Pavement Types and Design Factors
Historical Developments

- Prior to the early 1920s the thickness of pavement was based purely on experience.
- Pavement design has gradually evolved, since then, from art to science.
- Empiricism played an important role till recently in pavement design.
- The methods of flexible pavement design can be classified into five categories:
Historical Developments – Flexible Pavements

- **Empirical methods**
  - Without soil strength test (GI method, 1929)
  - With soil strength test (CBR method, 1929)
- **Limiting shear failure methods**
  - Terzagi’s (1943) bearing capacity formula was applied to determine the pavement thickness
- **Limiting deflection methods**
  - Pavement thickness was determined by limiting the surface deflection below an allowable value using Burmister’s (1943) two layer theory
- **Regression methods**
  - based on pavement performance or road tests (AASHTO, 1961)
- **Empirical – mechanistic methods**
  - This method of design is based on mechanics of materials that relates an input, such as a wheel load, to an output or pavement response, such as stress or strain.
  - Shell method, 1977
  - Asphalt Institute method, 1981
Historical Developments – Rigid Pavements

• Contrary to flexible pavements, rigid pavements were designed from the beginning using analytical solutions
• Flexural stress in concrete has long been considered as a major, or even the only design factor
• Analytical Solutions
  – Goldbeck’s (1919) Formula
  – Westergaard’s (1926 to 1948) analysis based on liquid foundations
  – Pickett’s (1951) analysis based on solid foundations – influence charts
• Numerical Solutions
  – Discrete–element method: Hudson and Matlock (1966) applied this method assuming the subgrade to be a dense liquid
  – Finite element method: Huang (1974) applied FEM for the analysis of jointed slabs on liquid as well as solid foundations
• Other developments include fatigue damage and pumping erosion
Pavement Types

• Flexible Pavements
  – Component layers: subgrade, drainage layer/sub-base, base course, binder course and surfacing course

• Rigid Pavements
  – Component layers: subgrade, drainage layer, sub-base (DLC), CC slab (PQC)

• Semi-rigid / Composite pavements
Layers in Flexible Pavement

- Natural Subgrade
- Compacted Subgrade
- Unbound base
- Asphalt Binder Course
- Asphalt Surface Course

Layers:
- Natural Subgrade: 500 mm
- Compacted Subgrade: 300 mm
- Unbound base: 250 mm
- Asphalt Binder Course: 120 mm
- Asphalt Surface Course: 50 mm

Interface Treatments
Principle of Flexible Pavement Design

Basic concept

• Dispersion of load / compressive stresses through flexible pavement layers

• Dispersion of stresses (tensile and compressive) through flexible pavement layers with stiff bituminous layers
Stress Distribution Through Granular Layers

A) LARGE BOULDER SOILING

B) LARGE SIZE STONES

C) STONE AGGREGATES
Fatigue Cracking and Rutting

Wheel Load

Asphalt Surface Course

Fatigue Cracking

Asphalt Binder Course

Unbound base

Granular Subbase

Compacted Subgrade

Natural Subgrade

Rutting

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Analysis and Design of Flexible Pavements

- Flexible pavements are analysed using layer theory which is derived from Boussinesq theory. Using this layer theory as a structural model, one can find the solutions for stresses, strains and deflections at any point in a layered system.

- Present day flexible pavements are designed using empirical mechanistic methods, in which the allowable number of repetitions of axle loads for a given pavement configuration is determined based on the response of the pavement to the action of these axle loads.
Types of Rigid Pavements

• Jointed Plain Concrete Pavement (JPCP)
  – No temperature steel

• Jointed Reinforced Concrete Pavement (JRCP)
  – Temperature steel placed at mid height and discontinued at the joints

• Continuously Reinforced Concrete Pavement (CRCP)
  – Not popular in India – very costly

• Prestressed Concrete Pavement (PCP)
  – Not popular
Jointed CC Pavement

- Dowel Bars
- Tie Bars
- Temperature Steel
- Longitudinal Joint
- Contraction Joint
- B
- L
- Longitudinal Joint
Cross Section of a Rigid Pavement

- Figure shows a typical cross-section of a rigid pavement.
- The pavement can be placed directly on prepared subgrade or on a singular layer of granular or stabilized material.
- The only layer of material under concrete and above subgrade is called base course or subbase.
Components of Cement Concrete Pavement

- Paving Quality Concrete (PQC)
- Sub-base Course / Dry Lean Concrete (DLC)
- Drainage Layer
- Prepared Subgrade
Analysis of Rigid Pavement

$\text{Reaction pressure } = p$

Deflection $= \Delta$

$\text{Wheel load}$

$\text{Elastic plate}$

$p \propto \Delta \text{ or } p = k \Delta$

Elastic plate resting on liquid/solid foundation characterised by its modulus of subgrade reaction, $k$
Rigid Pavement Design

• Joints are designed to take care of the environmental stresses
• Thickness of the CC pavement slab is decided based on the following two points:
  – The maximum bending tensile stress resulting out of maximum wheel load stress and critical environmental stress should be less than the flexural strength of concrete
  – The CC pavement should withstand the expected number of repetitions of axle loads during its design life