The installation and its operation during a hydrological year of the unsaturated variables UNIWA station

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1 Introduction

Understanding the dynamics of unsaturated soil variables is critical for various fields, including geotechnical engineering, hydrology, agriculture, and environmental engineering. The behaviour of soil in its unsaturated state plays a key role in water infiltration, plant growth, and the mechanical behaviour of soil. Monitoring unsaturated soil variables is a challenging task due to the complex interactions between soil texture, moisture, and atmospheric conditions, but still not widespread enough in research and engineering practice. To address this challenge, a field station was developed by the SOMELAB (Soil Mechanics Laboratory) team at the University of West Attica (UNIWA) in cooperation with EDAFOS Engineering Consultants S.A. as its industrial partner, which monitors unsaturated soil variables at three depths. Located at the backyard of SOMELAB it incorporates advanced sensors and loggers with continuous recording for soil suction and moisture content. This paper presents and discusses the design, installation, and initial findings of the field station, with special reference to the collected during Medicane Daniel in September 2023, which contributes to the understanding of spatial and temporal variability of unsaturated soil conditions.

2 Station and instrumentation

The location of the unsaturated soil variables field station at SOMELAB backyard ensures easy access for continuous data recording and instrumentation maintenance. The station is situated in a vegetated area with top soil of thickness less than 20 cm and at a position that avoids interference with tree roots and thick vegetation that could complicate excavation or sensor installation and response. Weather data are collected from a UNIWA meteorological station. The excavation and installation of the station was performed manually, minimizing soil disturbance and maintaining the site's natural conditions as much as possible. Soil sampling was also conducted at different layers during the excavation. Sensors were installed at depths of 0.45, 0.70 and 1.30m (see Fig. 1). The excavation was backfilled with the soil removed during the sampling process for each additional layer. Three different types of sensors are used: 1) Suction Ceramic Stone Sensors (TEROS 21) measuring both soil suction in the range of 0 to -100 MPa and temperature, which are installed at 0.45m, 0.75m, and 1.30m depths. 2) Tensiometers measuring suction in the range of 0 to -90 kPa and are installed with their ceramic tips at the same depths as the TEROS 21 sensors (0.45m, 0.75m, and 1.30m). They are intended to be used in future wetting tests at the site due to their smaller suction range. 3) Volumetric Water Content Sensor (TEROS 12) installed at the 0.45m depth, which measures volumetric water content, temperature and electrical conductivity. All sensors, except the tensiometers, are connected to a Data Logger recording data every 15 minutes.

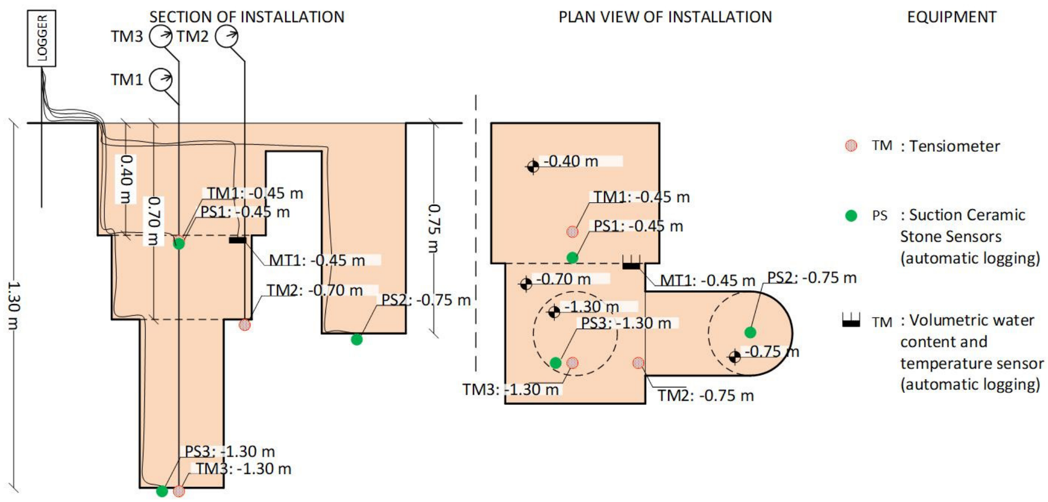

Fig. 1: Soil profile of the station and sensor location in cross-section on the left and plan view on the right (schematic out of scale and proportion).

3 Soil profile

The samples taken from the site were used to perform a set of classification tests, the results of which are summarized in Tab. 1.

Tab. 1: Index properties of the soil profile

Soil Depth (m)	Clay Fraction (%)	Fines (%)	w_L (%)	I_P	G_s	USCS
0.00-0.10	5.5	45.7	42.7	13.1	2.52	SM
0.10-0.25	-	14.5	N.P.	N.P.	-	SM
0.40-0.50	-	69.8	-	-	-	ML-CL
0.50-0.75	16.0	85.5	37.4	16.7	2.70	CL

The soil-water characteristic curve (SWCC) of the soil found at 0.10-0.25m depth was measured using the axis translation technique as applied in a pressure extractor with 1500 kPa air-entry value porous ceramic disks. Additionally, the salt solutions total suction control method was used to cover a greater range of suction values for the same sample. The SWCC was modelled using the equation proposed by van Genuchten (1980) (Eq. 1 with normalised water content w/w_o used instead of degree of saturation S_r). The air entry pressure estimated from the best fit of parameter a, of the simulation is 12.5 kPa.

$$S_r = \frac{1}{[1+(as)^n]^m} \tag{1}$$

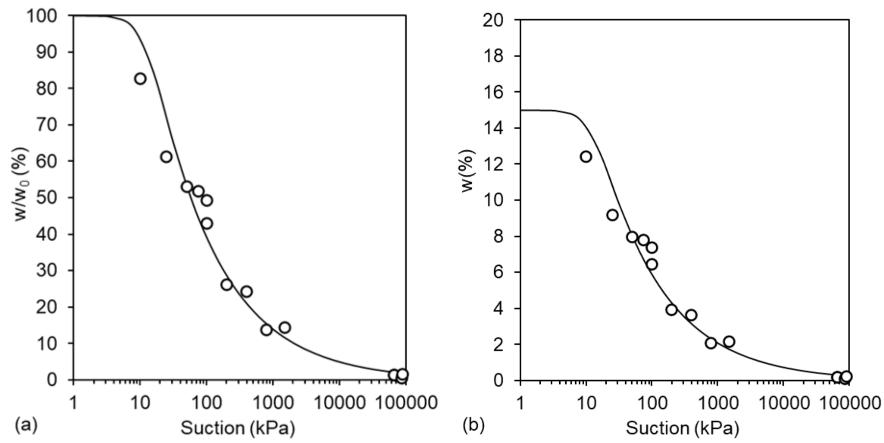

Fig. 2: SWCC data with the van Genuchten (1980) best-fit in terms of a) normalized water content -suction and b) initial water content-suction, for values of parameters n=3, a=0.08 and m=0.15.

4 Response of the UNIWA station during Medicane Daniel

The UNIWA UNSAT station was already built (25/7/23) by the time Medicane Daniel (8/9/23), so it managed to capture the extreme weather phenomenon in Attica. Despite that Daniel only slightly affected the region (approx. 100mm/24hrs in Attica instead of 1000mm/24hrs in Thessaly - Central Greece), a definite response was recorded (see Fig. 3). The practically stabilized suction values (typical of the dry season) of the order of MPa, decreased to zero in less than an hour and even down to a max depth of 0.7m. Similarly fascinating is the non-effect at a depth of 1.35m. A rainfall of 25% of the average annual rainfall for the region within 24hrs failed to cause any change in the pore pressure regime below 1m of soil depth with soil suction simply continuing unaffected its seasonal evolution. Degree of saturation was calculated from the volumetric water content and the density of the soil.

5 Conclusions

The paper presented an overview of a field station developed at UNIWA that monitors unsaturated soil variables, including soil suction and water content, at multiple depths. The station uses porous block sensors, tensiometers, and volumetric water content sensors to continuously record soil data and monitor the response of unsaturated soils to environmental conditions, particularly rainfall events. The preliminary field station data align with initial expectations, and the response of the sensors during the extreme weather event, Medicane Daniel demonstrates the effectiveness of the system. These data revealed a rapid decrease in soil suction following heavy rainfall but also indicated that deeper soil layers (below 1 meter) were practically unaffected by the storm's impact on suction levels, highlighting the spatial variability of soil moisture dynamics.

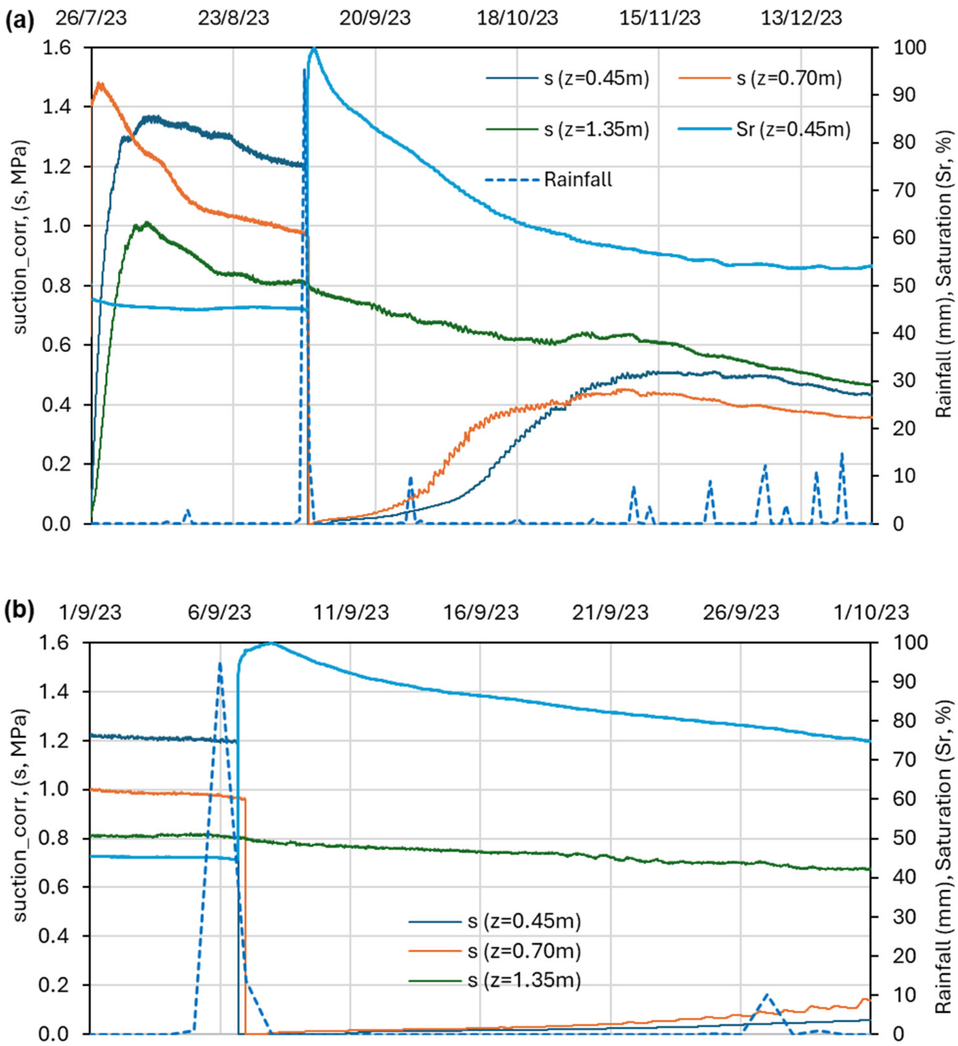

Fig. 3: Degree of saturation and suction response at 3 depths at UNIWA station vs rainfall, a) since installation of the station till the end of 2023, & b) for September 2023 only showing the effect of Medicane Daniel.

References

van Genuchten, M. Th., 1980. A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. *Soil Science Society of America J,* 44 pp. 892-898.