2.6 Pavement Types

In general, there are two types of pavement structures: flexible pavements and rigid pavements. There are however, many variations of these pavements types, including some with soil cement and stabilized bases that have cemented aggregate. Composite pavements (which are made of both rigid and flexible layers), continuously reinforced pavements, and post-tensioned pavements (pre-cast) are other types, which are usually, require specialized design and are not covered in this stage.

As with any structure, the underlying soil must ultimately carry the load that is placed on it. Having mentioned that a pavement function is to distribute the traffic load stresses to the soil (sub-grade) at a magnitude that will not shear or distort the soil. Typical soil-bearing capacities can be less than 345 kPa and in some cases as low as 14 to 21 kPa. When soil is saturated with water, the bearing capacity can be very low, and in these cases, it is very important for pavement to distribute tires loads to the soil in such a way as to prevent failure of the pavement structure. Figure 2.6 shows a difference in stress distribution through flexible and rigid pavements.

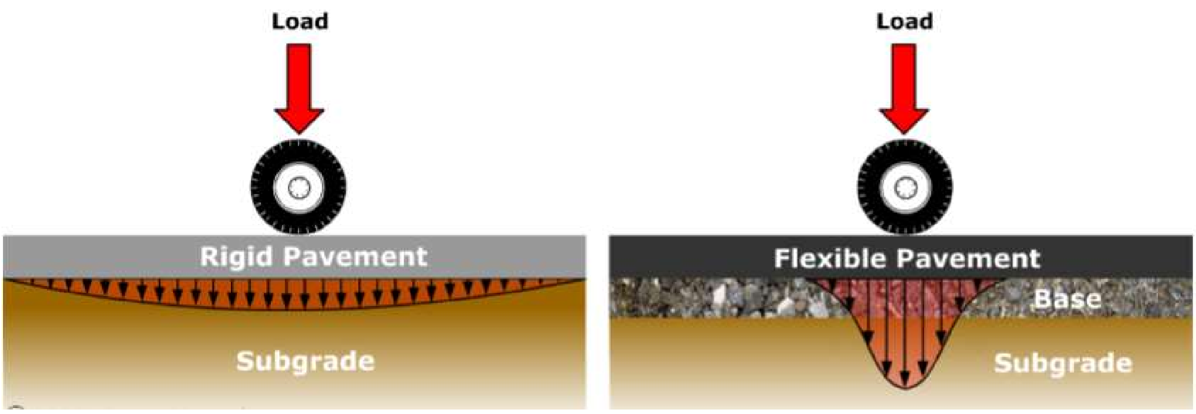

Figure 2.6: Stresses distribution under rigid and flexible pavements

In general, Table 2.2 illustrate the key points difference between flexible and rigid pavements while Figures 2.6 and 2.7 show the structure layers of flexible and rigid pavements respectively.

Table 2.2: Key points difference between flexible and rigid pavements

Flexible Pavements	***Rigid Pavements***
It consists of a series of layers with the highest quality materials at or near the surface of pavements	*It consists of one layer Portland concrete slab or relatively high flexural strength*
It reflects the deformation of sub-grade and subsequently layers on the surface	*It is able to bridge over localized failures and area of inadequate support*
Its stability depends upon the aggregate interlock, particles friction and cohesion	*Its structural strength is provided by the pavement slab itself and by its beam action*
Pavement design is greatly influenced by the sub-grade strength	*Flexural strength of concrete is a major for design*
It functions by a way of load distribution through the component layers	*It distributes load over a wide area of sub-grade because of its rigidity and high modulus of elasticity*
Temperature variations due to change in atmospheric conditions do not produce stresses in flexible pavements	*Temperature changes induce heavy stresses in rigid pavements*
It has self-healing properties due to heavier wheel load and therefore it is recoverable in some extent	*Any excessive deformations due to heavier wheel loads are not recoverable. For example, settlements are permanent*

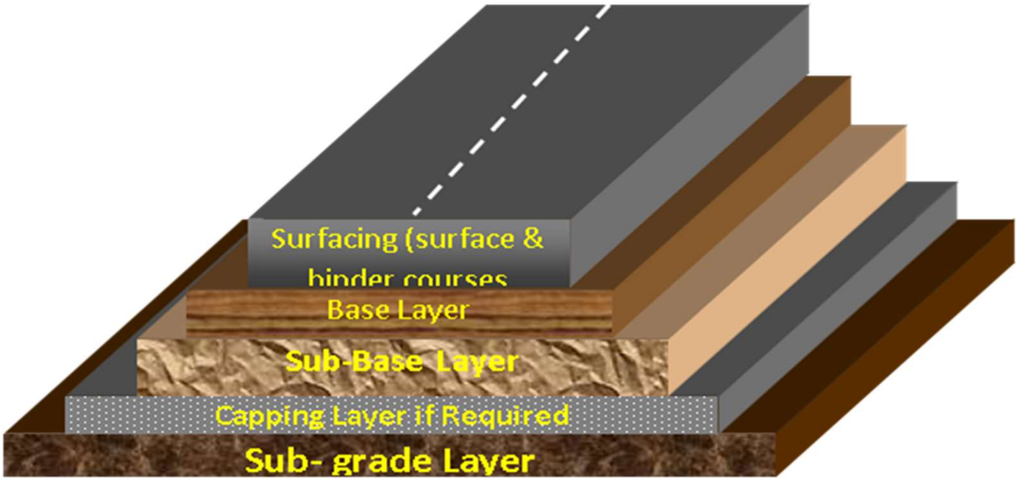

Figure 2.6: Typical structure of flexible pavements

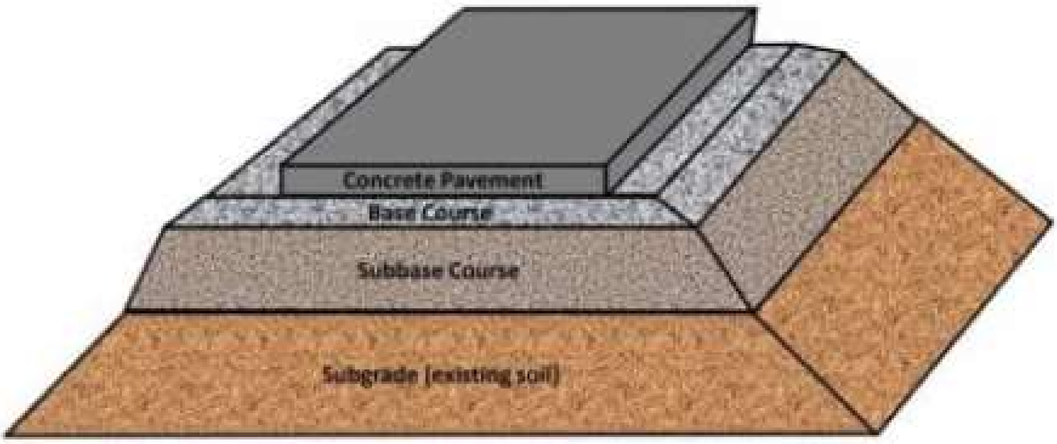

Figure 2.7: Typical structure of rigid pavements

2.6.1 Flexible Pavement

2.6.1.1 Types of Flexible Pavement

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement.
- Full - depth asphalt pavement.
- Contained rock asphalt mat (CRAM).

Conventional flexible pavements are layered systems with high quality expensive materials which are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water.

2.6.1.2 Typical layers of Flexible Pavement

Typical layers of a conventional flexible pavement includes seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural sub-grade. Figure 2.8 shows typical flexible pavement structure.

Seal Coat:

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

Tack Coat:

Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layer of binder course and must be thin, uniformly cover the entire surface, and set very fast.

Prime Coat:

Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface.

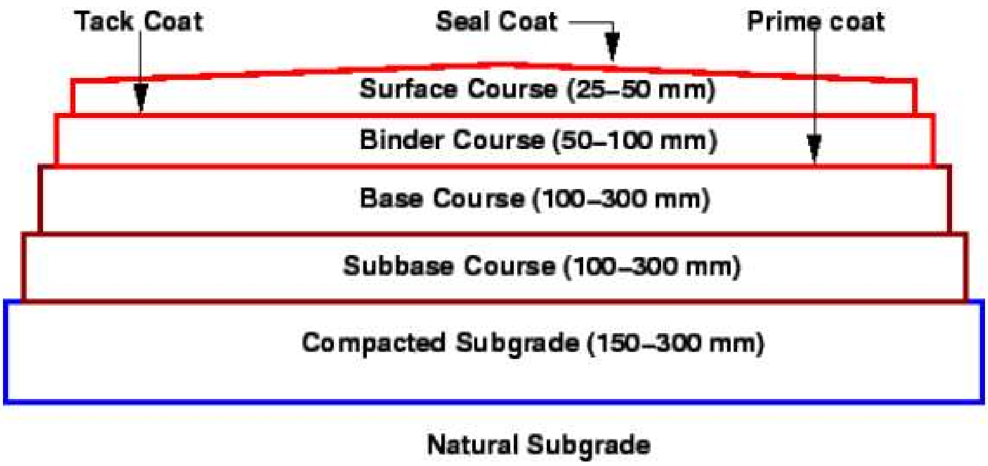

Figure 2.8: Typical flexible pavement structure.

Sub-grade:

The subgrade is usually the natural material located along the horizontal alignment of the pavement and serves as the foundation of the pavement structure. It also may consist of a layer of selected borrow materials, well compacted to prescribed specifications. It may be necessary to treat the subgrade material to achieve certain strength properties required for the type of pavement being constructed. Soil stabilization is the treatment of natural soil to improve its engineering properties. One solution to enhance the properties of sub-grade is to stabilize this layer. Soil stabilization methods can be divided into two categories, namely, mechanical and chemical. This can be achieved using one of these methods below;

1. ***Cement-stabilized soil*** is a mixture of water, soil, and measured amounts of Portlandcement−thoroughly mixed and compacted to a high density and then allowed to cure for a specific period, during which it is protected from loss of moisture.
2. ***Soil cement*** is a hardened material obtained by mechanically compacting a mixture of finely crushed soil, water, and a quantity of Portland cement that will make the mixture meet certain durability requirements.

3. ***Cement-modified soil*** is a semi hardened or unhardened mixture of water, Portland cement, and finely crushed soil. This mixture has less cement than the soil−cement mixture.
4. ***Plastic soil cement*** is a hardened material obtained by mixing finely crushed soil, Portland cement, and a quantity of water, such that at the time of mixing and placing, a consistency similar to that of mortar is obtained.
5. ***Soil-lime*** is a mixture of lime, water, and fine-grained soil. If the soil contains silica and alumina, pozzolanic reaction occurs, resulting in the formation of a cementing-type material. Clay minerals, quartz, and feldspars are all possible sources of silica and alumina in typical fine-grained soils.

Sub-Base Course:

The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure. If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course. A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Base Course:

The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage. It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Surface Course:

The surface course is the upper course of the road pavement and is constructed immediately above the base course. The surface course in flexible pavements usually consists of a mixture of mineral aggregates and asphalt. It should be capable of:

- Withstanding high tire pressures,
- Resisting abrasive forces due to traffic,
- Providing a skid resistant driving surface, and
- Preventing the penetration of surface water into the underlying layers.

The thickness of the wearing surface can vary from 75mm to more than 150 mm, depending on the expected traffic on the pavement. It should be noted that the quality of the surface course of a flexible pavement depends on the mix design of the asphalt concrete used.

2.6.1.3 Principle for flexible pavement

The primary function of the pavement structure is to reduce and distribute the surface stresses (contact tire pressure) to an acceptable level at the sub-grade (to a level that prevents permanent deformation). A flexible pavement reduces the stresses by distributing the traffic wheel loads over greater and greater areas, through the individual layers, until stress at the sub-grade is at an acceptable low level. The traffic loads are transmitted to the sub-grade by aggregate-to-aggregate particle contact. Confining pressures (lateral forces due to material weight) in the sub-base and base layers increase the bearing strength of these materials. A cone distribution loads reduces and spreads the stress to sub-grade as shown in Figure 2.9.

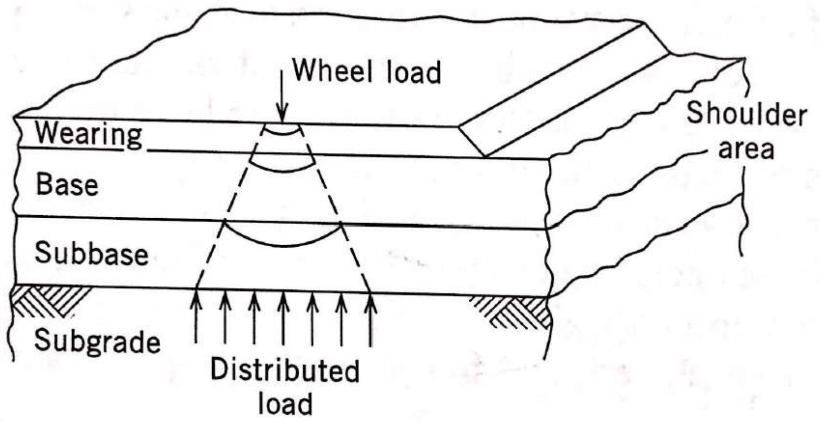

Figure 2.9: Distribution of load on a flexible pavement

2.6.1.3.1 Calculation of flexible pavement stresses and deflections

To design a pavement structure, one must be able to calculate the stresses and deflections in the pavement system. In the simplest case, the wheel load can be assumed to consist of a point load on a single-layer system as shown in Figure 2.10. This type of load and configuration can be analysed with Boussinesq solutions that were derived for soils analysis. The Boussinesq theory assumes that the pavement is one layer thick and the material is elastic, homogeneous and isotropic. The basic equation for the stress at a point in the system is

$$\sigma_z = K \frac{P}{z^2} \quad \text{(U.S. Customary)} \quad (2.10)$$

$$\sigma_z = 1000K \frac{P}{z^2} \quad \text{(Metric)} \quad (2.11)$$

Where;

σ_z = stress at point in kPa (Ib/in^2)
P = wheel load in N (Ib)
Z = depth of the point in question in mm (inches), and
K = variable defined as

$$K = \frac{3}{2\pi} \frac{1}{[1 + (^r/_z)^2]^{5/2}} \quad (2.12)$$

Where

r = radial distance in mm (inches) from the centreline of the point load to the point in question

Although the Boussinesq is useful for beginning the study of pavement stress calculations, it is not very representative of pavement system loading and configuration because it applies to a point load on one layer. A more realistic approach is to expand the point load to an elliptical area that represents a tire foot-print. The tire foot-print can be defined by an equivalent circular area with a radius calculated by

$$a = \sqrt{\frac{P}{p\pi}}$$ ……………………(U.S. Customary)………………………(2.13)

$$a = \sqrt{\frac{P}{p\pi/1000}}$$ ……………………(Metric)…………………………..(2.14)

Where:

a = equivalent load radius of the tire foot-print in mm (inches)

P = tire load in N (Ib)

p = tire pressure in kPa (Ib/in^2)

The integration of the load from a point to a circular area can be used to determine the stresses and deflections in a one-layer pavement system.

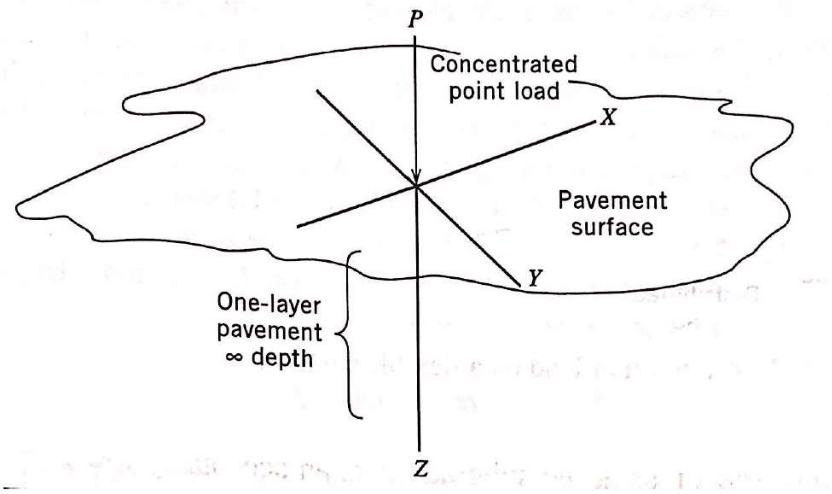

Figure 2.10: Point load on a one-layer pavement

However, Ahlivn and Ulery provided solutions for the evaluation of stresses, strain and deflections at any point in a homogenous half-space. Their work makes it easier to analyse a more complex pavement system than that considered in Boussinesq example. The one-layer equations by Ahlivin and Ulery can be used for material with any Poisson ratio which describes the change in width relative to length when a load is applied along the vertical axis. Based on Ahlvin and Ulery's work, the equation for the calculation of vertical stress is

$$\sigma_z = p(A + B) \quad \text{.......(2.15)}$$

The equation for radial-horizontal stress (which is a cause of pavement cracking) is

$$\sigma_r = p[2\mu A + C + (1 - 2\mu)F] \quad \text{.......(2.16)}$$

The equation for deflection is

$$\Delta_z = \frac{p(1+\mu)a}{E}\left[\frac{z}{a}A + (1-\mu)H\right] \quad \text{.......(2.17)}$$

Where:

σ_z = vertical stress in kPa (Ib/in^2)

σ_r = radial-horizontal stress in kPa (Ib/in^2)

Δ_z = deflection at depth z in mm (inches)

p = pressure due to the tire load in kPa (Ib/in^2)

μ = Poisson ratio

E = modulus of elasticity (known as Young's modulus, the ratio of stress to strain as a load is applied to a material in kPa (Ib/in^2) and

A,B,C,F and H = function values as presented in Table 2.3 that depends on z/a and r/a, the depth in radii and offset distance in radii respectively

Where

z = depth of the point in question in mm (inches)

r = radial distance in mm (inches) from the centreline of the point load to the point in question

a = equivalent load radius of the tire foot-print in mm (inches)

Example 2.1: *A tire with 689 kPa air pressure distributes a load over an area with a circular contact radius, a, of 127mm. The pavement was constructed with a material that has a modules of elasticity of 345000 kPa and a Poisson ratio of 0.45. Calculate the radial-horizontal stress and deflection at a point the pavement surface under the centre of the ire load. Also, calculate the radial-horizontal stress and deflection at a point at a depth of 508mm and radial distance of 254mm from the centre of the tire load. (USE: Ahlvin and Ulery equations).*