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Lysimeter experimentation: first results

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Lysimeter experimentation: first results

Summary

This technical report illustrates preliminary results of lysimeter experimentation.
Tests concern a pyroclastic soil sample of Nocera Inferiore that involved in a rapid flowslide on 4th of March 2005.
By means of its behaviour real-time monitoring, it will be possible to define exactly properties of soil and to understand how it responds to rainfalls, in terms of water pressure and volumetric water content of the soil.
In order to validate and to interpret lysimeter outputs, a mathematical model of lysimeter is developed using the software SEEP/W.
Seepage analyses studying can give more information about hydraulic properties of the soil sample, so it can be useful to understand the sequence of events occurred on 4th march 2005.

Keywords: lysimeter, monitoring, mathematical model

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1. Foreword

In order to study the effects of the rainfall on the slope stability, the Department of Geotechnical Engineering of University of Naples Federico II, has developed a device to determine soil water relations.
The lysimeter isolates a volume of soil or earth between the soil surface and a depth given and includes a percolating water sampling system at its bottom (Muller, 1996).
It is able to measure water content and suction of soils, isolating a volume of soil and collecting at its bottom the filtering water through the investigated volume.
Lysimeter is used to study several phases of the hydrological cycle: infiltration, runoff, evapotranspiration, and therefore to setting up a water balance.
In geotechnical applications it is used to estimate the relationships between soil properties and atmosphere. Indeed it is possible to evaluate the water retention curve of soils, and therefore their hydraulic behaviour.

2. Lysimeter features

Lysimeter is a thank with a large soil sample inside, that is able to measure some physical variables under controlled conditions.
It is in Sant' Angelo dei Lombardi, close to Avellino town, where is located the C.I.M.A. (Centro Irpino per l'Innovazione nel Monitoraggio Ambientale), the operating centre of A.M.R.A.
It has a square area of 1.25x1.25 m^2, and a depth of 0.80 m.
As laterals walls thickness is about 0.09m, the real area is 1.16x1.16 m^2, and then the effective depth is 0.75 m.
The tank is in nautical multi-stratum plywood which rests on frame made of aluminium square section bars 40x40x5 mm (Zingariello, 2008).

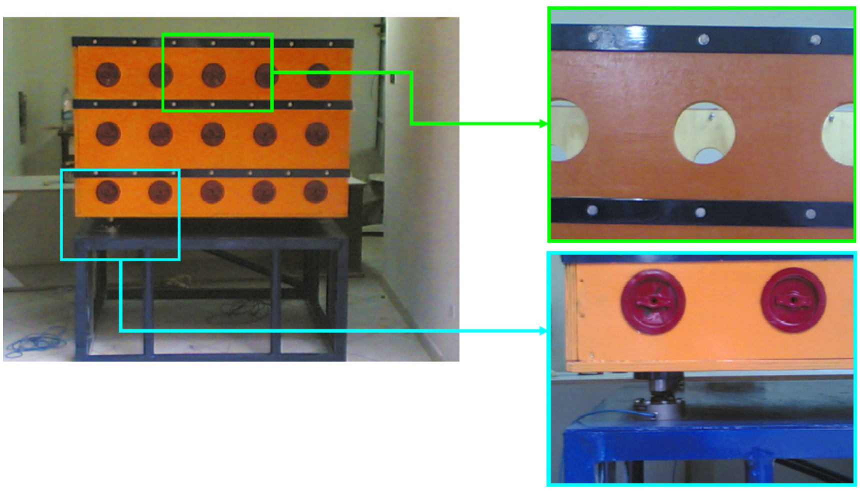

Fig.1 The lysimeter

Lysimeter is filled with a sample of pyroclastic soil that covers slopes close to Nocera Inferiore town, and involved in a significant rapid flowslide on 4th March, 2005.
We want to keep soil behaviour under control, in order to understand seepage dynamic triggering this tragic event.
Some circular holes are made to install sensors at different depths, in order to measure specific physical quantities (water content of soil, suction, soil temperature).
In unsaturated soils the permeability is not constant, but it is a function of the volumetric soil water content.
Rainfalls give rise to infiltration processes within the soil sample, so hydraulic conductivity ever changes.
In order to determine soil water content 5 TDR (Time Domain Reflectrometry) are installed at different depths (3, 20, 35, 54, 67 cm from the base).

Fig.2 TDR

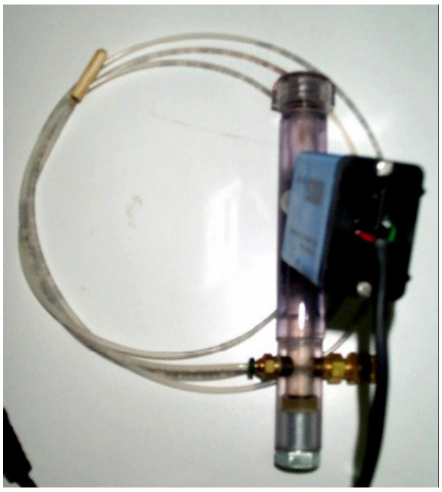

Fig.3 Tensiometer

As the water content is linked to matrix suction it needs to equipped the lysimeter with sensors that measure it.
There are 12 tensiometers, connected to a PC for data acquisition, that estimate directly negative pressure of water.
They consist of a porous ceramic cup, connected to a pressure-measuring device through a small-bore tube filled with de-aired water (Picarelli L., Vinale F., 2007).
The depths of tensiometers installation are the same of the TDR ones.

DEPTH	Number of TDR	Number of tensiometers
67 cm	1	2
54 cm	1	2
35 cm	1	4
20 cm	1	2
3 cm	1	2

At lysimeter' s bottom there is a geosynthetic cloth that allows water drainage preventing material losses.
The amount of water collected can be used to evaluate the filtrating water flow through a soil cover system, seepage water is thereby measured directly.
Therefore this will provide information about the amount of water that can be stored by soil during meteoric events.
Finally three load cells (1 ton capacity) are placed on a steel plate under the lysimeter, in order to measure soil weight; thus weighable lysimeter provide information about the change of water storage for any time period.
Close to the lysimeter there is a weather station in order to measure temperature, rain, and atmospheric pressure.

Few months have been spent for instrumentation setting and its calibration.
First measures of temperature, pressure and water content of the soil is achieved in October, when rainfalls become considerable, and they are saved with frequency of five minutes thanks to a battery that allow data capture into PC.
In fig. 4 are shown the firsts data processing of TDRs and the rain measured by weather station.
Time history is composed by 33 days (from the 14^{th} of October 2008 to 20^{th} of November 2008).
As you can see from the graphs, rainfalls occurred in October are perceived only at surface (azure and yellow curves), whereas deeper layers not suffer from it.
Instead rainfall event of November is more considerable, so involved also lower layers, but with some delay depending of soil permeability.

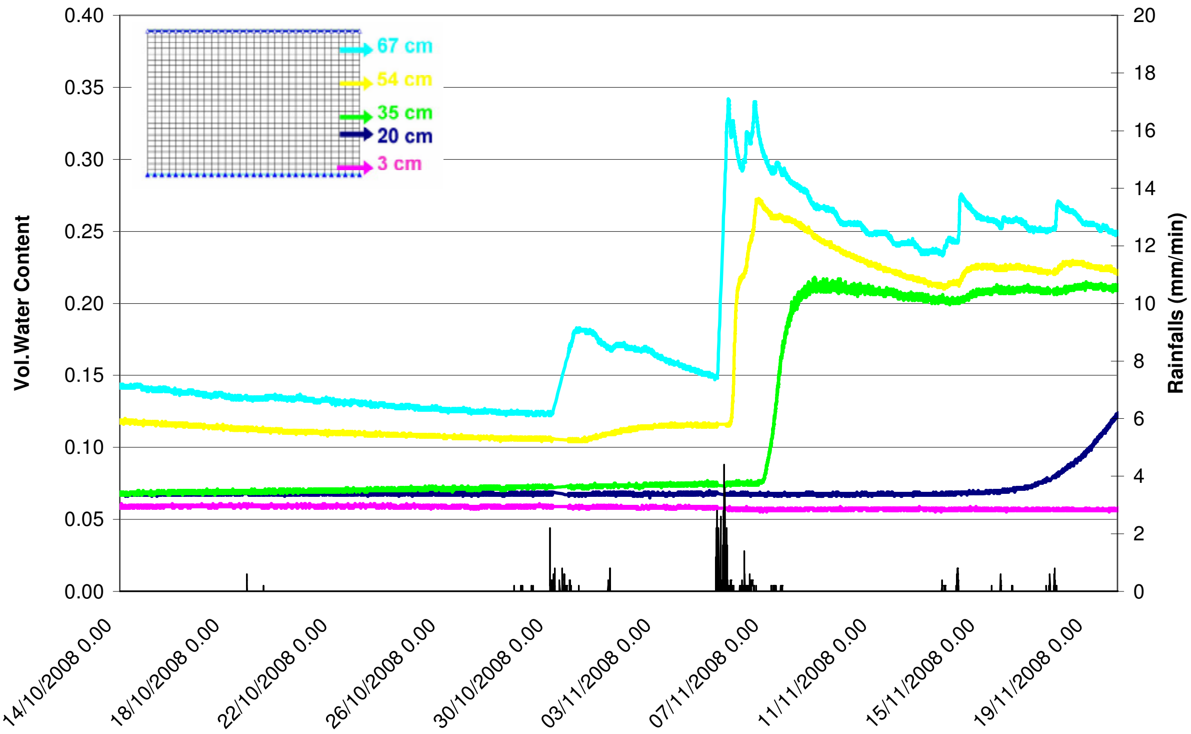

Fig.4 Water content trends of TDRs measures

Presently, properties of the shallow pyroclastic deposits of the Nocera Inferiore slopes are not well defined so, by means of lysimeter experimentation and following data processing, it will be possible to find out them.
Once hydraulic and mechanic properties of soil has been defined, we can understand the sequence of events occurred on 4th march 2005.

3. Mathematical model of lysimeter

In order to validate experimental results of lysimeter, a mathematical model has been established.
Lysimeter allows to monitor interaction processes between soil and atmosphere, whereas by means of mathematical model, we' ll try to explain them.
Experimentation tests can be reproduced by a finite element software.
Thus it is possible to simulate seep process into soil volume, which is the object of this study.
The use of a finite element model is instrumental in learning more about how a lysimeter works and in helping understand the dominant processes involved.
In this instance SEEP/W (Geo-Slope International LTD, 2004) is used.
As the first attempt, material properties, available from laboratory tests concerned the pyroclastic soil of Nocera Inferiore, are assumed.
Seepage analyses will be able to get properties closer and closer to the real-ones.

Volumetric water content curve is shown in fig. 5, whereas hydraulic conductivity curve is in fig. 6.

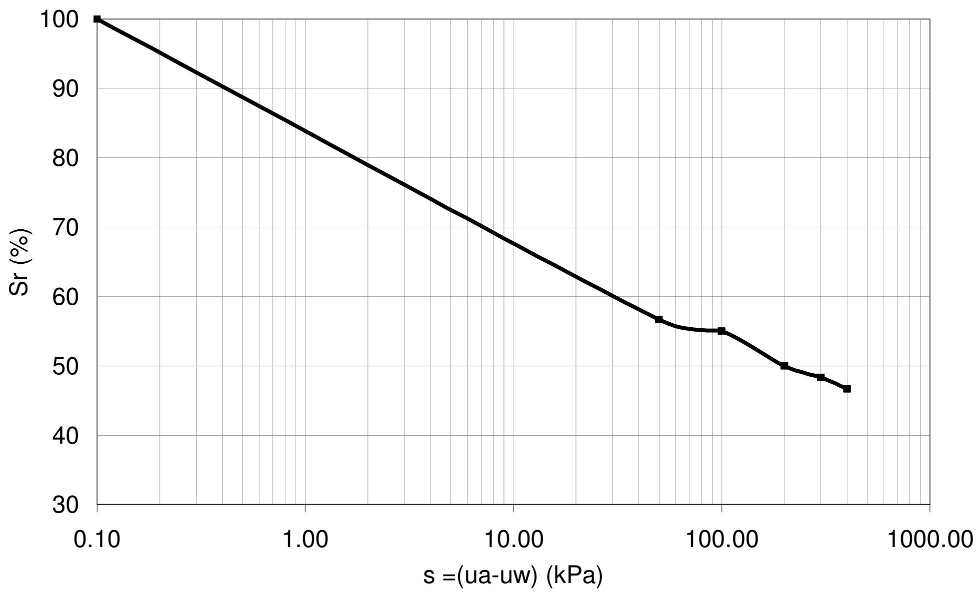

Fig.5 Volumetric water content function

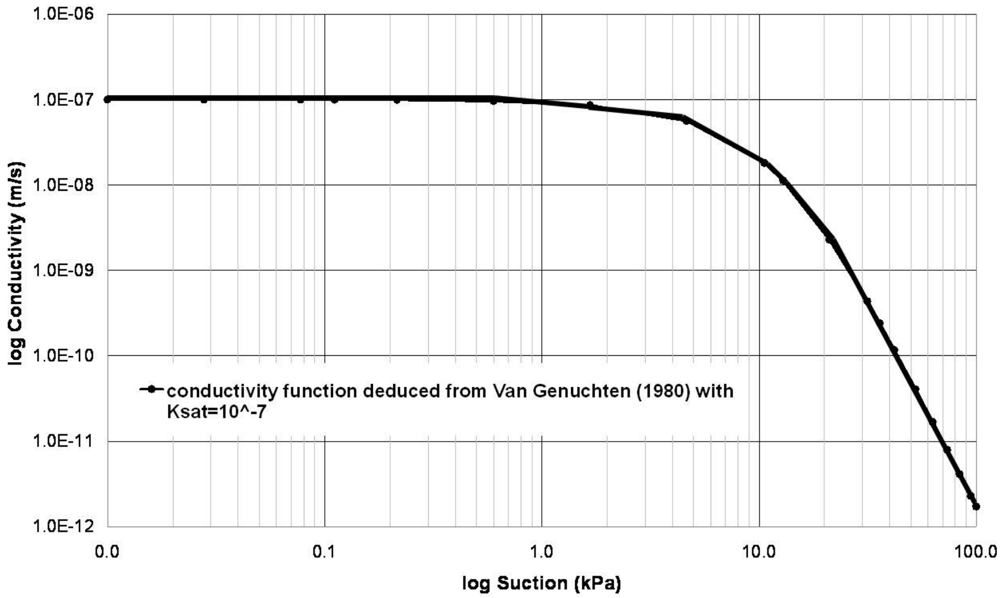

Fig.6 Hydraulic conductivity function

Initial and boundary conditions used to implement mathematical model are the same imposed by empirical evidence of lysimeter experiments.
SEEP don' t allow to set initial conditions in terms of volumetric water content of soil, so we have assumed water pressure values of tensiometers on 14th October at the same depth of the lysimeter (fig.7). This is not exactly correct but it would be good as first attempt in order to determine the real water retention curve of the soil.
At bottom we have imposed free drainage that simulate the geosynthetic cloth placed on the lysimeter' s bottom.
Lateral boundaries are impervious because the walls don't allow water drainage outside.

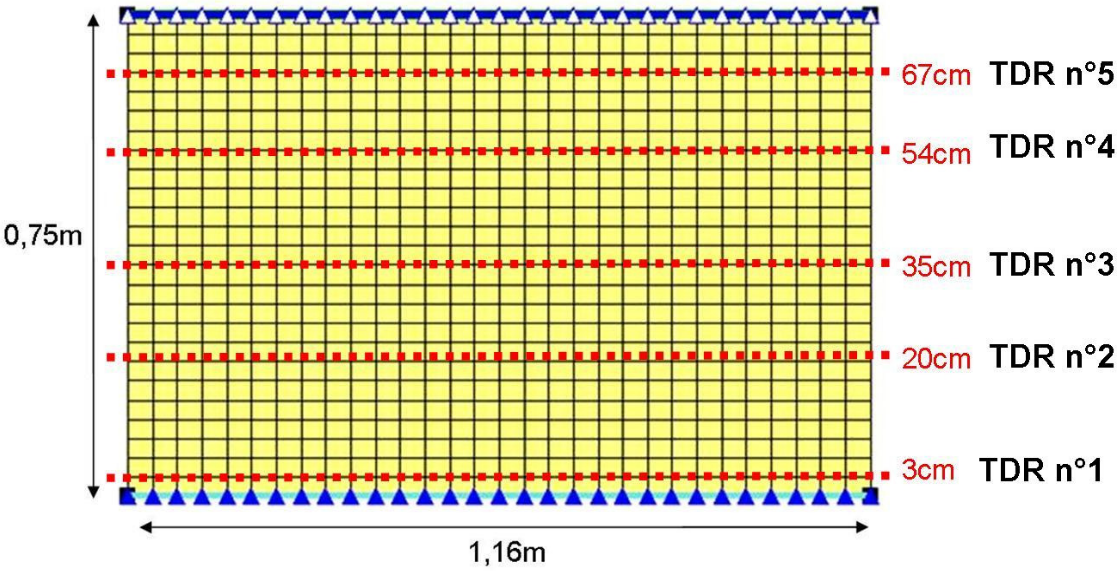

Fig.7 Lysimeter model

At surface of the scheme we assumed the rain intensity observed from 14th of October to 20th of November by weather station close to lysimeter (fig. 8).

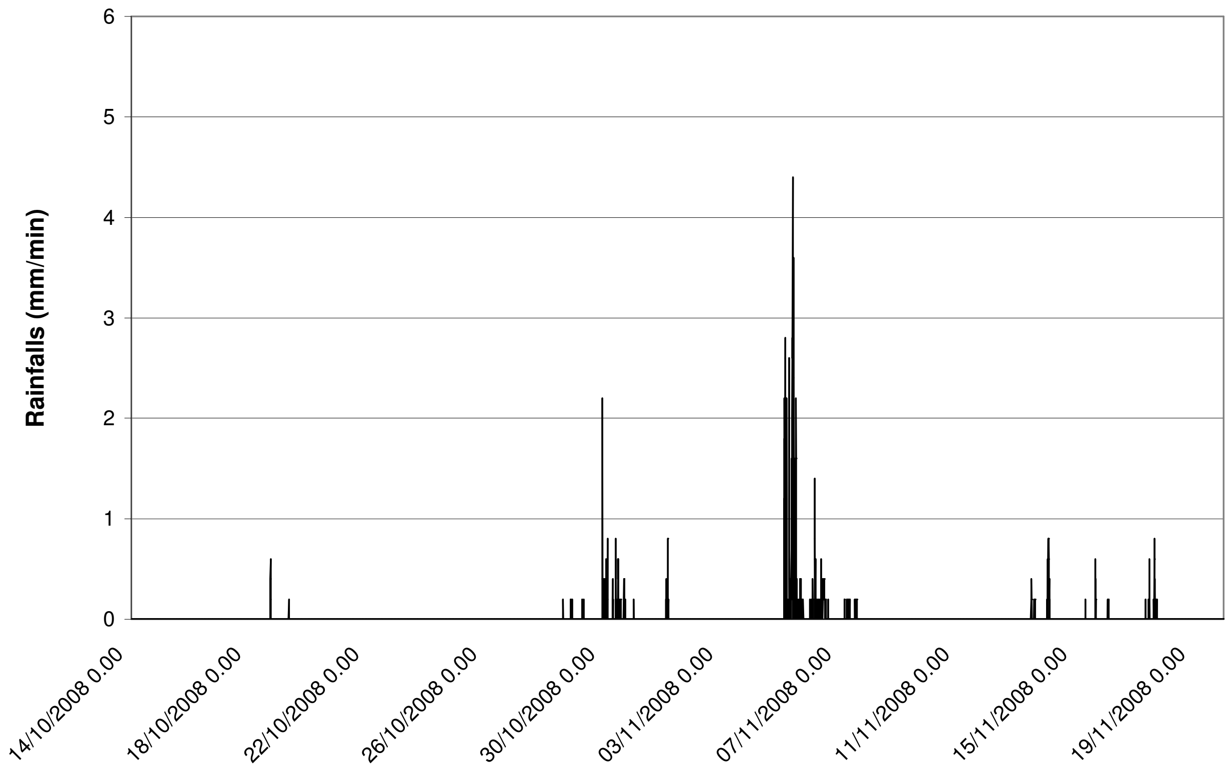

Fig.8 Rainfalls history (weather station close to lysimeter)

4. Results

In this work we have paid attention to water content trends.
In the next figures results in terms of volumetric water content of the soil are plotted at depths in which TDRs are installed, in order to compare experimental model and mathematical one.
Red curve is the result of numerical simulation, whereas the other one is the measure of TDR.

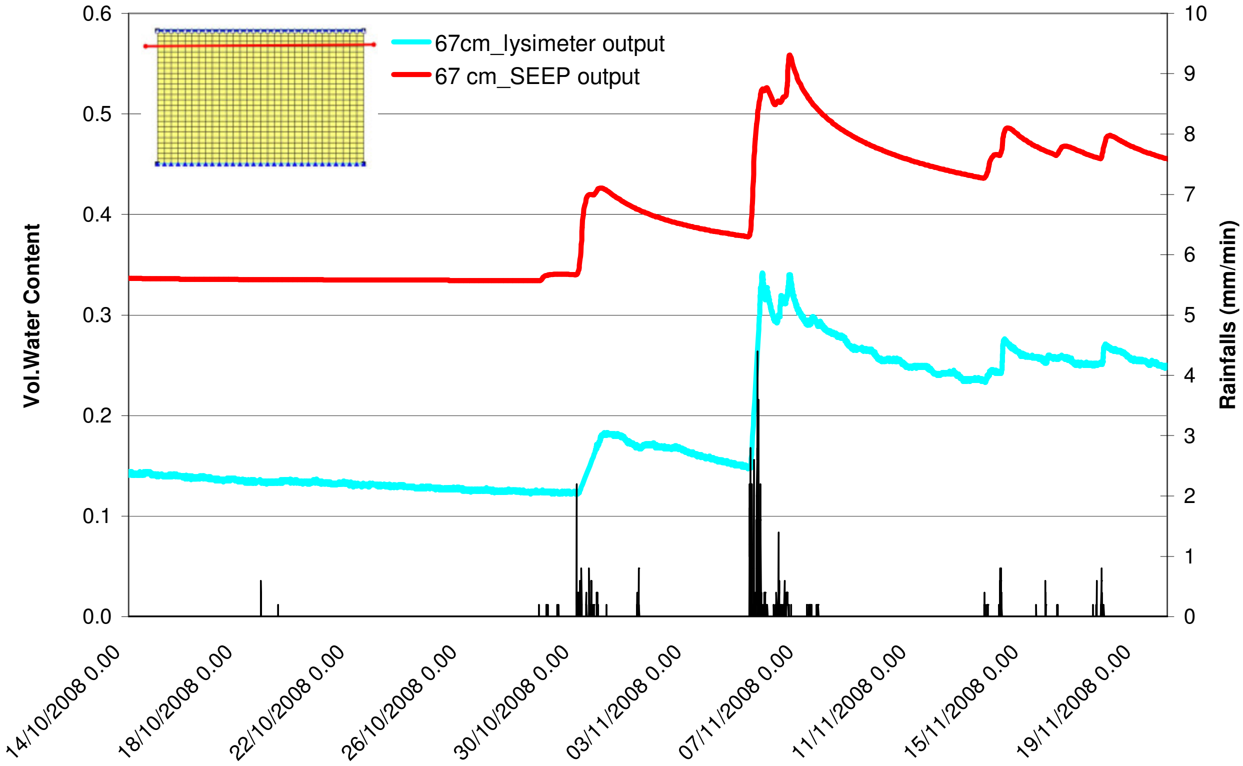

Fig.9 Water content trends at 67cm from the lysimeter' s bottom

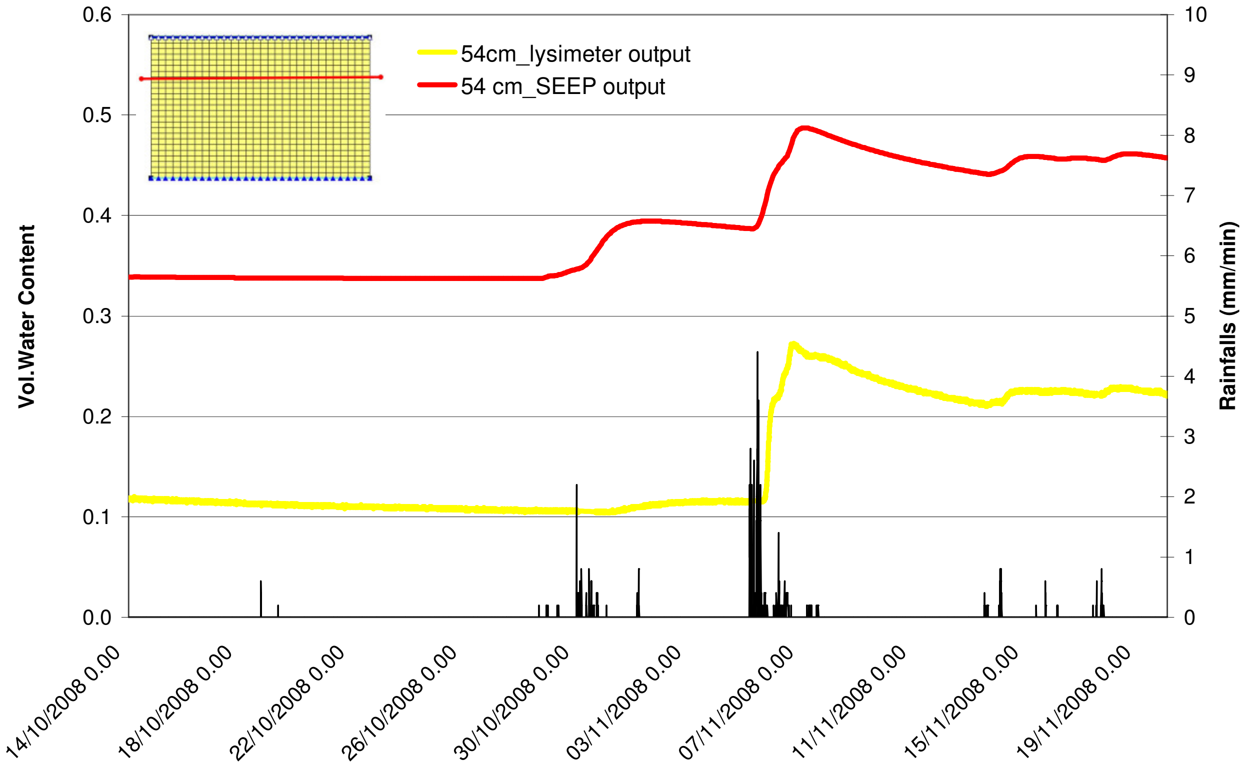

Fig.10 Water content trends at 54cm from the lysimeter' s bottom

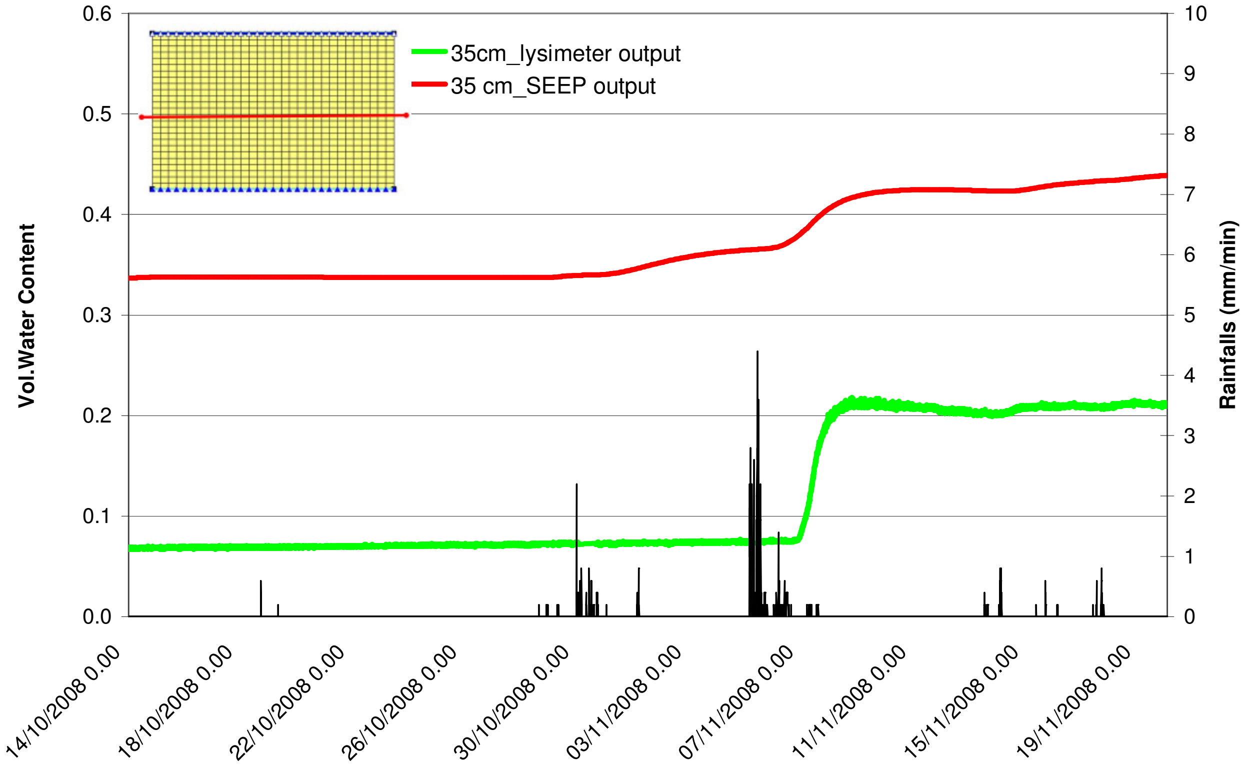

Fig.11 Water content trends at 35cm from the lysimeter' s bottom

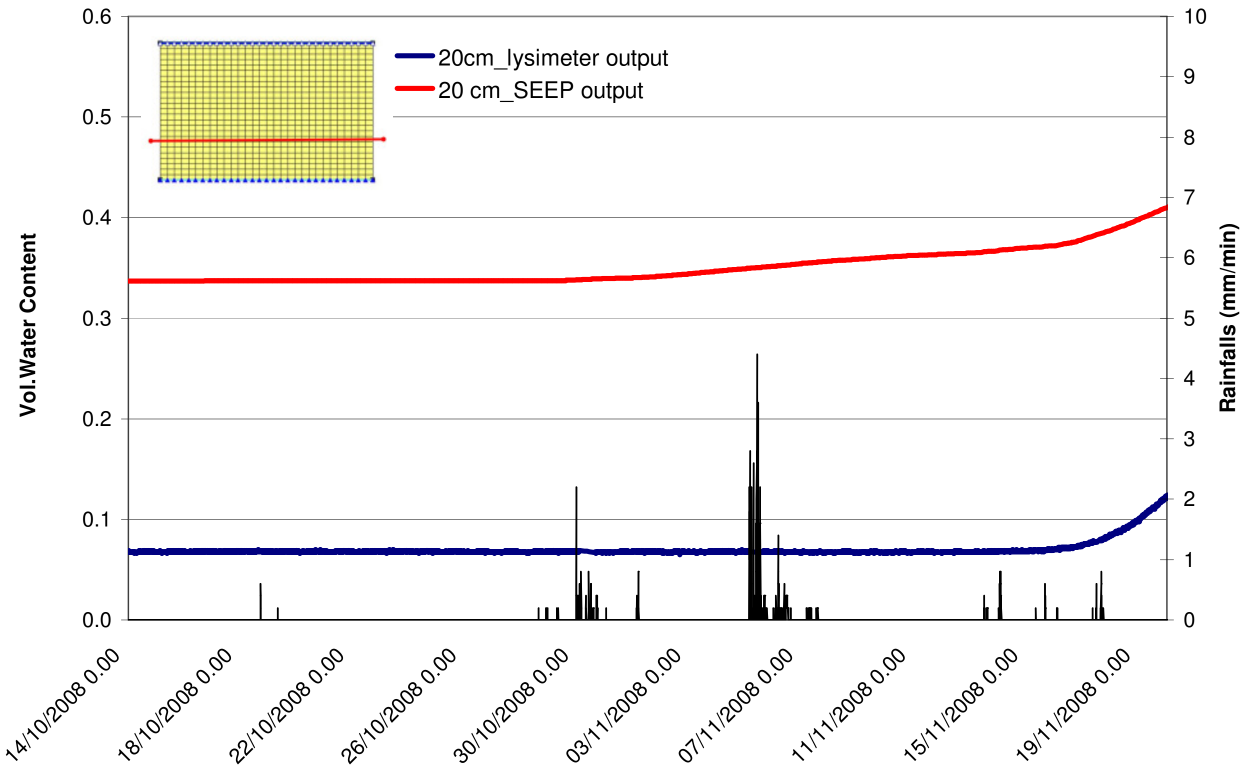

Fig.12 Water content trends at 20cm from the lysimeter' s bottom

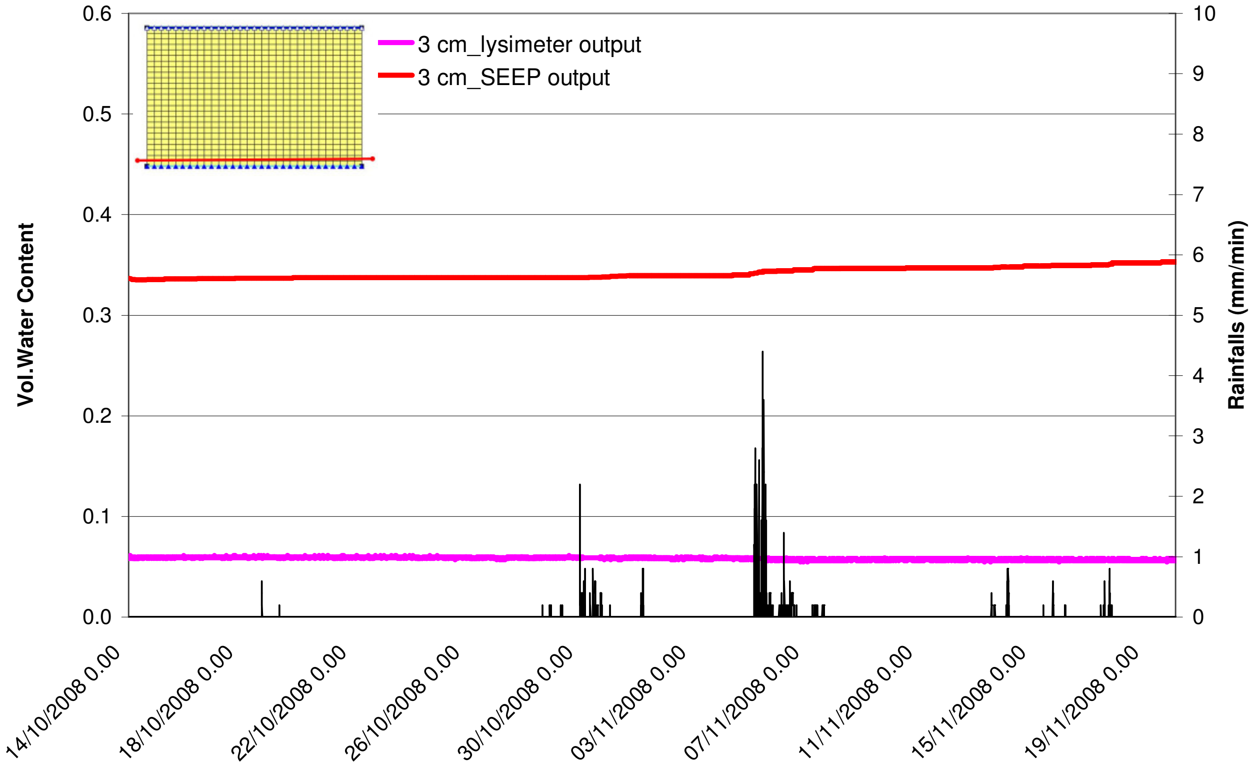

Fig.13 Water content trends at 3 cm from the lysimeter' s bottom

It is interesting to note that surface layer is affected by atmospheric conditions more than layers in depth; in fact water content trend at 3 cm from the base (fig. 13) is more or less constant, whereas at 67 cm (fig. 9) trend presents fluctuations highly pronounced in agreement with rainfalls.

All graphics show that trends obtained by SEEP/W are similar to trends achieved by TDR, even if initial condition is not the same; the reason of this is that in SEEP/W it is not possible to set initial condition in terms of volumetric water content of soil, so initial values are approximate.
Anyway the main goal of this work is to validate with a mathematical model the experimental measurement of TDR, so preliminary results are more than satisfactory.

5. Conclusions

This work describes first measures obtained from experimental activity with lysimeter.
It is a device able to characterize the hydraulic behaviour of soil by means of sensors inside the sample, that measure temperature, suction and water content of soil.
We focus attention on TDR water content measurements at different depths obtained during the first month of test.
Soil response to rainfalls is faster on surface and slower into layers in depth.
We have carried out a first attempt to analyse the water content measures.
In order to validate the results of lysimeter experimentation, numerical analyses have been performed, using the finite element software SEEP/W; it is able to interpret the seepage process through the sample.
At present hydraulic properties of Nocera Inferiore soil are not exactly defined, besides its behaviour causing flowslide on March 2005 is not well-know.
Therefore comparing sensors and seep analyses outputs, it is possible to get properties of soil closer and closer to the real-ones.
The input data to implement mathematical model are the same imposed by empirical evidence of lysimeter experiments.
So that it is possible to make a comparison between results of TDR measures and that ones of numerical analysis.
It seems that numerical outputs are in agreement with the behaviour observed into lysimeter.