# Geotextile and Granular Filter Performance after Four Years of Real Scale Test

A. Morilha Jr.
*Highway Department of State of Parana, Brazil*

J. A. U. Lopez & J. A. Salgado
*Engemin LTDA, Brazil*

L. G. Maroni & F. T. Montez
*Rhoda S/A - Bidim Division, Sao Paulo, Brazil*

ABSTRACT: Long term behavior of geotextiles as filters in drainage structures is often a concern of many users. In order to analyse this and other drainage issues, Highway Department os State of Parana has carried out a comprising practical research program, in which they included the construction and monitoring of six test sections of drains with different filters (granular materials and geotextiles). After four years, the sections were openned, and lab analysis were made in the collected materials.

The good performance of sections with nonwoven geotextiles was remarked, which led to the conclusion that, for the local conditions, their durability will be much higher than the pavement lifetime.

## 1 INTRODUCTION

Nonwoven geotextiles have been used in the State of Parana (South of Brazil) as filter of road drainage systems, since the 70's.

In the middle of the 80's, rumors that this kind of geotextile could clog, when used as filter for local soils, began to arise, although no conclusive facts have taken place to confirm such doubts. In order to analyze the long term filtering behavior of the geotextile in contact with the local soil, the Research Division of D.E.R./PR (Highways Department of the State of Parana), in cooperation with Rhodia S/A and Engemin LTD., developed a comprising drainage research program, involving field and laboratory observation, test sections and construction of simulator.

Besides the analysis of the geotextile performance, it was expected to obtain a better knowledge about the deep drains' performance and efficiency in natural soils, with its stratifications, its non homogeneous materials, its cracks and its preferential flow ways, which, in practice, make them different from the homogeneous soil generally considered in designs.

## 2 DRAINAGE RESEARCHES MANAGED BY D.E.R./PR

The researches carried out by D.E.R./PR may be divided in 3 stages:

### 2.1 Checking of the drains made a long time ago:

Six drain sections, with more than ten years of age were selected to be opened and inspected (four of them, with bad performance suspicion). Samples of geotextile were collected and analyzed: clogging or degradation was not evidenced in any of them. In those cases, other problems, detected to justify eventual unsatisfactory drain performance, were:

- Nonexistence of the drain itself.
- Nonexistence of water in the soil.
- Drain outlet blocking.
- Soil stratification in presence of impermeable layers, blocking the bottom of the ground water table and, in consequence, forcing it to emerge to a more permeable layer above the drain.
- Wrong interpretation of the expected behavior of the drain.
- Construction deficiency.

### 2.2 Large dimension drainage simulator

A drainage simulator was built in laboratory. It consisted of large dimension tank (length=6m, width=0.5m, height=1.7m) and a water feeding system. "Drains" to be tested are installed at one of the edges of this tank which is, then, filled with soil. The water feeding is made by the other edge. Windows in the simulator wall allow the observation of ground water table in the soil along the tank.

Partial results of this analysis were already published (Bosso, A.C.N. et al., 1991).

### 2.3 Experimental Drains

Constructions of several test drain sections, changing only the filters to be used, were the last step of the drainage research program. The main objective was to compare performance of different filters. For that, each section would be monitored to allow the measurement of drain outflow and the ground water table in several soil points.

Test sections were made in one part of the rural road between the BR-373 highway and Vila Esperança, at Prudentopolis.

## 3 EXPERIMENTAL DRAIN OF PRUDENTOPOLIS

### 3.1 Selected place

A roads cut was chosen in clayey latheritic soil, originated in folhelho (stratified clayish rock), reasonably homogeneous, plentiful of water arising. The total extension of the cut was 305.5m, average height=1.5m and longitudinal declivity from 1.0 to 4.0%.

In that cut, six drain sections were placed: four of them with nonwoven geotextiles of different weights, one with sand and crushed stone the other with crushed stone of continuous granulometry, considered "filter draining" by D.N.E.R. (National Department of Highways).

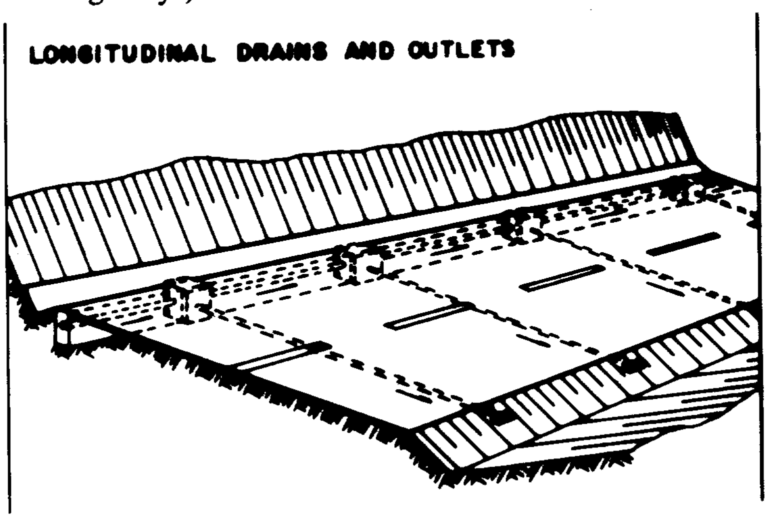


Fig. 1 Perspective view of test sections, collector boxes and drain outlets.

Concrete porous pipes of 20cm diameter were used in all sections. Collector boxes were built to promote physical separation between different drains as shown in Fig. 1.

Drain position was defined at random, in the order described in Table 1, from upstream to downstream. Cross sections of tested drains are shown in figure 2.

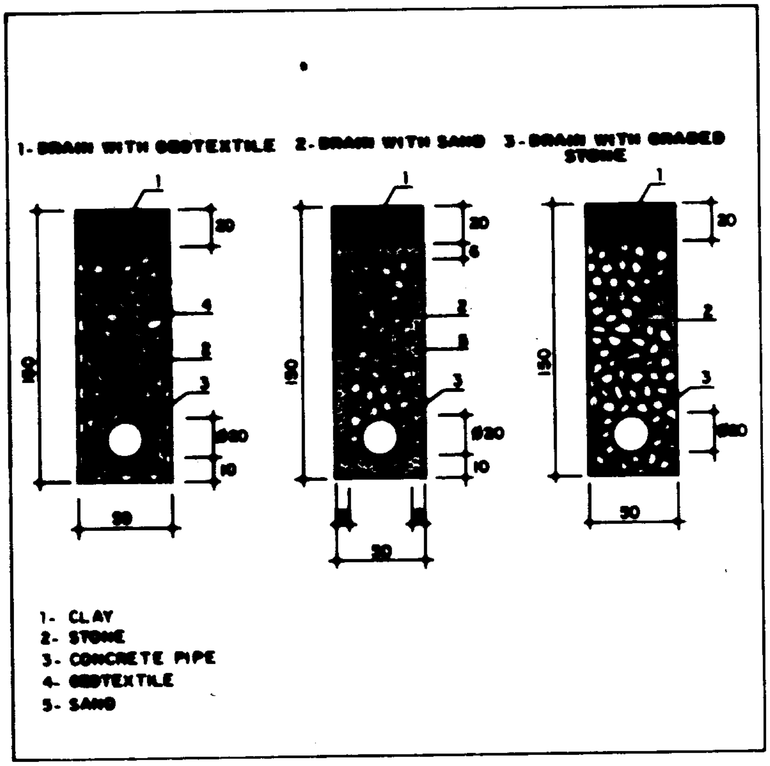


Fig. 2 Test Sections built in the research:
1. With geotextile (sections II, III, IV and V)
2. With sand and stone (section VI)
3. With graded stone - "DNER" type (section I)

Table 1: Experimental drain of Prudentopolis' test sections

| | Localization (stake)* Start | End | Extension (m) | Declivity (%) |
|---|---|---|---|---|
| Section VI: Sand+Stone (discontinuous) | 177+10 | 180 | 50.0 | 1.3 |
| Section V : Geotextile OP-15 (150 g/m$^2$) | 180 | 182+12 | 51.5 | 2.1 |
| Section IV: Geotextile OP-60 (600 g/m$^2$) | 182+12 | 185+2 | 50.1 | 1.2 |
| Section III: Geotextile OP-20 (200 g/m$^2$) | 185+2 | 187+12 | 50.0 | 2.6 |
| Section II : Geotextile OP-30 (300 g/m$^2$) | 187+12 | 190+2 | 49.9 | 3.5 |
| Section I : Crushed stones (well graded) | 190+2 | 196+16 | 54.0 | 3.6 |

* (Stake)-Topographic measure, equivalent to 20m

Typical geotechnical data of natural soil and granular materials used in the research are shown in Table 2.

It should be remarked that well graded stone (section I) do not meet "Terzaghi's filter retention criteria" for that natural soil. According to the same criteria, the sand used in section VI can be considered a good filter for that natural soil, but an intermediate layer, between sand and crushed stone, should be required, since $d_{15}$ (crushed stone) > 5 x $d_{85}$ (sand).

Table 2: Granulometry and Plasticity Index of natural soil and granular materials

| | $d_{85}$ (mm) | $d_{15}$ (mm) | Ip (%) |
|---|---|---|---|
| Well Graded Stone (Section I) | 25 | 0,75 | - |
| Crushed Stone (Section II to VI) | 15 | 5 | - |
| Sand (Section VI) | 0,45 | 0,21 | - |
| Natural Soil | 0,07-0,10 | <0,005 | 15-25 |

## 3.2 Geotextiles used in the research

The geotextiles used in the research were needlepunched nonwoven, 100% polyester continuous filaments (Bidim). Typical mechanical properties are shown in Table 3.

Table 3: Mechanical characteristics of the geotextiles used in the research

| Properties | Standard | Geotextile OP-15 | Geotextile OP-20 | Geotextile OP-30 | Geotextile OP-60 |
|---|---|---|---|---|---|
| Grab strength (N). | ASTM D 4632 | 520 | 800 | 1300 | 2400 |
| Puncture strength (N). | ASTM D 4833 | 330 | 440 | 580 | 1000 |
| Burst strength (MPa). | ASTM D 3786 | 1.4 | 2.2 | 2.9 | 6.0 |
| Tear strength (N). | ASTM D 4533 | 230 | 340 | 500 | 1000 |

According to Task Force 25 (AASHTO-ABC-ARBTA, USA), geotextile OP-20 meets survivability specifications for "Class A" drainage applications, while OP-15 exceeds requerements for "Class B applications. Experimental drain of Prudentopolis would be considered, still according to Task Force 25, a "Class A" application (trench depth around 1.5m).

## 3.3 Field instrumentation

Before drains' construction, four drilling hole lines were made along the cut, at a space of 50m. Each drilling line consisted of 3 holes, at a minimum depth of 1.5m below the cut. Two holes were made at the top of the cut, one at each side of the road, and the third one at the bottom of the cut, by the side of where the drains would be placed.

Drilling lines were placed at 177+10, 182+7, 187+9 and 192+12 stakes. After material collection for characterization tests, water level meters were installed in the drilling holes, which would allow the analysis of the ground water table variation in function of water precipitation (rain). A water level meter was installed inside the drain at each test section.

Daily outflow measurements were made for each test section.

## 3.4 Hydraulic results

Reports on ground water table variations and outflow at each test section, and water level inside each drain may be found in technical papers and reports published about the research (Lopez, J.A.U. et al., 1991; Lopez, J.A.U. et al., 1993).

Some observations and conclusions obtained at these research phases are:

- Although the section was apparently homogeneous, according to drilling information, it was immediately observed, after trench excavation, that it was indeed very heterogeneous (the were lenses of permeable materials in some points of the trench).
- Ground water outflow and water table measurements were very different from section to section, without a pre-determined logic. These changes were imputed to the random way of water percolation in natural soils, seeking cracks or permeable material layers.
- Central part sections, made with geotextiles, sistematically presented the hightest outflows. Section VI (sand+stone) presented the lowest outflows during the period of measurements.
- The water collected from geotextile drains was always clean (Section II, III, IV and V); from the continuous granular drain (Section I), it percolated very muddy, carrying clay particles in suspension. The same occurred, less intensively, from the sand drain (Section VI).
- In all sections, the ground water table lowering was observed, and all of them presented a similar efficiency, concerning the flowoff of affluent water.

## 4 DRAIN OPENING

In April 1993 (dry season), excavations were made at the board of test sections, aiming the observation of each drain conditions and its materials (Fig. 3). Samples of soils and geotextiles were collected and sent to laboratory tests.

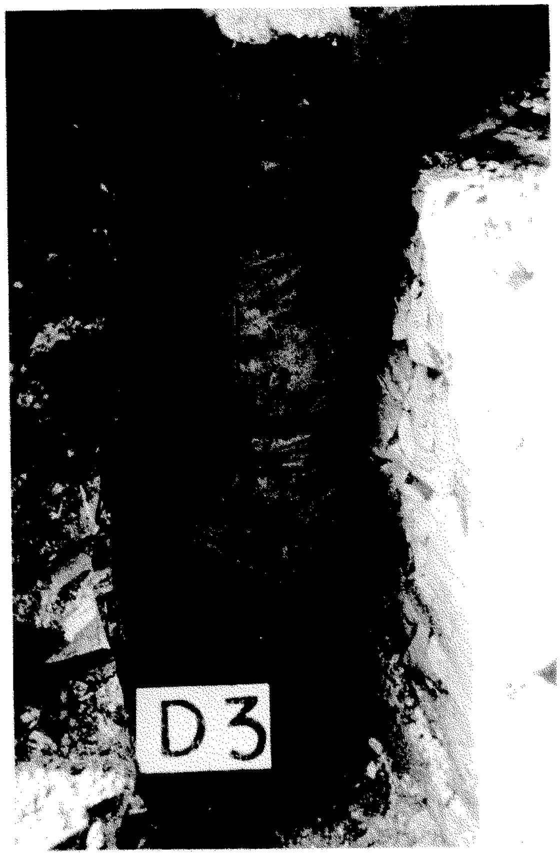


Fig. 3 Geotextile aspect after excavation (drain wall)

### 4.1 Materials visual analysis

During the drain opening it was observed:

- No free water was found in any drain section, but it was possible to observe the presences of water drops at the internal face of geotextiles (although the ground water table was very low at that time, the soil remained with a high degree of moisture).
- In all sections made with geotextiles, no clay was found in the crushed stone or inside the concrete pipe (Fig. 4).
- All geotextiles were in perfect conditions, without any obstruction, clogging, or meaningful changes in aspect or permeability (Fig. 5).

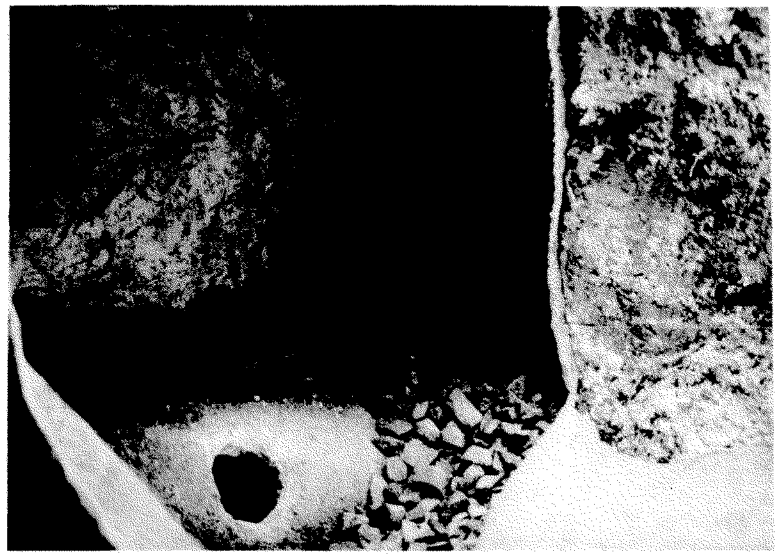

Fig. 4 Drain opening: visual aspect of geotextile, stones and pipe


Fig. 5 Materials of Section I (well graded stone + pipe):

. Right hand: aspect of granular material contaminated with soil;

. Left Hand: material found inside the pipe

- All geotextiles survived installation, although less resistant geotextiles (mainly OP-15) presented some scratches and marks, caused by crushed stone which did not affect their performance.
- In section VI drain (sand+stone), clayey material was found, contaminating crushed stone, sand and pipe. The outflow box presented also some clayey material deposit.

- In "filter-draining" granular drain (Section I), there was a big contamination of crushed stone and a large clayey material deposit inside the porous pipe (about 7cm). The outflow box presented a great amont of clayey material deposit.

- Bad performance of "filter-draining" granular drain (section I) was already expected, since the material did not meet the retention requerements of Terzaghi's filter criteria. The non ideal performance of section VI may be imputed to the same reason (between sand and crushed stone) or to some construction deficiency (it was very dificult and time-consuming to construct this test section).

## 4.2 Geotextiles analysis: laboratory tests

Approximately $2m^2$ of each kind of geotextile were collected and sent to laboratory, to perform permeability (AFNOR NFG 38016) and tensile strength test ("strip test", ASTM D 1117).

According to french standard AFNOR NFG 38016, a stacking of specimens were made, to assure the laminar water flow through geotextile structure. Attention was paid not to remove mass of soil and roots eventually attached to geotextile surface. Permeability tests of virgin geotextiles were made, to compare the results.

Results of tensile tests, for an average of at least three specimens are shown on Table 4. Due to the small number of specimens, presented values shall be considered just as indicative.

Table 4: Strength and permeability tests

| | Tensile Strength (kN/5cm) | | Strength Variation | Permeability (cm/s) | |
|---|---|---|---|---|---|
| | (virgin) | (test) | | (virgin) | (test) |
| OP-15 | 0.32 | 0.23 | - 28% | 0.85 | (*) |
| OP-20 | 0.45 | 0.39 | - 13% | 1.21 | 0.45 |
| OP-30 | 0.80 | 0.75 | - 6% | 0.98 | 0.78 |
| OP-60 | 1.75 | 1.81 | + 3% | 0.93 | 0.47 |

(*) Test not performade by lack of specimens

Analizing results of table 4, it can be said that permeability of geotextiles, impregnated with soil particles, after 4 years of life decreased from a range of values around 1.0cm/s to aproximately 0.5cm/s. That residual permeability value is much higher than local soils permeability (between $10^{-5}$ and $10^{-7}$cm/s).

Lab results confirm visual field observations about researched geotextiles permeability conditions.
Strength tests showed that heavier geotextiles (300 and $600g/m^2$) did not loose strength during installation and lifetime; variations may be imputed to test natural dispersion because of few specimens tested. Geotextile OP-20 ($200g/m^2$) presented little strength loss related to virgin material (from 10 to 15%). Lighter geotextile ($150g/m^2$) presented a considerable strength redution (aproximately 30%). That redution was imputed to instalation and exhumation damage, as observed during drain opening.

# 5 CONCLUSION

Several important conclusions, valid for similar situations, were taken from Experimental Drain of Prudentopolis. Such conclusions have been used support the recent D.E.R./PR designs. Some conclusions are:

## 5.1 Ground water and drain systems

- Drainage structures act as "attractors" and conductors, not only of free water flow in saturated soils, but also of capilar water in subsaturated soils, collaborating to reduce their moisture.

- Theoretical methods for waterflow calculation, drain spacing, lowering time, etc., are very difficult to be used in practice, because of anisotropy and heterogeneity in road cuts, even in apparently homogeneous ones. Empirical methods, as McClelland method, are easier to apply and supply very useful indicative values.

- Water flow in natural soil depends on a lot of undetectable variables. Because of that, drainage structures with a very large collection surface on the side of trench are suggested (making true interceptor "wall"), to collect any arising water along the road.

- 20cm pipes, commonly used in deep drainage, were visibly oversized to conduct the amount of effective collected water. In general, just gravel is enough to conduct the water that reachs the drain in a road section, or, at the upmost, a smaller pipe.

- It is much easier to construct drains with geotextiles than with sand as filter layer. In the case, the construction of test sections with geotextiles was 10 times faster than the descontinuous section (sand + stone).

- The need of deep drain in road sections must not be defined only when presence or absence of water is detected at soundings. Other informations must be considered as soil profile, discontinuance, topografic shape, etc.. Suplementary drainage works may be necessary, such as sub-horizontal drains of slopes.

## 5.2 Filters

- Drains with nonwoven geotextiles are less subjected to clogging in clayey soils. They are surely more durable than the other components of a road, as the pavement.

- Continuous granular drains with a composite "filter-draining" granulometry, tend to clog quickly in clayey soils. This clogging may occur before the end of road pavement lifetime.

- Discontinuous drains (sand+stone) have an intermediary durability, probably overcomming road pavement lifetime.

- For granular filters, it is essentiel to select materials with well defined granulometry (according to Terzaghi's Filter Criteria), in order to assure long term behavior of the drain.

## 5.3 Geotextiles

- Nonwoven geotextiles used in the research, even impregnated by some soil particles, presented coefficient of permeability much higher than the adjacent soils. Nonwoven geotextiles presented no clogging in any stage of the research.

- No degradation was remarked in exhumated geotextiles. Lighter geotextiles presented strength loss, imputed to installation damages.

- Even in drainage applications, where geotextile acts exclusively as filter, it is absolutely necessary to consider also its survivability to installation. For the particular installation conditions of those experiments drains, for example, the less resistent geotextile was close to the lower acceptable resistance limit. In such a case, a geotextile correct specification must consider not only its hydraulic properties, necessary to its filter performance, but also some mechanical properties, necessary to ensure its integrity during the installation and lifetime.

- Specifying geotextile by weight must be avoided because this property is not related to the geotextile performance in the work.


## ACKNOLEGMENT

Authors would like to thank Engineers José Antonio Araújo and Oswaldo Martins Pereira, from DER-PR, who were the idealizers of this Research Program. We would like to thank also Eng. Luiz Cesar Szabo (DER-PR), for his important support at the final stage of this research, and Prof[a] Delma Vidal (ITA, Aeronautics Technological Institute), for carrying out all tensile and permeability tests presented in this paper.


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