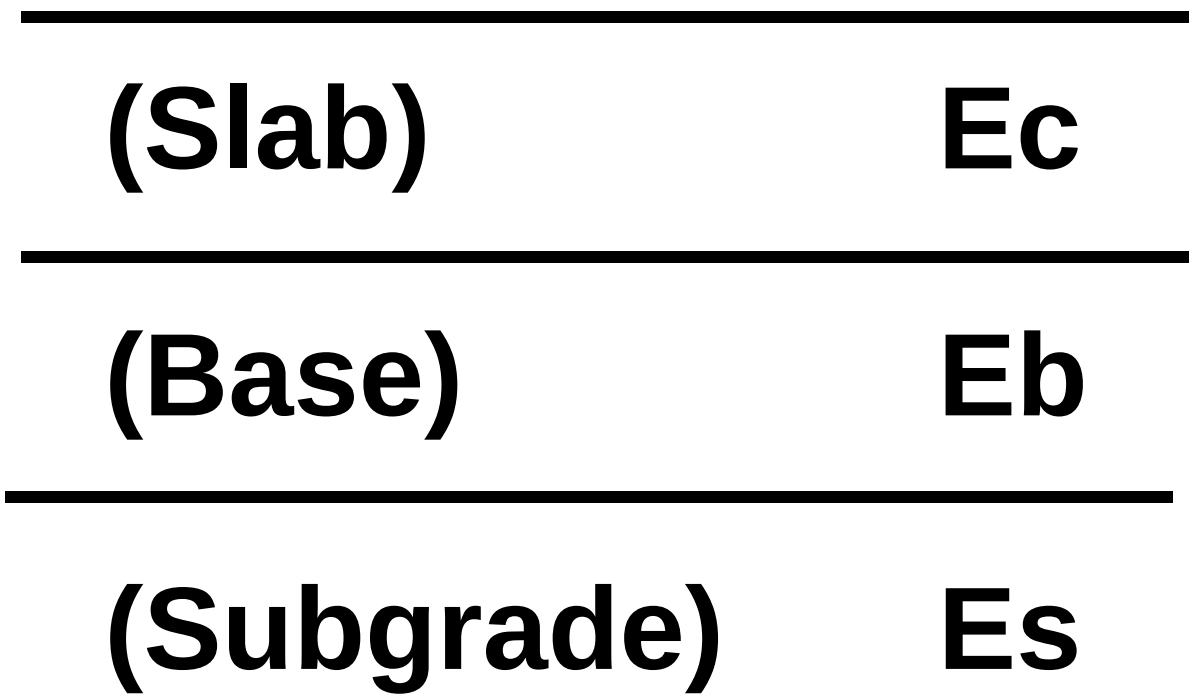

0.40
0.36
0.32
0.28
0.24
0.20
0.18
0.12
0.08
0.04
0
F_E (Deflector Factor at Distance r)
r=0 m
r=0.3 m
r=0.6 m
r=0.9 m
r=1.2 m
r=1.5 m
r=1.8 m
Example
l = 0.72 m, r = 0.3 m
Solution : F_E = 0.354
SOLID FOUNDATION
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0
l (m) (Radius of Relative Stiffness)


0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
0.015
0.010
0.005
0
r = 0.9 m
r = 1.2 m
r = 1.5 m
r = 1.8 m
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0
r = 0 m
r = 0.3 m
r = 0.6 m
Example
l = 0.92 m, r = 0.3 m
Solution : F_K = 0.095
LIQUID FOUNDATION
F_K (Deflector Factor at Distance r)
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0
l (m) (Radius of Relative Stiffness)

NUS-BACK vs. ILLI-BACK

- More reliable
- Equipment dependency
- Missing readings
- Faulty readings

3 - Layer Rigid Pavement



3 - Layer Rigid Pavement

$$D_1 = \frac{A}{E_b} F(\ell, c, r_1)$$

$$D_2 = \frac{A}{E_b} F(\ell, c, r_2)$$

$$D_3 = \frac{A}{E_b} F(\ell, c, r_3)$$

NUS - BACK 3

- PC - based solution
- Any 3 deflections
- Seed values not needed

Two - Slab Pavement

(Slab 1) Ec_1
(Slab 2) Ec_2
k Es

(Slab 1) Ec_1
(Slab 2) Ec_2
(Base) Eb
(Subgrade) Es

Semi-Closed-Form Backcalculation

- Unique k or Es(NUS-BACK2)
- Unique Eb & Es(NUS-BACK4)
- Nonunique Ec_1 & Ec_2

References

- Chapter 20 “Structural Evaluation of Highway Pavements” in The Handbook of Highway Engineering, edited by T. F. Fwa. (2006)
- Fwa T. F., Tan K. H. and Li S. (1999) Closed-Form and Semi-Closed-Form algorithms for Backcalculation of Concrete Pavement Properties. ASTM Special Publication, STP No. 1375, pp. 267-280.