OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Effect OfProbe Parameters for Determination of Soil Water Content by Using Time Domain Reflectometry

N.H.H.Abdullah[1],Ng W.K.[1],A. Ibrahim[1],M. R. Abd Majid[1],B.N. Ismail[1], R. Ramli[1],N.S.Mansor[1],M.A. Mat Tahir[1].

*Faculty of Civil Engineering, University Teknologi MARA Pulau Pinang, Pulau Pinang, Malaysia

ABSTRACT: *The application of Time Domain Reflectometry (TDR) in measuring soil water content is faster, reliable and non-destructive. Rapid increment of soil water content results in sudden reduction of soil shear strength, which will cause detrimental effect to the geotechnical structure. TDR uses two parallel probes to measure the resistance of a porous medium in which directly related to the volumetric water content, θv. Several factors affecting the accuracy of soil water determination such as probe diameter and spacing. It is also noted that the probes material are potentially will affect the results due to electrical resistance of respective materials. This paper presents the effect of probe parameters such as material (i.e. copper, aluminium, steel), diameter and spacing of probe to the accuracy of soil water content reading using TDR.*

Keywords:_Soil Water Content, Probe Parameters, Times Domain Reflectometry (TDR)._

I. INTRODUCTION

Soil water content is conventionally determined by using oven-dried method that took almost 24 hours to get the final results. In many conditions, this timely method would not help in preventing catastrophic failure of the geotechnical structure such as occurrence of landslide. It is proven that the increment of soil water content in unsaturated slope during heavy and short rainfall or light and prolonged rainfall will diminish the soil shear strength, hence triggering the slope movement [1]. Indirect methods to determine soil water content are electromagnetic (TDR), seismic, induced polarization, self-potential and electrical resistivity [2]. Among all, TDR is the simplest method and non-destructive. This method uses the dielectric constant (k) of the unsaturated soil to determine volumetric water content (θv). TDR emits electromagnetic wave through the cable, soil and the two probes inserted into the soil media. The propagating pulse in one return trip will be interpreted to obtain the electrical impedance (Z).

Determination of soil water content can be done by TDR because of the large difference between the dielectric constant of the water and other soil constituent such as air and mineral particles. According to Noborio [3], k for water is approximately 70-80 times higher than air or other particles. Therefore, the resistance of the propagation wave is depending on soil volumetric water content alone. Initial works to measure θv was done by Topp [4], where he proposed an empirical model, given that the dielectric constant of the media is known. Subsequent to that, studies in this field has evolved to include factors of different parameters. Topp suggested that 0.1 m to 1.0 m length of probe would yield results with high accuracy. It is also noted that the probe diameter and spacing will affect the accuracy of the readings [3].

The materials that build up the probe have its own electrical conductivity (k). K is the ability of material to allow current flows.It is reciprocal to the resistance capacity. This factor however has limited coverage in this research field. Therefore, study throughout this paper presents the effect of material's conductivity of the probe, along with the effect of diameter and spacing in determination of θv.

II. DETERMINATION OF Θ_V FROM TDR

Several methods to determine θv have been proposed from previous studies. In this paper, a straight forward step that is compatible with the TDR device used in this study is presented. The electrical impedance (resistance) that measure the opposition of the media when current is applied can be obtained directly. As proposed by Kraus [5], the dielectric constant (k) can be related to impedance (z) by;

$$Z = \frac{120}{\sqrt{k}} ln \frac{2s}{d} \qquad (1)$$

Where s is the spacing between two probes, and d is the probe diameter. Rearranging Equation (1), dielectric constant is given by;

$$k = \left(\frac{120}{Z} ln \frac{2s}{d}\right)^2 \qquad (2)$$

The θv can be determined by the empirical model as given by Topp [4].

$$\theta_v = (-530 + 292k - 5.5k^2 + 0.043k^3)x10^{-4}(3)$$

This model has been validated by some researchers i.e. Dalton [6], Reeves& Smith [7], and Inoue [8]. The θv (kg kg^{-1}) eventually can be related to gravimetric water content, θm (m^3 m^{-3}) by;

$$\theta_v = \theta_m \frac{\rho_B}{\rho_w} \qquad (4)$$

Where ρ_B is the bulk density of the soil sample and ρ_w is the density of water i.e. 1.0 Mg/m^3.

III. MATERIALS AND METHODS

The experimental set up in this study was as shown in Figure 1. The variation of spacing between the two probes is 60 mm, 120 mm and 180 mm. For each spacing distance, three different diameters are used interchangeably i.e. 6 mm, 8 mm and 10 mm. All the experiments are repeated with different probe materials such as copper (Cu), aluminium(Al) and steel. Copper is a chemical element with very high thermal and electrical conductivity. Aluminium is also natural chemical element with good thermal and electrical conductor, having lower conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Steel is an alloy of iron and other elements primarily carbon. Steel has poor electrical conductivity compared to other two materials.The conductivity percentage for each material used is shown in Table 1. The equipment used in this study to measure moisture content indirectly is TDR 20/20 supplied by AEA technology. The equipment is connected to a data logger which stores the data obtained during experiment.

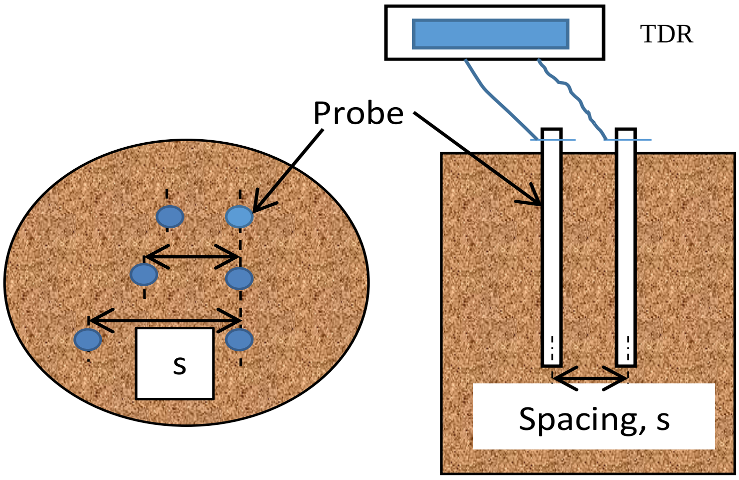

Figure 1 Arrangement of the probe inserted into the soil.

Table1 Percentage of Electrical Conductivity of Material

Material	% conductivity
copper	100
aluminiumm	61
steel	3-15

IV. EXPERIMENTAL RESULTS

From the experimental works, TDR captured the reading of impedance (Z)along the distance travel by the waveform. As can be seen in Figure 2, abrupt changes occurred as the waveform travel through different materials. Initially, the TDR is linked with coaxial cable before connecting to the different probe materials. The maximum reading of impedance is taken as the resistance value for analyzing the volumetric water content, θv of the soil.

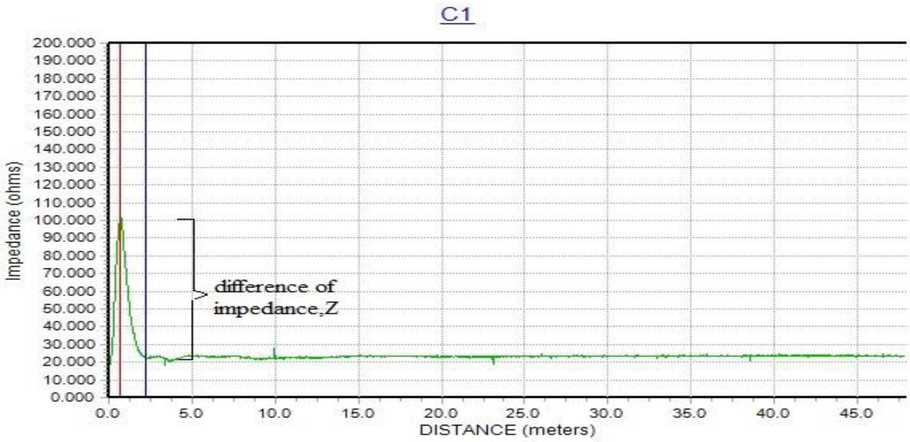

Figure 2 Sample of abrupt changes of waveform once travelling through different material

The experiment was done for three different probe spacing and three different diameters. From Figure 3, it is found that impedance (resistance) of the material is inversed linearly with the probe'sdiameter. Larger diameter of probes requires bigger insertion force in order to push the probe into the soil. This action will cause significant disturbance to the density of the surrounding soils [7]. Meanwhile, the impedance is increased linearly as the spacingbetween two probesis increased.The impedance value of the probe will affect the determination of dielectric constant (k). Indeed, k depends mainly on the contribution from three parameters which are impedance, spacing and diameter of probe.However, undulating patternswere observed from the relationship of the dielectric constant (k) to the impedance and ratio of spacing to diameter (2s/d) as can be seen in Figure 4. From trend line analysis, it can be concluded that k will increase as the impedance and ratio of 2s/d were increased.

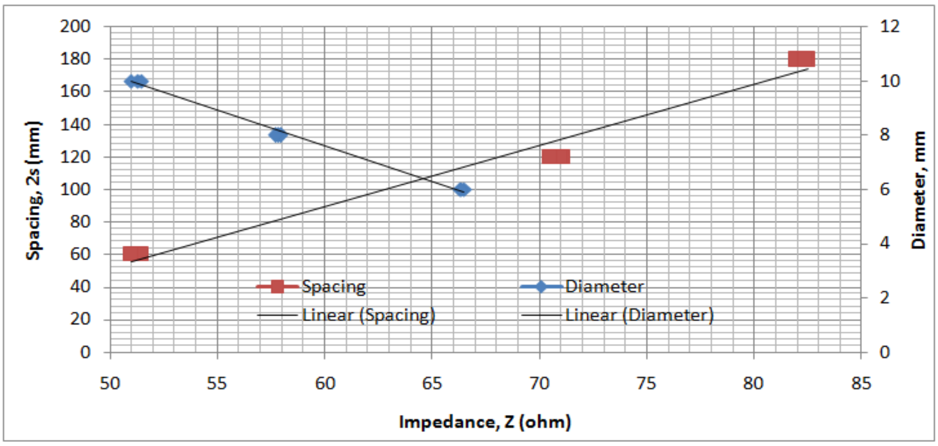

Figure 3 Relationship of probe spacing and probe diameter to the impedance (resistance) of the material

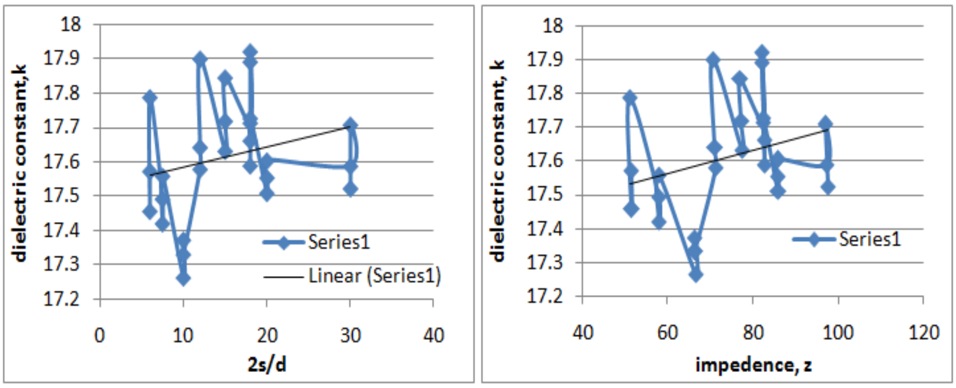

Figure 4 Relationship of Dielectric constant to the ratio of 2s/d (left) and relationship of Dielectric constant to the impedance (right)

The value of dielectric constant will affect the determination of volumetric water content (θv). The larger k value, the more error will be produced in the determination of the θv, as shown in Figure 5. Therefore, in order to minimize the error in determination of θv by using TDR, the impedance value must be small as possible. Impedance value can be reduced by using smaller size of probe diameter and larger spacing between two probes.

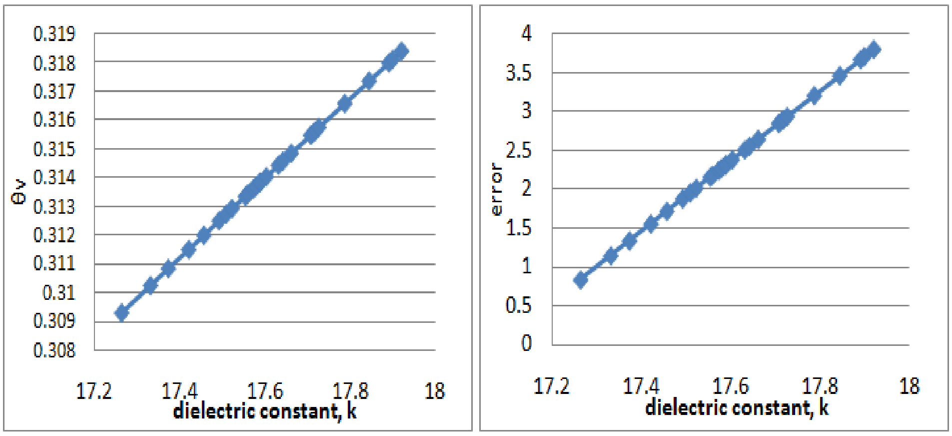

Figure 5 Volumetric water content (θv) versus dielectric constant (left) and percentage of error versus dielectric constant

Apart from probe diameter and spacing, the material that made up the probe are also significantly affecting the accuracy of water content determination by using TDR. The procedures are repeated for three different type of probe materials which are copper, aluminium and steel. Figure 6 show that probe made of copper produced the smallest error, followed by aluminium and steel. Different material possess different electrical conductivity (refer table 1), which will affect the impedence of the material. The higher conductivity level of a material will cause lower impedance (resistance). From earlier analysis, it is well understood that small impedance will produce small error. Therefore, to get better accuracy in determination of water content, material with high electrical conductivity must be used as the probe.

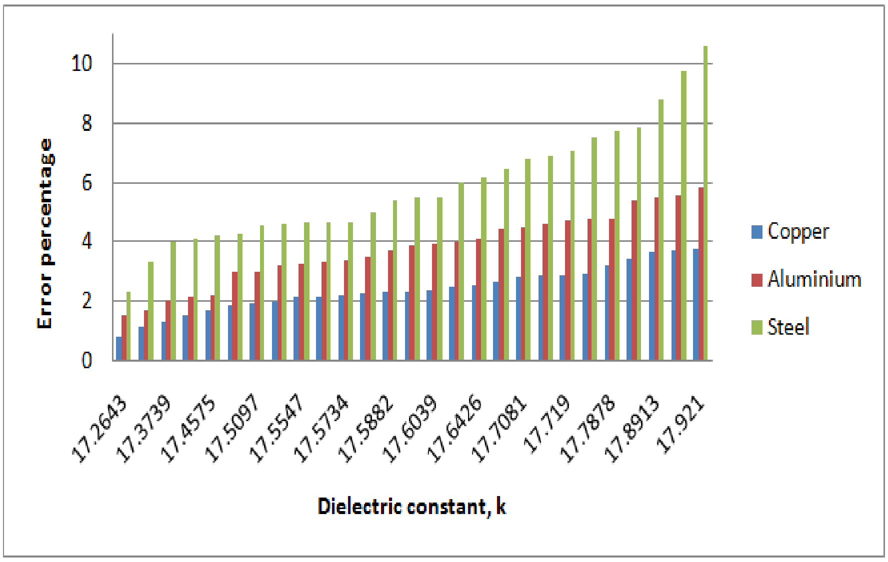

Figure 6 Error comparison of different type of probe materials

V. CONCLUSION

In determination of volumetric water content by using application of TDR, it is important to understand the factors that will give an accurate result, since this method is a simplified method as compared to conventional method. From this study, it is noted that the accuracy will increase if the diameter of probe is smaller. Vice versa, the accuracy will increase if the spacing between probes is increased. A good electrical conductivity will greatly influenced the accuracy value due to low resistance level of the material. For future study, it is recommended that a few more different type of materials to be investigated. Most importantly, the testing on different type of soil material should be carried out in order to investigate the effect of grain size distribution towards the accuracy of TDR in determination of soil water content.

ACKNOWLEDGEMENTS

The authors are grateful to Research Acculturation Grant Scheme (RAGS), Ministry of Education Malaysia forfunding this research work as well as UniversitiTeknologi MARA (UiTM).

REFERENCES

[1]. H. Rahardjo, E.C. Leong& R.B. Rezaur.Studies of rainfall-induced slope failures.Invited Lecture.National Seminar, Proceedings of the National Seminar, Slope 2002. 27-April 2002. Bandung, Indonesia. 15−29.

[2]. Keary, P., An Introduction to Geophysical Exploration (Blackwell Science Ltd, 2002).

[3]. Noborio, K. a, & Mullins, C.E., Measurement of soil water content and electrical conductivity by time domain reflectometry: A review. Computers and Electronics in Agriculture, 31(3), 2001,213-237.

[4]. G.C. Topp, Electromagnetic determination of soil water content: measurements in coaxial transmission lines, Water Rersources Research, 16(3), 1980, 574-582.

[5]. Kraus, J.D., Electromagnetics (McGrawHill London, 1984).

[6]. Dalton, F.N., & Van Genutchen, M.T. The time domain reflectometry method for measuring soil water content and salinity.Geoderma, 38(1-4), 1986, 237-250.

[7]. Reeves, T.L. & Smith, M. A. Time domain reflectometry for measuring water content in range surveys, Journal of Range Management, 45(4), 1992, 412-414.

[8]. Inoue, Y., Watanabe, T. & Kitamura, K., Protoptype time domain reflectometry probes for measurement of moisture content near the soil surface for applications to “on the move” measurements, Agricultural Water Management, 50, 2001, 41-52.