Selection of Geosynthetics and Related Products for Asphalt Reinforcement

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ABSTRACT: In this paper the use of inlays to prevent various types of distress to asphalt-concrete pavements is discussed. First the different types of reinforcement and inlays are defined and their function is discussed. Attention is paid to stiffness, forces involved, bonding and deformations, with respect to asphalt concrete. Secondly two types of road and road-surface distress are evaluated with respect to their appearance and the way they develop: unevenness and cracks. Subsequently specific solutions are proposed using inlays to deal with these types of road distress. Finally a matrix is given which shows the preferred solutions to various types of road distress using geotextiles.

1 INTRODUCTION

Interest in special applications for the maintenance of road constructions has increased enormously in the last 10 years. Promising results have led to the development of more products. These techniques are often called asphalt reinforcement, sometimes wrongly. Road authorities all over the world are using various products to prevent different types of road distress.
Normally reinforcement means redistribution of forces, mostly to a stiff material (steel) of a high tensile strength. If no stiff material is involved, the more general term "asphalt inlay" is preferred.
A questionnaire sent to Dutch road authorities revealed that there is no consistent use of these products to solve specific road distress. A C.R.O.W committee (Centre for Research and Contract Standardization in Civil and Traffic Engineering) in the Netherlands was set up to investigate the effects of the use of asphalt inlays.
This committee concluded that good analysis of the problem and a proper use of available products can lead to improved results of application of asphalt inlays, such as reinforcement.

2 PRODUCTS USED

Manufacturers of geotextiles and contractors have developed a large range of products that is used as asphalt inlays. The mostly commonly used asphalt inlays are evaluated in this paper, namely, grids, nets, woven fabrics, nonwovens and bituminous inlays. These inlays are used to prevent or reduce crack growth, reflection cracking, alligator cracking, rutting and corrugation.
Because of their different properties, the products can be divided into two groups:
- grids, nets and woven fabrics,
- nonwovens and bituminous inlays.

2.1 Grids, nets and woven fabrics

Grids, nets and woven fabrics are usually made of steel (see figure 2 and 3) synthetics or glass fibres. The structure of these materials produces compartments in the asphalt construction above the reinforcement, if the meshes are large enough. Compartment is the effect that aggregates are locally kept together, ensuring that a displacement of one particle generates displacements of others. Because of the effect of interlocking a load can be transferred from the asphalt to the reinforcing material. This effect gives the pavement an extra tensile stiffness and strength. The effect of the use of these products depends on:

- interlocking of the aggregates in the reinforcement;
- bonding of the bitumen to the reinforcement to establish the load distribution.

The three different types of inlays are shown in figure 1.

For a grid, since the nodes are fixed and there is no slippage, the 90° angle between the ribs in the undeformed grid (upper left figure) remains the same in the deformed grid (lower left figure). The force (Fs) exerted by the stone on the grid creates the reaction forces Fg.
For a net (upper right figure) although the nodes are fixed, the angle may vary. The reaction force (Fn) and the deformations differs from that seen with a grid. For a woven fabric (lower right figure), the slippage in the nodes gives a different reaction force, typical for a fabric. Hardly no compartment occurs.

2.2 Nonwovens and bituminous inlays.

Nonwovens and bituminous inlays have a low modulus of elasticity and absorb deformations without transferring them. Before a nonwoven is applied (see figure 4), a bituminous layer has to be sprayed upon the road surface. During the subsequent application of the hot asphalt mix, the bitumen melts and penetrates the new overlay. Bituminous inlays are commonly known as Stress Absorbing Membrane Interlayers (SAMI's) and are constructed by spraying a thick layer of polymer modified bitumen (± 2,5 kg/m2) on the road surface and covering it with a stone layer (2-4 mm).

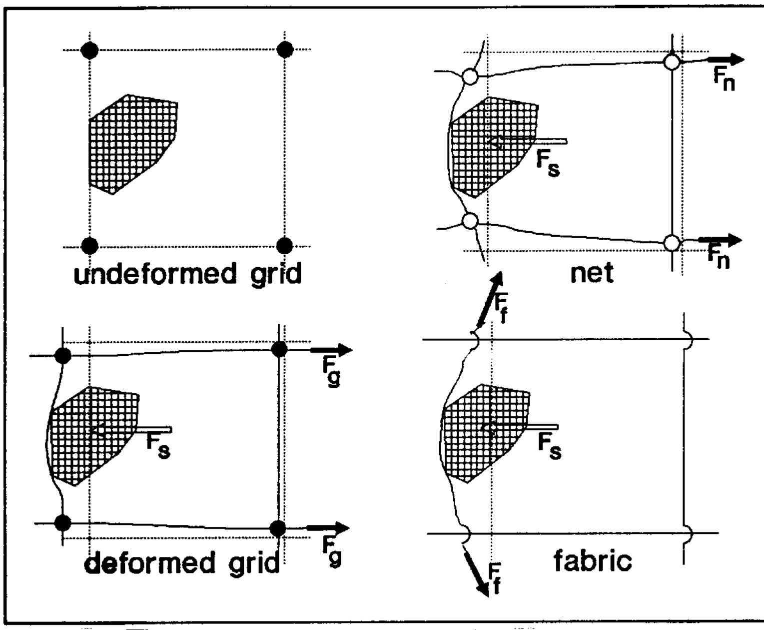

Figure 1 The load distribution in grids, nets and woven fabrics.

3 USE OF ASPHALT INLAYS IN THE NETHERLANDS

In 1990 and 1991 two questionnaires were sent to Dutch road authorities to obtain information on experience with reinforcement and inlays to overcome problems in asphalt road maintenance. From the first questionnaire sent to 825 road authorities it was concluded that many use asphalt inlays indiscriminately. The main purpose of the second questionnaire was to determine the reasons for using asphalt reinforcement and to identify the problems encountered.
The conclusions from the first questionnaire survey were confirmed. There is nearly no theoretical basis for using specific types of reinforcement and other asphalt inlays to solve specific road problems.

Some general conclusions are:
- ninety percent of the road authorities ware satisfied about the use of reinforcement or asphalt inlays;
- because most experiences with asphalt inlays are after 1985, 25% cannot give a conclusion about an eventually extend of pavement life;
- seventy percent of the road authorities indicated they were prepared to use reinforcement again.

The committee was of the opinion that specific instructions and training of road authorities could increase the effect of inlays by more than 10%.

Figure 2 Application of a woven fabric

4 DISTRESS AND POTENTIAL SOLUTIONS

External factors such as traffic loads and climate, lead to deterioration of asphalt road pavements.
In this paper, the appearance and development of road distress is discussed. The following types of distress are shortly considered: unevenness (longitudinal and transverse) and cracks (fatigue, reflection, temperature and longitudinal cracking). Methods of preventing and reducing these types of distress are discussed.

4.1 Unevenness

Unevenness is deformation of the road surface and can be caused by deformation of the asphalt layer, and/or the subbase, and/or the subgrade.

There are two major causes of deformation of the asphalt layer. The first is shear stresses caused by vertical traffic loads and leads to permanent deformation, which causes rutting. The second cause is horizontal stresses induced by braking and acceleration of vehicles.
This type of distress can be overcome by using an asphalt mix with a high resistance to deformation, such as polymer modified asphalt. This distress can also be prevented by reinforcement, dividing the asphalt layers in compartments, to the depth where the highest shear stresses occur.

Deformation of the subbase and the subgrade can be prevented in several ways:
- reducing the stresses and strains in the sub-base and subgrade
- preventing settlements after construction;
- preventing intrusion of water to reduce decline of the bearing capacity.
- using a subbase with a high stiffness;
- preventing instability;
- ensuring good drainage;
- using asphalt reinforcement to give the asphalt layers extra stiffness.

Local discontinuities can also cause deformation of the road surface. Good compaction and/or asphalt reinforcement can reduce this type of distress.

4.2 Cracking

Cracking reduces the structural strength of the pavement and leads to a rapid detoriation of the construction. Thus every effort must be made to prevent cracking and to reduce the effects once it has happened.
For cracking to occur it first must be initiated. Cracks will grow as a result of traffic loads, temperature, deformations and reflective cracking.
Cracks in the pavement allow water to penetrate to the subgrade. Water intrusion reduces the bearing capacity of the subbase and must therefore be prevented. The conventional solution is

either to fill the cracks or to apply an overlay. Inlays of nonwoven and bituminous materials can also be used.

4.2.1 Fatigue cracking

A crack may be initiated and grow as a result of the repeated traffic loads. These cracks grow in K1-mode (opening). When a wheel load passes, the opening bends, providing tensile stress in the tip of the crack causing the crack to grow.

4.2.2 Reflection cracking

If an overlay is applied on cracks in a road surface, the horizontal movements in the existing crack will also yield horizontal deformations in the overlay. This leads to continuation of the growth of the existing crack in the overlay, which is known as reflection cracking. The cracks grow because of the K1-mode and the K2-mode (see fatigue cracking for the explanation of the K1-mode).
Cracking because of the K2-mode occurs because of a difference in shear stresses on either side of the crack. This occurs when a wheel passes over the crack. First one side of the crack is loaded and then the other.

4.3 Preventing crack growth

As seen above, two types of cracking are: K1-mode and K2-mode.

4.3.1 K1-mode cracks

To reduce and/or prevent ongoing cracking caused by opening of existing cracks (bending of the asphalt layer), the stress intensity at the tip of the crack has to be reduced. This can be done in several ways:

- applying a stress absorbing membrane interlayer with a low modules of elasticity. Because of the low stiffness of this layer the stress intensity at the tip of the crack is not transferred directly to the asphalt layer above this bituminous inlay;
- using an asphalt mix with high resistance to cracking. This can be done by adding fibres to the asphalt mix, or using polymer modified bitumen;
- applying a reinforcement inlay (grid, net, woven fabric) with a high tensile strength that divides the asphalt overlay in compartments. If applied well, the inlay will participate in the bending mechanism and reduce the stress intensity;
- use a combination of the above mentioned solutions.

4.3.2 K2-mode cracks

The cracking caused by induced shear stresses (K2-mode) can be combatted by reducing differences in vertical displacement at both sides of the existing crack. This can be done by applying stiff reinforcement (grid, net, woven inlay) to reduce this.
Another option is to increase the structural strength of the construction by applying an overlay of sufficient thickness.

Ways to overcome cracks caused by horizontal instability and by differential settlement are shown in table 1.

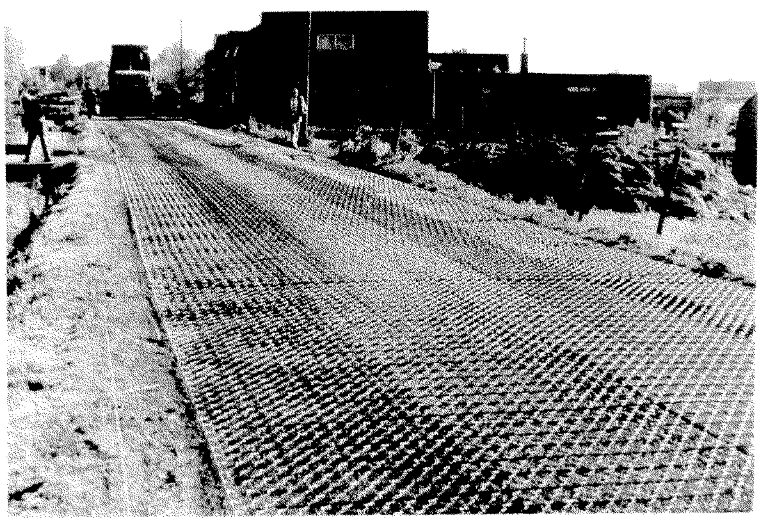

Figure 3 Application of a net (steel)

5 EFFECTS OF THE REINFORCEMENT

The main effects of asphalt inlays on road pavements are discussed with regard to:
- load transfer
- stiffness of the construction
- prevention of water intrusion

5.1 Load transfer

A good bond (asphalt/reinforcement) is required to transfer the forces of the asphalt to the reinforcement. This is obtained mainly by using a reinforcement that divides the construction into compartments that interlock with the ribs of the reinforcement. This will provide a good bond of the overlay to the old construction. A good bond between the bitumen and the inlay will increase the load transfer. This can be obtained by using a hard or polymer-modified bitumen.
The load transfer reduces the stresses and strains in the construction, indicating a higher stiffness of the construction.

5.2 Stiffness of the pavement

The stiffness of the pavement can achieved by applying an inlay.

5.2.1 Inlays in new constructions

An asphalt inlay less stiff than asphalt will lead to higher stresses (and strains) in the road. Consequently fatigue cracks will occur sooner.
A inlay more stiff than asphalt will extend the fatigue life of the pavement. It should be stressed that proper application is essential.
A stiff reinforcement should develop its tensile strength when the strains (displacements) in the road are still very small. This is hard to achieve, because of the high demands on the interlocking of the aggregates with the reinforcement. Once again proper application should be stressed.

5.2.2 Inlays on cracked constructions

A cracked construction will show relatively high strains. When reinforcement (with high tensile stiffness) with an appropriate overlay thickness is well bonded to the road, the strains and stresses in the overlay construction are reduced. The higher the tensile strength of the reinforcement, the lower the strains and stresses in the road.

Figure 4 Application of a nonwoven

A bituminous inlay (SAMI) or a nonwoven with low modules of elasticity can be applied, but neither measures will increase the bearing capacity of the road. An overlay contributes little to the bearing capacity of the total construction, when this kind of inlay is used. Because of the low modulus of elasticity the overlay and the construction are effectively debonded. Thus the tensile stresses and strains are high in the bottom of the overlay and lead to crack growth directly from the bottom upwards. This problem may be prevented by applying an overlay no thicker than 40 mm. Finally, a SAMI or a nonwoven should only be applied on roads with a good bearing capacity.

	Grid		Net		Woven	SAMI		Overlay
	steel	synthetic	steel	synthetic	fabric	Nonwoven	Bituminous	
Reflective cracking:								
- K1-mode	++	++	++	++	+	++	++	+
- K2-mode	++	+	++	+	-	-	-	-
Road widening	++	++	++	++	+	-	-	-
Longitudinal cracking:								
- edge locking	++	++	++	++	+	-	-	-
- fatigue	++	++	++	++	+	+	+	+
Transversal cracking	++	++	++	++	+	+	+	+
Hor.instability floating apart	++	+	++	+	-	-	-	-
Rutting:								
- asphalt	++	+	++	+	-	-	-	++
- sub-grade	+	-	+	-	-	-	-	+
Corrugation	+	-	+	-	-	-	-	+
Bearing capacity	+	+	+	-	-	-	-	++

Table 1 Possible ways to overcome road distress
++ = good solution; + = possible solution; - = no solution.

5.2.3 Prevention water intrusion

In any well designed road cracks can appear in the surface. Water intrusion through the cracks must be prevented. This can be done by applying either a SAMI (or SAM) or a non-woven inlay to retain the bearing capacity of the subgrade.

6 RECYCLING

The study also gave attention to recycling asphalt concrete containing inlays. No serious problems were met in this respect at that time.
A new C.R.O.W committee has been established to examine this problem further. Results are expected at the beginning of 1995.

7 CONCLUSIONS

The use of asphalt reinforcement or asphalt inlays will not overcome each type of road distress or pavement problems. A well designed road construction is required.
This paper has shown that some reinforcements and inlays can be used effectively for specific types of road distress. An overview is given in table 1.

REFERENCES

Asphalt reinforcement, sense or nonsense? (in Dutch), C.R.O.W. publication 69, Ede, 1993, The Netherlands.