Performance Tests and Design of Geocomposites for Drainage of Gas

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ABSTRACT : An original and important research programme was developped in order to assess out the efficiency of the geocomposite Somtube for the drainage of gas. In the first part, laboratory experiments, based on transmissivity tests, were performed on the non-woven layer and the incorporated pipes. They show how air transmissivity tests can be correlated to water transmissivity tests. In the second part, full scale tests, with this geocomposite, were performed in a 10 m x 2 m x 0.85 m box : air flow is injected below a soil layer, penetrates the geocomposite and is drained by the non-woven layer and the small pipes. Air pressures in the non-woven layer and in the pipes are measured as a function of the air discharge Comparisons between experimental results, theoretical model and correlations between air flow and water flow are presented.

1 INTRODUCTION

The Somtube geocomposite consists of a non-woven draining web enclosed within 2 needlefelt geotextile filters, in which mini draining tubes (22 mm ext. dia.) are inserted with space between them of 0.25, 0.50, 1.00, 2.00 m according to the technical requirements (fig. 1). This geocomposite, with its particular structure, has already been subject to specific theoretical and experimental studies for the water drainage (Faure and al, 1993).

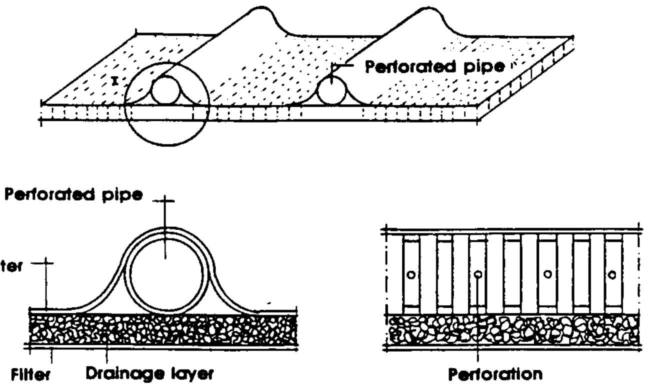

Fig. 1 : Somtube structure.

In the field of the gas drainage, a similar study has been performed: the geocomposite properties have been tested with air in both a laboratory and a real sized model of 20 m^2. The experimental results have been compared to the theoretical designing model set up for the gas drainage.

2 CHARACTERIZATION FOR THE GAS DRAINAGE

2.1 Theoretical considerations

In order to evaluate the flow in a pipe of a fluid of a cinematic viscosity, 2 non dimensional parameters R_e and λ are used :

$$R_e = \frac{Q}{A}\frac{d}{\nu} \quad \text{and} \quad \lambda = \frac{2gi}{(Q/A)^2}$$

R_e : Reynolds number
Q : fluid flow (air : Q_a, water : Q_w)
A,d : Area and hydraulic diameter of the pipe
ν : Fluid cinematic viscosity (air : ν_a, water : ν_w)
λ : Head loss coefficient
i : Flow gradient given by the ratio of the fluid height by the pipe lenth (air : i_a, water : i_w)
g : gravity.

To compare the air and water flow through the geocomposite, we make the assumption that, for the same Reynolds number R_e, the head loss coefficient λ remains the same in the draining web or in the mini draining tubes.

Draining web : as the study is related to the same product, the dimensional characteristics (A and d) are identical for the water and the air behaviour(Q is then the flow in the web per meter). If R_e is the same, then :

$$\frac{Q_a}{\nu_a} = \frac{Q_w}{\nu_w}$$

And if the head loss has to remain the same :

$$\frac{i_a}{Q_a^2} = \frac{i_w}{Q_w^2}$$

According that the geocomposite transmissivity θ for a fluid is given by $\theta = Q/i$, then :

$$\theta_a \nu_a = \theta_w \nu_a \qquad (\text{air} : \theta_a, \text{ water} : \theta_w)$$

As in a porous environment, we can define an intrinsic transmissivity: $\theta^* = \theta\nu/g$ (m^3).

Mini draining tubes : the water tests already performed had shown a non laminar flow even for gradients of 0.001, and highlighted that the water discharge capacity $(q_d)_w$ of the mini draining tubes, as a function of the flow gradient, could be expressed as :

$$(q_d)_w = \frac{Q_w}{i_w} = \alpha_w (i_w)^{n_w} \text{ with } n_w \approx -1/2$$

α_w : same dimensional coefficient as $(q_d)_w$ ($m^3.s^{-1}$).

The fact that n_w is very closed to -1/2 shows a turbulent flow (λ is constant). For an air flow with the same R_e, n_a will be also closed to -1/2. The head loss should also remain the same whatever the fluid. A calculation shows that :

$$\text{if } n_a = n_w \approx -1/2 \text{ then } \alpha_a = \left(\frac{\nu_w}{\nu_a}\right)^{2n+1} \text{ and } \quad \alpha_a = \alpha_w$$

then : $(q_d)_a = \alpha(i_a)^n$

2.2 Experimental results

To measure the air transmissivity in the draining web, the devices usually used for the water tests have been connected to an air feed:

- a pressure controller insures a front line pressure;
- a ball flowmeter measures the flow rate at the outlet;
- pressure valves located in front and after the sample are connected to differential manometers to measure the pressure drop up-side and down-side the sample.

Fig. 2 shows the variation of the intrinsic transmissivity for air and water in relation to the compression. Considering that the tests have not been carried out on the same samples, it's obvious that the air transmissivity of a draining web can be evaluated from the water trials, in the case where the Darcy's law is verified as in these trials.

Note : as the air trials were easier to perform (no sample saturation, no tank with constant level, low temperature influence on the air visosity), a reverse way can be considered as measuring the water transmissivity starting from the air trials.

The discharge capacity of the mini draining tubes has been measured by replacing the transmissivity cell by a 2 m long tube introduced in the above circuit, between the 2 pressure valves. The holes of the mini tubes have been pluged externally, just by surrounding the tubes with an adhesive rubber strip. The waterproofing were checked by a water trial.

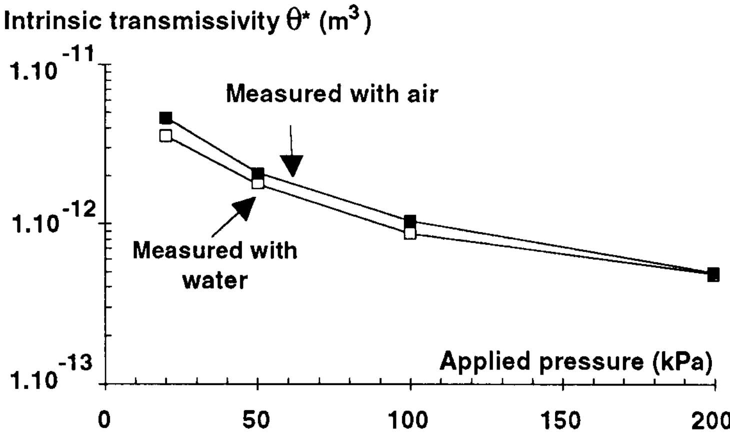

Fig. 2 : Variation of intrinsic transmissivity determined with air flow and water flow versus compression.

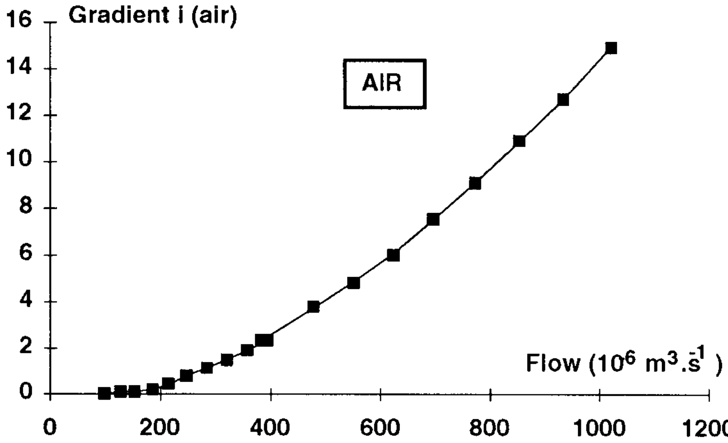

Fig. 3 : Variation of the flow gradient versus the air flow.

Fig. 3 shows the variation of the flow gradient versus the air flow. The use of a Log-Log diagram allows to determine easily the parameters α and n by a linear regression. The average values of these coefficients as result of several trials, are given below:

Air trial (0.5< i <10) α_a =2.59 10 m^3/s n_a =-0.509
Water trial (0.001< i < 1) α_w =2.54 10 m^3/s n_w =-0.507

The understanding of the discharge capacity in relation to the flow gradient brings values for the coefficients α and n to be of the same level.

3. DRAINAGE DESIGNING WITH THIS GEOCOMPOSITE

During its flow in the geocomposite, the fluid goes successively through the different parts: it goes first across the filter in touch with the soil, then flows into the draining web to the mini draining tubes and steps into them through the mini holes and finally flows into the mini tubes. At each step, head loss are generated, and as they added to each others, the water pore pressure in the soil to be drained goes up.

A computer designing method has been developped for the water flows (Faure and al, 1993). It makes a relation between the different pressures within the draining web and the flow to carry out, according to the geometrical and hydraulic characteristics: spaces between the mini draining tubes, the slopes, the flow under head or under gravity in the mini draining tubes, the limit conditions fixed by a constant feed flow or by an equipotential line within the soil.

For the gas drainage, the designing method remains the same providing that :

- the hydraulic characteristics of the draining web for the considered gases are taken into account (use of θ^*);
- the pressure and the hydraulic heads are expressed as a gas height;
- the specific "ungauged" weight of the gas versus the air (the specific weight of the gas less the specific weight of the air) for the upward gravity flow (gas lighter than air) or downward (gas heavier than air) is used.

The computer model has been tested on the real sized pilot trial described below.

4. VALIDATION OF THE GEOCOMPOSITE PROPERTIES IN REAL SIZED TRIALS

A pilot installation has been designed and set up in the Sommer plant of Sedan (France) in view to show the Somtube properties for the water drainage under a concrete slab in civil engineering works.

4.1 Installation description

A concrete tank (fig. 4) of 10 m long, 2 m wide and 0.85 m height has been internally waterproofed by a geomembrane. A perforated pipe of 160 mm laid down on the bottom of the tank will feed with air or water. This is covered with a 0.45 m layer of gravels. A thin sand layer of 0.05 m has been brought on and is separated from the gravels by a filtration geotextile. The Somtube geocomposite with 2 tube/meter is installed on this sand layer with the mini draining tubes in the length side. A concrete slab, 0.15 m thick, has been directly flowed on the Somtube with some accesses for pressure valves. 20 pressure measuring points are available : 3 cuts in the length side (2 on the mini draining tubes and 1 in the middle between the mini draining tubes) and 1 cut across at 9.80 m of the exhaust (fig. 4). The downward ends of the mini draining tubes are connected to a rain-pipe.

For the water trials, the feeding is insured by the plant water net, and the flow rate, controlled by an upward valve, is measured at the outlet of the rain-pipe.

For the air trials, 2 gauge controllers allow a perfect setting of the feeding pressure. The flow rate is measured by a gas counter located in front of the tank. The measurements taken at the counter are corrected according to the feeding pressure in order to get the air volume at the atmospheric pressure.

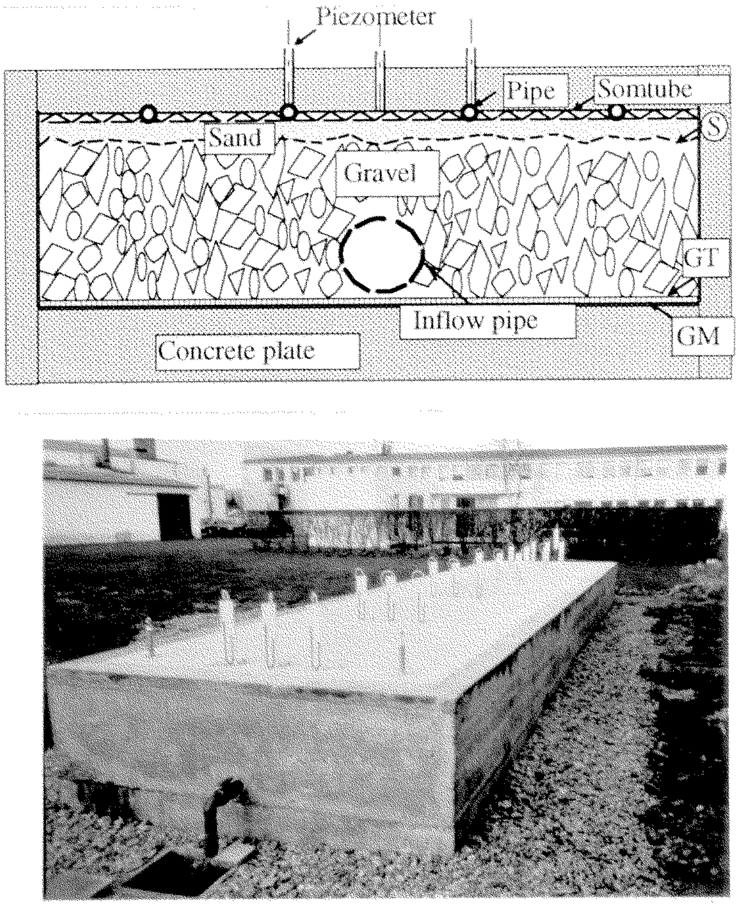

Fig. 4 : Real size pilot installation.

4.2 Results of the real sized trials

In view to test the waterproofing of the system, the water has been put on, and a first set of measurements has been done with a water flow. In the pressure valves, ball gauges have been fixed and have measured the hydraulic head at the geocomposite level. Fig. 5 shows the variation of the maximum pressure between the mini draining tubes (in mm of water column) in relation to the water flow rate. The theoretical curve as shown on the graphic, has been drawn with a sand permeability of 3.10^{-4} m.s^{-1}.

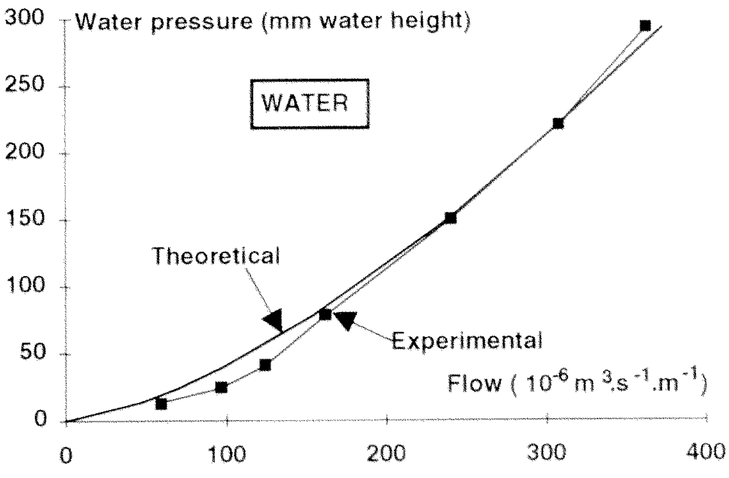

Fig. 5 : Theoritical and experimental curves of the pressure variation versus the water flow.

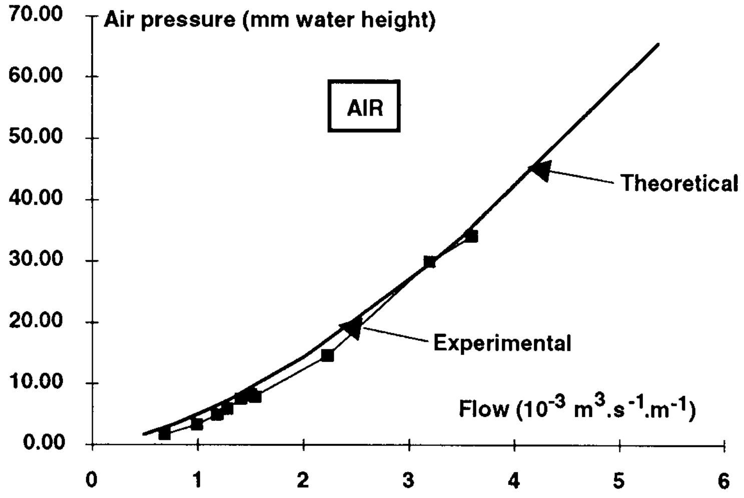

Fig. 6 : Theoritical and experimental curves of the pressure variation versus the air flow.

After the tank has been emptied, an air flow has dried the entire system for several weeks. Manometers have been located in the different pressure valves. Fig. 6 shows the theoretical and experimental curves of the pressure variation versus the air flow. The air permeability of the sand was estimated from its water permeability taken into account the viscosity ratio between air and water.

4.3 Comparison between air and water trials

The system with sand, the draining web and the mini draining tubes, creates a permeable environment in which the head loss should be the same, for a constant Reynolds number R_e whatever the fluid. That should bring us to consider the quantities Q/ν and h_{max}/Q^2, h_{max} being the maximum measured pressure expressed in fluid height. Those parameters are the only variable one in the values of λ and R_e. Fig. 7 shows a real good correlation between air and water trials.

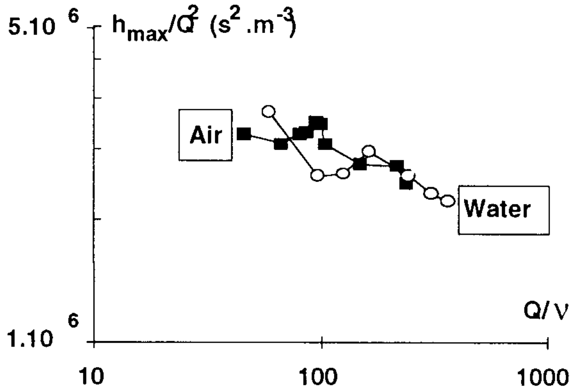

Fig. 7 : Correlation between air and water trials.

5. CONCLUSIONS

This experimental study, based on laboratory and real sized trials, confirms the validity of a theoretical correlation to evaluate the geocomposite properties for the gas drainage.

When the flow is driven by the draining web transmissivity, for instance without mini draining tubes, the intrinsic transmissivity allows to evaluate the gas flow rate drained for a given pressure, i.e :

$$\Delta h_w . \rho_w = \Delta h_a . \rho_a$$

Then according to the preceeding relations :

$$\frac{Q_a}{Q_w} = \frac{\theta_a}{\theta_w}\frac{\Delta h_a}{\Delta h_w} = \frac{\nu_w}{\nu_a}\frac{\rho_a}{\rho_w} = \frac{\mu_w}{\mu_a}$$

μ_a, μ_w : dynamic viscosity of air or water ($\mu_w/\mu_a = 55$).

When the head loss comes rather from the mini draining tubes (very long tubes), we should consider their discharge capacity q_d to evaluate the gas or water flow rate at a given pressure :

$$\frac{Q_a}{Q_w} = \frac{(q_d)_a}{(q_d)_w}\frac{i_a}{i_w} = \frac{\alpha(i_a)^{n+1}}{\alpha(i_w)^{n+1}} = \left(\frac{\rho_w}{\rho_a}\right)^{n+1} \approx \left(\frac{\rho_w}{\rho_a}\right)^{1/2}$$

$(\rho_w/\rho_a)^{1/2} = 28.$

Fig. 8 shows that the $Q.(\rho g)^{1/2}$ value is nearly the same in the real sized trials with both water and air, which confirms the validity of the method.

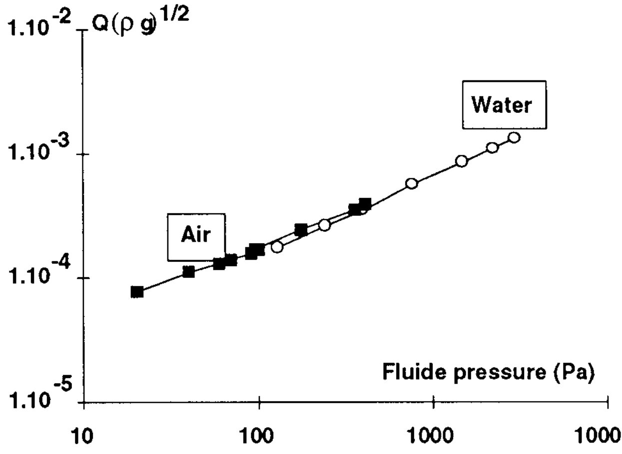

Fig. 8 : Correlation between air and water trials, with hypothesis of turbulent flow only in the pipes (Q in $m^3.s^{-1}.m^{-1}$ and (ρg) in $kN.m^{-3}$).

REFERENCE

Faure Y.H., Matichard Y., Brochier P., Suryolelono K. (1993). Experimental and theoretical methodology to validate new geocomposite structure for drainage, *Geotextiles and geomembranes*, Vol. 12, n°5, 397-412.