Geosynthetics for road pavements: European Contributions

Arnstein Watn
Research Director, SINTEF, Norway
Inge Hoff
Professor, Norwegian University of Science and Technology, Norway

Keywords: Geosynthetics, reinforcement, road, pavement, guidelines

ABSTRACT: Geosynthtic reinforcement has been used in road pavement, both in the unbound granular layers and in the overlay, in Europe for more than 40 years. Despite a number of good experiences from the field, technically sound design methods and methods for verification of the effect in the field are still missing. Recommendations for use in road pavements in national guidelines to a large extent are also missing. Based on the experiences from a large number of projects SINTEF has prepared a proposal for guidelines for the use of geosynthetics for reinforcement in road pavements, both in granular materials and in asphalt overlays. The guidelines give recommendations on use of geosynthetic reinforcement in roads based on an evaluation of type of deterioration mechanisms and possible effects.

1 INTRODUCTION

Geosynthetic reinforcement has been used in road pavements in Europe for more than 40 years. The beneficial effects in terms of reduced construction costs and/or enhanced service lifetime have been verified both in research projects and in field experiences. The geosynthetic reinforcement may be used both in the unbound granular base and in the asphalt or concrete overlay. A European research project, COST REIPAS /1/, has been initiated to look into the use of reinforcement of pavements with steel meshes and geosynthetics. In this paper we will, based on the preliminary results from COST REIPAS, try to give an overview of some of the typical applications and solutions that are used, some experiences that have been achieved and also try to look into ongoing work in Europe on research and development. The terminology used in this paper is based on the recommendations from COST REIPAS and is shown in Figure 1.

The purpose of using geosynthetic reinforcement is /2/:
-increase pavement fatigue life
-minimize differential and total settlement
-reduce rutting – surface and subgrade
-prohibit or limit reflective cracking
-increase resistance to cracking due to frost heave
-reduce natural mineral usage
-reduce maintenance costs
-increase of bearing capacity
-bridging over voids
-construction platform

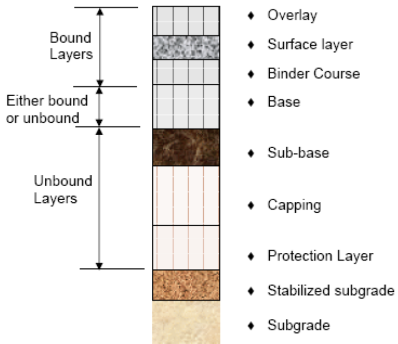

Figure 1 Terminology of pavement structure used in this paper /2/

The way geosynthetic reinforcement is used is to a large extent dependent on local conditions. Foundation conditions, types of granular materials, types of overlay, water, temperature and traffic conditions all have an influence on the structural solution and the types of reinforcement that are used and what effects are achieved.

Table 1 Function, location and type of reinforcement in unbound layers /2/

Function	**Base Course**	**Subbase Course**	**Capping Layer**	**Stabilised Subgrade**
Avoidance of Rutting	Polymer grids Steel fabrics Composite polymer grids/geotextiles.	Polymer grids Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles
Increase of Bearing Capacity	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles
Avoidance of Cracking due to Frost Heave	Steel fabrics Polymer grids	Steel fabrics Polymer grids		
Avoidance of Reflective Cracking in areas of road widening	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	
Avoidance of Fatigue Cracking	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles	
Control of Subgrade Deformation		Polymer grids Composite polymer grids/geotextiles.	Polymer grids Composite polymer grids/geotextiles.	Polymer grids Composite polymer grids/geotextiles.
Bridging over Voids		Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles	Polymer grids Steel fabrics Composite polymer grids/geotextiles. Geotextiles
Construction Platform	Not normally a base layer	Polymer grids Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles	Polymer grids Composite polymer grids/geotextiles. Geotextiles

Figure 2 shows an example from a test project reported by SINTEF of a grid reinforcement in the granular bearing layer of a low volume road in Vesterålen in Norway in 1984 /3/. A common problem in these areas is strengthening and paving of gravel roads on soft subsoil. In this case the old road was located in an area of peat subsoil with thicknesses up to 3m. The road had insufficient bearing capacity during the thawing period and was also subjected to extensive differential settlements. The strengthening of the road was done by using geogrid reinforcement directly on the old road and then placing a bearing layer with a thickness up to 1 m on top of the grid before the asphalt overlay was installed.

Measurements after the rehabilitation indicated that the reinforcement increased the bearing capacity of the subsoil and reduced differential settlements. The road has now been in use for more than 20 years since the rehabilitation was completed. Generally the experience has been good but repaving due to cracking of the asphalt overlay has been carried out including geosynthetic reinforcement in the asphalt overlay.

Figure 2 Installation of geogrid reinforcement in a road rehabilitation project in Vesterålen, Norway /3/.

2 APPLICATIONS

2.1 *Unbound layers*

Geosynthetic reinforcement used in the unbound layers is polymer geogrids, geotextiles and geocomposites. The reinforcement is installed under and sometimes within the unbound base, subbase, capping and stabilized subgrade layers of a pavement. A summary of the functions, location of the reinforcement and type of reinforcement are presented in Table 1.

The reinforcement can be used both for construction of new roads and for rehabilitation and upgrading of existing roads. When used in new roads the most common function is to effectively increase the bearing capacity of the soft subsoil by distributing the traffic wheel loads over a wider area with the reinforcement commonly placed directly on the subgrade. The beneficial effects are related to a reduced pressure being applied to the soft subsoil and hence less deformation during the construction period and less deformation (differential settlements and rutting) during the service lifetime. Generally the beneficial effects of the reinforcement are increasing with decreasing subgrade strength and increasing traffic loads. In cases with very soft subsoil, typically soft clay ond peat, a multilayer solution with reinforcement at the subgrade combined with a second or third layer up in the road structure is occasionally used. Geosynthetics are also commonly used for bridging of voids in areas prone to subsidence, e.g. old mining areas.

Typically in areas susceptible to frost, old gravel roads have frost susceptible material and have very low bearing capacity in the thawing period. Before installation of the new pavement structure it is common to use a separating geotextile and a grid reinforcement on top of the old road before the new base layer and an asphalt overlay are installed. The function of the reinforcement in such cases is to reduce the deformation of the old road structure to avoid extensive rutting and possible damage on the new road structure.

A wide range of materials are included in and under the unbound layers and they have many different functions and effects. Whilst all reinforcing materials provide some benefit to the pavement, it is not possible to define the benefit from standard laboratory testing

2.2 *Bound layers*

A wider range of materials are used for reinforcement of bound layers and address a number of problems. The types of geosynthetics used in the bound layers are polymer geotextiles, polymer grids, glass grids and geocomposites. The use of geosynthetics in bound layers is most commonly related to road rehabilitation. The use of geosynthetics may be both for upgrading and installation of asphalt on existing gravel surfaced roads or for repaving of existing paved roads with cracked overlay. Typical problems that are addressed by using geosynthetic reinforcement in the overlay are shown in Figures 4-7 and typical examples of deterioration mechanisms leading to cracking of the overlay are presented in Figure 8-11.

Figure 4 Gavel roads with insufficient bearing capacity, Snåsa, Norway

Figure 5 Surface rutting of asphalt overlay, Hitra, Norway

Figure 6 Cracking of overlay due to frost heave, Rælingen, Norway

Figure 7 Reflective cracking of asphalt overlay on concrete pavement, Svalbard, Norway

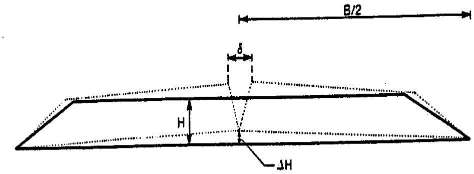

Figure 8 Frost heave mechanism

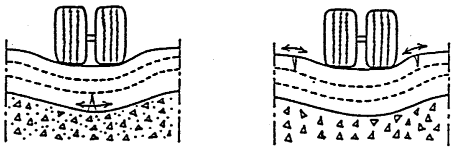

Figure 9 Cracking caused by rutting

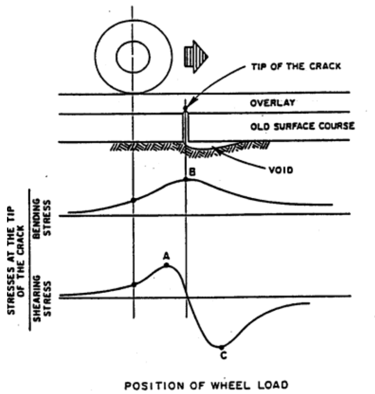

Figure 10 Reflective cracking mechanism

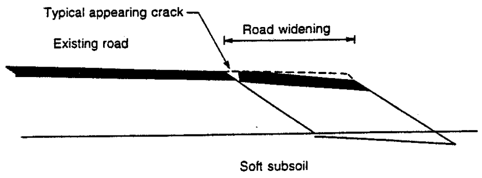

Figure 11 Cracking related to road widening

A summary of the functions , the location and type of the reinforcement and type of reinforcement used are presented in table 2.

Table 2 Function, location and type of reinforcement in bound layers /2/

Function	**Base Course**	**Binder Course**	**Surface Layer**	**Overlay**
Avoidance of Rutting		Steel fabrics	Steel fabrics Polymer grids	Steel fabrics Polymer grids
Increase of, and protection of, Bearing Capacity	Steel fabrics Paving fabrics	Steel fabrics Paving fabrics	Paving fabrics	
Avoidance of Cracking due to Frost Heave	Steel fabrics	Steel fabrics	Steel fabrics	
Avoidance of Reflective Cracking	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics
Avoidance of Fatigue Cracking	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics	Steel fabrics Glass grids Polymer grids Paving fabrics
Control of Differential Settlement	Steel meshes Polymer grids Paving fabrics Glass grids	Steel meshes Polymer grids Paving fabrics Glass grids	Steel meshes Polymer grids Paving fabrics Glass grids	

3 FUNCTION MECHANISMS AND DESIGN

3.1 *Unbound*

The design and performance of granular base layers in road structures is probably the oldest topics in civil engineering. From the old roman roads until today a lot of experience has been gained on loads, material properties, and structural behaviour. Also the use of reinforcement for stabilization of the granular bases of the road is a very well known technique from ancient times using different types of reinforcement. Originally naturally based materials, straw, wood, bamboo were used, later synthetic materials have taken over and sometimes even old and new materials meet, Figure 12.

Figure 12 Geosynthetic reinforcement are carried in on an access road of wooden reinforcement

The design of road structures includes a large variety of parameters, traffic loads, temperature, rain, snow, subgrade, drainage, and type of material in the pavement. Numerical models to describe the behavior and theoretical design have become very complicated and the inclusion of geosynthetic reinforcement does not simplify the task! Accordingly design of geosynthetic reinforced granular bases is to large extent based on experience and numerical models are at best trying to replicate what has been observed in the field.

For flexible pavements the linear elastic multi-layer mechanistic-empirical approach is widely used. In this approach the strain at the bottom of the bound layer, the vertical stress on top of the granular base and the compressive strain at the top of the soil are the critical parameters.

The possible function mechanisms of geosynthetic reinforcement in unbound granular base layers are /4/:

-increasing the resistance against elastic deformations by increasing the horizontal stress level in the structure

-increasing the load bearing capacity of the pavement structure by distributing the load onto a larger area of the underlying soil

-reducing the mobilization of the subsoil by reducing the shear stress transferred to the subgrade

-increasing the resistance to permanent deformation of the granular material itself by restraining horizontal movements of the granular particles (confinement)

The modelling both should take into account the effect of the elastic deformations of the pavement and effect on the resistance against the plastic (permanent) deformations. Generally the effect of geosynthetic reinforcement in the granular bases is mostly related to the resistance against plastic deformations and to a less extent influences the elastic properties.

In practice, when a pavement designer is interested in using a geosynthetic in a granular base layer he/she has to estimate the main effect of the function mechanisms. This means that modelling of the effect of the geosynthetic reinforcement has to take into account:

-effect on stiffness of the granular layer

-effect on the damage transfer function of the granular layer

-effect of reduced mobilisation of the subgrade

Since the effect of a given geosynthetic reinforcement is highly dependent on the local conditions (traffic load, subgrade, materials, and degree of flexure of the pavement) no general rules/guidelines for modelling of the effect are found. To a large extent design is based on producer specific empirically based design recommendations. However this commonly means that comparison between different solutions with geosynthetic reinforced base layers and comparison with more conventional solutions is very difficult. This also means that the use of geosynthetic reinforcement in the base layer only to a limited extent has been taken into account in general recommendations for road design.

3.2 *Overlay*

Most experience with geosynthetic reinforcement in the bound layers is related to the asphalt overlay. In the case of asphalt overlays, the geosynthetic is applied for new construction as well as for maintenance of old cracked overlays. In some cases geosynthetic reinforcement is also used to avoid reflective cracking when an asphalt overlay is placed on an old concrete overlay.

Cracking can be caused by three different mechanisms

-traffic loads

-temperature variations over time

-uneven soil movements (settlements, frost heave)

Two different function mechanisms are identified for the use of geosynthetic reinforcement in overlays /4/:

-reduction of tensile strain in the asphalt by mobilization of tensile stress in the reinforcement

-stress relieving interlayer to avoid transfer of tensile strain to underlying layers

Since the beneficial effect of the geosynthetic reinforcement is highly dependent on the type of cracking mechanism, it is impossible to give general guidelines for design based on laboratory experiments. A design model or design guideline to be used for geosynthetic reinforcement in overlays, should take into account /4/:

-dominating cracking mechanism

-traffic characteristics

-temperature variations

-properties of the pavement

-properties of the granular materials

-conditions for existing pavement (in case of repaving)

-geosynthetic properties

-interaction geosynthetic and surrounding overlay material (asphalt)

-construction equipment and procedures

Currently it seems that no model or method exists which takes all these factors into account in a consistent way. As with reinforcement in granular bases design is to a large extent based on experience ("this worked well last time") and is also product specific. The following models and procedures are currently used in practise and are described more in detail in /4/:

-Arcdeso
-Bitufor
-University of Nottingham

4 VERIFICATION OF EFFECTS

A number of field trials have been performed to evaluate the effect of geosynthetic reinforcement and also experiences are available to a great extent. However only a limited number have been documented in a way that they can be used as reference.

As a part of the COST REIPAS project, an investigation of methods being used to verify the effects from reinforcement in pavements was carried out. The investigation included both verification of properties as the basis for design and verification by testing in the field. A summary of the results of this investigation is given in Tables 3 and 4.

Table 3 Assessment of properties of the materials used to construct the pavement /5/

Test reference	Parameter	Product	Comment
Wide width tensile test, EN 10319	Tensile strength Tensile strain	Geotextiles Geogrids Geocomposites	
Area Weight, EN 965	Area weight	Geotextiles Geogrids Geocomposites	
Static puncture test (CBR-Test) EN ISO 12236	Maximum force	Geotextiles Geocomposites	
Dynamic perforation EN 918	Hole size	Geotextiles	
Junction strength GR1/GG2	Junction strength	Glass Fiber Grids and Paving fabric/grid composites	A measure of the ability of the fabric and the grid to adhere to each other in a composite product. This is very critical to installation and constructability.
Single strand strength GR1/GG2 ASTM D6637	Single strand trength	Geogrids Geocomposites	
Peel strength ASTM D 413	Peel strength	Glass Fiber Grids and Paving fabric/grid composites	A measure of the ability of the fabric and the grid to adhere to each other in a composite product. This is very critical to installation and constructability.
Wheel tracking test Technische Universität Munchen	Geometry Horizontal, vertical Stiffness	All products	

Table 4 Assessment of the in-service performance of the pavement /5/

Title of test	**Test reference**	**Parameter being assessed**	**Application**	**Type of product**	**Comments**
Surface profile meas-urements		Surface-Evenness	Rutting	All	
Benkel-man beam		Deflection / Bearing Capacity	Bearing Ca-pacity	All	Until now not used for rein-forced pavements
Depth control	ISB HILTI-Ferroscan		Rutting Refl. Crack.	Steel fabrics	Based on conventional meth-ods for reinforced concrete. Calibration procedure for as-phalt concrete needed.
Bearing capacity, plate bearing test	MSZ 2509/3:19 89 MSZT	Bearing modulus (MN/m^2) Rate of com-paction	Over the re-inforcement with geotex-tiles on the first layer of subsoil		Static test
Pullout test	GRI - Ge-osynthetic Institute, USA,PA	Pullout force, interaction	Reinforced soil	Geogrids	At present research only, not included in techn. specifica-tions
Interac-tion and perform-ance soil-geosyn-thetics	BS + pro-ject spe-cific crite-ria	Deformations of geogrids	Reinforced soil for em-bankments and walls 374	Geogrids	Only for few projects, accord-ing to techn. specifications
Trial section - rein-forced asphalt pave-ment		General ob-servation in long time pe-riod	Sections of highway	Geogrids - Tensar	Only several sections of one highway are instrumented for 10 year monitoring of per-formance of asphalt-concrete layers and total pavement
Cyclic triaxial testing	Research equipment	Accumulated deformations at cyclic loading	Properties of reinforced base course aggregate	Geotext geogrid geocomp	Used in research project
Large scale model tests		Observed de-formation under cyclic loading	Reinforced subgrade	Geogrid geotex	Crushed rock on soft clay.
Deflec-tion tests	Deflecto-graph				Verification of the impact of reinforcement on asphalt roads

5 NATIONAL RECOMMENDATIONS

As previously written, a lack of consistent methods for design and evaluation of effects is a major obstacle for recognition of geosynthetic reinforcement in road pavements. Even though a large number of projects have been completed utilizing reinforcement in the pavement this is generally not included in national standards and guidelines in the same way as conventional materials and structural solutions. However some recommendations are given on the use of geosynthetic reinforcement in pavements both for the granular materials and for overlays. In Table 5 an overview of some national guidelines and requirements are given

Table 5 National guidelines and recommendations for geosynthetic reinforcement in pavements

Country	Reference	Content
Sweden	ATB Väg 2004	Recommendations for structural solutions
Norway	The use of reinforcement for strengthening of road structures and airfields. Proposal for guidline. SINTEF report STF69 A92025 (1992) (in Norwegian)	Recommendations for design,structural solutions and construction
	Handbook 018 Road construction. The Norwegian Directorate of roads (in Norwegian , revised editions planned autumn 2004)	Recommendations for structural solutions
Germany	Merkblatt für die Anwendung von Geotextilien und Geogittern im Erdbau des Strassenbaus. Forschungsgesellschaft für strassen- und verkehrswesen (2003)	Recommendations on geosynthetic requirements
United Kingdom	No official documents	
The Netherlands	CROW Report 157. Dunne asfaltverhardingen: dimensionering en herontwerp	Method for the design of thin asphalt pavements with, and without geosynthetic reinforcement

6 TEST SECTIONS

A number of test section have been built to investigate the effects of geosynthetic reinforcement both in granular unbound layers and in overlays. In the following only a few examples are given to show the variety of projects that have been carried out.

6.1 *Test road at Hitra, in Norway*

The project was performed to investigate the effect of geosynthetic reinforcement for rehabilitation of an old gravel road on very soft subsoil subjected to settlements and low bearing capacity in the thawing period. The aim of the rehabilitation was to improve the bearing capacity of the road to avoid restrictions on the axle load during the thawing period and to restrict the deformations of the surface to avoid cracking of the asphalt pavement. The structural layout was designed by the municipality of Hitra with assistance from the local road authorities and SINTEF was responsible for the evaluation of the results /7/. The structural layout of the solution is presented in Figure 13.

The rehabilitation was performed in section over a period of several years and different types of geogrid reinforcement were used.

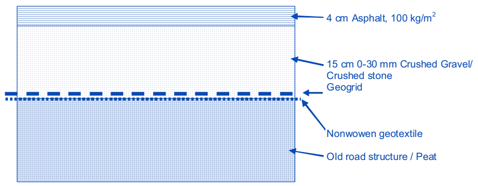

Figure 13 Structural layout of test road at Hitra /7/

Pictures from the installation of the reinforcement and after installation of the asphalt pavement are shown in Figure 14 and 15.

Figure 14 Hitra, Norway. Installation of geogrid

Figure 15 Hitra, Norway, Road after installation of asphalt overlay

The evaluation of the results indicated that the rehabilitation works had been successful as no substantial rutting or cracking of the asphalt overlay has been observed on any of the test sections. It was also concluded that falling weight deflectometer (FWD) was not suitable to evaluate the effect of the reinforcement for this application as it was mainly related to elastic properties while the beneficial effect of the reinforcement generally was related to the plastic deformations

6.2 *Test trial Germany*

Wilmers et al /8/ reported from a test project in Germany where 3 types of geogrid were installed in a test bin subjected to controlled traffic loads measuring total deformations, strain in the reinforcement, Figures 16, 17. The test bin was constructed in a way that the "underground" could be removed to evaluate the effect of the reinforcement both with relatively firm sand underground and without any support. This was done by means of an inspection tunnel which also made it possible to perform measurements and perform inspections from underneath the reinforcement, Figure 18. Plate load tests were performed to evaluate the effect of the reinforcement in terms of bearing capacity.

Figure 16 Test bin, Germany /7/

Figure 17 Installation of geogrid in test bin

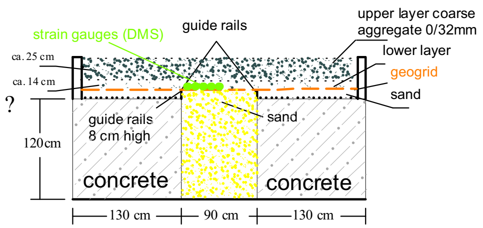

Figure 18 Lay out of test bin. The sand in the centre of the were excavate after compaction of the aggregate layer.

The strains and displacement of the geogrid were measured during plate load tests after compaction of the aggregate layer and after excavation of the sand.

The main conclusions from the trials were:

-the system functioned with all tested grids

-during plate-bearing tests with sand support the reaction of grids is measurable, but the reinforcing influence is negligible

-during plate loading on a system without sand support the grids were bearing the load, after the bearing layer lost the integral stiffness (break through)

-the elongation of grids is so, that they develop the force needed to bear the load – the elongation depends on the tensile modulus of the grid

7 EVALUATION OF STATUS AND NEED FOR DEVELOPMENT

Trafficking trials continue to be carried out using all types of geosynthetic materials. The identification of appropriate laboratory tests that will characterize the relevant properties of the reinforcing materials continues to be difficult. The investigation of the reinforcement mechanism and the interrelationship between the aggregate particles and the geosynthetic material is not yet well developed and will form the subject of future research projects.

There are very few national documents in Europe that specify, or even recognize the economic and technical benefits that can be achieved using geosynthetic reinforcement in pavements. These documents are generally recommendations and some national documents exclude the use of reinforcement because of a lack of knowledge of the subject. If all the benefits of the reinforcement of pavements are to be realized then initiatives such as COST 348 are vital to generate the enthusiasm in the authorities to investigate these applications. An overview of result from the COST 348 was presented by Watn et al /9/. The complications of the lack of appropriate tests to define the performance of a material in the road need to be addressed and this is probably the most critical area for development. Once the reasons for the performance of a particular reinforcement in the road are understood then the reinforcement materials themselves will develop to optimize that performance.

8 PROPOSAL FOR GUIDELINES

Based on more than 30 years of experience from the field and a number of trials both in laboratory and field SINTEF in 2006 prepared a proposal for guidelines for the use of reinforcement in roads /9/. The guidelines includes an introductory guidance for the different types of reinforcement and reinforcement qualities. The compendium focuses on guidance of choices for solutions in the use of reinforcement related to different types of deterioration mechanisms and related requirements for the reinforcement. The applications is split on reinforcement in construction of new roads and reinforcement used in strengthening of existing roads. Reinforcement is mainly regarded as relevant in rehabilitation of existing roads or when the subsoil requires extra measures to withstand the traffic during the construction period for new roads. For each application and solution there are recommendations for execution of the work and conditions which are vital to obtain a good result. The use of reinforcement is related to the categories listed in table 6.

Table 6 Location and categories of problem for use of reinforcement in road pavements

Location of reinforcement	Type of problem
Reinforcement in granular layers	Access road on soft subsoil
	Width extension
	Edge strengthening
	Strengthening to achieve higher permitted axle load (improved bearing capacity)
	Roads with reduced thickness of base and sub-base layer
Reinforcement in overlay	Frost heave cracks
	Edge cracking/other cracks
	Other cracks
Other damages	Other damages

Based on an evaluation of type of damage and deterioration mechanisms the guidelines propose possible structural solutions, including type and requirements for the reinforcement and guidelines for the verification of function and execution of the work.

An example of guidelines for recommendations on the use of different types of reinforcement related to cracking from frost heave is given in Figure 19.

Damage type	Synthetic grid	SRI	Glass fibre	Steel
Frost heave cracks, very big (>50 mm)			*	
Frost heave cracks, big (20-50 mm)			*	
Frost heave cracks, medium (5-20 mm)			*	
Frost heave cracks, small (< 5 mm)				

Figure 19 Recommendations for use of reinforcement for frost heave cracks

The colour code used indicates

Green- Should normally work and other possible solutions should be evaluated based on the costs

Yellow - May work well, but other methods should be considered first.

Red- normally not suitable and other possible solutions should be evaluated based on the costs

9 CONCLUSIONS

Geosynthetic reinforcement has been used for more than 40 years in road pavements in Europe. We believe that use of geosynthetic reinforcement in road pavements has a very wide potential and the beneficial effects of the reinforcement may both reduce construction costs and enhance road performance. Despite the large amount of research projects and a large number of successful projects in the field with good experience, geosynthetic reinforcement is still not recognised as a solution at the same level as more conventional methods. This is to a large extent due to the lack of technically sound models for the function mechanisms of the reinforcement and non product related design models.

Currently general road design is to a large extent based on semi empirical methods and this makes the inclusion of new materials and methods difficult. A number of research projects have been carried out in order to develop models and methods but still there is a lot of work to do. The main focus should be on collecting experiences from the field to verify the effects of reinforcement and combine this with technically sound and non product related models to evaluate the effects of the reinforcement. On this basis design methods should be developed that take into account the site specific conditions and the characteristics of the reinforcement.

10 REFERENCES

/1/ Cost Action 348 (2002): Memorandum of understanding for the implementation of a European Concerted Research Action Designated as COST Action 348 "Reinforcement of pavements with steel meshes and Geosyntehtics. COST – European Cooperation in the field of Scientific and Technical research). The goal of COST is to ensure that Europe holds a strong position in the field of scientific and technical research for peaceful purposes, by increasing European co-operation and interaction in this field.
(http://cost.cordis.lu/src/whatiscost.cfm)

/2/ Cost Action 348 (2004): Reinforcement of pavements with steel meshes and geosynthetics (REIPAS). Draft Report of WG 1 chaired by Chris Jenner.

/3/ Myhre, J. (1985): Strengthening of a road on peat using Tensar geogrid and Terram Geotextile. SINTEF report STF61 F85011.

/4/ Cost Action 348 (2004): Reinforcement of pavements with steel meshes and geosynthetics (REIPAS). Design Models and Procedures for Geosynthetics in Pavements, draft report of WG 4 chaired by Arian de Bondt.

/5/ Cost Action 348 (2004): Reinforcement of pavements with steel meshes and geosynthetics (REIPAS). Development and testing work, draft report of WG 3 chaired by Gudmund Eiksund.

/6/ CROW Publicatie 157 (2002): Dunne asfaltverhardingen:Dimensionering en herontwerp.

/7/ Watn A and Øiseth E (2000): Geosynthetic Reinforcement in Roads – test Road at Hitra, Sør-Trøndelag, Norway. SINTEF report STF22 F00604.

/8/ Wilmers et al (2003):Load Bearing Behaviour of Geogrids – Large scale tests. Geotechnical Engineering with Geosynthetics, Proceedings of the third European Geosynthetics Conference.

/9/ Watn, A. et al (2005): Geosynthetic Reinforcement for Pavement Systems – European Perspectives. Proceeding Bearing Capacity of roads and Airfields (2005).

/10/ Hoff, I and Øiseth E, (2006): Use of reinforcement in roads. Proposal for guidelines. Lecturing compendium NGF-seminar 2006. (in Norwegian)