Potential Benefit from Synthetic Reinforcement in Asphalt Overlays

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ABSTRACT: Synthetic reinforcement in asphalt pavements has been used in Norway for about 25 years. Mainly it has been used in connection with repaving of road sections with severe cracking problems. The principal reasons for cracking of asphalt overlays are frost heave, traffic induced rutting due to plastic deformations in granular layers and differential settlements in the base layers and in the subgrade. The evaluation of when and how to use reinforcement should be based on the appearing degradation mechanisms. As the governing mechanisms depend on plastic deformations, it is useless to evaluate beneficial effects of the reinforcement by the use of elastic properties. As a general rule reinforcement should primarily be used to improve service lifetime and not to reduce overlay thickness. Correct installation of the reinforcement is crucial for the result.

1 INTRODUCTION

The Norwegian climate with rapid temperature changes, frost-heave and water-ingress results in very difficult conditions for our roads and traffic areas. Over the last 25 years the axle loads and the tyre pressures on the vehicles have increased dramatically resulting in severe asphalt pavement cracking. Synthetic reinforcement in asphalt pavements was introduced in Norway about 1970. It is either used to improve deterioration characteristics or to increase permitable axle loads. Normally the type of reinforcement has been high-strength synthetic reinforcement, woven polyester grid and stretched polypropylene grid. The experiences has been very variable from highly successful to examples of failures due to incorrect design and installation.

SINTEF has performed a research project including a theoretical study of the reinforcement function, a collection of Norwegian experiences and a proposal for design guidelines. This paper gives a summary of some basic principles for the use of high strength synthetic grid reinforcement in asphalt pavements. It also includes an evaluation of potential benefits connected to some important deterioration mechanisms and some general recommendations connected to the design and the installation.

2 BASIC PRINCIPLES AND FUNCTIONS

Synthetic reinforcement in asphalt pavements is used to reduce cracking and thereby increase service lifetime of the structure. Cracking is generally caused by tensile strains in the asphalt. The ability to sustain tensile strain for asphalt materials varies with type of bituminous binder, temperature, type of loading, loading rate and strain duration but is generally very restricted. Tensile cracks frequently occur at strain levels of 1 ‰ ($t < 0°C$) to 2-3 % (20°C). This implies that strain concentrations are fatal for the asphalt with regard to cracks.

The reinforcement enhance the tensile strength of the asphalt course. This is done by absorbing horizontal stresses and reducing the peak strain by distribution of the strain over a larger area. Additionally the reinforcement reduce the amount of shear stress transferred to the material under the reinforcement. Accordingly asphalt pavements with reinforcement can sustain larger deformations and higher loads without cracking.

Deformations in the asphalt overlay will generate tensile stress in the reinforcement due to transferred shear stresses between the asphalt and the reinforcement. The amount of transferred shear stress depend on the asphalt and reinforcement deformation properties and the interaction between the asphalt and the reinforcement. Maximum reinforcement tensile stress is limited by the possible transferred shear stress between the asphalt and the reinforcement.

Synthetic reinforcement has minimal effect of the elastic properties of a continuous asphalt layer. This is verified both from theoretical computations and field measurements. Evaluation of beneficial effects based on elastic behaviour (e.g falling weight deflectometer) accordingly is useless. Grid reinforcement may, however, to some extent increase the elastic properties after the initial cracking of the pavement has occurred.

3 EFFECT ON ASPHALT PAVEMENT DETERIORATION

A thorough examination of deterioration diagnostics is fundamental for the evaluation of potential benefits from reinforcement in asphalt overlays. Deterioration of asphalt pavements is induced by several types of loads (traffic loads, thermal loads, ground settlements) and deterioration mechanisms (frost heave, shear deformations, compaction, temperature induced tensile strain). The resulting cracks are often a result of a combination of different mechanisms and the dominating mechanisms often change with time.

The following 5 main application areas for synthetic reinforcement are identified:

* Frost heave cracking
* Cracks caused by rutting
* Cracking caused by differential settlements
* Reflection cracking
* Thermal induced cracking.

3.1 Frost heave cracking

Frost heave cracking is caused by uneven frost heave normally transverse to the road direction resulting in longitudinal cracks. Frost heave may be of considerable magnitude, differential heaves across the road of more than 10 cm causing cracks of several cm width are not unusual. Frost heave mechanism and resulting cracks is shown in figure 1.

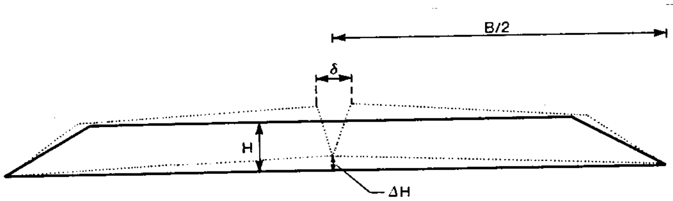

Figure 1 Frost heave mechanism and cracks

The road body will, when it is frozen during the winter, have a considerable tensile strength. Cracks frequently show up in early spring. At this stage the upper part of the road is no longer frozen but the frost heave is still present.

It is not possible by synthetic reinforcement to reduce the frost heave itself. The reinforcement is though capable of distributing the tensile strain over a larger area, thus bringing it below the acceptable level for the asphalt. This may indicate a maximum strain in the reinforcement of about 1-2 %. Stresses imposed to the geotextile from frost heave may have a duration of months and be of a magnitude of 10-15 kN/m. If the frost heave is to high, cracks will occur immediately, despite the frost induced tensile strength. If so, the acceptance level of strain for the asphalt at this temperature may be to low for the synthetic reinforcement to be effective.

3.2 Cracking caused by rutting

Rutting is induced by traffic loads. The traffic loads induce tensile strains both at the top and in the bottom of the asphalt layer. Traffic loads on the road shoulder may also give vertical deformations, causing edge cracking. Traffic induced stresses primarily acts perpendicular to the road direction, resulting in longitudinal cracks. Typical crack locations are indicated in figure 2.

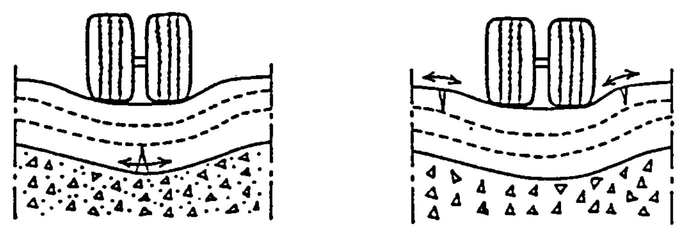

Figure 2 Cracking caused by rutting

Deformations caused by the bypass of a single vehicle is normally small, causing mainly elastic deformation. Each deformation do though have a plastic (permanent) part. The plastic part of the deformation varies but may be significant where heavy loads are acting in a period with low bearing capacity (i.e high loads in the thawing period).

Synthetic reinforcement does generally not influence the elastic deformation. Through the accumulation of the plastic deformations a prestressing in the reinforcement may occur. Thus the reinforcement applies a permanent horizontal stress to the construction. This reduces the horizontal shear stress transferred to the materials below the reinforcement, as illustrated in figure 3.

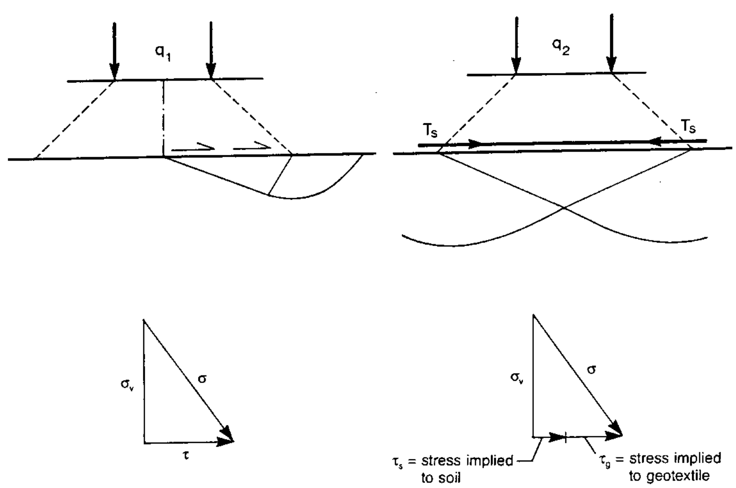

Figure 3 Reduction of transferred shear stress to materials below the reinforcement

This reduction of shear-stresses reduce the degree of mobilization causing smaller plastic deformations. This effect is mainly significant where plastic deformations occur in the granular materials in the base layer. The effect will be most distinct when the thickness of asphalt overlay is small and the granular base materials are unstable. The positive effect of the reinforcement is visible both by reduced cracking and reduced long term rutting.

The magnitude of permanent stress and strain in the geotextile is small, typical values for permanent strain are less than 1 %. The effect is basicly dependent on the possibility of mobilised shear stress between the asphalt and the reinforcement and to "lock in" this as permanent stresses.

3.3 Cracking caused by differential settlements

Differential settlements in the road base are a common problem especially in connection with soft underground. Severe cracking often occurs in connection with road widening on soft underground as shown in figure 4.

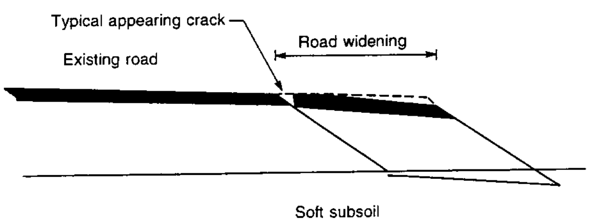

Figure 4 Cracking caused by differential settlements after road widening.

Synthetic reinforcement in the asphalt pavement cannot reduce the differential settlement itself. By distributing the resulting strain over a larger area the strain can be within the acceptance limit of the asphalt.

Reinforcement stress induced by settlements is of a long term nature. Limitations of strain in the asphalt indicate that reinforcement long term strain is never to exceed 2-3 %. Corresponding reinforcement long term stress may be of a magnitude of 10-15 kN/m.

3.4 Reflection cracking

Discontinuities in an underlying pavement result in strain concentrations in the asphalt overlay. The term "reflection cracking" is frequently used to describe the mechanism of crack propagation from an old underlying deteriorated pavement to a newly constructed overlay. This mechanism is frequently appearing in asphalt overlays over concrete pavements (runways, hardstandings). Reflection cracking is caused by stress concentrations from cycles of thermal contraction, repeated traffic loads or by a combination of these mechanisms.

The strain distributing effect of the reinforcement results in a delay of the cracking propagation. Stresses and strains transferred to the reinforcement are small and of a short term nature. Reinforcement strain is typically less than 1 %, with a corresponding stress of less than 5 kN/m.

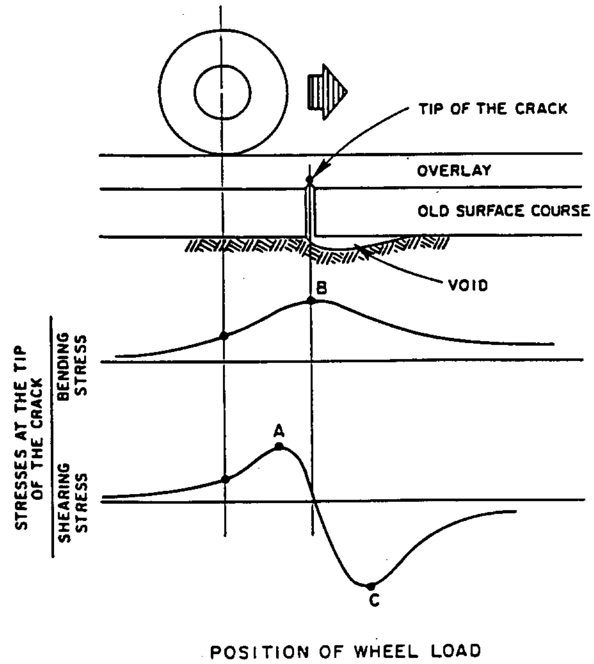

Figure 5 Stress concentrations caused by traffic load (after Barksdale et al, 1990)

3.5 Thermal induced loads

Temperature induced cracks are caused by thermal shrinkage of the asphalt typically resulting in cracks transverse to the road at regular distances (e.g 30-40 m).

Synthetic reinforcement is not able to withstand the forces induced by thermal shrinkage. By distributing the tensile strain over larger area the reinforcement leads to more fine cracks instead of a few big ones. Stresses and strains transferred to the geotextile may have a duration of months. Asphalt strain limitations indicate that maximum reinforcement strain may be 1-2 % with corresponding stress of 10-15 kN/m^2.

4 DESIGN AND INSTALLATION

Beneficial reinforcement stress-strain properties can be indicated from the evaluation of degradation mechanisms. The reinforcement is acting within and in cooperation with the asphalt materials. Therefore, stress-strain behaviour of the asphalt-reinforcement matrix is the main concern. An evaluation of potential benefits based on single reinforcement properties (e.g tensile strength) is consequently useless.

The reinforcement should cooperate with the asphalt material under various stress-strain and temperature conditions. Asphalt properties change with temperature from being stiff and concrete-like on a cold winter day to almost viscous-like on a warm summer day. To be effective reinforcement stress-strain properties have to harmonise with the asphalt material. In addition, reinforcement properties regarding surface coating and aperture size are of great importance.

In Norway we have not been able to find significant differences in the effects between different types of synthetic reinforcement if they are properly installed. Installation techniques and corresponding amount of work do though differ considerably for the different types of reinforcement.

Installation technique and quality is crucial for the result and has proved to be a most challenging subject in reinforcing asphalt pavements. The installation is decisive for the bond between the old and the new overlay and for the interaction between the reinforcement and the asphalt material. Generally the possibility for improper installation increase with increasing complexibility of the installation procedure. Installation procedures should therefore be as simple as possible.

Installation procedures differ between different types of reinforcement but some general rules are common.

* Continuity
Reinforcement edges and overlaps are weak points. The reinforcement should primarily be continuous in the direction of the main principle strain in the pavement. Most degradation mechanisms require continuous reinforcement perpendicular to the road. For thermal induced cracking, reinforcement should be placed continuous longitudinal to the road.

* Overlay thickness
The thickness of the asphalt overlay over the reinforcement is essential. A reduced overlay thickness may cause severe problems with delamination and sliding. An overlay thickness over the reinforcement of minimum 50 mm is required. Reinforcement should not be used to reduce overlay thickness (installation cost) but to improve deterioration characteristics (life time costs).

* Interface
The surface of the old pavement should be clean, dry and without considerable irregularities. Irregularities greater than 10 mm should be levelled out. Existing cracks transversal to the road being more than 6 mm and longitudinal cracks more than 10 mm wide and 5 m long should be filled with asphalt.

* Chipping seal
The chipping seal represents a potential sliding interface and should be minimized. Installation may with some types of reinforcement be done with almost no chipping seal. Only light spread by hand to prevent the truck wheels from adhering to the reinforcement is necessary. This installation technique has proven to be very beneficial and is strongly recommended.

* Straight laydown
The reinforcement must be placed straight at the interface without buckling. Some types require a mechanical stretching and fixing while others, when installed cross-wise, may be installed directly on the bituminous tack coat and only stretched by hand.

* Asphalt material
The choice of asphalt material is essential. So far, medium and stiff types of asphalt, seem to work better with the existing types of reinforcement than softer types of asphalt.

REFERENCES

Barksdale, R.D. et al: Fabrics in Asphalt Overlays and Pavement Maintenance. *Transportation Research Board 171. 1991.*

Haas, R.C.G. and Papagianakis, A.T.: Understanding pavement rutting. *Special Workshop on Rutting in Asphalt pavements. Roads and Transportation association of Canada. 1986.*

Haas R. and Ponniah J.E.: Design oriented evaluation of alternatives for reflection cracking through pavement overlays. *Reflective Cracking in pavements. 1989.*

Kirschner R. and Flügge F.: Polymer asphalt inlays for retarding reflective cracking in asphalt pavements. *The East-West European Road Conference. 1993.*

Ruth, B.E.: Pavement rutting-Plastic deformation. University of Trondheim, NTH. 1990.

Solheim O. M and Watn, A.: Reinforcement for area stabilisation. Proposal for guidelines (in Norwegian). 1992.