# On site test of reinforced freeway with high-strength geosynthetics

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ABSTRACT: The S.G.C. E78 Grosseto-Fano freeway, in the part Siena-Bettolle, crosses, among other things, the alluvial sedimentary environments of Tuscany region characterised by the presence of saturated clay loam soils, which are particularly plastic. Such subsoil conditions, along with the modest height of the embankments –generally less than one-meter high- have required a high-strength geosynthetic under the base of the road structure. During the construction phase of the road, a trial field was prepared, where several plate bearing tests were performed in order to check the influence of various geosynthetics on the deformation modulus. In addition, it was possible to check the geosynthetic influence on the thickness of the road structure base. The aim of this paper is to provide additional information on the practical use of the geosynthetics in road construction as reinforcement.

## 1 INTRODUCTION

The use of geotextiles and geogrids as reinforced and separator layers on the subsoil of the Italian road structures, is by now a well-known and widespread technique and represents an economical and reliable technology.

The influence and the effects due to the presence of geosynthetics in road structures have been extensively studied by numerous authors, when big ruts are allowed (Giroud e Noiray, 1981) and for small ruts (Milligan et al., 1989, Houlsby e Jewell, 1990). In the first case, the considerable soil deformations, even higher than 10 cm, generates a membrane effect on the geosynthetic, which performs reacting against the traffic load and, as a result, with a vertical component limiting and spreading the load transmission on the subgrade. In case of small deformations, the geosynthetic acts absorbing the shear strengths due to the traffic loads that, otherwise, would be transmitted to the subsoil.

Meyer and Elias (1999) have developed a design method for sub-base stabilisation based on the previous studies.

Actually, the geotextile-soil interaction problem is too complex to be approached from an analytic point of view due to the fact that there is not a geometric and mechanical linearity between the acting materials. The Finite Element Method is, in some cases, the only possibility of analysis in non-linear field (Chinni, 1992) because it permits to address all the above aspects. Losa (1996), using the model proposed by Vlasov (1966), has discussed one interesting solution, from a theoretical point of view, even remaining in the elastic linear field.

The presence of numerous variables makes the theoretical solution complicated because it requires the knowledge of many parameters associated with the material constitutions, which are hardly available in normal on site working conditions.

In this cases the on site tests become a direct and efficient way for choosing the most suitable geosynthetic taking in consideration the characteristics of the various soil layers (subsoil, subbase, base, etc) in several climatic conditions.

## 2 ON SITE TEST ON GROSSETO - FANO FREEWAY

The experimentation took place in the widening project of the Grosseto-Fano road, in the area between Siena and Bettolle, at km 27+500. The test field presents soft silt-clay subsoil of poor characteristics with the underground water level close to the surface (approx. at – 0,8 m during the test). Figure 1 shows the set-up of the trial field.

Figure 1. On site work phases

A rectangular area of 9m x 12m was prepared in the following way:

1) Excavation of 0.20 m of soil from the existing ground level;
2) Compaction of the subsoil;
3) Installation of Geosynthetics;
4) Laying of the granular filling soil with various thickness;
5) Compaction of the granular filling;
6) Execution of the plate bearing test;

The bearing test were performed using a circular plate with a diameter of 300 mm. The test results are expressed trough the conventional modulus of deformation ($M_d$), defined by the following equation:

$$M_d = \frac{\Delta p}{\Delta w} \varnothing \quad (1)$$

Where $\Delta p$ is the pressure interval between 0.15 e 0.25 MPa, $\Delta w$ is the settlement variation due to that pressure increasing and $\varnothing$ the plate diameter (300 mm).

Figure 2 shows the configuration placement of the geosynthetics in the test field. The effective area has been divided by 12 modulus of 3m x 3m. Five of them have been left unreinforced to allow a comparative test with the reinforced ones.

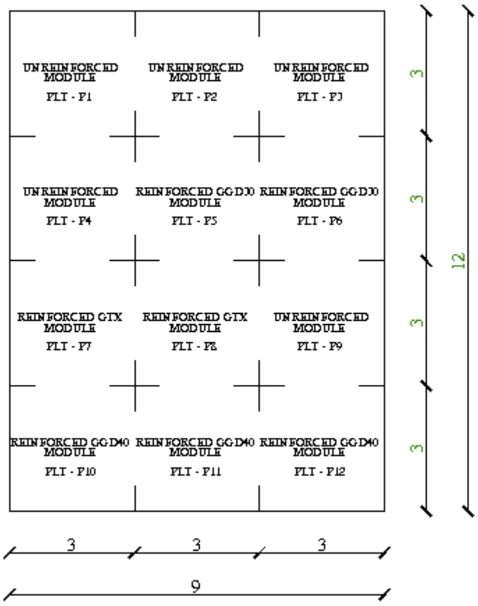


Figure 2. Scheme of module configuration

For every module has been adopted different thickness of granular filling carried out by the successive lifting of thin layers previously installed.

# 3 MATERIALS

The typical section is composed of a granular filling layer (base course material) with thickness variable between 0.15 and 0.50 m, installed on a layer of geosynthetic, which was extended on the subgrade.

## 3.1 *Subgrade*

The subsoil, mainly constituted by loam and clay, was found to have the characteristics as shown in table 1.

Table 1. Subgrade soil parameters

| $w_N$ (%) | $w_L$ (%) | $w_P$ (%) | PI (%) | $S_u$ (kPa) | CBR (%) |
|---|---|---|---|---|---|
| 29.4 | 39.0 | 17.1 | 21.9 | 8.70 | 2.20$^{(*)}$ |

(*) Soaked sample

The subsoil belongs to the A6 group of CNR UNI 10006 classification with passing sieve UNI 0.075 (200 ASTM) of 68.6 % (CL of USCS classification).

### 3.2 *Aggregate*

The granular filling used in the trials comes from the crushing process of the travertin rocks and presents the particle size distribution shown in table 2.

| UNI (mm) | Passing (%) |
|---|---|
| 40 | 100.0 |
| 25 | 98.2 |
| 15 | 89.4 |
| 10 | 61.4 |
| 5 | 42.7 |
| 2 | 27.8 |
| 0.4 | 21.5 |
| 0.18 | 20.1 |
| 0.075 | 19.0 |

Table 2. Sieve analysis of aggregate

The granular filling has not plastic characteristics and belongs to the $A_{1b}$ group of CNR UNI 10006 classification.

### 3.3 *Geosynthetics*

Three types of geosynthetics were used for the trial: two types of a coated aramid geogrid embedded in a thermo-bonded polyester/polyamide non-woven (GGD30 / GGD40) and a woven fabric in Polypropylene (GTX). These two kinds of materials were chosen to compare the performance of a new sophisticated high modulus geocomposite with the PP woven fabric used with good results on the Firenze, Pisa, Livorno freeway (Oliveri et al. - 1996).

The main technical characteristics of the adopted geosynthetics, considering only the reinforcement function at short time, are shown in table 3.

| Type | Reinforce-ment | $\alpha_f$ (kN/m) | $\varepsilon_f$ (%) | $\mu$ (g/m$^2$) |
|---|---|---|---|---|
| GGD30 | Aramid | 30 | 3.5 | 150 |
| GGD40 | Aramid | 40 | 3.5 | 170 |
| GTX | Polypro-pylene | 80 | 15 | 390 |

Table 3. Geosynthetic parameters

## 4 RESULTS OF PLATE BEARING TEST

Table 4 shows the output of the deformation modulus $M_d$ obtained for every area applying the formula (1) and following the configuration of the scheme 2. For every place is indicated the aggregate thickness (t) and the type of reinforcement (if used).

| PLT | t (mm) | Reinforcement | $M_d$ (MPa) |
|---|---|---|---|
| P1 | 230 | No | 17.0 |
| P2 | 230 | No | 14.2 |
| P3 | 200 | No | 13.8 |
| P4 | 300 | No | 15.2 |
| P5 | 300 | GGD30 | 35.0 |
| P6 | 150 | GGD30 | 20.0 |
| P7 | 150 | GTX | 13.4 |
| P8 | 300 | GTX | 28.0 |
| P9 | 500 | No | 20.3 |
| P10 | 220 | GGD40 | 40.5 |

| | | | |
|---|---|---|---|
| P11 | 300 | GGD40 | 57.0 |
| P12 | 500 | GGD40 | 107.0 |

Table 4. Plate Load Test modulus

The allowable deformation modulus for ANAS (Italian bureau for public roads) under the road structure must be higher than 50 MPa. Such values have been reached with the aramid geogrid GGD40 for sub-base course of at least 300 mm thick. Therefore, this thickness can be defined as the minimum sub-base thickness to be install in the present area if a high modulus aramid geogrid of 40 kN/m is used.

The adoption of a woven fabric in PP with high nominal strength (80 kN/m), but also with high strain at break (>15%), does not guarantee the stiffness of the road structure, because the acting loads are insufficient to produce a significant deformation of the soil layers to activate the membrane effect of the geotextile (and, in consequence, to develop high values of its tensile strength).

In the present paper the creep behaviour of the geosynthetics has not been considered. This aspect is important mainly when the material has to perform as reinforcement for a long term. The reinforcement function permits to reduce the sub-base thickness or, keeping the thickness, to increase the service life of the road. In such cases, the geosynthetic is tensioned during the construction phase. From this point of view, aramid as a raw material, has much better performance as compared to the polypropylene: Characteristic tensile strength of aramid about 0,6.$\alpha_{f\text{-}ar}$ (kN/m); Characteristic tensile strength of PP about 0,2 $\alpha_{f\text{-}pp}$ (kN/m); after 100 years (Meyer and Elias - 1999).

Other aspect that has not been taken in consideration is the separation and filtration effect of the geosynthetic layers placed between two different types of soils.

## 5 CONCLUSIONS

Analysing the results summarised in table 4; the following conclusions can be drawn:

1) The existing subsoil, if loaded considering the actual design thickness for the sub-base, cannot ensure the necessary bearing capacity for the road structure;
2) The use of a geogrid with high modulus (low deformations) allows the reduction of sub-base thickness. Therefore less excavation material has to be taken to waste disposals, less granular filling is needed from quarries, less transport movements, less compaction, shorter execution times. In other words, less use of energy and natural resources.
3) In large projects, in which geosynthetics are prescribed as reinforcement, on site plate bearing tests can give further information which can be used to adjust the design solution.
4) When a geosynthetic is used as reinforcement, a relevant parameter is the ratio stress-strain (high E-modulus so very low strains) under service conditions.

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## REFERENCES

Vlasov V.Z. and Leontev N.N. (1966) Beams plates and shells on elastic foundation. Israel Program for Scientific Translation. Tel Aviv.

Giroud J.P. and Noiray L. (1981) Geotextile-reinforced unpaved road design. ASCEE, JGED, No 1 107, No GT9, pp. 1233-1254.

Milligan G.W.E., Jewell R.A., Houlsby G.T. and Burd H.J. (1989) A new approach to the design of unpaved roads – Part I. Ground Engineering. April. pp. 25-29.

Milligan G.W.E., Jewell R.A., Houlsby G.T. and Burd H.J. (1989) A new approach to the design of unpaved roads – Part II. Ground Engineering. November. Pp. 37-42.

Houlsby G.T. and Jewell R.A. (1990) Design of reinforced unpaved roads for small rut depths. 4th International Conference on Geotextiles, Geomembranes and Related Products. The Hague, NL.

Chinni M. (1992) Rinforzo delle sovrastrutture stradali mediante l'utilizzo di geosintetici. Degree Thesis. Bologna University.

Oliveri S., Ucciardo S., Oliverio R., Roberti R. and Russo L.E. (1996) Ripristino con geosintetici di pavimentazioni della superstrada Firenze – Pisa – Livorno. IX Convegno sul tema: Geosintetici nelle costruzioni di terra – applicazioni in Italia. Bologna

Losa M. (1996) Influenza delle membrane geotessili sulle prestazioni delle sovrastrutture stradali. Convegno SIIV, I materiali nella sovrastruttura stradale. Ancona, I.

Meyer N. and Elias J.M. (1999) Design methods for roads reinforced with multifunctional geogrids for subbase stabilisation. German Conference on Geosynthetics "KUNSTSTOFFE IN der GEOTECHNIK". Technical University Munich, D.