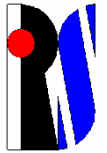


EXPERIMENTAL EVALUATION OF FIBERGLASS REINFORCED POLYMER (FRP) GRIDS FOR ROAD APPLICATIONS



Research Project 2008 – *FibreNet s.r.l.*

Introduction

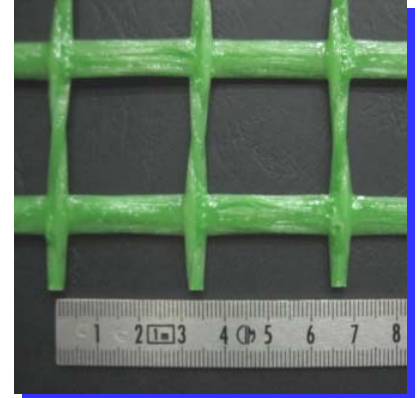
Rehabilitating and reinforcing road surfaces are key tasks for road engineers, who are required to offer adequate solutions depending on the type of distress degradation and propagation, so that the original mechanical properties of a pavement are efficiently restored and, in some cases, upgraded

In fact, both old and new road infrastructures today are known to bear huge traffic volumes and axle loads, which actually accelerate degradation and loss of functional characteristics.

With an aim to rehabilitating and/or improving load-bearing capacity, geosynthetic or metal reinforcements can be introduced between the pavement layers. Reinforcement can be obtained by increasing load-bearing capacity of a pavement or by controlling damage propagation.

A type of geosynthetic materials in widespread use in road applications are grids, which are capable of mechanically increase fatigue resistance, reduce rutting and limiting reflective cracking. The result generated by interposing a grid is heavily dependent on the grid's stiffness and tensile resistance.

This experimental investigation was focused on studying a FRP (fiberglass reinforced polymer) composite grid with 33 mm mesh width. The effects on stiffness, fatigue resistance and shear resistance of double-layered asphalt specimens were studied by means of a laboratory investigation. The aim was to assess and compare with other similar products available in the market the real potential uses of FIBRENET grids in road applications.



Laboratory investigation – Materials and test equipment

1. Equipment for specimen preparation:

- Marshall compactor (mix control);
- Superpave Gyratory Compactor (mix control);
- Roller Compactor.

2. Traditional test methods for mix control:

- Volumetric properties (air void content);
- Marshall test (Marshall stability and stiffness);
- Indirect tensile (or Brazilian) test (Indirect tensile strength).

3. Performance assessment and corresponding measured parameters:

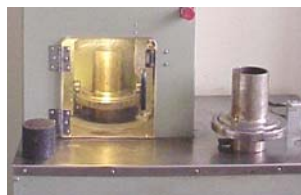
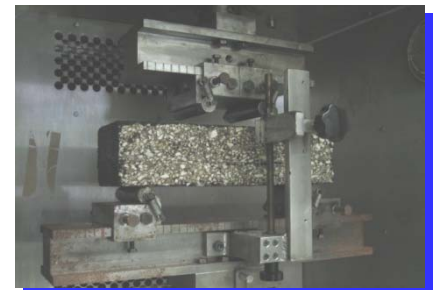
- Interlayer shear tests @ 20°C with ASTRA “Ancona Shear Testing Research and Analysis” equipment (peak and residual interlayer shear stress);
- Interlayer shear tests @ 20°C with LPDS equipment (peak interlayer shear stress without normal stress applied);
- Fatigue tests @ 20°C in four-point bending configuration (cycle number at flex point).

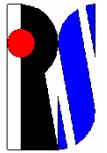
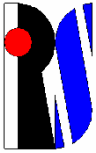
4. Interlayer grid between two layers prepared with:

- Dense graded asphalt mix for wearing course (prepared with traditional bitumen and limestone aggregates).

The grid has been coupled with:

- Traditional cationic bitumen emulsion;
- Modified bitumen emulsion (sbs).





Laboratory testing investigation – Specimens preparation

1. Type of specimens obtained from DOUBLE-LAYERED SLABS

4.5 cm top layer + 3 cm bottom layer, with the following interface configurations:

TE
Traditional emulsion
(0.15 kg/m² residual bitumen)

GTE
Grid + Traditional Emulsion
(0.15 kg/ m² residual bitumen)

GME
Grid + Modified Emulsion
(0.15 kg/ m² residual bitumen)

2. Slab preparation steps:

- Compaction of 1st layer;
- Preparation of interface;
- Compaction of 2nd layer.

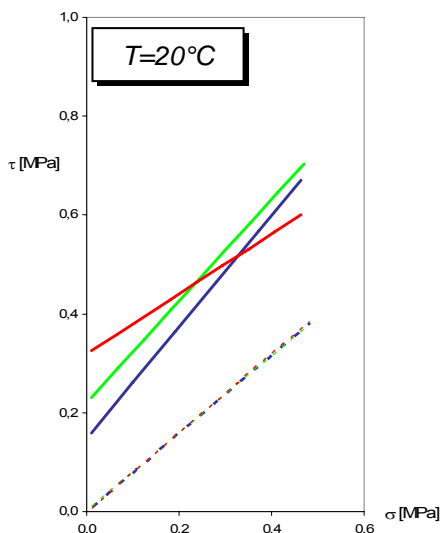


3. Number of double-layered specimens:

- 27 cylindrical cored specimens, 100mm-wide, for ASTRA tests (3 configurations x 3 normal stresses x 3 repetitions)
- 9 cylindrical cored specimens, 150mm-wide, for LPDS tests (3 configurations x 3 repetitions)
- 12 prismatic specimens for four-point bending tests (4 configurations x 3 repetitions)



Result analysis – ASTRA shear tests (UNI TS 11214)



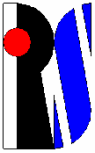
Relative comparisons

Shear tests were carried out with different normal stresses applied to the interface (0-0.2-0.4 MPa) to obtain peak and residual friction envelopes for each interface configuration. The following remarks can be drawn from the results:

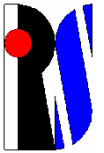
- The values of ϕ_f , residual friction angle remain almost unchanged for all interface configurations (TE, GTE, GME). Once the failure condition is reached, the grid does not significantly change the residual friction between the two sections of the specimen. Moreover, the residual friction angle values are consistent with the ones available in literature for fiberglass grids under the same conditions.
- Because the layers are separated by the meshes of the grid, the cohesion at the interface is reduced as compared to the TE configuration.
- In the GME configuration, such reduction in cohesion is less remarkable than in the GTE configuration. The greater the normal stress applied, the weaker the contribution by the modified emulsion, as shown in the figure by converging GTE and GME envelopes.

	Φ_f	C_0 (MPa)	Φ_p
TE	38,52°	0,319	31,29°
GTE	38,34°	0,147	48,50°
GME	38,14°	0,221	45,79°





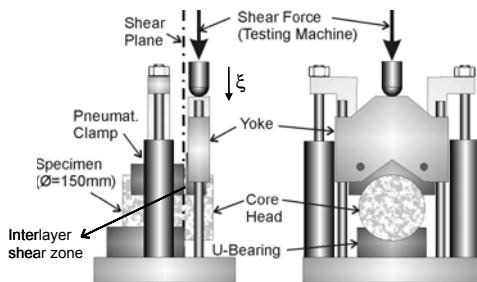
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Result analysis – LPDS shear tests

In order to obtain more representative and complete experimental results, direct shear tests were performed on 150mm-wide specimens, with an equipment called LPDS (*Layer-Parallel Direct Shear* – modified Leutner test). This other test investigation was aimed at finding any possible size effects of mesh size (33 mm) as compared to the size of specimens used in ASTRA tests (100mm wide). The results obtained from LPDS tests confirmed the same results of ASTRA tests, showing that the grid application causes a reduction in shear resistance. Moreover, the modified emulsion provides a higher cohesion contribution.

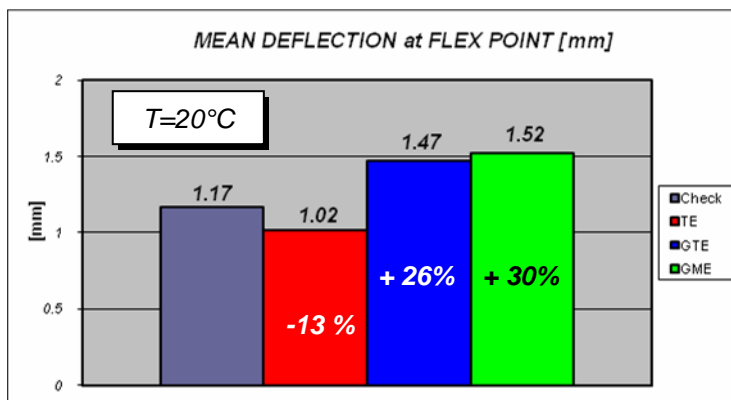
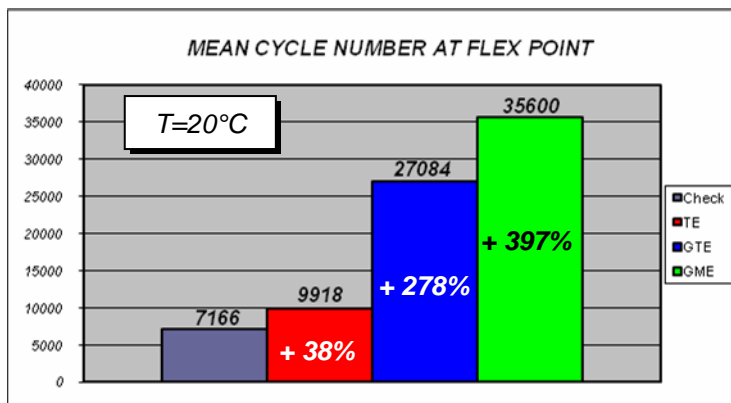


	$\tau_{peak}(N/mm^2)$
Check	0.452
GTE	0.229
GME	0.295

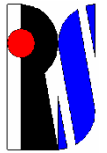
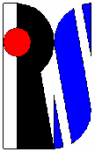


Result analysis – Fatigue tests

The key parameter used when assessing fatigue life in a four-point bending test is conventionally the average number of cycles at the flex point of a curve obtained by representing permanent deformation depending on load cycles. The determination of the flex point, obtained by means of an appropriate mathematical modeling, helps assessing the corresponding number of cycles whereby a double-layered system changes its mechanical behavior. After this number of cycles, the deformation growth is more than proportional. 8-hour-long dynamic tests were performed at 20°C, applying a sinusoidal load with 1-Hz frequency and an amplitude between 1kN (maximum load) and 0.025 kN (preload).



The tests were interpreted by making reference to the results obtained with *check specimens*, with no emulsion or grid at the interface. The results obtained show that the grid tends to cause a remarkable increase in the fatigue resistance of the double-layered system and, coupled with a modified emulsion, to contribute up to 4 times as much as the check configuration. Traditional emulsion (TE) specimens produced a 38% higher number of cycles at flex point as compared to the check specimens and a lower flex point deflection value, that is representative of a higher stiffness of the system. On the other hand, reinforced specimens showed a higher flex point deflection value against a remarkable increase of number of cycles. The increase of the flex point deflection values in reinforced specimens (GTE and GME) as compared to specimens with traditional emulsion (TE) can be due to the weaker bond between layers, as showed by lower cohesion values at the interface. In fact, while the grid grants longer fatigue life of a double-layered system by absorbing tensile stress, it tends to create interface separation/de-bonding, reducing the overall stiffness of the system.



Comparative analysis

The results obtained from the tests performed on FIBRENET grid were compared to other reinforcement types generally used in road applications, and namely:

- Fiberglass-reinforced polyester grid – R1
- Bitumen-coated fiberglass grid, with 12.5mm-sized mesh – R2
- Bitumen-coated fiberglass grid, with 25mm-sized mesh – R3

Shear resistance

The FIBRENET grid, under shear stress, behaves consistently with the other grids that show comparable interlayer shear resistance reductions and better results when used with the modified emulsion.

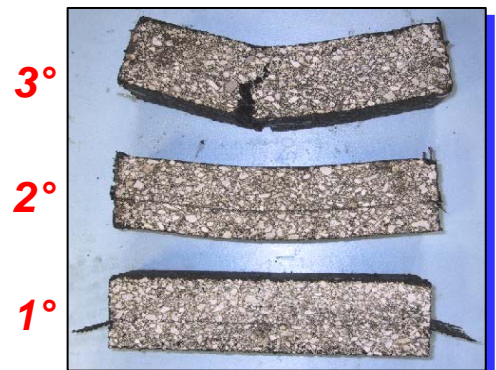
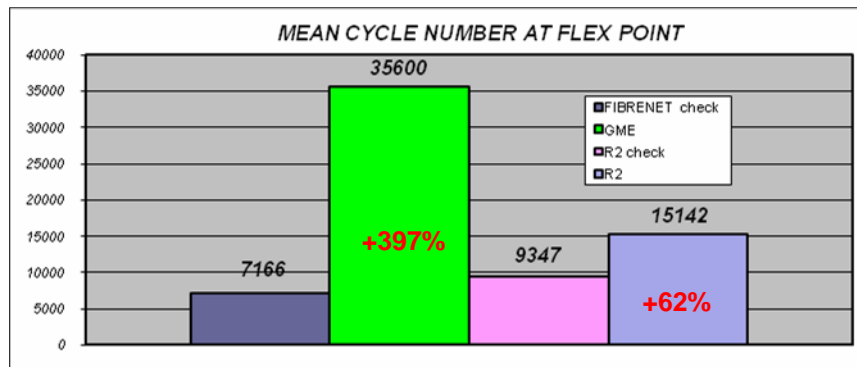
Fatigue resistance

The evolution of bending fatigue deformation in FIBRENET grid differs from the other reinforcements, showing a higher percentage increase in service life compared to the unreinforced check configurations. In fact, the FIBRENET grids prove to offer higher deflection values at flex point resulting from a weaker stiffness of the double-layered system due to the grid.

In order to highlight the high performance of the FIBRENET grid, the diagram hereafter illustrates a comparison in terms of number of cycles at flex point of FIBRENET grid and R2 grid. The picture, related to R2 grid, represents a 3-steps failure behavior:

1° - elastic response; 2° - permanent deformation; 3° - crack growth in the upper layer.

The third step was never reached by FIBRENET grid during the test.



CONCLUSIONS

Several conclusive remarks can be drawn about FIBRENET fiberglass grids, based on the experimental investigation and corresponding results:

1. FIBRENET grid considerably increase the fatigue resistance of double-layered systems, more remarkably than other reinforcement types, because of its high stiffness and tensile strength;
2. reinforced specimens show higher values of failure deformation as compared to unreinforced check specimens
3. like other reinforcement types, FIBRENET grid generate a reduction of interlayer shear resistance, although the combined use of a modified emulsion helps to limit the de-bonding/separation effects and generally offers to a double-layered system higher performances as compared to unreinforced configurations.

Concerning FIBRENET grid, further experimental investigations are planned and consist in constructing real-scale sections to assess the evolution overtime of performances under the real traffic loads and weather conditions, which will be correlated to other laboratory tests.

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