Introduction

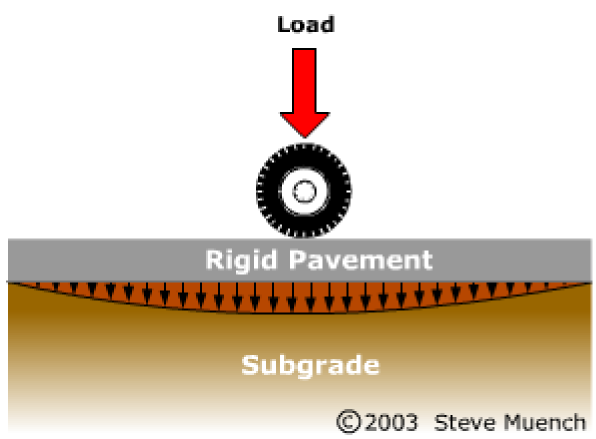
Road Pavement

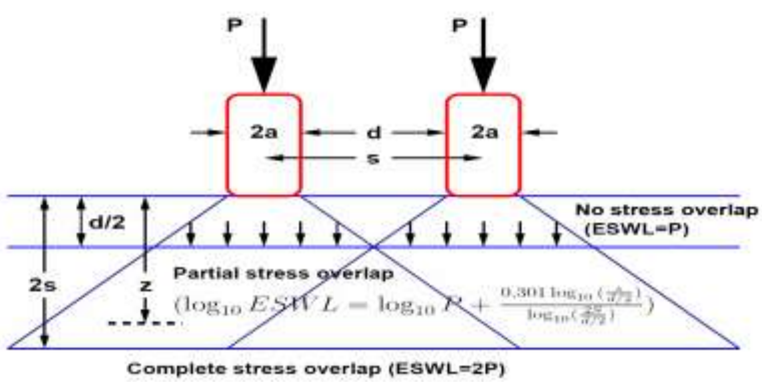
A structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade.

Sub-grade the top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above.

Pavement Purpose

- Load support (Want to distribute the load to avoid permanent deformation)
- Smoothness
- Drainage





Types of Pavement Structures in Roadways:

1- Flexible Pavement
2- Rigid Pavement
3- Alternatives

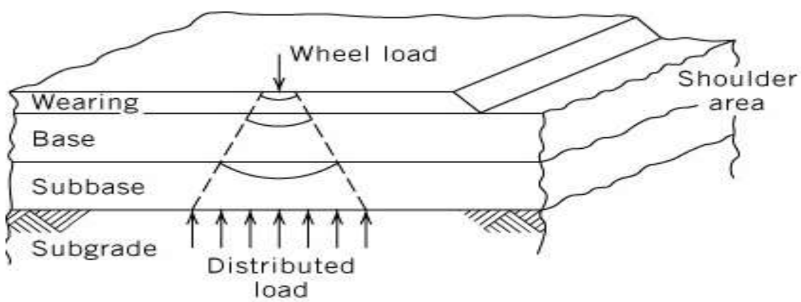
<u>Flexible Pavement</u>

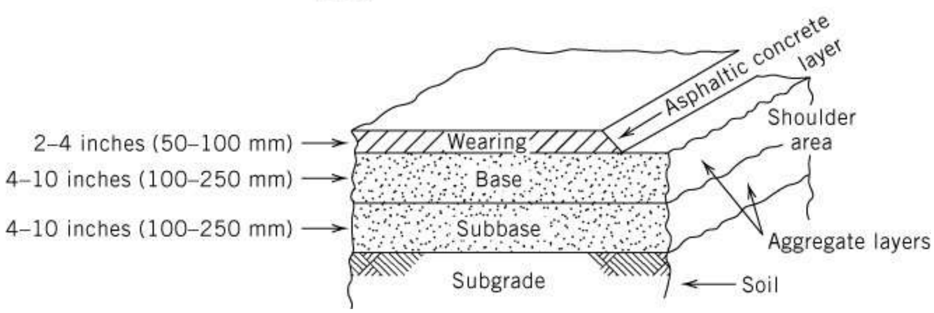
The flexible pavement may be constructed in a number of layers and the top layer has to be the strongest as the highest compressive stresses are to be sustained by this layer in addition to the wear and tear due to the traffic. Flexible pavements are commonly designed using empirical design charts or equations taking into account some of the design factors. There are also semi-empirical and theoretical design methods.

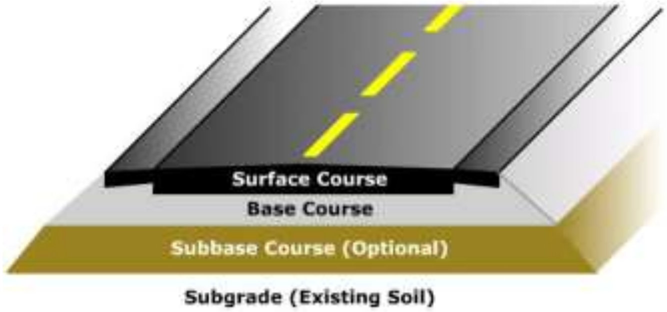
Asphalt pavement materials are a mixture of asphalt and aggregate.

Typical Layers of a Flexible Pavement

Surface Course is the layer directly in contact with traffic loads and is constructed with dense graded asphalt concrete (waterproof, anti-skid).
Binder Course purpose is to distribute the load to the base course. binder course requires lesser quality of mix as compared to the course above it.
Base Course provides additional load distribution and contributes to the sub-surface drainage. higher strength material than subbase, often a cementing material is used. Cementing material can be Portland cement or asphaltic cement, or other material
Sub-Base Course the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure.







Types of Flexible Pavement According to Aggregate Structure
Dense Graded

Open Graded

Gap Graded

Types of Asphalt Pavements According to Asphalt Liquifying Method:

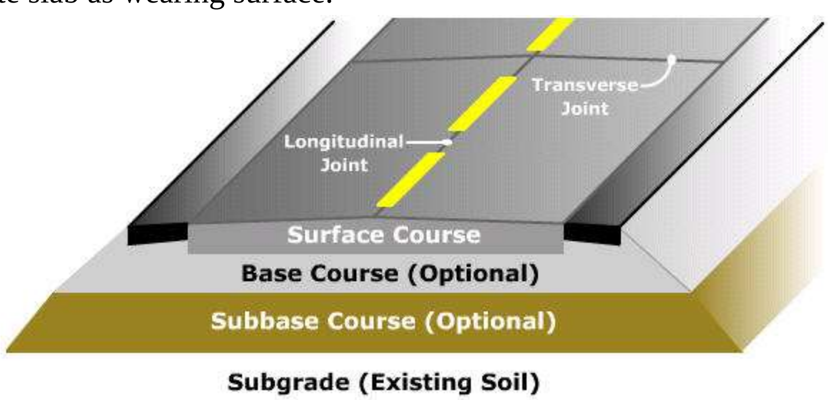
1- Hot mix: Made by heating the asphalt and aggregate together in a plant
2- Cold mix: Made by combining the asphalt and aggregate in a plant, without heating.

Rigid Pavement

Rigid pavements are those which possess worthy flexural strength. The rigid pavement transmits the wheel load stresses through a wider area below the slab action. The rigid pavements are made of Portland cement concrete. The plain cement concrete slabs are expected to take up about 40 kg/cm2 flexural stress. Joints are also used in the construction of rigid pavement and have high completion costs but low maintenance costs.

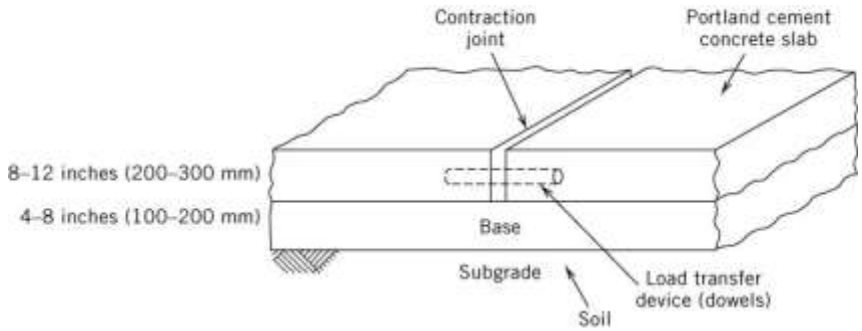
Typical Layers of Rigid Pavement:

1. Soil subgrade
2. Granular sub-base course
3. Base course (optional)
4. Cement concrete slab as wearing surface.



Rigid pavements are usually provided under the circumstances.

- very heavy rainfall
- poor soil conditions



- poor drainage
- extreme climatic conditions
- combination of some of these conditions may lead to the development of cracks on the pavement.

Factors Affecting Rigid Pavement:

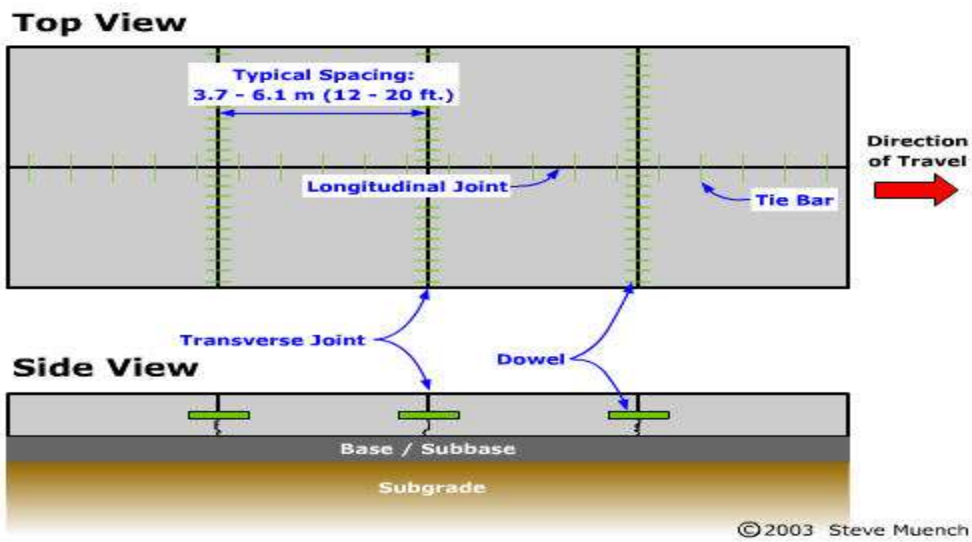
The factors which affect the design and performance of rigid pavement or cc pavement are listed below

- wheel load
- Temperature variations at the location of the road
- types of joints and their spacing
- sub-grade and other supporting layers

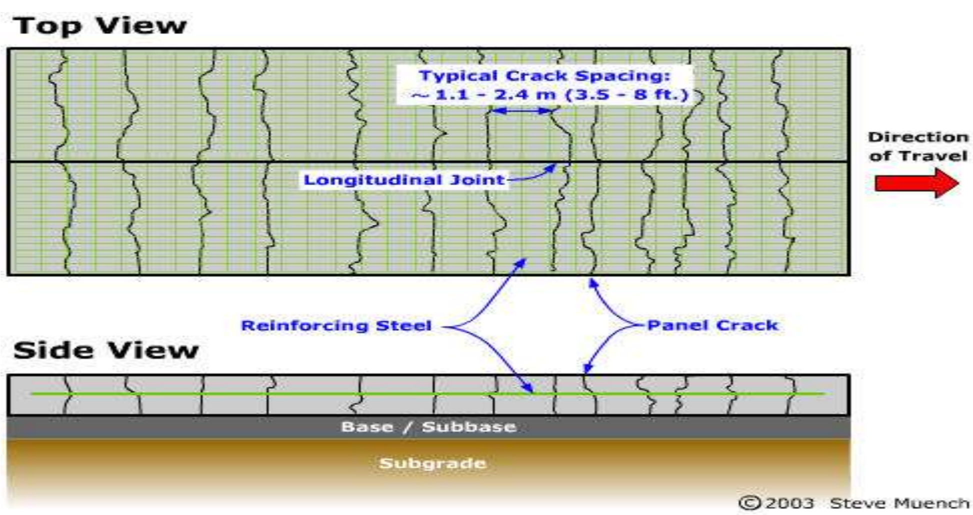
Types of Rigid Pavement

1- Jointed Plain Concrete Pavement (JPCP) (Joints accommodate shrinkage during drying)
2- Continuously Reinforced Concrete Pavement (CRCP)

Jointed Plain Concrete Pavement (JPCP)



Continuously Reinforced Concrete Pavement (CRCP)



Alternatives and Bio-asphalt

There are a number of alternatives to asphalt, some of which are bio-based. A few of the most common alternatives are:

1- Concrete: A common alternative to asphalt, concrete is a mixture of cement, sand, and gravel. It is durable, relatively inexpensive, and can be used for a variety of applications.
2- Paving Stones: Paving stones are a popular alternative to asphalt, and are made of natural or synthetic materials. They can be used for driveways, walkways, and other applications.
3- Cobblestones: Cobblestones are a type of paving stone that are made of natural materials. They are often used in historic districts and other areas where a traditional look is desired.
4- Brick: Brick is a type of masonry that is made of fired clay. It is durable, weather-resistant, and can be used for a variety of applications.
5- Pavers: Pavers are a type of brick that are used for paving roads, driveways, and other areas. They are made of natural or synthetic materials, and are available in a variety of colors and styles.
6- Asphalt Pavement: Asphalt pavement is made of asphalt, a type of concrete. It is durable, weather-resistant, and can be used for a variety of applications.

Types of Failure Encountered in Flexible Pavements:

1- Alligator cracking or Map cracking (Fatigue)
2- Consolidation of pavement layers (Rutting)
3- Shear failure cracking
4- Longitudinal cracking
5- Frost heaving
6- Lack of binding to the lower course
7- Reflection cracking
8- Formation of waves and corrugation
9- Bleeding
10- Pumping

1. Alligator cracking or Map cracking (Fatigue)

The primary cause of this type of failure.

- Relative moment of pavement layer material
- Repeated application of heavy loads
- swelling for shrinkage of subgrade or other layers due to moisture variation

2. Consolidation of pavement layers (Rutting)

- Formation of ruts falls in the type of failure.
- A rut is a depression or groove worn into the road by the travel of wheels

this type of failure is caused due to the following reasons

- repeated application of load along the same wheel path resulting in longitudinal ruts.
- wearing the surface course along the wheel Path result in shallow ruts.

3. Shear failure cracking

shear failure causes upheaval of payment material by forming a fracture or cracking.
Following are the primary causes of shear failure cracking.

- Excessive wheel loading
- low shearing resistance of pavement mixture.

4. Longitude Cracking:

This type of crack extends to the full thickness of the pavement.
Following are the primary causes for longitudinal cracking

- differential volume changes in subgrade soil
- settlement of fill materials
- sliding of side slopes

5. Frost heaving

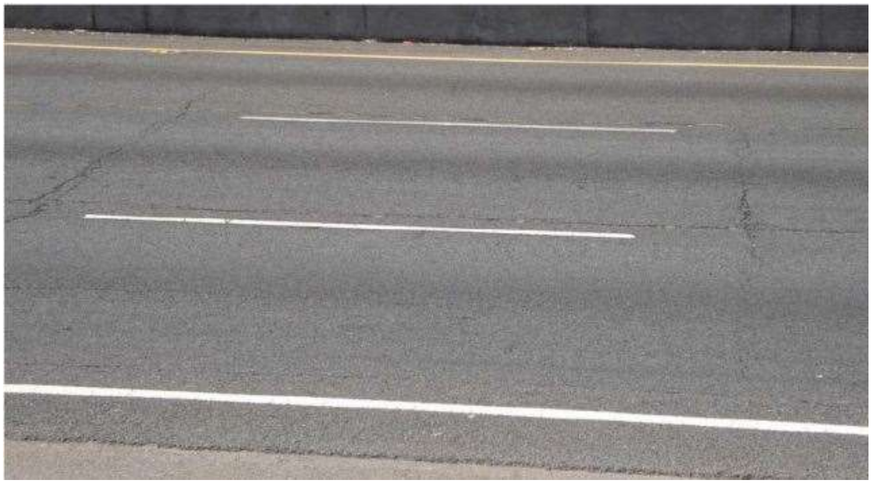
Frost heaving courses upheaval of a localized portion of the pavement. the extent of Frost heave depends upon the ground water table and climate condition.

6. Lack of binding to the lower course

when there is a lack of binding between the surface course and the underlying layer, some portion of surface course loses up materials creating patches and potholes.

- slippage cracking is one of the forms of this type of failure.
- lake of primary coat or tack coat in between two-layer is the primary reason behind this type of failure.

7. Reflection cracking
Reflection Cracking
type of failure occurs when a bituminous surface course is laid over the existing cement concrete pavement with some cracks. this crack is reflected in the same pattern on the bituminous surface.



8. Formation of waves and corrugation
Transfers undulations appear at regular intervals due to the unstable surface course caused by stop-and-go traffic.

9. Bleeding

- Excess bituminous bonder occurring on the p pavement surface courses bleeding.
- bleeding courses a shiny, glass-like, reflective surface that may be tacky to the touch.
- usually found in the wheel paths.

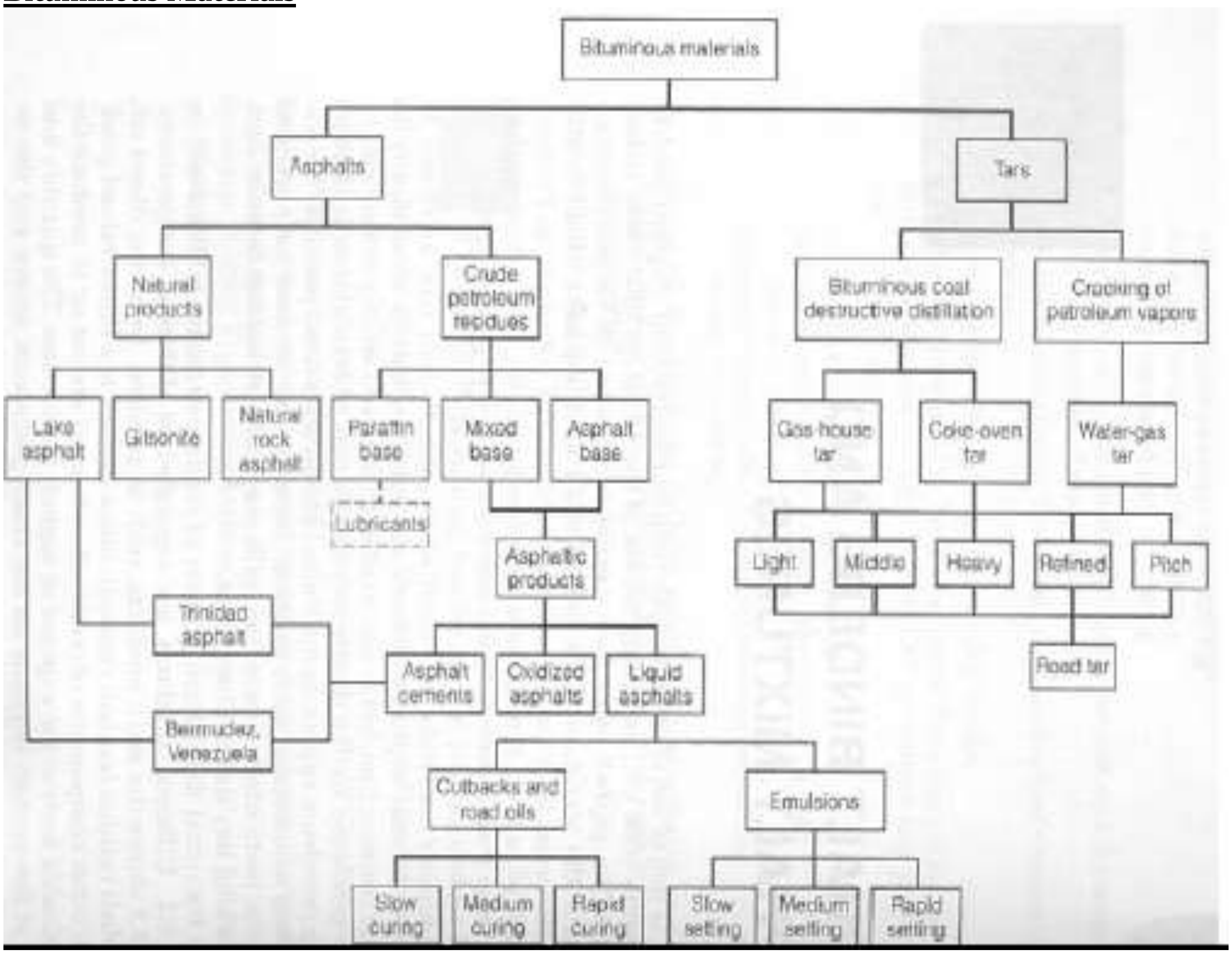
10. Pumping

Seeping or ejection of water and fines from beneath the pavement through cracks is called pumping.

Comparison of Flexible and Rigid Pavements:

- The stresses are not transferred from grain to grain to the lowest layers as in the case of flexible pavement layers. The rigid pavements are made of Portland cement concrete – either plain, reinforced, or prestressed concrete.
- The main point of difference in the structural behavior of rigid pavements as compared to the flexible pavement is that the critical condition of stress in the rigid pavement is the maximum flexural stress occurring in the slab due to wheel load and the temperature changes, whereas in the flexible pavement it is the distribution of compressive stresses.
- The rigid pavements are usually designed and the stresses are analyzed using the elastic theory, assuming the pavement as an elastic plate resting over an elastic or a viscous foundation.

Bituminous Materials



Asphalt	Tar
– Soluble in petroleum products – Generally, a by-product of petroleum distillation process – Can be naturally occurring	– Resistant to petroleum products – Generally, by-product of coke (from coal) production

Asphalt Binder

The asphalt binder, sometimes referred to as the asphalt cement binder or the asphalt cement, is an essential component of asphalt concrete—it is as the name implies the cement that holds the aggregate together.

The asphalt is a sticky, black and viscous substance that is used to bind the aggregate together. It is used as a paving material because it is durable, flexible, and resistant to wear and tear. Asphalt can also be used to make roofs, sidewalks, and parking lots.

Asphalt

Asphalt Usage

Canadian market (1999) .... 3.75 million of t/year
USA market (1999) ....38.00 millions of t/year
World market ....~ 130.00 millions of t/year
80 ~ 90 % of asphalts are used in pavements
10 ~ 20 % of asphalts are used in roofing, waterproofing and for other purposes
World: 2.0 ~ 2.5 billions t/year of asphalt paving mixes

Paving asphalt represents **3 ~ 4 %** of the total annual crude oil throughput in USA and Canada

Asphalt Sources

1- Natural asphalt
2- Petroleum Based Asphalts (crude oil)

1- Natural asphalt

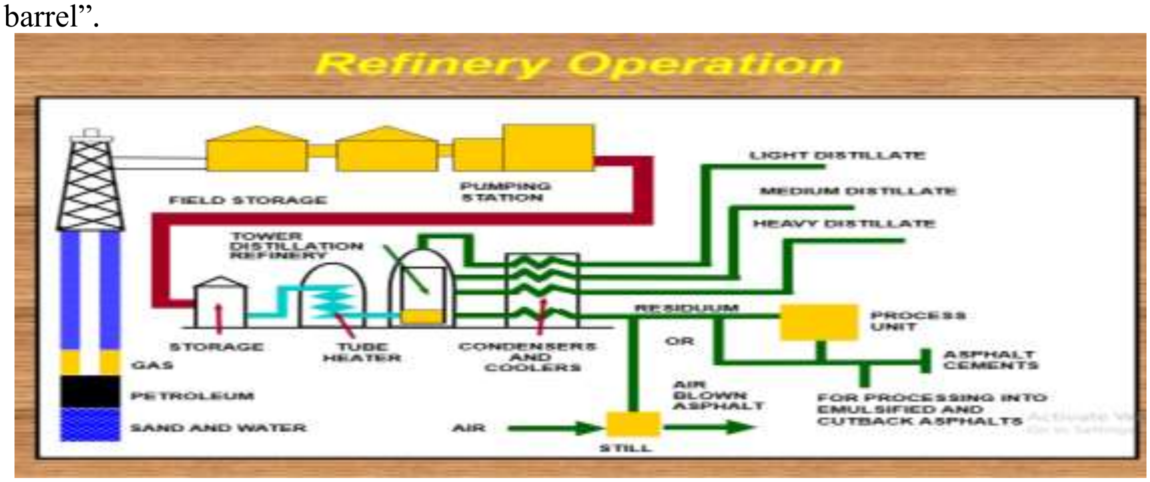
Rock Asphalt

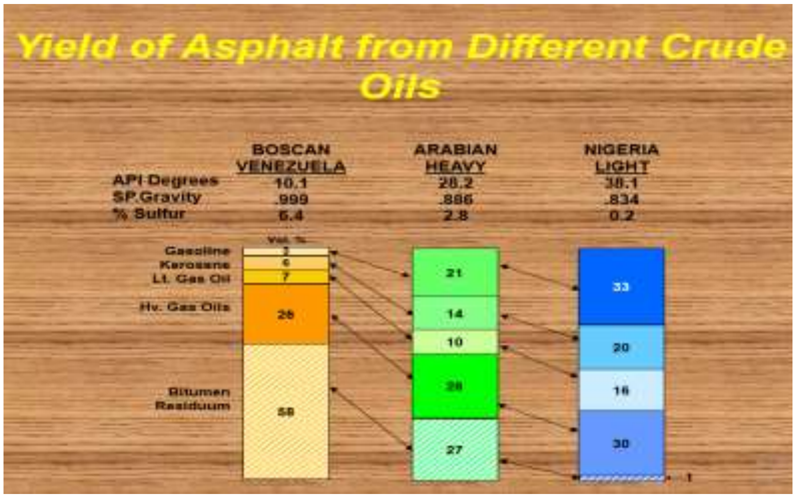
Asphalt Sand

Native Asphalt

2- Petroleum Based Asphalts (crude oil)

Asphalt is waste product from refinery processing of crude oil sometimes called the "bottom of the barrel".





Asphalt manufacture

1- Distillation
2- Extraction
3- Cracking processes
4- Oxidation
5- Modification

Properties depend on:

- Refinery operations
- Composition crude source-dependent

Asphalt Cement Components

1- Asphaltenes
   - Large, discrete solid inclusions (black)
   - High viscosity component
2- Resins
   Semi-solid or solid at room temperature
   » Fluid when heated
   » Brittle when cold
3- Oils
   - Colorless liquid
   - Soluble in most solvents
   - Allows asphalt to flow

Properties of Asphalt

Critical conditions during construction and service

- Construction:
  - » mixing
  - » spreading appropriate viscosity
  - » compacting
- Service:
  - » plastic deformation (rutting)
  - » thermal cracking
  - » fatigue cracking
  - » water sensibility

Types

Asphalt cements
- Generally, refinery produced material
- Air blown asphalt cements

Cutbacks
- Asphalt cements "cut" with petroleum solvents

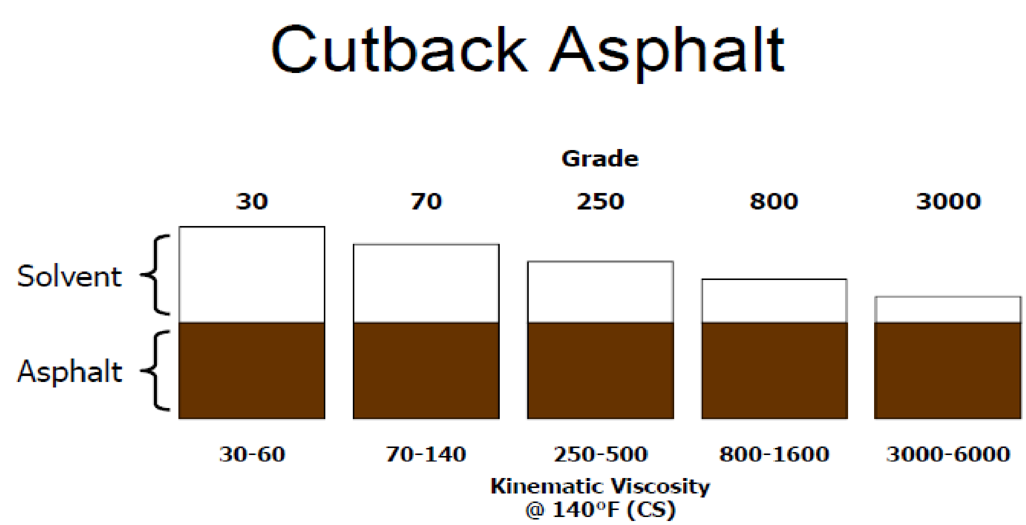
Emulsions
- Mixture of asphalt cement, water, and emulsifying agent

Cutback Asphalt

Rapid cure (RC) (Thinned with Naphtha or Gasoline)
- High volatility of solvent
- Tack coats, surface treatments

Medium cure (MC) (Thinned with Kerosene)
- Moderate volatility
- Stockpile patching mix

Slow cure (SC) (Thinned with Low viscosity oil)
- Low volatility
- Prime coat, dust control



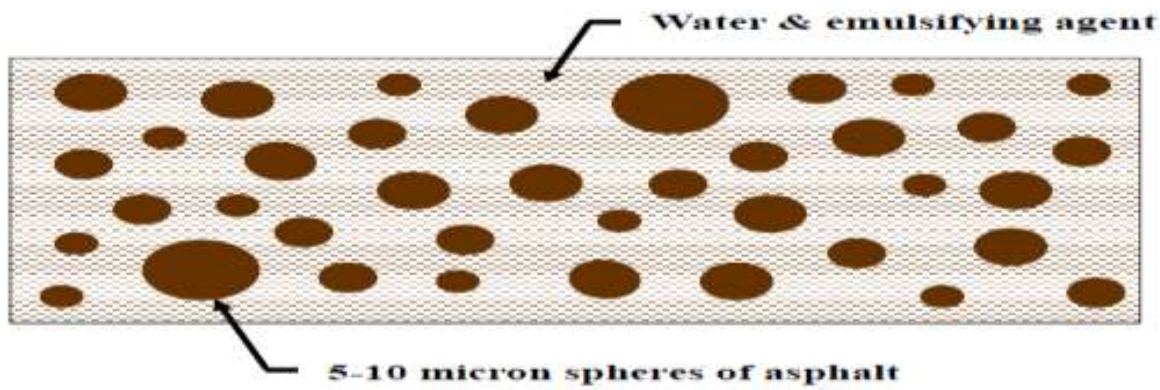
Emulsified Asphalt

- Rapid Setting (RS or CRS)
  Used for Surface coats, penetration macadam
- Medium Setting (MS or CMS)
  Used for open-graded asphalt-treated base
- Slow Setting (SS or CSS)
  Used for dense-graded asphalt-treated base

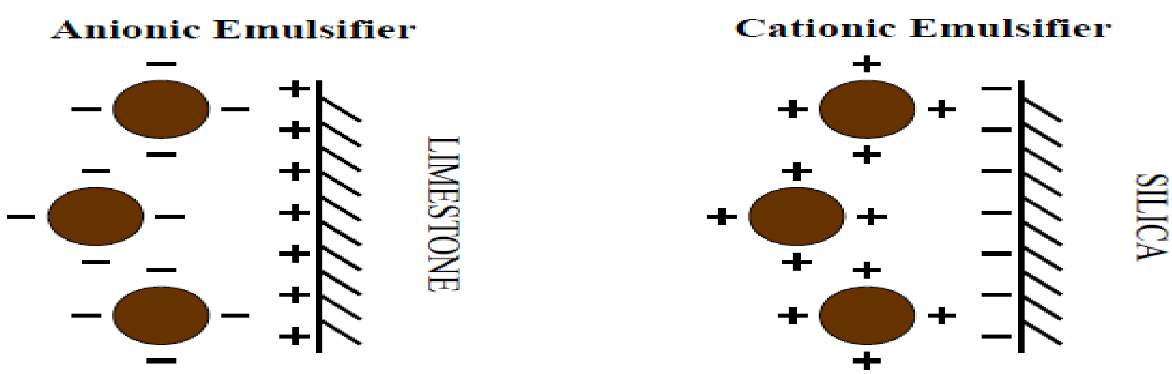
Emulsifier gives surface charge to asphalt droplets suspended in water medium

- Anionic
  - Negative charge
  - Alkaline
  - Good with limestones (positive charge)
- Cationic
  - Positive charge
  - Acid
  - Good with silica gravels (negative charge)

Emulsified Asphalt



Emulsified Asphalt



Examples:

Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.

Tack coat is a very light application of asphalt emulsion diluted with water. And it provides bonding between two layers of binder course.

Prime coat is an application of low viscous cutback Bitumen to an absorbent surface like granular bases om 'Which binder layer is placed and provides bonding between two layers.

Purchasing of Asphalt Cements

Need to be able to specify desirable characteristics

"Desirable characteristics" have evolved over time and with increasing technological advances

Purchasing requires specifications

Desirable Characteristics

Consistency
Durability
Ductility
Adhesion
Flashpoint

Specifications of Paving Asphalts

Beginning of specifications - around 1900

Classification of asphalts for commercial purposes in the first half of the century - exclusively conventional tests

First: grading test - penetration at 25°C

1960's in USA: grading test - viscosity at 60°C

Canada: hybrid - penetration/viscosity

1990's in USA : Superpave specification ("performance related")

The role of specifications:

- specify properties that directly reflect asphalt behaviour
- express these properties in physical units
- provide limits for those properties to exclude poor performing products
- provide information from which the service performance can be predicted

Important properties of asphalt:

- mechanical
- adhesive
- durability

Conventional tests used for asphalt characterization:

– penetration, ductility, softening point R&B, flash point, spot test, Fraass breaking point…..

Ageing characteristics:

– Thin Film Oven Test, Rolling Thin Film Oven Test, Pressure Aging Vessel…

Rheological tests:

– Bending Beam Rheometer, Direct tension Test, Dynamic Shear Rheometer

SUPERPAVE Mix Design Method

The United States (US) government funded five years research by Strategic Highway Research Program (SHRP) during 1987-1992 conducting tests by experts in the asphalt pavement laboratories. They introduced a new mix design method known as **Superior Performing Asphalt Pavement (Superpave)**.

Superpave mix design is a set of **innovative asphalt cement, aggregates, and mixtures test techniques and requirements**. Superpave mix design is an example of an **enhanced system** for specifying asphalt cement and mineral aggregates, creating asphalt mixture designs, and predicting the performance of asphalt mixtures.

Also, this method **shares** many characteristics with **standard** mix design processes. It integrates **volumetric proportioning principle**s of mix components, which have long been used in the Marshall mix design procedure (FHWA, 1998).

The utilization of the **Superpave Gyratory Compactor** (SGC) is a key new aspect of the Superpave mix design for experimental compaction. This compactor is critical in the design of Superpave mixtures because it accurately predicts the density properties of mixtures soon after they have been compacted and subjected to project-specific climate and traffic conditions.

Field performance is directly correlated with tests and analyses. The experimental compaction in the laboratories and the performance tests are the primary pillars of Superpave technology. Appropriate preparation of the specimens before testing, especially the compaction process utilized to produce samples, is crucial in the mixture design.

The **aggregate skeleton** of the mixture determines how the mixture reacts to the applied **level of compaction** and how quickly its density changes for each gyration. The **mechanical properties** of the aggregate skeleton can provide as an indicator for the strength of the asphalt mixture and, in turn, the anticipated field performance of the pavement.

The **volumetric characteristics** of asphalt mixtures are an important basis for the design of the Superpave mix. It is thought that the properties of the densification curve produced throughout the mixture's gyratory compaction are related to the stability of the aggregate skeleton. Despite the stiffness of the entire asphalt pavement, the SGC consistently provides shear strain on the sample.

Following mix design, the mixture analysis is the next significant stage to estimate particular levels of **asphalt performance** and the anticipated types of defects in the recently developed mixture. In addition, incorporates the behavior of the pavement response and bituminous distressed techniques to estimate the performance of the pavement including rutting, fatigue cracking, thermal cracking, and moisture sensitivity.