Conference Paper, Published Version

Malaya, C.; Sreedeep, S.

A Study on Water Retention Characteristics of Fly Ash

Proceedings of ninth International Conference on Hydro-Science and Engineering (ICHE 2010), IIT Madras, Chennai, India.
2 - 5 August 2010

A STUDY ON WATER RETENTION CHARACTERISTICS OF FLY ASH

C. Malaya[1] and S. Sreedeep[2]

***Abstract**: The potential effects of water retention characteristics (WRC) on porous media make it a vital measurement in every type of soil and admixture study. The water retention characteristics of soil are generally expressed in terms of graphical relationship between water content (or saturation) and suction. It is believed that each soil/material has got unique WRC. The present study aims to investigate the influence of compaction conditions on WRC of a fly ash. Fly ash has found wide application in soil mechanics and agriculture, which necessitates understanding its WRC. WRC have been obtained for fly ash using a tensiometer and a volumetric water content sensor. The details of the methodology adopted are discussed in this paper. The study indicates that the WRC obtained in terms of volumetric water content are sensitive to the changes in initial compaction water content. The details of the test set up used in this study are also presented in this paper.*

***Keywords**: water retention characteristics; fly ash; matric suction; volumetric water content; water content; dry unit weight.*

INTRODUCTION

Fly ash is a by-product of coal ignition that requires disposal worldwide. Few studies have been conducted on the potential use of fly ash to improve soil physical properties and workability (Mapfumo and Chanas, 1998). Since fly ash from various sources can differ widely in several properties, its characterization in the laboratory is essential to evaluate the potential to use a particular fly ash source for soil amendment. Fly ash has found wide applications in agriculture, construction of embankments, and many other geotechnical applications, where in the water retention characteristics (WRC) become a very important property. There are very few studies found in the literature related to the WRC of fly ash. With this in view, an attempt has been made to measure the WRC of a fly ash.

WRC are quite useful for understanding different behavior of unsaturated soil and numerous research works have demonstrated this (Fredlund and Rahardjo, 1993, Houston et al., 2006, Patil and Rajput, 2009). From these studies, it is quite explicit that unsaturated soil properties such as hydraulic conductivity, shear strength, compressibility, contaminant transport, heat migration,

1 Research Student, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India, Email: m.chetia@iitg.ernet.in
2 Assistant Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India, Email: srees@iitg.ernet.in

swelling potential are dependent on the WRC (Fredlund and Rahardjo, 1993, Yang et al., 2004, Birle et al., 2008, Masrouri et al., 2008).

It is observed that WRC are influenced by different physical, chemical, mineralogical and mechanical properties. Among these properties, the influence of compaction conditions, (water content and dry unit weight), are much discussed by the researchers. However, there are different contrasting studies pertained to the effect of compaction conditions on WRC (Krahn and Fredlund, 1972, Marinho and Stuermer, 1999, Sun et al., 2007, Birle et al., 2008). Therefore, there is a need to further explore its influence on different soil/material type. With this in view, an attempt has been made to understand the effect of compaction conditions on WRC of a fly ash. For this purpose, drying WRC corresponding to different initial compaction conditions were obtained for fly ash using a tensiometer and a volumetric water content sensor. The study indicates that the WRC obtained in terms of volumetric water content are more sensitive to the changes in initial water content than the initial dry unit weight.

EXPERIMENTAL DETAILS

A perspex box illustrated in Fig. 1, equipped with T5 tensiometer (UMS GmbH, Munich) and ECH_2O-TE volumetric water content sensor (Decagon Inc., USA), was used to measure suction (ψ_m) and volumetric water content (θ), respectively, of dynamically compacted fly ash in the perspex mold (Malaya and Sreedeep, 2009, Malaya and Sreedeep, 2010). Sensors were secured in place to ensure proper contact with the fly ash.

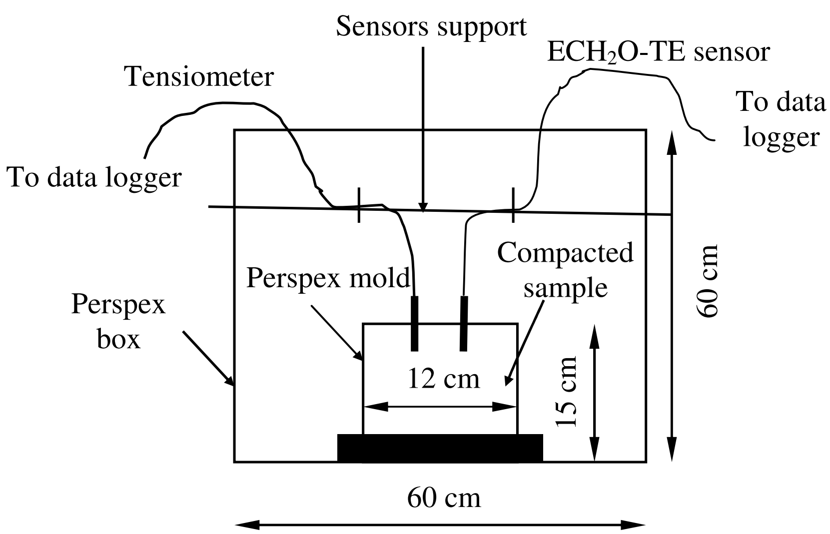

Fig. 1. Schematic layout of suction and volumetric water content measurement box.

The tensiometer used in this study can measure matric suction (ψ_m) up to 100 kPa and characterized by very short response time. For logging the suction measurement automatically, the tensiometer is connected to a DL6 data logger. ECH_2O-TE capacitance-type sensors determine 'θ' based on the dielectric constant or permittivity of the material in which they are inserted. The sensor works in the frequency range of 70 MHz. A detailed description of the technology of these sensors is reported in the literature (Bogena et al., 2007, Kizito et al., 2008, Malaya and Sreedeep, 2009, Malaya and Sreedeep, 2010).

MATERIAL AND SAMPLE PREPARATION

The fly ash designated as FA was used in this study, which is characterized for its specific gravity and grain size distribution by following the guidelines presented in the literature (relevant parts of IS 2720). The details of the characterization are listed in Table 1.

Table 1. Physical properties of the fly ash FA

Property	FA
Specific gravity	2.12
Coarse sand size (4.75-2 mm)	0
Medium sand size (2-0.425 mm)	2
Fine sand size (0.425-0.075 mm)	34
Silt size (0.075-.002 mm)	64
Clay size (< 0.002 mm)	0

The air-dried fly ash was mixed with required amount of distilled water and compacted into the perspex mold of 12 cm diameter and 15 cm height, by giving different number of blows to achieve different packing dry unit weight (γ_d). The prepared samples were then saturated by ponding with distilled water and further removing the excess water on top. After saturating the fly ash sample, T5 tensiometer and ECH_2O-TE volumetric water content sensor were inserted into the packed samples. The samples were allowed to air dry and ψ_m and θ of the samples were continuously recorded using the respective data loggers. These data were used to develop measured WRC.

RESULTS AND DISCUSSION

The data obtained from the T5 and ECH_2O-TE measurements were used to plot the WRC corresponding to different compaction states as depicted in Fig. 2. It can be noted from the figures that different initial paths are followed by the curves corresponding to different compaction state. The initial portion of the WRC shifts upwards with the increase in initial compaction water content (*w*). One of the advantage of this study over those reported in the literature is that the volumetric water contents are measured ones and not estimated.

Effect of Initial Water Content on WRC

Fig. 3 depicts the WRC of the fly ash samples at similar compaction dry unit weight but with different initial water contents. From the figure it can be observed that there is an initial difference in both, which gradually reduces and shows the tendency of convergence at ψ_m close to 60 kPa. Therefore, it can be summarized that the initial water content influences the initial portion of drying WRC. In the high ψ_m range the WRC appear to be independent of the initial compaction conditions. This observation is in agreement with studies reported in the literature (Tinjum et al., 1997, Vanapalli et al., 1999, Tarantino and Tombolato, 2005, Birle et al., 2008).

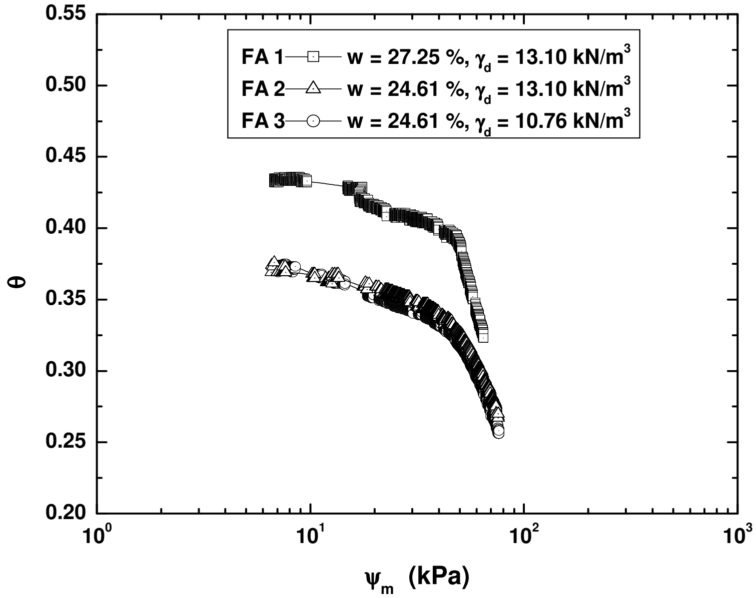

Fig. 2. Measured WRC for the fly ash FA corresponding to different initial compaction states.

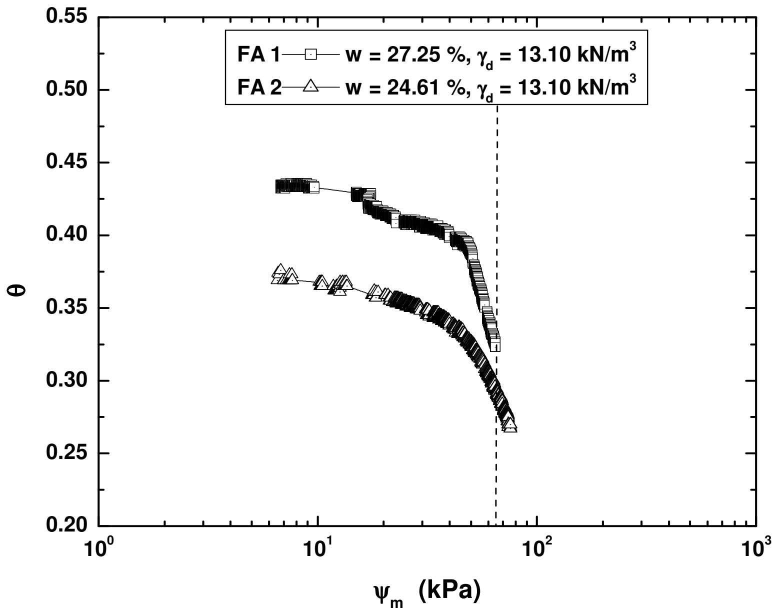

Fig. 3. Measured WRC for the fly ash FA corresponding to same initial dry unit weight and different initial water content.

Effect of Initial Dry Unit Weight on WRC

Fig. 4 shows the comparison of continuous drying WRC for two fly ash samples at same initial compaction water content but at different initial dry unit weight. It can be noted that both the drying WRC matches perfectly. Therefore, it can be summarized that the initial dry unit weight of fly ash FA does not have significant influence on the WRC. This observation is in agreement with the results reported by Birle et al. (2008).

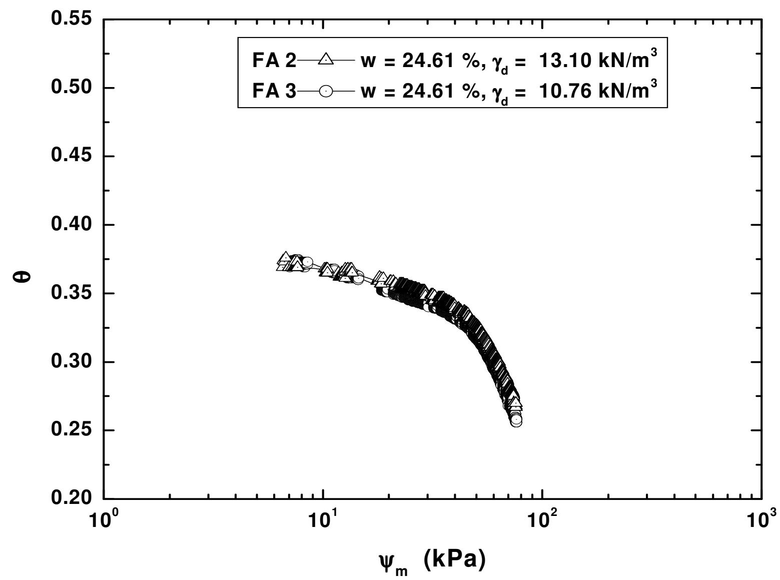

Fig. 4. Measured WRC for the fly ash FA corresponding to same initial water content and different initial dry unit weight.

CONCLUDING REMARKS

The study deals with an investigation on the influence of compaction conditions on water retention characteristics of fly ash. WRC were obtained using a T5 tensiometer and ECH$_2$O-TE volumetric water content sensor. The study demonstrates that different initial paths are followed by WRC corresponding to different compaction state. The WRC shift upwards with the increase in initial compaction water content (w). Further, it can be noted that dry unit weight has insignificant influence on WRC of fly ash used in this study.

REFERENCES

Birle, E., Heyer, D. and Vogt, N. 2008. Influence of the initial water content and dry density on the soil-water retention curve and the shrinkage behavior of a compacted clay. *Acta Geotechnica*, Springer, 3, 191-200.

Bogena, H. R., Huisman, J. A., Oberdorster, C. and Vereecken, H. 2007. Evaluation of a low-cost water content sensor for wireless network applications. *J. Hydrol.*, 344, 32-42.

Decagon Devices Operator's Manual Version 2 ECH$_2$O-TE/EC-TM. *Water Content, EC and Temperature Sensor Manual (2006)*. Decagon Devices, WA99163.

Fredlund, D.G. and Rahardjo, H. 1993. *Soil mechanics for unsaturated soils*. John Wiley and Sons, Inc., New York.

Houston, W.N., Dye, H.B., Zapata, C.E., Perera, Y.Y. and Harraz, A. 2006. Determination of swcc using one point suction measurement and standard curves. *Unsaturated Soils 2006*.

IS: 2720 : Part III : Sec 2 : 1980. Indian standard on test for soils, part III determination of specific gravity-sec 2 : fine, medium and coarse grained soils. *Bureau of Indian Standards*, New Delhi.

IS: 2720 : Part 4 : 1985. Indian standard methods of test for soils, part 4 grain size analysis. *Bureau of Indian Standards*, New Delhi.

Kizito, F., Campbell, C. S., Campbell, G. S., Cobos, D. R., Teare, B. L., Carter, B., and Hopmans, J. W. 2008. Frequency, electrical conductivity and temperature analysis of a low-cost capacitance soil moisture sensor. *J. Hydrol.*, 352, 367-378.

Krahn J. and Fredlund D.G. 1972. On total, matric and osmotic suction. *Soil Science*, 114, 339-348.

Malaya, C. and Sreedeep, S. 2009. A comparative study on the measured and estimated soil-water characteristic curve of a sandy soil. *Indian Goetechnical Conf.*, 23-26.

Malaya, C. and Sreedeep, S. 2010. Evaluation of estimated soil-water characteristic curve for a poorly graded sandy soil. *Third International Perspective on Current and Future State of Water Resources and the Environment,* EWRI, ASCE, IIT Madras, Chennai.

Mapfumo, E. and Chanas, D. S. 1998. Plasticity and density-moisture-resistance relations of soils amended with fly ash. *J. Env. Tech.*, 19, 543-554.

Marinho, F.A.M. and Stuermer, M.M. 1999. The influence of the compaction energy on the SWCC of a residual soil. *Advances in Unsaturated Geotechnics*, 125-141.

Masrouri, F., Bicalho, K. V. and Kawai, K. 2008. Laboratory hydraulic testing in unsaturated soils. *Geotech. and Geol. Engrg*, Springer, 26, 691-704.

Patil, N. G. and Rajput, G. S. 2009. Evaluation of water retention functions and computer program "Rosetta" in predicting soil-water characteristics of seasonally impounded shrink-swell soils. *J. Irr. and Drain. Engrg.*, 135(3), 286-294.

Sun, D., Sheng, D. and Xu, Y. 2007. Collapse behaviour of unsaturated compacted soil with different initial densities. *Can. Geotech. J.,* 44, 1252-1264.

Tarantino, A. and Tombolato, S. 2005. Coupling of hydraulic and mechanical behaviour in unsaturated compacted clay. *Geotechnique* 55(4), 307-317.

Tinjum, J.M., Benson, C.H. and Blotz, L.R. 1997. Soil-water characteristic curves for compacted clays. *J. Geotech. and Geoenviron. Engrg* 11: 1060-1069.

Vanapalli S.K., Fredlund D.G. and Pufahl D.E. 1999. The influence of soil structure and stress history on the soil-water characteristics of a compacted till. *Geotechnique*, 49, 143-159.

Yang, H., Rahardjo, H. and Fredlund, D. G. 2004. Factors affecting drying and wetting soil-water characteristic curves of sandy soils. *Can. Geotech. J.*, 41, 908-920.