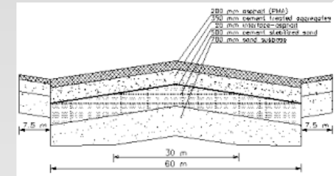
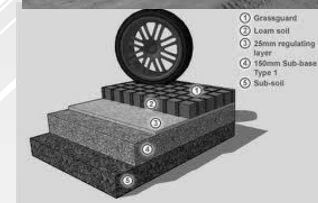
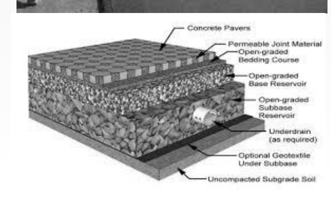
# LECTURE 2

# Major defect types in flexible pavements






Pavements are designed such that they provide a safe and comfortable driving surface to the public. Of course they should be designed and constructed in such a way that they provide this surface for a long period of time at the lowest possible costs.

This implies that the thickness design and the material selection should be such that some major defect types are under control, meaning that they don’t appear too early and that they can be repaired easily if they appear. Major defect types that can be observed on flexible pavements are:

- cracking,
- deformations,
- disintegration and wear

A short description of these defect types and their causes is given hereafter. Later in these notes it will be described how these defect types are taken care of in pavement design.

Cracks in pavements occur because of different reasons. They might be traffic load associated or might develop because of thermal movements or some other reason. Figure 2 e.g. shows a combination of wheel track alligator cracking and longitudinal cracking. These cracks are wheel load associated. Please note that the cracks only appear in the right hand wheel track close to the edge of the pavement. This is an indication that the cracks are most probably due to edge load conditions resulting in higher stresses in the wheel track near the pavement edge than those that occur in the wheel track close to the center line. Because of this specific loading condition, cracks might have been initiated at the top of the pavement.

*Figure 2: Longitudinal and alligator cracking in the Wheel path.*

Figure 3 is a picture of a cracked surface of a rather narrow pavement. If vehicles have to pass each other, the outer wheels have to travel through the verge. From the edge, damage that is observed one can conclude that this is regularly the case. The base material, which is visible in the verge, seems to be a stiff and hard material. This is an indication that some kind of slag that shows self-cementing properties was used as base material.

*Figure 3: Cracking observed on a narrow polder road in the Netherlands.*

Further indications of the fact that such a base material has been used can be found from the fact that the pavement surface is smooth; no rutting is observed. The extensive cracking of the pavement surface might be a combination of shrinkage cracks that have developed in the base. It is however also very well possible that the adhesion between the asphalt layer and the base is rather poor. If this is the case then high tensile strains will develop at the bottom of the asphalt layer causing this layer to crack.

*Figure 3: Cracking observed on a narrow polder road in the Netherlands.*

Figure 4 is a typical example of low temperature cracking. In areas with cold winters, this type of cracking is quite often the dominating cracking type. Due to the very cold weather, the asphalt concrete wants to shrink. In principle this is not possible and tensile stresses develop as a result of the drop in temperature. The magnitude of the tensile stress depends on the rate of cooling and the type of asphalt mixture; especially the rheological properties of the bituminous binder are of importance. If the tensile stresses are becoming too high, the pavement will crack at its weakest point. Further cooling down of the pavement results in additional cracking and existing cracks will open. It is obvious that crack spacing and crack width are interrelated. A large crack spacing results in wide cracks and vice versa. Low temperature cracking can be the result of a single cooling down cycle but also can be the result of repeated cooling down cycles (low temperature fatigue)

*Figure 4: Low temperature cracking observed on a highway in Minnesota.*

Figure 5 is an example of temperature related block cracking. The pavement of course not only shrinks in the longitudinal direction but also in the transversal direction. In that case the friction between the asphalt layer and the base is of importance. If that is high, high tensile stresses might occur in the transversal direction causing longitudinal cracks. Combined with the crack pattern shown in figure 4, this results in block cracking. As mentioned before, low temperature cracking can be the major cause of maintenance and traffic associated cracking is only of secondary importance in such cases.

*Figure 5: Low temperature associated block cracking observed on a highway in Minnesota.*

However, when heavy wheel loads are passing a crack like the one shown in figure 4, high tensile stresses will develop at the crack edge simply because of the fact that there is no load transfer. This problem might increase during the spring when moisture enters the crack and weakens the supporting layers. All this means that although traffic associated cracking is not the main problem, traffic can cause accelerated damage development near cracks.

A type of cracking that has many similarities with low temperature cracking is reflective cracking. In that particular case, a crack or joint in the layer underneath the asphalt layer tends to propagate through the asphalt layer. The problem often occurs in pavements with a cement treated base or overlaid jointed concrete pavements (figure 6). Reflective cracking can even occur in new pavements when the cemented base shrinks due to hardening. Shrinkages cracks that develop in the base can easily reflect through the asphalt top layer especially if this layer is thin. If however, the cement treated base is pre-cracked or if shrinkage joints have been made, the problem of reflective cracking can be minimized

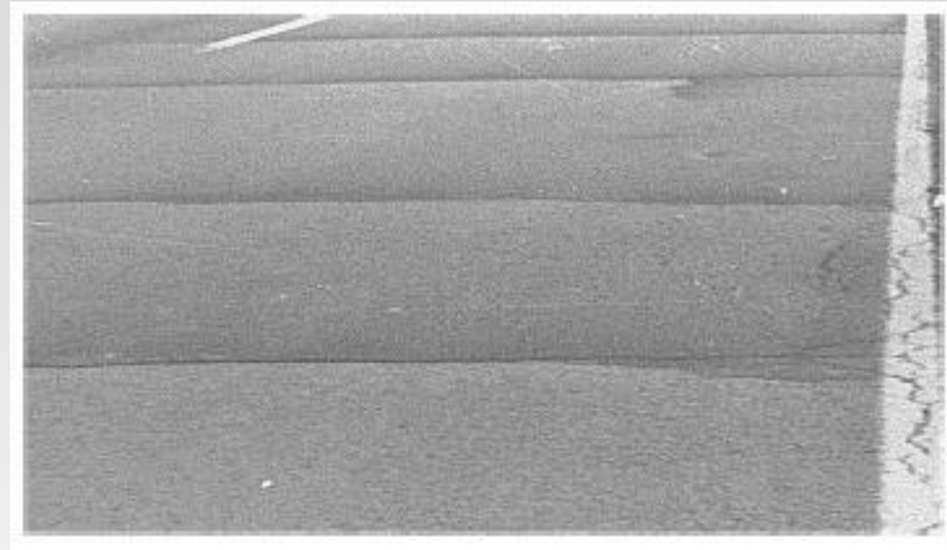


*Figure 6: Example of reflective cracking in an overlaid jointed concrete pavement.*

Of course cracks can develop for many other reasons then traffic and environmental effects. One example of such “another reason” is given in figure 7 which shows severe cracking in the emergency lane due to the widening of the embankment next to that lane. Due to the widening, excessive shear stresses developed in the existing embankment resulting in the development of a shear plane leading to severe longitudinal cracking not only in the emergency lane but also in the slow lane (this lane is already repaired as the picture shows). The problem was aggravated by the fact that a significant height difference occurred across the longitudinal crack resulting in very dangerous driving conditions for motor cyclists. This type of cracking is clearly due to a soil mechanics problem and therefore is beyond the scope of these lecture notes.

Figure 7: Severe longitudinal cracking due to shear failure in the existing embankment as a result of widening the road (extended embankment is on the right had side).

## 2.2 Deformations

Deformations in pavements can be divided in

- longitudinal deformations and
- transverse deformations.

Longitudinal deformations can further by divided in

- ❑ short wave deformations
- ❑ medium wave deformations
- ❑ long wave deformations.

Short wave deformations are of the order of a few centimeters and are mainly caused by surface irregularities such as raveling (this will be discussed later).

Medium wave deformations are in the order of a few decimeters and usually are caused by imperfections in the pavement structure itself.

Long wave deformations are in the order of meters and are caused by settlements, swelling soils, frost heave etc. Although they cause major annoyance, long wave deformations are, because of their origin, outside the scope of these lecture notes

Therefore, we will restrict ourselves to short and medium wave length longitudinal deformations, also called unevenness or roughness.

Figure 8 shows a severely cracked farm to market road in Ohio. Due to the extensive amount of cracking, the pavement has become rather rough. It is quite clear from the picture that cracking has not only resulted in longitudinal but also transverse deformations. It is a typical example of medium wavelength roughness.

Figure 8: Roughness due to severe cracking.

Figure 9 shows a pavement in Zimbabwe. Lack of maintenance has resulted in potholes which obviously result in a large decrease of driving comfort. Even dangerous situations might occur when driving at night. The reason for the potholesis that pavement has cracked severely, comparable to a condition shown in figure 8, and at given moment small pieces of the surface layer have been driven out. Erosion of the potholes due to rain and wind results in depressions of significant size and depth.

Figure 9: Roughness due to potholes as a result of severe cracking.

Figure 10 was taken on a provincial road close to the Delft University in the Netherlands. The long wave longitudinal unevenness that can be observed is clearly the result of settlements. Please note that the settlements also have caused deformations in the transverse direction.

Figure 10: Longitudinal deformations due to settlements.

Next to longitudinal deformations, transversal deformations can occur. These can be the result of movement of the subsoil (settlements, swell, frost heave), but they also might be the result of traffic.

The best known transversal deformation type due to traffic is rutting or permanent deformation that occurs in the wheel paths. A typical example of rutting is shown in figure 11.

Figure 11: Rutting in an asphalt pavement.

- Rutting can develop in the asphalt layer(s) or in the unbound base, subbase or subgrade.
- Rutting can be the result of a densification process or as a result of shear failure. The rutting shown in figure 11 is clearly caused by shear failure in the asphalt layer. Shear failure can be recognized by the ridges that have developed next to the depression.

Figure 11: Rutting in an asphalt pavement.

Furthermore, one can state that the narrower the depression the higher the layer is located in the structure where the shear failure has developed. The same is true for corrugations or washboard formation that is quite often observed near traffic lights or on unsurfaced roads.

Figure 12 shows a type of longitudinal unevenness that is quite often observed on pavements with a base course made of blast furnace slags. Because of the chemical reactions that take place, the material wants to expand resulting into compressive stresses that at a given moment become higher than the compressive strength of the material. Buckling of the base course is then the result leading to ridges which negatively influence driving comfort and which might have a negative effect on traffic safety because of loss of cargo from trucks

Figure 12: Unevenness due to "buckling" of the base made of blast furnace slag.

## 2.3 Disintegration and wear

Ravelling, bleeding and pothole formation can be rated as signs of disintegration and wear. Pothole formation has already been discussed in the previous section so we will concentrate ourselves in this section on raveling and bleeding.

- Bleeding is a defect type that can be recognized as black, “fatty” looking spots on the pavement surface.
- It is an indication of overfilling of the voids in the aggregate skeleton with bituminous mortar.
- It is an indication that the mixture is not well designed.

Due to the high bitumen content, the mixture suffers probably from lack of stability at higher temperatures and high traffic loads might squeeze out the bituminous mortar.

Another reason might be that because of the low void content, there is not enough space for the bituminous mortar when it expands with increasing temperatures.

In any case, the result is the same being a black, shiny surface with hardly any macro or micro texture and thus a low skid resistance.

Raveling is the loss of aggregate from the surface layer. It can occur on any type of asphalt mixture but especially open graded mixtures like porous asphalt concrete (void content > 20%) are sensitive for this damage type (figure 13). Ravelling develops because of cohesive failure in the bituminous mortar or adhesive failure in the interface between aggregate and bituminous mortar

Figure 13: Raveling in porous asphalt concrete.

Note: some aggregate particles are "naked" without any mortar bonded to the aggregate surface.