DEVELOPMENT OF GEOCOMPOSITES AS A DRAINAGE SYSTEM IN ROAD INFRASTRUCTURE

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ABSTRACT

The absence of a system with proper subdrainage is one of the main reasons for having premature repairs on the road structures generating excessive increases of maintenance costs and substantially reducing the life service of pavement structures.

Management of groundwater levels and moisture control of the base materials or foundation construction of subdrainage systems is required. The subdrainage systems can be handled with the traditional French subdrainage, or subdrainage with Geocomposites, Geonet; both systems of acquisition, conduction and evacuation of fluids.
Development of road Geonet is based on transmissivity test which consists in determining the passage of water through the geocomposite applying different stresses with several types of geonets and nonwoven geotextiles until obtaining the best hydraulic behavior.

1 INTRODUCTION

Prolonging the service life-span for roads has been a permanent concern on the part of public and private entities as is the case of concessionaries at national and international level, which are in charge of the execution and subsequent care of the roads. Tests carried out on new materials that rationalize in any way the maintenance cost that the pavement structure may require have brought new horizons. With the advent of Geonet for the subdrainage system in roads, investigators have made a significant contribution to engineering, thus showing that the performance of this element has been adequate for the subdrainage system in roads.

Subdrainage systems or filters are a fundamental element for the conservation of the road infrastructure because they are a medium for water evacuation by infiltration and groundwater control, which directly affect the pavement structure reducing the resilient modulus of the materials.[2]

After more than a decade of field and laboratory tests as well as studies, quantification of the benefit of “Geodren vial” in road infrastructure projects was achieved. Likewise,” Geodren vial” has been used almost routinely throughout Latin America.

As part of a continuous improvement process, the aim was to optimize circular Geodrain and develop “Geodren Vial” that would benefit the pavement structure not only to improve the performance of hydraulic properties but also to have economic benefit reflected in reduction of future maintenance because of the installing of a subdrainage system.

2 IMPORTANCE OF SUBDRAINAGE SYSTEM FOR ROAD INFRASTRUCTURE

According to Moreno C.[4], the factors that contribute the most to deterioration of pavement structure are as follows:
Deficient lateral drainage of superficial layers
Deficient lateral drainage of support layers of slab (rigid pavements)
Deficient subdrainage
Deficient joint seal (rigid pavements)
Deficient routine maintenance
Nowadays, deficient manage of drainage continues to be one of the biggest triggers of problems in projects executed as we can see in pictures 1 to 2

Picture 1. Transmilenio slab damage on North highway; Bogotá Colombia

Picture 2. Road deteriorated due to groundwater Usme; Colombia

A stable and efficient drainage system needs to be composed by a filtration medium and a draining one. For the case of Geonet development, which is a geocomposite consisting of needlepunched nonwoven geotextile (a textile element with high permeability) and a Geonet (synthetic element that has a high capacity of transportation of fluids in its plane - transmissivity), each element plays a specific role. Nonwoven geotextiles have the function of retaining particles from the ground while allowing the passage of water and preventing fine particles migration. Geonet is the draining medium in charge of collecting and leading the water that passes through the filter to its final disposition. When Geonet has a drainage piping that plays the role of evacuating fluids it is called “GEODREN VIAL”. [1]

Subdrainage in roadways allows reducing unfavorable effects of internal water on the stability of roads. Internal water has normally two origins, an internal one and an external one. Water can manifest itself by capillary ascension from groundwater (more precisely because of suction in liquid phase, or even in vapor phase). Also, isolated or spread water sources that can appear in slopes or in the bench not only make it difficult to carry out new building works but also compromise the stability of roads after their construction.
Rainwater is not totally evacuated through superficial drainage devices; part of it infiltrates through slopes, shoulders, and occasionally through pavement.[3]

Drainage and subdrainage are of vital importance. Excess of water in soils generates:

- Increase of pore pressure and decrease in effective stress.
- Hydrostatic pressures and flow subpressures
- Decrease of resilient modulus of base/subbase and subgrade material
- Change of load transmission mechanism [1] as can be seen in figure 1

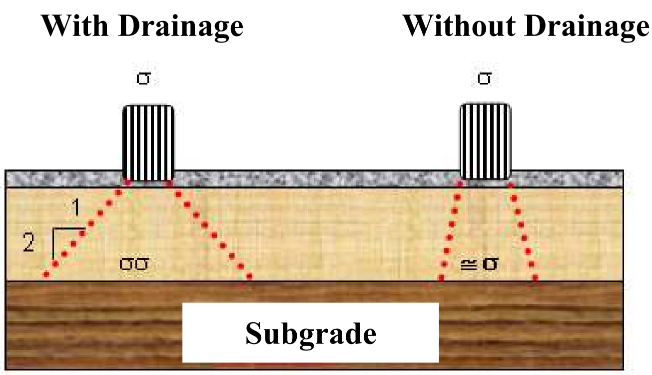


Figure 1. Stress Distribution

The basic principle for obtaining good distribution of intergranular stress through road structural layers is the fact that these layers are well drained.

When the structural layers are completely saturated, the stress transmission that is generated with vehicle passing occurs almost vertically. As a consequence, the stress transmitted directly to the subgrade is almost the same as the one generated in the running surface. The functioning of the structure of the pavement is based on “shielding” or stress distribution through each layer of the pavement structures so that these are reduced to the subgrade level.

The “life service” of a pavement is different from its “effective life”. This life span depends basically on the kind of damage the road suffers and the variation of its serviceability index, directly related with the existence of a subdrainage system.

3 “GEODREN VIAL” DEVELOPMENT

Based on ASTM D – 4716 [5] and the Colombian technical norm NTC 3253 [6] “Método de ensayo para la determinación de la tasa de flujo por unidad de ancho y transmisividad hidráulica de un geosintetico a cabeza constante (flujo en el plano)”, it was aimed to carry out several tests with different geonets and geotextiles to come out with a geocomposite with better characteristics than those of the geocomposite developed until October 2009 (called circular Geonet, which consists of a 5-mm thick Geonet and a nonwoven geotextile).

This test is designed to determine the flow rate per unit width within the plane of the geocomposite under varying normal compression stress and a constant head; similarly, the test can be conducted with different hydraulic gradients so that field conditions can be simulated.

3.1 Equipment used

The equipment used to determine the flow rate that passes through the test specimen (Geonet) is shown on picture 4. The individual components and accessories are as follows:

- Base: a sturdy metal base with smooth flat bottom and sides capable of holding the test specimen (Geonet) of sufficient area thickness. All seams between the bottom surface and sides of the base must be water tight and not inhibit in-plane flow of water through Geonet.
- Reservoir: a plastic or glass water reservoir extending the full width of the base. The reservoir shall have provision for maintaining a constant water level at any of several elevations.
- Loading mechanism capable of sustaining a constant normal compressive stress on Geonet ranging from 10 kPa to at least 500 kPa on a loaded area (12-by 14-in).
- Outflow Weir: a plastic, glass or metal reservoir extending the full width of the outlet side of the specimen having, at the opposite side, a rectangular weir at an elevation higher than the elevation of the upper surface of the specimen. The weir is used to sustain the steady constant head condition on the outflow side of the specimen
- Outflow Collector: A catch through extending the entire width of the base is used for collection and measurement of the outflow from the specimen.
- Manometers: open manometers are located at the inlet and outlet ends of the specimen (Geonet), in the reservoir box and outflow weir respectively. The manometer taps are placed at the same level as the base of the specimen. Extend the manometers with clear tubing to a height at least as high as the maximum water level in the reservoir

Picture 4. Set-up of flow rate and transmissivity equipment

3.2 Procedure

- Place the test specimen on the test device base ensuring that all wrinkles or folds are removed.
- Seal the sides of the specimen parallel to the direction of flow by wrapping the test specimen in a thin sheet of low compressibility plastic or rubber membrane, using a cast-in-place rubber or wax edge seal, or other measure (to prevent side leakage).
- Seat the top plate (platen) in the test assembly applying a small seating stress of 5 to 10 kPa and slowly fill the reservoir with water allowing water to flow through the test specimen.
- Seat the specimen under the minimum normal compressive stress for a minimum period of 15 min. After that, fill the reservoir to the level corresponding to the hydraulic gradient selected for the test.
- Determine the system hydraulic gradient by computing the difference in water elevations between the reservoir and weir manometers and dividing this value by the length of the specimen subjected to the normal compressive stress.
- Once steady flow through the specimen is observed, allow at least $0.0005m^3 \approx 0.5$ lt of water to flow through the specimen. Record the time required for at least an additional $0.0005m^3 \approx 0.5$ lt of water to pass through the specimen. If this time exceeds 15 minutes, record the quantity of flow at 15 minutes for use in calculations of the flow rate per unit width, or hydraulic transmissivity or both. Repeat the flow reading at least three times per each hydraulic gradient selected.
- So as to complete the study, normal compressive stress is increased and the procedure above is repeated.
- Calibration curves for the test device with the appropriate calibration block thicknesses or a statement that a device calibration was conducted and that the equipment hydraulic losses are less than 5% of the losses measured in the tests

3.3 Materials employed

The materials employed to perform the laboratory tests are:

- Nonwoven geotextile: "plane, permeable, polypropylene, non woven needlepunched by needles" shall have capacity to let water pass through, but not fine soil particles.
- Geonet (HDPE): high density polyethylene which is the porous medium in charge of and leading the flows passing through the geotextile.
  The kinds of geonets tested are:

  - GR495 gray 5,8 mm
  - GR 694 black 4,7 mm
  - GR 555 black 6,2 mm
  - GR 770 black 5,0 mm
  - GR 649 black 7,5 mm

- "GEODREN VIAL": geocomposite made with a combination of a nonwoven geotextile and a Geonet which has to be heat- laminated on both sides in order to facilitate hydraulic flow through its plane. "GEODREN VIAL" comes along with a PVC drain piping in charge of leading flow to evacuation zone.

3.4 Calculation

The flow rate per unit width and/or hydraulic transmissivity values for each test specimen are calculated

3.4.1 Flow rate

The flow rate per unit width q_w is calculated as follows:

$$q_w = \frac{Q}{W}$$

Where:
q_w = flow rate per unit width $m^3/s - m$
Q = measured average quantity of fluid discharged per unit time m^3/s
W = width of the specimen (m)

3.4.2 Transmissivity

Transmissivity q is calculated as follows:

$$q = \frac{R_t Q_t L}{W H}$$

Where:
q = hydraulic transmissivity (m^2/s)
R_t = temperature correction factor
Q_t = measured average quantity of fluid discharged per unit time (m^3/s)
L = length of specimen subjected to the normal compressive stress (m)
W = width of the specimen (m)

H = difference in total head across the specimen.

3.5 *Calculation of maximum effort applied to "GEODREN VIAL"*

In the case of a subdrainage system of a pavement structure, the maximum normal effort to which the geocomposite will be subjected because of the land pressure at a determined depth is calculated by using the following equation:

$$\sigma_N = \gamma * h * K_a$$

Where:
σ_N = maximum normal effort (Kpa)
γ = specific weight of soil in which the geocomposite will be installed (KN/m^3)
H = height at which normal stress is maximum (m)
K_a = lateral pressure quotient
The comparison of Geonet installed as a subdrainage system, that is, vertically (figure 2) at a depth of 1.0 m, is made with the transmissivity test and the gradient (i) equals 1.0.

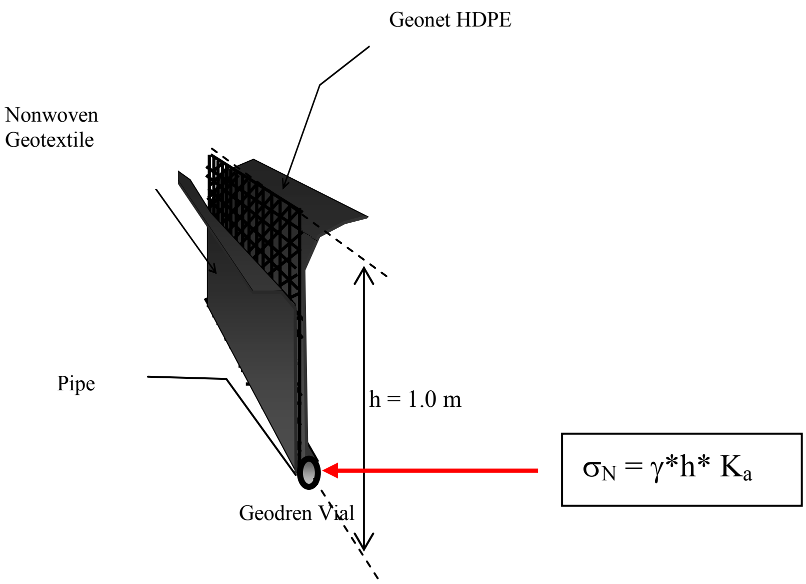


Figure 2. Application of maximum effort applied to "GEODREN VIAL" at a depth of 1.0 m

The average normal effort σ_N that Geonet can have at a depth of 1 m is approximately 7 kPa, which indicates that with a pressure of 10 kPa carried out in the laboratory the approximate flow rate that passes through Geonet can be determined.

3.6 Results

The geonets tested were accompanied by nonwoven geotextile to make up the geocomposite (Geonet). The result of the behavior of the flow rate in machine and cross-machine direction with different pressures as well as gradient variation is shown as follows:

- Gradient 1.0: hydraulic gradient corresponds to the relation between the difference in height and difference in length. For the case of “GEODREN VIAL” when used as a subdrainage system we have a gradient of one (i=1.0), value obtained when Geonet is installed vertically. That is, when its height is one meter (1.0 m) and the length through which water passes is one meter (1.0 m).
- Gradient 0.5 and 0.1: transmissivity test with gradients of 0.5 and 0.1 at different pressures is made at laboratory to determine the behavior of the geocomposite in applications such as weepholes for reinforced soil walls and landfill flow control, among others.
- This work focuses on the development of a “GEODREN VIAL”, that is, the behavior of the geocomposite installed vertically. In graphics 1 and 2, results of flow rate at different pressures in machine and cross-machine direction with gradient of one (i=1.0) are shown.

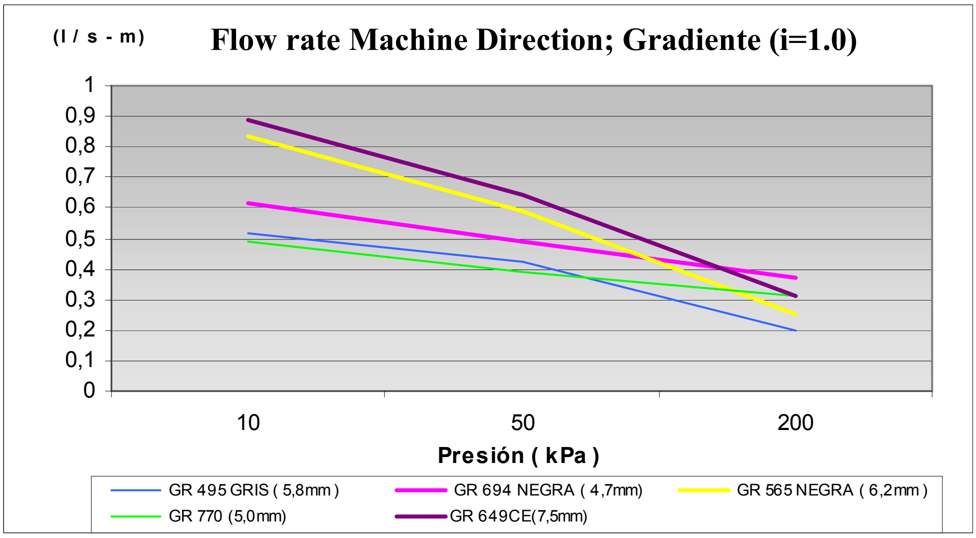


Chart 1. Geonets comparison, flow rate in machine direction and gradient i=1.0

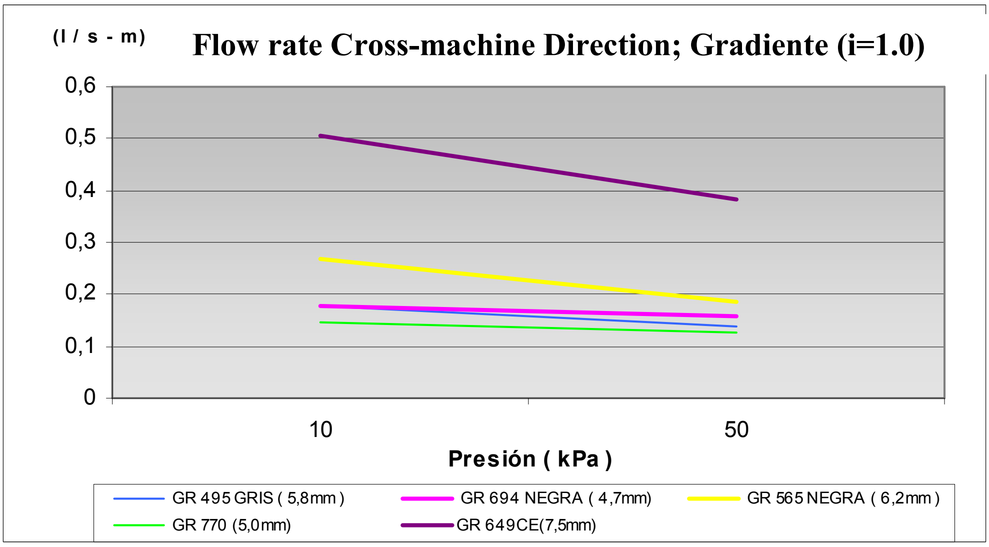


Chart 2. Comparison of geonets, flow rate in cross-machine direction and gradient i=1.0

In the tests done to geocomposites in machine direction (chart 1), pressures of 10kPa, 50 kPa, and 200 kPa were applied in order to simulate the condition of the subdrainage system in the back of a retaining wall.

In tests done to geocomposites in cross-machine direction (chart 2), pressures of 10kPa and 50 kP were applied in order to simulate the condition of the "GEODREN VIAL" applied vertically, as it was shown in numeral 2.5 , where maximum effort to which the geocomposite can be subjected at a depth of one meter (1.0 m) is 7kPa.

3.7 Economic analysis

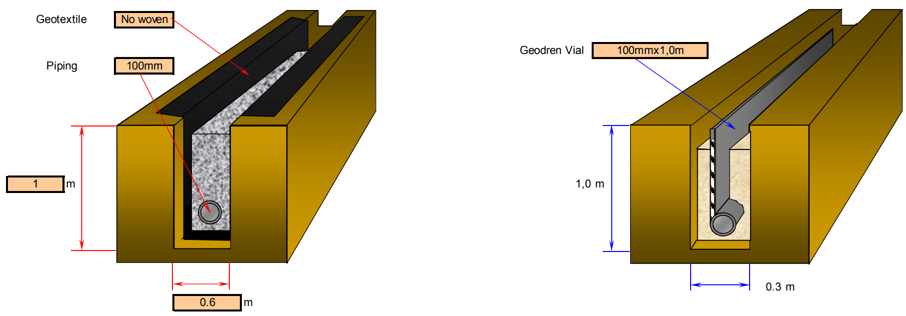
An economic comparison between a traditional French subdrainage system and Geonet is shown below. Prices are in US dollars and are based on Peruvian markets. It is recommended to verify the project location and the proximity of material exploitation in order to know how feasible is obtaining materials; however, with "GEODREN VIAL" system, materials with fewer specifications than traditional French system can be used, as long as fill material does not have a plasticity index minor to 7% and its permeability is greater than 10E-3cm/s

COST ANALYSES PER LINEAR METER OF GEODREN PAVCO VS FRENCH DREN

TRADITIONAL FRENCH SUBDRAINAGE					
Description	**Unit**	**Quantity**	**Cost**	**Descount**	**Total**
Non woven Geotextile	m^2	3.50	$0.95	0%	$3.33
PVC drain piping 100mm	ml	1.00	$4.00	0%	$4.00
Fill Material*	m^3	0.78	$12.00		$9.36
Excavation and removal	m^3	0.78	$6.19		$4.83
Labor	Hr/Ml	1.00	$5.54		$5.54
TOTAL					**$27.05**

SUBDRAINAGE WITH GEOCOMPOSITES - GEODREN VIAL					
Description	**Unit**	**Quantity**	**Cost**	**Descount**	**Total**
Geodren Vial 100mmx1,0m	ml	1.00	$9.70	0%	$9.70
Permeable material (Thick sand)*	m^3	0.39	$6.00		$2.34
Excavation and removal	m^3	0.39	$6.19		$2.41
Labor	Hr/Ml	1.00	$5.54		$5.54
TOTAL					**$19.99**

SAVING FOR LINEAR METER, USING SUBDRAINAGE SYSTEM WITH "GEODREN VIAL" 26%



Notes: * The average prince of the material wiht borrow zones or quarries near the zone of the project. For every project it is necessary to analyze this item.

4 CONCLUSIONS

- The greatest flow rate after comparing the samples tested was the combination of GR 649 Geonet, -7.5 mm of thickness with nonwoven geotextile with $46*10^2$ cm/s permeability, obtaining a 0,9 l/s-m flow in machine direction at a pressure of 10 kPa and a 0.3 l/s-m flow at a pressure of 200kPa. The flow rate in cross-machine direction at a pressure of 50 kPa is 0.38l/s-m, therefore, the 7.5 thick Geonet and the needlepunched nonwoven geotextile combination is the one that has better behavior as a subdrainage system in a road.

- In relation to circular Geonet (initial development) an increase greater than 50% in flow rate in both directions appears.

- In terms of cost-benefit, "GEODREN VIAL" has a 26% saving vs. French traditional system when the latter includes drainage piping, which implies optimization of the budget of the project agreeing with an adequate draining system.

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