Pavement Design Principles

Dr. Antonis Michael
Frederick University

Notes Courtesy of Dr. Christos Drakos
University of Florida

Topic 1 – Pavement Design Principles

What is Design?
• Conceive & develop plans for something to serve a specific function
• Must define function prior to design

What is the Function of a Pavement?
• To provide vehicle access between two points

• More specific function for pavements:
  – Access → Under all climatic conditions (drain)
  – Durable → Sufficient structure for loads
  – Safe → Adequate friction
  – Smooth → Good ride quality, level
**Topic 1 – Pavement Design Principles**

**How many Elements into the Design of a Highway?**
- Route → Geometric design
- Materials → Mix design
- Pavements → Thickness design

**What information do you need as an Engineer?**
- Topography
  - Route (Access)
  - Drainage (Hydrology)
  - Cut / Fill (Cost)
- Existing soils
  - Must carry loads
  - Determine structural requirements
  - Affect drainage and drainage requirements

---

**What information do you need as an Engineer? (cont)**
- Weather (Rainfall – Temp. variation)
  - Drainage
  - Frost Heave
  - Durability of Asphalt/PCC Roads
    - Rutting / Bleeding (HOT)
    - Low temperature cracking (COLD)
- Traffic (Load levels)
  - Structural requirements
- Use (Primary or secondary facility)
  - Acceptable quality
  - High or low maintenance
- Design life
  - High initial cost → Low maintenance cost (high access)
  - Low initial cost → High maintenance cost (low access)
Topic 1 – Pavement Design Principles

What information do you need as an Engineer? (cont.)

- Available materials / Contractors
  - Type of structure (AC or PCC)
  - Stabilization requirements

MANY ASPECTS TO DESIGN OTHER THAN SIZING COMPONENT

Topic 1 – Pavement Design Principles

What will this course cover?

- Pavement types:
  - Flexible (Asphalt Concrete)
  - Rigid (Portland Cement Concrete)
- Failure modes/causes:
  - Rutting
  - Cracking
- Stresses in the pavement structure:
  - Distribution of stresses and strains
  - Multilayer analysis
- Traffic Characterization
  - Predict traffic loads over a certain period of years
- Material Characterization
  - Define material properties
- Design Procedures
  - AI
  - AASHTO
Topic 1 – Pavement Design Principles

Pavement History – Major Developments

• Wheel
  – 3500 BC / ASIA
  – Roads begun; movement to Egypt

• First Long-distance Highway
  – 3500 to 323 BC / Persia
  – 1755 miles; three-month trip

• First Engineered Road
  – 300 BC / Romans (Appius Claudius)
  – Built 53,000 miles of road
  – Via Appia: 360 miles, 14-ft wide, 3-5 ft thick, hand placed!
  – Lasted 2000 years; Recognized two essentials:
    ▪ Dry Road bed
    ▪ Impervious surface

Topic 1 – Pavement Design Principles

First Engineered Road

Concrete
(Stone & other material with Lime)

Squared Stones

Fine Dry Soil (Well-compacted)
First Modern Roads

- 1764 France (Tresaguet)
- Labor costs too high; smaller stones, thinner sections
- Maintained two essentials mentioned above; 10 years design life

Use of Tar and Asphalt

- 1830’s USA - England (McAdam)
- Impervious surface; asphalt/tar mixed hot; sand added to fill voids
Pavement History – Other Developments

- **Portland Cement Concrete (PCC)**
  - 1850 Austria – first PCC roads
- **Rubber-tired Motor Cars**
  - 1900 USA – caused dust & pollution problems
  - Generated need for binders
  - Higher speed requiring more smoothness
- **Highway Research Board (Currently: TRB)**
  - 1920 USA
  - Research efforts to improve pavement design
  - Looked at better materials & construction methods
  - Initiated rapid development in pavement technology
- **20th Century Pavements**
  - Better understanding of stress distribution
  - Use stiffer/stronger materials near the surface

### 1. Introduction

1.1 What is Pavement Structure?

![Pavement Structure Diagram]

#### Subbase Course
- Subgrade (existing Soil)
- Asphalt Concrete
- Shoulder

1.2 Purpose of Pavement Structure

- Protect Subgrade → reduce stresses & strains to tolerable level
- Prevent excessive settlement or collapse
- Remove water → Structural integrity & safety

How does the structure protect the subgrade?
1.3 Stress Distribution under Wheel Load

Two ways to reduce $\sigma_z$:
- Increase stiffness
- Increase thickness

Vertical Stress Distribution along the horizontal axis; highest near the center

1.4 What do we need to compute?
- Subgrade stresses ($\sigma$) & strains ($\varepsilon$)

Since we want to protect the subgrade, is it enough to design the pavement to minimize subgrade $\sigma$ & $\varepsilon$?
- Need $\sigma$ & $\varepsilon$ within structural layers; must ensure all layers can withstand stresses

- Max $\sigma_z$ at surface
- $\sigma_z$ decreases with depth
- As the $\sigma$ decreases the quality of the material may be lower
Topic 1 – Pavement Design Principles

2. Pavement Types

2.1 Two Concepts

- Thicker section of lower stiffness materials
  - Flexible pavements → Asphalt Concrete
  - Shape can conform to subgrade irregularities without failure

![Flexible Pavement Diagram]

- Thinner section of higher stiffness materials
  - Rigid pavements → Portland Cement Concrete
  - Stiff enough to bridge subgrade irregularities

![Rigid Pavement Diagram]
2.2 Typical Flexible Pavement Structures

- Full depth asphalt pavement

Asphalt-aggregate mixture

Asphalt-aggregate mixture, or granular material treated with asphalt

Prepared Subgrade

- Asphalt pavement with untreated base (and subbase)

Asphalt-aggregate mixture

Base, Granular material; sometimes cement treated

Subbase, Granular material or selected soil; Normally not treated

Prepared Subgrade
2.2 Typical Flexible Pavement Structures

- Asphalt pavement with PCC

2.3 Typical Rigid Pavement Structures

- Jointed Plain Concrete Pavement (JPCP)
  - Possibly doweled

Purpose of Joints

- Designated crack – relieves thermal stresses
2.3 Typical Rigid Pavement Structures

- **Jointed Reinforced Concrete Pavement (JRCP)**
  - Always doweled
  - **Purpose of Reinforcement**
    - Holds cracks together
    - Does not add structural capacity
    - Diameter: $D/3 - \frac{1}{2}D$
  - **Purpose of Dowels**
    - Load transfer steel
    - 1/4 to 1½ Ø; ≈ 18” long
    - Never bonded

- **Continuously Reinforced Concrete Pavement (CRCP)**
  - Cracks spaced @ 3-8 ft

- **Prestressed Concrete Pavement (PCP)**
  - Slab Length 300 to 700 ft