

# RESEARCH ON GEOGRIDS IN ASPHALT PAVEMENTS

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## INTRODUCTION

A proper road network is crucial for the economy of a country and even an entire continent. For the primary system, the motorways, this implies that its usage should be safe, the arteries should be spread around the major economic centres and there should be enough capacity for a steady and undisrupted traffic flow. For the secondary system, the rural roads, this implies that the width and bearing capacity should be such that there are no limitations for the transport and distribution of goods from/to local factories and customers.

From the sixties until the eighties of the 20<sup>th</sup> century, the basis of the primary road network has been built in Western Europe. Since then the focus is on maintenance. Due to the increased load (cargo weight) per truck axle, the introduction of super-single tyres, the continuously growing traffic numbers and the political difficulties to achieve widening of roads, the individual layers of pavement structures are degrading at a faster rate, while there is in fact no time frame left to do structural maintenance. Also there is the desire that pavements should last longer and when a maintenance treatment on a specific jobsite is necessary, it should be carried out in a short(er) period of time. Furthermore, maintenance intervals for pavements should become more accurately predictable, so they can be planned better in combination with other works on for instance bridges, safety barriers, dynamic traffic management infrastructure, etc. With respect to the rural roads, it has become clear that because of the reduced budgets (or lack of priority with respect to other topics in a city household), more cost-effective ways to upgrade pavements are needed.

From the foregoing it can be concluded that in modern societies there is a clear need for reliable, robust and cost-effective (structural) maintenance technologies for roads. The (right) use of grids in asphalt layers can certainly meet this demand.

## HISTORY OF GRIDS IN BITUMINOUS LAYERS

During the 1960's the first applications on the use of grids in asphaltic layers have been reported in the USA. The experience with the steel welded fabrics, which came from the concrete building industry, was positive from the effectiveness point of view. However, this type of reinforcement was more or less impossible to place and remove. This was the reason that it died.

In the early nineteen-seventies a synthetic grid was tried in the Netherlands. Problems were reported with respect to the installation, the lack of bond (adhesion) with the surrounding asphalt and the anchorage. Market penetration was also not successful, because of insufficient know-how about the mechanism behind these products; road authorities were for instance trying to check the degree of improvement by means of deflection measurements or rolls were too narrow (creating pullout problems). Last but not least, at that time the focus in the road sector was on new roads.

Around 1985 several different types of grid products successfully entered the market in the Netherlands. These consisted of polyester, polypropylene, glass and steel. All products in fact originated from other fields within the construction industry. This is also the reason that in the early days some failures took place with some products, because they were found not to be suited for the quite special demands in case of the application in an asphalt overlay. Some suppliers offered products which could not be installed properly; they were copied from the earthworks industry without realising this. It meant that some products were pulled back from the market or improved by the manufacturer. Since the 1990's reinforcement by means of grids, Fig. 1, is an accepted method to tackle reflective cracking in asphaltic pavements in the Netherlands.

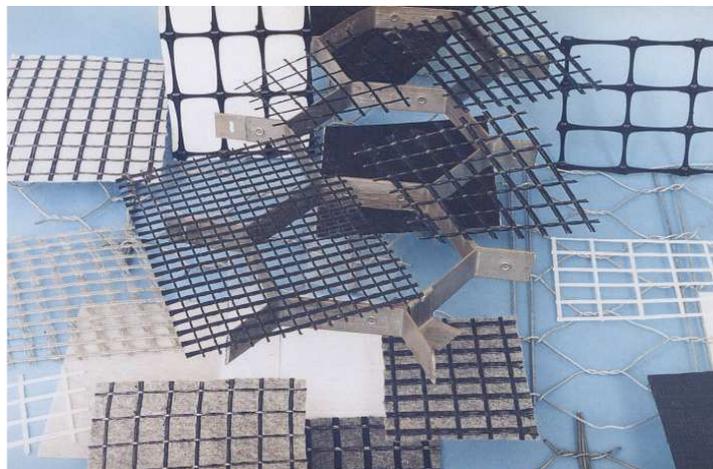


Figure 1. Asphalt grid reinforcement available on the market around 1999

## PHENOMENON OF REFLECTIVE CRACKING IN ASPHALT PAVEMENTS

Many pavements, the life of which are thought to be extended by means of a new surface course, reveal soon after construction of this overlay a crack pattern similar to that which was visible in the old existing surface (RILEM 1989, 1993, 1996 and 2000). This propagation of cracks or joints from the old pavement into and through the overlay is commonly known in the field of pavement engineering as “reflective cracking”, Fig. 2. It occurs in all types of pavement structures (flexible and semi-rigid/composite) and imposes heavy strains on national and local road authorities. This is because cracks in pavement surfaces allow water penetration into the structure (weakening its foundation), cause ravelling at the edges of the crack (thus breaking windshields of cars), increase the roughness (thereby disrupting comfort and creating dynamic loadings) and also generate noise and vibrations. Since filling cracks with bitumen is not a durable option (must be repeated after each winter), is unsafe for motorists and creates poor esthetics, a better alternative is required. More than twenty years of experience has shown that in general (but not always) grid reinforced overlays can be a good and cost-effective solution.

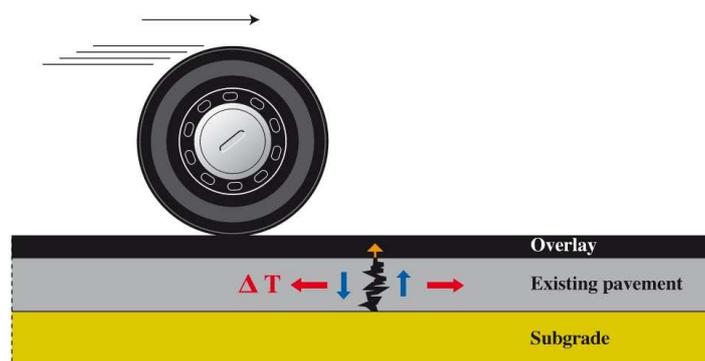


**Figure 2.** Typical reflective cracking on a cement treated base (left) and concrete slabs (right)

Depending on a number of factors, reflective cracking can be caused by the following mechanisms, de Bondt (1999):

- Traffic (especially during cold periods)
- Daily temperature cycles (extreme)
- Seasonal temperature variations (summer/winter)
- Shrinkage of soils in dry periods
- Downward subsoil movements (uneven settlements)
- Upward subsoil movements (frost heave)

The first three mechanisms are the major ones worldwide, Fig. 3.



**Figure 3.** Worldwide active reflective cracking mechanisms

In the case of traffic, the crack initiation phase as well as the crack propagation phase within the overlay mixture are both of importance for the overall life, whereas in case of temperature cycles the crack initiation phase is the dominant factor, Brooker *et al.* (1987) and de Bondt (2000).

Based on proper investigations and analyses (also in-situ), it is possible for an experienced, well-educated pavement engineer to deduce which mechanism has been or will be active on a specific site, de Bondt (1999). It is important to perform this work, because for example depending on the type of loading, an asphalt mixture (an elasto-visco-plastic material) responds differently with respect to the phenomenon cracking. Also, the effect of maintenance options and via this, their cost-effectiveness, strongly depends on the specific project circumstances/details.

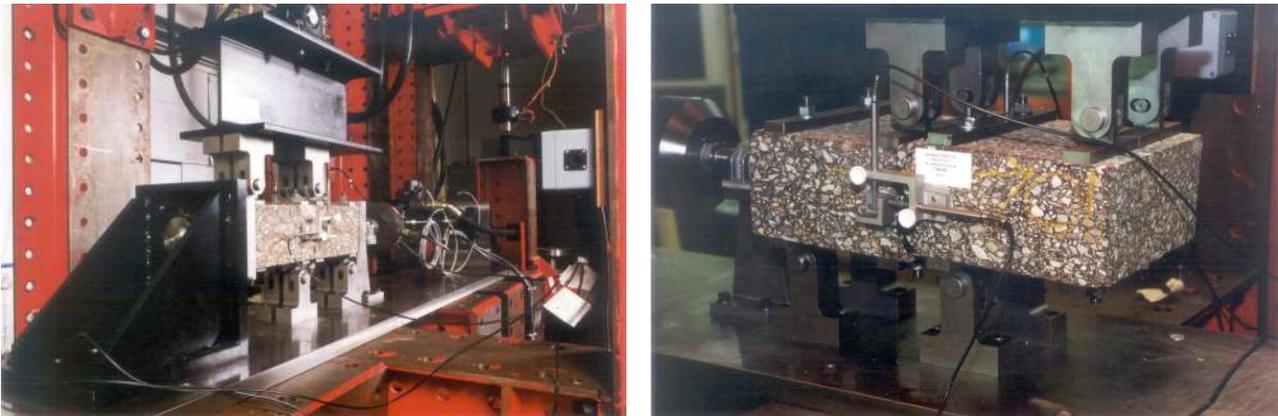
## MECHANISMS OF ASPHALT REINFORCEMENT

The effect of a geosynthetic grid reinforcement in asphalt depends on the:

- Type and severity (movement) of the cracks/joints
- Characteristics and nature of loading of the pavement structure
- Properties of the geosynthetic (mechanical, durability, etc.)
- Anchorage (bond) method/procedure
- Quality of installation (including the paving operation)

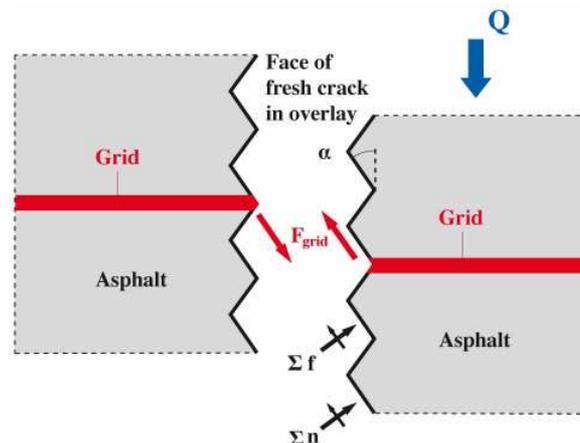
It has been found by means of finite element computations, laboratory work and (limited) field experience that depending on the factors listed above, a lifetime increase of up to a factor 5 compared to a similar unreinforced overlay can be achieved. A factor  $x$  means that it takes  $x$  times more traffic load repetitions or temperature cycles, before a reflected crack is visible at the surface of the overlay. Typical grid reinforcements, with tensile strength values from 15 up to 250 kN/m<sup>1</sup> (according to EN 15381:2008), are mainly activated during the crack propagation phase in case of traffic loading (in bending as well as in shearing mode). In case of thermally induced reflective cracking the reinforcement is already activated during the crack initiation phase.

The fact that grid reinforcement in asphalt is also beneficial under so-called pure mode II shearing action in a (new!) crack in an overlay has become apparent from extensive fundamental research carried out by de Bondt at Delft University of Technology, de Bondt (1999). To get an insight into the effect of the presence of reinforcement on the load carrying capacity of cracks in asphaltic mixtures, shear tests were performed on plain as well as reinforced cracks, Fig. 4. The specimens were taken from a pavement trial section specially made for this purpose; the asphalt layers were laid down and compacted with ordinary (routine) construction equipment. First of all, aggregate interlock tests were performed under different confining pressures. The measurement data enabled the development of a theoretical saw-teeth model (including a specific crack inclination angle  $\alpha$ ) explaining and describing the behaviour.



**Figure 4.** Newly developed 4-point shear testing device for plain cracks (left) and reinforced cracks (right)

From a series of shear tests on reinforced cracks, it could be concluded that these types of cracks can transfer shear without externally applied normal pressure. This is possible, because adequately anchored reinforcement is capable of generating a normal force  $\Sigma n$  at the crack (via crack dilatancy), which allows friction  $\Sigma f$  along the planes of the crack to occur, Fig. 5. The contribution of the (indirectly) generated friction along the teeth of the crack (by the grid) is even larger than the one generated by the reinforcement directly. It is obvious that this mechanism only occurs if asphaltic mixtures are composed with proper sized mineral aggregates (grading > 2 mm); in case of sand mixes there is no shear carrying capability of a reinforced asphalt crack in pure mode II.



**Figure 5.** Schematic illustration of forces acting in a reinforced crack under external shear loading

From measurements on several commercially available reinforcing systems (in 1999), at a temperature of 20 °C, it appeared that not only the axial product stiffness EA of a reinforcement is an important factor, but also its resistance to pullout and its anchorage length. The way in which the junctions between the ribs/strands of a reinforcing product are manufactured controls if pullout restraint is developed via bearing of the mineral aggregate of the asphalt mixture in the grid apertures or via friction and adhesion along the strands. It is important to realise that the component adhesion in generating pullout restraint is a typical aspect of the application of grids in asphalt layers; this because bitumen sticks (and its shear stiffness is temperature and rate displacement dependent).

It also became clear that the required anchorage length in the field and in fact also during laboratory tests, depends on the type of loading (traffic or temperature cycles) and testing temperature. This effect is often underestimated by laboratories, which do not analyse the mechanics of their test set-up before starting to work with it; it leads to unwanted biased results. Adequate mobilisation of the reinforcement is an important issue.

## DESIGN OF REINFORCED ASPHALT PAVEMENTS

The current situation in practice with respect to design is that:

- Generally applicable (accepted and standardised) design methods for (reinforced and unreinforced) maintenance treatments are not available
- Design is often based on personal experience (often not documented) or extrapolated laboratory simulation data; the latter is not always allowed since circumstances differ in the field from project to project
- Tender specifications are incomplete or not representative
- Criteria for the evaluation of alternatives are missing
- Product characterisation is not uniform

Since the beneficial effect of a given grid reinforcement highly depends on the type of cracking mechanism which is dominant on a particular jobsite and is also extremely case dependent (especially the quality of the soil plays an important role), proper design based on (extrapolated) laboratory experiments and/or accelerated load testing data is not possible. The requirements for any design model or procedure for grids in asphaltic pavements, which is meant to be used for routine purposes, can be summarised as follows, de Bondt (2006):

- It should tackle the right cracking mechanism on the jobsite which is analysed
- If relevant, the traffic characteristics (number, type of vehicles, speed) specific for the jobsite need to be taken into account
- If relevant, the temperature variations in time (day/night, season) specific for the jobsite have to be incorporated
- The pavement and soil properties relevant for the jobsite should be used
- In case of maintenance, the existing condition of the pavement has to be one of the input parameters
- The mechanical and durability characteristics of the grid (the in-situ stiffness/strength including the potential effect of damage during installation) must be incorporated in sufficient detail
- The interaction between grid and surrounding asphalt mixtures has to be taken into account
- The computational engine (procedure), which is behind the design method should be described in such a way that it can be evaluated (judged) by third parties
- The method should have been validated with long-term monitoring field data
- Life-cycle costing analyses should be possible in an easy way
- For an average jobsite the (user-friendly) design process should not take too long for an average skilled pavement engineer who is familiar with the mechanistic-empirical approach.
- The end result of the design process should be tender specifications and a sketch of the laying plan of the grid. The tender specifications should be in a generally accepted format, where product description is according to international standards (CEN, ISO)

Furthermore, it is recommended that parameters which give an indication about road user costs and driving comfort are outputted. This because it is interesting for clients to know the effect of maintaining the pavement with a grid on well-known parameters such as the Present Serviceability Index or the International Roughness Index.

From the questionnaire performed by the COST-countries within COST-project 348, it is clear that only a small number of design models and procedures is available, of which not one really already meets all the requirements which are mentioned above. This is also caused by the fact that the design of maintenance treatments for cracked pavement structures, in which no grid is included, is a subject which hardly has had any attention in the road construction community in the past. In almost all cases the selection of e.g. the mixture properties and the thickness of an asphaltic overlay are based on empirical knowledge. This implies that relatively new options (such as for example grids) need a very long waiting period before they can be judged, which is unacceptable from an economical point of view. Design models and procedures which have been found to be sometimes used in practice at the moment or have just become available, are (listed in alphabetical order): ARCDESO (de Bondt *et al.*, 2005), BITUFOR (Vanelstraete *et al.*, 2000), OLCRACK / THERMCR (Thom, 2000).

All in all, it is clear that there is still a lot to do in terms of design procedures for grid reinforced asphaltic pavements.

Unfortunately, the state of design practice in standard pavement engineering is quite poor; most design decisions are still based on experience only. Quite often this experience is only personal, not even based on scientific long-term field investigations. Even in case of the relatively well defined situation of new pavement construction, the mechanistic-empirical design approach is still not generally used.

### CURRENT AND POTENTIAL FIELD OF APPLICATION

At the moment grid reinforced asphalt is used in overlays on flexible pavements which show alligator (fatigue) cracking, transverse (low-temperature) or block cracking, longitudinal top-down cracking, edge stability cracking problems or wide (open) longitudinal construction joints. Furthermore, they are applied in asphaltic overlays on transverse and longitudinal joints in PCC-slabs or on top of continuously reinforced concrete. Also there are applications in asphalt overlays on top of cracked asphalt on cement treated bases; this is in fact on old reflected cracks. Applications along road widenings (the transition new/old) can be found in all pavement types.

Depending on the application area, the characteristics of the grid system and the quality of the installation procedure, there have been of course positive and negative experiences in the field. This also has to do with the fact that not each product is suited for each situation. Designers and product specifiers should realise this and suppliers have to take their responsibility. Figure 6 shows the results of long-term field performance monitoring on a semi-rigid pavement structure.

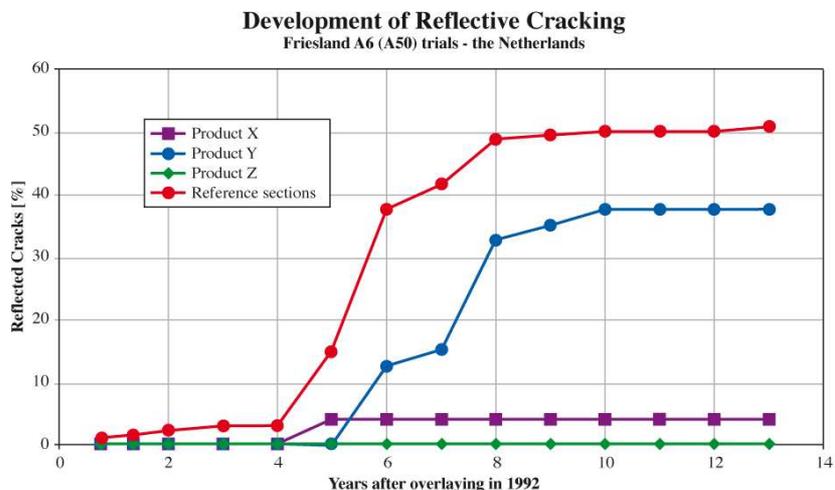


Figure 6. Long-term grid performance data from the motorway A6 (A50) in the Netherlands

Hardly ever it is decided to apply grid reinforcement in a new construction of the pavement types which were mentioned above. This has to do with the impossibility to back-up the reinforced case with a design or it is simply not (seen as) a cost-effective option. Out-of-the-box thinking might suggest that in case of for example a 30-year PPP-project the introduction of a grid (with a certain minimum product stiffness and durable pullout resistance) at the bottom of only the slow lane (lane 1) of a new or reconstructed motorway, creates a perpetual pavement without the need for an entire cross-section of thick asphalt across all lanes (lane 2, lane 3 and the emergency lane), Fig. 7.

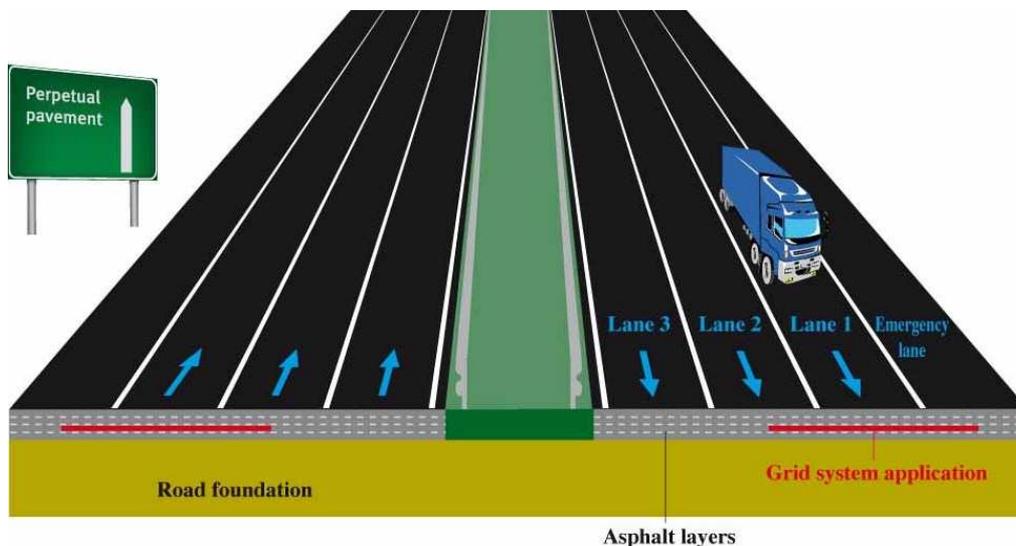


Figure 7. Potential grid application in large scale new construction

## **INNOVATIVE EXAMPLES OF APPLICATION**

Areas in asphalt pavement construction where grids are successfully applied outside the standard way of using them, are for instance invisible joint systems, slab rocking details and asphalt solar collector systems. In case of invisible joint systems (de Bondt, 2002) specific grids are used in different asphalt layers on top of each other (up to even 5 layers). This to make a jointless and maintenance free transition between a bridge and the road possible; it is done in such a way that an asphalt plug joint (which has a short life) is not necessary. In case of slab rocking details a combination of special grid, polymer modified bitumen and asphalt mixture is composed in such a way, that it is not needed to take out a PCC-slab which shows rocking (large differential movement) at the joint. In asphalt solar collector systems, grids are used to enable first of all the installation of the pipes; during the service life of the road they make sure that the structural integrity is kept.

All innovative applications mentioned above have in common that they need specialised 3D finite element computational analyses for design. It is thus not easy. For grid manufacturers it is difficult to invest in these applications, since the squared meters of sold product are small. However, for the end-user (and society) these innovative applications can be of extreme benefit.

## **CONCLUSIONS**

During the past 20 years it has become clear that grid reinforcement applications in asphaltic pavements are clearly solving the needs in our society. There is even more potential. To materialise this potential, improve the cost-effectiveness and avoid the risk of bad (non-suited) applications, research needs have come up in recent time. The main issues are design and adequate product characterisation. An efficiently organised and knowledgeable international industry/university/government consortium should be able to cover these needs.

## **FUTURE RESEARCH NEEDS**

Based on twenty years of experience in fundamental research (including laboratory testing), design, practical application/installation, long-term field performance, product development, standardisation and strategic market overviews, the following research needs can be listed:

- Design procedures for the major areas of application (linked to unreinforced design tradition/methods)
- Development/improvement of a series of laboratory test methods to fully characterise the mechanical and durability properties of new (unknown) high-quality and low-quality (surrogate) grids entering the market (to become part of some form of CEN type testing)
- Perform (and report!) long-term field performance studies to validate (future) design procedures
- Clarify the issue of the optimum adhesion between (cracked) pavement layers; this currently creates unnecessary confusion in practice
- Development of an adapted 4-point bending fatigue test for reinforced asphalt samples, which can be carried out in each asphalt laboratory which is doing the standard European Union 4-point bending fatigue test for asphalt mixes
- Studies on cost-benefit ratio's on grid applications in new asphaltic pavements (whole-life costing)

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