Pavement and Foundation Engineering

Laboratory

- Design of Flexible Pavement by Group Index Method

  (U.S. Highway Engineers Group Index Method)
- Design of Flexible Pavement by California Bearing Ratio Method

  (CBR Method)
- Design of Rigid Pavement by Westergaard Method

- Design of Flexible Pavement using AASHTO Guidelines.
- Design of Rigid Pavement using AASHTO Guidelines.

Methods of Pavement Design

Four Groups:

1. Group A
2. Group B
3. Group C
4. Group D

Group A:

Empirical Methods using no soil strength tests (Basic properties of soils are involved)

- ***U.S. Highway Engineers Group Index Method***
- ***Civil Aeronautic Administration, USA Method***

Group B:

Empirical Methods using soil strength (CBR Test is generally performed)

- ***CBR Method***
- ***North Dakota Cone Method***
- ***U.S. Navy and Flexible Pavement Committee Method***
- ***Canadian Department of Transport Method***
- ***Markwick Method for Rigid Pavement***
- ***Overseas Road Note-31***
- ***AASHTO Design Guide***

Group C:

Methods based partly on theory and partly on experience

(Fundamental stress strain properties of subgrade soils and sometimes the base material are determined by shear or bearing test)

- ***Westergaard's Method (based on Plate Load Test)***
- ***Shear Strength Method***
- ***Golder's Method***
- ***Kansas Highway Department Method***
- ***V. R. Smith Method***

Group D:

Wholly Theoretical Method

(These are based on mathematical analysis of the stresses and strains throughout the pavement and subgrade and the true stress strain characteristics of the various materials)

- ***Burmster's Analysis and Design Method***

Functions of the Pavement

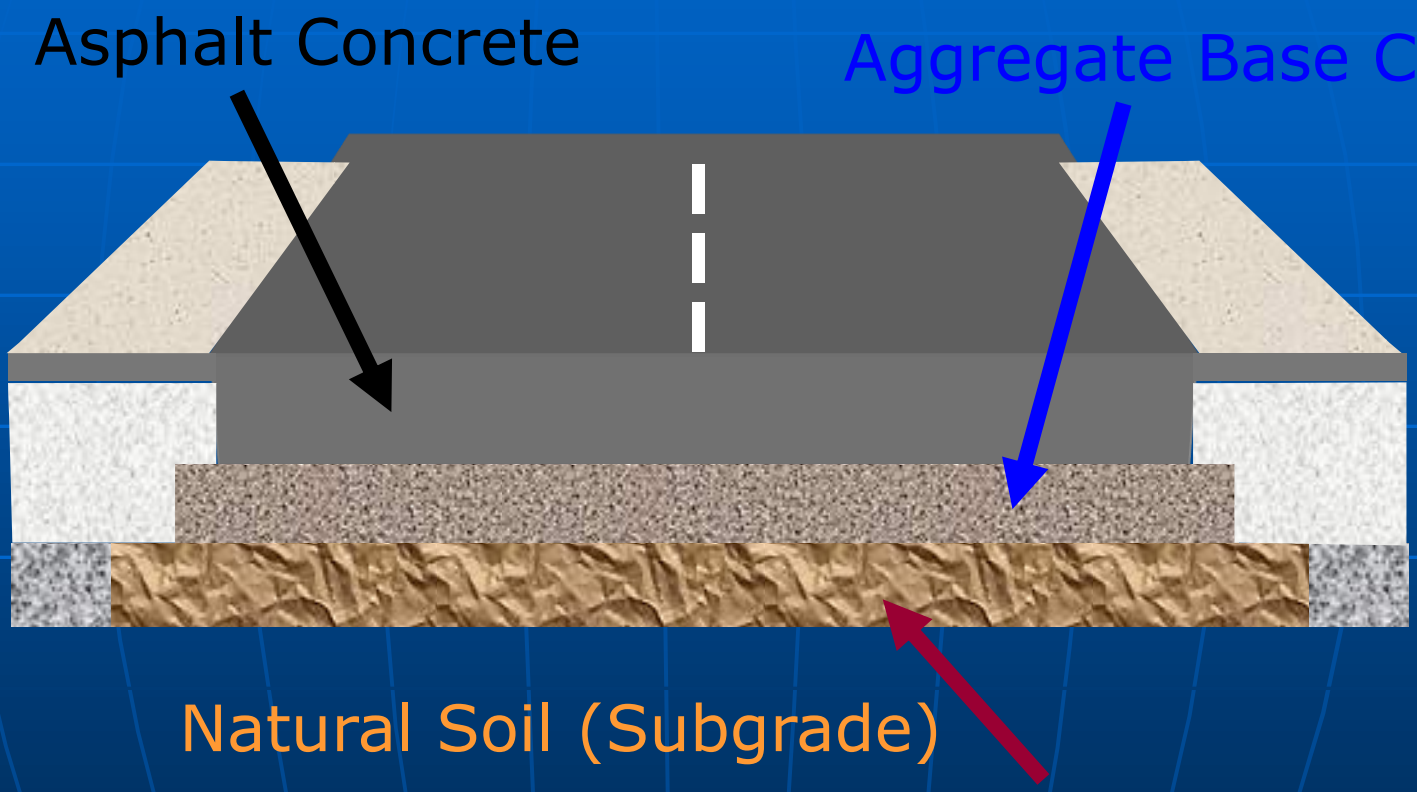
- **Reduce and distribute the traffic loading so as not to damage the subgrade**
- **Provide vehicle access between two points under all-weather conditions**
- **Provide safe, smooth and comfortable ride to road users without undue delays and excessive wear & tear**
- **Meet environmental and aesthetics requirement**
- **Limited noise and air pollution**
- **Reasonable economy**

Requirements of Pavement Structure

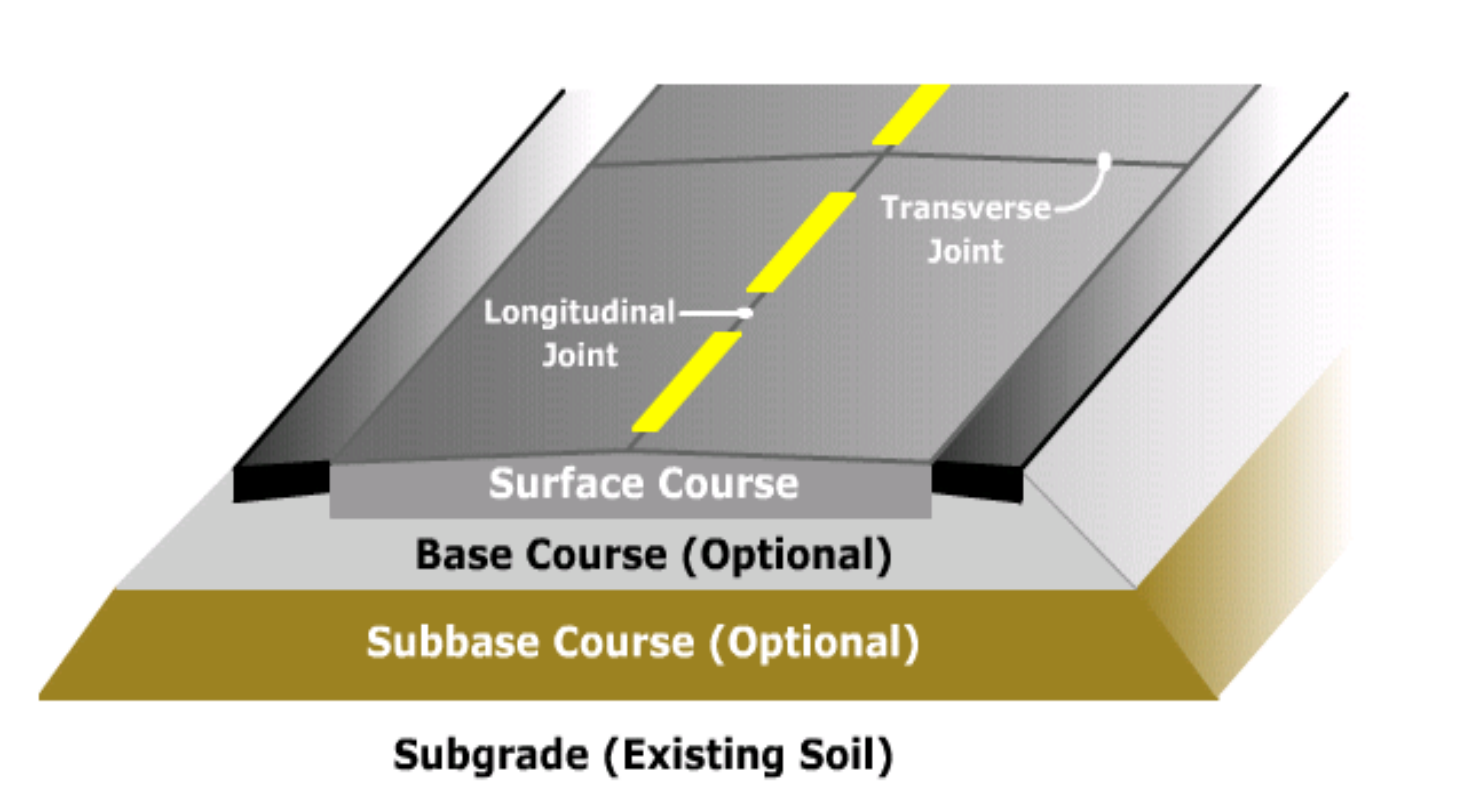
- **Sufficient thickness to spread loading to a pressure intensity tolerable by subgade**
- **Sufficiently strong to carry imposed stress due to traffic load**
- **Sufficient thickness to prevent the effect of frost susceptible subgade**
- **Pavement material should be impervious to penetration of surface water which could weaken subgade and subsequently pavement**
- **Pavement material should be non-frost susceptible**
- **Pavement surface should be skid resistant**

Types of Pavement

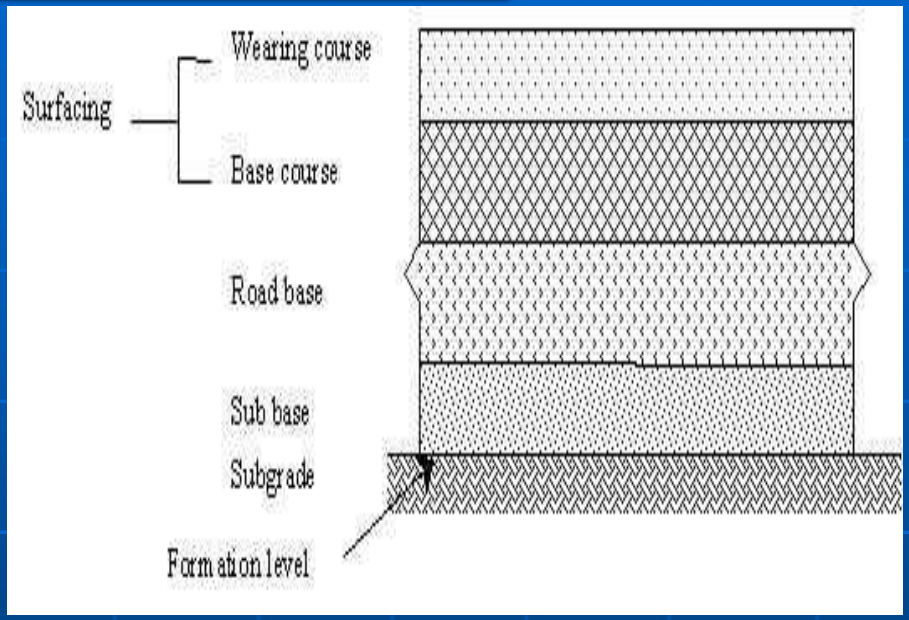
Flexible Pavements



Rigid Pavements



Flexible Pavement



- Elastic
- Three main layers
  - Surfacing
    - Wearing course
    - Asphaltic Base course (Intermediate or Binder Course)
  - Road base or Base Course
  - Sub-base
- Supported by Subgrade

- Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of different materials.

- Each layer receives the loads from the above layer, spreads them out, then passes on these loads to the next layer below. Thus, the further down in the pavement structure a particular layer is, the less load (in terms of force per unit area) it must carry.

Structure of Flexible Pavement

- In order to take maximum advantage of this property, material layers are usually arranged in order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) at the bottom.

- Surface Course: This is the top layer and the layer that comes in contact with traffic.
- Base Course: This is the layer directly below the surface course and generally consists of aggregates (either stabilized or un-stabilized).
- Sub-base Course: This is the layer (or layers) under the base layer. A sub-base is not always needed.

Subgrade:

The "subgrade" is the material upon which the pavement structure is placed. Although there is a tendency to look at pavement performance in terms of pavement structure and mix design alone. The subgrade can often be the overriding factor in pavement performance.

Surface Course

- The surface course is the layer in contact with traffic loads and normally contains the highest quality materials.
- It provides characteristics such as friction, smoothness, noise control, rut and shoving resistance and drainage.

- In addition, it serves to prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and subgrade. This top structural layer of material is sometimes subdivided into two layers.

Wearing Course

- This is the layer in direct contact with traffic loads. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn. A properly designed (and funded) preservation program should be able to identify pavement surface distress while it is still confined to the wearing course. This way, the wearing course can be rehabilitated before distress propagates into the underlying intermediate/blinder course.

Intermediate/Binder Course

- Intermediate/Binder Course: This layer provides the bulk of the HMA structure. It's main purpose is to distribute load.

Base Course

- The base course is immediately beneath the surface course. It provides additional load distribution and contributes to drainage and frost resistance. Base courses are usually constructed out of:
  - Aggregates: Base courses are most typically constructed from durable aggregates that will not be damaged by moisture or frost action. Aggregates can be either stabilized or un-stabilized.

- HMA: In certain situations where high base stiffness is desired, base courses can be constructed using a variety of HMA mixes. In relation to surface course HMA mixes, base course mixes usually contain larger maximum aggregate sizes, are more open graded and are subject to more lenient specifications.

Sub-base Course

- The sub-base course is between the base course and the subgrade. It functions primarily as structural support but it can also:
  - Minimize the intrusion of fines from the subgrade into the pavement structure.
  - Improves drainage.
  - Minimize frost action damage.
  - Provides a working platform for construction.

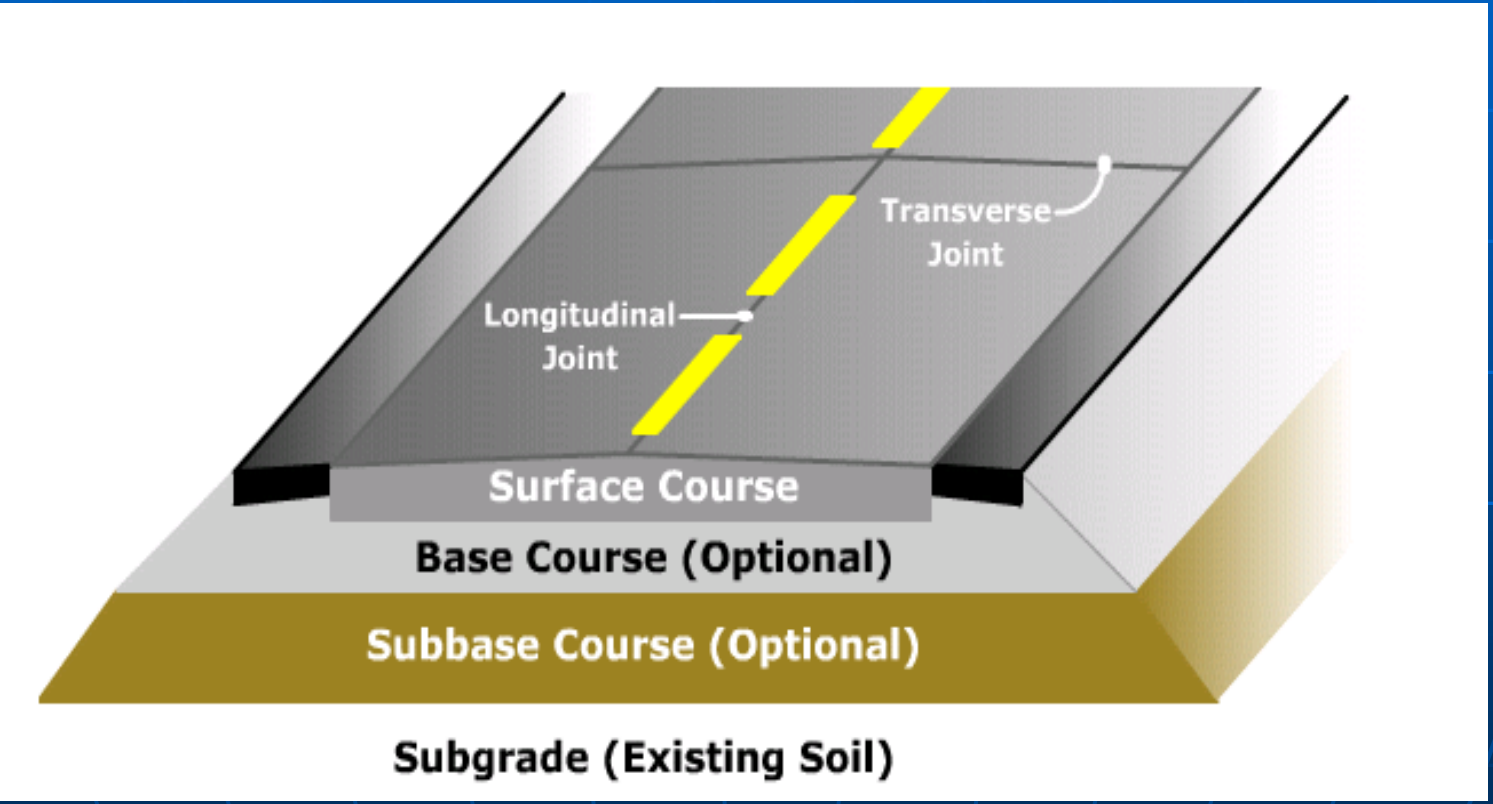
- The sub-base generally consists of lower quality materials than the base course but better than the subgrade soils.
- A sub-base course is not always needed or used.
- For example, a pavement constructed over a high quality, stiff subgrade may not need the additional features offered by a sub-base course so it may be omitted from design.

- However, a pavement constructed over a low quality soil such as a swelling clay may require the additional load distribution characteristic that a sub-base course can offer. In this scenario the sub-base course may also consist of high quality fill used to replace poor quality subgrade.

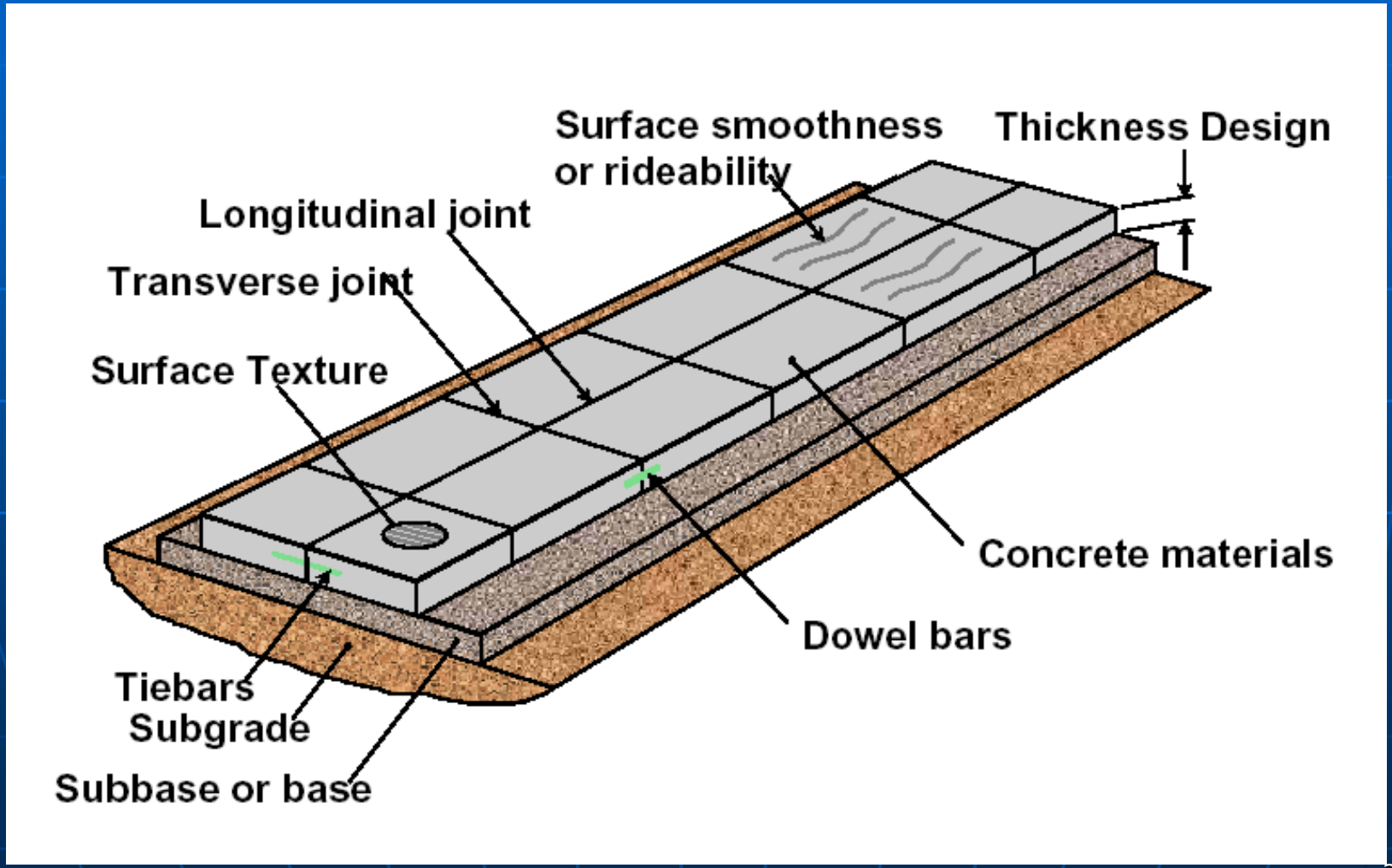
Subgrade

- Although a pavement's wearing course is most prominent, the success or failure of a pavement is often dependent upon the underlying subgrade, the material upon which the pavement structure is built.

Rigid Pavements



Basic Components of Concrete Pavement



- Rigid pavements are so named because the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. A rigid pavement structure is typically composed of a PCC surface course built on top of either
  - the subgrade or
  - an underlying base course.

- Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one, or at most two, structural layers.
- There are other types of surfaces also i.e.; reinforced, continuously reinforced etc.

Structure of Rigid Pavement

- Surface course. This is the top layer, which consists of the PCC slab, reinforced or continuously reinforced slabs .
- Base course. This is the layer directly below the PCC layer and generally consists of aggregate or stabilized subgrade.
- Sub-base course. This is the layer (or layers) under the base layer. A sub-base is not always needed and therefore may often be omitted.

Surface Course

- The surface course is the layer in contact with traffic loads and is made of PCC or RCC. It provides characteristics such as friction, smoothness, noise control and drainage. In addition, it serves as a waterproofing layer to the underlying base, sub-base and subgrade.
- The surface course can vary in thickness but is usually between 150 mm (6 inches for light loading) and 300 mm (12 inches for heavy loads and high traffic). Figure shows a 300 mm (12 inch) surface course.

PCC Surface

Rigid Pavement Slab
(Surface Course) Thickness

Base Course

- The base course is immediately beneath the surface course. It provides
  - Additional load distribution,
  - Contributes to drainage and frost resistance,
  - Uniform support to the pavement and
  - A stable platform for construction equipment.
  - Bases also help and prevent subgrade soil movement due to slab pumping.

  Base courses are usually constructed out of:

  – *Aggregates base*. A simple base course of crushed aggregates has been a common option since the early 1900s and is still appropriate in many situations.

- *Stabilized aggregate or soil*. Stabilizing agents are used to bind otherwise loose particles to one another, providing strength and cohesion. Cement treated bases (CTBs) can be built to as much as 20-25 percent of the surface course strength.
- *Dense-graded HMA*. In situations where high base stiffness is desired base courses can be constructed using a dense-graded HMA layer.
- Permeable HMA. In certain situations where high base stiffness and excellent drainage is desired, base courses can be constructed using an open graded HMA.

- Lean concrete. Contains less Portland cement paste than a typical PCC and is stronger than a stabilized aggregates. Lean concrete bases (LCBs) can be built to as much as 25-50 percent of the surface course strength. A lean concrete base, functions much like a regular PCC surface course and therefore, it requires construction joints and normally cracks over time. These joints and cracks can potentially cause reflection cracking in the surface course.

Sub-base Course

- The sub-base course is the portion of the pavement structure between the base course and the sub-grade. It functions primarily as structural support but it can also:
  - Minimize the intrusion of fines from the subgrade into the pavement structure.
  - Improves drainage.
  - Minimizes frost action damage.
  - Provides a working platform for construction.
- The sub-base generally consists of lower quality materials than the base course but better than the subgrade soils. Appropriate materials are aggregates and high quality structural fill.

Subgrade

- Subgrade provides support to the overlying concrete slab. If it is of good quality then slab can be laid over it without providing sub-base otherwise if it is extremely poor then a sub-base layer should be incorporated.
- For design purpose the only thing to know about subgrade is its classification and the unit pressure coming from slab to subgrade should be calculated for its selection. However, it must be resistant to moisture damages.

Pavements Comparison

Flexible pavements:

- Multi layer construction
- Energy consumption due to transportation of materials
- Increasing cost of asphalt due to high oil prices

Rigid pavements:

- Single layer
- Generally last longer
- May require asphalt topping due to noise / comfort issues