Design of Flexible Pavements

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1. Introduction

This course is focused on the design of flexible pavements. Before we start with a discussion on stress and strain analyses in such pavements, we better ask ourselves "what is a flexible pavement" or "what do we define as being a flexible pavement". In this course all pavements which are not considered to be a cement concrete pavement or a concrete block (small element) pavement are considered to be a flexible pavement. This implies that also pavements with a relatively stiff cement treated subbase or base are classified as a flexible pavement. Some examples of what is considered to be a flexible pavement are given in figure 1.

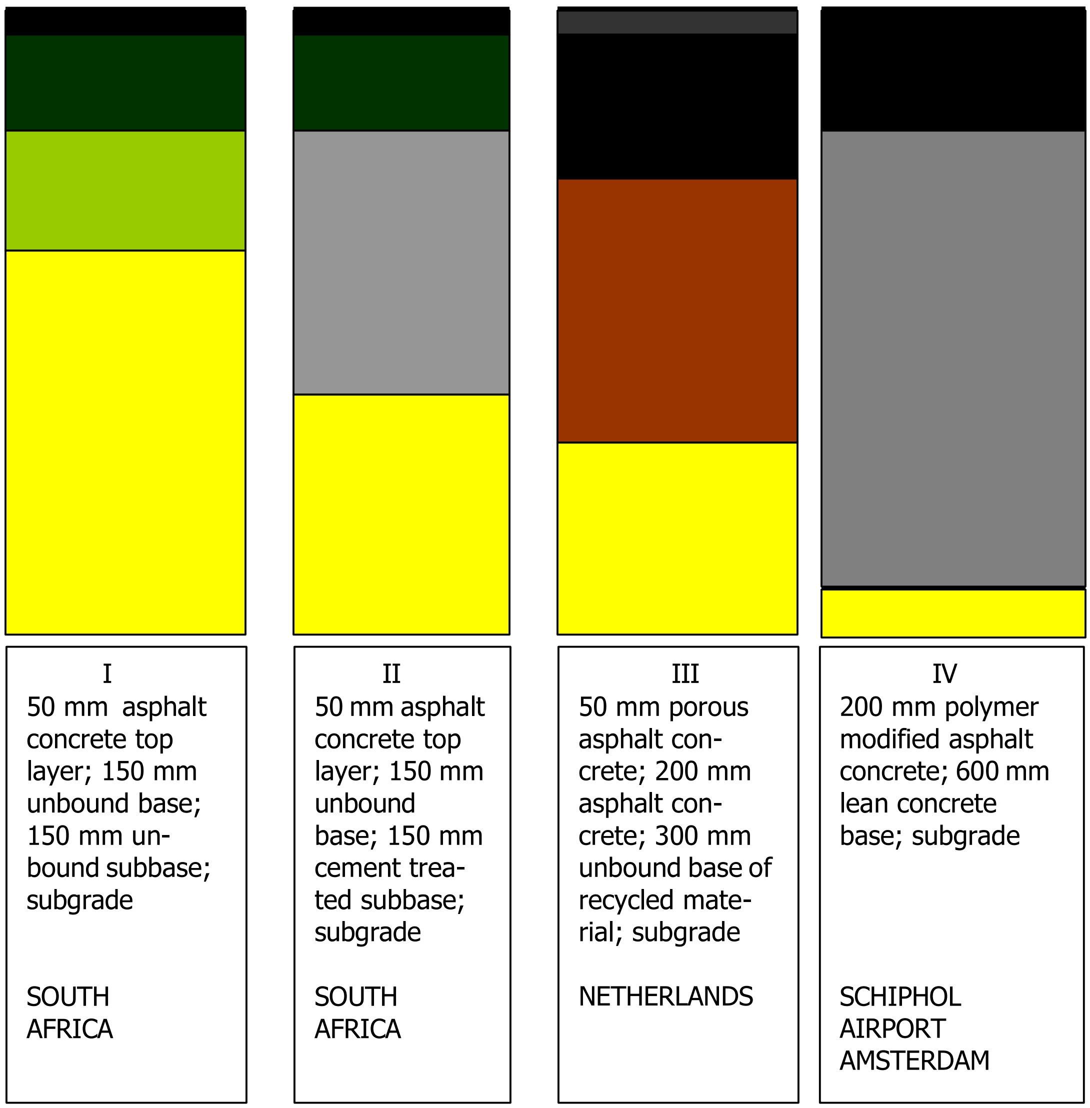

Figure 1: Different types of flexible pavement structures.

In the South African structures, the bearing capacity of the pavement is provided by the unbound base and subbase (structure I) or by the unbound base and cement treated subbase (structure II). The asphalt top layer provides a smooth riding surface and provides skid resistance. These structures have been successfully used in South Africa for moderately (structure I) and heavily loaded (structure II) roads. The "secrets" of the success of these pavements are the high quality,

abundantly available, crushed materials used for the base and subbase and the high levels of compaction achieved. Furthermore the minimum CBR required for the subgrade is 15%. When that is not reached, improvement of the subgrade should take place. The cement treated subbase as used in structure II not only provides a good working platform for the construction and compaction of the unbound base but also influences the stress conditions in the pavement such that relatively high horizontal confining stresses develop in the unbound base. As we know from the lectures on unbound materials (CT4850), unbound materials become stiffer and stronger when the degree of confinement increases.
Structure III is an example of a highway pavement structure in the Netherlands. One will observe immediately the striking difference between structure II which is used for heavily loaded pavements in South Africa and structure III that is used in the Netherlands for these purposes. The reasons for these differences are quite simple being that the conditions in the Netherlands are completely different. There are e.g. no quarries in the Netherlands that can provide good quality crushed materials; these have to be imported from other countries. However, limitations in space and strict environmental requirements require to recycle materials as much as possible. Since it has been shown that good quality base courses can be built of mixtures of crushed concrete and crushed masonry, extensive use is made of unbound base courses made of these recycled materials. A porous asphalt concrete top layer is used (void content > 20%) for noise reducing purposes. The thickness of the entire pavement structure is quite significant because the bearing capacity of the subgrade is quite often not more than 10%. The main reason for the large thickness however is that the road authorities don't want to have pavement maintenance because of lack of bearing capacity. Such maintenance activities involve major reconstruction which cause, given the very high traffic intensities, great hinder to the road user which is not considered to be acceptable. For that reason pavement structures are built such that maintenance is restricted to repair or replacement of the top layer (porous asphalt concrete). With respect to compaction of the unbound base it should be noted that it would be very hard to achieve the same results in the Netherlands as in South Africa. In South Africa the excellent compaction is achieved by soaking the base material and using a high compaction effort. The excessive amount of water used easily disappears because of the high evaporation rates. The recycled materials used for base courses in the Netherlands contain a significant amount of soft material (masonry) which is likely to crush if the compaction effort is too heavy. Furthermore the excessive amount of water used for compaction will not disappear easily because of the much lower evaporation rates. Using the South African way of compacting granular base and subbase courses in the Netherlands will therefore not lead to similar good results.
Structure IV is the structure used for the runways and taxiways of Amsterdam's Schiphol Airport. The airport is situated in a polder with poor subgrade conditions (CBR $\approx$ 2%). Combined with the airport's philosophy to maximize the use of the runway and taxiway system and minimize the need for maintenance, this results in rather thick pavement structures. A total thickness of 200 mm polymer modified asphalt concrete is used to reduce the risk for reflective cracking. For that reason the lean concrete base is also pre-cracked.

From the discussion given above it becomes clear that the type of pavement structure to be selected depends on the available materials, climatic conditions, maintenance philosophy etc. From the examples given above it also becomes clear that one has to be careful in just copying designs which seem to be effective and successful in other countries. One always has to consider the local conditions which influence the choice of a particular pavement type.

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 this course it will be described how these defect types are taken care of in pavement design.

2.1 Cracking

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.

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

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 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. 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.

Purchase this course to see the remainder of the technical materials.