Rigid pavements

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Table of Contents

Introduction:

What is Pavement?

A pavement is one type of hard surface made from durable surface material laid down on an area which is intended to carry vehicular or foot traffic. its main function is to distribute the applied vehicle loads to the sub-grade through different layers. The road structure should provide sufficient skid resistance, proper riding quality, favourable light reflecting characteristics, and low noise pollution. Its goal to reduce the vehicle transmitted load, so that they will not exceed bearing capacity of the sub-grade. The pavements or roads are paying a crucial role in the development of any construction. There are two major types of pavements based on their structure,

1. Flexible pavement.

2. Rigid Pavement

What is Rigid Pavement?

Rigid pavements, also known as concrete pavements, are a type of road or pavement structure that provides a durable and long-lasting surface for vehicular traffic. They are composed of several key components, each serving a specific function to ensure the pavement's performance and longevity. The components of rigid pavements include the subgrade, base course, subbase course (when used), concrete slabs, joints, and surface treatments. Understanding the roles and interactions of these components is essential in designing and constructing rigid pavements that can withstand heavy loads, resist cracking, and provide a smooth and safe driving surface. The stresses in these pavements are transferred through slab action, as opposed to the grain-to-grain action in the flexible pavement. The rigid pavements are made of Portland cement concrete-either plain, reinforced, or prestressed concrete. The plain cement concrete slabs are expected to take up about 40 kg/cm2 flexural stress.

This article shall elaborate the Rigid pavements, their steps, types, and construction steps.

*Where rigid pavement needed?

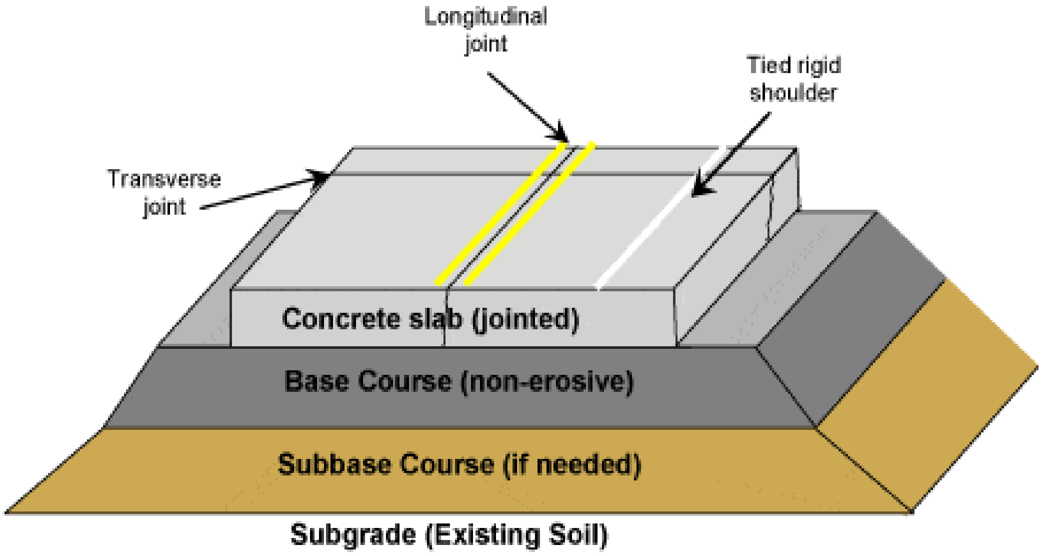
*Rigid pavements are usually provided under the circumstances:

1- Very heavy rainfall.
2- Poor soil conditions.
3- Poor drainage.
4- Extreme climatic conditions.

*Structure of Rigid Pavement:

The structure of Rigid pavement consists of the following layers:

- Surface Course
- Granular Base Course
- Granular Subbase course
- Subgrade



Surface Course:

The uppermost layer of rigid pavement, also known as the surface course, is a concrete slab that directly withstands vehicle loads. Its water resistance prevents water penetration into the underlying layers. The concrete slab provides friction to vehicles, preventing skidding. Typically, the thickness of the concrete slab ranges from 150 to 300 mm.

Granular Base or Stabilized Base Course:

Positioned as the second layer from the top, the base course, also called the granular base or stabilized base, is constructed using crushed aggregates. This layer allows for additional load distribution on the surface course and provides a solid foundation for the rigid pavement. Installing a subsurface drainage system is beneficial, and in frost-prone areas, the stabilized base course helps control frost action and minimises subgrade soil swelling. The foundation course should have a minimum thickness of 100 mm.

Granular Subbase or Stabilized Subbase Course:

The third layer, in contact with the base course and subgrade soil, is the granular subbase or stabilized subbase course. While of lower quality compared to the base coarse aggregates, they are of higher quality than the subgrade soil. In low-traffic situations, a subbase course may not be necessary, but when the loading exceeds 100,000 pounds, it should be included. Its primary function is to support the upper layers, control frost action, and prevent fines from the subgrade soil from infiltrating the surface layers. Additionally, the subbase course improves drainage capabilities.

Subgrade Soil:

The subgrade soil forms the existing soil layer that undergoes compaction using machinery to establish a strong foundation for the rigid pavement. Subgrade soils experience less stress compared to the top layers as tensions decrease with depth. Subgrade soils can vary significantly, and their response to forces from the upper layers depends on factors such as texture, density, moisture content, and strength. Therefore, a thorough subgrade inspection should be conducted prior to construction. The layers above the subgrade should be designed to minimize the displacement of subgrade soil layers and reduce the pressure exerted on the subgrade soil.

Types of Rigid Pavement:

Rigid pavements are made of concrete and are designed to distribute loads over a wide area, providing a durable and long-lasting surface for roads, airports, and other heavy-duty applications. There are three common types of rigid pavement:

Jointed Plain Concrete Pavement (JPCP):

JPCP is the most commonly used type of rigid pavement. It consists of long slabs of concrete with transverse and longitudinal joints. Transverse joints are typically spaced at regular intervals to control cracking caused by the natural expansion and contraction of the concrete due to temperature changes. Longitudinal joints are placed at the edges of the pavement and provide lateral support to the slabs. JPCP is cost-effective and relatively easy to construct.

Jointed Reinforced Concrete Pavement (JRCP):

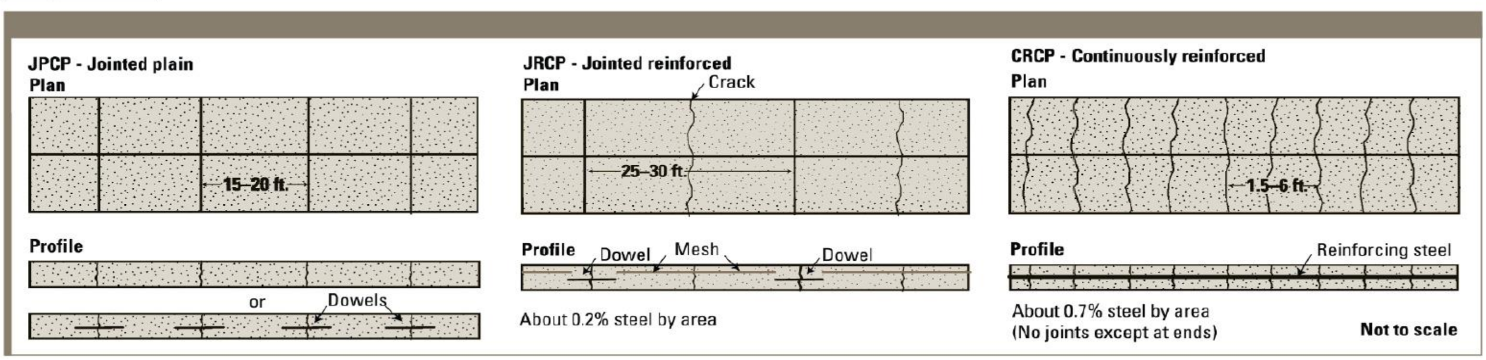
JRCP is similar to JPCP but includes steel reinforcement within the concrete slabs. The reinforcement helps to control cracking and improve the overall strength of the pavement. It is often used in areas where heavy truck traffic or high wheel loads are anticipated.

Continuously Reinforced Concrete Pavement (CRCP):

CRCP is a type of rigid pavement that does not contain any transverse joints. Instead, it has continuous steel reinforcement throughout the entire pavement section. The absence of transverse joints eliminates the need for joint maintenance and reduces the

potential for faulting and pumping. CRCP is commonly used for highways and roads

Figure 1



with heavy traffic loads.

Types of joints in rigid pavements:

Joints are formed in concrete slabs as part of the process of constructing rigid paving for roads. Joints are discontinuities in the pavement slab that are necessary to allow for expansion, contraction and warping. Rigid paving consists of a reinforced or unreinforced insitu concrete slab laid over a thin granular base course. The rigidity and strength of the pavement enables the loads and stresses to be distributed over a wide area of the subgrade.

Joints are spaced depending on a range of factors:

*The amount of reinforcement used.

*The proposed traffic intensity.

*The slab thickness.

*The frictional restraint of the subgrade.

*The temperature at which the concrete is laid.

Joints comprise a filler which separates the slabs, and a sealing compound which is used to fill the top 25 mm of the joint to prevent the entry of water and grit. Suitable jointing materials include impregnated fibre board, cork, sheet bitumen, and rubber. The joint sealing compound must have good adhesion to concrete, extensibility without fracture, resistance to flow in hot weather, and durability.

A system of dowel bars in introduced between slabs to prevent slab movement and ensure load-transfer. Dowel bars are positioned at mid-depth of the slab at centres of 300 mm. The diameter of the bar usually ranges from 20-30 mm but varies with the slab thickness. A plastic sleeve 100 mm-long is inserted on one end of the dowel to allow free movement of the slab. The sleeve should contain a pad of compressible material at the end.

Types of roads joints:

There are a number of different types of joints:

*Expansion joint

*Contraction joint.

*Construction joint.

*.Warping joint.

Expansion joint:

These are provided along the transverse direction to allow the expansion and contraction of a concrete slab due to temperature and subgrade moisture variation. They are intended to prevent potentially damaging forces accumulating within the slab itself or surrounding structures. Maximum spacing of expansion joints range from 25-27 m in jointed reinforced concrete slabs, and from 40 m (for slabs <230 mm thick) to 60 m (for slabs >230 mm thick) in unreinforced concrete.

Contraction joint :

These are also known as ‘shrinkage’ joints and are provided along the transverse direction to allow for contraction or shrinkage of the slab during the curing process. Maximum spacing of contraction joints ranges from 12-24 m in reinforced slabs, and from 4-5 m in unreinforced slabs.

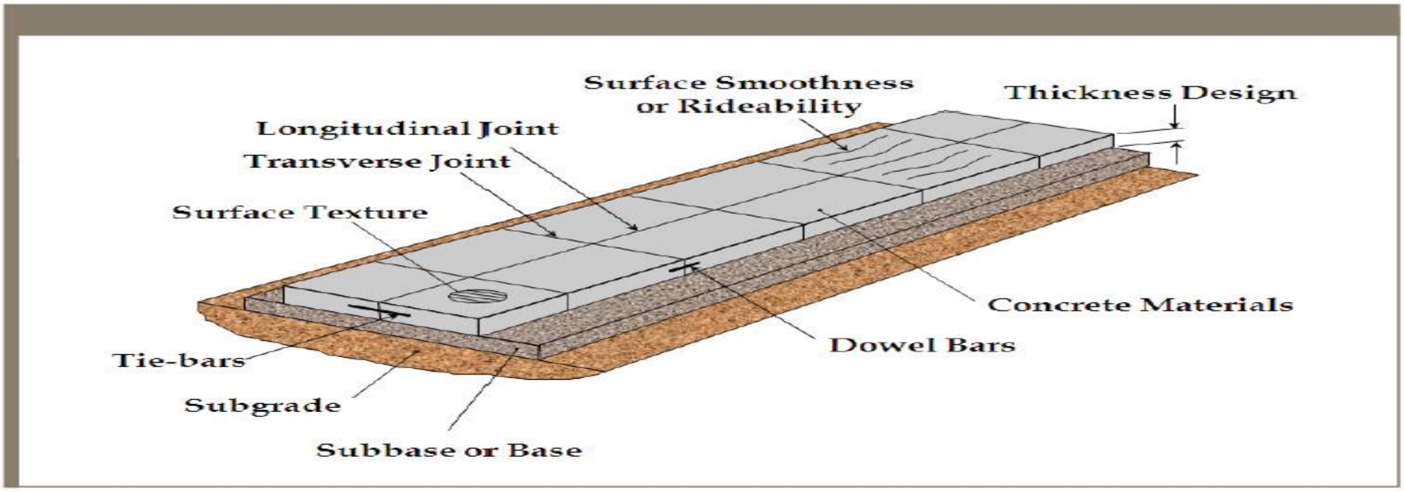
Construction joint:

Construction joints are provided whenever the construction work stops temporarily. They can be either along the transverse or longitudinal direction.

Warping joint :

Warping joints are provided along the longitudinal direction to prevent warping of the concrete slab due to temperature and subgrade moisture variation.

Figure 2



Difference Between Rigid Pavement and Flexible Pavement:

Some important differences between rigid pavement and flexible pavement are discussed below.

Aspect	Rigid Pavement	Flexible Pavement
Material	Portland cement concrete (PCC)	Bituminous materials (asphalt)
Load Distribution	Transferred through flexure of concrete slabs	Distributed through the layers of asphalt
Structural Behaviour	Rigid and inflexible	Flexible and resilient
Strength	High flexural strength and rigidity	Relatively lower strength
Construction	Constructed using concrete slabs	Constructed using multiple asphalt layers
Maintenance	Less susceptible to deformation or rutting	May experience deformation and rutting
Cracking	Tends to develop random cracks	May develop reflective or fatigue cracks
Resurfacing	Requires complete replacement of slabs	Can be resurfaced or overlayed with new asphalt
Cost	Higher initial cost	Lower initial cost
Noise Generation	Generates higher tire-pavement noise	Generates relatively lower noise levels
Climate Suitability	Performs well in hot and dry climates	Performs well in cold and wet climates
Curing	Curing required	No need of Curing
Temperature variation	Temperature stresses are developed due to temperature variation	No effect due to temperature variation
Durability	It has a higher durability	Its durability is less
Joints	Joints required	No requirement of joints
Lifespan	They have a lifespan of 20 to 30 years	They have a lifespan of 10 to 15 years.

Construction Steps of Rigid Pavement:

The construction of rigid pavement typically involves several steps. Here are the general steps involved in the construction of rigid pavement:

Preparing the Subgrade:

This is the first step in the construction of rigid pavement. It involves cutting and filling work, and a thorough soil compaction of the subgrade soil.

Provision of Subbase Course:

This course comprises broken stone pieces mixed with sand and is generally provided in rigid pavements in case the subgrade soil is weak.

Preparation of Base Course :

This is a drainage layer and is made up of boulders and stones. The voids between these stones are filled with smaller irregular-shaped stones. Notably, the minimum thickness of the base course layer should be 6 inches.

Preparation of Surface Course:
The surface course in rigid pavement comprises PCC or RCC slab. The thickness of this course should not be less than 12 inches for heavy traffic and not less than 6 inches for light traffic.

Features of Rigid pavement:

Rigid pavements have several distinctive features that make them suitable for various applications. Here are some key features of rigid pavement:

The wheel load is transferred to the soil subgrade through slab action.

The initial cost of construction is high.

Expansion, contraction, and construction joints are required in rigid pavements,

The durability of these pavements is high.

They have a long life up to 30 years.

These pavements require curing of concrete.

Rigid pavements have high flexural strength.

Advantages of Rigid Pavement:

Rigid pavements offer several advantages that make them a preferred choice for various applications. Here are some key advantages of rigid pavement:

- Durability: Rigid pavements, made of concrete, are highly durable and have a long service life. They can withstand heavy traffic loads, resist weathering, and maintain their structural integrity over time. Properly designed and constructed rigid pavements can last for several decades, reducing the need for frequent repairs or replacements.
- Load Distribution: Rigid pavements distribute applied loads over a wide area, minimising stress on the underlying subgrade. The rigid nature of the concrete slabs allows for efficient load transfer, preventing excessive surface deformations and ensuring a smooth and stable riding surface for vehicles.
- Strength: Rigid pavements exhibit high compressive strength, making them capable of carrying heavy loads without significant deformation or structural failure. The strength of the concrete used in rigid pavements can be tailored to meet specific design requirements based on anticipated traffic loads.
- Reflective Cracking Resistance: Rigid pavements have good resistance to reflective cracking, which refers to cracks that propagate from the underlying layers to the pavement surface. The rigid concrete slabs act as a barrier, preventing cracks from transferring through the pavement layers and reducing the need for frequent repairs due to cracking.
- Low Maintenance: Rigid pavements generally require less maintenance compared to flexible pavements. They do not experience issues such as rutting,

which is common in flexible pavements. The absence of rutting and reduced vulnerability to surface distresses contribute to lower maintenance costs and less frequent maintenance interventions over the pavement's lifespan.

- Skid Resistance: Rigid pavements offer good skid resistance, providing traction for vehicles and enhancing road safety, especially under wet or slippery conditions. The surface texture of the concrete and any surface treatments applied during construction can further enhance skid resistance.
- Stiffness: Rigid pavements have high stiffness, resulting in minimal deflections under traffic loads. This stiffness helps reduce rolling resistance, which can improve fuel efficiency for vehicles. Additionally, the rigidity of the pavement provides a smoother and more comfortable ride for vehicles.
- Design Flexibility: Rigid pavements offer design flexibility, allowing for customisation based on specific project requirements. They can be designed to accommodate a wide range of traffic volumes, including heavy truck traffic or high axle loads.
- Recycling Potential: Rigid pavements have good potential for recycling and reusing concrete material at the end of their service life. The demolished concrete can be crushed and used as aggregate in new concrete or for other construction applications, reducing waste and promoting sustainability.

Disadvantages of Rigid Pavement:

While rigid pavements offer numerous advantages, they also have some potential disadvantages. Considering these factors is important when deciding on the appropriate pavement type for a specific project. Here are some disadvantages of rigid pavement:

- High Initial Cost: Rigid pavements generally have a higher initial construction cost compared to flexible pavements. The cost of materials, such as concrete and reinforcement, as well as the specialised construction techniques involved, can contribute to higher upfront expenses.
- Lack of Flexibility: Rigid pavements are rigid and inflexible, which means they have limited ability to accommodate minor ground movements or settlements. In areas with expansive soils or poor subgrade conditions, rigid pavements may be prone to cracking or uneven settlement, requiring additional measures to mitigate these issues.

- Complex Construction: The construction of rigid pavements requires specialised equipment and skilled labour. Precise preparation of the subgrade, accurate placement of reinforcement (if used), and proper curing of the concrete are crucial for achieving the desired quality and performance. The complexity of construction can result in longer project durations and higher construction costs.
- Limited Reflective Crack Control: While rigid pavements offer good resistance to reflective cracking, they may still experience some cracking over time, particularly at joints and where the pavement meets other structures (e.g., bridges). Proper joint design, installation, and maintenance are essential to minimise the risk of reflective cracking, but it remains a potential concern.
- Difficult Repairs: Repairing damaged or deteriorated sections of rigid pavement can be more challenging compared to flexible pavement. It often involves removing and replacing entire concrete slabs or sections, which can be labour-intensive and costly. Additionally, repairs may require longer curing times, leading to extended periods of traffic disruption.
- Noise Generation: Rigid pavements can generate more noise compared to flexible pavements. The rigid surface can cause increased tire-pavement noise, especially at higher speeds, resulting in potentially higher noise levels in adjacent areas. Noise reduction measures, such as textured surfaces or noise barriers, may be needed in sensitive locations.
- Limited Design Flexibility: While rigid pavements offer some design flexibility, they may have limitations when it comes to accommodating certain design features or irregular alignments. Their rigid nature makes it more challenging to incorporate curves, intersections, or complex geometric layouts compared to flexible pavements.
- Environmental Considerations: The production of concrete for rigid pavements can have a higher carbon footprint compared to the production of asphalt for flexible pavements. Concrete production involves the emission of greenhouse gases during cement manufacturing and the extraction of raw materials. However, measures such as using recycled materials and optimising mix designs can help reduce the environmental impact.

Challenges of Rigid Pavement:

Rigid pavements come with their fair share of challenges. One significant challenge is the occurrence of cracks, which can be attributed to temperature fluctuations and heavy loads. Additionally, inadequate drainage can lead to erosion and various forms of damage. However, despite these challenges, rigid pavement continues to be a preferred option for numerous high-traffic locations.