

**THE INFLUENCE OF SOME PARAMETERS ON PENETRATION
RESISTANCE OF A SILTY SOIL**

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Abstract: *This paper presents the influence of some parameters on penetration resistance of a silty soil such as dry density, compaction water content and prior immersion time. Obtained results show an increase of penetration resistance with dry density, decrease with compaction water content and prior immersion time which leads to the change of suction of soil caused by the change of infiltration of water. In the case of a low dry density and a long prior immersion time, the influence of the compaction water content is not significant. The effect of suction diminution is more and more weak over time of prior immersion, and it plays a minor role for the soil having a high water content or a low dry density.*

Keywords: penetration resistance, dry density, compaction water content, prior immersion time, infiltration, suction.

1. INTRODUCTION

Penetration resistance of soil is one of the parameters evaluating the growth of root in hydraulic structure, and the effect of soil resistance on the end of a stake when the stake is pressed into the soil. Roots must deform the soil matrix in order to penetrate pores with diameters that are smaller than those of the root. As the resistance to root penetration increases, the rate of root growth is reduced, the morphology of the root is changed and important processes occurring in the shoot are adversely affected (Young et al., 1997; Passioura, 2002). Reductions in rooting depth for various tree species grown in compacted soils have been attributed to increases in mechanical resistance. A commonly accepted technique is to measure mechanical impedance with a penetrometer which has been used widely as comparative measures of soil strength and as rapid appraisals of soil compaction in the field. Numerous parameters effecting the penetration resistance of soil such as compaction water content, dry density, the rate of root, ... In this work, we use a penetrometer device in laboratory to study the influence of dry density and compaction water

content on a silty soil, and to compare with the result of other works, and the influence of the diminution of suction caused by the increase of water content when a soil sample is immersion into water during a prior immersion time.

2. EXPERIMENTAL APPARATUS AND MATERIAL

2.1. Experimental apparatus

The scheme of an experimental penetrometer device is shown in *Figure 1*. This is a device for measuring the penetration resistance of soil. This device consists of: force sensor (A), displacement sensor (B) penetrometer rod (C), press with constant speed of displacement (D), cone of penetrometer (E) and data logger (F).

The penetrometer rod is made in steel and consists of a sleeve of 12 mm diameter and a rod of 8 mm diameter whose one end is connected with the force sensor, another fixed in the cone of penetrometer whose the largest diameter is 15.5mm and the apex angle of the sharp point is 90°. The force measured by the sensor corresponds to the peak force exerted on the cone only. The presence of the lateral sleeve eliminates the measurement of the friction exerted by the soil on the rod.

The sample is initially placed within the mold in a tank filled with water for a time of immersion, then it is placed on the press plate,

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the end of the cone is placed in contact with the sample surface, the displacement sensor is placed on the mold and starts the recording of the test data program.

Before running the test, it is necessary to set the speed of the press (D), to obtain a good result, it is better to use a low speed. In our work, a speed of 1 mm/minute was used.

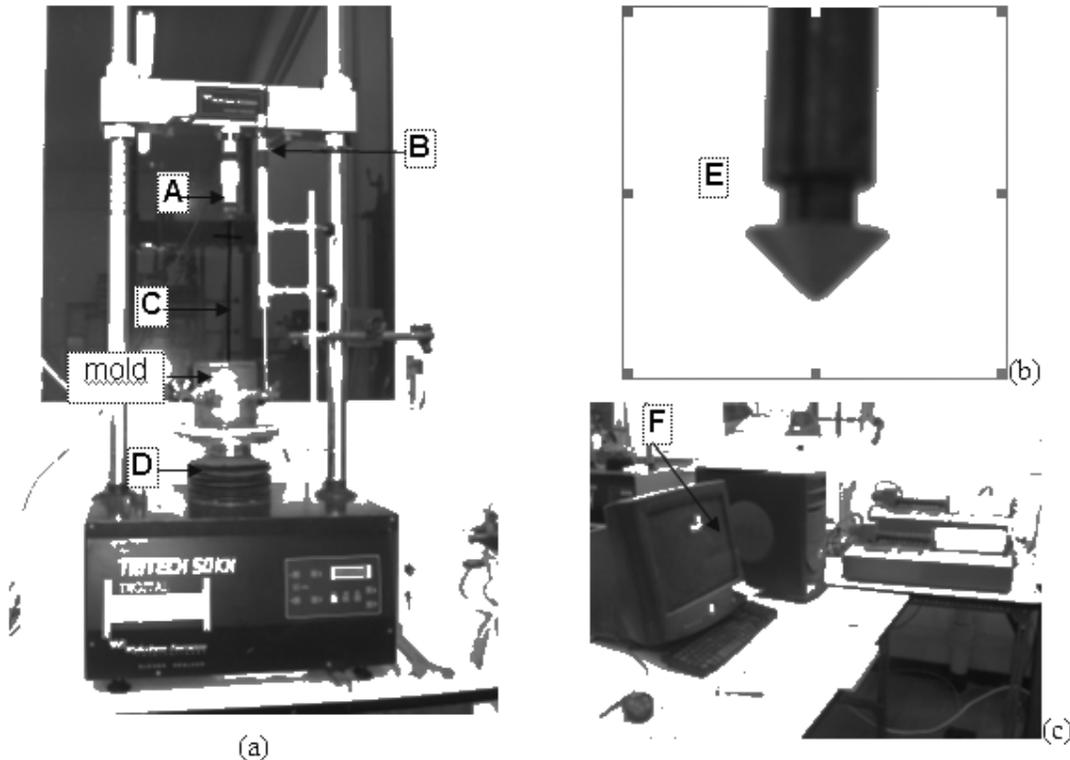


Figure 1. Photo of penetrometer test; (a) penetrometer device; (b) cone of penetrometer; (c) Data logger

2.2. Material

The material used in this work is a silty soil which was taken from a dike from the south of France. Soil testing was performed to determine the soil properties: Atterberg limits (XP CEN ISO/TS 17892-12), particle size distribution (XP CEN ISO/TS 17892-4), Standard Proctor compaction test (NF P94-093). The liquid limit (w_L) ranges from 30 to 35%, the plastic limit (w_P), from 14 to 16%, the plasticity index (I_P), between 13 and 16%, and the methylene blue value, $VBS = 1.8$, which is consistent with the relatively high soil plasticity. The optimum water content (w_{OITN}) is 17.2%, and the corresponding maximum dry unit weight γ_{dOITN} is about 16.8 kN/m^3 (corresponding dry density of 1.72 g/cm^3).

3. RESULTS AND DISCUSSION

3.1. Selection of a representative value of the penetration resistance

The variation of the penetration resistance of soil as a function of the depth of penetration into the soil is shown in Figure 2. The penetration resistance measured is that exerted on the cone of penetrometer.

The evolution of penetration resistance depending on the soil depth has four phases: two curved segments OB and CD and two line segments BC and DE. In the segment OB, the cone of penetrometer is not yet fully inserted into the soil and the soil is displaced laterally to the surface. In segment BC, the soil is compacted by the cone thus the penetration resistance increases due to decrease of the void

ratio. In the segment DE, the repel of soil which occurs during the insertion of the cone no longer reaches the surface and the resistance increases slightly with depth.

To facilitate comparisons in different cases, we chose the point A (point of intersection between two straight lines BC and DE) in *Figure 2* to deduce the critical penetration resistance. We chose the point A even if the water content changes according to the depth of soil due to the pre-soaking time in our work because the depth corresponding to the point A is located in the area where the water content is nearly stable.

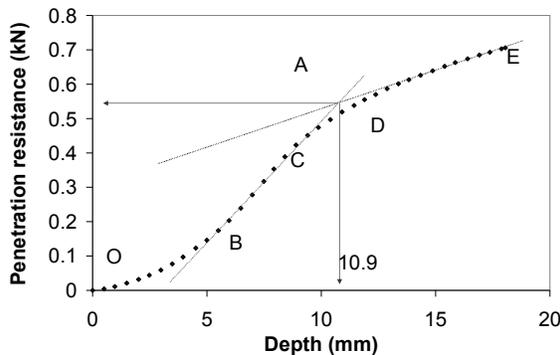


Figure 2. Example of a penetration resistance curve as a function of the depth of soil

3.2. Influence of density dry

The results in *Figure 3* show an increase of penetration resistance of soil with an increase of dry density, it can be explained by the increase of normal shear strength. The more soil is moist, the more influence of dry density on the penetration resistance is low. According to Fredlund et al. (1978), the shear strength is determined by the equation (1):

$$\tau = c' + (\sigma_n - u_w) \tan \phi' + (u_a - u_w) \tan \phi^b \quad (1)$$

Where, τ is the shear strength; c' is the effective cohesion; σ_n is the normal stress; ϕ if the internal friction angle; u_a is the air pressure in the pores; u_w is the pressure water in the pores, and ϕ^b is the angle indicating the rate of increase in shear strength with suction.

In fact, the increase in the dry density leads to an increase in normal stress (σ_n) then, the shear strength increases with the normal stress.

These were confirmed by previous works (Weaich et al., 1992; Taibi, 1994; Nishimura and Fredlund, 2000).

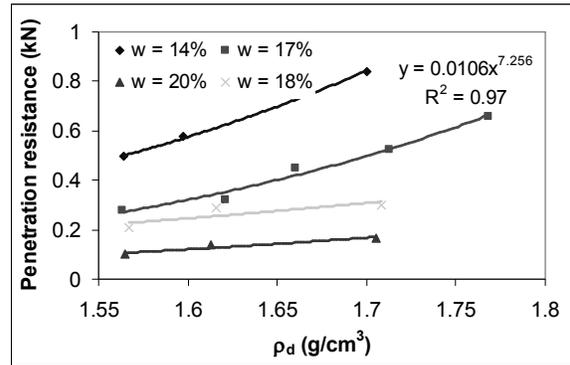


Figure 3. Evolution of the penetration resistance as a function of the dry density for different compaction water contents

According to the results, we conclude that the penetration resistance increases in power function as the dry density, which is in agreement with the conclusions of Mirreh and Ketcheson (1972), Bennie Burger (1988), Weaich et al. (1992), Panayiotopoulos et al. (1994), Vaz et al. (2011).

3.3. Influence of compaction water content

It found that the penetration resistance of soil decreases with an increase of compaction water content (*Figure 4*).

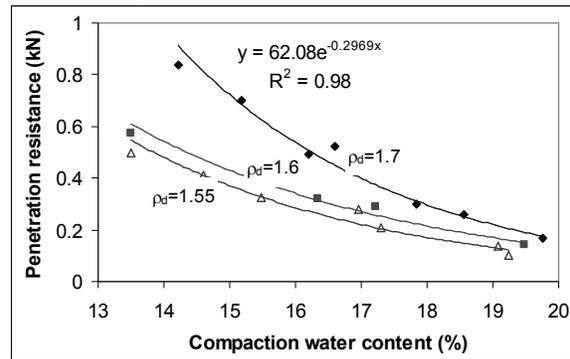


Figure 4. Evolution of the penetration resistance as a function of the compaction water content for different dry densities

Higher of the dry density the influence of compaction water content is clearer. We believe that the increase in water content leads to a decrease in suction (Fleureau et al, 2011), which decreases the penetration resistance of the soil. These results are in agreement with those of

Fredlund et al. (1978); Nishimura and Fredlund (2000).

The results are in agreement with the conclusion of the work of Bennie and Burger (1988); Vaz (2003); Vaz et al. (2011).

A similar trend is observed when we plot the relationship between penetration resistance and the degree of saturation. In *Figure 5*, it found that the penetration resistance decreases as the degree of saturation increases, regardless of the dry density, which is in agreement with the conclusions of the work of Weaich et al. (1992). It found that the more the dry density is increases, the more of the influence of the degree of saturation is clear.

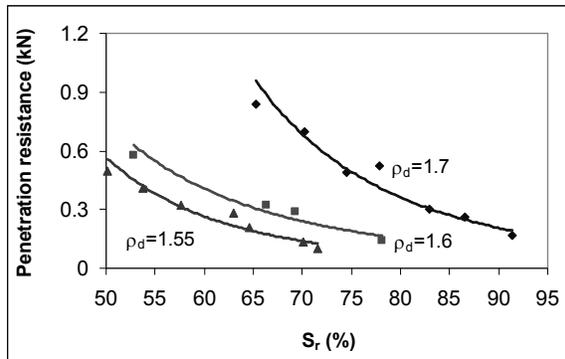


Figure 5. Evolution of the penetration resistance as a function of the degree of saturation for different dry densities

3.4. Influence of prior immersion time

In order to study the influence of infiltration of water into a soil sample, a series of test were performed after placing the sample under a static hydraulic load of 10 cm at different prior immersion times.

Results obtained show a decrease of penetration resistance with an increase of prior immersion time but when the prior immersion time is higher than 1000 min this influence is negligible. It found in *Figure 6* that the influence of prior immersion time is negligible if the compaction water content is higher than w_{OPN} ($w \approx 19\%$, 20%). In the case where the compaction water content of soil is less than the optimum or is approximately equal this one, the penetration resistance rapidly decreases with increase of the pre-immersion time when it is

less than 500 minutes (especially less than 200 minutes). It found that the more the initial water content is low, the more influence of the pre-immersion time is clear.

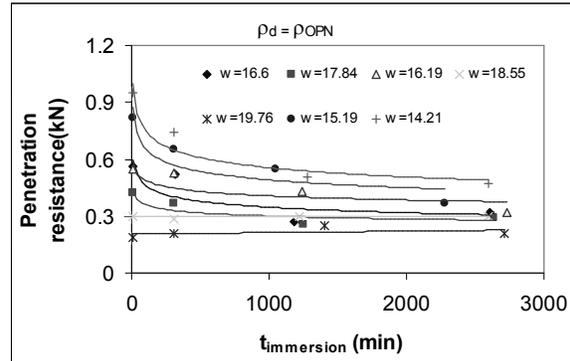


Figure 6. Evolution of the penetration resistance as a function of the prior immersion time for different compaction water contents

In *Figure 7*, it found that at low dry density ($\rho_d = 1.56 \text{ g/cm}^3$ and 1.62 g/cm^3) the penetration resistance is necessarily influenced by prior immersion time, and if the dry density is very dense ($\rho_d = 1.76 \text{ g/cm}^3$) the influence of prior immersion time is negligible.

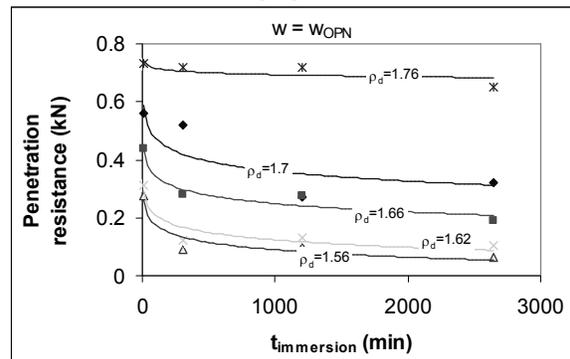


Figure 7. Evolution of the penetration resistance as a function of the prior immersion time for different dry densities

To explain this effect, we believe that the reduction in the penetration resistance when the immersion time prior increases caused by the infiltration of water into the sample that reduces the suction of the soil. A series of infiltration tests were performed for the samples possessing the same conditions. From the results shown in *Figure 10*, base on the result of Souli's work (Fleureau et al., 2011) we can deduce the suction values corresponding to changes in the

water content as a function of prior immersion time (Figure 10). It found that the quickly increase in water content with $t_{\text{immersion}}$ leads the quickly decrease of suction with the prior immersion time when it is less than 500 minutes. These results are in agreement with the decrease in the penetration resistance as a function of the prior immersion time. On the other hand, once the sample placed under water with prior immersion time the soil swells more and more with time of immersion (Figure 9) leading the reduce of the dry density of sample.

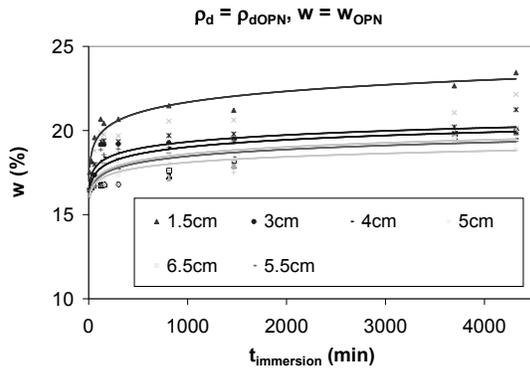


Figure 8. Evolution of water content as a function of the prior immersion time for different depths in the soil

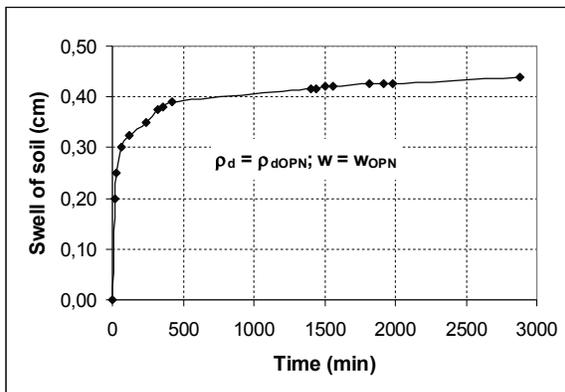


Figure 9. Evolution of swell of soil as function of the prior immersion time

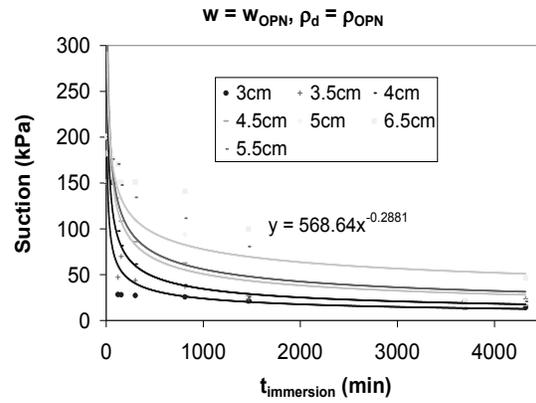


Figure 10. Evolution of suction as a function of the prior immersion time for different depths in the soil

3. CONCLUSION

Base on the results obtained from the tests on the cohesive soil of silty soil, we can conclude:

- Immersion of sample in water leads a decrease of suction but this effect of suction diminution is more and more weak over time of prior immersion,

- Penetration increases with an increase of dry density. The more soil is moist, the more influence of dry density on the penetration resistance is low.

- Penetration decreases with an increase of compaction water content, but effect of water content depends on the prior immersion time and dry density. In the case of a low dry density and a long prior immersion time, the influence of the water content is not significant.

- The pre-immersion time results in a reduction of the shear strength, but it plays a minor role for the soil having a high water content or a low dry density.

REFERENCES

Bennie A.T.P, Burger R.du T (1988), "Penetration resistance of fine sandy apedal soils as affected by relative bulk density, water content and texture", South Africa Journal of Plant Soil, 5(1), p5-10.
 Fleureau J.M, Dao L.Q, Oualmakrane M, Souli H, and Bannour H (2011), "Etude des mécanismes mis en jeu lors du Jet Erosion Test", EDF-ENISE Final Report. Paris, p90.

- Fredlund D.G, Morgenstern N.R, Widger R.A (1978), “*The shear strength of unsaturated soils*”, Canadian Geotechnical Journal, 15(3), p313-321.
- Mirreh H.F, Ketcheson J.W (1972), “*Influence of soil bulk density and matric pressure on soil resistance to penetration*”, Candian Journal of Soil Science, 52, p477-483.
- Nishimura T, Fredlund D.G (2000), “*Relationship between shear strength and matric suction in an unsaturated silty soil*”, Proceedings of the Asia Conference on Unsaturated Soil, UNSAT ASIA 2000, Singapore, p563-568.
- Panayiotopoulos K.P, Papadopoulou C.P, Hatjioannidou A (1994), “*Compaction and penetration resistance of an Alfisol and Entisol and their influence on root growth of maize seedlings*”, Soil and Tillage Research, 31, p323-337.
- Passioura, J.B (2002), “*Soil conditions and plant growth*”, Plant Cell Environ, 25, p311-318.
- Taibi S (1994), “*Comportement mécanique et hydraulique des sols soumis à une pression interstitielle négative – Etude expérimentale et modélisation*”. PhD report, Ecole Centrale Paris, Paris.
- Vaz C.M.P (2003), “*Use of a Combined Penetrometer-TDR Moisture Probe for Soil Compaction Studies*”, Embrapa Agricultural Instrumentation, São Carlos, Brazil, pp8.
- Vaz C.M.P, Manieri J.M, De Maria I.C, Tuller M (2011), “*Modeling and correction of soil penetration resistance for varying soil water content*”, Geoderma, 166, p92-101.
- Weaich K, Cass A, Bristow K.L (1992), “*Use of a penetration resistance characteristic to predict soil strength development during drying*”, Soil and Tillage Research, 25, p149-166.
- Young I.M, Montagu K, Conroy J, Bengough A.G (1997), “*Mechanical impedance of root growth directly reduces leaf elongation rates of cereals*”. New Phytol, 135, p613–619.

Tóm tắt:

ẢNH HƯỞNG CỦA MỘT VÀI THÔNG SỐ ĐẾN SỨC KHÁNG XUYÊN CỦA ĐẤT Bùn SÉT

Bài báo giới thiệu ảnh hưởng của một vài thông số đến sức kháng xuyên của đất như là dung trọng khô, độ ẩm đầm nén và thời gian ngâm trước. Kết quả thu được thể hiện độ tăng của sức kháng xuyên với dung trọng khô, độ giảm so với độ ẩm đầm nén và thời gian ngâm trước cái dẫn đến sự thay đổi lực hút dinh gây ra bởi sự thay đổi của hiện tượng thấm nước. Trong trường hợp dung trọng khô thấp và thời gian ngâm trước dài, ảnh hưởng của độ ẩm đầm nén là không đáng kể. Tác động giảm lực hút dinh càng yếu khi thời gian ngâm trước tăng lên, và nó đóng vai trò thứ yếu đối với đất có độ ẩm cao và dung trọng khô thấp.

Từ khóa: sức kháng xuyên, dung trọng khô, độ ẩm đầm nén, thời gian ngâm trước, thấm, lực hút dinh.

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