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Soil Water Retention Curves of Three Different Soils using Different Methods

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ABSTRACT

The corrosion of metals in soils is a serious concern. To protect underground foundations, and steel and cast-iron pipes from corrosion, traditional galvanized coatings are not sufficiently effective in the long term. Alternative coatings therefore need to be evaluated. Soil wetness has been identified as a major influencing factor governing corrosion in soils. The optimal soil wetness for corrosion to be at its maximum rate is at its so-called air transition point, at which both the water and air phase, and their supply rate are continuous. This transition point is soil-dependent and can be derived from a soil water retention curve. The aim of this study is to determine the air transition point by determining water retention curves with the help of two commonly used methods. These were the filter paper method using Whatman No. 42 filters, a cheap and simple method widely used in geotechnics, and the modified evaporation method now becoming popular in soil science known as Hydraulic Property Analyzer (Hyprop). We used three test soils, an artificial soil (classified as sand), a natural loam, and a sandy loam. Soils were left untreated (non-compacted) and were compacted with a Proctor ASTM-698 to achieve preset densities. The highest dry densities obtained from the Proctor test were 2.070 g/cm^3 for the sandy loam, 1.950 g/cm^3 for the loam, and 1.51 g/cm^3 for the artificial soil, at optimum water content (volumetric) of 11%, 18.4%, and 19.5%, respectively. While the soil water retention curves generated from both methods on the Proctor-compacted samples strongly resembled with each other from near saturation till residual wetness for all three soils, they did match much less for the non-compacted samples. The latter was due to differences in dry densities between the untreated soils

Keywords: Soil Water Retention Curve; Air Transition Point; optimum Moisture Content; Filter Paper Test; Hyprop

1 INTRODUCTION

One of the major issues in soil studies is the corrosion of metals, which has an impact on economic and social development. Significant economic detriment upon buyer and supplier in form of maintenance cost associated with the above and underground structure. Especially in underground foundations in form of pile foundation and buried pipelines carrying oil and gas, corrosion not only reduces the service life of these structure can also lead to failure and loss of natural resources and toxicity within the surrounding environmental spheres. Therefore an extensive study needs to be established and to fully understand the phenomena of corrosion is essential to protect the underground infrastructures and the sustainability of the environment. The soil moisture content is one of the influential parameters in corrosion in soil (Azoor, Deo, Birbilis, & Kodikara, 2019), (Romanoff, 1957). Soil water interfacial characteristics have a direct impact on corrosion (Akkouche et al., 2016), (Almeida, Teixeira, Silva Filho, Assis Júnior, & Leão, 2015),(Azoor, Deo, Birbilis, & Kodikara, 2018). In soil science, the maximum corrosion lies in between at optimum moisture level. The soil moisture is expressed in terms of degree of saturation (Sr) which refers to the ratio volume of water to the volume of void spaces. The degree of saturation value ranges from 0%-100% (0% fully unsaturated and 100% fully saturated). The unsaturated soil and its properties depend on moisture content, pore structures, soil texture and compaction level, which is density or porosity. The relationship between degree of saturation (Sr) and soil suction (ψ kN.m/m^3, kPa) can determine the moisture retention and characteristics in soil typically illustrated by a plot known as soil water retention curve (SWRC)(Fredlund, 2006).

In this research area three different soils were used with two different methods (Hprop and Filter Paper), which was done with both compacted and uncompacted samples.

2 EXPERIMENTAL WORK

2.1 Materials

The three evaluated soils were provided by ArcelorMittal R&D Gent. The first soil, Loam Lembeek, is a loam soil excavated in Lembeek. The second soil is Artificial Soil, a mixture of eurosoils, which is classified as sand and the final soil is Schist Clay as sandy loam that comes from Ardennes shown in Figure 1.

2.2 Filter Paper Test

The filter paper test is globally accepted and a cheap way to calculate the suction indirectly in the soil by measuring gravimetric water content of filter paper at equilibrium, in which filter papers used as sensors (Fredlund & Rahardjo, 1993). The test is performed using ASTM D-5298 for both matric suction using contact filter method and total suction using non-contact filter paper method by Whatman 42 filter papers having diameter of 55mm and 70mm shown in (Figure1).

Moreover, it is important to take into account the influence of using of in-contact or non-contact filter paper on moisture content results. If the contact between soil surface and filter paper is not adequate, it will not provide precise results. Meanwhile at lower suction in non-contact filter paper test the vapours converts into water droplets due to condensation and encounter with filter paper may also affect the results. Therefore the measurement of both procedure is quite caring and sensitive and also requires 3-5sec to transfer the filter papers from set-up to sealed containers for weight measurement (Fredlund and Rahardjo, 1993).Therefore, these both methods (contact, non-contact FP) were dependent user. Especially measuring the water content of FP requires great consideration and quick handling is necessary.(Khan, Di Emidio, & Bezuijen, 2022).

2.3 Hyprop

The traditional techniques using the filter paper is time consuming and requires several months to determine the data points for SWRC. Whereas the Hyprop (Hydraulic Property Analyzer) is a laboratory instrument is used to determine hydraulic properties of different soil using two precision mini-tensiometers established on evaporation method to calculate water potential at different points.(Schindler, 1980). As the sample dries, the instrument calculates different water potential and changing time, simultaneously. It measures high resolution water retention data within few days (0-100kpa) (Schelle, Heise, Jänicke, & Durner, 2013). The test analyses wide range of soil textures and classes such as sand, silt, silt loam, and clay (Zhuang et al., 2017).

3 METHODOLOGY

The three soil samples, named as Loam Lembeek, Artificial Soil, and Schist Clay were provided by ArcelorMittal R&D Gent, including their own soil tubes fully saturated uncompacted samples. The other soils samples were compacted using modified proctor test as per ASTM 698 to achieve the optimum moisture content, upon those moisture content the samples were prepared for filter paper test and Hyprop, the table 1 illustrate the properties of soil samples.

Filter paper method is used in many geotechnical engineering fields to determine suction, developed by scientist and agronomist.(Chandler, Crilly, SMITH, SMITH, & BRE, 1992), Whatman 42 ash-less filter papers used as per ASTM D5298-03 illustrated in (Figure 2).

Figure1. a) Loam Lembeek (loam), b) Artificial Soil (sand), c) Schist Clay (sandy loam)

Figure 2. *Whatman 42 filter papers, desiccator and container for filter paper samples*

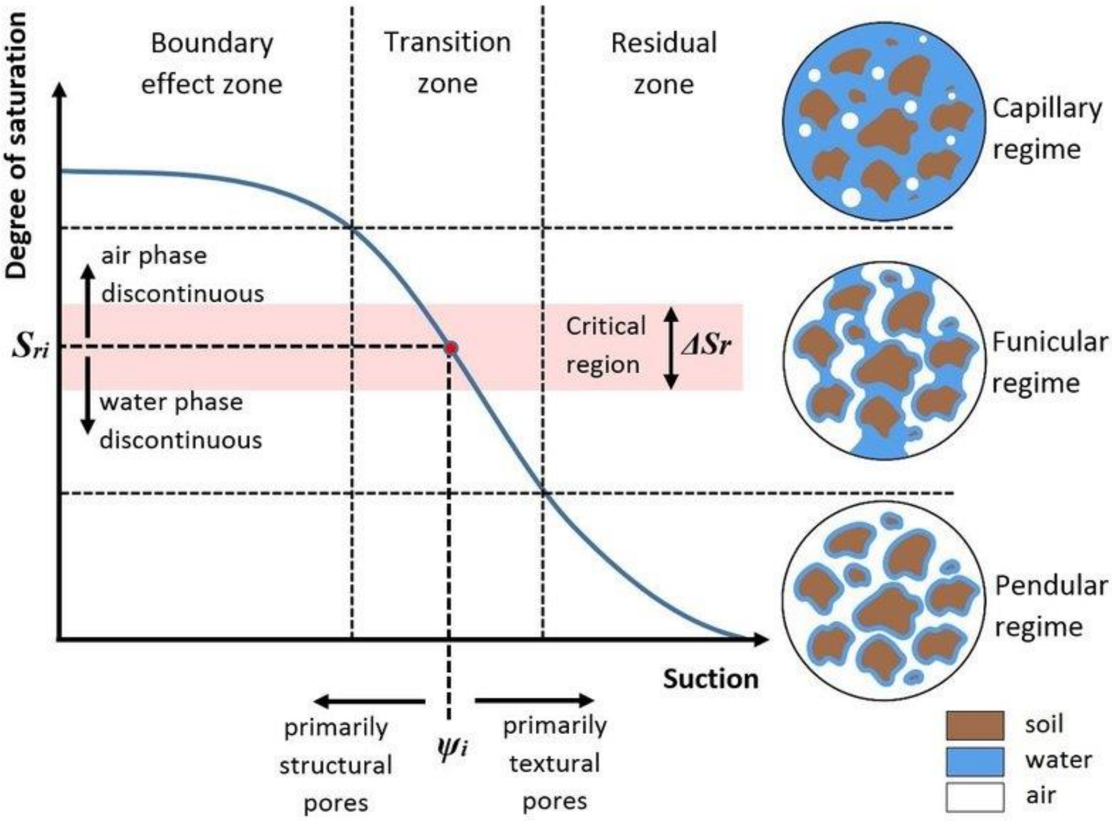

Figure 3. Schematic of the Soil Water Retention Curve (SWRC) (Azoor et al., 2019)

On the other hand, Hyprop is a quick method to determine the soil suction.

The test results of both (compacted and un-compacted), were used to evaluate the Air Transition point (ATP).

Table 1. *Properties of soil samples*

Properties/Soil	Loam Lembeek	Artificial Soil	Schist Clay
Sand (%)	2	79,6	45,2
Loam (%)	85,3	4,5	46,5
Clay (%)	12,7	15,9	8,3
Classification	Loam	Sand	Sandy Loam
CEC (cmol/kg)	12,16	13,16	3,29
IOC (%)	1,3	< 0,2	< 0,2
TOC (%)	< 0,2	13	< 0,2
pH	7.8	5,7	6.4
Dry bulk density, uncompacted (g/ml)	1,44	1,14	1,68
Wet density, uncompacted 100 % saturation (g/ml)	1,77	1,51	1,96
Gravimetric Water content (%)	22,9	32,46	16,67
Volumetric Water content (%)	33,0	37,0	28,0

4 RESLUTS AND DISCUSSIONS

4.1 Loam Lembeek (Loam)

The Figures 4a and 4b, illustrate that the result from matric suction and Hyprop, which align for Loam Lembeek. The result applies for both compacted and un-compacted samples. While the Hyprop provide faster results than filter paper method. The shift of the curve in Figure 4b, of Hyprop test is due to change in dry density of un-compacted samples. In filter paper the dry density is 1.43g/cm^3 and 1.44g.cm^3, while for Hyprop 1 it is 1.40 and 1.35g/cm^3 respectively, which cause the shift of curve.
Corrosion occurs in the funicular regime (see Figure 3) (Azoor et al., 2019), the funicular regime is delineated by projecting the two intersection of the three tangents of the curve vertically on the curve. In the compacted soil samples from Loam Lambeek, the funicular regime is delineated by the volumetric water content of 23.19% and 31.06%. The matric suction here is 187.30kPa and 81.63 kPa. The ATP achieve at a volumetric water content of 26% and having a matric suction of 149 kPa. For uncompacted sample in Figure 4b, the water content and suction achieve in Hyprop 1 is 26% WC and 179 kPa and its align with FP test which are 26% WC and 78 kPa respectively.

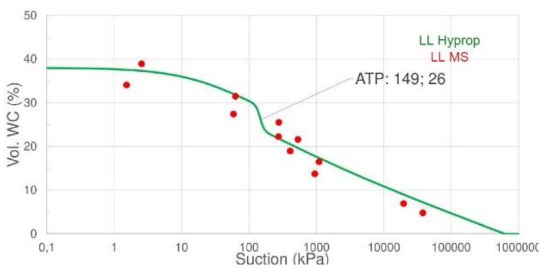

Figure 4a. *SWRC for Compacted Samples*

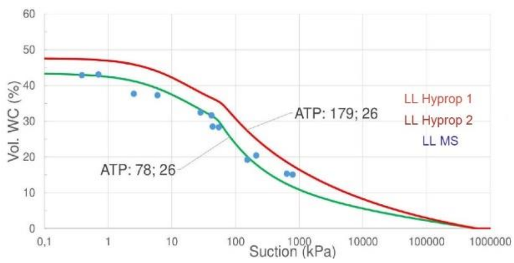

Figure 4b. *SWRC for uncompacted Samples*

4.2 Artificial Soil (Sand)

In Figure 5a, it can be seen that the result of the matric suction by filter paper test and Hyprop aligned for compacted artificial soil having the same dry density which is 1.30g/cm³ and 1.29g/cm³ respectively. For FP, the dry density is 1.07g/cm³ and for Hyprop 1 and 2 it is 0.93 g/cm³ and 0.95g/cm³ respectively. On the ATP the suction recorded for compacted soil is 85.5kPa and WC is 30.9%, while for uncompacted soil on ATP, the suction was found 84.5kPa at 39.5%. While for uncompacted soils the dry density differs that the reason the data points of SWRC using FP is shifted from Hyprop 1 and 2 curves.

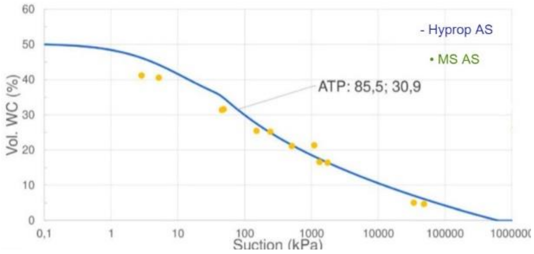

Figure 5a. *SWRC for Compacted Samples*

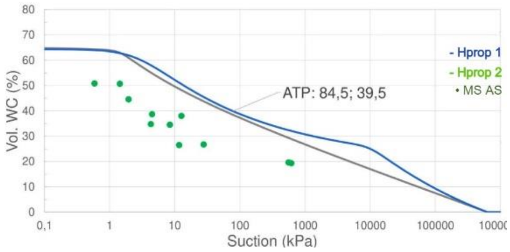

Figure 5b. *SWRC for uncompacted Samples*

4.3 Schist Clay (sandy Loam)

The Figure 6a, shows the aligned for both tests (Hyprop and FP) and having 783,0kPa suction and 16.5% WC at ATP. Moreover on graph 6b have 297.1kPa and having 11.2% WC. The funicular matric suction in uncompacted schist clay is in between 582.06kPa and 85.92kPa having 4.15% and 20.15% WC.

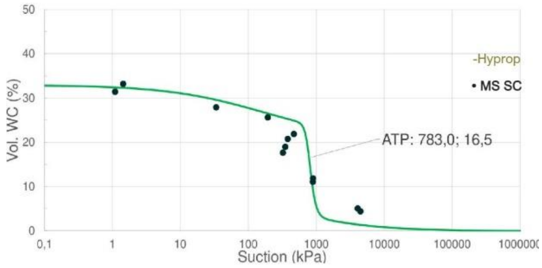

Figure 6a. *SWRC for Compacted Samples*

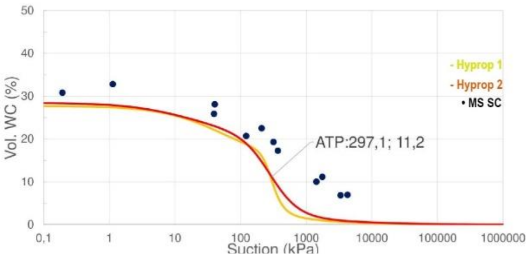

Figure 6b. *SWRC for Uncompacted samples*

5 CONCLUSIONS

Corrosion is the phenomena, whereby metal/alloys are affected by interaction with their surrounding environment. The properties of material changes chemically, physically, and mechanically underground and in open air. Water and air play vital roles in these phenomena, whereas water provides the necessary transport of electrolytes and air provides the oxygen. The rate at which material corrodes underground is not constant. This strongly depends on the moisture content of the soil, when both water and air phases are continuous, a constant supply of electrolytes and oxygen begins. The soil in the transition zone of the funicular regime shown in Figure 3, the corrosion rate is highest within the air transition point as the most aggressive conditions. The air transition point is the tipping point of Soil Water Retention curve (SWRC).

This research was conducted to find the most corrosive state at air transition points in three soils using two methods, Hyprop and Filter paper tests at optimum moisture content for compacted and uncompacted soil samples to evaluate the suction and WC at ATP. It was observed that the maximum corrosive state lies in between the air transition point. For the compacted soil sample, the air transition points of Hyprop and FP tests were aligned, respectively, for all three soils. While SWRC of Filter paper and Hyprop tests of un-compacted soil samples follow the same trend, but give different value this is due to change in densities of both samples compacted and uncompacted.

Moreover, the air transition point of the SWRC of funicular regime is just one parameters which effect the corrosion rate further research could be carried out to find the other parameters such Electric resistivity, pH value and Potentiodynamic Polarization test can be performed at the obtained water content of the air transition point. The soils can be tests in alternative method such as sand box and pressure plate, where the air transition point is always below 1500kPa. The value obtained can be compared with Hyprop and Filter Paper for further confirmation of accuracy.

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