EFFECT OF MIXING RATIO ON BUBBLING PRESSURE OF POROUS CERAMIC DISCS PRODUCED WITH SAW DUST AS THE BURNT OUT MATERIAL

***C. J. Ejieji and M. Ahmed**

Department of Agricultural and Biosystems Engineering,
University of Ilorin, Ilorin, Nigeria.
***Corresponding author: Email: joejieji@gmail.com; cjejieji@unilorin.edu.ng**

ABSTRACT
The control of the amount of burnt out material in production of porous ceramics is important for the attainment of the desired pore size distribution which influences other characteristics such as bubbling pressure. Five different mixing percentage ratios of sawdust burnt out material to kaolinite clay, of 10:90, 20:80, 30:70, 40:60, 50:50 by volume, were therefore used in the moulding of porous ceramic discs 10.2 cm in diameter and 1.5 cm thickwhich were fired in a kiln to 1100 ^{o}C. The bubbling pressuresof three replicate discs per mixing ratiowere determined by the gas transport method. The corresponding sawdust content of the mixtures by weight were found to be3.33, 7.19, 11.72, 17.12 and 23.65 % respectively. Average bubbling pressure of the discs was found to vary inversely with sawdust content of the mixture and rangedfrom 10.33 MPa for the 50:50 Mixture to 66.33 MPa for the 10:90 Mixture. The regression relationship between the average bubbling pressures (MPa) and Mixture sawdust content by weight (%) was found to be best described in form of a decaying power function with a coefficient of determination of 0.986. It was therefore suggested that regression relationship could be useful in the specification of sawdust-kaolinite clay mixtures for the production of porous ceramics discs for special applications.

Key words: bubbling pressure, porous ceramics, sawdust

INTRODUCTION

Ceramics unlike other porous materials developed from metals and plastic are hydrophilic (Carter and Norton, 2007). This property in addition to fact that they are generally inert and can be produced with very consistent and uniform pore structures have made them materials of choice forspecial applications such as in the pressure plate apparatus and the tension table usually employed in the laboratory measurement of soil water retention. Knowledge of soil water retention is required in the determination of soil water characteristic curve (Ejieji et al., 2013).In a pressure plate or tension table test for soil water retention, the water held by capillary forces in the pores of the soil sample is in hydraulic contact with the water in the pores of the ceramic plate on which the soil sample is placed thus forming a continuum for mass flow.Under pneumatic pressure water flows out of the soil through the ceramic plate with the outflow continuing until equilibrium is attained. At this point, the matric potential of the water still retained in soil is equaland opposite to the applied pressure. If the applied pressure equals or exceeds, the bubbling pressure of the ceramic plate, the air would break the air-water interface of the pores andbulk-flows through the plate thus invalidating the test. The pressure range over which a ceramic plate or disc could be used in soil water retention test is therefore determined by its bubbling pressure. The pore size distribution of discsand membranes influence their bubbling pressure (Calvo et al., 1995; Nakao, 1994)

Kaolinite claywhich has a fine-grained sheet like structure is widely used in the production of porous ceramic due to its high plasticity. In order to improve the porosity,burnout materials of carbonaceous nature are added during the manufacturing process.When the mass is fired the carbonaceous matter burns out and the corresponding pore spaces remain. A review of burnt out materials has been provided by Ndungu (2015). Sawdust is a commonly available burnt out material. Itburns at about 850^{o}C.Hardwood sawdust is however preferred to that from soft wood because it does not bloat as much sawdust from other types of wood, resulting in more uniform pores and fewer defect in the porous ceramic disk (Kabagambe, 2010; as cited by Ndungu, 2015).

The porous ceramic plate is a very important component tension table and pressure plate apparatus. The high cost of the imported equipment and lack of resources for its acquisition limit soil water retention studies of our local soils. The objectives of this paper therefore is to determine the effect of mixing ratios of sawdust to kaolinite clay on the bubbling pressure of porous ceramic discs. The expectation is that the finding would aid the mixing specifications for local production of ceramic discs for tension table fabrication.

MATERIALS AND METHOD

Collection of materials, composition and moulding of clay-sawdust mixture

The kaolinite clay powder used was obtained from a processing plant atUkpella, Edo State, Nigeria and the hardwood sawdust from asawmill located beside BekindPetrol Filling Station along University Road, Tanke, Ilorin. The sawdust was air-dried after which it and the clay were separately sifted through the No 50 sieve to yield particle sizesnot exceeding 300µm.Five mixtures of the clay and sawdust designated as A, B, C, D and E were prepared by measuring out the volumes of the materials as shown in Table 1to obtain the pre-mixing volumetric ratios indicated also in Table 1.The volume of water used in each case was 1768ml. The mixing process lasted for at least 15 minutes in order to ensure good blending before the addition of water to the powdery mixture. The wet mixture was then wedged by folding the clay over upon itself repeatedly and applying pressure until a smooth doughwas formed. The kneadeddough was pressed into a mould and a wooden roller used to gently compact dough in the mould. The mould was a plastic ring 10.2 cm in internal diameter and 1.5 cm high. It was improvised from a domestic effluent waste pipe. To facilitate the removal of the mould, the ring was cut vertically at one location. It was then held together at the cut location with a paper tape which was undone each time the mould was to be removed. The disc in the mould was weighed and allowed to dry for aweek.The volume of materials reported in Table 1 were sufficient to make at a least three disc discs per mixture used in subsequent tests.

Firing and determination of the bulk density and apparent porosity

The air dried discs were fired for 5 hours in kiln at a temperature of 1100^{o}C after which they were allowed to cool for 24 hours before being carefully brought out to attain room temperature. Each disc was then weighed. The bulk density obtained was by dividing the weight by the volume estimated from the knowledge of its diameter and thickness.

Table 1.Volumes of material measured out for composition of the mixtures(the pre-mixing volume percentage compositions of the mixtures are indicated in parentheses).

Material	Volumes of materials measured out for the various mixtures (ml)				
	A	B	C	D	E
Kaolinite	6750 (90.0)	6000 (80.0)	5250 (70.0)	4500 (60.0)	3750 (50.0)
Sawdust	750 (10.0)	1500 (20.0)	2250 (30.0)	3750 (40.0)	3750 (50.0)

The apparent porosity of the discs was determined by the saturation method. Using the method, each of the discs was soaked in distilled water at room temperature for 48hours in order to saturate the disc. The increase in weight (g)after soaking was taken to be equal to the weight of water in the water-saturated pores and converted to the equivalent water volume assuming density of water to be 1g cm^{-3}. The equivalent water volume was then expressed as a percentage of the bulk volume of the disc for the estimation of the apparent porosity.

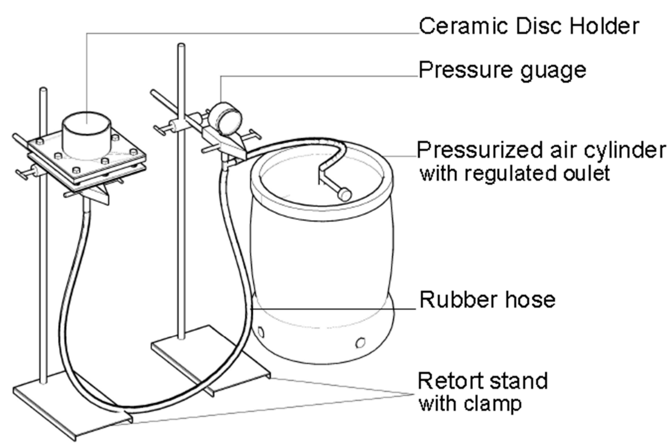

Fig. 1. Isometric sketch of the test rig for bubbling pressure determination

Determination of the bubbling pressure

For the determination of the bubbling pressure, the bubble-point test was conducted on the saturated discs by the bubble gas transport technicfollowing the American Society for Testing and Materials Standard (ASMT) Method F316 as described by Brock (1997). A test rig was improvised for the purpose(Figure 1). The main components of the rig were the disc holder, a pressurised gas cylinder and a pressure gauge. The details of the disc holder fabricated withgalvanized iron sheet and pipe are presented in Figure 2. The iron sheet was 2mm thick. The saturated disc was sandwiched between the flanges at the lower end the reservoir of the disc holder and that at the upper end of the conical base of the holder. The three were held tightly together using eight bolts and nuts. Once firmly bolted the open circular region inside the reservoir became aligned and continuous with that at the top of the conical base with the disc as the only barrier. The rubber seals provided as indicated in Figure 2 blocked water and air leakages. At its lower end, the conical base bears at the at the bottom a 2mm thick galvanized iron tube 10 mm in internal diameter with which it was connected with a rubber hose to pressurised air supply from a gas cylinder with regulated out let. The supply gas pressure was monitored with a pressure gauge connected to the supply line (Figure 1).

During the bubble point test, water was added to the disc holder reservoir. The air pressure in the supply line was gradually increased by manipulation of the gas cylinder control knob. The pressure at which formation of air bubbles on surface of the disc inside the reservoir was noticed was recorded as the bubbling pressure.

All the tests in this study were in three replications for the various mixtures.

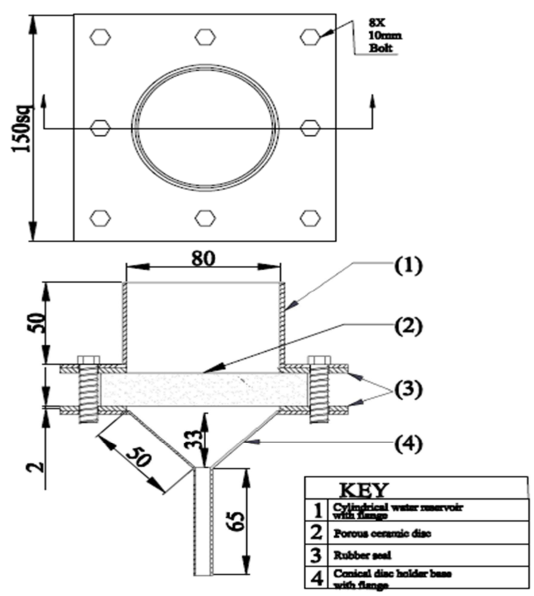

Fig. 2. Details of the ceramic disc holder

RESULTS AND DISCUSSION

The average properties of the porous ceramic discs from the various mixtures are presented in Table 2. The apparent porosity and bulk density of the discs varied directly and inversely, respectively, with the sawdust content. The sawdust mixed with the clay burnt offduring firing leaving open pores which improved the porosity but decreased the bulk density.

The findings are in agreement with those of Ndungu (2015). The bubbling pressure decreased with sawdust content. The average bubbling pressure of the discs from Mixture A is lower than that of a commercially available pressure plate of comparable bubbling pressure (Soil Moisture Equipment Corporation, No date). The materials and production processes were however different from those in this study. The results in Table 2 should be useful in the determination of the mixing ratios for production of porous ceramic discs for soil water retention studies.

Table 2. Average properties of the porous ceramic discs from the various mixtures.

	Sawdust-Kaolinite clay Mixtures				
Property	A	B	C	D	E
Before firing					
Volumetric mixing (Sawdust:Kaolinite) ratio (%)	10:90	20:80	30:70	40:60	50:50
Sawdust content by weight (%)	3.33	7.19	11.72	17.12	23.65
***After firing**					
Bulk density (gm cm^{-3})	1.51	1.34	1.28	1.21	0.89
Apparent porosity (%)	36.99	37.98	45.67	54.06	55.78
Bubbling pressure (MPa)	66.33	39.00	19.67 [a]	14.00 [a,b]	10.33 [b]

* Means followed by the same letter are not statistically different at 0.05 level

In particular the result for the statistical separation of the mean bubbling pressures imply that for tension tables where test pressures of a maximum of 10 MPa are envisaged, Mixture C should be considered in the production of the appropriate ceramic discs. A regressionequation in form of a decaying power function was found to best describe the relationship between bubbling pressureand sawdust content of the mixtures as follows

$$Y = 231.13X^{-0.98} \qquad (1)$$

where$Y$ is the bubbling pressure (MPa) and X is the sawdust percentage content by weight of the sawdust–kaolinite clay mixture used to produce the disc. The coefficient of determination was high with a value of 0.986. It is worth noting that the relationshipdescribed by Equation (1) may limited to the conditions of this study.

CONCLUSIONS AND RECOMMENDATIONS

The bubbling pressure of the porous ceramic discs decreased with increase in sawdust content of the sawdust–kaolinite clay mixture used in their production. The decrease in bubbling pressure followed the trend of a decaying power function. This finding would be useful in specification of mixing ratios for porous ceramic disc production. The strength and hydraulic conductivity of the discs have not been investigated and would require further study. Processes for the production of thinner discs with bubbling pressures higher than were obtained in this study require further investigation.

REFERENCES

Carter, C. B. and Norton, M. G. (2007). Ceramic Materials: Science and Engineering. Springer Science and Business Media, New York, 716pp.

Calvo,J. I., Hernandez, A., Pradanos, P, Martinez,L. and Bowen, W. R. (1995). Microporous membranes II. Bulk characterization of track-etched filters by air porometry and mercury porosimetry. Journal of Colloid and Interface Science 176: 467 – 478.

Ejieji C.J., Baiyeri, M. R. and Adebayo, A. A. (2013). A study of the water characteristic and pore size distribution of a tropical alfisol. LAUTECH Journal of Engineering and Technology, 7(2): 1 – 7

Brock, T. D. (1997). Membrane filtration: in Dickenson, T C. (ed.) Filters and Filtration Handbook, Elsevier Science Madison

Nakao, S. (1994). Review: Determination of pore size and pore size distribution. 3.Filtration membranes. Journal of Membrane Science 96(1-2):131-165

Ndungu, J. N. (2015). Nanoporous ceramics filters for water purification. M. Sc. Department of Physics, University of Nairobi, Nairobi, Kenya.

Soil Moisture Equipment Corporation. (No Date). Porous ceramics: physical properties of porous ceramics. http: www.soilmoisture.com(date accessed 15/01/2016)