COMMON TYPES
OF DISTRESSES ON ASPHALT PAVEMENTS

A REPORT

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BY

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COMMON TYPES OF DISTRESSES ON ASPHALT PAVEMENTS

Rutting is defined as the longitudinal permanent deformation or plastic movement of the asphalt pavement under the action of repeated loadings over the wheel path. Rutting is usually caused by the densification and shearing of the different pavement layers. It is visually identified by the depression in the pavement surface along the wheel paths. Even though visible on pavement surface rutting may occur on any of the layers.

Rutting is a serious safety issue for drivers. When water accumulates in the ruts, there is a potential for hydroplaning. The hydroplaning phenomenon consists of the buildup of a thin layer of water between the pavement and the tire and results in the tire losing contact with the surface, with the consequent loss of steering control.

Three main mechanisms lead to the following three types of rutting:

١-Structural Rutting, *٢-Instability Rutting,* *٣-Surface/Wear Rutting.*

It is important to differentiate between these three types of rutting and their potential causes. Different mechanisms lead to a variation in visual characteristics of rutting. Shapes of transverse surface profiles differ between failures in the **HMA** surface mixtures and failures in the underlying support layers.**(HMA - hot mix asphalt).**

١-Structural Rutting:

The deformation of one or more layers underlying the **HMA** layer results in structural rutting. Base and/or sub grade materials are unable to sustain the load stresses resulting in depressions and lack of support to the superior layers, manifesting on surface rutting.

A cross sectional diagram of structural rutting is shown in **(Figure ١.)** Structural rutting can be visually identified rather easily. Two main characteristics distinguish structural rutting from other modes of rutting. Structural ruts are wide and do not have humps on their sides as compared with instability rutting described later.

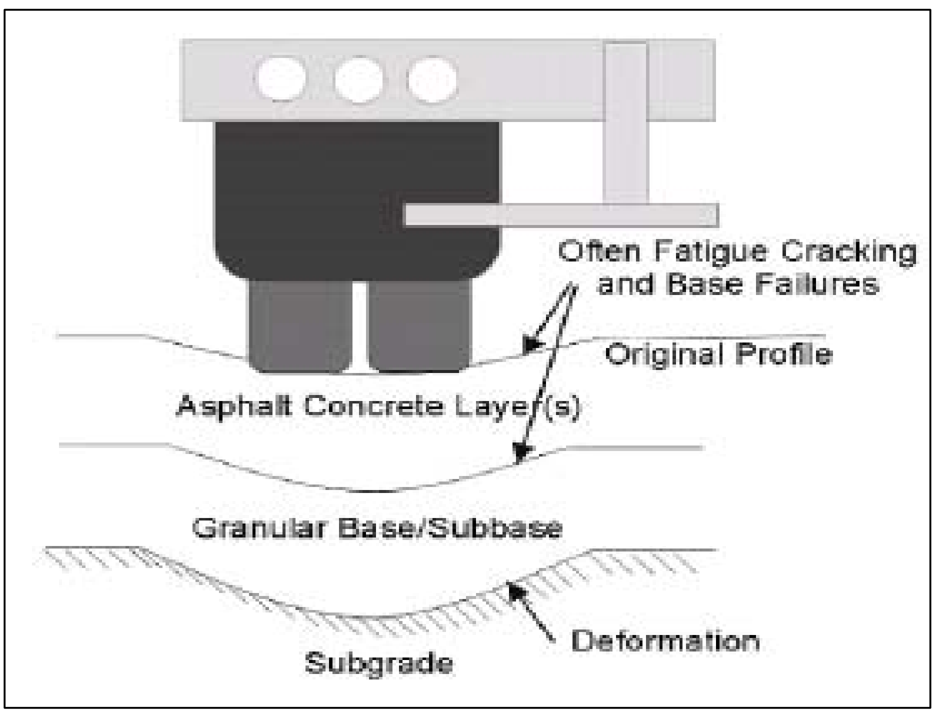


Figure ١: Structural Rutting on Asphalt Pavements

The surface deformation is dependent on which of the layers is failing to support the load. The visual characteristics will be different when the sub grade is failing as compared to the base. **.(Figures٢ and ٣)** illustrate and compare the difference between the surface deformation profiles due to base and sub grade failures. When the base is failing, a small hump will be visible at the surface in the middle of the two wheel paths, while the deformation due to sub grade failure will have no humps at all with a wider wheel path depression.

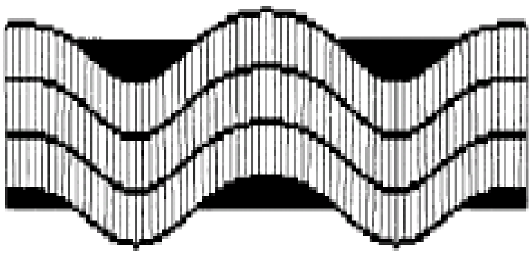


Figure ٢: Surface Deformation Due to Deformation.

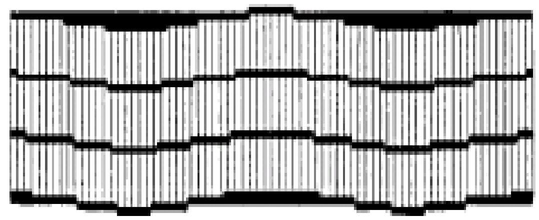


Figure ٣: Surface Deformation Due to Base Sub grade Deformation.

Inadequate design, poor construction, and improper material specification in asphalt pavement systems generally cause structural rutting. Traffic conditions, weak substructure, or even poor drainage are essential parameters in pavement design. Miss-estimation of these parameters leads to inadequate design and affect the pavement system which could induce structural rutting.

٢-Instability Rutting:

Instability rutting or plastic flow is the type of rutting that is due to inadequate **HMA** mix design rather than the structural design. The shear deformation, rather than densification, is the primary rutting mechanism in **HMA** surface mixtures when the supporting layers are reasonably stiff. This kind of rutting is visually recognized by the humps formed on the sides of the rut as shown in **Figure ٤.**

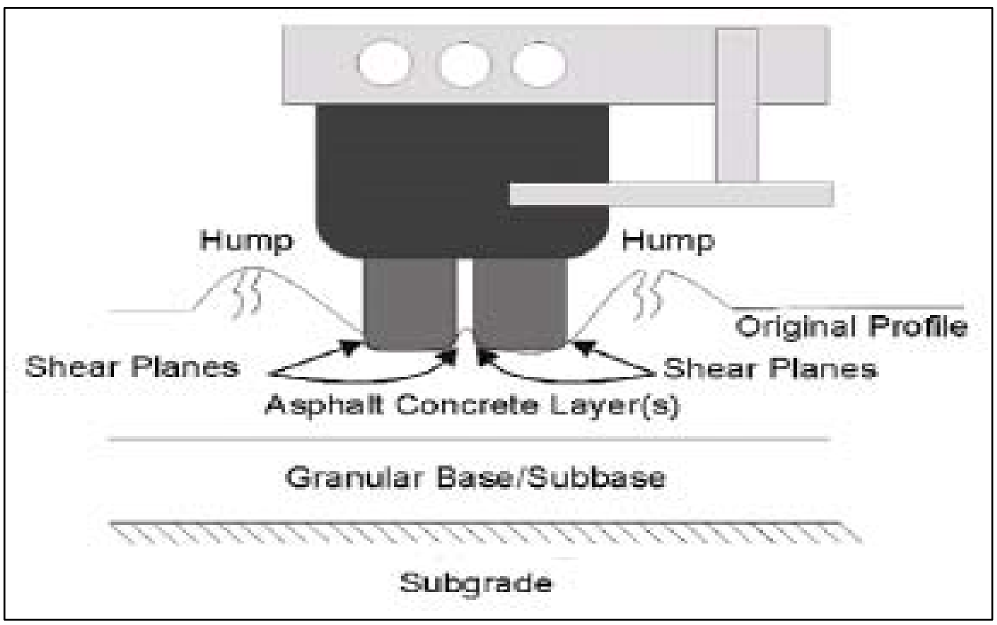


Figure ٤: Instability or Plastic Flow on Asphalt Pavements.

This type of distress is more visible in slow trafficked area of the pavement such as intersections which represent a variance in the loading conditions applied to the pavement. Braking, accelerating, turning, standing, and slow moving stresses at intersections induce instability rutting. It may also be contributed to factors such as:

* **High pavement temperatures.**
* **Improper materials.**
* **Rounded aggregates.**
* **Too much binder and/or filler.**
* **Insufficient or too high air voids.**

During warm summer months the sun radiation and the exhaust of the slow/standing vehicles raise the pavement temperature. At higher temperatures a reduction in the **HMA** stiffness occurs, which may induce instability rutting in the **HMA** layer. Dripping engine oil and other vehicle fluids are also concentrated at intersections and tend to soften the asphalt. At intersections, stopped and slow moving traffic allow exhaust to elevate asphalt surface temperatures even higher. A properly designed mixture with a stiffer asphalt binder and strong aggregate structure will resist plastic deformation of the hot mix asphalt pavement.

٣-Surface/Wear Rutting:

Wear rutting is the consolidation in the wheel paths of the **HMA** layer due to insufficient compaction effort which is usually reflected in not achieving the target density. Consequently additional compaction to the asphalt layer is generated by vehicle loading without any base/sub base yielding or the formation of **HMA** humps as seen in**(Figure ٥.)** The following list of factors contributes to this type of rutting:

* **Insufficient compacting effort within the lower base layers.**
* **Not enough roller passes while paving, weight of roller and way of compact.**
* **HMA cooling before target density.**
* **Asphalt moisture or dust.**
* **Low asphalt content in the mix.**
* **Lack of cohesion in the mix (tender mix, gradation problem ,and other mix design problem.**

Wear rutting is also the result of chains and studded tires wearing away the pavement surface during winter season.

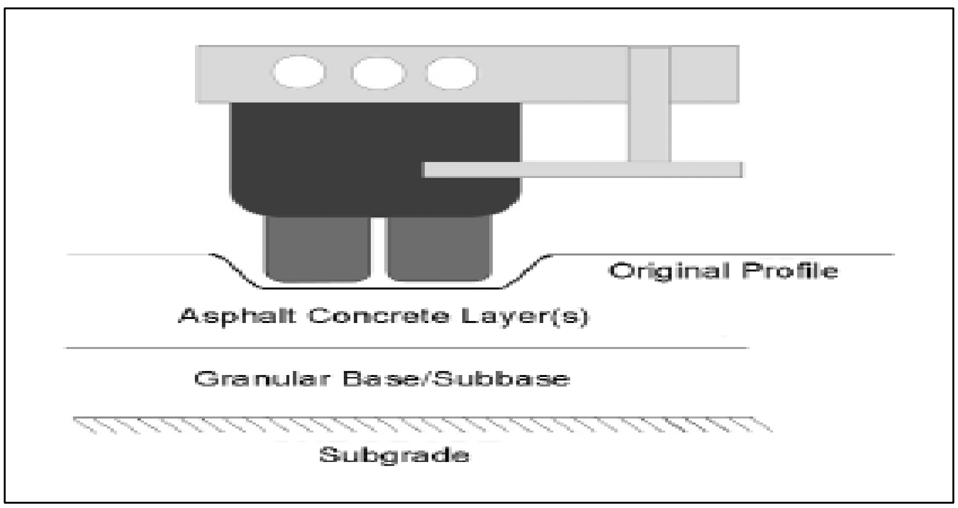


Figure ٥: Wear Rutting on Asphalt Pavements

Shoving

Shoving of an asphalt concrete pavement is defined as the longitudinal surface displacement of the **HMA**. Shoving is usually caused by an unstable asphalt layer that is not strong enough to resist horizontal stresses. Acceleration and deceleration of vehicles represent a continuous loading the same direction that generally causes shoving as shown in **(Figure ٨.)** Excess binder in the mix, mistakes on the gradation, and erroneous temperature during compaction are parameters that cause a weak asphalt mixture. These potential problems along with poor bonding between the **HMA** and the underlying layer decrease the resistance to horizontal stresses leading to shoving. Shoving can be easily identified by distortion of pavement markings, and vertical displacements (dips and bumps). In many cases shoving is manifested with a large “bow wave" in front of the braking section or areas where **HMA** abuts a rigid object such as utilities. Shoving affects ride quality and may represent a safety hazard.

Figure ٦: Shoving on Asphalt Pavements.

Fatigue Cracking

Fatigue in asphalt pavement manifests itself in the form of cracking from repeated traffic loading. Three main factors that affect the initiation and propagation of fatigue cracking are the mix design, pavement structure, and construction procedures. The main visual characteristics of fatigue cracking are the interconnection of cracks in a chicken wire/alligator pattern as seen on **(Figure ٧.)**

Fatigue cracking is an important mechanism in the deterioration of asphalt pavement because of the harmful effect this cracking has on the stiffness and strength of pavement. Cracking allows water to percolate to the underlying layers, weakening the support and therefore accelerating permanent deformation of the pavement sections.

Other Distresses

The dominant distresses at intersections are rutting, shoving and fatigue cracking, however other distresses may manifest at the intersections. The sources of the dominant distresses can also generate additional distresses and the distresses themselves can represent a source of other distresses. Such is the case of moderate to high severity fatigue cracked areas, where the interconnected cracks form pieces that when moved while subjected to traffic leave a Pothole behind. Another surface defects such as bleeding, raveling and polished aggregates are distresses present at intersection which are potential mixture related performance problems.

Figure ٧: Fatigue or Alligator Cracking on Asphalt Pavements.

MODELLING RUTTING IN FLEXIBLE PAVEMENTS

١. REVIEW OF AVAILABLE RUTTING MODELS

١.١ Introduction

During the last two decades many attempts have been made by both researchers and practitioners alike to develop models that could predict the deterioration of a pavement over time, including models for the prediction of rutting. Each model, however, has certain inherent limitations due to the assumptions and data used during the development of the model.

١.٢ Mechanisms of Rutting

Traffic-associated permanent deformation and rutting in particular, results from a rather complex combination of densification and plastic flow mechanisms. Densification, is the change in the volume of material as a result of the tighter packing of the material particles and sometimes also the degradation of particles into smaller sizes. Rutting due to densification is usually fairly wide and uniform in the longitudinal direction with heaving on the surface seldom occurring, as illustrated in **(Figure ١.١.)** The degree of densification depends greatly on the compaction specifications during construction. The density specification should be selected in accordance with the expected loadings and pavement type. Failure to reach the specified compaction during construction will result in an increase of densification under traffic, most of which occurs early in the life of the pavement. It is important to note that for similar rut depth values, the deformation within the pavement may be located within a single weak layer, or more evenly distributed through the depth of the pavement, as illustrated in **(Figure ١.١.)**

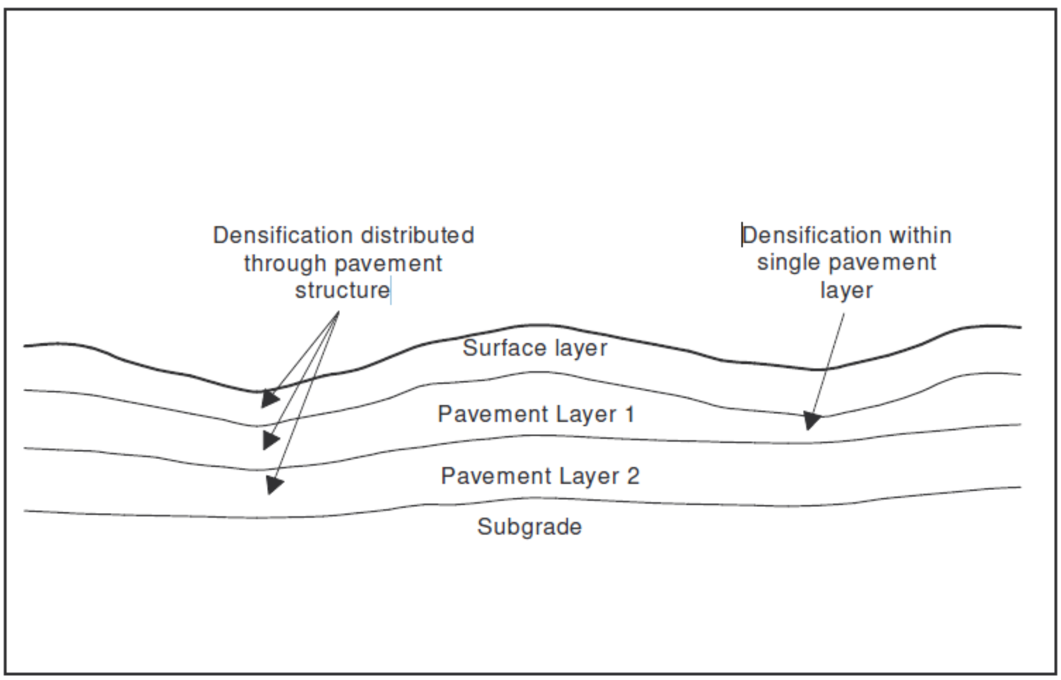


Figure ١. ١: Typical rut profile as result of densification

Plastic flow involves essentially no volume change, and gives rise to shear displacements in which both depression and heave are usually manifested. Plastic flow occurs when the shear stresses imposed by traffic exceed the inherent strength of the pavement layers . The rutting in this case is usually characterized by heaving on the surface alongside the wheel path, as illustrated in **(Figure ١.٢ .)** Plastic flow is controlled through the structural and material design specifications, which are normally based on a measure of the shear strength of the materials used (for example, the California Bearing Ratio **(CBR)** for soils, and Marshall and Hveem stability for bituminous materials). The best known example of plastic flow is shoving within the asphalt layers, as illustrated in **(Figure ١.٢)**

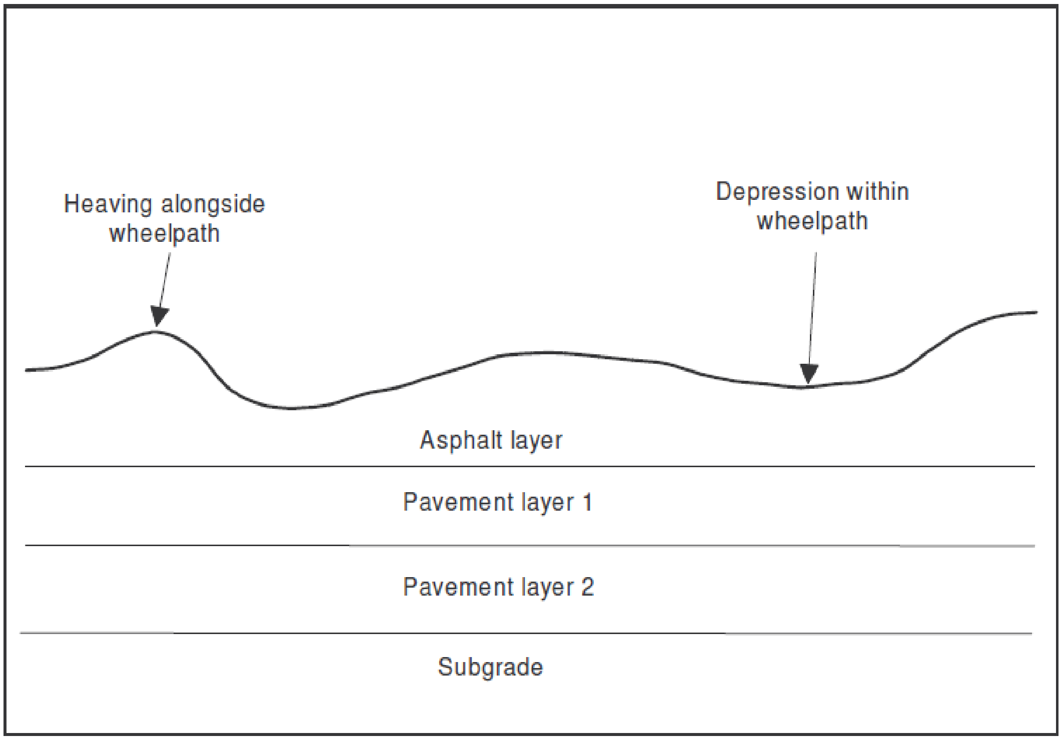


Figure ١.٢: Typical Rut Profile as Result of Plastic Flow (Shoving)

١.٣ Factors Influencing Rutting

١.٣.١ Introduction

The resistance of pavement structures to rutting is dependent on a number of factors which either relate to applied loads (traffic type and traffic volume), the environment (temperature, rainfall), the pavement structure (materials used and their composition), the construction process, or to a combination of the above. The factors of importance for the various pavement types included within **HDM-٤** are discussed in this section. The general influences of the factors are based on the findings of laboratory and field observations of numerous experiments.

١.٣.٢ Generalized trends of behavior

In Considering general trends in the behavior of pavements containing different materials, it must be remembered that the state of materials changes with time.
Consequently, the general trends in behavior that are discussed refer to the original as built state of the material. In discussing these trends the pavement types are described in terms of the materials contained in the base of the pavement. The flexible pavement types included in HDM-٤ that have distinctly different behavior patterns are:

- ***Granular base (GB) pavements***
- ***Cement-treated base (SB) pavements***
- ***Asphalt base (AB) pavements***

Granular Base Pavements:

The general trends in deformation of granular base pavements are illustrated in (Figure ١.٣.) The behavior can be classified into three phases: an initial phase, where some deformation occurs in the wheel tracks; a stable phase, during which little deformation occurs; and finally an increased rate of deformation. The factors influencing the magnitude and duration of various phases are:

Construction compaction:

The amount of early deformation, also referred to as post construction compaction, depends on the densification achieved during the construction of the pavement layers and the quality of the pavement layers. The higher the quality of the layer, the higher the specified level of compaction, and thus the lower the expected initial densification, as seen in (Figure ١.٣.)

Material quality:

The rate of increase in deformation during the stable phase also depends on the initial quality of the material. Where the initial quality of the material is very poor and has low densities, high traffic loadings may result in quick shear failure, typical of untreated pavement layers, and the stable phase may be non-existent or very brief, as seen in (Figure ١.٣.) For relatively high quality materials the performance under traffic is much better, and the susceptibility to water ingress is much lower.

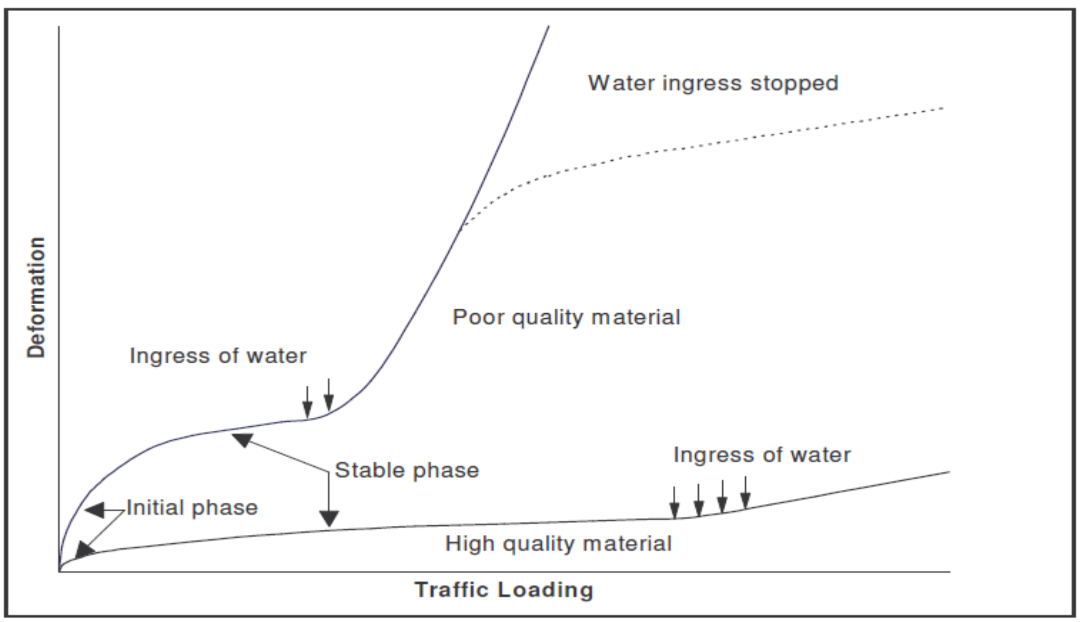


Figure ١.٣: Relative behavior of granular materials

Moisture content:

Over time the pavement surface may crack. The increased moisture content due to ingress of water through a cracked surface layer will result in a decrease in shear strength of granular pavement layers which, when over- stressed by traffic, will result in the shear failure of the layers and thus the increased deformation observed in the final phase. The rate of increase is once again dependent on material quality (high quality materials are less susceptible to ingress of water), the amount of water ingress (rainfall), and traffic loading.

Traffic loading: The traffic loading is a combination of the magnitude and volume of the loads; these are combined into the number of standard loads through the fourth power law. Traffic loading is one of the most important factors contributing to rutting. Traffic induces stresses within the pavement structure that have to be withstood, and thus determines the quality of materials required, as well as the behavior of the pavement in various phases. It is important to note that a few excessive loads or tire pressures for which the pavement was not designed may cause stresses exceeding the shear strength of the material and thus plastic flow, resulting in the premature failure of the layer.

Cement-treated base pavements

The general deformation trends of cement-treated base pavements are illustrated in (Figure ١.٤.)For these pavements, the expected initial increase in deformation due to post construction compaction is much lower and even negligible in most instances. This is followed by a stable phase during which little or no deformation occurs, and finally a phase during which the rate of deformation increases. This final phase often only occurs after moisture ingress through secondary cracking causes fines to be pumped out from under the cement-treated base of the pavement. Furthermore, it is most often only during this phase that the difference in behavior between high and poor quality materials becomes evident. In general, the resistance to deformation of cement-treated base pavements is similar to or even better than the deformations expected from very high quality (crushed stone) granular materials. Furthermore, the susceptibility to moisture of the cement-treated material is also less than that of the granular material used to construct the cement-treated layer. The factors influencing the magnitude and duration of various phases are similar to those discussed for granular materials. It is important to note that for cement-treated base pavements, most of the relative strength of the pavement is usually concentrated within these layers, and as such construction quality has a considerable influence on the performance of the layer.

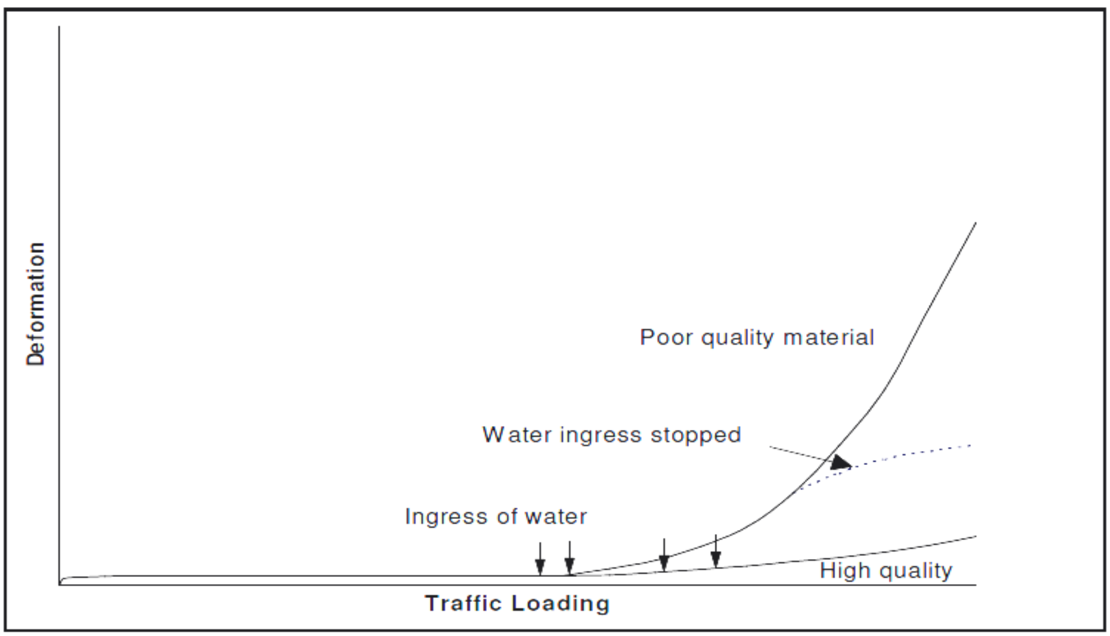


Figure ١.٤: Relative behavior of cement-treated materials

Asphalt-Treated Base Pavements

The general deformation behavior of asphalt base pavements is illustrated in(Figure ١.٥.)The behavior during the various phases is similar to that of granular base pavements. Three phases are once again distinguished: an initial phase, where some deformation occurs in the wheel tracks, followed by a phase of gradual decrease in rut rate to a constant rate, and finally a phase with an increased rate of deformation. The main difference in behavior between asphalt layers and granular layers occurs in the final phase, where asphalt layers are far more water-resistant than granular layers, but as a result of their viscous-elastic behavior they are more temperature susceptible. The factors influencing the magnitude and duration of various phases are construction compaction, material quality (which, for asphalt layers, refers to the mix properties of binder content, air voids and aggregate type), and traffic loading. As a result of the nature of asphalt layers, the influence of moisture content is replaced by that of temperature.

***Binder content*:**

The selection of a suitable binder content for a given grading of aggregate is one of the main problems in the design of a bituminous mixture. From the point of view of deformation, asphalt mixes should contain just enough binder to give cohesion and to enable adequate compaction to be achieved, without undue risk to plastic deformation under the prevailing conditions of traffic and temperature. Too much binder will lubricate the mix to such an extent that the mixture will lack internal friction and become unstable.

Air voids content:

The percent of air voids within an asphalt mix also influences the behavior of the mix. The higher the percent of air voids, the more resistant the mix is to deformation. But due to the increased permeability to air, an increased rate of hardening of the binder will occur, reducing the fatigue life of the asphalt. If the air voids content is too low, the asphalt mix will become unstable, resulting in plastic flow of the layer under heavy trafficking, slow moving loads or high maximum temperature. Numerous studies indicate that the minimum air voids after trafficking should always exceed ٣ percent to avoid potential plastic flow, but should be less than ٥ percent to keep hardening of the binder (under tropical conditions) to a minimum.

Aggregate type and quantity:

The resistance to permanent deformation of an asphalt mix is also dependent upon the interaction between particles of the coarse aggregate to form a mechanical interlocking structure; the higher the particle to particle contact within the mix, the more resistant the mix will be to deformation. Thus both the shape and texture of coarse aggregate is of importance. It also has been found that the higher the stone content the lower the deformation, but the more difficult it is to achieve the required compaction.

***Temperature*:**

The dependence of the flow properties of bituminous mixtures on temperature is due to changes in the rheological properties of the binder, the dominant factor being the great dependence of viscosity on temperature. From simulation tests and general experience it is well known that the resistance to deformation of bituminous materials decreases rapidly as temperature increases, especially if the ambient temperature approaches or exceeds the softening points of the binders used in such
mixes.

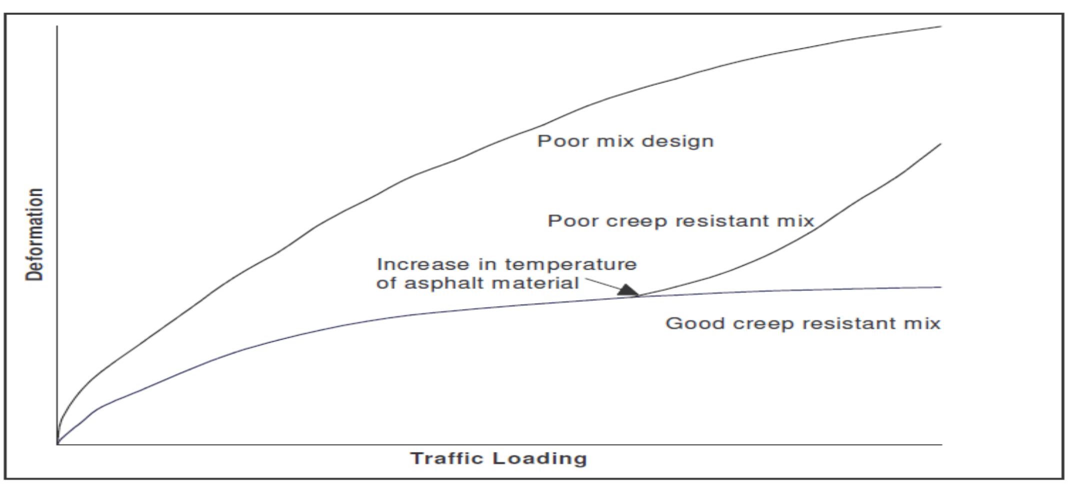


Figure ١.٥: Relative behavior of asphalt materials

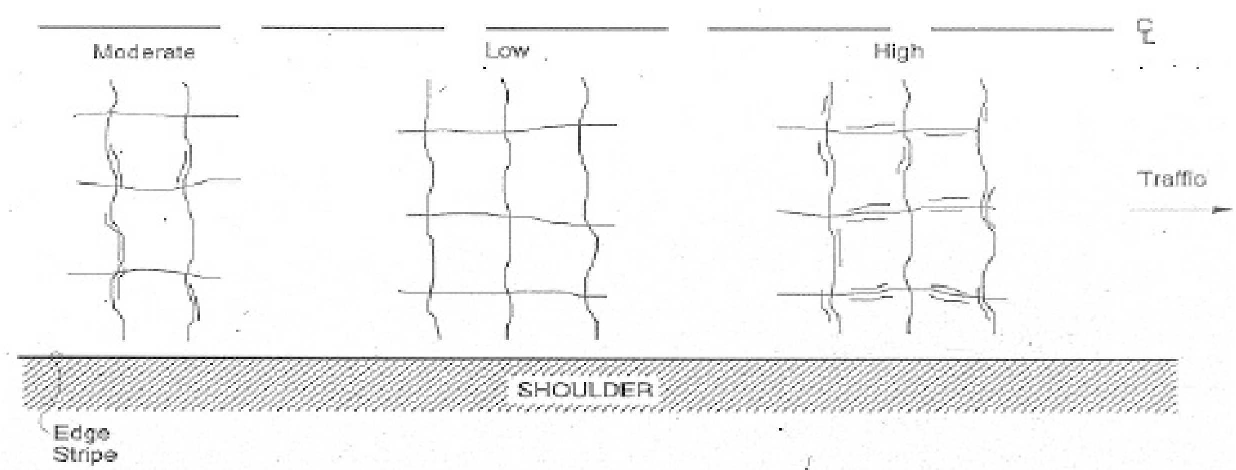
Flexible Pavement Distress in Image

Alligator or Fatigue Cracking

Series of interconnecting cracks caused by the fatigue failure of asphalt surface or stabilized base under repeated traffic loading.

Block Cracking (Thermal Cracking)

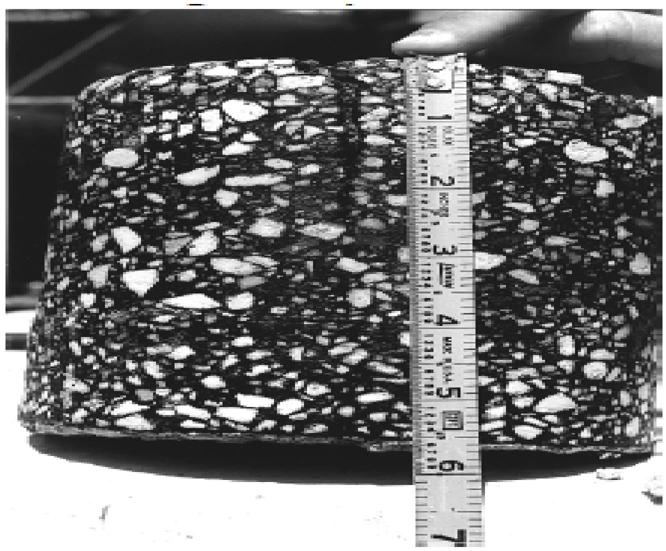
Block cracks divide the asphalt surface into approximately rectangular pieces. Blocks range from ٠.١ to ٩.٣ m



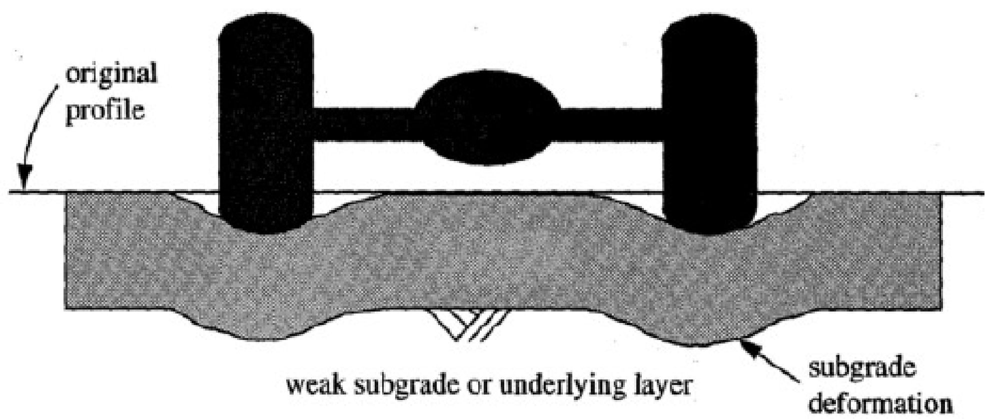
Longitudinal Cracking

Longitudinal cracks are running parallel to the pavement centerline, while transverse cracks extend across the centerline.

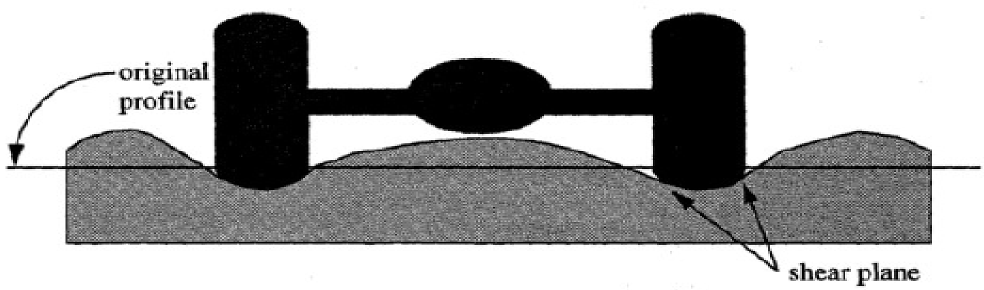
Longitudinal Cracking –Top Down cracking.



Consolidation(Structural) Rutting



Instability Rutting



Slippage (Slippery)

Slippage is characterized by crescent or half-moon shaped cracks generally having two ends pointed into the direction of traffic.