Steel Grids, an Efficient Way to Improve the Durability of the Pavement

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ABSTRACT: A synthesis of the test results with steel grids in trial road constructions was made in the so called STEELSYNT project. The material for this synthesis has been: the TPPT (Pavement Structures Research Programme) test constructions, the European reinforcement research programme called Reflex and some HVS test projects. HVS (Heavy Vehicle Simulator) is a mobile accelerated loading test facility. All test results both in laboratory and in field conditions showed that rutting can be remarkably reduced by using steel grids in bitumen bound layers or unbound base. In average this reduction lies between 40 - 60 %. The reinforcement works best in the cases where the bearing capacity of the pavement is low. A steel grid prevents the development of longitudinal frost cracks in the reinforced area. The longitudinal cracks usually move to the edges of the road where the grid ends. Steel grid also mitigates the transverse frost cracking by curtailing the width of the cracks and by preventing the development of small cracks. The test results showed also that steel grid delayed fatigue to some extent. The Reflex project prognoses that reflection cracking of the cement bound gravel base can be reduced 35 % by steel grids. The studies so far have not found that longitudinal unevenness could be levelled with reinforcements. Falling Weight Deflectometer is not a suitable measurement tool to quantify the improved performance of a reinforced pavement, so new methods are needed.

KEY WORDS: Steel grids, geotextiles, rutting, cracking.

1 INTRODUCTION

The summary is based on the synthesis of the test results with steel grids in test road constructions, so called STEELSYNT project (Korkiala-Tanttu et al. 2003a). The behaviour of the reinforcements has been studied in many research projects. The test material for this synthesis has been: the TPPT (Pavement Structures Research Programme) test constructions (Tammirinne et al. 2002), the European reinforcement research programme called Reflex (Pihlajanmäki et al. 2002) and some HVS test projects (like 'Steep slope' or 'Frost test'). HVS (Heavy Vehicle Simulator) is a mobile accelerated loading test facility. The aim of the synthesis was to define the practical benefit of the usage of steel grids concerning following matters: permanent deformations (rutting), cracks caused by the fatigue, cracks caused by reflection, cracks caused by frost heave, longitudinal unevenness and other matters.

2 PERMANENT DEFORMATIONS (RUTTING)

All test results both in laboratory and in field conditions showed that rutting (the depth of the rut) can be remarkably reduced by using steel grids in bitumen bound layers or unbound base. In average this reduction lies between 40 - 60 %. There are some tests that indicate even 60 % reduction of rut depths. The effect of the steel grid is small in structures with thick bound layers or otherwise good bearing capacity. The reduction of rut depth with 40 % - 60 % means that the service life of a reinforced pavement is about 50 - 100 % longer than the service life of an unreinforced pavement in respect to rutting. The reinforced structures had been reinforced mainly with steel grids.

The efficiency of the reinforcement depends on the conditions where it is used. The reinforcement works best in the cases where the bearing capacity of the pavement is low. If the bearing capacity of the pavement is high, reinforcement does not reduce the rutting speed much (Fig. 1). In the tests the surface moduli - which indicate bearing capacity - have been measured with falling weight deflectometer or with Benkelmann beam in the 'Frost test'.

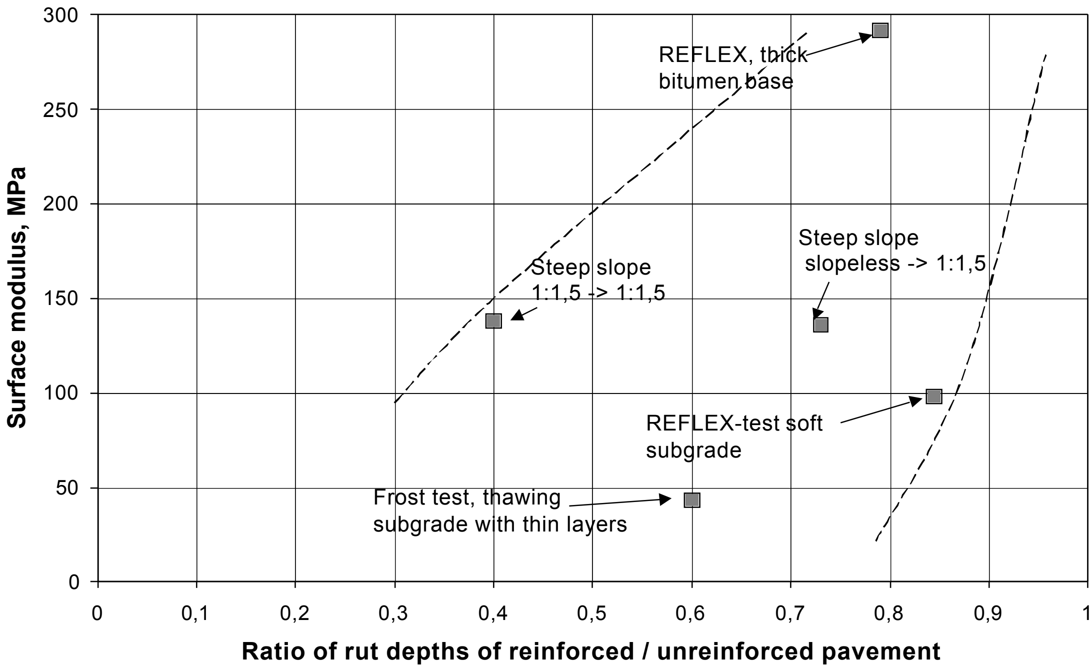

Figure1: The ratio of rut depths of reinforced and unreinforced pavements in respect to the surface modulus in different HVS tests. The reinforcement works more efficiently when the surface modulus is low.

The objective of the HVS test series 'Steep slope' was to study what effect the reinforcement grid used in the rehabilitation of rutted structures has on decelarating rutting un structures with low bearing capacity edges. Another aim was to find out whether different reinforcement grids differed in decelerating rutting. Figure 2 and Table 1 present the used reinforcements, the positions of the structures - also in relation to the old, rutted structures - and their numbering.

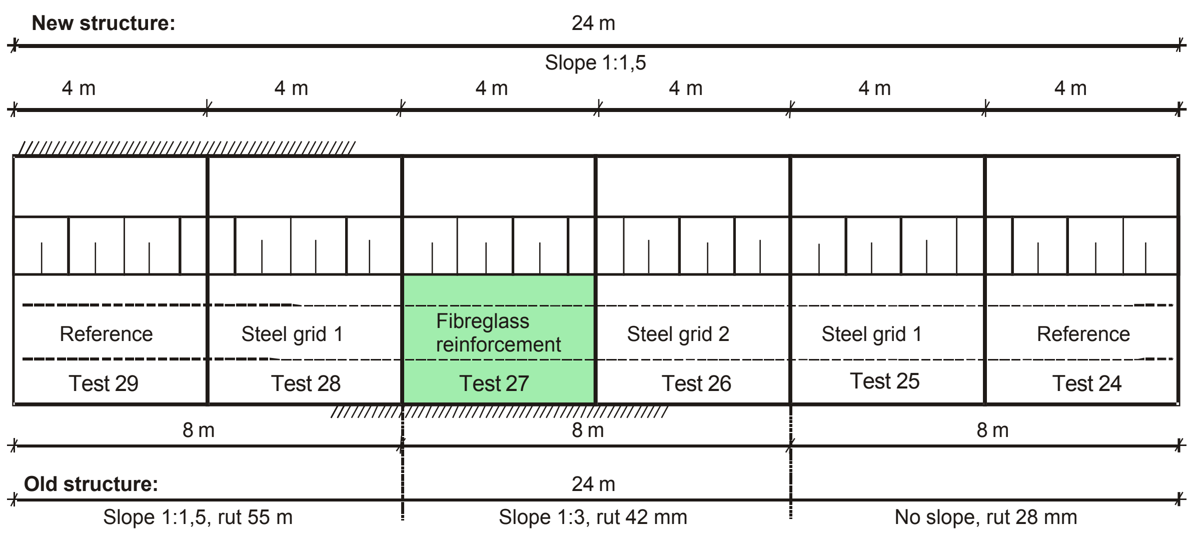

Figure2: HVS 'Steep slope': test strucutres and their state before rehabilitation.

Table1: HVS 'Steep Slope' tested structures, used reinforcements and their state before rehabilitation.

Structure	LV-structure	Rut depth before, mm	Reinforcement
24	No slope	28 mm	Reference with no reinforcement
25			Steel grid 1 (BH500 - 6/5 - 150/200)
26	Gentle slope 1:3	42 mm	Steel grid 2 (BH500 - 8/5 - 150/200)
27			Fibreglass reinforcement
28	Steep slope 1:1,5	55 mm	Steel grid 1 (BH500 - 6/5 - 150/200)
29			Reference with no reinforcement

The cross-section of the test structure is illustrated in the Figure 3. The reinforcement grids were anchored outside the test basin around a 36 mm diameter steel tube. The purpose of the anchoring was to simulate the anchoring effect caused by the weight of the other lane with a full-width steel grid is installed on a 7 m wide normal road.

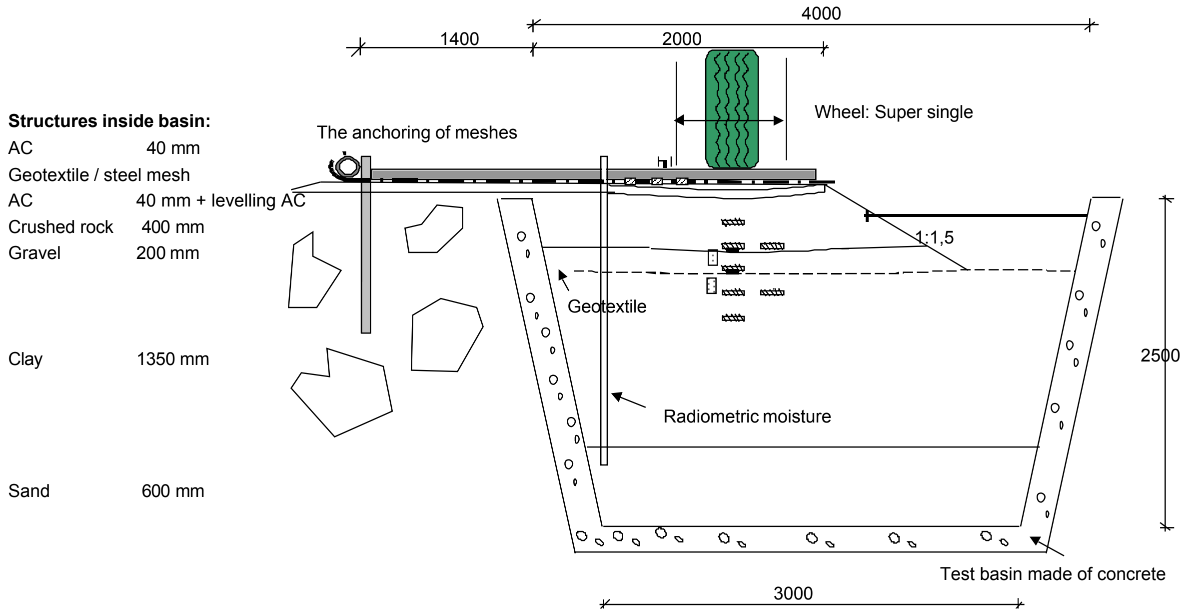

Figure3: Cross-section of the test structure with the steep slope.

Table 2 and Figure 4 present the results of the research by showing the efficiency of the reinforcement in different HVS tests. Both figure 1 and table 2 direct that a reinforcement works more efficient when the surface modulus is low.

Table2: The efficiency of the reinforcement in different HVS tests.

Structures and tests	Frost test, thawing subgrade and thin layers	Reflex, soft subgrade	Steep slope (slopeless ->1:1,5), thin layers, soft subgrade	Steep slope (1:1,5), thin layers, soft subgrade	Reflex, thick bitumen base
Surface modulus, MPa	40	100	136	138	290
Reduction of rut depth with reinforcement	35 - 45 %	15 - 20 %	23 -31 %	55 - 60 %	15 - 25 %
Benefit of the reinforcement to the service life of the pavement	100 - 250 %	50 - 60 %	40 - 50 %*	130 - 190 %*	50 - 60 %

* According to the extrapolations to a rut depth of 15 mm

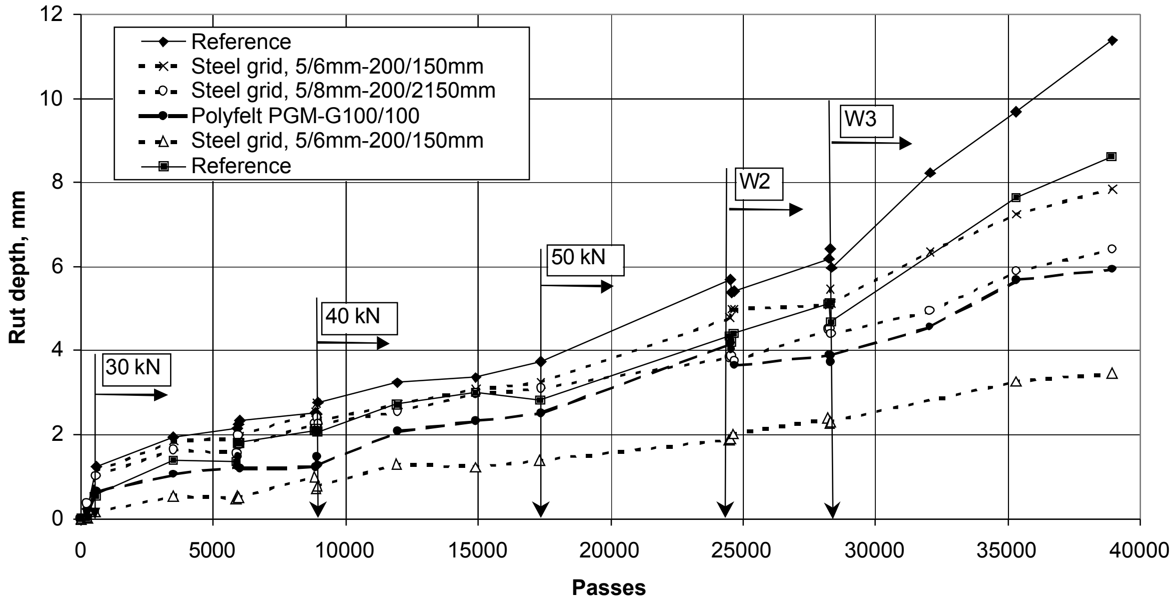

Figure4: The rutting of the 'Steep slope' test structures. In case 1 the slopeless structure was modified to a structure with 1:1,5 slope. In case 2 a 1:3 slope were toughened to a 1:1,5 slope. In case 3 the slope was 1:1,5 in both tests. W2 and W3 stand for the different water tables. The structures with the same slope history may be compared directly with each other.

In some special cases it is possible that the benefit of the steel grid to prevent rutting is not as great as described above. In the expanded polystyrene (EPS) test series (Kangas et al. 2000) where steel grid was installed into the base course near the surface of the EPS the benefit of the reinforcement to the service life of the pavement was only 10 %.

In the 'Steep slope' test (Korkiala-Tanttu et al. 2003b) the efficiency of the rehabilitation methods were compared. The structures have been tested in the 'Low-volume' road test where the effect of slopes was studied by comparing slopeless (case 1), 1:3 (case 2) and 1:1,5 (case

3) slopes. Structures rutted and cracked in the Low-volume tests were levelled with asphalt concrete and the slopeless and 1:3 sections were modified to sections with 1:1,5 slopes. Then two different steel grids and a glassfibre grid reinforcement Polyfelt PGM-G100/100 were installed in the surface. The used steel grids were B500H 5/6 - 200/150 and B500H 5/8 - 200/150 grids, where the first numbers show the thickness of the rod and second numbers show the pitch size in longitudinal and transversal direction accordingly. A new 40 mm thick asphalt concrete layer was laid over the test area. There were also two unreinforced reference structures, which were otherwise identical. The rutting of the structures in different loading situations was measured with laser profilometer (Fig. 4). The test load was increased from 30 kN to 50 kN and the water table was risen two times during the test (W1=in subgrade, W2 = on the top of the subbase and W3 = in the middle of the base layer).

Case 3 is the structure where the slope inclination was 1:1,5 in both tests. Case 2 (slope 1:3) and case 1 (slopeless) were both modified to the slope inclination 1:1,5. Case 3 shows that the rut depth of the reinforced structure is about 0,4 times as deep as in the unreinforced structure in all stages of the test. Case 2 shows that steel grid with an 8 mm's rod works as well as the Polyfelt PGM-G100/100 grid does, also when comparing to the functioning of 6 mm rods in the cases 1 and 3. The HVS test results indicate that different reinforcement materials worked all equally well.

According to the statistics (database of Finnish Road Administration) an overlay with a steel grid seems to reduce rutting more effectively than an overlay without a grid, when the speed of the rutting was high before the rehabilitation. The same applies for a grid in the unbound base.

3 CRACKS CAUSED BY FATIGUE

Test results show that steel grid delays fatigue to some extent. The test results of Frost test show that the amount of cracks will be reduced by about 20 %...30% in structures with a steel grid in the unbound base when compared with equal structure without a grid during thawing of subgrade. In the Reflex tests, where the bearing capacity of the structure was originally better, a steel grid with the pitch size of # 75 mm delayed fatigue only slightly and a steel grid with the pitch size # 150 mm had no better performance than unreinforced pavement. The calculations in the Reflex project indicate some 5 %...10 % reduction to the resilient strains in the reinforced pavement compared with unreinforced pavement.

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4 CRACKS CAUSED BY REFLECTION

The Reflex project prognoses that reflection cracking of the cement bound gravel base can be reduced 35 % by steel grids. Some other unspecified research results indicate that cracking due to the widening of the road can be reduced by reinforcements. No amount for this reduction was presented.

5 CRACKS CAUSED BY FROST HEAVE

A steel grid prevents the development of longitudinal frost cracks in the reinforced area according to the TPPT test results and over twenty years of field experience with reinforced and unreinforced structures. The longitudinal cracks usually move to the edges of the road where grid reinforcement ends. Steel grid also mitigates the transverse frost cracking by curtailing the width of the cracks and by preventing the development of small cracks.

The grid must be installed in the whole width of the road. No overlapping of the steel grid is needed in longitudinal direction to prevent frost cracks. On the contrary the space between adjacent grids can be up to 500 mm, if the frost heave is less than 100 mm. If the frost heave is bigger than 100 mm, the grids should be installed with edge joint (close to each other with no space between them).

The TPPT test structures show that the frost heave differences in the cross section can be levelled with steel grids. The Reflex project recommends that at least 50 mm asphalt layer should be spread upon the steel grid. The used steel grid can be quite light.

6 LONGITUDINAL UNEVENNESS

The investigations so far have not found that longitudinal unevenness could be leveled with reinforcements.

7 DESIGN AND INSTALLATION

The typical dimensions of steel grids in Finland are:

- longitudinal rods 5 mm.
- transversal rods 6 - 8 mm
- longitudinal pitch size 200 mm
- transversal pitch size 150 mm

Even though reinforcement clearly improves the performance of a pavement it is difficult to proof this better performance with Falling Weight Deflectometer measurements. This phenomenon was detected for both steel grid and glassfibre grid reinforcements. The surface moduli of a reinforced pavement measured with FWD are usually only slightly bigger than the moduli of an unreinforced pavement, yet the difference between service lives can be twice. The possible method to prove reinforced pavement's better performance could be the strain gauges at the bottom of the asphalt or the use of plate load tests.

When a steel grid is used to prevent cracking caused by the frost or to reduce rutting of a narrow road it should be installed in the whole width of road. If a steel grid is used to reduce rutting of a wide road it should be installed in the whole width of the lane.

It is recommended that steel grids should be installed in the unbound layers. It is presumable, that grids operate as well in both unbound and bound layers. Yet, the reason for this recommendation is that there have been some failures with steel grids in bound layers. The failures relate to the techniques and safety at work.

According to the Reflex project's results the steel grids should be installed in a certain depth. The depth recommendations are following:

- If the rutting in the subgrade was to be reduced by a steel grid in unbound layers, the grid should be installed to a depth of at least 200 mm.
- If the steel grid was planned to install into bound layers, the best depth would be 80 mm.

The Reflex project's results are based on both laboratory tests and calculations. The full scale model tests (HVS tests) do not confirm these recommendations for installation depth.

HVS test results indicate that the binding between two asphalt layers with reinforcement inbetween has a clear effect on the efficiency of the reinforcement. Two nearly similar test structures were constructed in the Otaniemi test basin. In the other structure the efficiency of the steel grid concerning the service life of the structure was about 77 % and in the other it was over 200 %. There are two matters that affected this difference. The first one was the fact that rehabilitated structures were in a little different state when the loading began. The second matter was detected when the structures were digged out. The asphalt layers in the structure with lower efficiency had become detached from each other during the test while in the other structure (with better efficiency) the asphalt layers had stuck to each other better. It is obvious that the use of a steel grid makes the binding between asphalt layers worse than it would be without a grid. In the HVS tests the best binding was detected from the glassfibre grid reinforcement (Polyfelt PGM-G100/100), which had been glued with bitumen emulsion. That is why attention should be laid also to the installation of the reinforcement. Before installation the surface of the asphalt must be cleaned up carefully, preferably with pressure cleaning or with sweeping machine. Reinforcement can be installed to the cleaned surface. Before spreading the new asphalt layer the surface can be warmed up or it can be treated with bitumen emulsion.

According to test results it seems that the measures (like pitch size) of the steel grid do not effect the rutting speed. However some calculations in Reflex show that pitch size # 75 mm should be recommended instead of pitch size #150 mm.

The steel grids are recommended to be installed with the transverse steel rod upside. There are two reasons for this. One is because this prevents the grid to protrude its upper layers during the next work stages. In the bound layers the upper rod attaches better to the asphalt and also works better even if the binding between old and new asphalt is only partial. Usually it is the transverse rod, which operation is more important than the longitudinal rod's operation.

8 OTHER MATTERS

An important factor, that restricts the utilisation of steel grids, is the problems with rehabilitation of the pavements with steel grids. There are difficulties in both milling and stabilisation of these pavements in cases where the layer thickness above the steel reinforcement was less than 50 mm.. Typically the problems are with the breakdown of the milling machines but also some problems have been with the safety at work. With other reinforcement materials (like glassfibre grids) this is not a problem.

The experiences with utilisation of reinforcements in pavements are quite restricted. So the estimation on the long term performance (like stability, corrosion a.o.) has some uncertainty.

9 CONCLUSIONS

Though the benefits of using reinforced pavement structures are obvious, there is still work to be done to get general acceptance for this technology as a true alternative to common road construction techniques. The limitations of the utilization of the reinforcement are uncertainties related to a lack of proper design methods for reinforced road structures as well as a lack of “official” guidelines or recommendations. The ESF-COST 348- REIPAS project, which is combining the expertise of partners from 21 European countries and the United

States, is making efforts to enhance the use of reinforced pavements and road structures in future.

REFERENCES

Kangas, H.; Onninen, H., Saarelainen, S., *Testing a pavement on thawing, frost-susceptible subgrade with the heavy vehicle simulator*, Finnra reports 31/2000, Helsinki 2000, 69 s.

Korkiala-Tanttu, L., Kivikoski H., Rathmayer H. and Törnqvist J.: *Effect of steel grids on the durability of the road,* Helsinki 2003. Finnish Road Administration. Finnra Reports 34/2003. 42 p. + app. 13 p. ISSN 1457-9871, ISBN 951-803-096-0, TIEH 3200822.

Korkiala-Tanttu, L., Laaksonen, R., Törnqvist, J., 2003c, *Reinforcement of the edge of a steep-sloped pavement. HVS-Nordic-research.* Helsinki 2003. Finnish Road Administration. Finnra Reports 38/2003 46 p. + app.

Pihlajamäki, J., Wiman, L., Gustafson, K.*, REFLEX Final report T4:02 Full scale Accelerated Tests*. www.vti.se 2002. 45 s.

Tammirinne, M., Valkeisenmäki, A., Ehrola, E., *Tierakenteiden tutkimusohjelma 1994-2001. Yhteenvetoraportti.* Tiehallinnon selvityksiä 36/2002. Helsinki 2002. 104 s.