Third International Conference on Geotextiles, 1986, Vienna, Austria

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UNSURFACED ROADS REINFORCED BY GEOTEXTILES—A SEVEN YEARS EXPERIMENT

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LES CHAUSSEES NON REVETUES RENFORCEES PAR GEOTEXTILES — 7 ANS D'ETUDES

This paper presents a final synthesis of the intensive researches on the reinforcement of unsurfaced roads on soft subgrade, which were carried out for seven years in the french laboratories of Ponts et Chaussées (full-scale experiments) and at the University of Grenoble (experiments on a scale model).

Several geotextiles (wowen and non-wowen) and several reinforcement structures were tested with an experimental road on soft subgrade.

A program of 30 cyclic loading tests, following those presented at Las Vegas, has shown the part of geotextile, of subgrade and subbase.

A fatigue relationship for reinforced roads is proposed, which allows to évaluate the reinforcement effect with only one bearing plate test in case of a traficability test.

I - EXPERIMENTATION IN NANCY

The object of the full scale experiment which was realized in the "Laboratoire Régional des Ponts et Chaussées"de NANCY (France) was to compare the efficiency of different reinforcement structures looking for the part of parameters, length of anchoragê, tensile stiffness of geotextile, friction soil-geotextile.

I.1. Description of the site and the tested structures

Four structures have been experimented in addition of a reference structure without geotextile. The reinforcement has been realized either with a geotextile located at the interface subbase-subgrade with a short lateral anchorage (width of geotextile 4.50 m) or a long lateral anchorage (width of geotextile 7.0 m) or with two geotextiles, the first located at the base and the second at the middle of the subbase or with a container (thickness half of the subbase).

The subgrade soil is a clay of cohesion measured with scissometer between Cu = 30 kPa and Cu = 50 kPa. To make easier the comparison with the different sections, the theorical high of subbase has been considered constant and equal to Hr = 0.40 m. The subbase is a crushed limestone 0/60 of characteristics C'= 0 kPa Ø'= 47°.

The geotextile characteristics have been determinated by an initial predimensionment effected with the Recommandations of the French Comity of Geotextiles and Geomembranes (1) making vary the tensile stiffness and friction of geotextile in order to analyze the part of the dimensionment parameters.

Two geotextiles have been used, a non-wowen needle punched of polyester and a wowen of polypropylene which characteristics are presented on the table 1.

Type	Bidim U 24 non-wowen	Bidin U 34 needle punched	Scotlay (100 g) wowen	Scotlay (200 g)
Name	B.D. 210	B.D. 280	T 110	T 205
mass per unit area (g/ m²)	210	270	110	205
Force per unit width at failure (KN/m)	12	16	11.5	27.5
Strain at failure (%)	50	50	14	16
Porosity (µm)	125	125	200	200
Tensile stiffness (KN/m)	35	40	100	200

Table 1 : Characteristics of used geotextiles.

The traffic has been realized with a truck having an axle of 130 KN running at a speed of 20 Km/h. The circulation has been assured always in the initial rut changing the sense at each time.

I.2. Observations

In spite of the relative homogeneity of characteristics of unsurfaced roads, the interpretation of measures has needed to take into account the real values of modulus and bearing capacity on each section.

The evolution of the rut with the number of passages (figure 1) confirm the results on scale models (4) :

- Best behaviour of the road with a tensile stiffness J higher (BD 280, J= 40 KN/m, and T 205 J= 200 KN/m with a same total width L= 4.5 m).

- Best behaviour of the road with a geotextile having a best anchorage (T 205, J= 200 KN/m L = 4.5 m and L = 7 m).

- Good behaviour for the structures with two geotextiles of small tensile stiffness (2 x BD 210 J= 35 KN/m L = 5.3 m better than T 205 J= 200 KN/m L = 7 m).

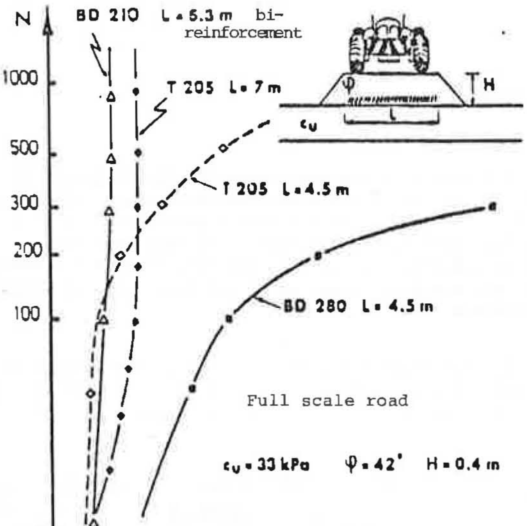


Figure 1

Experiment on full scale road. Evolution of the number of passages versus the rut for different reinforced structures.

This experiment has also allowed to study the alteration of geotextiles with the traffic. In particular it has been determinated a critical depth (H= 0.20 m) of the geotextile under which the abrasion risk is very important. For a too low depth it has been observed a best behaviour of the non-wowens.

The traction tests realized after the experiment have only shown an important falling after the cumulated traffic of 117 000 KN for the geotextiles located under a depth subbase of 0.20 m.

I.3. Quasi-static approach of behaviour

- Elastic behaviour

The analysis of the behaviour of unsurfaced roads has been studied with the plate elastic modulus (Ev_2) evaluated by correlation from the restitution coefficient of the "Dynaplaque" test (2). Twenty six tests have been achieved on the sections. They give the global modulus of the structure subgrade, geotextile and subbase.

On account of the heterogeneous subgrade we have determinated for each section the "equivalent modulus of Young" without geotextile, measured on the subgrade from an elastic calculation (1). The figure 2 presents the modulus Ev_2 of the section with geotextile according to the "equivalent modulus of Young" without geotextile.

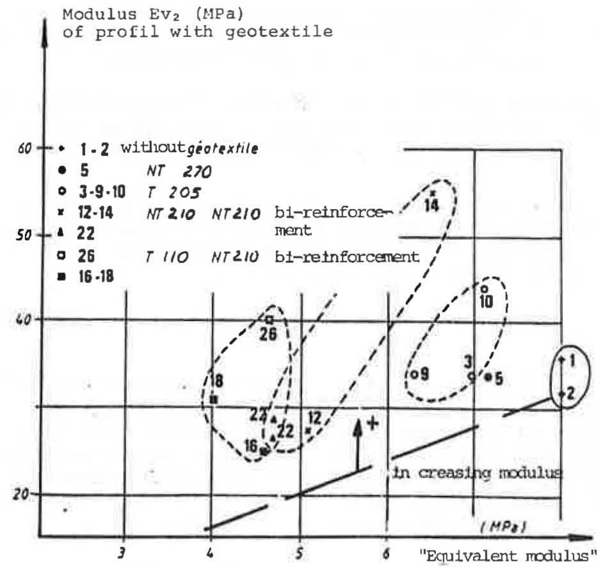


Figure 2

Considering only a qualitative aspect we shall see that the type of structure is a fundamental parameter for the behaviour of the unsurfaced roads in small strains |better behaviour bi-reinforcement (profils 12 to 26) than mono-reinforcement (profils 3 to 10)|, while the effect of the tensile stiffness geotextile seems less important although significative |profil 5 (tensile stiffness 40 KN/m) to compare with the profils 3-9-10 (tensile stiffness 200 KN/m) or profils 12-14-22 (tensile stiffness 2 x 30 KN/m) to compare with profils 16-18-26 (tensile stiffness 30 KN/m + 100 KN/m)|.

- Behaviour in large strains

In order to simplify, the analysis has been limited to the profil 5 with a mono-reinforcement B.D. 280 of width 4.5 m. The deformed profil of the geotextile after a traffic of 310 passages is presented on the figure 3. He allows to confirm the double-function of the geotextile (membrane effect and slab effect) (3).

The approach of the slab effect has been tried by a theorical evaluation. Assimilating the unsurfaced road to a beam layed on the soil of linear reaction modulus we obtain :

$$\frac{B^* - B^*_o}{2\,H} = \frac{1}{2\,H}\,\Pi\,\sqrt[4]{\frac{4\,J\,H^2}{k}} - \frac{B}{2\,H}$$

with

$\frac{B^* - B^*_o}{2\,H}$ slab effect

- J tensile stiffness
- H depth of the subbase (m)
- K modulus of the subgrade (kPa/m)
- B width of the wheel.

In case of the profil 5 calculation gives a value of 0.45 for the slab effect to compare with the measured value of 0.42 considering a distribution without geotextile inclined at $\pi/4 - \emptyset/2$ in the subbase. Yet it should be necessary to validate this approach on more measures.

Otherwise the increase of bearing capacity with a geotextile has been calculated on this profil from the calculations presented by Delmas and al (4).

The quasi-static increase of bearing capacity with a geotextile has been evaluated at 15 % in comparison with the bearing capacity of the structure without geotextile while this of the membrane effect is only 6 %.

The anchorage calculations, considering an elasto-plastic friction law for the interaction soil-geotextile and a linear elastic behaviour of the geotextile, show that on this profil the anchorage is mobilised at 100 %. This is confirmed by the experimental measures as the sliding measured at the geotextile edges is of 3 cm while the relative soil-geotextile displacement necessary to attempt the limit friction is of 1.7 cm with $tg\,\emptyset g/tg\emptyset = 0.7$.

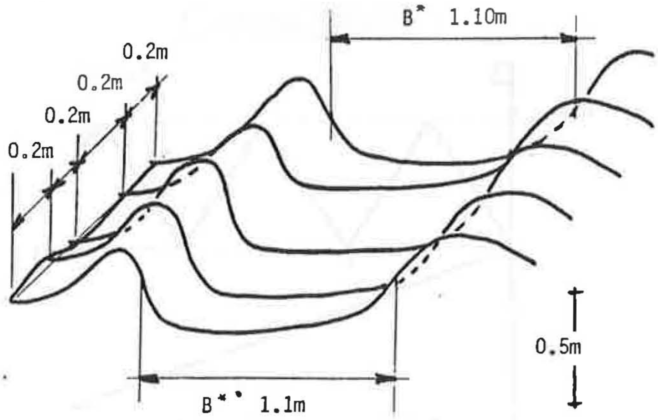


Figure 3 : Deformed profil 5 of geotextile after a traffic (N=310) (BD 280).

II - STUDY OF THE FATIGUE BEHAVIOUR AT I.R.I.G.M.

II.1. Scale model tests

II.1.1. Général conditions of experiment

The tests which have been achieved at the university of GRENOBLE are loading tests of a soil-structure (subbase of angle of friction Ø over a clay of cohesion Cu) (figure 4) to simulate an unsurfaced road on soft subgrade. A cyclic loading (maximal pressure p_m and frequency 1 Hz) (figure 5) simulate the traffic of cars. Experiments also include for the same road structures, tests with a uniforme rate called "quasi-static loading tests" (p_s is the pressure to a rut r).

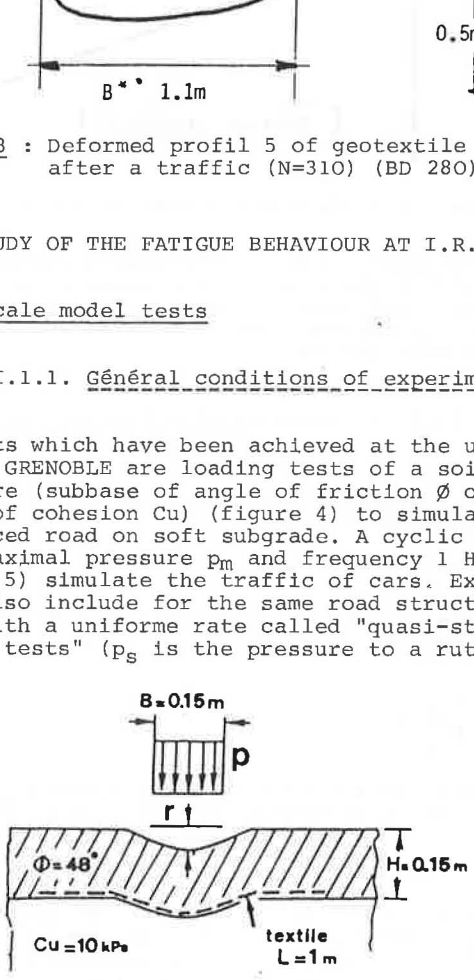


Figure 4 : Scale model used for the fatigue test of road.

The control of similitude conditions and the detail of experimental conditions are in the references (4, 5, 6).

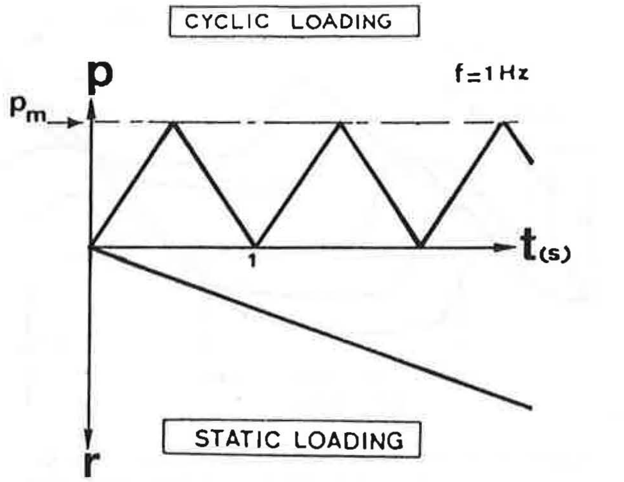


Figure 5 : Loading conditions of the scale model

In this paper we have only considered one type of reinforcement geotextile between the two soils, a polyester non-wowen of mass per unit area μ = 150 g/m^2 and of tensile stiffness J= 20 KN/m (BD 150).

II.1.2. Existence of a fatigue limit pressure p_m (r)

HALIBURTON (9) has proposed for the non-reinforced unsurfaced roads :

$$r < r_1 \rightarrow p_m < p_{ml} = \pi \, Cu$$

to compare with the theorical static limit pressure (p_s = (π + 2) Cu) :

$$\frac{p_{ml}}{p_s} = \frac{\pi}{\pi+2} = 0.61$$

For the reinforced roads he suggests p_{ml} = 6 Cu, which is an indefinite result because it cannot take into account the type of reinforcement géotextile.

We have, as for us, worked out the concept of a fatigue limit pressure from the same basic idea, using the experimental program developped at the GRENOBLE University and in particular leaning on the comparison beetween the diagrams of cyclic loading tests p (N, r) and of quasi-static loading tests p_s (r) (figure 6).

We see on the diagrams p (N, r) that the rut of the plate is still increasing with the unloading as soon as :

$$p\ (N, r) > \alpha \cdot p_s\ (r)$$

The remarkable charater of this behaviour is that α is independant of r.

We have already shown that α was not very dependant of the geotextile reinforcement structure (8).

α = 0.60 for a non-reinforced two-layered
α = 0.45 for a reinforced two-layered with a high tensile stiffness geotextile (J= 150 KN/m).

We shall compare the measured value α = 0.60 with the value achieved by MALIBURTON α = 0.61.

The principle of the existence of a fatigue limit pressure p_{ml} (r_1), such as an infinite number of cycles N does not involve a rut superior to r_1, being acquired, we shall now tempt to define a fatigue criterion, integrating the idea of fatigue limit pressure.

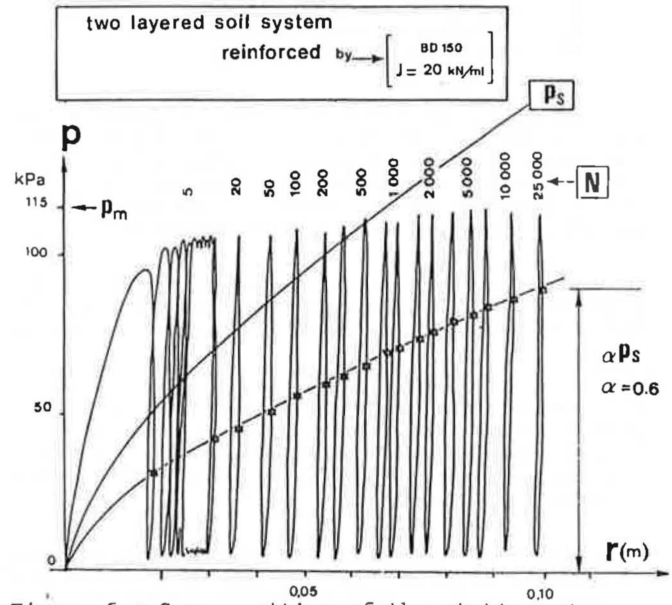


Figure 6 : Superposition of the static and cyclic loading diagrams.

II.1.3. Fatigue criterion (independant of the rut r)

We had previously proposed (7) a fatigue critérion for the reinforced roads, generalizing the test of HAMMIT (10). We now propose a new hyperbolic relation, with the great advantage of being independant of the rut r.

$$\frac{p_m}{p_s(r)} = \frac{\alpha \log N\ (r) + \beta}{\log N\ (r) + \gamma}$$

From the diagrams like those of the figure 7, we obtain for each rut r a value p_s (r) and a pair of values [p_m, N (r)].

The obtained points for every p_m and every r are regrouped on a diagram like this of the figure 8 for a road structure.

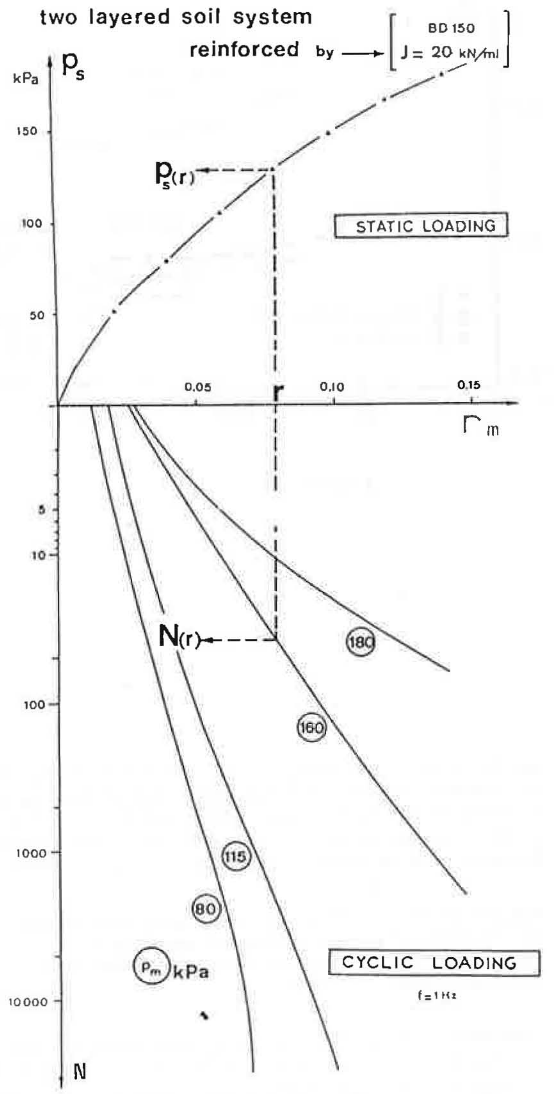


Figure 7 : Cyclic and static diagrams allowing the establishement of the fatigue criterion (figure 8).

From 40 pairs of experimental values $[(P_m/P_m\ (r)$ et N (r)] we obtain the middle graph (method of the "moindres carrés") of the figure 8 :

$\alpha = 0.60 \qquad \beta = 1.45 \qquad \gamma = 0.5$

It is remarkable that the value $\alpha = 0.60$ determinated at II.1.2. is still good for the fatigue criterion. On the other hand β and γ vary with the tensile stiffness geotextile J (12).

If these results are corroborated by full scale experiment roads, they will present a great practical interest ; in fact the proposed criterion can be used as a trafic equivalent relationship.

The criterion can be obtained from :

- a traficability test with a loading pressure (p_m) superior to the service pressure, that allows to shorten this expansive test.

- a quasi-static loading test P_s (r) easier than a traficability test.

II.2. Conclusions on the similitude experiments

Many authors have already shown the benefic influence of a geotextile on the fatigue behaviour of unsurfaced roads founded on soft subgrade, from scale models.

We propose as a complement a new writing of the fatigue criterion, available for the non-reinforced and reinforced roads, allowing to establish a relationship beetween quasi-static loading tests and traficability tests.

If we apply this result to the experiment of NANCY, we can present the experimental points on the diagram (P_m/P_s, N) (figure 9). In spite of the limited number of significative points, it seems that the form and the respective order of the obtained graphs would be in harmony with the precedent theorical approach.

That allows to propose for the experimental unsurfaced road of NANCY the limit values of the fraction p_m/p_s (table 2).

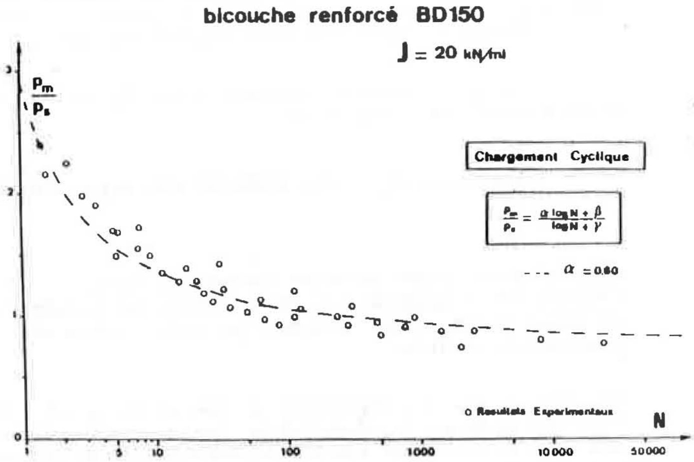
Structure	P_m/P_s limit
non-reinforced	0.60 (theor)
B.D. 280	0.45 (exp)
T 205 (L= 4.5 m)	0.40 (exp)
T 205 (L= 7.0 m)	0.32 (exp)

Table 2

Thanks

The writers thank the agency at NANCY of SCETAUROUTE and RHONE POULENC FIBRES for the help they brought to the experiment of NANCY.

Figure 8 : Determination of a fatigue criterion independant of the rut for the reinforced unsurfaced roads.



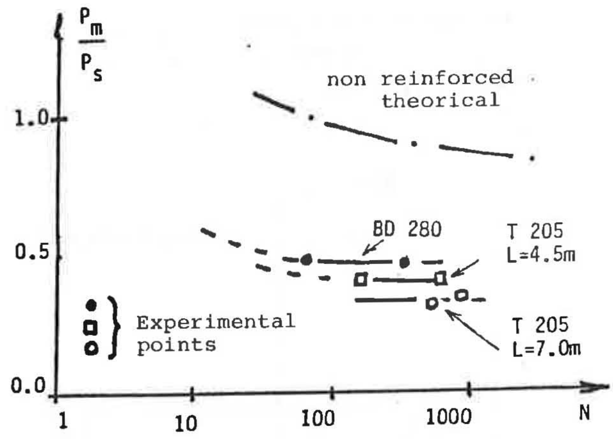


Figure 9

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