DEVELOPMENT AND APPLICATION OF A NEW TYPE OF GEOGRIDS

G. Gandin[1] and P. Rimoldi [2]

[1] *Manager, Alpe Adria Textil Srl, Udine, Italy (e-mail: pggand@alice.it)*
[2] *Technical and Managing Director, World Tech Engineering Srl, Milano, Italy (e-mail. wte.rimoldi@fastwebnet.it)*

Abstract: During the last two years a new type of geogrid has been developed in Italy, with the aim of allowing the most efficient use of reinforcement even in difficult situations. The new geogrid is produced by weft insertion warp knitting of high tenacity polyester fibres, making the primary mesh, and a secondary mesh knitted with thin HDPE fibres. While the primary mesh, with 20 to 60 mm apertures, provides the tensile strength and the interlocking capacity for coarse particles, the secondary mesh, with 2 to 4 mm apertures, provides interlocking capacity for fine particles, retention of fines on the face and strong adhesion to the subgrade when sprayed with bitumen or tack coat. The new geogrids have been already applied in several important projects: reinforced soil walls and embankments, road and airport asphalt paving. The paper introduces the properties of the new geogrid and illustrates the main projects where it has been successfully used, pointing out the problem that have been solved and showing the final results of its application in different conditions.

Keywords: geogrid, properties, interaction, pavement, reinforced slope, reinforced soil wall

INTRODUCTION

Geogrids form a family of products, specifically engineered for soil and asphalt reinforcement, whose main characteristic is the open structure, with apertures allowing interlocking of soil granules. Apertures can have square, rectangular or elliptical shape, usually with a minimum dimension of 20 mm. Experience shows that this kind of structure is inadequate in some cases: soils with very wide gradation, including both fine and large particles; reinforced structures with coarse fill and vegetable soil at face; asphalt reinforcement, where the small solid surface doesn't allow to fix properly geogrids to asphalt course. The experience gained by the Authors in the production, design and installation of geotextiles and geogrids, particularly for road / airport pavements and soil reinforcement applications, led to the concept and manufacturing development of a family of innovative geogrids. The new products have been developed in Italy, with the aim of allowing the most efficient use of reinforcement even in the above mentioned difficult situations. The new geogrids have been already applied in several important projects: reinforced soil walls and embankments, road and airport asphalt paving.

This paper introduces the properties of the new geogrid and illustrates the main projects where it has been successfully used, pointing out the problem that have been solved and showing the final results of its application in different conditions.

REINFORCEMENT OF ROAD AND AIRPORT PAVEMENTS

In the sector of reinforcement of road and airport pavements (AASHTO, 1981, Barksdale *et al.*, 1989, Cancelli *et al.*, 1996, Gregory and Bang, 1994) the Geosynthetics market basically offers two possibilities:

a) geogrids with open structure, produced either by weaving, knitting, extrusion or bonding; their main characteristics are:
   - excellent interlocking capacity;
   - weak adhesion to the support surface, due to the large open area (making 80 – 90 % of total area);
   - difficult installation due to adhesion to the wheels of machinery produced by resiliency and/or pantograph effect;

b) nonwoven geotextile – geogrid geocomposites, with following main characteristics:
   - good interlocking capacity;
   - easiness of installation, thanks to the high dimensional stability;
   - detrimental separation of the above and bottom asphalt layers.

Then a conceptual development started, with the idea of taking profit both of the interlocking capacity of geogrids and of the easiness of installation of geotextiles; finally Alpe new type of Geogrid, ARTER® GTS A, was developed specifically developed for asphalt reinforcement. This product is able to provide the high mechanical characteristics of polyester Geogrids and at the same time to guarantee an adhesion to the support similar to the one of nonwoven Geotextiles.

Such result has been obtained thanks to a network of thin threads, introduced in the textile phase into the main meshes of the geogrid, as shown in Fig. 1. The new geogrid is produced by weft insertion warp knitting of high tenacity polyester fibres, making the primary mesh, and with a secondary mesh knitted with thin polyester fibres. While the primary mesh, with 35 x 35 mm apertures, provides the tensile strength and the interlocking capacity for coarse particles, the secondary mesh makes a gossamer with 2 – 4 mm apertures, which provides interlocking capacity for fine particles, retention of fines on the face, strong adhesion to the subgrade when sprayed with bitumen or tack coat.

The new Geogrid is produced with the K-DOS method, that is by warp knitting with weft insertion of high tenacity polyester fibers, making the primary mesh, and textile fixing of junctions: in this way the Geogrid structure, having

fixed junctions, afford an optimal dimensional stability and a high capacity of aggregate confinement. These geogrids perfectly adhere to the support layer without creating a separation between the binder and the wearing course: the asphalt of the wearing course is confined by the Geogrid, while being perfectly bonded to the binder. The gossamer dramatically increases the dimensional stability of the knitted geogrids, thus making the product light and easy to install.

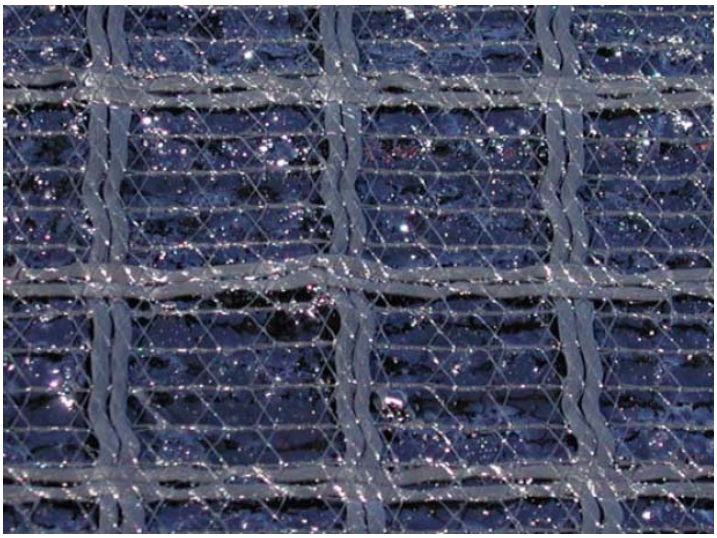

Figure 1. The structure of the new geogrid for asphalt reinforcement

The textile structure of the geogrids is entirely covered with a protective polymeric coating, made up of EVA (Ethylene Vinyl Acetate). This polymer presents a low softening point at 135°C approx. During the lay-down of asphalt the EVA layer partially melts, thus contributing to the adhesion of the Geogrid to the sub-layer. For increasing the easiness of installation the geogrids are rolled with the interposition of a very thin polyethylene sheet (see Fig. 2), which allows the product to be kept intact and affords an easy and quick installation.

When the wearing course and the binder are not perfectly bonded, the shear stresses produced by acceleration and mainly by braking of heavy vehicles cannot be entirely transmitted to the binder, thus the wearing course may be subject to local delamination. Delaminated areas are then subject to increased stress and degrade quickly, with the formation of permanent rutting, cracking and deformation of the road surface.

The new geogrids avoids such problem, since they provide an effective reinforcing element, able to provide adequate resistance to fatigue stress produced by vehicles passage, without impairing the resistance to shear stresses. As a result of the introduction of the new geogrids the life time of the wearing course is enhanced by a factor of 3 to 10, as a function of asphalt and subgrade characteristics, and of the quality of installation.

The use of the new geogrids is suitable for:

- repaving of deteriorated old asphalt layers;
- widening of roads and airport runways and taxiways;
- joints of bridge decks and road pavings;
- areas prone to differential settlements; and
- reconstruction of paving over excavation areas.

Summarising, a geogrid with a secondary, gossamer type mesh, affords:

- excellent lateral confinement of aggregate;
- excellent adhesion to the support surface thanks to the thin filaments of the gossamer;
- easiness of installation thanks to high dimensional stability; and
- no separation between asphalt layers.

Installation tests proved that the conceptual assumptions are true and that no special work is required, hence even untrained workers can lay the new geogrids. The new geogrids are now produced both with polyester and with glass fibres. Standard grades present 50 x 50 kN/m or 100 x100 kN/m tensile strength, with 10 % peak elongation for polyester and 2 % peak elongation for glass fibres. Standard rolls are 4.40 m wide and 100 m long. From the beginning of production to date, a total of 800.000 sq.m. have been installed, for the reinforcement of roads, highways, and airports pavements, almost equally divided between polyester and glass fiber geogrids.

Installation

The new geogrids for asphalt reinforcement are rolled with the interposition of a very thin Polyethylene sheet (see Fig. 2), which allows to keep the product intact and affords an easy and quick installation. In fact, by pulling the

Polyethylene sheet, the Geogrid unrolls uniformly on the support layer, without creating folds or waves. Therefore two workers can lay down a whole roll of geogrids, 100 m long, in few minutes (Fig. 3).

Figure 2. By pulling the Polyethylene sheet, the geogrid unrolls uniformly on the support layer, without creating folds or waves

Figure 3. Two workers can lay down a whole roll of geogrids, 100 m long, in few minutes

The procedure for the installation of the new geogrids for asphalt reinforcement is the following:

1) keep geogrid rolls in a dry and clean area; don't stack rolls to avoid deformations;
2) mill the old wearing course;
3) smooth and clean the surface: remove dust and oil spills; fill the grooves larger than 20 mm; main irregularities shall be eliminated either by milling or filling with 20 mm asphalt; milling grooves shall not be deeper than 10 mm;
4) spray the tack coat, preferably made up of pure bitumen, at a rate of 0,30 – 0,50 l/sq.m., or of cationic emulsion, 50 % bitumen and 50 % water, at a rate of 0,80 – 1,20 l/sq.m., through a tank truck with spraying bar (Fig. 4); sprayed bitumen temperature shall be lower than 145°C; sprayed area shall be 200 mm wider than the Geogrid;
5) in case of bitumen emulsion, wait about 1 hour until the emulsion breaks and the water completely evaporates;
6) lay the geogrids, taking care to keep it smooth on the support layer, without folding or waving: first position the roll; fix the roll, at the beginning with large headed nails or by laying a small quantity of asphalt on the first metre (Fig. 5); unroll the geogrid by pulling the Polyethylene sheet (Fig. 2); smooth down any remaining folding and waving; cut the geogrid around any hitch or trap (Fig. 6); overlapping of contiguous rolls shall be 100 mm wide along side edges and 150 – 200 mm at roll end, with the new roll placed below the edge of the previous roll; rolls shall be unrolled along the road axis or anyway in the same direction of the finisher movement; in case of uneven surface, in order to avoid lifting of the geogrid, or folding and waving during the next passages of truck and finisher, the geogrid may be pre-tensioned by pulling (by means of a winch or a truck) a steel bar passing in and out the geogrid meshes at the end of the roll;
7) in case of curves or special geometries, cut the geogrid in size pieces, including the overlapping width as above described; in case of formation of waves, cut the geogrid at the centre of the wave, fold the two edges, overlap and fix down;
8) lay the wearing course by means of the finisher (Fig. 7); usually the geogrid doesn't suffer damages or lifting caused by the tyres; anyway trucks and finisher shall move very slowly and smoothly over the geogrid, avoiding sharp curves and braking;
9) roll the asphalt to the finished thickness with a steel drum roller;
10) smooth asphalt around hitches and traps and complete with all details.

The whole procedure can be carried out with non qualified labour and with common machines for asphalt works.

Figure 4. Spraying of the tack coat through a tank truck with spraying bar

Figure 5. A small quantity of asphalt allows to keep the geogrid roll in the right position

Figure 6. Manual cut of the geogrid around hitches or traps

Figure 7. Laying the asphalt by a finisher

Case History

Recently, the new geogrids have been used for the reinforcement of the new wearing course within the repaving works of Buttrio street, in Pozzuolo del Friuli town (near Udine, north eastern Italy). One week after installation asphalt samples have been bored through a Milwaukee Cat. No. 4004/4 machines, with 160 mm diameter borer (see Fig. 8). Both samples of asphalt reinforced with the new geogrids and samples of unreinforced asphalt have been bored. In fact an area has been repaved with the same asphalt, unreinforced, following the same procedures as for the reinforced one. Samples have been sent to a Laboratory for performing index tests and mechanical tests.

Visual examination of samples allowed to get important preliminary results:

- both the reinforced and the unreinforced samples show good adhesion of the wearing course to the binder (Fig. 9);
- the new geogrid is perfectly incorporated into the asphalt and no sign of separation between the wearing course and the binder appears (Fig. 10).

The installation of the new wearing course, reinforced with the new geogrids, yielded the following results:

- during rolling the asphalt, confined by the Geogrids, doesn't slip forward in front of the roller, hence waving of the asphalt surface doesn't occur;
- as a consequence, asphalt surface results smooth and uniform (Fig. 11);
- the new wearing course shows an excellent adhesion to the milled subgrade;
- geogrids didn't suffer any damage during installation and are therefore able to provide the wearing course with an effective confining and reinforcing action;
- the wearing course is actually reinforced and affords higher resistance and durability.

Preliminary results of laboratory tests on reinforced and unreinforced asphalt samples showed that:

- reinforced asphalt specimens yields a higher breaking load than unreinforced ones;
- reinforced asphalt specimens show a smaller deformation under load than the unreinforced ones;

- unreinforced specimens show, at failure, a single and large cracking, while the reinforced specimens break at higher load and higher deformation, showing a network of finely divided crackings;
- geogrids delay or even eliminate the propagation of cracks upward into the new wearing course, just thanks to the limited width of the cracks;
- geogrids yield, even in the post cracking phase, a high level of resistance to traffic loads for the reinforced course in comparison with the unreinforced one.

Figure 8. Asphalt boring

Figure 9. The unreinforced samples

Figure 10. The reinforced samples

Figure 11. Asphalt surface results smooth and uniform

BASE REINFORCEMENT

After the successful introduction of the new geogrids for asphalt reinforcement, the same type of product has been developed for base reinforcement in road and railway applications. In this case the geogrids are produced exclusively with high tenacity polyester fibres, and coated with EVA. Standard tensile strengths span between 20 and 600 kN/m,

with peak elongation of 10 %. Long term tensile strength, evaluated through creep testing, has been set as 60 % of ultimate strength.

REINFORCED SOIL

For reinforced soil slopes and walls applications a special product has been developed, still with the secondary gossamer type mesh. The commercial name of these new geogrids is ARTER® GTM. This new geogrid is produced by weft insertion warp knitting of high tenacity polyester fibres, making the primary mesh, while the secondary mesh is knitted with thin HDPE fibres. Fig. 12 shows the technical characteristics of this new geogrid:

- DOS knitting technology;
- Longitudinal elements made up of high tenacità polyester yarns, black color, UV treated;
- Transversal elements made up of high tenacità HDPE yarns, black color, UV treated;
- Gossamer made up of HDPE monofilaments, green colour.

This special geogrid has been developed with the aim of having one only product able at the same time to reinforce the soil, to contain the fines at the face, and to support the growing vegetation. Having one only product to install means savings in labour costs, reduced area required for stocking geogrids at job site, reduced visual impact thanks to the prevailing green colour of the geogrid. These geogrids are supplied in 5.30 m wide and 100 m long rolls. Standard grades present 60 kN/m, 100 kN/m, and 150 kN/m tensile strength.

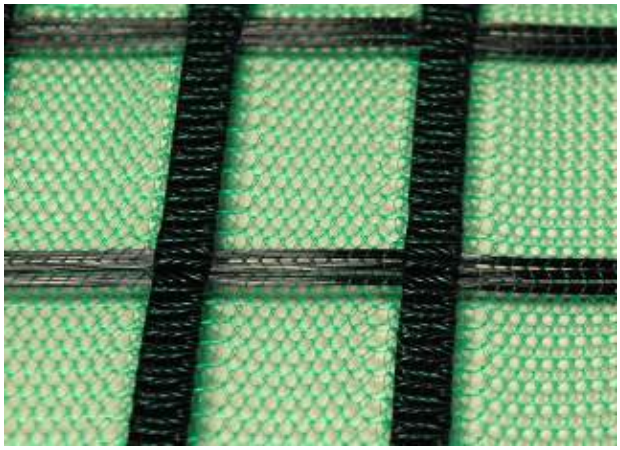

Figure 12. The structure of the new geogrid for soil reinforcement

Figure 13. The new geogrid on the face of a vegetated reinforced slope

Case history

The new geogrid for soil reinforcement has been already used in many soil reinforcement projects. The reinforced soil embankments of regional road S.R. 232 "Panoramica Zegna“ in Cossato (Province of Biella), Piedmont, Northern Italy (Rimoldi et Al, 2008). The Piedmont Regional Road Agency, ARES Piemonte, is building this new stretch of highway, with the aim of bypassing the town centers of Cossato, Vallemosso and Trivero. The Contractor Lauro SpA of Borgosesia (Biella) carries out all the construction works.

The new road stretch crosses many small valleys in the area, hence the design layout includes several tunnels, viaducts, and reinforced soil embankments, showing the following features:

- maximum embankments height: 18.7 m;
- total vegetated vertical face: approx. 12.700 sq.m;
- overall length of reinforced soil embankments: 2,000 m (on 5,200 m total project length).

The tallest embankments have been designed with the cross section composed of three tiers with two horizontal berms; the bottom and intermediate tiers are set at 80° slope, in order to minimize land expropriation, while the top tier is set at 60° slope for better landscaping effects. All reinforced soil embankments have been built using the local soil, mainly made up of silty sand.

The new geogrids have been specified for soil reinforcement: geogrids have a main mesh of 30 mm, with the second mesh of 2 – 4 mm; the gossamer type mesh allows a better interlocking of the silty sand and affords to retain the soil at the face and to provide an excellent medium for supporting growing vegetation. Actual geogrids have 60 kN/m, 100 kN/m, and 150 kN/m tensile strength, according to the height of embankments.

Figures 14, 15, 16 show the size and complexity of the project. It can be noted that the new geogrids are able to retain the topsoil at the face and provide support for hydroseeding, finally affording an excellent quality of the vegetation and naturalization of the reinforced soil embankments.

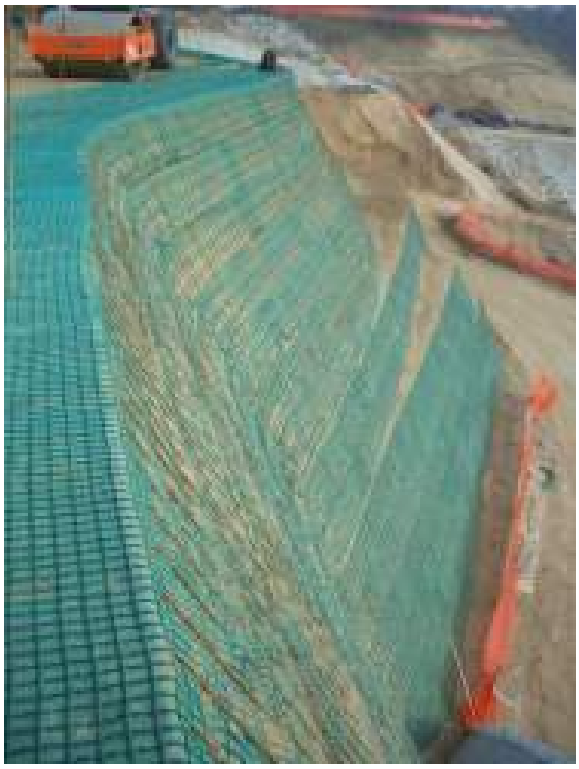

Figure 14. The 18 m high road embankment in Cossato, reinforced with the new geogrid: the green colour immediately affords reduced visual impact

Figure 15. Reinforced soil structures at tunnel exit in Cossato, showing the growing vegetation

Figure 16. Road embankment and wing walls, showing the excellent quality of the vegetation and naturalization.

CONCLUSIONS

A new type of geogrid has been developed in Italy, with the aim of allowing the most efficient use of reinforcement even in difficult situations. The new geogrid is produced by weft insertion warp knitting of high tenacity polyester or glass fibres, making the primary mesh, and with a secondary, gossamer type, mesh knitted with either thin polyester, glass or HDPE fibres. While the primary mesh, with 20 – 60 mm apertures, provides the tensile strength and the interlocking capacity for coarse particles, the secondary mesh, with 2 – 4 mm apertures, provides interlocking capacity for fine particles, retention of fines on the face, strong adhesion to the subgrade when sprayed with bitumen or tack coat. The new geogrids have been already applied in several important projects: reinforced soil walls and embankments, road and airport asphalt paving, base stabilization. The excellent results that have been obtained prove that the double mesh is a very effective way of solving problems when the primary mesh alone is not adequate. Case histories has been illustrated, showing the properties of the new geogrids, pointing out the problem that have been solved, and enhancing the final results of their application in different conditions.

REFERENCES

American Association of State Highway and Transportation Officials, 1981. AASHTO interim guide for design of pavement structures. AASHTO, USA.

Barksdale, R.D., Brown, S.F. and Chan, F., 1989. Potential benefits of geosynthetics in flexible pavement systems, National Cooperative Highway Research Program Report. AASHTO, USA.

Cancelli A., Montanelli, F. and Rimoldi, P., Zhao, A. 1996. Full scale laboratory testing on geosynthetics reinforced paved roads, Proc. Int. Sym. on Earth Reinforcement, Kyushu, Giappone.

Gregory G.H. and Bang S., 1994. Design of flexible pavement subgrades with geosynthetics, Proc. of 30th Symp. Eng. Geology and Geotechnical Eng.

Rimoldi P., Lorizzo R., Pettinau D., Roncallo C., Secci R., 2008. Impressive reinforced soil structures in Italy, Proc. GeoAmericas 2008 Conference, Cancun, Mexico.