

The road pavement structure engineering essay



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A road pavement is a structure of superimposed layers of selected and processed materials which is placed on the sub grade. Supporting the wheel loads applied to the carriageway and distributing them to the underlying sub grade is the main structural function of a pavement (O'Flaherty, 2002).

Modern pavement design is normally concern with the developing of the most economical combination of pavement layers that will ensure that, the transmitted stresses and strains from the carriageway do not go beyond the supportive capacity of each of the layers during the design of the road.

Pavements are classified into two main types namely:

Flexible pavements and

Rigid pavements

Rigid pavement and components layers.

Rigid pavements are commonly referred to as Portland cement concrete because they are surfaced with Portland cement concrete (PCC). They are referred to as “ rigid” because they are substantially stiffer than flexible pavements due to PCC's high stiffness. Due to high modulus of elasticity, rigid pavement structure deflects very little under loading (Thomas, 2008).

Rigid pavements react to a wheel load as a very stiff material (concrete) than over much softer materials (sub base and sub grade). Because of its relative rigidity, the rigid pavement develops significant bending moments and uses these bending moments to act as a beam to spread the wheel load over a large area of the sub base and sub grade as shown in figure 1. 1.

Rigid pavements are built by compacting the sub grade, addition of a layer which represents the sub base, and is chosen more frequently in which the

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layer has better material properties compared to the sub grade (Hadi and Arfiadi, 2001). The essence of the layer is to provide a working platform as well as to help in distributing the vehicular loading when applied at the surface of the base. The rigid pavement is divided into three types namely:

Jointed plain (unreinforced) concrete pavements (PCP).

Jointed reinforced concrete pavements (JRCP).

Continuously reinforced concrete pavements (CRCP).

The Jointed plain (unreinforced) concrete pavements (PCP) and Jointed reinforced concrete pavements (JRCP) slabs are both provided with transverse and longitudinal joints while the Continuously reinforced concrete pavements (CRCP) have no transverse joints except at construction joints but are normally provided by longitudinal joints (O'Flaherty, 2002).

Figure 2. 1: Rigid pavement load distribution

Figure 2. 2: Basic rigid pavement structure.

Figure 2. 2 shows a typical rigid pavement structure consisting of the following:

Surface course

The surface course is the top layer of a rigid pavement which consists of a Portland cement concrete (PCC) slab. The layer is being composed of pavement quality concrete with considerable flexural strength which also enables the surface course to act as a beam and bridge over any minor

irregularities in the surface of the layer below (O'Flaherty, 2002). As road traffic runs directly on the top of the slab, the concrete surface must provide a smooth and comfortable ride as well as good skidding resistance under all weather conditions. The characteristics provided are:

Friction.

Smoothness.

Noise control and

Drainage.

It prevents entrance of surface water into the underlying base, sub base and sub grade (NAPA, 2001).

Base course

The base course is a layer immediately below the surface course and generally consists of aggregate. Base course are usually constructed out of aggregate and functions as follows:

The layer provides additional load distribution.

Contributes to drainage and frost resistance.

Uniform support to the pavement and

A stable platform for construction equipment. (WAPA, 2002)

Sub base

The sub base is a layer between the base course and the sub grade which generally consists of lower quality materials than the base course, but much better than the sub grade soils. The appropriate materials are aggregate and high quality structural fill. It functions as follows:

Minimize the intrusion of fines from the sub grade into the pavement structure.

Provides a working platform for construction.

Improve drainage and minimize frost action damage.

The sub base is not always needed and may therefore be omitted.

Sub grade.

The sub grade is a layer under the concrete pavement. It must be sufficiently stable to withstand the stresses caused by construction and compaction traffic during which the sub base and the concrete slab are being laid. The sub grade provides the uniform support required throughout the life time of the pavement. The sub base is usually omitted from the pavement if the sub grade is strong.

Flexible pavement and components layers.

Flexible pavements are surfaced with asphalt materials in which the total pavement structure bends due to traffic loads. A flexible pavement structure is composed of several layers of materials with better quality on top where the intensity of stress is high due to traffic loads while the materials at the bottom has low intensity of stress due to low quality (WAPA, 2002). Each

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layer of the pavement receives the loads from the layer above, spreading them out before the loads are being passed to the next layer below (see figure 2. 3). A flexible pavement structure consists of the surface course and the underlying base and sub base courses as shown in figure 2. 4 in which the layers contributes to structural support and drainage (Thomas, 2008). The layers underlying are less stiff but still serves as important to the pavement strength, drainage and frost protection. The asphalt is used as the surface course because it is the stiffest and contributes most to pavement strength.

Figure 2. 3: Flexible pavement load distribution.

Figure 2. 4: Basic flexible pavement structure.

Figure 2. 4 shows a typical flexible pavement structure consisting of the following:

Surfacing

The surfacing is the uppermost layer of a flexible pavement. This layer provides a safe, smooth, stable, and non-skidding riding surface such as a carriageway for traffics as its primary function, were as its secondary function is to contribute to the structural stability and to protect the pavement from natural elements. When a surfacing is composed of bituminous materials it may result in a single similar layer but when heavily trafficked roads, two distinct layers are form namely wearing course and base course. The wearing course forms the carriageway surface upon which vehicles run and provides the following.

Offer good skid resistance

Allow for the rapid drainage of surface water.

Protect the underlying road structure.

The base course is a structural platform which ensures that the wearing course has a good riding quality when built and also helps to distribute the applied load. The base course can be composed of a more permeable material if the wearing course is rigid.

Road base.

The road base is the main structural layer in a flexible pavement which provides the platform for the surfacing. The road base distributes the loads transmitted to it so that the strength capacities of the weaker sub base and sub grade are not exceeded. They are designed to be very dense and highly stable and resistance of fatigue cracking and structural deformation.

Sub base

The sub base is a separate layer beneath the road base. The sub base within the pavement is a structural layer which further distributes the applied wheel loads to the weaker sub grade below. It acts as a working platform which protects the sub grade from site and construction vehicles as the pavement is being built.

Sub grade

The sub grade is the foundation layer, which is also the structure that must give support to all the loads coming onto the pavement. The layer can either be the natural earth surface or in more usual instances it will be compacted soil existing in a cut section (Paul and Karen, 2004). As the thicknesses of upper layers are dependent on it, thereby the strength of the sub grade layer is important. The combined thickness of the sub base if used, base and surface course must be great enough in reducing the stresses which occur in the sub grade to values that are not sufficient great to cause excessive distortion.

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Skid resistance

Skid resistance is a frictional force developed along the pavement surface when a tire is prevented from rotating slides (Highway Research Board, 1972). Skid resistance is developed to some extent along the pavement surface in order to determine and measure the resistance of the vehicle due to skidding. According to Jose and Rafael 2009, the term skidding is generally used to describe the contribution of the pavement to the development of friction. It denotes a measurement of friction obtained under standardized conditions in which the various parameters are controlled so that the effect of the road surface characteristics can be isolated (Jose and Rafael, 2009).

Skidding arise as a result of frictional force acting along the tire pavement surface contact exceeds, which thereby resulting to the vehicle's lost of directional stability. The magnitude of the friction depends on a number of factors relating to road surface characteristics and conditions such as

aggregate on the surface of the road which leads to skid resistance between the vehicle tyres and the surface, and the vehicle characteristics includes the tyre and vehicle speed.

Skidding accidents usually occur on wet pavements and are hence referred to as wet pavement accidents. The lubricating effect of the water film present at the tire pavement interface is caused as a result of the reduced friction. On dry pavement, skid resistance is sufficient to counteract the demand for friction in most situations. But skid resistance diminishes considerably on wet pavement depending on pavement conditions. However, testing procedures and previous skid related studies focused on wet pavement conditions.

Tire pavement skid resistance has long been recognised as the primary factor of controlling vehicle direction and speed, as well as ensuring short braking distances (Alexandros and Olympia., 1998). Nonexistent of tire to road friction causes skidding; this is one of the essential factors leading to traffic accident. Skid resistance serves as an importance pavement evaluation parameter because:

Inadequate skid resistance will lead to higher incidences of skid related accidents.

Most agencies have an obligation to provide users with a roadway that is “reasonably” safe.

Skid resistance measurements can be used to evaluate various types of materials and construction practices (Ibrahim, 2005).

Friction

Friction is the resistance of motion between two surfaces in contact, which its magnitude is measured by coefficient of friction. In traffic condition, the surface of contact is the road tire interface, while the wheel load is the normal load. The magnitude of the friction depends on a number of factors relating to road surface characteristics and conditions such as aggregate on the surface of the road which leads to skid resistance between the vehicle tyres and the surface, and the vehicle characteristics includes the tyre and vehicle speed. As the vehicle travels on a road, friction occurs at the wheel road interface, allowing the vehicle to steer, to accelerate, to brake and to stay on the road when travelling around a curve. (Heinrichs et al., 2004)

The pavement friction coefficient is divided in to two components namely:

The longitudinal friction coefficient and

The transverse friction coefficient.

The longitudinal friction coefficient

The direction in which the vehicle is moving is measured by the longitudinal friction coefficient. It influences directly the distance required for a vehicle to decelerate and during unexpected situations in which braking is required; it determines the drivers safety margin.

The transverse friction coefficient

The skid resistance which is perpendicular to the direction of the vehicle movement is measured by the transverse friction coefficient. Where changes

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of direction are required, it allows the driver to direct the vehicle in curves and in other situations. The maximum safe speed at which a curve can be driven much depends on the combination of transverse friction, super elevation and curve radius (Jose and Rafael, 2009). Both longitudinal and transverse components of friction are being compensated when steering and braking are under taking simultaneously.

Figure 2. 5: Road surface friction system.

The magnitude of forces capable of being transmitted between a vehicle and the road is being influence by the road surface friction (RSF). The forces are commonly transmitted through a wheel and tire system. For wet road surface, the road surface friction (RSF) is generally low compare to that of dry road surface. A Road accident occurs as a result of unawareness of RSF changes by the driver before applying baking in time to avoid an accident. Applying a lightly bake in order to determine how slippery a road surface is can leads to loss of vehicle control depending on the poor condition of the RSF (Vannan and Frederick, 2003).

The figure 2. 5 represents a drive tire and a wheel which is rotating in clock wise direction as the vehicle is accelerating. As the road surface friction falls below the maximum level, the torque that is being applied by the tire to the road surface will cause the tire to slip relative to the road surface through the slippage angle S . The magnitude of the angle S is proportional to the length of the slip in distance and duration and duration of the slip.

Measurement of friction

Coefficient of friction ($\hat{1}/4$) is being calculated by dividing the motion frictional resistance F , by the load acting perpendicular to the interface, L (Hass and Zaniewski, 1994). The coefficient of friction is dependent on the pavement surface properties which are wheel properties and load conditions. Another factor is the friction factor f , which is equals to F/L where as the skid number SN , is equals to $100*f$ (Ibrahim, 2005).

The skid resistance is generally quantified using some form of friction measurement such as friction factor and skid number.

Friction factor (f) = F/L which is same as the coefficient of friction.

Skid number (SN) = $100*f$

Where F = Frictional resistance to motion in plane of interface.

L = Load perpendicular to interface.

Pavements does not have a certain friction factor because friction involves two bodies which are the tires and the pavement, which are extremely variable due to pavement wetness, vehicle speed, temperature, tire wear and as well as the tyre type. In general, dry pavements have relatively high friction resistance than wet pavements. The rate of accident on wet pavements is twice as high as dry pavements. Table 1. 1 shows some typical skid numbers in which the higher the SN number, the better it is (from Jayawickrama et al., 1996).

Table 1. 1: Typical Skid Numbers (from Jayawickrama et al., 1996)

Skid Number

Comments

< 30

Take measures to correct

â%¥ 30

Acceptable for low volume roads

31 - 34

Monitor pavement frequently

â%¥ 35

Acceptable for heavily travelled roads

Factor affecting skid resistance properties

Surface porosity of the pavement layer.

Polishing of the surface aggregate.

Contamination of the road surface such as rubber, oil, and water.

Rutting due to compaction and lateral distortion.

Bleeding and flushing of bituminous binder of the surface (Ibrahim, 2005).

Surface Texture

Skid resistance depends on pavement surface consisting of two major characteristic and these characteristics are known as:

Macro texture and

Micro texture.

Micro texture

Micro texture refers to the small scale texture of the pavement aggregate component (which controls contact between the tire rubber and the pavement surface) and hence produced from the coarse aggregate (Ibrahim, 2005). Reduction in micro texture is due to polishing of the aggregate therefore resulting in the smoothing and rounding of exposed aggregates.

Micro texture is the major contributing factor to skid resistance at low speed. Micro texture penetrate through the water film when the surface of the road is wet, resulting in decrease in skid resistance. Due to the action of heavy traffic, the pavement surface is been polished and the skid resistance falls to an equilibrium level depending on the number of heavy vehicles along the road as well as resistance to polishing of the aggregate used in the surfacing (Jose and Rafael, 2009).

Micro texture is a surface texture irregularity which is measured at the micro scale of harshness and for a given conditions of weather effect, traffic action and pavement age, it is known to be a function of aggregate particle mineralogy. As micro texture irregularities are classified between 0.005mm and 0.3mm, the lower limit reflects the smaller size of surface irregularities which affect wet friction. Irregularities greater than 0.3mm cannot penetrate

into the soft rubber material of the tire and thus do not affect in such a way, the tire friction. The average micro texture depth of a harsh surface pavement is 0.05mm (Alexandros and Olympia., 1997).

Macro texture

Macro texture refers to the large scale texture of the pavement as a whole due to the aggregate particle arrangement (which controls the escape of water under the tire and hence the loss of skid resistance at high speeds) and hence it is being controlled by the shape, size, layout and gradation of the coarse aggregates (Ibrahim, 2005). Macro texture can also generate energy losses in the tire when it is skidding by a process known as hysteresis; some of the energy used to deform the tire tread when it slides over the texture is being absorbed by the tire as it returns to its original shape. As the vehicle speed increases, the skid resistance decreases which depends on the texture depth (Jose and Rafael, 2009).

Inadequate macro texture as a result of faulty construction practice drops skid resistance especially in the medium to high speed range, therefore enhancing accident risk because the harsh asperities of the aggregate penetrate the film of water, contact and harsh the tire thus obstructing skidding. Deep macro texture indicates that the pavement surface has a large area of void, in which excess water is being drained from the tire pavement contact region. Irregularities of macro texture are considered between 0.3mm and 0.5mm in which larger irregularities are more or less considered as pavement defaults. The method of assessing pavement macro texture is by the sand patch method and the average macro texture depth of

a pavement surface is considered rough if it is more than 1.0mm
(Alexandros and Olympia., 1997).

RESEARCH OBJECTIVE AND SCOOP

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LITERATURE REVIEW

DATA COLLECTIONS

CONCLUSION AND RECOMMENDATION

DISCUSSION

DATA ANALYSIS

CASE STUDY