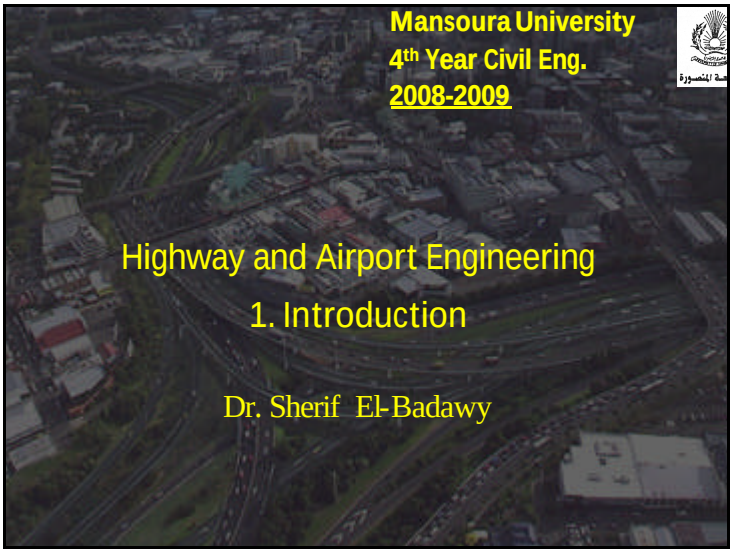


Course Contents

- **Structure Design**
  - »**Dr. Sherif El-Badawy**
- **Geometric Design**
  - »**Dr. Mostafa Kamel**
- **Airport Engineering**
  - »**Dr. Metwally Elskely**

Geometric Design

- Stopping and Passing Sight Distance
- Horizontal Alignment
- Vertical Alignment
- Cross section Elements
- Intersections
- Interchanges
- Parking

Structural Design Course Objective

Ability to Analyze and Design Flexible and Rigid Pavements

Structure Design Course Contents

- Pavement types, design factors
- Material characterization
  - Subgrade
  - Subbase and Base
  - Binder
  - HMA
- Traffic loading and analysis

Course Contents (Cont'd)

- Drainage materials and design
- Pavement performance, distress, serviceability, friction
- Joints, tie bars, dowel bars in concrete pavements

Course Contents (Cont'd)

- Design of flexible highway pavements
- Design of rigid highway pavements

(Both 1993 method and the M-E method)

Popular Perception

"Pavements are very simple engineered systems."

Harsh Reality

Pavement geometry is very simple, but everything else is very complex!

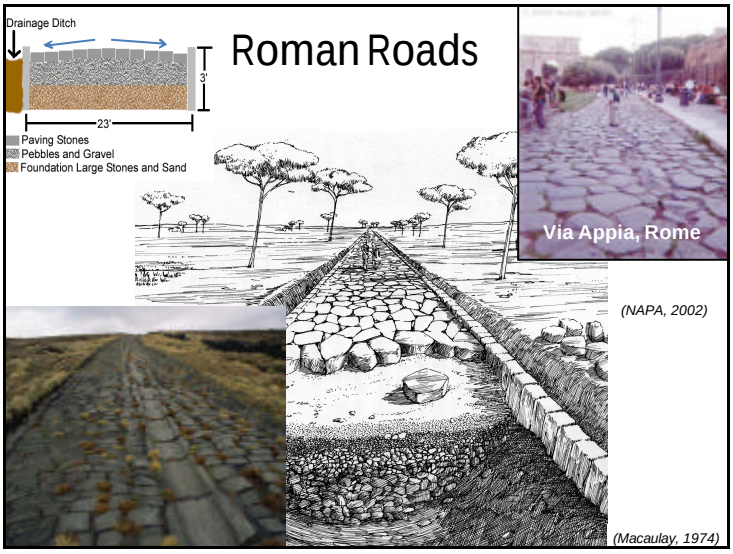
- Materials
  - Availability
  - Behavior
- Traffic Loads
  - Volume
  - Magnitude
  - Dynamic effects
- Environment
  - Temperature
  - Moisture
  - Freeze/Thaw
- Distresses
  - Variety
  - Interactions
- Construction
  - Rehabilitation

Objectives of Pavement Design

To provide a surface that is:

- Strong
  - Surface strength
  - Moisture control
- Smooth
- Safe
  - Friction
  - Drainage
- Economical
  - Initial construction cost
  - Recurring maintenance cost

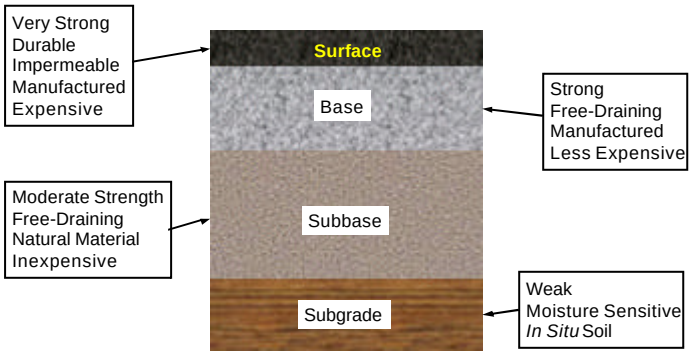
Roman Roads



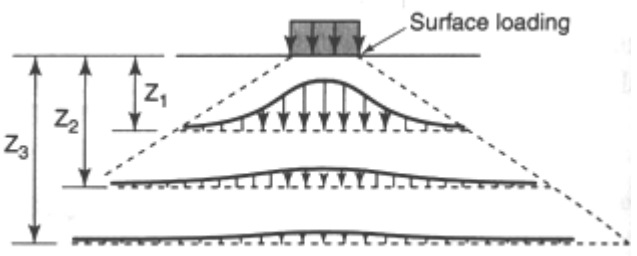
Pavement Structural Types

- **Flexible**
  - Asphalt concrete (AC)
- **Rigid**
  - Portland cement concrete (PCC)
- **Composite**
  - Asphalt + Portland cement concrete
  - Stabilized granular layers

Flexible Pavement Layers



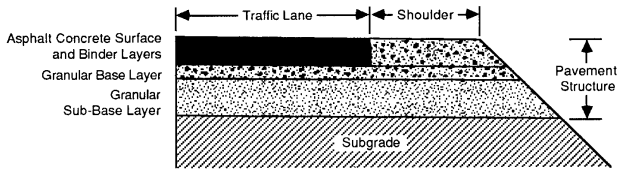
Stronger Layers "Shield" Weaker Materials



Depth Effect

(McCarthy, 1998)

Flexible Highway Pavement



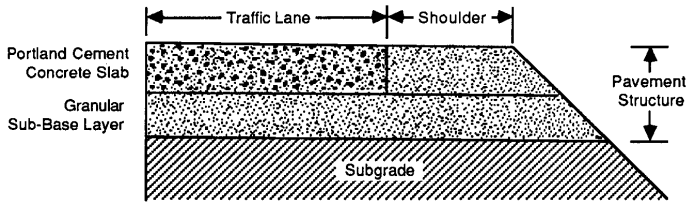
(Haas, Hudson, and Zaniewski, 1994)

Flexible Highway Pavement

Types of Flexible Pavements:

- Thin (< ~2" AC)
  - AC just a wearing surface
  - Strength provided primarily by unbound granular layers
- Thick
  - AC both a wearing surface and structural layer
  - Additional strength provided by unbound granular layers
- Full-Depth
  - AC provides all strength

Rigid Highway Pavement



(Haas, Hudson, and Zaniewski, 1994)

Rigid Highway Pavement

Types of Rigid Pavements:

- Jointed Plain Concrete Pavement (JPCP)
- Jointed Reinforced Concrete Pavement (JRCP)
- Continuously Reinforced Concrete Pavement (CRCP)
- Prestressed Concrete Pavements (PCP)

Types of Rigid Pavements

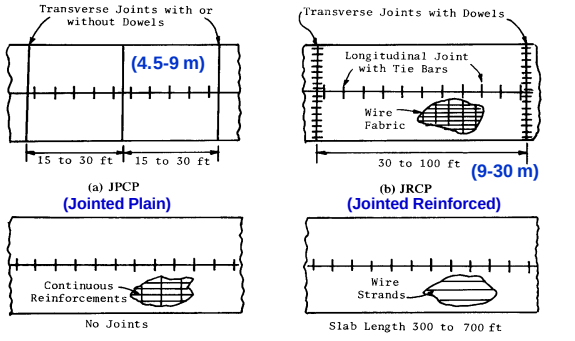


Figure 1.8 Four types of concrete pavements (1 ft = 0.305 m).

(Huang, 1993)

Composite Pavements

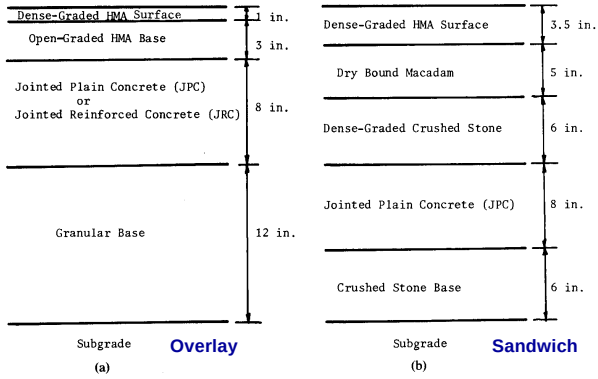


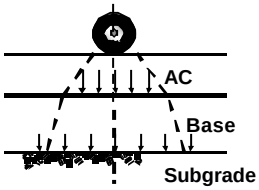
Figure 1.9 Two different cross sections for composite pavements (1 in. = 25.4 mm).

(Huang, 1993)

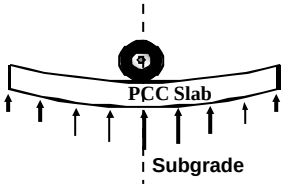
Flexible vs. Rigid Pavements

- Load distribution
- Initial cost
- Durability

Load Distribution



- Layered system
- All layers carry part of load



- Slab action
- Slab carries most load

Initial Cost

- Flexible pavement has lower initial cost
  - But may not have lower life-cycle cost

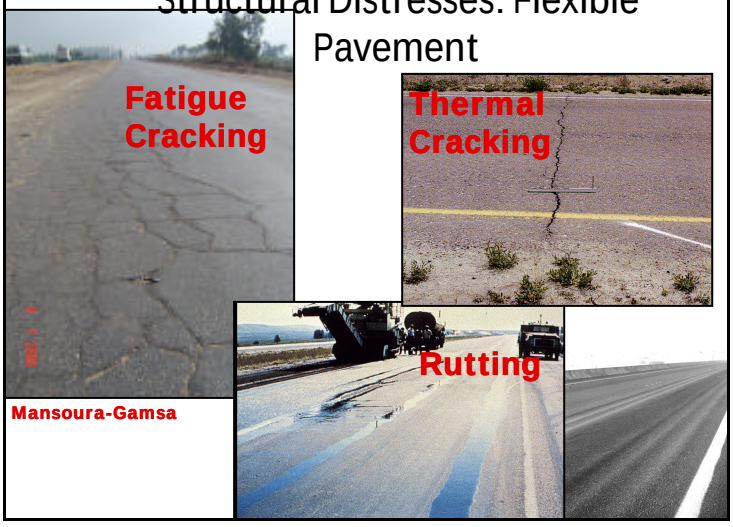
Durability

- Flexible pavement is less durable than rigid pavement

Function of Base/Subbase

- Flexible Pavement
  - **Structural support**
  - Drainage
  - Control of frost effect
  - Reduce effect of volume change of subgrade
- Rigid Pavement
  - Drainage
  - **Prevent pumping**
  - Control frost effect
  - Reduce effect of volume change of subgrade
  - Construction platform

Structural Distresses: Flexible Pavement



Distresses vs. Failure

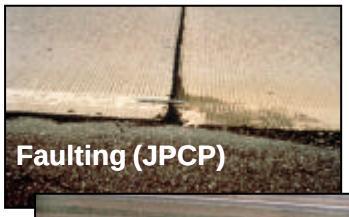
When a distress or a combination of distresses reaches a certain unacceptable level it is considered failure

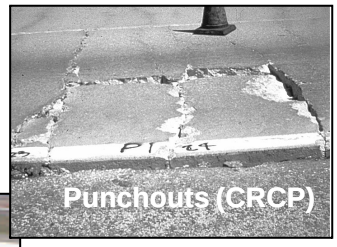
Types of Distresses

Flexible Pavement

- Rutting
- Alligator Fatigue cracking (bottom-up)
- Longitudinal Fatigue cracking (top-down)
- Thermal cracking
- Roughness
- Bleeding
- Etc.

Structural Distresses: Rigid





Types of Distresses

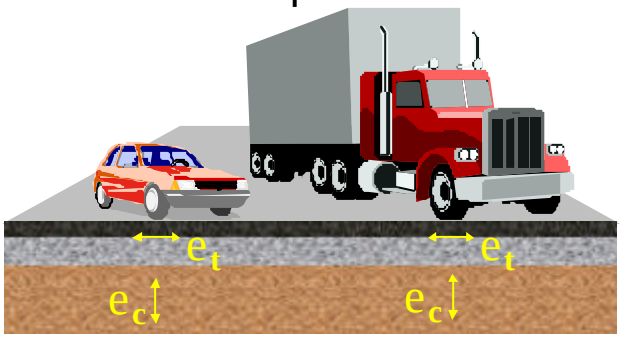
Rigid Pavement

- Cracking
- Faulting
- Pumping
- Blow-up
- Scaling
- Spalling
- Etc.

Pavement Design Methodologies

- Experience
- Empirical
  - Statistical models from road tests
- Mechanistic-Empirical
  - Calculation of pavement stresses/strains/deformations
  - Empirical pavement performance models
- Mechanistic
  - Calculation of pavement stresses/strains/deformations
  - Mechanics-based pavement performance models

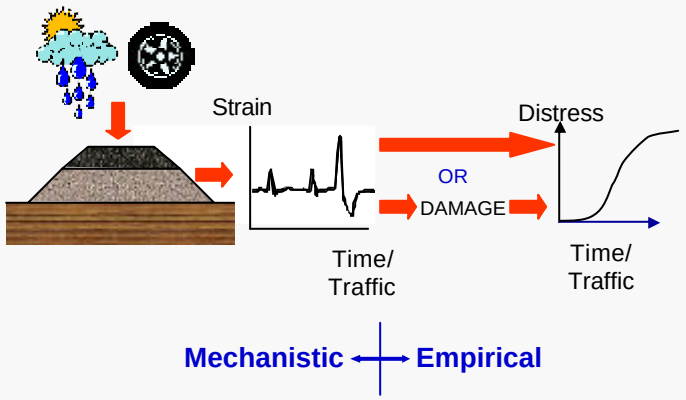
Critical Response Values



e_t at surface + bottom of all bound layers (cracking)

e_c at midthickness of all layers + top of subgrade (rutting)

Mechanistic-Empirical Performance Prediction for Pavements

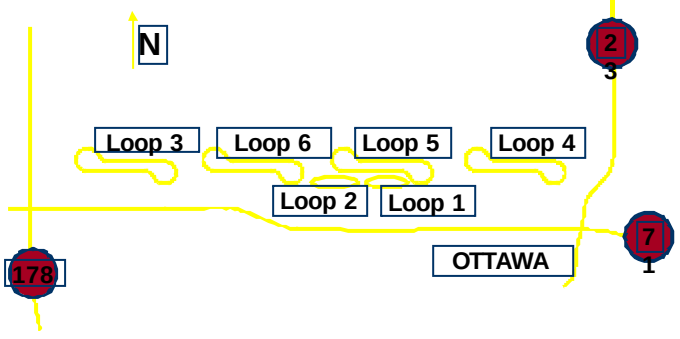


Major Research Projects

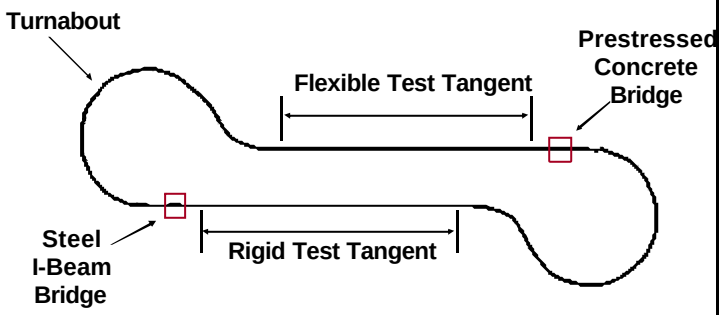
- AASHO Road Test
- Strategic Highway Research Program (SHRP)
- Mechanistic-Empirical Pavement Design Guide

AASHO Road Test (Late 1950's)

Layout of AASHO Road Test



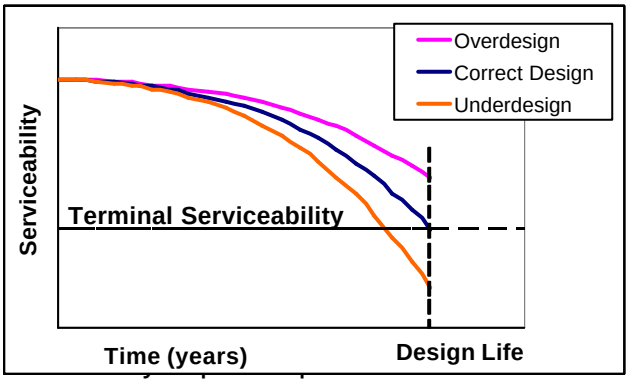
Loop 5 Layout

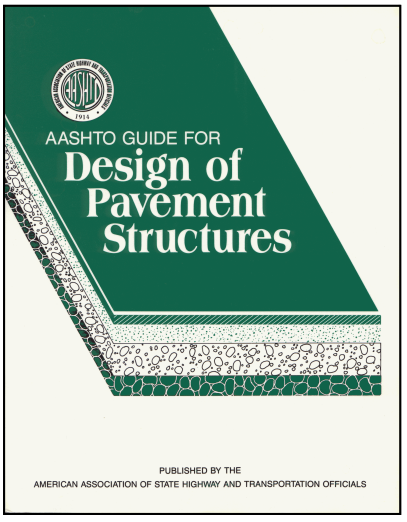


AASHO Road Test Major Findings

- Concept of Serviceability
- Effect of pavement thickness on performance
- AASHTO 1993 Pavement Design Guide

Serviceability Vs. Time



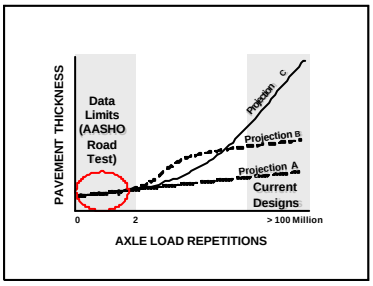


1993 Version

Limitations of AASHO Road Test

- Specific climate, subgrade, materials
- Short performance period (low traffic level)

Higher Traffic Volumes



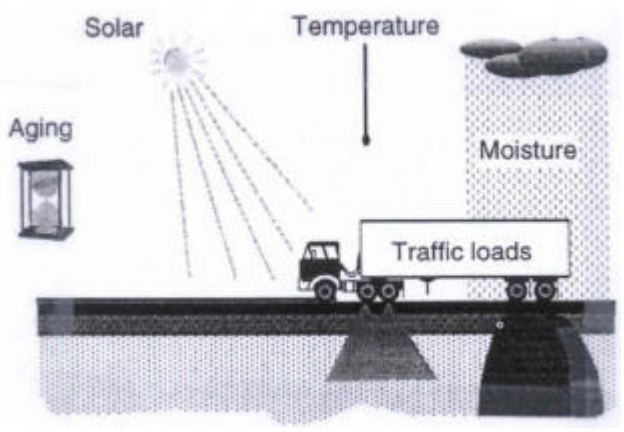
SHRP

- 5-year program (1987-1993)
- $150 million on highway research
  - Asphalt ($50 million)
  - Concrete and construction
  - Highway operation
  - Long-term pavement performance

M-E Pavement Design Guide

- The M-E Design Guide is a Design Process which includes a lot of new features:
  - Analysis of New and Rehabilitated HMA and PCC Pavements
  - Traffic (Load Spectra instead of ESALs).
  - Climate (EICM).
  - Advanced Material Characterization (Three Levels).
  - Sublayering to capture HMA aging and Unbound layer moisture change.
  - Linear Elastic and Finite element analysis.
  - M-E Distress Models (Based on Damage Accumulation).
  - Reliability Analysis
  - User friendly Design software provided with the guide.

Factors Affecting Pavement Performance



Factors Affecting Pavement Performance

- Traffic
- Soil and pavement materials
- Environment
- Construction and maintenance

Traffic

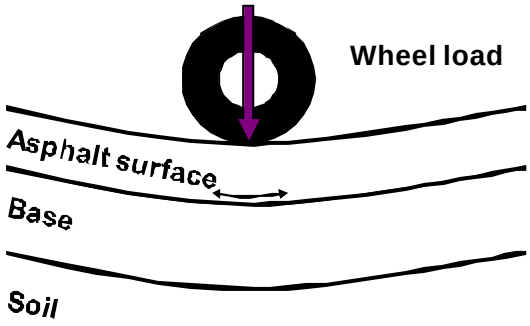
Traffic has a major effect on pavement performance

- Traffic volume
- Traffic load
- Tire pressure
- Rate of applying load (Speed)

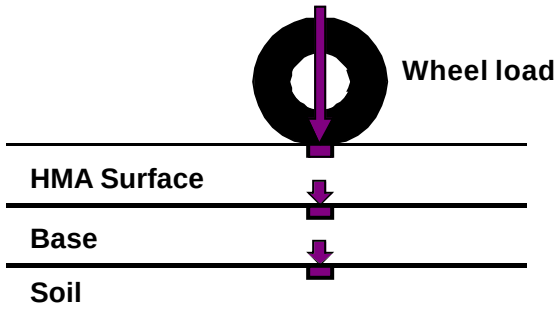
Larger tire pressure is more harmful to pavement

Parked cars have larger effect

Fatigue Cracking



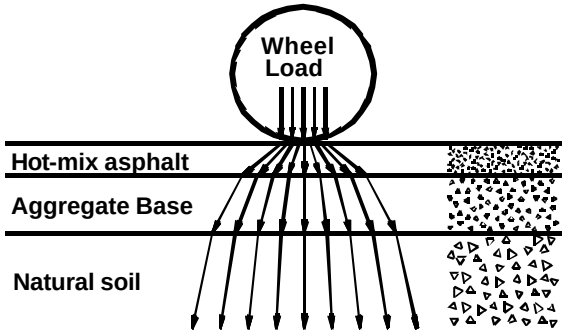
Permanent Deformation



Factors Affecting Pavement Performance

- Traffic
- Soil and pavement materials
- Environment
- Construction and maintenance

Material Quality



Factors Affecting Pavement Performance

- Traffic
- Soil and pavement materials
- Environment
- Construction and maintenance

Environmental Factors

- Moisture
- Temperature
- Aging

Factors Affecting Pavement Performance

- Traffic
- Soil and pavement materials
- Environment
- Construction and maintenance

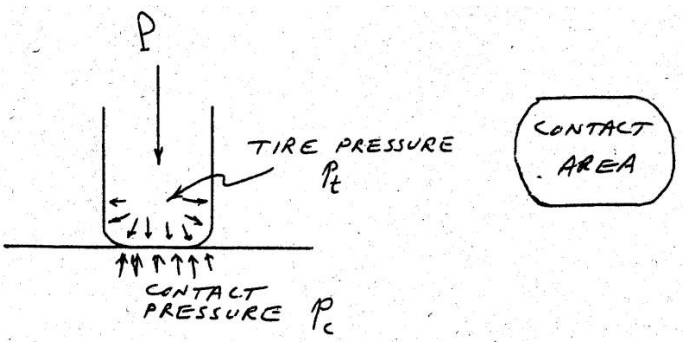
Construction and maintenance

- Construction and maintenance practice largely affects performance

Construction


YNAPAC

Tire Pressure, Contact Pressure & Contact Area



Tire Pressure & Contact Pressure

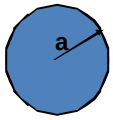
- Contact pressure is not constant throughout the contact area
- For simplicity we usually assume:
  - Constant contact pressure
  - Contact pressure (p_c) = Tire pressure (p_t) = p

Contact Area

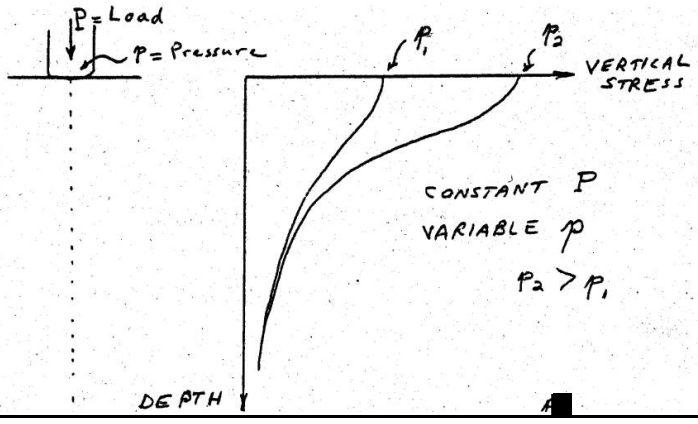
- Assuming circular contact area (A) with a radius (a)

A = Load (P) / Pressure (*p*)

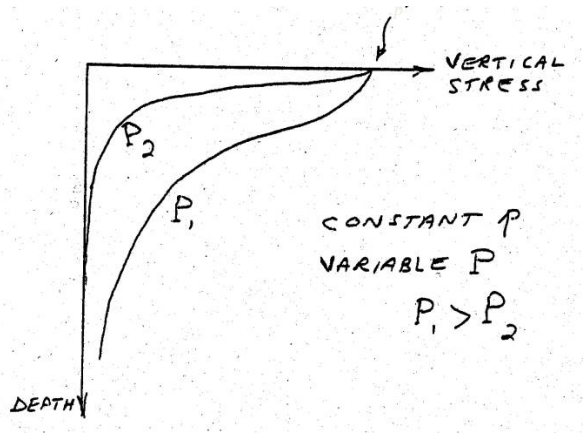
$$a = \sqrt{A/p} = \sqrt{P/p.p}$$



Effect of Changing Tire Pressure



Effect of Changing Load



Comments on Tire Pressure & Loads

- Changing tire pressure affects upper layers
- Changing load affects deeper layers
- Required quality of surface is mostly determined by tire pressure
- Required pavement thickness is mostly determined by load magnitude