Calibration of Soil Water Characteristic Curve Using FX Model

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Abstract
In the present scenario, soil mechanics plays a vital role. In the past few decades there is a wide range of exposure to the unsaturated soils as a significant portion of earth is consisting of arid and semi-arid climatic conditions. Unsaturated soils frequently undergo wetting and drying process due to seasonal variations. Due to this process, expansive soil may undergo swelling-shrinkage process. Considering the similarity between wetting-drying and freezing-thawing process, this study was an attempt to analyse the effect of the freezing-thawing process on suction behaviour of expansive soil. Suction is the basic and most important parameter which influences the behaviour of soil. Filter Paper method is used to for the study as an economical approach to evaluate suction. For the experimental study, samples were moulded to achieve full compaction (100% of Proctor density) for different degree of saturation. The moulded samples were passed through required number of the freezing-thawing cycles (0, 1, 3, & 5 nos.) and soil-water characteristic curves (SWCC) are formulated for all F-T cycles.

Keywords: Unsaturated soils, Suction, Soil water characteristic curve, geotextiles, freezing thawing cycles.

1. Introduction

The soil suction has a significant influence on the behaviour of unsaturated soils. The state of the soil while it is under reduced pressure is known as soil suction. It is developed as a result of a complicated energy state established by the interplay of soil, water, and air in the soil. The negative pressure created by this complicated energy is known as soil suction. As a result, suction is often defined as the amount of energy necessary to remove a unit volume of water from a given mass of soil. The effects of soil suction in unsaturated vs. saturated soil are investigated. The existence of suction in unsaturated soil modifies the behaviour of characteristics such as water potential, permeability, strength, and others that are constant in saturated soil. Fredlund and Rahardjo present an overview of the development of soil suction theory (1993). As a summary, "Soil Suction is generally referred to as the free energy condition of soil water"(Edlefsen& Anderson, 1943). The partial vapor pressure of the soil water can be used to calculate the free energy state (Richards). The thermodynamic relationship between suction and partial pressure of the pore-water vapor can be written:

$$\Psi = (RT/\ u_{wo}w_v) * ln(u_v/u_{vo})$$

Where; R = Universal Gas Constant T = Absolute Temperature u_{wo} = Specific Volume of Water (inverse of the density of water) w_v = Molecular Mass of Water Vapor u_v = Partial Pressure of Pore Water Pressure u_{vo} = Saturation Pressure of Water Vapor Over a Flat Surface of Pore Water u_v/u_{vo} - Referred to as Relative Humidity (RH in %) If a reference temperature of 20°C is selected, above equation reduced to;

$$\Psi = -135022\ ln(u_v/u_{vo})$$

According to Seki K (2007), the suction is a measure of the attraction between the soil and water. This allows water to rise to a height greater than that of the natural state. Suction is the most important parameter of hydraulic and mechanical behavior of unsaturated soils.
(Blatz JA et al., 2008) listed three components of suction in unsaturated soils: matric suction, adsorption in the case of clay minerals, and osmotic suction. The matric suction expresses the ability of water retention of soil components. Capillary suction, the difference between the pressures of air and water (pore pressure) and adsorption suction, the actions of physic-chemical adsorption of clays are the types of matric suction. Osmotic suction is the ability to retain water by the salts present in dissolved form in the pore water. The total soil suction can be seen as the sum of two components: Matric suction; Ψ_m and osmotic suction π;

$$\Psi = \pi + \Psi_m$$

The purpose of this study is to obtainsoil water characteristic curve (SWCC) of an expansive soilfor different number of freezing-thawing cycles (0,1,3, 5) at optimum compaction usingFredlund and Xing (1994) modeland to validate the results parameters obtained.

2. Material and methodology

For the purposes of the study, a sample of soil was collected from Jahangirpura, Surat, Gujarat. Throughout the investigation the experimental testing method and process was followed as prescribed in IS: 2770. The properties of tested soil are tabulated in Table 2.1.A semi-permeable paper barrier called filter paper is positioned perpendicular to a liquid or air flow. It is employed to remove tiny solid particles from gases or liquids.

3. Results and discussions

The results of SWCCs were attained by performing filter paper method, and are presented. All specimens were prepared at different water content of 90%, 80%, 70%, 60%, 50% of degree of saturation and at dry density of 1.63 gm/cc (MDD) for soil specimen. The results presented are in terms of volumetric water content and matric suction. All results of SWCCs are fitted using Fredlund and Xing (1994) model. The fitting parameters α, A_f, n, and m, for specimen tests of soil at Proctor density for different freezing-thawing cycles (0,1,3,5) by FX model are shown in the Table 3.1.

4. Conclusion

Freezing – thawing effect on soil water characteristic curves were investigated for an expansive soil. The experimental data of SWCCs obtained form Filter paper method were best fitted using Fredlund and Xing model (1994). The experimental data were best fit using the equation proposed by Fredlund and Xing (1994). The equation provides good fit for expansive soil.

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Tables and Figure

Tables

Table 2.1 Physical property of soil

Property	Value
Specific Gravity	2.16
Liquid Limit (LL) (%)	52.58

Plastic Limit (PL) (%)	27.65
Plasticity Index (PI) (%)	24.93
Optimum Moisture Content (OMC) (%)	16.31
Maximum Dry Density (MDD) (g/cc)	1.63
Soil Classification	CH

Table 3.1Fredlund and Xing Fitting parameter

FT cycles	0	1	3	5
A_f	999.3571	1020.687	2499.945	1660.453
R^2	0.9740	0.9751	0.9361	0.9969
Air entry (kPa)	98.2	351	2712	1340
Residual water content (%)	29.8	29.4	0.1	29.8
N	2.5456	1.987	1.9125	18.3015
M	0.2475	0.70150	0.2976	0.1269

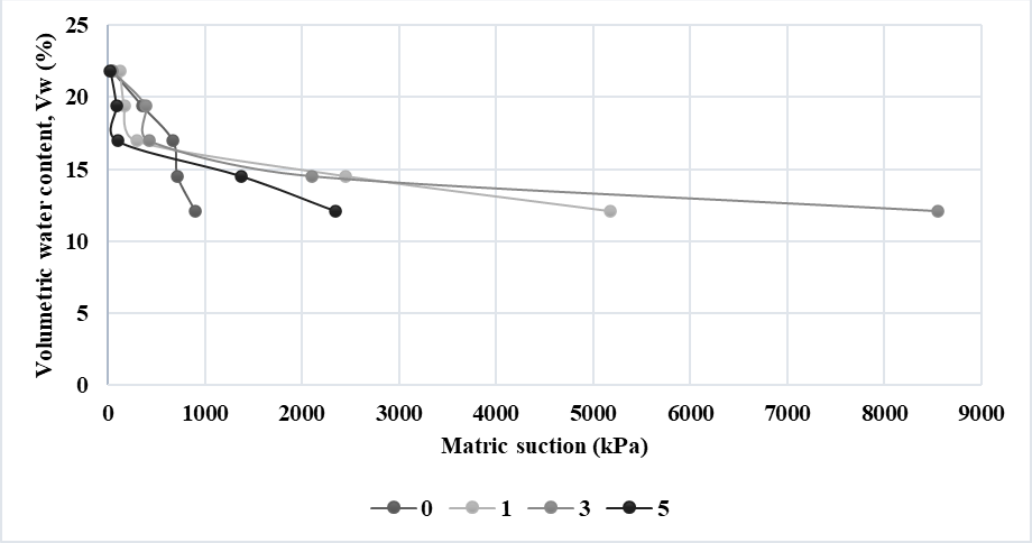

Figure 3.1 Soil water characteristic curve for different freezing – thawing cycles

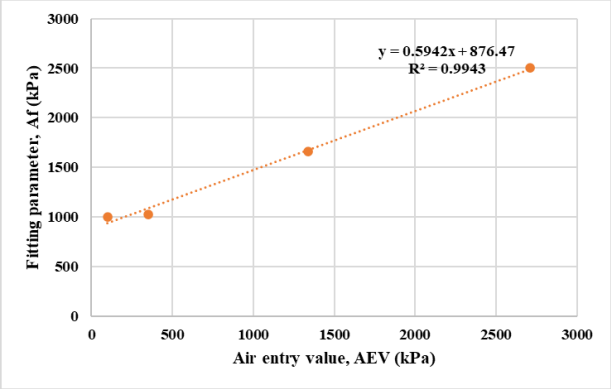

Figure 3.2Fitting parameters versus air entry value, AEV

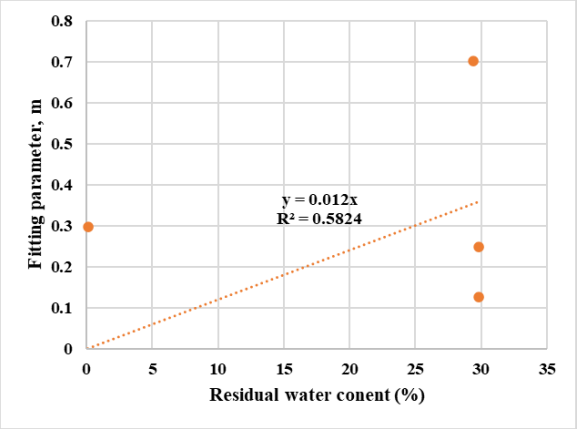

Figure 3.3Fitting parameters versus residual water content