ROAD REINFORCEMENT

GlasGrid®
for asphalt overlays

The Advantages for You

LIFE

- Improvement of asphalt pavement lifetime by 200–300% due to reflective crack mitigation
- 50% reduction in future investment costs (e.g. maintenance, rehabilitation and use)
- Improved natural ability of asphalt to reduce cracking by up to 3 times by providing a tensile element to the asphalt
- Protection of the base against water penetration and better drainage capabilities of the road by 10%
- Support for reduction of the downward rut depth by 25%
- Structural benefit by about 60% depending on the type of ADFORS GlasGrid and pavement section

INSTALLATION

- Proven extensive asphalt layer bonding requirements by Leutner shear test 12 kN or 15 kN needed in most of EU countries (150 mm cores)
- Improved compatibility with bitumen and damage resistance during construction due to patented polymer coating
- Quick and efficient installation with self-adhesive solution
- Easy cutting
- Edge marking for easy overlapping

REUSE & ENVIRONMENT

- Up to 5x extending cracking resistance of new asphalt layers when milled and partially add as recyled asphalt into the new asphalt mix
- Excellent milling performance
- Unlimited recyclability
- Thermal and chemical stability
- Reduction of CO_2 emissions due to pavement life extention
- Use of natural raw materials

30 YEARS OF PROVEN PERFORMANCE WORLDWIDE

CONTENT

1. INTRODUCTION

The ability of asphalt to withstand tensile stress is limited. As a result, the life of asphalt overlays on cracked asphalt and concrete pavements is often shorter than expected design life. Reflective cracking of asphaltic concrete overlays is propagation of cracks or joints from the old pavement into and through the overlay soon after construction. Such mechanism is called reflective cracking. It can be caused by traffic, temperature variations (daily or seasonal) and/or uneven soil movements upward, downward or a horizontal nature. Once a crack is at the surface, deterioration of its faces will be accelerated by the abrasive action of the applied shear forces, caused by passing traffic in combination with the presence of water. The prevention of reflective cracking has always been an area of concern when designing for asphaltic concrete overlays. The following options are available to delay or arrest reflective cracking in overlays to be constructed on existing cracked pavements for the extension:

- to use a thicker overlay,
- to optimize the stiffness and the strength of the overlay mixture by adding fibers or applying polymer modified bitumen,
- to place stress-relieving systems between the old pavement and the overlay,
- to use reinforcement systems at the bottom of the overlay.

The research presented in this paper is related to asphalt reinforcement systems used to extend the life of the pavement. The role of reinforcement is:

- to reinforce the overlay,
- to delay, or arrest the crack propagation process in the overlay by transferring the tension at the bottom of the overlay after the asphaltic mix has cracked at this location,
- to improve the flexural performance by enabling to carry a large bending moment for a given strength of the asphalt concrete.

A wide range of reinforcing products is available on the market, varying in type of material used (glass, polyester, polypropylene, steel, other), geometry of the cross section and fabric construction (fabrics: knitted or woven grids, non-woven fabrics, and composite fabrics, consisting of geogrids and non-wovens). This results in strengths ranging generally between 15 and 250 kN/m.

2. CRACKING

Cracking and deformation that typically deteriorates flexible or semi flexible pavements are suffering to extensive traffic loading, age hardening of asphalt binder, or temperature cycling. Moisture can readily enter a cracked pavement, weakening the underlying layers, further accelerating damage to the pavement. Research has shown that cracks are likely to reappear at a rate of more than 2 cm (1")/year after rehabilitation construction such as in unreinforced asphalt overlays. The cracking in the new overlay surface is due to the inability of the overlay to withstand strain, shear and tensile stresses created by a number of factors as movements of the underlying pavement. These movements are mostly caused by either:

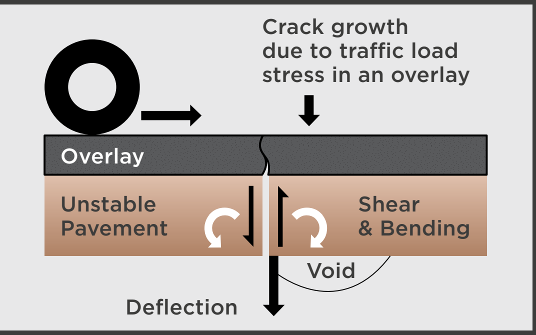
1. traffic loading,
2. and/or by thermal cycling
(expansion and contraction).

When repairing roads of asphalt construction, since the 1980s there have been repeated attempts to increase the useful life of the repair by using inlays in or between the asphalt layers. The focus is on the reduction of the costs of pavement maintenance by making use of the "armouring effect" of inlays, whilst at the same time preventing cracking. Since 1983 has been successfully produced and continuously developed reinforcement system ADFORS GlasGrid which allows since the time reduce distresses in the pavement with main benefits include:

1. maintenance cost reduction. ("life cycle costs reduction"),
2. significant extension of road life over conventional surfacing,
3. reduction of asphalt thickness, in some circumstances, saving on material costs,
4. reduced CO_2 emissions and environmental impact associated with longer maintenance intervals,
5. reduced hidden costs to businesses and the general public through delays caused by road closure and traffic restrictions.

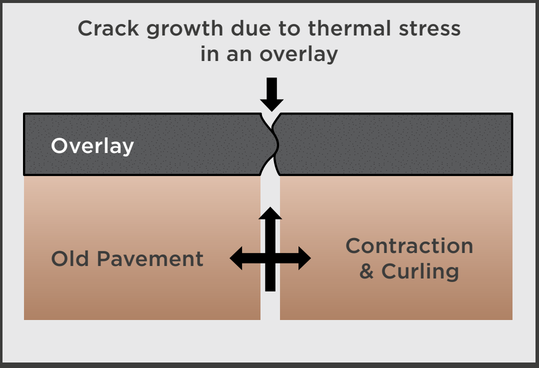
2.1. Traffic Loading

Load associated cracking occurs when due to traffic shear and bending forces create stresses that exceed the fracture strength of the asphalt overlay. This is a pavement stability issue. Pavement instability is generally due to the presence of one or more of the following: poor soil conditions, improper drainage, increased traffic load, and age. Unstable Portland cement concrete (PCC) slabs are often identified by excessive movement or deflection during loading accompanied by the presence of water and fines pumping upward at the joint. Once these fines exit the pavement structure they leave behind a void. Voids negatively affect support for the PCC slab, resulting in the slab becoming even less stable.



2.2. Thermal Stress

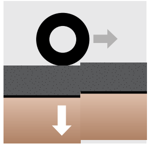
Temperature associated cracking occurs when horizontal movement of base pavement layers, creates tensile stresses in the overlay that exceed the strength of the asphalt. Overlays placed on both Asphalt cement concrete (ACC) and PCC pavements are subject to thermal cracking. Thermal cracks usually appear in transverse and longitudinal directions. Thermal rates of expansion and contraction vary between materials such that any slab joint spacing almost always assures premature joint reflection.

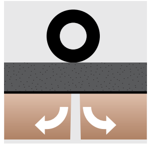


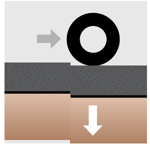
2.3. Mechanism

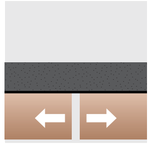
Bituminous bound layers crack in-situ because of their inability to withstand strain, shear and tensile stresses created by a number of factors as described above.

Cracks are initiated by failure modes as


Vertical shear

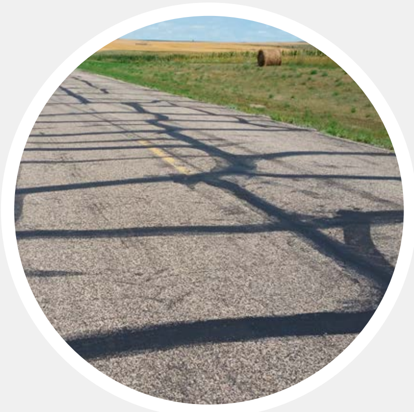

Bending


Vertical shear


Thermal movements

Such stresses and strains will typically lead to one of the following pavement deterioration[1]:


Reflective cracking from concrete bays


Reflective cracking from thermal movement


Reflective cracking from expansion joints


Cracking from utility trench


Surfacing failure caused by underlying setts


Alligator cracking due to structural failure

3. ASPHALT PAVEMENT INTERLAYERS

A conventional rehabilitation of a cracked flexible pavement involves milling off the existing top layer and installing a new asphalt course (mill & fill approach), but cracks are still present in the existing (old) asphalt layers. As a result of the horizontal and vertical movements at the crack tip, the cracks will propagate rapidly to the top of the rehabilitated pavement.
In a similar case, deteriorated concrete pavements are typically rehabilitated by installing new asphalt layers over the old concrete slabs. The temperature variations lead to a rapid crack propagation especially at the expansion joints to the top of the new asphalt overlay. As summary, it can be stated that simple hot mixed asphalt (HMA) overlays are not cost-effective against reflective cracking.
In order to delay the propagation of cracks into the new asphalt layers, there are several techniques to rehabilitate cracked pavements. However, one of the most popular method among new techniques recommended is the use of interlayer systems between the old pavement and the new overlay, such as geosynthetics.

Solutions available on the market:

1. SAMI (Stress absorbing membrane interlayer) which can be applied as SAMI nonwoven or SAMI surface sealing. Both options provide to the asphalt structure stress relief of forces due to soft (bitumen based) interlayer.

2. GRIDS
Can be designed and produced to 3 main types with specific additional functions for the pavement structure:

- Grids
  - Provide reinforcing function (R), stresses are absorbed and distributed by the reinforcement ribs.
- Composite grids
  - Can provide combination of reinforcing (R) and stress relief (STR) function which is created by nonwoven fabric saturated by bitumen. Composite grids consist of grid bonded with light PP or PES nonwoven fabric (≤ 80 g/m²) as carrier allowing installation on the milled or existing rough surfaces.
- SAMI composite grids
  - The grid bonded with heavy SAMI PP or PES nonwoven fabric (≥ 130 g/m²). Can provide combination of reinforcing (R), stress relief (STR) and waterproofing function (B)[2] due to SAMI nonwoven interlayer saturated by adequate amount of bitumen.

Asphalt interlayers are generally applied on 3 types of the underlying surface:

- Milled pavement surface
- Oxidized old surface with various deteriorations
- New freshly laid pavement surface (bituminous levelling course or new construction layer - bituminous or PCC)

Correct interlayer product with respect to the final performance must be carefully chosen. In such correct installation aid must be considered to bring the full performance of interlayer for the structure.

4. ADFORS GLASGRID ASPHALT PAVEMENT INTERLAYERS

ADFORS GlasGrid is composed of high strength glass filament yarns knitted into a grid and coated with an elastomeric polymer to stable grid matrix. ADFORS' advanced coating improves the toughness and durability of glass filaments, protects the interlayer from damage during installation and asphalt compaction. Additionally, is designed to enhance the bond between layers of asphalt necessary for reaching the high performance in final construction (≥ 12 or 15 kN on 150 mm cores).

In pavement structure ADFORS GlasGrid interlayer grids reduce stresses and strains in the pavement caused by the load from transport and temperature changes. The geogrid reinforcement function is provided by two major aspects. The first one is given by the properties of the reinforcement grids limiting the crack propagation, the second one is given by the deformation of the grid, which absorbs the energy at the crack tip, thus stopping the crack growing outward. Every time a crack starts to develop in pavements with geogrids, the geogrid ribs transfer tensile forces corresponding to the movement or opening of the crack surface. Thanks to that, the geogrid is able to prevent the propagation and growth of the crack. As soon as the process is stopped, vertical shearing displacement of the crack surface will be prevented or reduced because of interlocking of aggregates in the asphalt mixture, which will prolong the life of the pavement. In general, the geogrid may be regarded as a viscous layer after its installation. When the crack extends from the overlay to the reinforcing layer, the geogrid will absorb the energy at the tips of the crack. The absorbing effect will disrupt the energy distribution in the crack thus will slow the crack growth.

As summary ADFORS GlasGrid helps control the development of peaks in strain at the bottom of new asphalt layers.

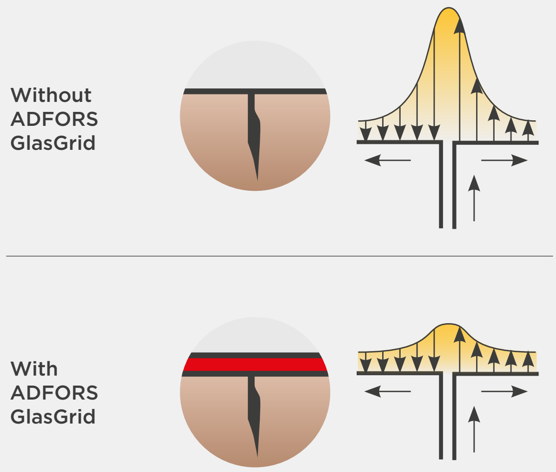


Figure 1: Schematic peak strain reduction by ADFORS GlasGrid

In asphalt pavements ADFORS GlasGrid is greatly effective due to its material properties. By comparison of ADFORS GlasGrid and asphalt properties can be concluded:

a) Asphalt breaks (cracks) an elongation no greater than 2%, therefore the usefulness of any reinforcement must be within the range of 0–2%.
b) ADFORS GlasGrid is approximately 10 times stiffer than asphalt at warm temperatures, and when the mix cools down, or as the mix age-hardens, the ADFORS GlasGrid to asphalt stiffness modulus ratio decreases.
c) The reinforcement in asphalt has to be able to respond to very short duration low strain loads, and as such must be able to generate high strength at low strain, greater than what the asphalt can offer, for it to be able to provide a benefit.
d) Many engineers will argue appropriately that micro strains will occur in asphalt at likely 1% that would induce irreparable damage to the asphalt pavement. **This reinforces the need to high tensile at very low elongation.**
e) Therefore, ultimate elongation is not useful if the value is greater than the substrate it is going to reinforce can handle.

Summarize of material properties are shown in Figure 2 where „effective range" of reinforcing grids shows the needed properties for asphalt crack mitigation.

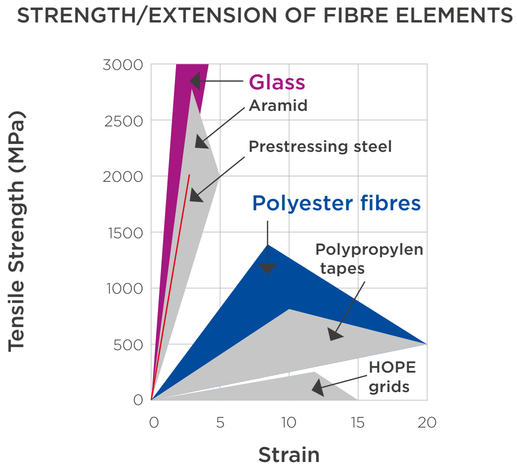


Figure 2: Tensile Strength vs Extension properties for different reinforcing materials

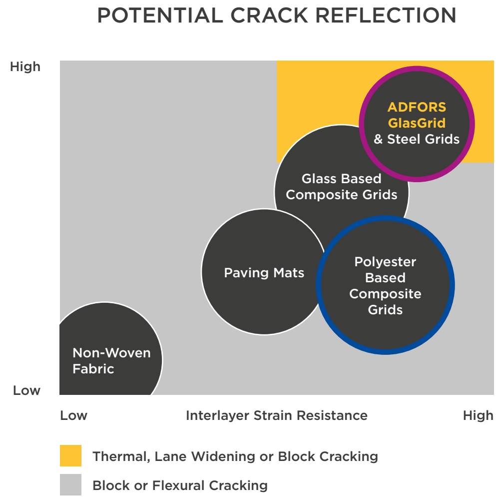


Figure 3: Potential crack reflection for different reinforcing materials

From the Figure 2 above is clearly seen that based on "Strength/Strain" ratio difference between raw material used for finish interlayer product makes significant difference between ability to resist crack propagation. Final effectiveness of finish products available on the market is summarized on Figure 3. ADFORS GlasGrid compare to other materials as for example polyester or polypropylene is able to be manufactured in much higher ultimate tensile strength and therefore also in the interlayer due to low strain (elongation) to reach much higher reinforcing effect to resist crack mitigation. Therefore is much more suitable for reinforcing the pavement structures.

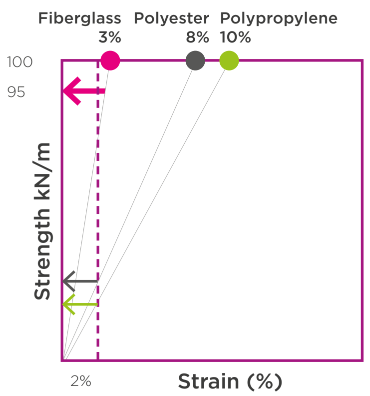


Figure 4: Comparison of raw material strength under 2% strain, same theoretical ultimate tensile strength product.

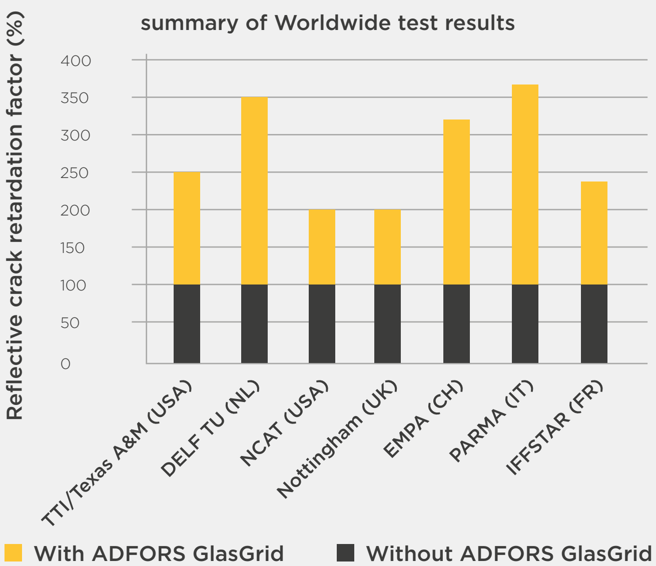
Realistic reinforcing effect of products on the market can be explained by 2 approaches:
- comparison of activated strength of reinforcing product vs. asphalt properties under identical strain (under strain no greater than 2%)
- Thermal expansion ratio between reinforcing material and asphalt or cement concrete material

Such information can be taken from the technical datasheets of ADFORS GlasGrid products and available products on the market.
In Figure 4 can be seen that ADFORS GlasGrid made from fiberglass outperforms polyester and polypropylene based reinforcement 2-3 times in respect to its activated strength under identical strain of 2% reaching 95kN/m effective tensile strength.

5. ADFORS GLASGRID INTERLAYER PERFORMANCE

For some years now, various manufacturers have been offering products that are specifically designed for use in asphalt road construction. However, there are no uniform requirement criteria or technical guidelines for the use of these products that would enable contractual issues such as warranties, acceptance criteria etc. to be clarified. A working paper[3] written in 2006 and further extended in 2013 only describes the range of product groups on the market, without defining any mandatory features.

Since ADFORS GlasGrid introduction in the early 80's, ADFORS GlasGrid may be the most tested interlayer product on the market and has been tested by numerous facilities. These have quantified the benefits of using ADFORS GlasGrid and help define its areas of application. This testing and research has continually supported the initial proposition by TTI/A&M, that ADFORS GlasGrid glass fibre grids improve the life of an asphalt pavement by 200–300% through reflective crack retardation, limit rutting and bring structural benefit and allow final reuse of interlayer due to recycling.



* Unreinforced asphalt sections have been normalized to one for clarity

Figure 5: Reflective crack retardation

5.1. Interlayer shear bond of reinforced bituminous layers

In practice, when using asphalt interlayers it has been found that not all features of asphalt pavements can be transferred without restriction. For example, the bond between two layers of asphalt, for which the same construction requirements apply as for new construction, are adversely affected when using asphalt inlays to a varying degree. This often leads to disagreements between the parties and must be considered when the regulatory framework is being updated. It is therefore needed to strictly follow manufacturers application and installation guidelines.

A reinforcing interlayer is only effective with perfect shear bond with the matrix. The tensile forces are transferred to the surrounding bituminous layers via the interlayer bond. **In various countries EU and world directives and road construction standards a shear force ≥ 12 kN respectively ≥ 15 kN between constructed bituminous layers is required (Leutner shear test on 150mm core diameter).** In some countries such values are not forces and only visual inspection of layers in core are performed in basis of yes or no adhesion validation. Also some countries and specifically for thin layers use rather pull off strength test.

The pavement shear bond is provided by two components: Interlayer interlocking of surfaces + adhesion provided by bonding agent.

Several internal and third party[4] investigation proved the ability of ADFORS GlasGrid for perfect interlayer shear results. Application rates are recommended for each product in updated ADFORS GlasGrid installation manuals taking into account the type of ADFORS GlasGrid product, bonding agent and construction conditions.

Recommended bonding agent is C69BP4 OB, cationic bitumen emulsion with 69% polymer-modified bitumen for surface treatment with Class 4 refractive index.

Laboratory results has been numerous times proven by the history of field projects. Best performing materials and solutions are used on the airport runways. As example latest field test of TPA Croatia (Strabag quality control laboratory) on the Airport Dubrovnik projects in 2018 proved the needed shear values for the ADFORS GlasGrid to be more than 12 kN respectively 15 kN in the construction, securing the final performance on bituminous reinforced layer. Based on numerous testing sites and real projects over the ADFORS GlasGrid interlayer use, the installation on surfaces has been recommended as in Figure 6. To achieve maximal performance, job site must be consulted with ADFORS representative.

		Grids Self-adhesive		Composite Grid	SAMI Grid	
ADFORS GlasGrid interlayer		GG	TF	CGL	CG	PG
Interlayer function		R	R	R/STR/B	R/STR/B	R/STR/B
Installation surface	Well milled surface	Not recommended use, adapted installation procedure must be considered		0,6–1,0 kg/m²	1,2–1,8 kg/m²	No need
	Very poorly milled surface			1,0–1,2 kg/m²	1,8–2,5 kg/m²	No need
	Current heavily oxidized surface	0,4–0,6 kg/m²	No need	0,7–0,9 kg/m²	1–1,2 kg/m²	No need
	New surface	0,3–0,5 kg/m²	No need	0,5–0,8 kg/m²	1–1,2 kg/m²	No need

Figure 6: ADFORS GlasGrid interlayer bonding agent recommendation.
Full material properties and installation recommendations are stated in chapter 7 Material properties.

5.2. Interlayer damage resistance of reinforced bituminous layers

On the market are presented several interlayer products.
They can be divided by basic fibre roving material they are made of. For example as in Figure 7.

	E – modulus (N/mm²)	Elongation at break (%)	Milling of the overlying layer
Glass	≥ 73.000	≈ 2,5-4,5	Is possible
Polyester	≈ 15.000	≈ 12,0	Can be problematic
Steel (comparison)	210.000	> 5	Can be problematic

Figure 7: Basic material properties in respect to milling and reuse

Basic material predetermines the final interlayer product performance (tensile properties, elongation at break, thermal stability, recyclability, etc.). Final product available on market can be divided in 2 basic groups:

- Uncoated finish product
- Coated finish product

Uncoated product is mostly knitted from unprotected fibres of various raw materials (glass fibre, polypropylene, basalt, etc.). Coated finished product is a composite, made of a matrix (structure), the coating, and reinforcement – the glass fibre bundle. The role of the matrix is to allow load transfer to the fibres. The more uniform the cross section and better coated the fibres are, better is the overall composite performance.
There is no standard procedure or tendering rule for finish product and its performance in the interlayer. Especially no existing standard tests made directly after installation and compaction on job site detecting the performance of the interlayer in the pavement. Shear performance (test) described in the chapter before is not considering any aspect of damage of the product and its performance in construction.

The performance of glass fibre reinforcement products is significantly affected by the coating on the glass fibre, thus is critical for any fibre based products. Using specially designed coatings and improved coating processes can optimize the overall performance of the final reinforcement products. Coatings (binders or finishes) are organic compounds applied to fabrics after weaving to protect the fibres and provide the fabric stability and they are generally developed for specific applications. It is clear that ADFORS GlasGrid with especially engineered elastomeric coating bringing effective and enhanced protection against key constrains for final application in the pavements:

- Compromised stability of product during installation (unwinding, installation)
- Damage to the product during installation (tearing, cross direction stability breaks)
- Damage due to traffic of paving machinery over installed interlayer (pavers, trucks with HMA)
- Damage during compaction of HMA over the installed interlayer (aggregates in the mix damaging the fibres and lowering or fully compromising tensile properties and crack relief function of interlayer)

During the development and production since 80´s, Saint-Gobain ADFORS has developed and patented special engineered coating for optimal interlayer performance. Its composition and coating process of the roving allow:

- to penetrate the fibre roving and protect each glass filament (protection),
- to each fibre to "cooperate" and give final extended tensile properties 11 to 40%,
- to extend bond to the asphalt layers due to softening by temperatures (cross linking).

ADFORS GlasGrid is glass fibre based grid coated with elastomeric polymer coating with key advantages:

- **Extended mechanical properties of the finished product (tensile strength, stiffness)**
- **Higher ability to bond layers and increase shear strength of interlayer (coating softness under temperature allowing bond with bitumen based pavement layers)**
- **Optimized installation efficiency**
- **Superior protection against damage during installation and final asphalt layer compaction**

5.2.1. Coating type effectiveness

Coating performance was studied and assessed based on mechanical test results and optical microscopy images of the grid cross-sections[5]. The key performance was investigated:

"Effect of ADFORS Thermal Stable Elastomeric Polymer Based Coating vs. Bitumen based coating to glass roving properties before and after simulated field installation was tested."

Tests aimed to determine the effect of coating on the strength of glass fibre roving. The two coatings used were: ADFORS Thermal Stable Elastomeric Polymer Coating (next text as ADFORS TEP coating) used for existing road reinforcement products, and an asphalt emulsion based coating. Uncoated (greige) glass fibre roving was included in the study as control for coated glass. Extreme condition where chosen to simulate damage during and after paving and simulates the abuse a paving material experiences during compaction using a Marshall compactor. 75 blows from the Marshall hammer mechanism where used. Upon completion of the asphalt system (base course, interlayer, wearing course), samples is broken apart and the roving is carefully removed and tested for its tensile properties.

Figure 8 presents the single end roving tensile performance measured before and after simulating the construction conditions in the field. It can be observed that ADFORS TEP coating or Bitumen based coating or emulsion based coating improves the initial tensile performance with about 50 to 60%. However, although the initial tensile strengths of ADFORS TEP coating and Bitumen based coating are comparable, there is a considerable difference in tensile retention after simulation of paving process.

- Bitumen emulsion based coating only slightly outperforms glass roving without coating by only 12%.
- Compare to ADFORS Thermal Stable Elastomeric Polymer Coating reaching additional tensile retention +49% compare to the glass uncoated roving.
- **ADFORS Elastomeric coatings compare to emulsion based coating protects the glass fibre reinforcement more than 2x**

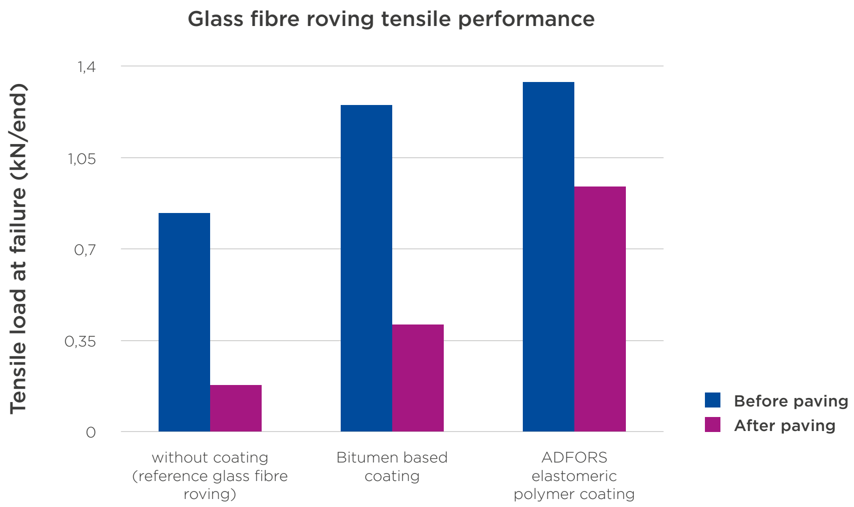


Figure 8: Performance results of different type of coatings for glass grid protection

The results obtained for composite fabrics suggest even though tack coat can improve strength and provides some protection for the glass roving, specially designed coatings are critical for tensile properties of fiberglass products.

Results are in line with microscopic observation of the cross section of the coated yarn. Here can be seen that coating is fully penetrated into the yarn bundle and protects each glass fibre. Due to that fact full ADFORS GlasGrid reinforcement grid resist paving and construction damage during driving of construction trucks and paving process over the installed reinforcement. On Figure 9 is cross section on yarn bundle with glass filaments protected by coating.

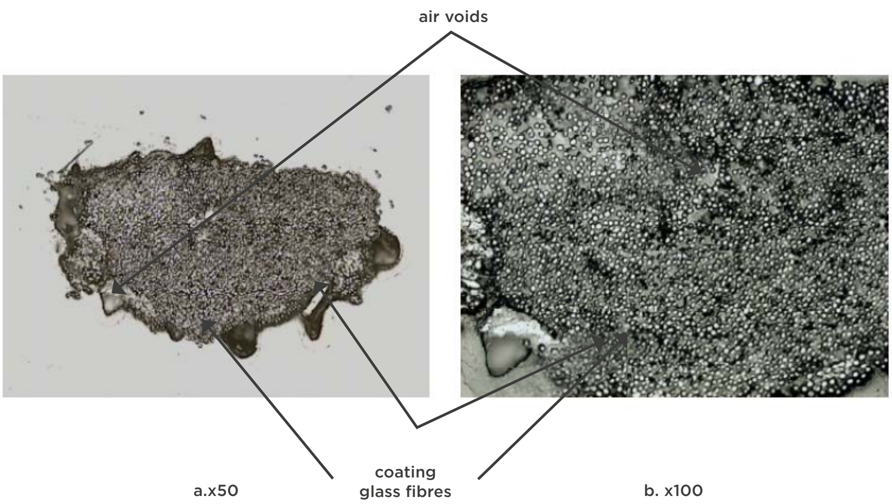


Figure 9: Single coated glass fibre roving with ADFORS Thermal Stable Polymer Based coating (full penetration and protection of glass yarns)

As a result of study is concluded:

- **Coated glass fibre products outperform uncoated similar glass composite road reinforcement products both before and after simulating the construction conditions in the field compared to greige products.**
- **Specially designed ADFORS Thermal Stable Elastomeric Polymer Coating can significantly improve the overall performance, and is critical for fiberglass products.**
- **Superior ADFORS Thermal Stable Elastomeric Polymer Coating design formulation is particularly critical to glass composite road reinforcement products while exposed to wear and abrasion during compaction.**
- **Elastomeric coatings compare to emulsion based coating protects the glass fibre reinforcement more than 2x.**

5.2.2. Damage test

Final performance of the interlayer product must be evaluated in all construction aspects. This involves:

- Product performance after manufacturing (CE mark = manufacturing quality ensuring)
- Product performance after installation (possible damage after construction process)
- Interlayer performance after installation (adhesion to the construction layer = adhesion test, interlayer stability, evenness of the installation, etc.)
- Interlayer performance of bituminous reinforced layers after full construction

ISO 10722:2007 describes an index test procedure for simulating mechanical damage to geosynthetics, caused by granular material, under repeated loading. The damage is assessed visually and by the loss of tensile strength to simulate the resistance of the interlayer product after upper bituminous layer is compacted. Test was carried out at accredited laboratory KIWA GmbH – TBU in Germany. Summary of results is in the Figure 10 below.

	Unprotected glass fibre reinforcement	ADFORS GlasGrid
	Residual Tensile strength (%)	Residual Tensile strength (%)
50 kN reinforcement	≈ 40	≈ 85
100 kN reinforcement	≈ 46	≈ 95

Figure 10: Damage test results (coated vs uncoated reinforcement after simulation of damage)

Results confirm that ADFORS GlasGrid with ADFORS Thermal Stable Elastomeric Polymer Coating has not suffering from severe damage of interlayer during compaction of asphalt layers. Results show:

- **No loss of tensile strength for ADFORS GlasGrid 100 kN**
- **About only 10% loss of tensile strength for ADFORS GlasGrid 50 kN**

This results clearly demonstrate superior performance of ADFORS GlasGrid interlayer reinforcement. When compare to pure glass fibre reinforcement (reference samples) without engineered polymer coating is visible loss of tensile properties:

- About 50% loss of strength for 100 kN uncoated grids
- About 60% loss of strength for 50 kN uncoated grids

In chart below is shown example of comparison of real tensile properties on interlayer product after installation and placement in the pavement measured by EN ISO 10319.

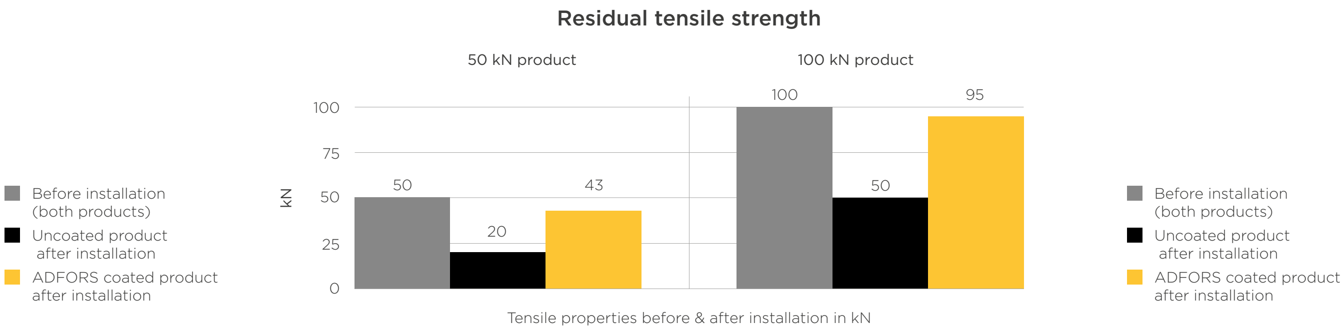


Figure 11: Example of comparison for interlayer tensile properties after installation (coated vs uncoated reinforcement)

- **ADFORS Thermal Stable Elastomeric Polymer Coating significantly improve the overall performance, and thus they are critical for fiberglass products.**
- **Superior ADFORS coating design formulation is particularly critical to glass composite road reinforcement products while exposed to wear and abrasion during compaction.**
- **ADFORS GlasGrid outperform uncoated glass composite road reinforcement products by approx. factor 2x in retaining tensile properties**
- **Therefore comparison and use of ADFORS coated product vs. uncoated glass fibre products in field can be justified by different tensile properties.**

5.3. Interlayer for reduction of the rut

In general, the intended functions of reinforcement are to reduce cracking and rutting in order to extend pavement life and/or to decrease the asphalt layer thickness. It is known that the use of grids to reinforce asphalt pavements can result in reducing surface rutting by a factor of two or more and increasing the fatigue life up to five times. The rutting performances of a ADFORS GlasGrid are evaluated using the third-scale Model Mobile Loading Simulator (MMLS3). A rutting test protocol was developed and utilized at North Carolina State University[10]. The interface mechanisms of the reinforcements were also investigated using a digital image analysis technique.
In this study, a S9.5B mix, composed of aggregate with a 9,5 mm normal maximum size and PG 64-22 and CRS-2, one of the tack binder was used for the hot mix asphalt (HMA) slabs. For the reinforcing materials in the HMA, ADFORS GlasGrid was used as in Figure 12 and shear flow distribution under load as in Figure 13.

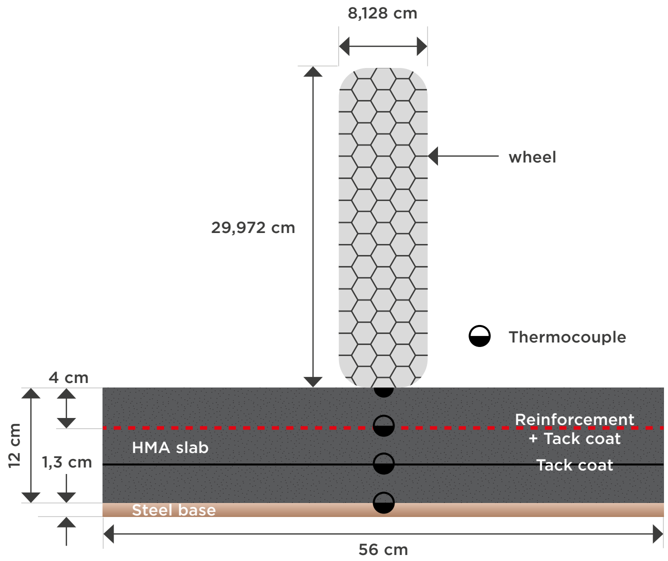


Figure 12: Cross section on pavement structure

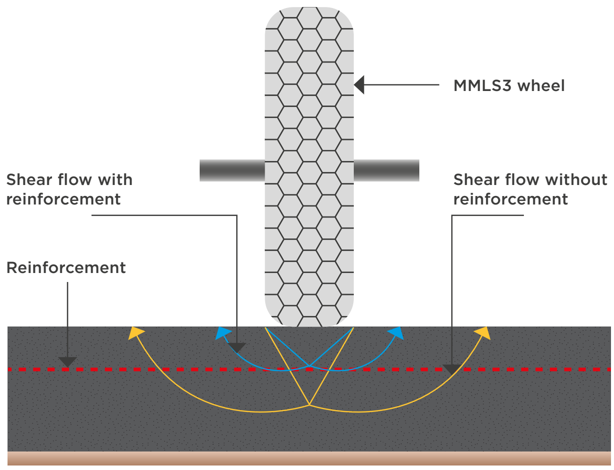


Figure 13: Contour of shear flow zone

All rut depth growth and transverse profiles of the control, ADFORS GlasGrid and slabs in terms of wheel load number at 50 °C were evaluated. The development of the rut on the reinforced and unreinforced section is represented by Figure 14. The effectiveness of the reinforcements is summarized in Figure 16 using the ratio of control to reinforcements in their rut depths after 400k MMLS3 loads.

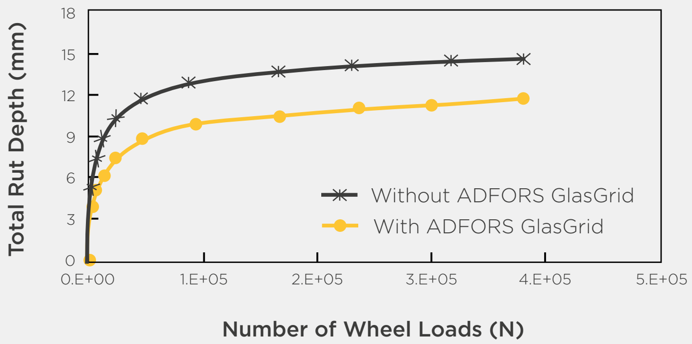


Figure 14: Rut depth under 400k MML3 loads

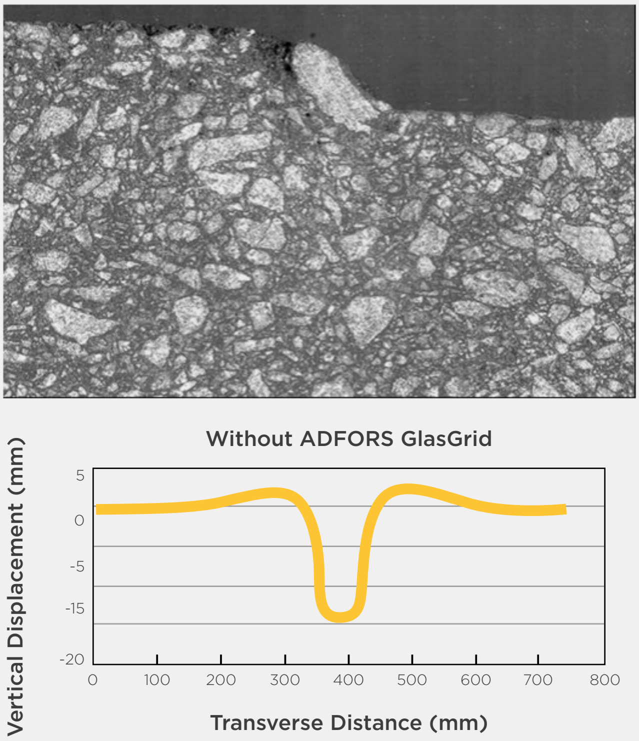


Figure 15: Transfer profiles after 400k MML3 loads (without ADFORS GlasGrid)

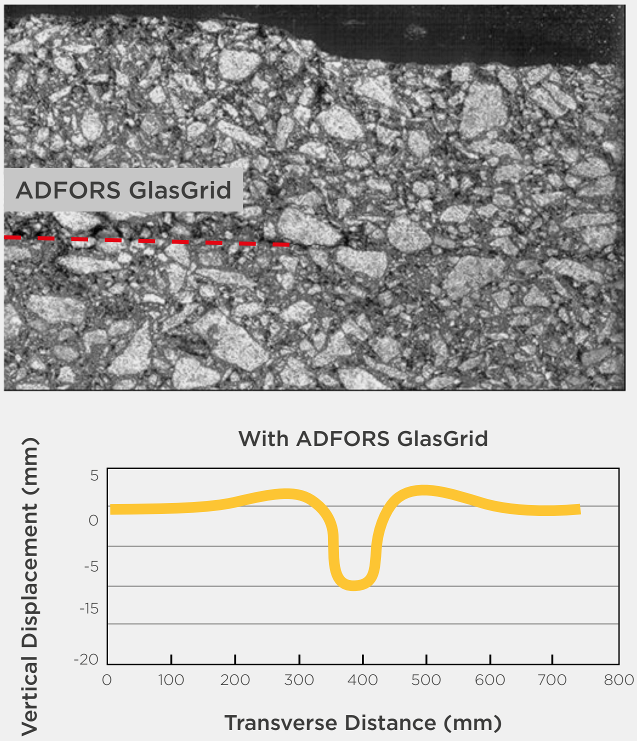


Figure 16: Transfer profiles after 400k MML3 loads (with ADFORS GlasGrid)

A comparison of the data presented in Figure 15 and Figure 16 clearly demonstrates the beneficial effect of ADFORS GlasGrid in reducing the rut depth regardless of the method used in the rut depth measurement (i.e. downward rut depth versus total rut depth).

An examination of the rutting profiles displayed in Figure 17 indicates that the ADFORS GlasGrid reinforcement not only reduces the downward rutting (26% reduction), but also reduces the height of the humps in the shear flow area and, therefore, the total downward rut depth (25% reduction).

Effectiveness of rut reduction [%]

	Control	ADFORS GlasGrid
Downward Rut Depth	0	26
Total Rut Depth	0	25

Figure 17: Effectiveness of reinforcement at 50 °C [%]

Shear flow resistance is evaluated by using the ratio of rutting area to shear flow area. The ADFORS GlasGrid slab has the smallest rut area, the smallest shear flow area, and the smallest shear flow area ratio.

1. **The results from the reinforced slabs confirm that the reinforcements reduce the downward rut depths.**

2. **The ADFORS GlasGrid slab shows the shallowest rut depth and the greatest shear flow resistance. The increased load bearing capacity that is due to the tension resistance of the ADFORS GlasGrid and the confinement and increased friction due to the aggregate particles locked in the ADFORS GlasGrid openings seem to be the major factors for this rutting performance improvement.**

3. **The interface conditions generated by the reinforcements play an important role in the rutting performance.**

5.4. Interlayer for mitigation of cracking and structural enhancement

5.4.1. Parma University preventing cracking testing

Crack mitigation benefit

At University Parma ADFORS GlasGrid were tested to evaluate benefits to tensile stress/strain reduction and reflection crack prevention to extend pavement life. Central 3 point bending tests were conducted according to ASTM – E399, using both beam and slab samples designed to simulate bottom-up cracking. Test specimens were 60 mm thick, composed of levelling 20 mm and wearing 40 mm layers to simulate field cross-sections. HMA mixtures, composed by the same asphalt binder but different aggregate gradations, were used. The first one is a 2-mm nominal maximum size mix typically used for levelling courses, while the second one is a 12.5-mm nominal maximum size mix typically used for wearing courses. Testing was conducted at 20 °C for the control and 115-15 kN/m ADFORS GlasGrid reinforced specimens under a central loading metal dowel. This configuration allowed for the evaluation of the interlayer's ability to enhance the overlay system behaviour in terms of post-cracking ductility and energy absorption. Strain localization and damage distribution were recorded and measured by using a Digital Image Correlation (DIC) System that achieves a highly accurate strain map of the specimens during loading on 60 mm x 60 mm central area.

As can be seen in the Figure 18 DIC images, the difference between reinforced and unreinforced specimens is dramatic. Strain maps on the reinforced specimen confirm ADFORS GlasGrid’s ability to act as a barrier against propagation of cracks to the upper layer. Conversely, the strain maps on the unreinforced specimen show a big crack developing in the central region which extends from the bottom edge to the surface layer along the vertical plane.

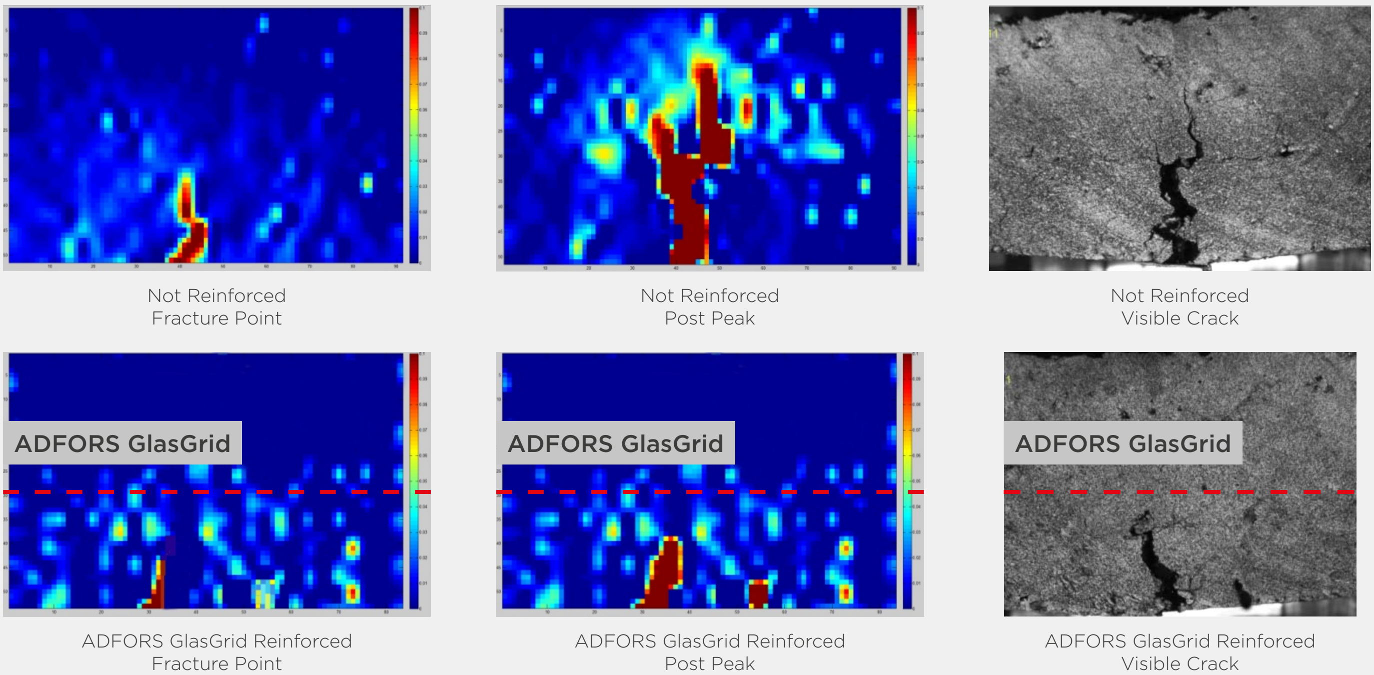


Figure 18: Crack propagation via Asphalt beam cross section (DIC method)

It is clearly evident that the presence of the ADFORS GlasGrid reinforcement is able to enhance the ductile properties of the pavement system. The qualitative load-displacement behaviour as on Figure 19 is very similar up to fracture initiation. Then ADFORS GlasGrid allows the specimen to deform more plastically before failure meaning that much higher strain levels are required to damage the pavement system. The tensile stress-strain response of the different specimens is shown in Figure 19. The results confirm what observed from the load-displacement results: the stress at fracture/the fracture energy density, or rather the energy required to crack the pavement structure is strongly enhanced by the presence of ADFORS GlasGrid.

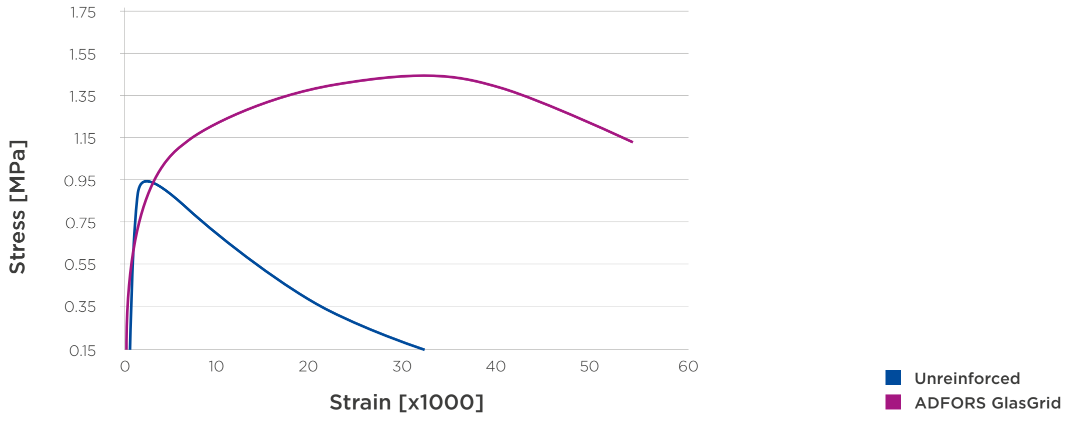


Figure 19: Stress-strain curves obtained from 3PB on beams

Flexural test results in Figure 20 (as Total Energy Absorbed) by the interlayer systems proves that presence of the ADFORS GlasGrid is able to increase the cracking resistance of the pavement minimum 3 times. The primary benefit of ADFORS GlasGrid is to significantly reduce tensile stresses in the surface layer shifting the maximum tensile and shear stress from the bottom of the surface layer to the bottom of the interlayer itself, thus reducing the fracture potential in the surface. This implies that the reinforcement is effective before the crack has reached it.

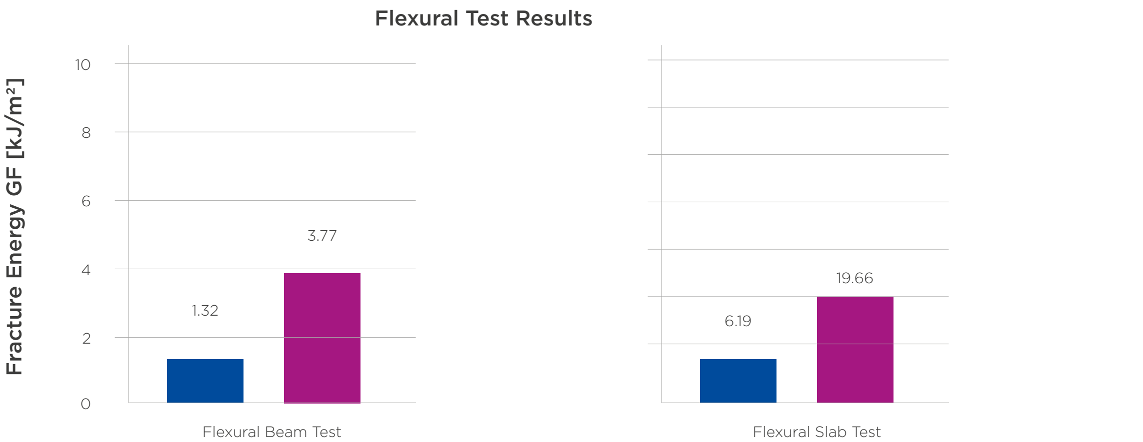


Figure 20: Flexural Test results

As result ADFORS GlasGrid reinforced structure:

- Provided enhanced ductile behaviour, improving the tensile toughness of the asphalt.
- Presence of the reinforcement is able to increase the cracking resistance of the pavement from as minimum 3 times.
- Due to the enhanced bond allowed asphalt concrete specimens deform much more before the damage became great enough for a crack to initiate.
- ADFORS GlasGrid reinforced specimens required at least three times higher strain to failure compared to the unreinforced.

5.4.2. IFSTTAR accelerated pavement testing

The LCPC accelerated pavement testing facility, in Nantes, France, is an outdoor circular carousel, with a diameter of 40 meters. The installation comprises a central 750 kW motor unit and four arms carrying the wheel loads, which can reach a maximum speed of 100 km/h. The experimental pavement has a mean radius of 17,5 m and a width of 6 m, and thus a total length of approximately 110 m. The position of the load can be adjusted at a different radius on each arm, for instance to test simultaneously the effect of different load configurations. During loading, a lateral wandering of the loads can be applied. The arms can be equipped with various load configurations: single or dual wheel, single, tandem or tridem axles. A large range of loads can be applied: between 40 and 80 kN on a single half axle, up to 135 kN with multiple axles. A very low stiffness suspension system allows to continue to run on pavements presenting severe deteriorations.
The tests were carried out on typical French low traffic pavement structures. Each structure had a length of 10 m and consisted of:

- a bituminous wearing course (70 mm thick),
- a granular subbase (300 mm thick),
- a sandy subgrade soil, with a bearing capacity of about 95 MPa.

On the reinforced section, a 2 cm thick bituminous layer was first applied. The ADFORS GlasGrid was placed on this first layer, and a tack coat was applied. Then, the grid was covered by a second, 5cm thick bituminous layer. The unreinforced section, received the two same bituminous layers (2 cm + tack coat +5 cm), but without grid at the interface (Figure 21).

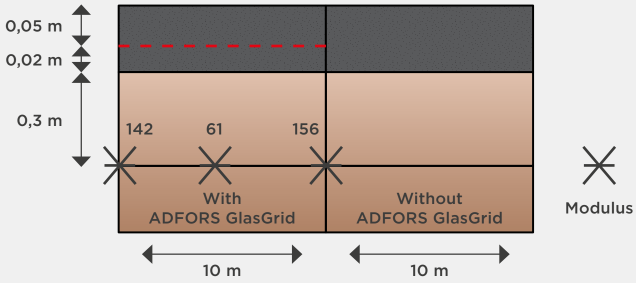


Figure 21: Pavement test sections

Figure 22: Reference section at the end of the test (left)
Section with ADFORS GlasGrid at the end of the test (right)

The bituminous mix is a standard French 0/10 mm wearing course bituminous material, (EB 0/10 roulement 35/50 according to standard EN 13108-1). This material contains 5,5 % of grade 35/50 bitumen. The mechanical behaviour of this mix was characterized by classical complex modulus and fatigue tests on trapezoidal specimens (EN 12697-31 and EN 12697-24). The specimens had an average void content of 6,2 %. The reference complex modulus of the mix at 15 °C and 10Hz is 11320MPa. Experimentally, the fatigue parameters obtained for the mix are e6 = 116 μ strains and b = -0.206.

The loading programme started in April 2011. Until September 2011, approximately 1.000.000 standard 65 kN dual wheel loads have been applied. 200.000 additional load cycles, with a load increased to 70 kN have been applied. During the experiment, loading has been stopped approximately every 100.000 cycles to perform various distress measurements (rut depth, extent of cracking). Response of internal transducers has also been recorded regularly.

As result on the unreinforced section, the first cracks were observed after 800.000 load cycles. Until 1,2 million loads, the extent of cracking increased regularly on this section, reaching 70% at the end of the test. On this section, the following crack patterns were observed: first, very fine isolated transversal cracks appeared. Then, under traffic, these cracks started to open, and fines started to come out. Other thin transversal cracks developed nearby. The transversal orientation of the cracks is typical of fatigue cracking observed on the carrousel, for pavements with thin bituminous layers[11].

On the reinforced section, no crack was observed until the end of the test. The results show that the fiberglass grid significantly improves the resistance to cracking of the bituminous layer. Pictures of the two structures at the end of the test are presented in Figure 22.

The Experiment shown that cracking appeared first on section without ADFORS GlasGrid after 800.000 cycles. At the end, 70% of the section was cracked. Section with ADFORS GlasGrid presents no cracking until the end of the test and resist 1,2 mil traffic loads.

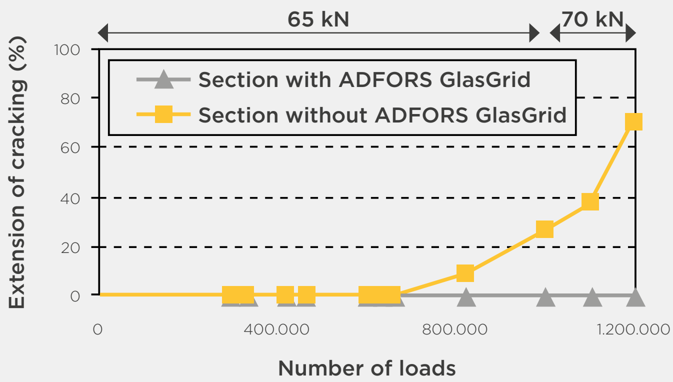


Figure 23: Extension of cracking in percent on the 2 sections

5.4.3. NCAT full-scale accelerated pavement testing

The Pavement Test Track is a full-scale, accelerated performance test facility for flexible pavements managed by the National Centre for Asphalt Technology (NCAT) at Auburn University USA. Forty-six unique 60m test sections are installed around a 2,8km oval and subjected to accelerated damage via a fleet of tractors pulling heavy triple trailers. The primary objective of the project is to identify pavements with superior field performance and lower life cycle costs through the application of a design lifetime of truck traffic (10 million equivalent single axle loadings, or ESALs, over 2,6M km) in 2 years. Within one section, NCAT evaluate the installation and performance of ADFORS GlasGrid geogrid reinforced interlayer. **Placement of the section in year 2000, pavement performance was quantified after 20 million ESALs in 2006 and continuing until today.**

Figure 24: NCAT – The Pavement Test Track is a full-scale

Conclusions:

- ADFORS GlasGrid self-adhesive with 100kN tensile strength can be installed without significantly hindering the overall construction process or compromising construction quality.
- No change to the standard construction methodology was necessary.
- No damage of ADFORS GlasGrid (even though the test section was in sharp turning of the heavy construction equipment including a material transfer device) was occurred.
- No adjustment was made to production and placement temperatures.
- **Fiberglass grid appeared to be in excellent condition 5½ years after it was installed (Figure 27).**
- ADFORS GlasGrid reinforced section is crack free compare to the unreinforced section.
- The section containing ADFORS GlasGrid interlayer was left in place, and will continue to be monitored.

Figure 25: Section with ADFORS GlasGrid shows no cracking

Figure 26: Unreinforced section with cracking

Figure 27: ADFORS GlasGrid carefully removed from the pavement after 5½ years with no damage

5.4.4. Structural benefit

Aim of the test is quantifying the benefit of ADFORS GlasGrid reinforced bituminous layer on the structural performance. In general, the fatigue is an accumulation of damage in a material under the action of repeated stress, leading to cracking of the material. Pavement cracking layers is the main mode of degradation. Bituminous layers, except wearing courses of very small thickness, have a structural effect [Kim, 2009]. To describe this effect and the behaviour of a road structure in time, the mechanical properties of asphalt must be modelled by considering four properties:

- The rigidity and its evolution over time
- Fatigue and the damage evolution law
- Permanent deformations and their accumulation over time
- The initiation and propagation of cracks

The fatigue test is performed on specimens of dimensions 630 x 100 x 100 mm at 10 °C, 25 Hz with three strain levels. Used asphalt mix is BBSG, class 3. The values are selected to determine the fatigue resistance in the range from 10^4 to $2x10^6$ cycles. During the test of alternate bending, the beam is bent in a sinusoidal manner at the stress frequency of 25 Hz and amplitude of imposed initial displacement. The force is applied through the loading frame connected to the 2 inside retaining brackets.
The exploitation of test results led to the establishment by regression fatigue curve of logarithmic coordinates. Extracted slope and the relative deformation resulting in an average life of 10^6 cycles, **called ε6, which are structural design parameters. Unreinforced and ADFORS GlasGrid reinforced samples have been compared**.

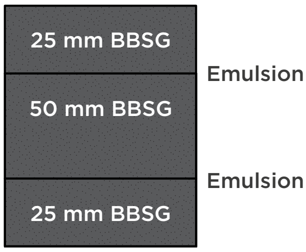


Figure 28: Unreinforced sample with interlayer position

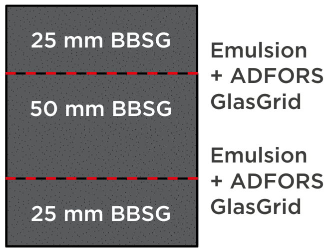


Figure 29: ADFORS GlasGrid reinforced sample with interlayer position

Tests were performed on beams of non-reinforced asphalt concrete (NR) and reinforced by a ADFORS GlasGrid from Saint-Gobain ADFORS, using a fatigue press, specially designed for this study while respecting European standards. Experimental results were used in calculating the fatigue curves BBSG (NR) and BBSG reinforced with ADFORS GlasGrid. From the form of fatigue curves ln N=f (lnε), we estimated the value of ε6 for each of the samples: ε6 = [111; 116] µm / m for BBSG and ε6 = 124,7 µm / m for the ADFORS GlasGrid reinforcement composite.
ALIZE software was used to design flexible structure type: 7 cm BBSG C3 and 25 cm GNT2 based on a platform PF3,Traffic 500 trucks/d, CAM 0.5, Risk 10%, PF3 platform. Results are summarized in Figure 30.

Increase in service life in %

	without ADFORS GlasGrid	with ADFORS GlasGrid
Allowable stress ε6	113	124,7
Traffic PL/Hour	143 468	233 161
Increase in service life in %	0	+ 61,5%

Figure 30: Quantified benefit of the ADFORS GlasGrid interlayer

Result of the test verified that ADFORS GlasGrid in the bituminous concrete structure increases the value of epsilon6 (ε6) from 7,5% to 12,3% (average 10%) compared to the initial value of beam without grid. For the assumptions, the life of BBSG / ADFORS GlasGrid complex is increased by about 60%. Allowing 60% more traffic pass on the ADFORS GlasGrid reinforced section compare to standard solution.

5.5. Recyclability of interlayer after lifetime

The investigation on the milling susceptibility was performed on the test track at the Institute of Road and Traffic Engineering of the RWTH Aachen University. At this test site all pavements have been done according to the RStO[6]. Based on an anti-frost layer and an existing asphalt base course a 10 cm asphalt binder course AC 16 B S was placed. Afterwards, the asphalt reinforcement ADFORS GlasGrid 200kN (means the stiffest and most robust interlayer) was installed according to the product application guidelines. At last a 4 cm thick surface layer of SMA 8 S was built on the top. To investigate the influence of the asphalt reinforcement ADFORS GlasGrid on the removal of the asphalt construction, a cross-layer milling depth of 6 cm was chosen, so that the asphalt overlay and the upper part of the binder course including the reinforcement grid were picked up by the milling machine in a single step. Figure 32 shows the milling process in the reinforced area of the asphalt pavement.

- **The milling tests and the pursued milling depth could completely be realised.**
- **There were no adverse effects at all on the milling process from process engineering point of view during the milling operation.**
- **The milling drum showed no obvious features in terms of adhered or entangled fibre strands.**
- **The milled material showed a fine piece size distribution, of which the glass fibre strands were uniformly distributed in the asphalt granulate.**
- **An analysis at five samples resulted in an average fibre length of about 14 cm with a medial fibre content of about 1.0 M.-% related to the total mass. The strands were between 2 and 20 cm long.**

Figure 32: Milling the reinforced area

- No adverse effects at all on the milling process from process engineering point of view.
- By the side of the milling drum, no adhering fibre material was observed.

Figure 33: Asphalt granulate

- The glass fibre strands were uniformly distributed in the milling material (asphalt granulate)

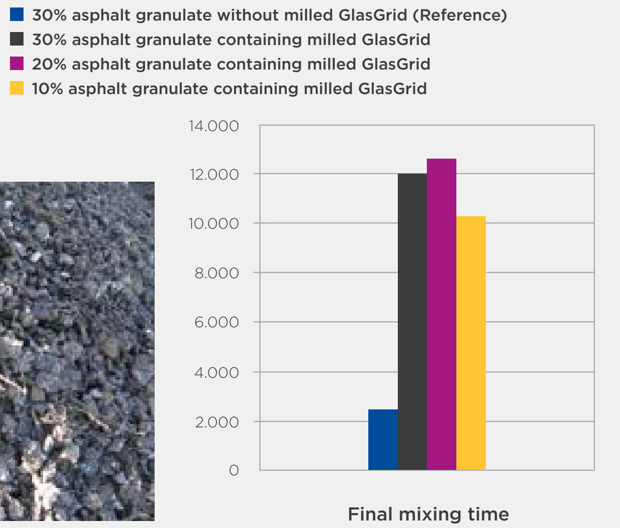


Figure 34: Numbers of loading cycles to failure (180sec mixing time, +5 °C)

- 5X higher the number of loading cycles to failure if add to recycled asphalt mix

The fatigue behaviour at low temperatures was considered as the evaluation criteria, which is addressed by means of cyclic tension tests according to EN 12697-46. **Furthermore, it can be seen that even small amount of milled glass fibre added to the new asphalt mix results in a considerable higher number of loading cycles compare to unreinforced specimens.**

5.6. Interlayer environmental innocuousness

Use of any material in the construction must follow the principle of the harmlessness to the environment. Any product which possibly contains the substances or components harmful to the environment must be removed from the job site.
General assumptions are, that polymeric raw materials are not water-soluble and hence do not affect soil or groundwater. There are water-soluble, flushing or edulcorating additives like stabilisers, auxiliary materials or pigments. These substances are in particular the reason of the demand of the verification of environmentally innocuousness.

To verify ADFORS GlasGrid environmental harmless, chemical analysis following M Geok E [FGSV-2016][7] and EAG-EDT [DGGT-2005][8] was performed.

Test was carried out at GEOscope GmbH & Co. KG, Germany. This verification can be given via ingredients and declaration of environmentally innocuousness on the safety data sheet for the corresponding product or via a chemical analysis. Both sources mentioned above are describing a procedure for this purpose. The procedure is referring to methods for the preparation of samples and the analysis mentioned in attachment 1 of BBodSchVO-2009[9]. Organic and inorganic substances are measured and must be under described limits.
Final criterion in the test is the development of the total TOC from the first eluate to the fifth eluate. The critical value for the total TOC in the fifth eluate is 20 mg/l and shouldn't be exceeded. See results of the test in Figure 35.

ENVIRONMENTAL HARMLESS

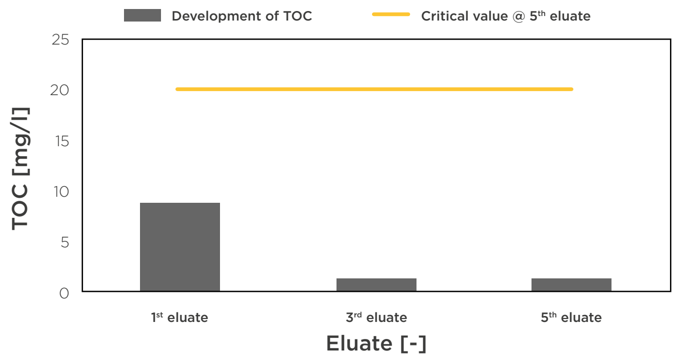


Figure 35: ADFORS GlasGrid Environmental harmeless (TOC limits fulfilled)

The verification of every single value has shown that the ADFORS GlasGrid can be graded as environmentally innocuous following M Geok E. This evaluation is valid for all types of the product family.

6. FIELD HISTORY

ADFORS GlasGrid has a history of more than 30 years of application at various types of locations. Within this period thousands of projects have been completed. Some of these projects have been monitored and examples are summarized below. More references upon request.

6.1. Centralia airport, Exeter, Ontario, Canada

The central apron of this airport had a composite pavement which suffered from PCC reflective cracking and wearing course ageing. The apron was treated with a levelling course, ADFORS GlasGrid asphalt reinforcement and a wearing course in 1993. After 19 years of service still not crack was visible at the pavement surface.

CROSS-SECTIONAL DESIGN

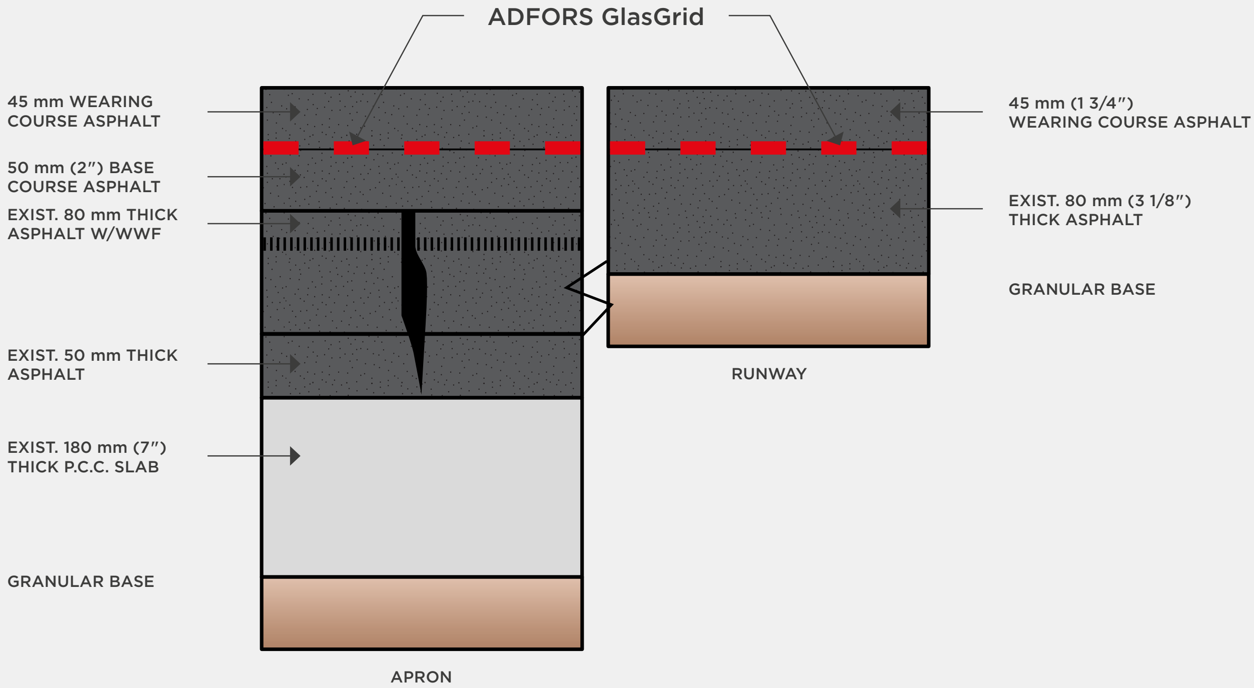


Figure 36: Design

Figure 37: Situation 1992 before treatment

Figure 38: Situation after treatment in 2012

Figure 39: Situation after treatment in 2018

Figure 40: Situation after treatment in 2018

6.2. Highway 96, Lumberton, Texas, USA

This highway is one of the main arteries of Interstate 10 and links Beaumont, Texas with several smaller cities. The road is extensively trafficked by commercial vehicles and heavy trucks. In 1993, an Annual Average Daily Traffic (AADT) flow of 20.600 was recorded.
In order to reduce thermal and fatigue-related reflective cracking, The Texas Department of Transportation approved the installation of ADFORS GlasGrid over the entire width of a one-mile segment in the area most affected by cracking. The grid was placed on the top of a levelling course and covered with a 40 mm Asphalt wearing course. At each end of the test section, control sections constructed without ADFORS GlasGrid were monitored along with ADFORS GlasGrid reinforced overlays for a period of six years. The results are presented in Figure 41 below and clearly show a substantial improvement in the condition of the road sections reinforced with ADFORS GlasGrid, with significantly fewer cracks reflected at the surface.

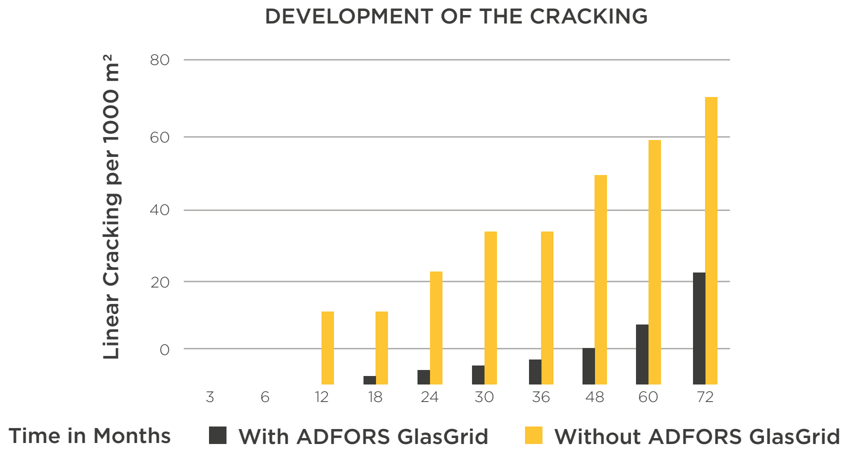


Figure 41: Comparison of condition
of unreinforced road section and reinforced road section with ADFORS GlasGrid

6.3. Highway I-93, Concord, New Hampshire, USA

Figure 42: Situation 2005

Figure 43: ADFORS GlasGrid
installed only in slow lane 2006

Treatment was done in 2006 where ADFORS GlasGrid has been installed on levelling course 25 mm and overlaid by asphalt concrete 40 mm. Performance was evaluated in 2014 showing no cracking in sections with ADFORS GlasGrid compare to unreinforced sections.

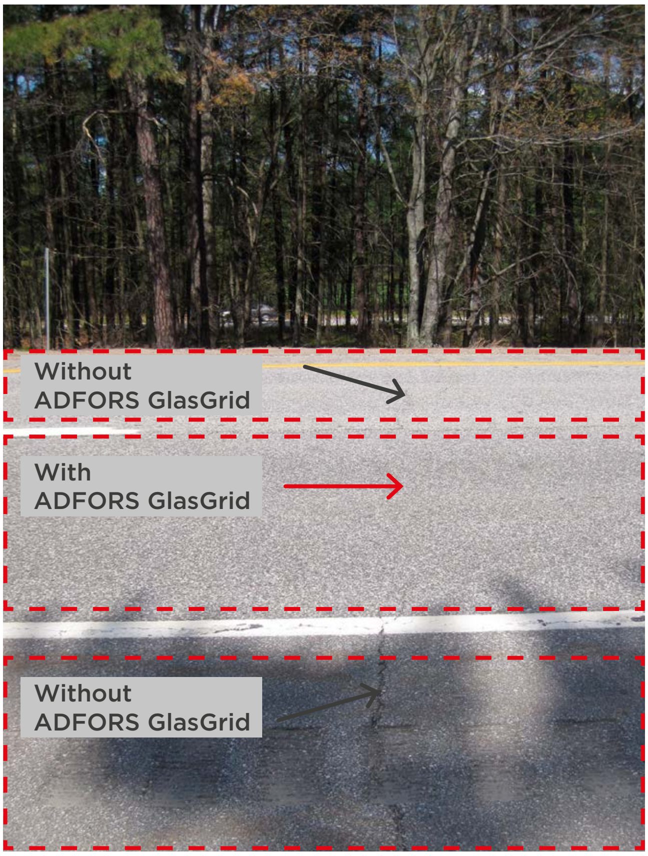


Figure 44: View from left untreated road shoulder with cracks, slow lane treated with ADFORS GlasGrid with no cracking, fast lane untreated with cracking, in 2014

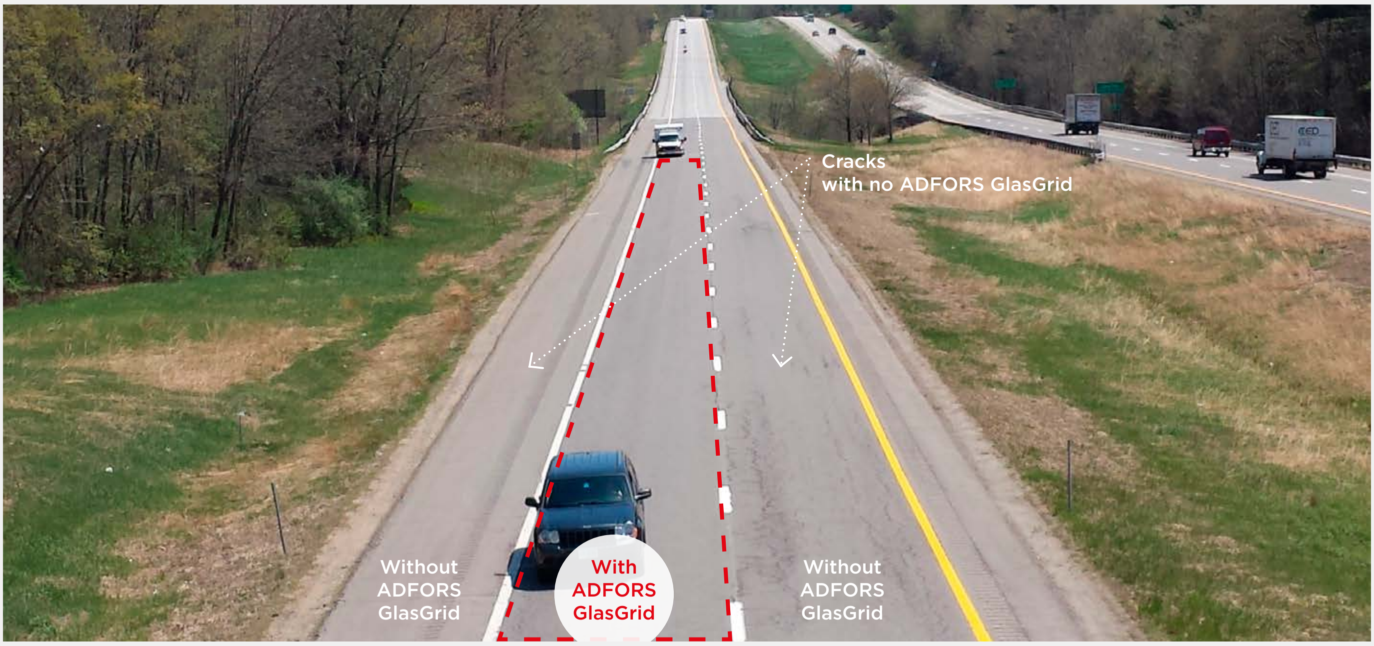


Figure 45: View from bridge – from left untreated road shoulder with cracks, slow lane treated with ADFORS GlasGrid with no cracking, fast lane untreated with cracking, in 2014

6.4. Motorway A50 in the Netherlands

The Dutch Road Administration (Rijkswaterstaat) decided to construct test sections using several types of reinforcement in the overlay of the motorway A50 in the summer of 1992. The 3,2 km long stretch of this 2x2 lane motorway (including emergency lane) showed extensive transverse reflective cracking. The road has a 400 mm thick base consisting of cement stabilized sand (28-days compressive strength of about 8 MPa), which is resting on a sand subbase/subgrade. The pavement was constructed in 1971, using 160 mm of asphalt surfacing on the cement treated base. The pavement was overlaid for the first time in 1981 by a 45 mm thick overlay. The overlay of 1992 had a thickness of 50 mm. The aim of the Regional Office Friesland of the Dutch Road Administration with the trials was to get an understanding of the effectiveness in the field of several (in total 5) new or commercially already available reinforcement products/systems which were claimed to delay or arrest crack propagation through a relatively thin asphaltic overlay (50 mm). Before the construction of the overlay in 1992, an extensive set of measurements on crack movements (traffic as well as thermally induced), as well as very detailed crack inspections was carried out. From this work, it could be concluded that on this site reflective cracking due to temperature cycles was the dominant factor. In this study reflective cracking due to cracks in a cement treated base needed to be mitigated. The Figure 46 shows the results after 12 years of monitoring.

ADFORS GlasGrid has been showing superior performance in retarding the thermal cracking from PCC slab rehabilitated pavement.

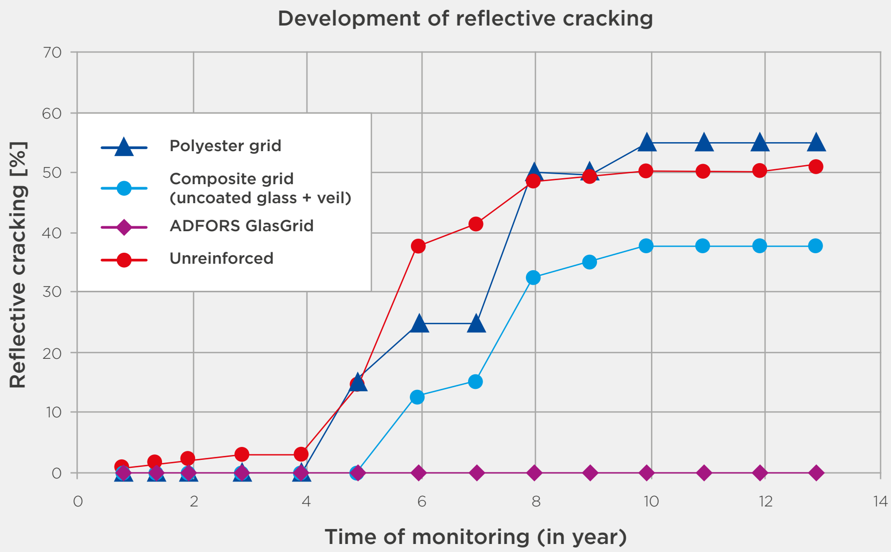


Figure 46: Reflective cracking result after 12 years of monitoring

6.5. Atatürk International Airport Istanbul, Turkey

Project: Atatürk International Airport Runway Rehabilitation
Product: ADFORS GlasGrid GG100
Quantity: 300.000 m²
Installation date: May 2010
Overlay design:
4 cm SMA-19 mm nominal
6 cm HMA-19 mm nominal
6 cm HMA-19 mm nominal
ADFORS GlasGrid GG100
10 cm CRL-19 mm nominal

Project details:
A major overall reinforcement and expansion of the runway, which included significant volumes of fill to correct the pavement profile, needed to be completed. The old PCC was removed and reinstated with ADFORS GlasGrid reinforced ACC. The result was a longer and wider runway that has the ability to handle heavier aircraft loadings.

Figure 47:
Installation of ADFORS GlasGrid
at Atatürk Airport in 2010

Figure 48:
Installation of ADFORS GlasGrid
at Atatürk Airport in 2010

7. MATERIAL PROPERTIES

Products installed in the pavement structure must be designed to be easy and correct to install in real project conditions. Key summary of required Installation aids allowing grid to be installed on surface are summarized in Figure 49.

		Grids		Composite Grids	SAMI Grids	
ADFORS GlasGrid interlayer		GG	TF	CGL	CG	PG
Interlayer Function		R	R	R/STR/B	R/STR/B	R/STR/B
Installation benefits	Self-adhesive	•	•			•
	Incorporated bituminous layer					•
	Incorporated bonding film[12]		•			
	Install on milled surface			•	•	•
	Install on existing or new surface	•	•			

Figure 49: ADFORS GlasGrid interlayer systems

NOTE:
• – recommended key properties
R – reinforcement function
STR – stress relief function
B – interlayer barrier function

There are three main categories of geogrids classified by method of installation. Such recommendation may vary due to individual material properties. All ADFORS products properties are available upon request (TF, PG product lines).

7.1. Grids

These grids are applied on flat/smooth new surfaces or on existing surfaces with minor damage only. Adhesion layer on the underside of the grid is used for grid bonding to the surface. This layer is activated by pressure – e.g. by roller. The tack coat is applied after grid installation for bonding of asphalt layers in volume specified by the design. It is recommended to add 0,1–0,3 kg/m² of tack coat residual asphalt according to manufacturer´s recommendation for filling of asphalt structure and the installed grid and bond the asphalt layers. Self-adhesive product is defined by adhesive backing as part of the product without using any tack emulsion before application or nails to fix the grid on the surface. Minimum requirements for adhesive product are defined by chapter 8.7. "Adhesion test". Material not meeting requirement cannot be consider as self-adhesive as could due to lack of adhesion/fixation cause damage to the geogrid and asphalt layers during paving process.

Grids (self-adhesive)						
		METHOD	UNITS	GG50	GG100	GG200
Material properties	Mesh size (centre to centre)		mm	25 x 25	25 x 25 12,5 x 12,5	25 x 19
	Coating – grid protection			Elastomeric polymer	Elastomeric polymer	Elastomeric polymer
	Mass per unit area	ISO 9864	g/m²	205	405	603
Mechanical properties	Grid protective coat softening point	EN ISO 3146	°C	≥230	≥230	≥230
	Elasticity coefficient of used material		MPa	73.000	73.000	73.000
	Tensile strength (MD x XD)	EN ISO 10319	kN/m	55 x 55 - 5	115 x 115 - 15	115 x 215 - 15
	Tensile resistance at 2% strain	EN ISO 10319	kN/m	46 x 46 ± 10	95 x 95 ± 20	95 x 180 ± 20
	Secant stiffness at 1% strain (MD x XD)	EN ISO 10319	N/mm	2.200 x 2.200 ± 200	4.600 x 4.600 ± 600	4.600 x 8.600 ± 600
	Tensile elongation (MD x XD)	EN ISO 10319	(%)	≤3/3	≤3/3	≤3/3
Use/performance	Adhesive surface			pressure sensitive	pressure sensitive	pressure sensitive
	Adhesive test		N	≥90	≥90	≥90
	Reuse	Certified report		Recyclable	Recyclable	Recyclable
	Residual strength after installation damage test	EN ISO 10722	%	≥85	≥95	≥95
	Design function	EN 15381		R	R	R

Figure 50: ADFORS GlasGrid grids

7.2. Composite Grids

These grids are applied primarily on milled surfaces of rough structure up to 8 mm of milling cuts. For this purpose, the grids have a light weight non-woven textile on the underside. The tack coat is applied on road surface and the grid with the geotextile is applied onto it. The top asphalt layer can be applied after development of the tack coat. Tack coat dosing must be adapted to design parameters and absorption capability of the geotextile. The total volume should consist of the amount defined by the design for layer bonding, plus the volume according to absorption properties of the non-woven textile. Absorption properties of the textile differ for individual textile types and local installation conditions. In general, it is recommended to add approximately 0,3–0,6 kg/m² of residual asphalt to the total amount of tack coat according to manufacturer´s recommendation. Such installation may be considered with adjusted procedure also for installation on smooth surface.

Composite Grids						
		METHOD	UNITS	CG50L	CG100L	CG200L
Material properties	Mesh size (centre to centre)		mm	25 x 25	25 x 25	25 x 19
	Coating – grid protection			Elastomeric polymer	Elastomeric polymer	Elastomeric polymer
	Mass per unit area	ISO 9864	g/m²	239	439	637
	Textile weight	ISO 9864	g/m²	≤40	≤40	≤40
Mechanical properties	Grid protective coat softening point	EN ISO 3146	°C	≥230	≥230	≥230
	Elasticity coefficient of used material		MPa	73.000	73.000	73.000
	Tensile strength (MD x XD)	EN ISO 10319	kN/m	55 x 55 - 5	115 x 115 - 15	115 x 215 - 15
	Tensile resistance at 2% strain	EN ISO 10319	kN/m	46 x 46 ± 10	95 x 95 ± 20	95 x 180 ± 20
	Secant stiffness at 1% strain (MD x XD)	EN ISO 10319	N/mm	2.200 x 2.200 ± 200	4.600 x 4.600 ± 600	4.600 x 8.600 ± 600
	Tensile elongation (MD x XD)	EN ISO 10319	(%)	≤3/3	≤3/3	≤3/3
Use/performance	Reuse	Certified report		Recyclable	Recyclable	Recyclable
	Residual strength after installation damage test	EN ISO 10722	%	≥85	≥95	≥95
	Design function	EN 15381		R/STR/B	R/STR/B	R/STR/B

Figure 51: ADFORS GlasGrid composite grids

7.3. SAMI Grids

These grids are applied primarily on milled surfaces of rough structure up to 8 mm of milling cuts where additional grid properties are required in order to develop a hydro-insulation layer. The application is the same as in the previous paragraph, however the non-woven textile is of higher basis weight depending on the design and therefore the additional tack coat must be applied reflecting the local conditions and design specification. Absorption properties of the textile differ for individual textile types and local installation conditions. The amount of tack coat must be increased depending on properties of the geogrid, the non-woven textile and type of tack coat by 0,6–1,4 kg/m² of residual asphalt according to manufacturer´s recommendation. Such installation may be considered with adjusted procedure also for installation on smooth surface.

SAMI Grids						
		METHOD	UNITS	CG50	CG100	CG200
Material properties	Mesh size (centre to centre)		mm	25 x 25	25 x 25	25 x 19
	Coating – grid protection			Elastomeric polymer	Elastomeric polymer	Elastomeric polymer
	Mass per unit area	ISO 9864	g/m²	335	535	733
	Textile weight	ISO 9864	g/m²	≤140	≤140	≤140
Mechanical properties	Grid protective coat softening point	EN ISO 3146	°C	≥230	≥230	≥230
	Elasticity coefficient of used material		MPa	73.000	73.000	73.000
	Tensile strength (MD x XD)	EN ISO 10319	kN/m	55 x 55 - 5	115 x 115 - 15	115 x 215 - 15
	Tensile resistance at 2% strain	EN ISO 10319	kN/m	46 x 46 ± 10	95 x 95 ± 20	95 x 180 ± 20
	Secant stiffness at 1% strain (MD x XD)	EN ISO 10319	N/mm	2.200 x 2.200 ± 200	4.600 x 4.600 ± 600	4.600 x 8.600 ± 600
	Tensile elongation (MD x XD)	EN ISO 10319	(%)	≤3/3	≤3/3	≤3/3
Use/performance	Reuse	Certified report		Recyclable	Recyclable	Recyclable
	Residual strength after installation damage test	EN ISO 10722	%	≥85	≥95	≥95
	Design function	EN 15381		R/STR/B	R/STR/B	R/STR/B

Figure 52: ADFORS GlasGrid SAMI Grids

8. REALIZATION

The following steps present a general recommendation aiming for providing quality installation of the geogrid. Installation of a specific product should be consulted with the Saint-Gobain ADFORS manufacturer or its technical representative, who can provide detailed and updated installation and handling instructions.

8.1. Preparation and road surface conditions

- Do not start with installation of geogrid until evaluation of actual condition of road surface and completion of all necessary repairs.
- Seal all potholes, cracks up to 3 mm to 8 mm deep in an admissible manner depending on the defect type.
- In the case depth of defects exceeds 8 mm, apply at least 20 mm levelling layer prior to installation of geogrid.
- Level all irregularities and make sure the surface is clean and dry.
- Road surface temperature during installation of the geogrid must be within the range of 5 °C to 60 °C.
- Local instructions should be in line with the temperature range specified for installation of asphalt layers.
- Do not install the geogrid in rain or if precipitations last during installation of the top layer.
- Prior to installation of the geogrid the surface must be cleaned mechanically by brushing and vacuum cleaning, including removal of oil, vegetation, dust, earth and other contamination.
- No extra charges related to surface cleaning will be applied to manufacturer or seller of the grids.
- If surface preparation is within responsibility of other parties, notify the chief engineer/project manager or the site supervisor in the case of improper surface preparation. Do not start with installation of the geogrid until correction of all issues.
- Cracks should be marked and documented before installing the geogrid and after installation of levelling layer. Identification and registration of cracks will facilitate finding location of cracks and centring of the geogrid properly on each crack as needed for local installation, unless the design specifies areal application of the geogrid.

8.2. Material storage

- Before application, store unopened packages in vertical position in a dry, sheltered environment free of dust, pollution and high humidity in order to prevent distortion or contamination.
- Store the product under temperatures ranging from minus 30 °C to maximum 80 °C and relative humidity under 85%.

8.3. Grids

- Geogrids must be applied by trained personnel.
- Make machine or manual installation of the geogrid with the adhesive layer on the underside as to adhere it to the base.
- The geogrid must be applied as a flat surface without folds or roller waves. Manual brush can be used to press down and smooth the surface. In sharp curves the grid and the overlapping strips must be folded in the finisher driving direction (shingle).
- If any such fold is larger than 25 mm, cut it and overlap in the top layer laying direction.
- Ensure good adhesion by pressing the surface with a brush or roller in order to prevent later roll wave development on the material.
- Run over with a rubber coated roller. Keep the roller clean.
- Apply the tack coat and apply the top layer of asphalt after the tack coat develops.
- Cover with hot asphalt mixture; the asphalt surface after compaction must be at least 40 mm thick.
- The whole geogrid system must be covered with asphalt on the same day as grid application.

8.4. Composite and SAMI Grids

- Geocomposite must be applied by trained personnel.
- Apply the tack coat according to design documentation and based on consultation and recommendations of the manufacturer/supplier.
- The general recommended final tack coat spray rate should accommodate range of potential project/ environmental local conditions, type of geotextile and type of emulsion. Recommended is polymer modified tack coat with minimum 60% bitumen content.
- Install the product so that the side with non-woven textile is on the underside and capable of absorbing the tack coat.
- The geocomposite must be applied as a flat surface without folds or roller waves. Manual brush can be used to press down and smooth the surface. In sharp curves the grid and the overlapping strips must be folded in the finisher driving direction (shingle).
- If any such fold is larger than 25 mm, cut it and overlap in the top layer laying direction.
- Apply the geogrid immediately after application of the tack coat in order to ensure required absorption of bitumen to the textile. Press the material down with a brush or a roller to ensure proper adhesion and prevent later roll wave development.
- Run over with a rubber coated roller. Keep the roller clean.
- Cover with hot asphalt mixture; the asphalt surface after compaction must be at least 40 mm thick.
- The whole geogrid system must be covered with asphalt on the same day as grid application.
- Installed grid which improperly adhered to the base due to high humidity or contamination of the surface should be replaced at the expense of the contractor (implementing company).
- The grid can be applied directly on milled road if the depth of mill cuts does not exceed 6 mm. In case of deeper cuts apply the levelling layer first and consequently install the geogrid.

8.5. Important instructions

- If used glass fibres as a base grid material it can irritate skin and therefore workers must wear appropriate work gloves when handling and working with the grid.
- Cut the grid with a sharp carpet knife during installation by structures and sewage inlets.
- The grids must be applied with minimum folds. This problem can be avoided by proper tensioning of the grid during rewinding. If any such fold is larger than 25 mm, cut it and overlap in the top layer laying direction. Press the fibreglass grid immediately so that the top part of the fold absorbs the tack coat. Both parts must be penetrated.
- The grid will not adapt to curves. Therefore, install shorter pieces of the grid in curves.
- Joints between role ends must be overlapped within the length of 100 to 150 mm or as recommended by the manufacturer. Make sure the overlap is applied in the direction of asphalt application and that tack coat is applied between individual layers of the overlap.
- Longitudinal overlapping must be at least 50 mm long, unless specified otherwise by the manufacturer.
- The grid must be installed over sewer holes, inlets and other structures and consequently cut out.
- Only construction and emergency service vehicles can drive over the grid at the speed of up to 20 km/h before application of the cover layer. In the case of grid damage by running of vehicles replace and substitute the damaged parts with new material as recommended by the manufacturer.
- The installed grid must be protected against damage before covering with top layer.
- Apply a thin layer of asphalt or sand locally in order to prevent adhesion of the tack coat on tires.

8.6. In-situ quality check

- Testing and inspection should be provided by a representative (technical supervisor) of the investor. Notify the chief engineer 72 hours prior to testing.
- Testing and inspection should be provided by an independent laboratory.
- Adhesion test to verify self-adhesion function of supplied grid must be done prior paving. During construction provide a minimum of one test per 300 m² of surface area and record result in kg. If material is not fulfilling requirements in chapter 8.7. should be removed from the site as not adhesive material.

8.7. Adhesion test

- Place 1 m² of fibreglass grid on properly prepared and flat levelling layer representing the design condition.
- Activate the adhesive by rolling over with a roller or by application of sufficient pressure for adhesive activation.
- Geogrid has to adhere to the surface only by its adhesive backing. Not tack coat or any joints and nails can be used to fix the geogrid.
- Use a calibrated spring-balance and attach the hook to the centre of the grid.
- Pull perpendicularly up from the surface until the grid starts to get loose.
- Record the result in kg.
- If the result is 9 kg or more, you can start with application of the cover layer. If the grid slips or shifts, interrupt installation immediately and consult the condition with grid supplier. If adherence lower than 9 kg is detected, do not continue in installation without implementation of adequate correction action.
- The test should be provided for each 300 m² of geogrid installed.

8.8. Services provided by the manufacturer, supplier

It is recommended to have a manufacturer´s representative present at the installation site at the commencement of asphalt reinforcement system installation. The contractor/implementing company should notify this representative good in advance.

8.9. Protection

- Protect the installed product for the entire duration of works until project completion.
- Repair or replace damaged product before finishing installation of the top layer(s).

9. DISCLAIMER

- The installation of any asphalt reinforcement interlayer shall follow the local regulations for asphalt road construction.
- This guideline outlines recommendations for a quality installation and is based on familiarity with the product, and the consolidation of decades of project site experiences.
- If you have any questions or unique installation parameters, do not hesitate to contact us.
- Warranty claims cannot be based and forced on present information in this guideline. Each project should be consulted with Saint-Gobain ADFORS technical specialist.

In as much as Saint-Gobain ADFORS has no control over installation design, installation workmanship, accessory materials, or conditions of application, Saint-Gobain ADFORS does not warrant the performance or results of any installation or use of ADFORS GlasGrid. This warranty disclaimer includes all implied warranties, statutory or otherwise, including the warranty of merchantability and of fitness for a particular purpose. The purchaser and/or user should perform its own tests to determine the suitability and fitness of the product for the particular purpose desired in any given situation.

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10. REFERENCES

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Saint-Gobain ADFORS is a global company within the Group Saint-Gobain. We are an industry leader in the manufacture and distribution of a wide range of reinforcement fabrics. We offer a diverse selection of products, including some of the world's best-known reinforcement brand names.

Our worldwide manufacturing plants ensure reliability, quality and cost-effective material supply, while our research facilities and global sales offices deliver world-class service. We are committed to providing innovative solutions to your challenges and to developing breakthrough products.

Final Consideration

The installation of any asphalt reinforcement interlayer shall follow the local regulations for asphalt road construction. If you have any questions or unique installation parameters, do not hesitate to contact us.

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glasgrid.cz@saint-gobain.com
www.glasgrid.com/eu

SAINT-GOBAIN

SAINT-GOBAIN ADFORS CZ s.r.o.
Sokolovská 106
570 01 Litomyšl • Czech Republic
Tel. : +420 461 651 111
Fax : +420 461 651 231
glasgrid.cz@saint-gobain.com
www.adfors.com

CE 1021-CPR-040/15-1
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