THE USE OF COMPACTED TROPICAL CLAY TREATED WITH RICE HUSK ASH AS A SUITABLE HYDRAULIC BARRIER MATERIAL IN WASTE CONTAINMENT APPLICATIONS

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Introduction

- Protection of our environment from pollutants emanating from wastes generated by man made activities and disposal systems in the less developed countries is now a matter of growing concern
- Due to its detrimental effects on the environment, especially on soil and groundwater which ultimately affects the health of the populace

Introduction Cont'd

- Waste management in Nigeria is characterized by poor land-filling practices
- Dumping of refuse in drainage or river channels, open dumps in low lying areas with no protection barrier or organized planning for waste dumping.
- Compacted clayey soils are commonly used as hydraulic barriers in waste containment systems
- Which include liners and covers for landfills, impoundments, hazardous liquid wastes

Background

- Several pozzolanic materials such as fly-ash, blast furnace slag, bagasse ash, etc. have been used to treat fine grained soils to produce compacted clay which serve as effective hydraulic barrier systems
- Rice milling generates the product known as husk which surrounds the paddy grain
- Benue state in Nigeria is an agrarian state with large quantities of rice produced annually.

Background Cont'd

- The rice husk produced by the milling process is burnt to generate energy and the resulting rice husk ash (RHA) a waste.
- In some places they are just dumped in open land fill sites. See Plate 1
- Tropical clayey soils treated with rice husk ash for use as a hydraulic barrier material in waste containment systems has the potential to use up large quantities of rice husk ash generated
- This could be useful in places where rice production is high

Plate 1. A waste dump in Makurdi – Benue State showing heaps of rice husk ash.

Aim and Objectives

- This work aims at the study of the physical properties of a tropical clayey soil treated with RHA for potential usage as isolation barriers in waste containment application.
- Determined how the material could be compacted; at what compaction moisture the required hydraulic conductivity were achieved.
- Determined if the material had a low potential to shrink and crack when dried (desiccation)
- Ascertain if the compacted material had adequate shear strength.

Research

- Material
- ✓ **Soil**: soil used was collected from a drainage excavation site at about 1.0m
- ✓ X-ray diffraction studies on the soil show Illite as the dominant clay mineral.
- ✓ It is yellowish brown in colour and classified as A-6 (8) according to AASHTO soil classification system and CL according to the Unified Soil Classification System (ASTM, 1992).

Research Contd'

- ✓Rice Husk Ash: was obtained from a rice mill
- ✓The husk was stacked in heaps and openly burnt
- ✓The resulting ash was then passed through sieve with 75μm aperture
- ✓ The RHA was mixed with the soil in stepped increment of 4% from 0% to 16% by weight of dry soil to form five different soil – RHA mixture.

Research Contd'

- Methods
- ✓ Index properties: were done in accordance with British Standards (BS 1377,1990)
- ✓ Compaction: Three compactive energies namely standard Proctor, West African Standard or Intermediate, and modified Proctor were used
- ✓ Hydraulic Conductivity: was measured using the rigid wall permeameter under falling head condition

Research Contd'

- ✓ Compacted soil-rice husk ash samples at the different rice husk ash contents (0%, 4%, 8%, 12% and 16%) and different moulding water contents (-2%, 0%, +2% and +4% of the OMC, respectively) using the three compactive effort were permeated and hydraulic conductivity values measured

- ✓ Volumetric Shrinkage: was measured by extruding compacted cylindrical specimens, allowed to air dry for 30days on the laboratory table

Research Contd'

- ✓ Unconfined Compressive Strength test was carried out by compacting air-dried soil-rice husk ash mixtures at four moulding water content (i.e.-2%, 0%, +2% and +4%) using the three compactive effort mentioned
- ✓ Specimens were trimmed into cylindrical undisturbed specimens, having diameter of 38mm and length of 76 mm
- ✓ They were placed in a load frame machine driven strain controlled at 0.10 %/min and crushed unconfined until failure occurred

Results and Discussion

Table1. Physical properties of the natural soil and stabilized soils used.

Property	Natural soil. 0% Rice Husk Ash	4% Rice Husk Ash	8% Rice Husk Ash	12% Rice Husk Ash	16% Rice Husk Ash
Natural Moisture Content,[%]	6.5	-	-	-	-
Liquid Limit, [%]	34.4	36	37.6	39.4	40.8
Plastic Limit, [%]	13.4	17.2	20.9	25	28.4
Plasticity Index, [%]	21	18.8	16.7	14.4	12.4
Linear shrinkage, [%]	11.4	10.7	10	9.3	8.6
Percentage Passing BS No. 200 sieve	56.83	52.68	54.07	52.44	58.65
AASHTO classification	A-7-6 (8)	-	-	-	-
USCS Classification	CL	CL	CL	CL	CL
Specific Gravity	2.54	2.5	2.44	2.37	2.31
Maximum Dry Density [Mg/m^3]					
Standard Proctor	1.7	1.68	1.62	1.55	1.48
West African Standard	1.85	1.79	1.69	1.60	1.57
Modified Proctor	1.94	1.89	1.79	1.62	1.57
Optimum Moisture Content [%]					
Standard Proctor	13.8	14.8	16.2	21.2	24.0
West African Standard	13.5	13.8	14.5	19.6	22.2
Modified Proctor	11.6	12.0	13.5	18.0	18.9
Colour	Yellowish brown				
Dominant Clay mineral	Illite				

Result and Discussion Cont'd

- Atterberg limits results show overall improved index properties
- Index property results reveal that the various soil-rice husk ash mixes are suitable materials for hydraulic barriers; according to Daniel (1993) and Rowe et al. (1995)
- The MDD and OMC of the treated soil decreased and increased, respectively, with higher RHA content.
- The MDD also increased with higher compactive effort while the OMC reduced with higher compactive effort for each of the specimens.

Result and Discussion Cont'd

- Hydraulic Conductivity: It generally decreased as the moulding water content increased
- Compaction under higher moulding water contents results in soils devoid of macro pores that conduct flow
- Soft wet clods of soil are easier to remould resulting in smaller interclod voids and hence lower hydraulic conductivity
- Increased compaction effort for all treatment with rice husk ash led to decreased hydraulic conductivity

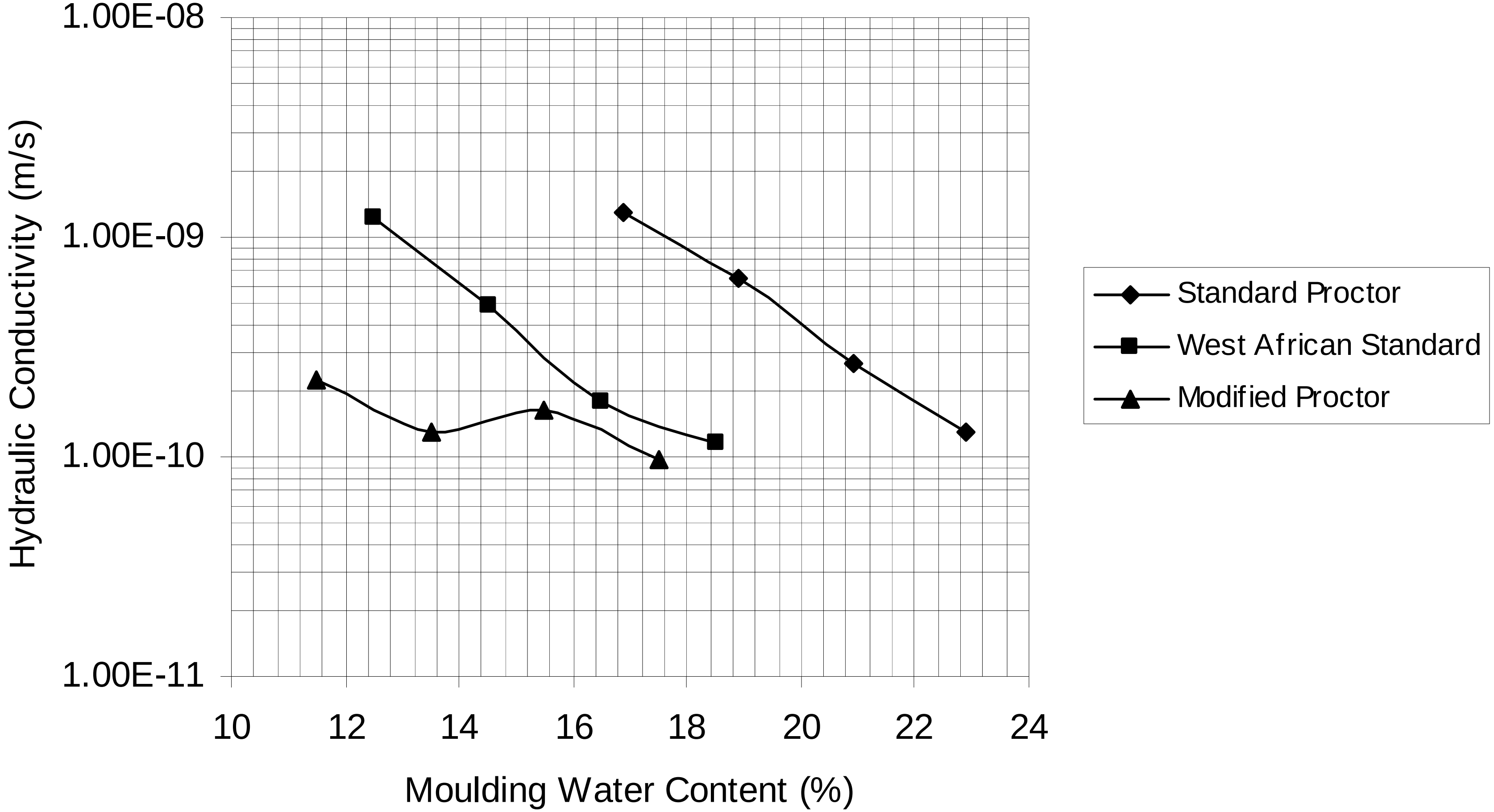

Fig. 1 Variation of hydraulic conductivity with moulding water content for 8% RHA content.

Table 2. Minimum hydraulic conductivity with corresponding water content for minimum and maximum permissible hydraulic conductivity for the various compactive effort and rice husk ash treatments.

Rice Husk Ash Treatment (%)	Compactive Effort	Minimum hydraulic conductivity (m/s)	Water Content (%) at minimum hydraulic conductivity	Water content (%) at maximum permissible hydraulic conductivity for soil liners (1×10^{-9} m/s)
0 (Natural soil)	Standard Proctor West African Standard Modified Proctor	1.38×10^{-10} 1.06×10^{-10} 2.33×10^{-12}	13.8 17.5 13.6	12.2 <11.5 <9.6
4	Standard Proctor West African Standard Modified Proctor	2.43×10^{-10} 1.77×10^{-10} 1.24×10^{-10}	18.8 17.8 12.0	13.4 <11.8 <10
8	Standard Proctor West African Standard Modified Proctor	1.29×10^{-10} 1.17×10^{-10} 9.79×10^{-11}	22.9 18.5 17.5	17.6 12.8 <11.5
12	Standard Proctor West African Standard Modified Proctor	3.27×10^{-10} 2.53×10^{-10} 1.02×10^{-10}	23.2 21.6 20.0	21.7 19.6 <16
16	**Standard Proctor West African Standard Modified Proctor**	9.26×10^{-10} 3.43×10^{-10} 9.32×10^{-11}	28.0 26.2 22.9	25.8 20.6 <16.9

Result and Discussion Cont'd

- Volumetric Shrinkage: Generally, volumetric shrinkage strain (VSS) increased with higher moulding water content, in agreement with works of other researchers
- Samples compacted at higher moulding water content, had more water in their void spaces that resulted in higher shrinkage on drying
- Since volumetric shrinkage is proportional to the volume of water leaving the pore spaces

- Results show that the moulding water content at which the maximum permissible 4% volumetric shrinkage strain was obtained reduced with higher compaction efforts and increased with higher RHA treatment.
- This probably could be due to increased water contained in the voids of compacted specimen at lower compactive efforts and higher RHA treatment leading to increased shrinkage.

Table 3 Minimum volumetric shrinkage strain with corresponding water content at minimum and maximum permissible volumetric shrinkage at various compactive effort and rice husk ash treatments.

Rice Husk Ash Treatment (%)	Compactive Effort	Minimum volumetric shrinkage strain (%)	Water Content (%) at minimum volumetric shrinkage strain.	Water content (%) at maximum permissible volumetric shrinkage strain for soil liners (4%)
0 (Natural soil)	Standard Proctor West African Standard Modified Proctor	3.0 3.1 2.4	11.8 11.5 9.6	<17.0 17.5 14.6
4	Standard Proctor West African Standard Modified Proctor	3.0 2.7 2.2	12.8 11.8 10.0	17.4 15.8 14.0
8	Standard Proctor West African Standard Modified Proctor	2.8 2.8 2.4	14.2 12.5 11.5	17.2 17.0 15.5
12	Standard Proctor West African Standard Modified Proctor	5.9 3.8 3.1	19.2 17.6 16.0	Nill 18.6 19.2
16	Standard Proctor West African Standard Modified Proctor	6.0 5.6 4.2	22 20.2 16.9	Nill Nill Nill

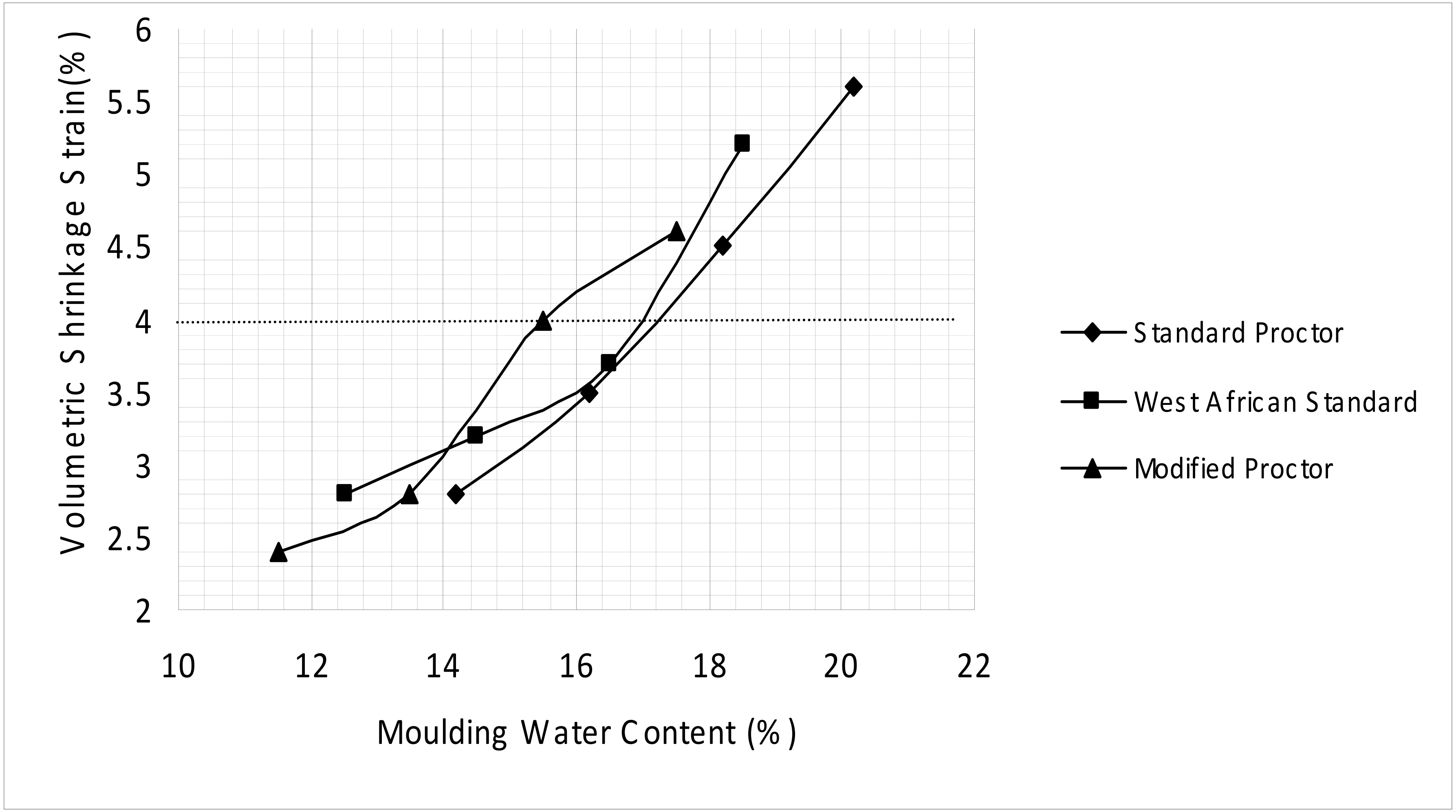

Fig. 2 Variation of volumetric shrinkage strain with moulding water content for 8% RHA content

- Unconfined Compressive Strength: The UCS generally reduced with higher moulding water content.
- This was so because the basic factor responsible for the strength of a soil is frictional resistance between soil particles in contact.
- With increasing moulding water content, the soil fabrics were increasingly deflocculated hence the shear strength reduced.

- From the results obtained in all cases of rice husk ash treatment, increase in rice husk ash content led to reduced strength.
- This is because increment in rice husk ash content lead to increase of optimum moisture content due to the presence of more fines; making more free water available in the soil, and reduced strength
- Furthermore, increase in compaction energy led to increased strength because of closer packing of the soil fabric

Table 4. Maximum UCS with corresponding water content at maximum and minimum permissible UCS for the various compactive effort and rice husk ash treatments.

Rice Husk Ash Treatment (%)	Compactive Effort	Maximum unconfined compressive strength (kN/m²)	Water Content (%) at maximum unconfined compressive strength (kN/m²)	Water content (%) at minimum permissible unconfined compressive strength for soil liners (200 kN/m²)
0 (Natural soil)	Standard Proctor	324.0	11.8	17.6
	West African Standard	460.3	11.5	>17.5
	Modified Proctor	884.0	9.6	>15.6
4	Standard Proctor	287.2	12.8	17.0
	West African Standard	410.6	11.8	>17.8
	Modified Proctor	713.0	10.0	>16
8	Standard Proctor	207.4	14.2	15.2
	West African Standard	386.0	14.5	>18.5
	Modified Proctor	614.0	11.5	>17.5
12	Standard Proctor	183.2	19.2	<19.2
	West African Standard	322.0	17.6	>23.6
	Modified Proctor	513.0	16.0	>22.0
16	Standard Proctor	158.0	22.0	<22.0
	West African Standard	276.0	20.2	>26.2
	Modified Proctor	478.0	16.9	>22.9

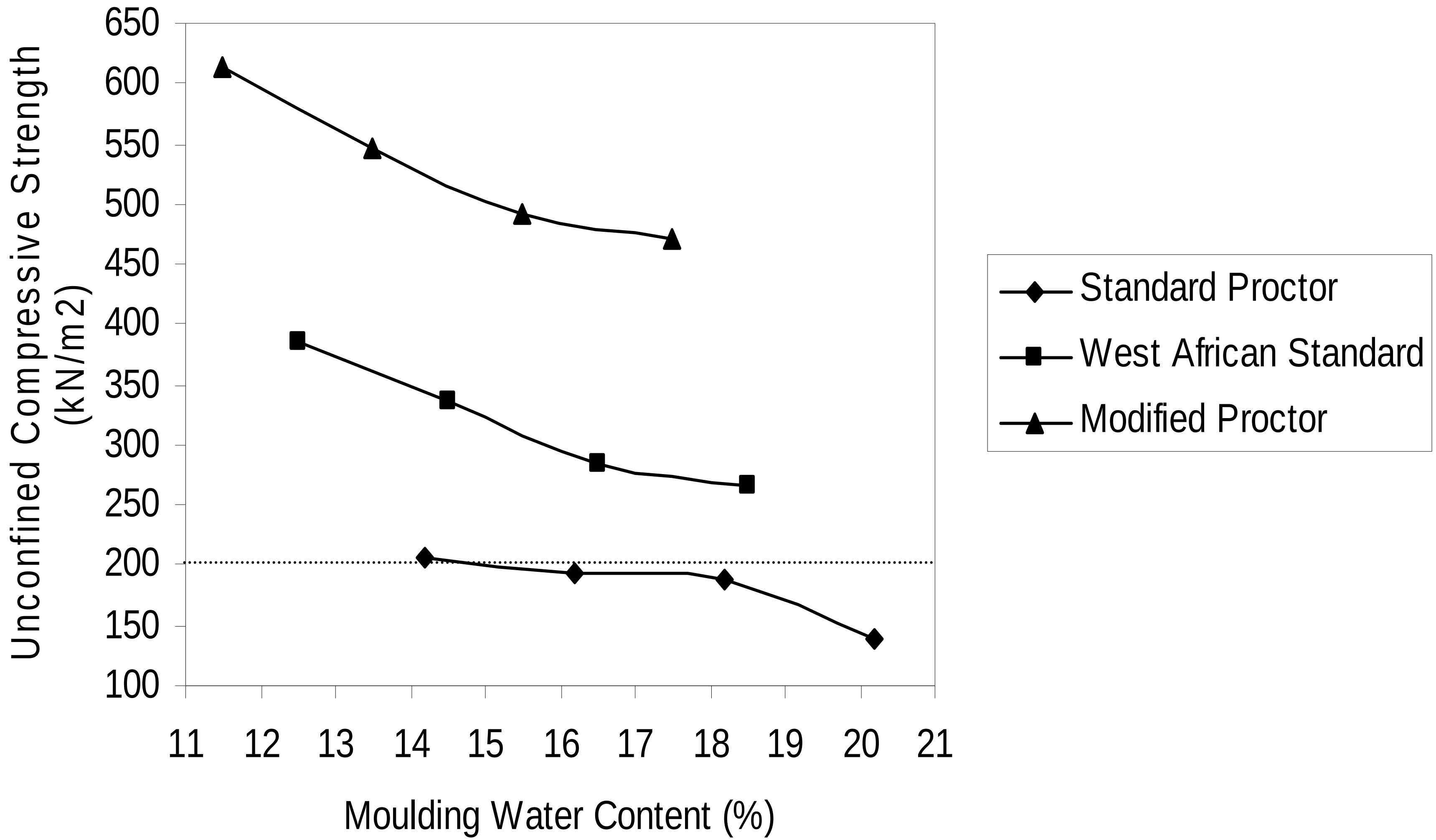

Fig. 3 Variation of unconfined compressive strength with moulding water content for 8% RHA content

Acceptable Zones

- Daniel and Benson (1990) described a procedure for determining compaction criteria for soil liners and covers by relating the dry density and moulding water content to permissible limits of the various design parameters.
- Three criteria were established
- ✓ The compacted soils were required to have low hydraulic conductivity, and a maximum of 1×10^{-9} m/s was adopted.
- ✓ That shrinkage cracking caused by desiccation should not be excessive and a maximum permissible volumetric shrinkage strain of 4% was adopted

- ✓ The compacted soils must have adequate shear strength not less than 200kN/m^2.
- ✓ The acceptable zones for shear strength, hydraulic conductivity, and volumetric shrinkage strain for 8% rice husk ash treatment respectively, are shown in Figs. 4 – 6.

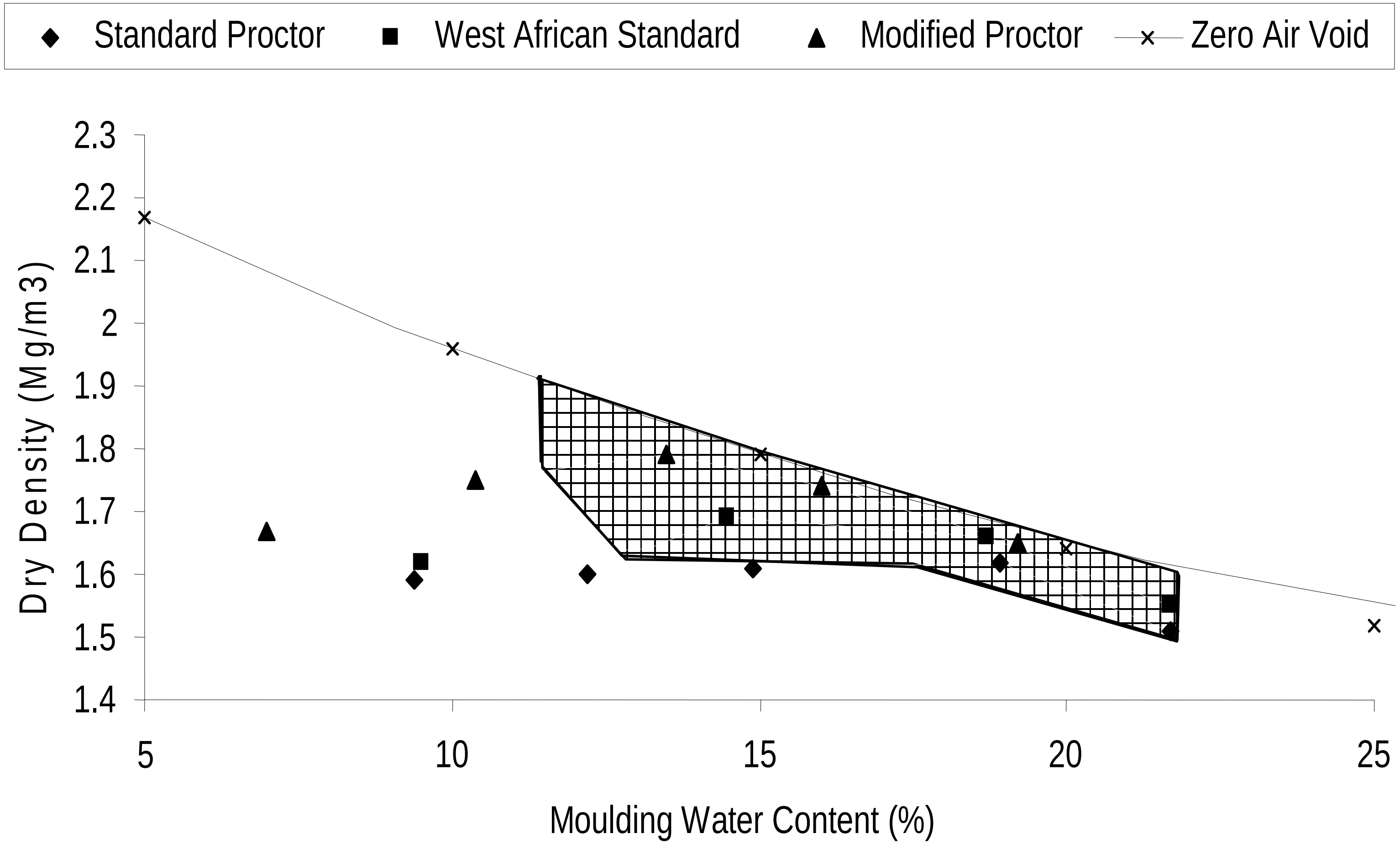

Fig. 4. Acceptable zone for hydraulic conductivity for 8% RHA

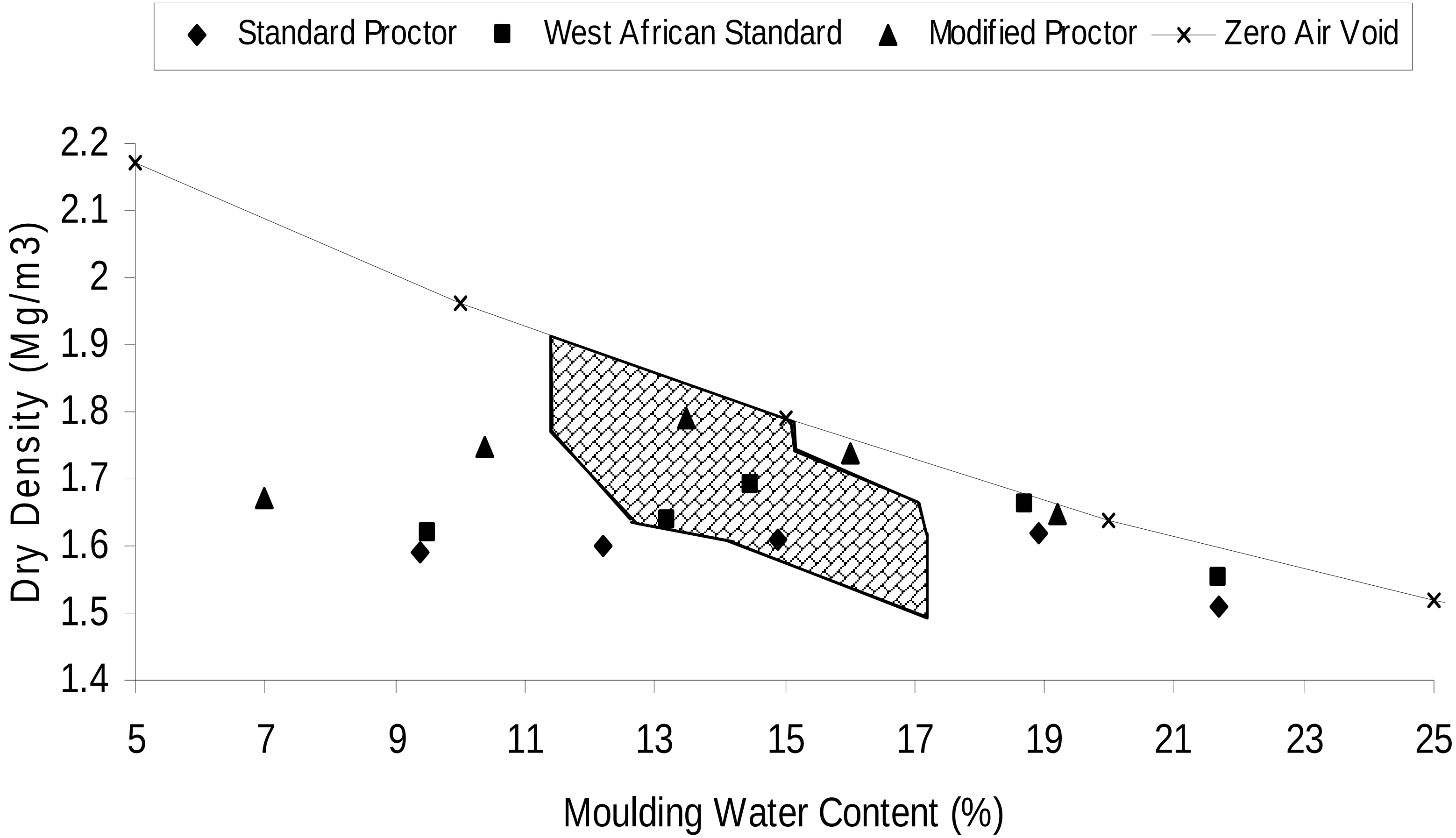

Fig. 5 Acceptable zone for volumetric shrinkage strain at 8% RHA

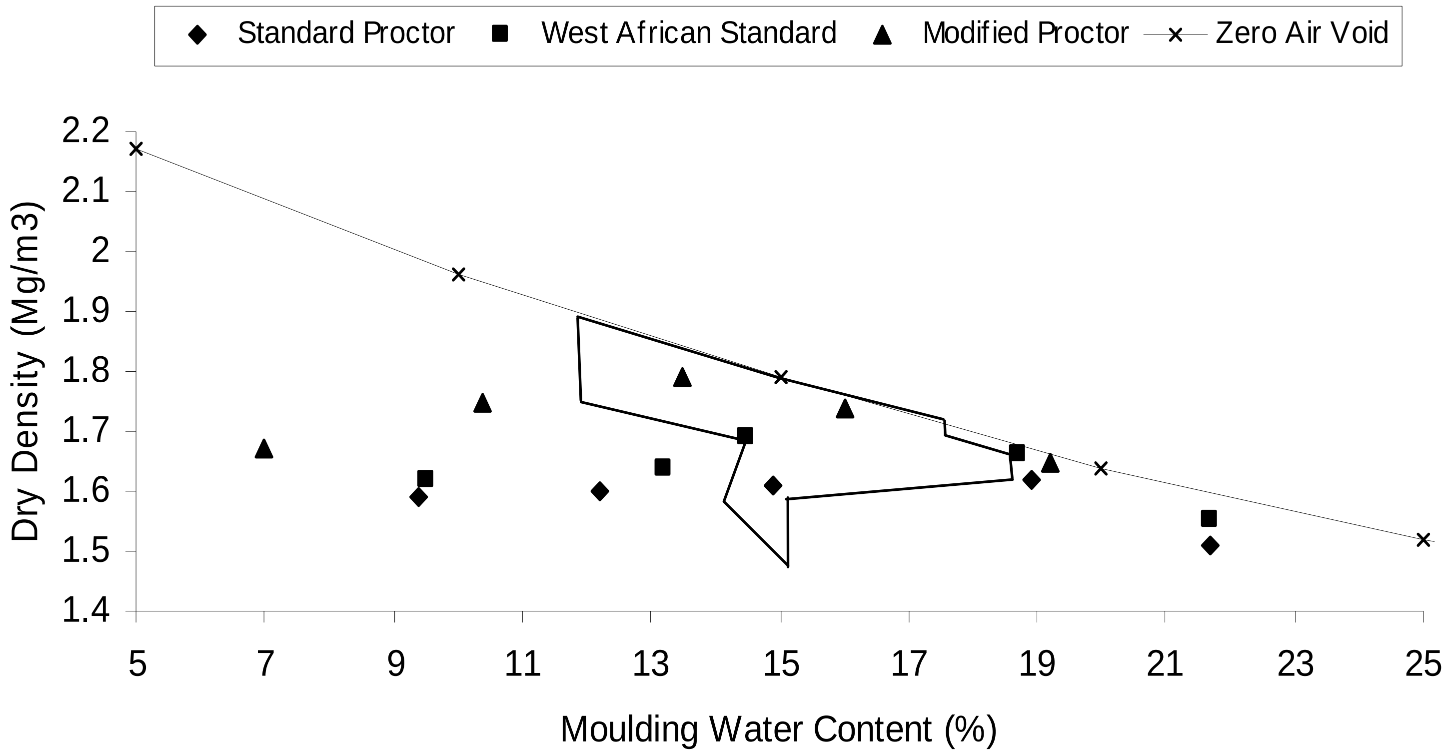

Fig. 6 Acceptable zone for unconfined compressive strength shrinkage strain at 8% RHA

Overall Acceptable Zones

- Overall acceptable zones in which permissible limits of the various design parameters for the natural soil, 4%, and 8% rice husk ash treatments, respectively, are superimposed in Figs 7.
- Soil-rice husk ash mixes should be adequately compacted at the water content range for the various compactive efforts as shown in Table 5 for the construction of suitable hydraulic barriers.

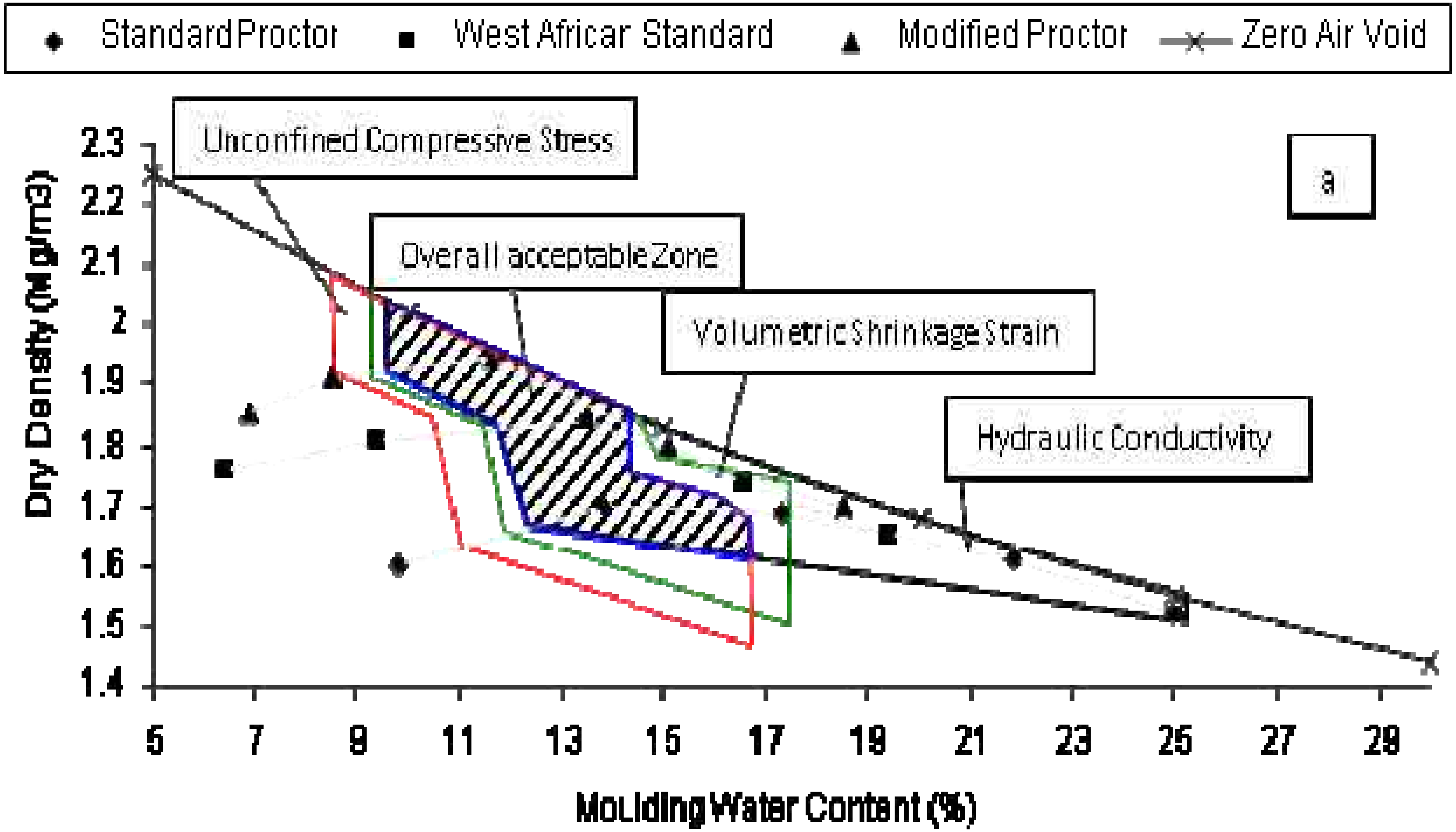

Fig. 7a. Overall acceptable zone for natural soil

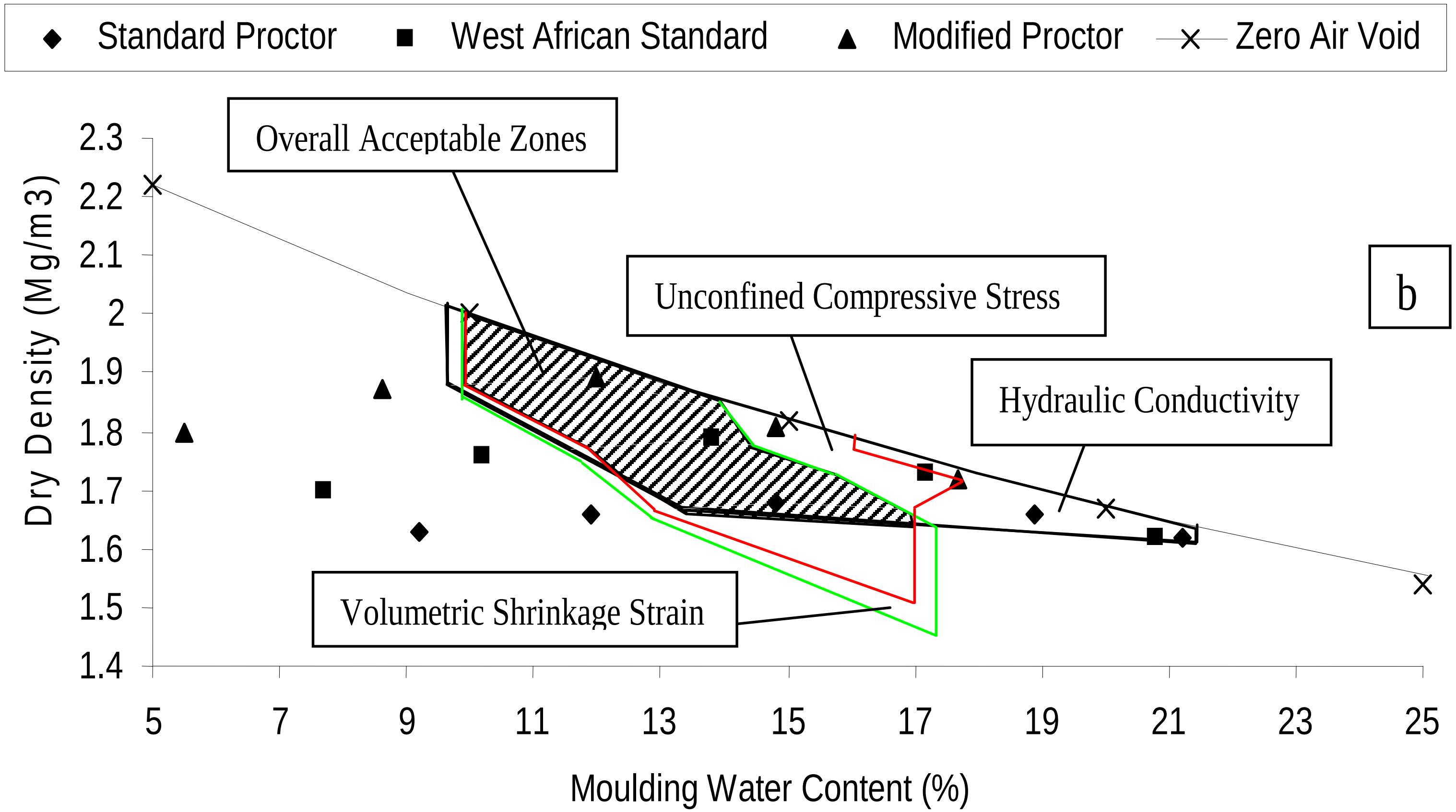

Fig. 7b. Overall acceptable zone for 4% RHA

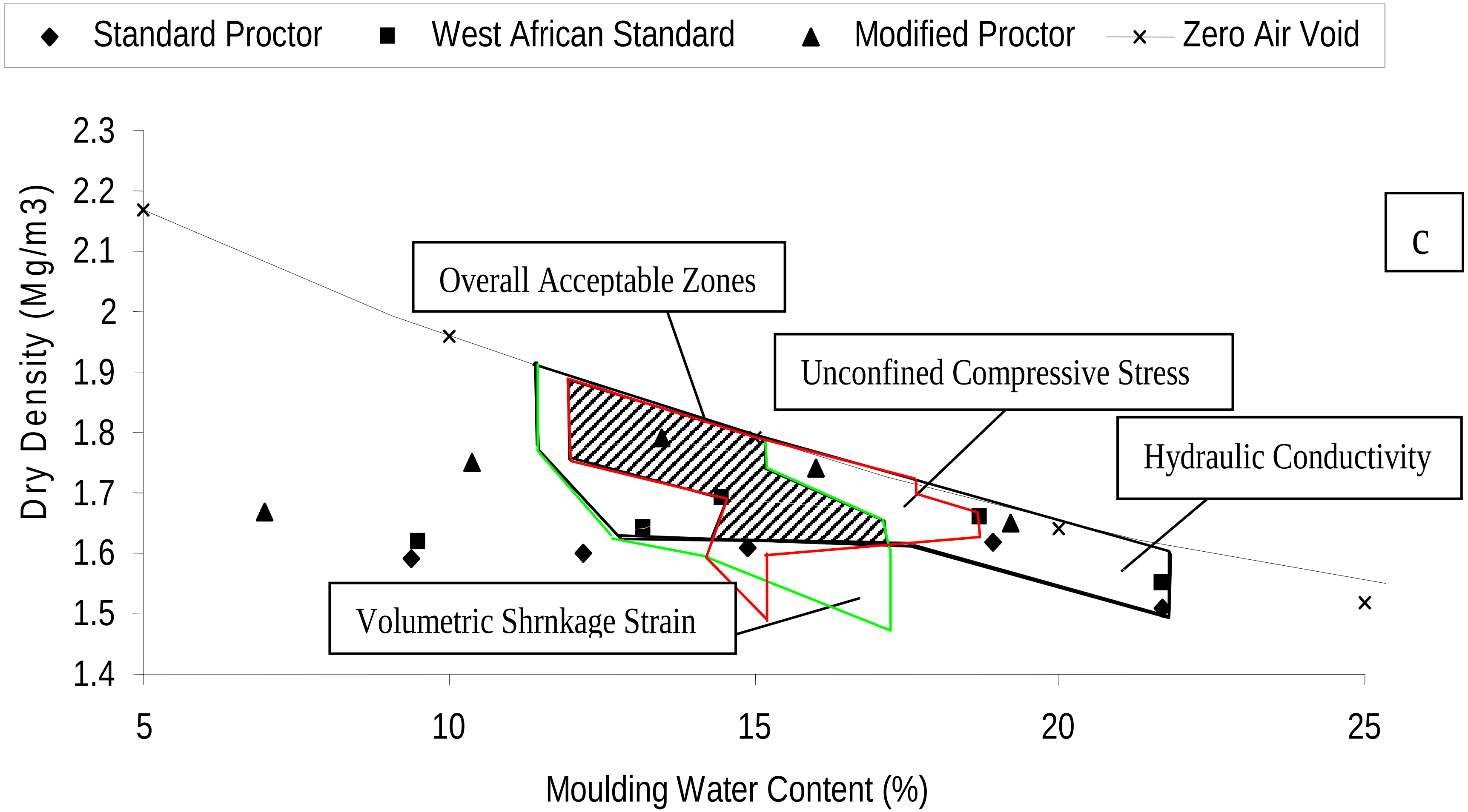

Fig. 7c. Overall acceptable zone for 8% RHA

Table 5. Acceptable Range of Moulding Water Content for the various rice husk ash treatments and compactive efforts.

Slag Treatment (%)	Compactive Effort	Acceptable Range of Moulding Water for Hydraulic Conductivity	Acceptable Range of Moulding Water Content (%) for Volumetric Shrinkage	Acceptable Range of Moulding Water Content (%) for Unconfined Compressive Strength.	Overall acceptable Range of Moulding Water Content.
0 (Natural soil)	Standard Proctor West African Standard Modified Proctor	12.2 to 13.8 <11.5 to 17.5 < 9.6 to 13.6	11.8 to 17.0 11.5 to 17.3 9.6 to 14.6	11.8 to 17.5 11.5 to >17.5 9.6 to >15.6	12.2 to 16.7 11.5 to 14.3 9.6 to 14.6
4	Standard Proctor West African Standard Modified Proctor	13.4 to 18.8 <11.8 to 17.8 < 10 to 12.0	12.8 to 17.4 11.8 to 15.8 10 to 14.0	12.8 to 17.0 11.8 to 17.8 10 to >16	13.4 to 17.0 11.8 to 15.8 <10 to 14
8	Standard Proctor West African Standard Modified Proctor	17.6 to 22.9 12.8 to 18.5 < 11.5 to 17.5	14.2 to 17.2 12.5 to 17.0 11.5 to 15.5	14.2 to 15.2 14.5 to 18.5 11.5 to 17.5	14.2 to 17.2 14.5 to 17.0 11.5 to 15.5
12	Standard Proctor West African Standard Modified Proctor	21.7 to 23.2 19.6 to 21.6 <16 to > 20.0	19.2 17.6 to 18.6 16 to 19.2	19.2 17.6 to 23.6 16.0 to >26.2	Nill Nill Nill
16	Standard Proctor West African Standard Modified Proctor	25.8 to > 28.0 20.6 to > 26.2 <16.9 to 22.9	22 20.2 16.9	22.0 20.2 to >26.2 16.9 to >22.9	Nill Nill Nill

Conclusion

- A yellowish brown compacted tropical clay with illite as the dominant clay mineral was treated with up to 16% rice husk ash content.
- Its potential was investigated for use as a hydraulic barrier material in waste containment application
- Based on index properties, the material possesses suitable amount of fines and sand fraction along with good plasticity characteristics required to achieve very low hydraulic conductivity suitable for hydraulic barriers.

Conclusion Cont'd

- The MDD and OMC of the treated soil decreased and increased, respectively, with higher RHA content.
- The MDD also increased with higher compactive effort while the OMC reduced with higher compactive effort for each of the specimens.
- The hydraulic conductivity generally decreased as the moulding water content and compactive effort increased.
- Permissible hydraulic conductivity of 1×10^{-9} m/s for soil hydraulic barriers was obtained at various compactive efforts and rice husk ash treatment

Conclusion Cont'd

- Volumetric shrinkage strain increased with higher moulding water content
- Moulding water content at which the permissible 4% volumetric shrinkage strain was obtained reduced with higher compaction efforts and increased with higher RHA treatment.
- Permissible volumetric shrinkage strain was obtained for up to 8 % RHA treatment.
- The UCS generally reduced with higher moulding water content, rice husk ash treatment, but increased with compactive effort.

Conclusion Cont'd

- Permissible UCS values of 200kN/m^2 were obtained at various compactive efforts and RHA treatment
- Compaction planes defined by hydraulic conductivity, volumetric shrinkage and UCS based on previously established permissible values were obtained.
- An overall acceptable zone at 12% and 16% RHA treatment were not feasible for use as a hydraulic barrier limiting its useage to 8% RHA.

Conclusion Cont'd

- It is worthy to note that the soil alone will be suitable for the construction of a hydraulic barrier based on the results obtained
- In addition to the economic benefits derived using the treated soil-rice husk ash mixtures
- The use of this agro-industrial by-product instead of disposal will help in ameliorating associated environmental problems

THANK YOU