The effects of dimensional mould sizes on volumetric shrinkage strain of lateritic soil

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Abstract

Dimensional influences of specimen size on the volumetric shrinkage strain values of a lateritic soil for waste containment system have not been researched upon. Therefore, this paper presents the result of a laboratory study on the volumetric shrinkage strain (VSS) of lateritic soil at three different dimensional sizes of mould (split former mould, proctor mould and California bearing ratio mould) at three energy levels; British standard light (BSL), West African standard (WAS) and British standard heavy (BSH) respectively. Compactions were done at different molding water content of -2% to +6% optimum moisture content (OMC). At -2% to +2% molding water content for the split former mould the volumetric shrinkage strain met the requirement of not more than 4% while at +4% and +6% only the WAS and BSH met the requirement. The proctor mould and the CBR mould on the other hand gave a lower value of volumetric shrinkage strain in all compactive effort and the values are lower than the 4% safe VSS suggested by Tay et al., (2001). Based on the VSS values obtained if the CBR mould can be used to model site condition it is recommended for use to simulate site condition for Volumetric shrinkage strain for all molding water content and compactive effort.

Keywords

Lateritic soil; Volumetric shrinkage strain; Molding water content; Compactive effort

Introduction

The evaluation of volumetric shrinkage strain (VSS) of specimen is very important in determination of cracks generated and its attendant effect on the hydraulic conductivity of specimens to be used in cover and liner systems.

Desiccation in laterite soils causes loss of water from hydrated sesquioxides and or minerals and transformation of the amorphous gelatinous sesquioxides from the mobile state to the immobile crystalline state [1].

Desiccation of soils alters their properties including reduction in soil plasticity. Laterite soils occur in tropical areas where seasonal changes in water content occur. The process of laterite soil formation are associated with major genetic features including profile characteristics, physical, chemical and mineralogical composition, and post formation changes associated with the environment including desiccation [2].

Although, several studies [3-6] has been carried out to assess the effect of drying or desiccation on properties of tropical soil including laterite soils, the effects of desiccation on shrinkage of compacted laterite soils considering three different sizes of mould has not been reported on published literature.

Laboratory studies conducted by Osinubi and Nwaiwu [7-9] indicated that fine grained laterite soils can be used as hydraulic barrier layers (that is liner and cover materials)for constructing waste containment structure.

The aim of this study is to determine the trend in volumetric shrinkage of compacted soil using three mould i.e. California Bearing Ratio (CBR) mould, Proctor Mould, and Split Former mould. Previous studies [10-12] on the shrinkage of compacted soils and associated cracking problems have involved non-laterite soils most of which occur in temperate regions.

Specimen of three laterite soils were compacted using three compaction energy levels over a range of molding water contents and air dried prior to the measurement of shrinkage strains.

Thus, this study was aimed at evaluating the influence of dimensional size of specimen on the volumetric shrinkage strain values of a lateritic soil specimen for waste containment system.

Materials and methods

The soil to be used in this study is a laterite which will be collected from a borrow pit in Shika village, Zaria Local Government Area, Kaduna State in Northern part of Nigeria, (latitude 11°15’N and longitude 7°45’E), by using the method of disturbed sampling at 1m depth from the natural earth surface to avoid organic matter influence. The soil was subjected to tests in accordance with [13].

Maximum dry density

The compaction tests were carried out for the soil all according to [13] Part 4, using the British Standard light, West African Standard and the British Standard heavy. 3 kg of the soil sample was mixed thoroughly with 4% of water (and the water was added at 4% for each of the compaction). The sample was then compacted into the (2360 cm^3, 1000 cm^3 and 30 cm^3) (of mass m1); in three layers of approximately equal mass with each layer receiving 27 blows of 2.5 kg rammer falling through a height of 300 mm, for the British Standard light compaction; 10 blows of 4.5 kg rammer in five layers for West African Standard compaction and 27 blows of 4.5 kg rammer in five layers for the British Standard Heavy. The blows were uniformly distributed over the surface of each layer. The collar was then removed and the compacted sample leveled off at the top of the mould with a straight edge. The mould containing the leveled sample was then weighed to the nearest 1 g, m_2. Two small samples were then taken from the compacted soil for the determination of moisture content. The sample was then removed from the mould, crushed and addition water added (8%) and the same procedure was repeated until minimum of five set of samples were taken for moisture content determination. The bulk density in Mg/m^3 was later calculated for each compacted layer using:

$$\rho = \frac{m_2 - m_1}{1000} \quad (1)$$

The dry density was also calculated using the equation:

$$\rho_d = 100\rho/(100 + w) \quad (2)$$

where *w* is the moisture content of each compacted layer, p is the bulk density, p_d is the dry density, m_1 is the mass of the mould and m_2 is the mass of the mould and compacted soil.

The values of the dry densities as obtained from eqn. (3.8) were plotted against their respective moisture contents and the maximum dry density (MDD) was deduced as the maximum point on the resultant curves.

Optimum moisture content

The corresponding values of moisture contents at maximum dry densities (MDD), deduced from the graph of dry density against moisture contents, gives the optimum moisture content (OMC). Figure 1 shows the Digital Multifunction Electric Soil Compacting machine and an Extruder used to extrude the samples to be kept in the laboratory at 29 ±2°C to dry naturally.

***Figure 1**. Digital multifunction electric soil compactor and an extruder*

Volumetric shrinkage

The volumetric shrinkage upon drying was measured by extruding cylindrical specimens, compacted using the BSL, WAS and BSH energy levels for the three different sizes of mould. Air dried soil were compacted at – 2%, 0%, +2%, +4% and +6% of the optimum moisture content (OMC). The extruded cylindrical specimens were placed on a laboratory bench at a uniform temperature of 29 ± 2°C for 30 days to dry naturally. This method is considered to be better than the method used by [10] in which compacted cylindrical specimens were made dry in an air-conditioned building. This is because natural drying in the laboratory is considered to duplicate field conditions. Measurements of diameters and heights for each specimen were taken with the aid of a vernier caliper accurate to 0.05mm.

The average diameters and heights were used to compute the volumetric shrinkage strain. Figure 2 shows the three different sizes of sample been measured using Vernier Caliper device.

Figure 2. *Vernier Caliper measuring the three different soil samples*

Results and discussion

The properties of the soil are summarized in Table 1.

Table 1. Properties of the Soil

Properties	**Quantity**
Percentage passing BS NO 200 seive	56.27%
Natural Moisture Content	20.2%
Liquid Limit	39%
Plastic Limit	NP
Linear shrinkage	17.5%
Free swell	40%
Plasticity Index	39%
Specific Gravity	2.42
AASTHO Classification	A – 7- 6(10)
USCS Classification	CL
Group index	10
Maximum Dry Density mg/m^3	
British Standard light	1.73
West African Standard	1.87
British Standard heavy	1.97
Optimum moisture content %	
British Standard light	16.5
West African Standard	13.0
British Standard heavy	12.1
Ph	6.70
Dominant clay mineral	Kaolinite
Color	Light brown

The soil belongs to the CL group in the Unified Soil Classification System [14] or A-7-6(10) soil group of the AASHTO soil classification system [15]. The oxide composition of the soil is summarized in Table 2 and the picture of the three sizes of sample used for the study is shown in Figure 3.

Table 2. Oxide compositions of lateritic soil,*From [16]

Oxide	CaO	SiO_2	Fe_2O_3	Al_2O_3	MnO	MnO_2	TiO_2	K_2O	P_2O_5	Na_2O	MgO	SO_3	LOI
Laterite*	0.28	35.6	24	27.4	0.067	2	-	-	-	-	-	0.85	14.6

***Figure 3**. Soil sample for split former mould, proctor mould and California bearing ratio mould used for the study*

The variations of Volumetric shrinkage strain of lateritic soil at various molding water content (-2%, 0%, +2%, +4% and +6%) and compactive effort are shown in Figures 4 – 6.

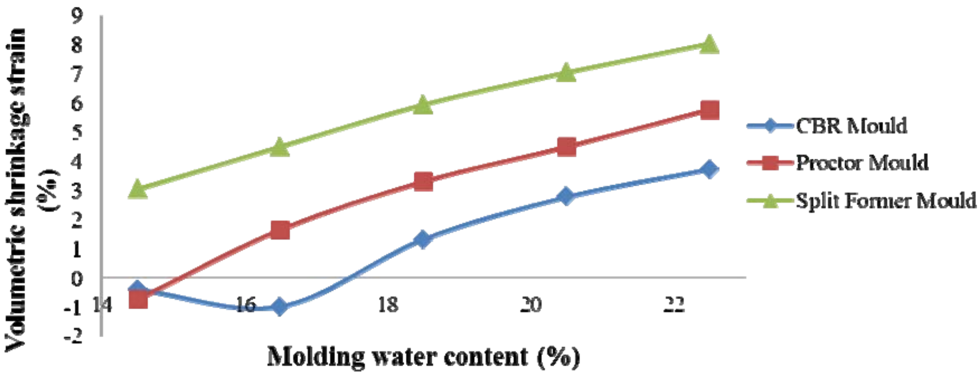

***Figure 4**. Variation of volumetric shrinkage with molding water content at BSL compactive effort*

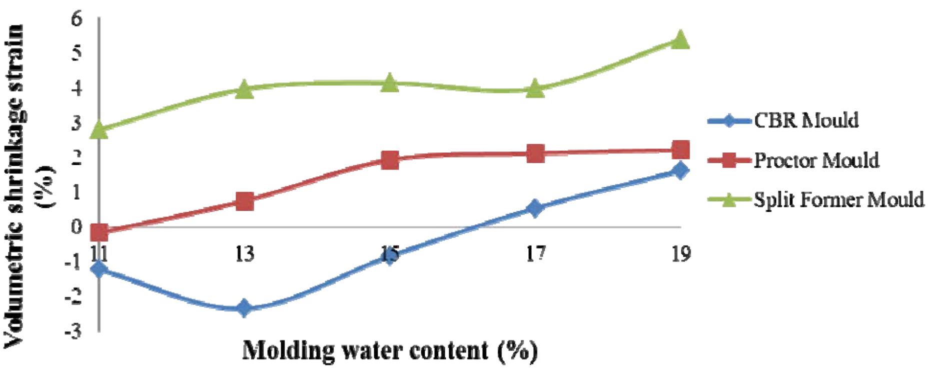

***Figure 5**. Variation of volumetric shrinkage with molding water content at WAS compactive effort*

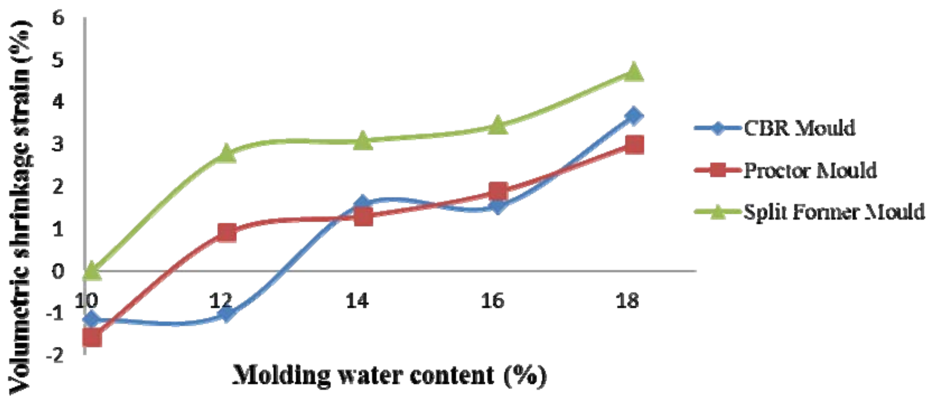

Figure 6*. Variation of volumetric shrinkage with molding water content at BSH compactive effort*

For all the compactive effort, CBR mould gave the lowest value of VSS while the split former mould gave the highest VSS value. The reason for the low value of VSS recorded for CBR mould is as a result of the longer time it took the moisture to travel to the surrounding surface for the moisture to evaporate from the soil. Split former mould gave the highest value of VSS because the size of the sample is very small so it took shorter time for the soil moisture to travel to the surface and the rate of evaporation is very high. Figure 4 above shows that as the molding water content increases the value of VSS increases for all mould for the BSL.

The value of VSS for split former mould increases from 3.04% at -2% OMC to 8.03% at +6% OMC, Proctor mould increased from -0.74% at -2% OMC to 5.77% at +6% OMC and the CBR mould increases from -0.4% at -2% OMC to 3.72% at +6% OMC.

Result from the WAS compaction Figure 5 also shows an increase in the VSS values with split former mould increasing from 2.79% at – 2% OMC to 5.38 at 6% OMC, proctor mould increasing from -0.18% at -2% OMC to 2.21% at+6% OMC while the CBR mould increases from -1.24% at -2% OMC to 1.61% OMC respectively. The result of BSH Figure 6 shows that the value of VSS for split former increased from a value of -0.0014 at -2% OMC to 4.71% at +6% OMC, proctor mould VSS value increased from -1.57% at -2% OMC to 2.99% at +6% OMC and the VSS for CBR mould increased from -1.17% at -2% OMC to 3.66% at +6% OMC respectively.

The reasons for this increase in VSS are not far-fetched because dry shrinkage in fine grained soil according to Mitchell (1976) depends on particle movement as a result of pore water tension developed by capillary menisci. Finally, according to results obtained by [17], [12], [18], [4] and [19], the shrinkage stain depended on three (3) main parameters mold water content, dry density (compaction effort), and soil plasticity index.

Molding water content

The effects of molding water content of -2% OMC, 0% OMC, +2% OMC, +4% OMC and +6% OMC on the compactive effort and mould sizes are shown in Figure 7 to Figure 11.

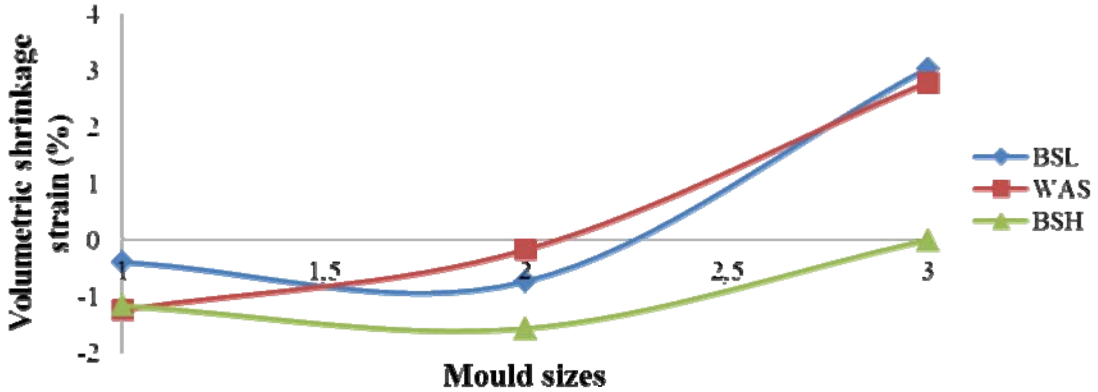

Figure 7*. Variation of volumetric shrinkage strain with various mould size at -2% molding water*

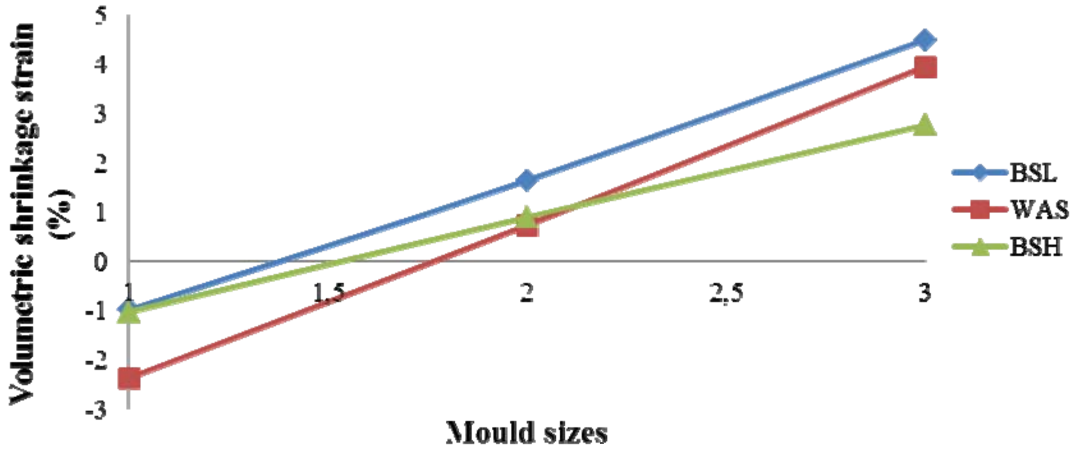

Figure 8*. Variation of volumetric shrinkage strain with various mould size at 0% molding water*

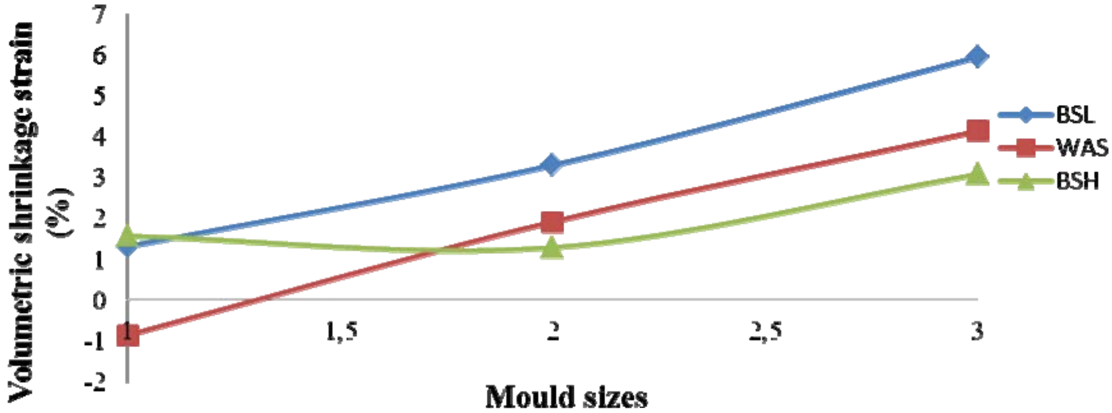

Figure 9*. Variation of volumetric shrinkage strain with various mould size at +2% molding water*

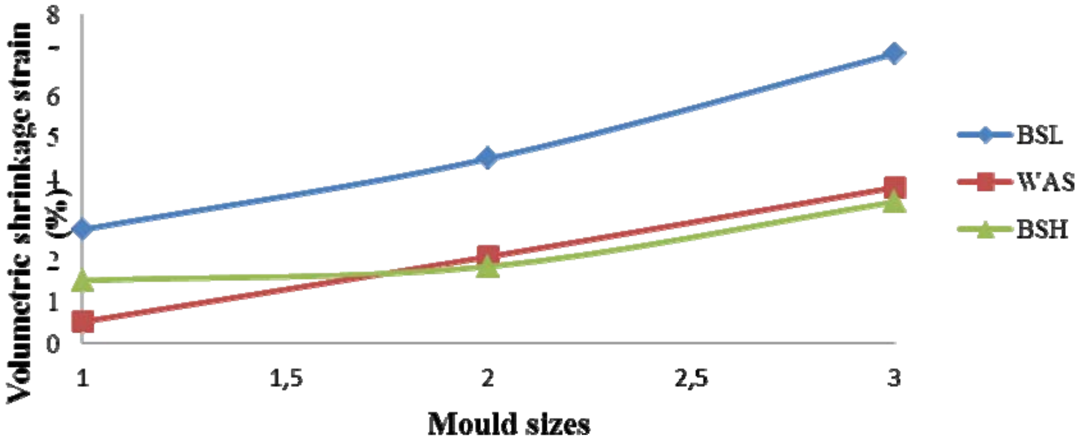

Figure 10. *Variation of volumetric shrinkage strain with various mould size at +4% molding water*

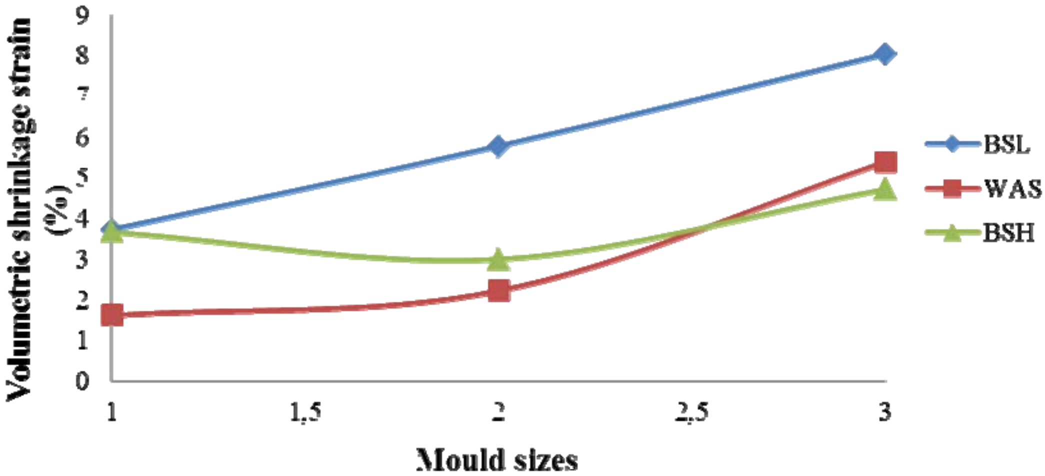

Figure 11. *Variation of volumetric shrinkage strain with various mould size at +6% molding water*

Higher shrinkage values were recorded at the smallest mould which is the split former for all the molding water content.

At -2% to +2% molding water content for the split former mould the volumetric shrinkage strain met the requirement of not more than 4% while at +4% and +6% only the WAS and BSH met the requirement. The proctor mould and the CBR mould on the other hand gave a lower value of volumetric shrinkage strain in all compactive effort and the values are lower than the 4% safe VSS suggested by [20]. Though the CBR mould gave a lowest value of VSS compare with the sample compacted with proctor mould.

Conclusion

Our study show that the volumetric shrinkage strain increased with higher molding water content and decreases with compactive effort.

The volumetric shrinkage strain varied greatly between the dry and wet side of the optimum. It increased towards wet side and decreased towards the dry side, where it showed tendency to expand The VSS value gotten from the split former mould shows that only at -2% to +2% molding water content met the requirement while for +4% to +6% does not met the requirement of less than 4% for all the three compactive efforts respectively.

Based on the VSS values obtained if the CBR mould can be used to model site condition it is recommended for use to simulate site condition for Volumetric shrinkage strain, but if the convention proctor mould is to be used then Proctor mould at molding water content between –2% to +2% at WAS and BSH compaction energy are recommended to stimulate site condition of value of Volumetric shrinkage

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