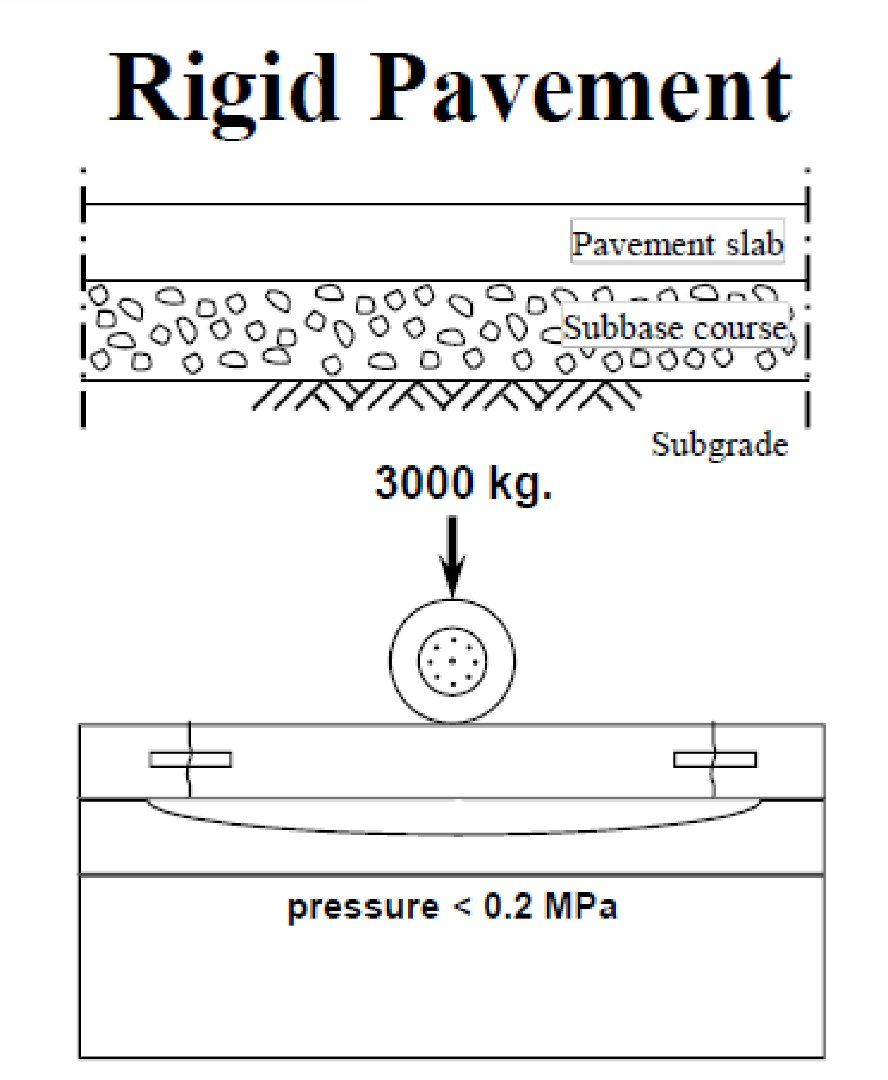
TOPIC 9

Structural Design of Pavements

Part 2

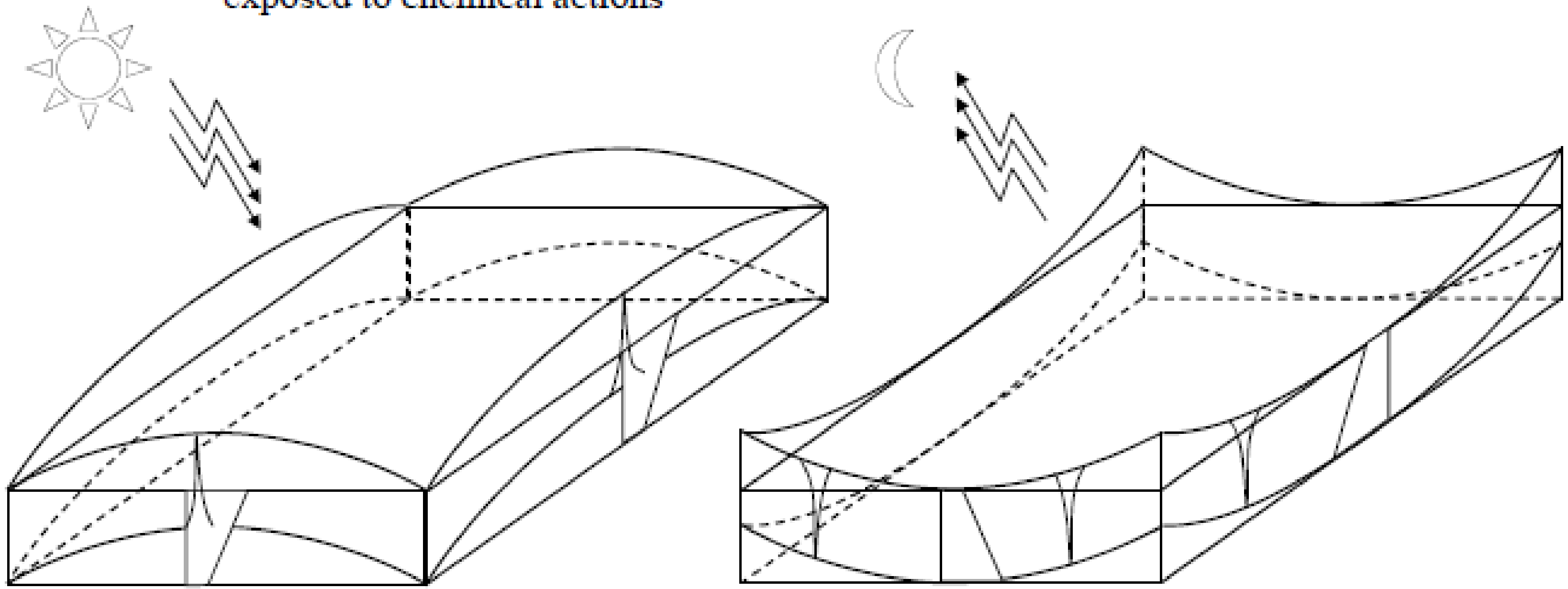
Structural Design of Rigid Pavements



Introduction

Structural Components of a Rigid Pavement

- Pavement slab:
  - Portland cement concrete (PCC)
  - Carries traffic loads through a bending action and distributes it over a large area of the subbase or subgrade
  - Designed and constructed for long service lives
  - Maintenance costs are less than those for flexible pavements
  - Subject to environmental stresses due to temperature or moisture changes
  - Can be used for heavy-traffic roads, weak subgrade, and if the pavement surface is exposed to chemical actions



Structural Components of a Rigid Pavement

- Subbase course:
  - A granular or stabilized layer added between the subgrade and the pavement slab
  - May or may not be used
  - Helps in drainage, controlling capillary rise, and controlling volume changes in the subgrade
  - Reduces the subgrade pumping
  - Provides a more suitable surface for constructing the pavement slabs
- Subgrade

Structural Components of a Rigid Pavement

Types of Reinforcing Steel

Temperature steel:

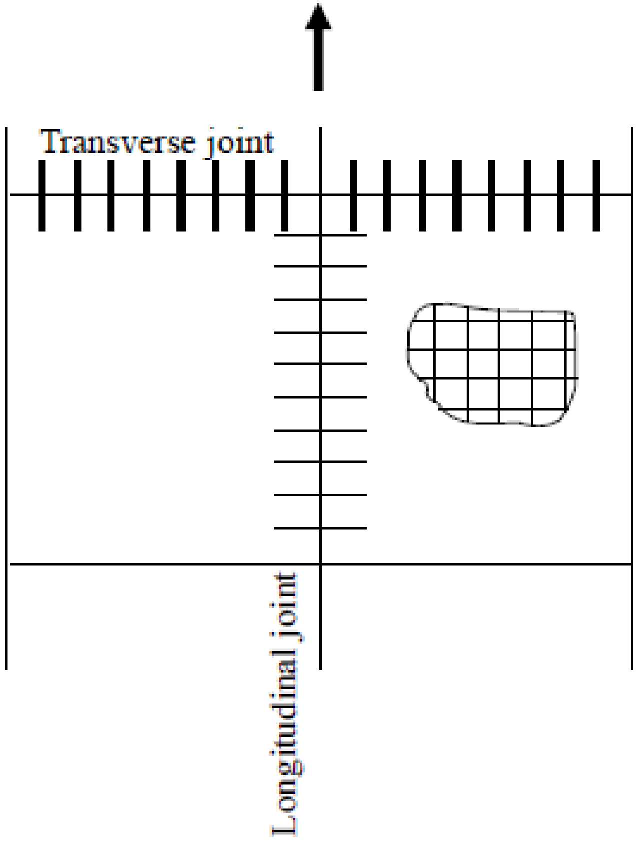
- Bar mat
- Does not prevent cracking but controls the crack width
- Amount of steel depends mainly on the dimensions of pavement slab
- Does not add directly to the pavement's flexural strength

Dowel bars:

- Load transfer mechanism across transverse joints between successive slabs
- Large diameters
- At least one end of the bar should be smooth and lubricated to facilitate free expansion

Tie bars:

- Tie adjacent slabs across longitudinal joints
- Much smaller diameters
- Should be deformed or contain hooks



Types of Rigid Highway Pavements

- PCC pavement type depends on the length of pavement slabs

Plain concrete pavement:

- Joints are placed at short distances (10 to 20 ft)
- No temperature steel
- Usually, no dowel bars

Simply reinforced concrete pavement:

- Joint spacing ranges from 30 to 100 ft
- Temperature steel and dowel bars are used

Continuously reinforced concrete pavement:

- No transverse joints except construction joints or expansion joints where necessary
- High percentage of steel (temperature steel)

Design of Rigid Pavements

- Design can be empirical or theoretical
- Objective is to determine the minimum thickness of PCC slabs required to control fatigue and erosion

PCA Design Method

- Based on a combination of theoretical studies, test results, and experience
- Applicable to plain, simply reinforced, and continuously reinforced concrete pavements

Design of Rigid Pavements

Design Considerations

Flexural Strength of Concrete:

- Determined in terms of modulus of rupture (M_r)
- M_r is obtained by the third-point method

Subgrade and Subbase Support:

- Determined in terms of modulus of subgrade reaction (K)
- If a subbase is used, K is increased according to Table 20.22

Table 20.22 Design *k* Values for Untreated and Cement-Treated Subbases

(a) Untreated Granular Subbases

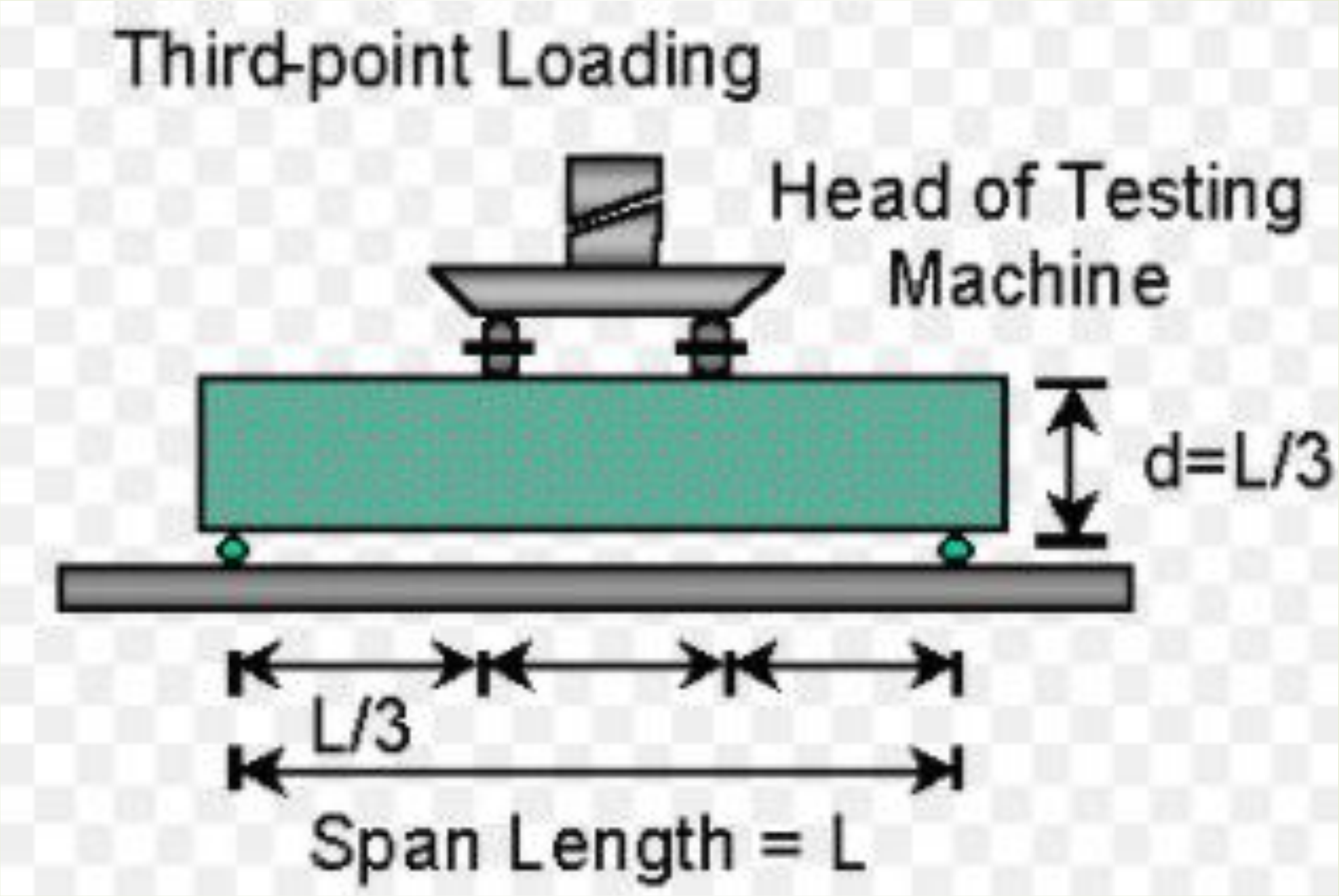
	Subbase *k* Value (lb/in.^{3})			
Subgrade k Value (lb/in.^{3})	*4 in.*	*6 in.*	*9 in.*	*12 in.*
50	65	75	85	110
100	130	140	160	190
200	220	230	270	320
300	320	330	370	430

(b) Cement-Treated Subbases

	Subbase *k* Value (lb/in.^{3})			
Subgrade k Value (lb/in.^{3})	*4 in.*	*6 in.*	*9 in.*	*12 in.*
50	170	230	310	390
100	280	400	520	640
200	470	640	830	—

SOURCE: R.G. Packard, *Thickness Design for Concrete Highway and Street Pavements*, American Concrete Pavement Association, 1984. Used with permission.

Design of Rigid Pavements



Design of Rigid Pavements

Traffic Loads:

- Computed in terms of the cumulated number of single and tandem axles of different loads projected for the pavement design period
- Axle loads are magnified by a load safety factor (LSF) taken as:
  - 1.2 → interstate and multilane highways (high truck volumes)
  - 1.1 → arterials (moderate truck volumes)
  - 1.0 → roads and residential streets (low truck volumes)

Design of Rigid Pavements

Design Procedure

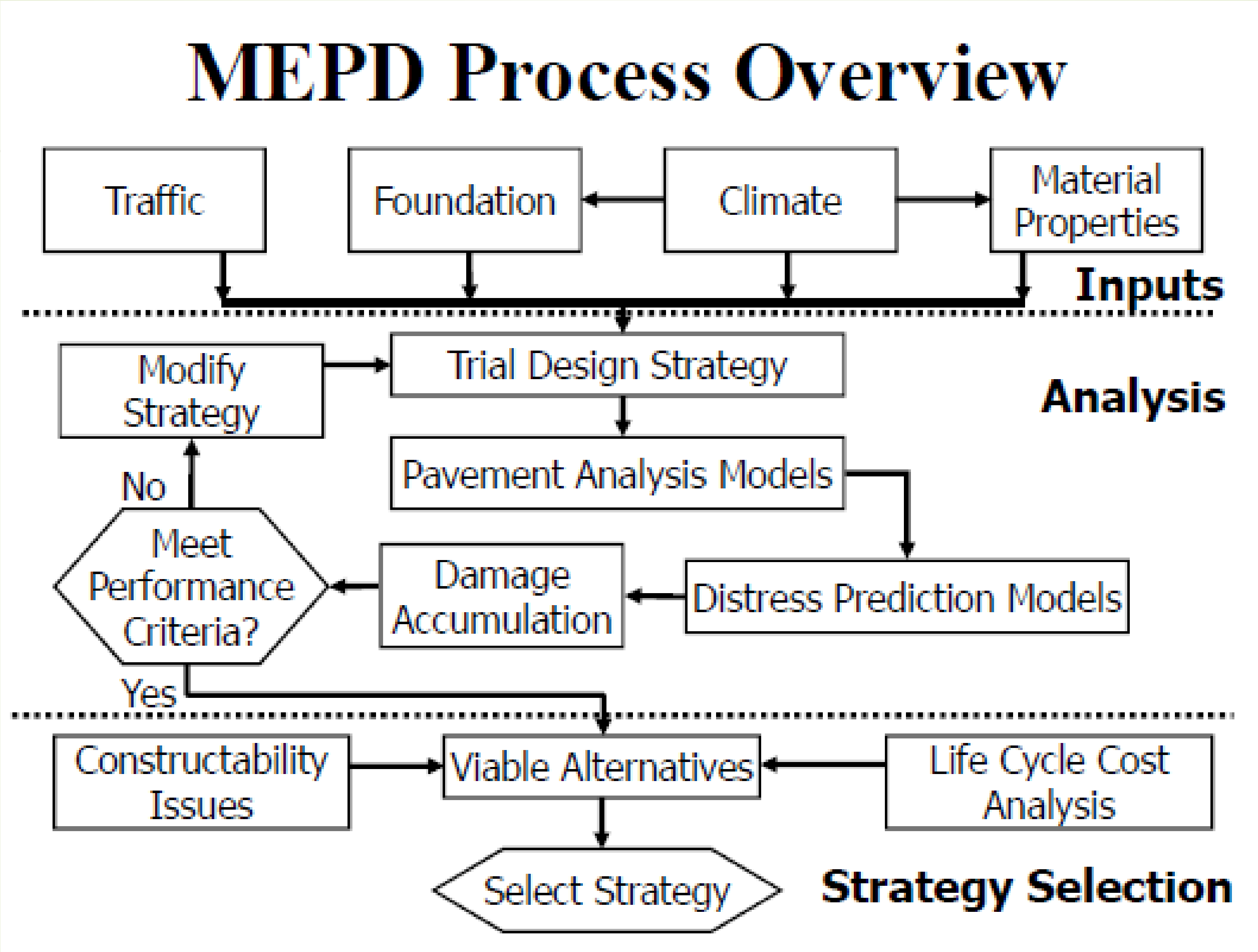
- Determine the cumulated number of repetitions of each axle load, and the LSF
- Determine the *K* of subgrade-subbase based on *K* (subgrade) and the type and thickness of the subbase
- Determine the concrete M_r, and select a trial thickness
- Fatigue Analysis:
  - Determine the equivalent stress values for single and tandem axles
  - Determine the stress ratio factors
  - For each axle, determine the allowable repetitions and the fatigue percent
  - Summation of all fatigue percents $\ngtr$ 100%
- Erosion Analysis:
  - Determine the erosion factors for single and tandem axles
  - For each axle, determine the allowable repetitions and the damage percent
  - Summation of all damage percents $\ngtr$ 100%

Example - Design of Rigid Pavements

AASHTO's MEPDG

- Up to 1993, AASHTO design method was based on empirical performance data and equations based on the AASHO Road Test
- In 2002, NCHRP Project 1-37A had a goal to develop a design guide utilizing existing mechanistic models and data
- The Mechanistic-Empirical Pavement Design Guide (MEPDG) was then completed in 2004 and released to the public for review and evaluation
- A number of revisions and improvements were incorporated into the 2008 Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice
- The MEPD method is more accurately an analysis method
  - Provides the amount of distress over time
  - An iterative design method

AASHTO's MEPDG



AASHTO's MEPDG

- Three main stages:
  - Input (evaluation)
    - **Traffic**
    - **Foundation**
    - **Climate**
    - **Material properties**
  - Analysis
    - **Flexible pavements**
      - » *Fatigue cracking*
      - » *Thermal cracking*
      - » *Longitudinal cracking*
      - » *Rutting*
      - » *Smoothness (IRI)*
    - **Rigid pavement**
      - » *Transverse slab cracking (JPCP)*
      - » *Transverse joint faulting (JPCP)*
      - » *CRCP punchouts*
      - » *Smoothness (IRI)*
  - Strategy Selection

AASHTO's MEPDG

- As a design procedure, follow five basic steps:
  - Select a trial design (trial pavement structure)
  - Select appropriate performance indicator criteria (threshold values) and design reliability level for the design
  - Obtain all inputs for the trial pavement structure
  - Evaluate the trial design
  - Revise the trial design as needed

Thank You!!!