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SAND – BLACK CLAY MIXTURES AS IMPERVIOUS BARRIER IN EARTH-CORE ROCKFILL DAMS: LABORATORY STUDY

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1. INTRODUCTION

1.1. Rockfill Dams may be either of

- Upstream Impervious Memberane type; or of
- Impervious Barrier Earth Core (IBEC) type.

This paper addresses the IBEC type.

1.2. Suitability Criteria of Materials for IBEC

Any material that, in a suitably compacted state has:

- Low Permeability, $K \leq 1 \times 10^{-6}$ cm/s
- Low Volumetric Shrinkage Strain ≤ 5%
- Reasonably high strength, MDUW ≥ 15 kN/m^3

1.3. Typical Materials

- Clayey Silt
- All naturally occurring soils satisfying 1.2. above
- All mixtures of soils satisfying 1.2. above

This paper examines the optimum mixture(s) of Bama Ridge Sand **(BRS)** and Black Cotton Soil **(BCS)**.

2. MATERIALS AND METHODS

2.1. Soils Studied

- BCS and BRS; Both occur extensively in N.E. Nigeria from Lat.10° 35'-11˚41'N and Long. 12° 14'-13° 07'E

PROPERTY	BCS	BRS	UNITS
pH	7.4.	6.67	-
EC	0.09	0.03	mS/cm
Specific Gravity	2.30	2.69	-
Free Swell	55	40	%
Liquid Limit (LL)	46.8	-	%
Plastic Limit (PL)	29.3	-	%
Plasticity Index (PI)	17.9	-	-
Linear Shrinkage	15.99	-	%

2.1. Soils Studied cont…

PROPERTY	BCS	BRS	UNITS
Gravel	-	0.4	%
Sand Silt	12.3 31a	97.6 -	% %
Clay Fines	56.7 -	- 2.0	% %
Cu= D60/D10 Cc= (D30 XD30)/(D60 x D10)	- -	4.04 1.21	- -
D10 D50	- -	0.24 0.80	mm mm
AASHTO Classification	A-7-5	A-3	-
USCS Classification	ML	SP	-

2.2. Methods of Testing

S/NO.	TEST	AUTHORITY
1.	pH & EC	Black (1965)
2.	LL, PL, PI, K. Compaction Characteristics with BSL & BSH	BS 1377 (1990) and Head (1992)
3.	Compaction characteristics with WAS	Ola (1983)
4.	Volumetric Shrinkage Strain, VSS* = 100 x (Initial Volume – Final Volume)/Initial	Nwaiwu (2006)
5.	Mixing Rates BRS:BCS = 0:1, 1:9, 1:4, 3:7, 2:3, 1:1	In this Study
6.	Compacting Energies: (a)British Standard Light, BSL (b)West African Standard, WAS (c)British Standard Heavy, BSH	As 2 above As 3 above As 2 above

** VSS in % @ 2% Water Content wet of Optimum*

3. RESULTS AND DISCUSSION

3.1(a) Variation of Soil Properties with % of BRS in Mixture

S/NO	% BRS	0	10	20	30	40	50
1.	pH	7.4	7.2	7.01	6.94	7.03	6.67
2.	EC, mS/cm	0.09	0.07	0.18	0.06	0.06	0.05
3.	Sp. Gravity	2.30	2.42	2.48	2.52	2.61	2.63
4.	Liquid Limit, %	46.8	43.6	37.6	33.5	32.0	30.0
5.	Plastic Limit, %	29.3	28.0	22.9	23.2	22.4	21.4
6.	Plasticity Index	17.5	15.6	14.7	10.8	9.6	8.6
7.	Linear Shrinkage %	16	15.7	11.1	11.2	12.5	10

3.1(b) Plasticity Characteristics of Sand-Black Clay Mixtures

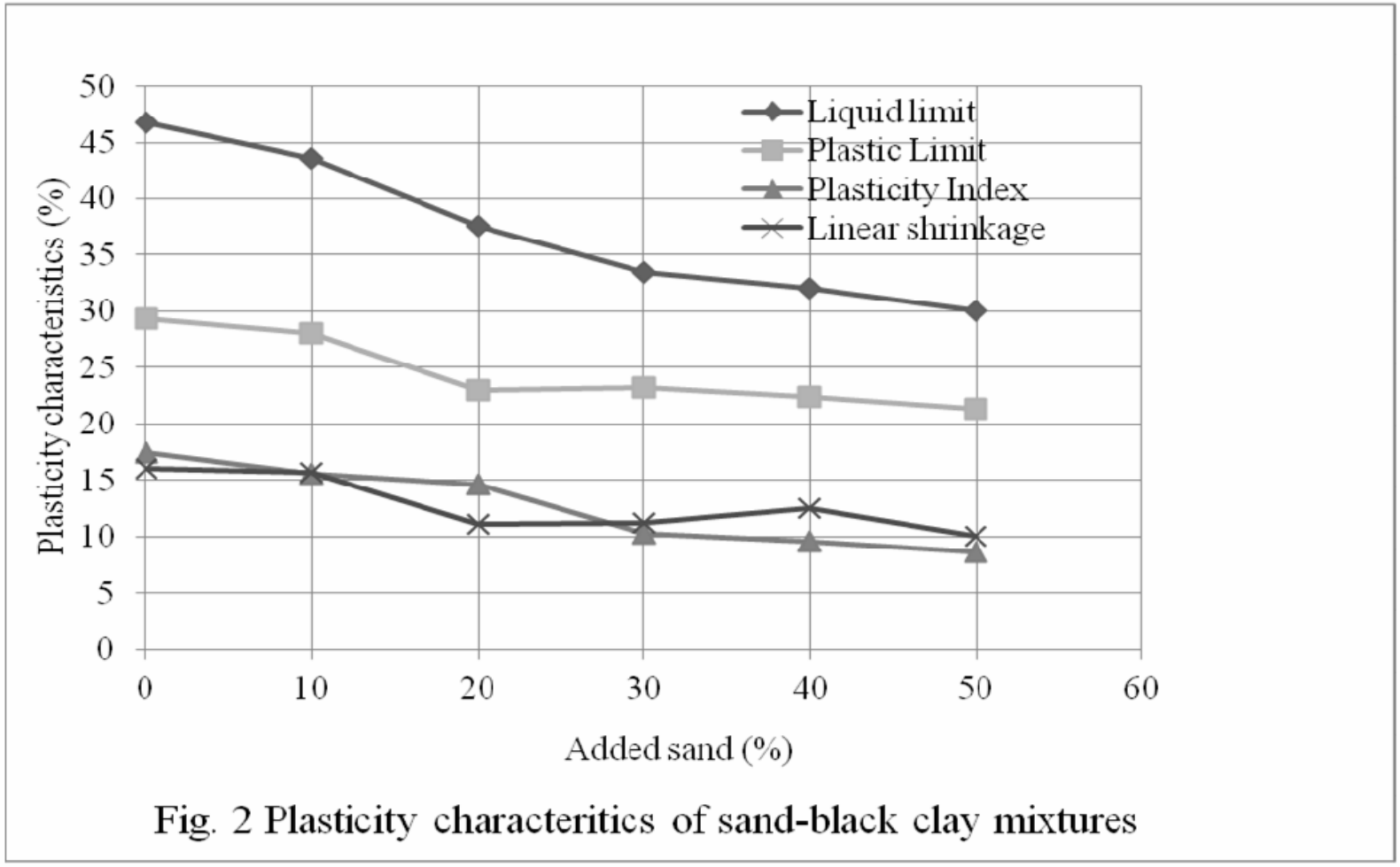

Fig. 2 Plasticity characteritics of sand-black clay mixtures

3.2 Response to Compaction and % of BRS in Soil Mixture

% BRS	0	10	20	30	40	50
MDUW (kN/m^3) with						
BSL	13.87	16.12	16.24	16.94	18.14	20.59
WAS	14.59	16.35	16.78	17.58	18.14	21.21
BSH	15.16	17.04	18.63	19.03	20.33	22.63
OMC (%) with						
BSL	20.8	18.81	16.67	15.06	12.79	9.59
WAS	16.5	15.18	14.85	12.06	9.46	8.16
BSH	14.6	12.10	11.20	8.45	7.92	6.56
K (cm/s)* x 10^8, with						
BSL	5.25	12.2	17.9	22.7	30.6	34.6
WAS	3.28	5.57	8.22	12.6	19.7	21.3
BSH	1.35	1.96	2.56	3.44	4.14	5.41

* K = Hydraulic Conductivity = Coeff. of Permeability, e.g. for zero BRS with BSL is 10^{-8} x 5.25.

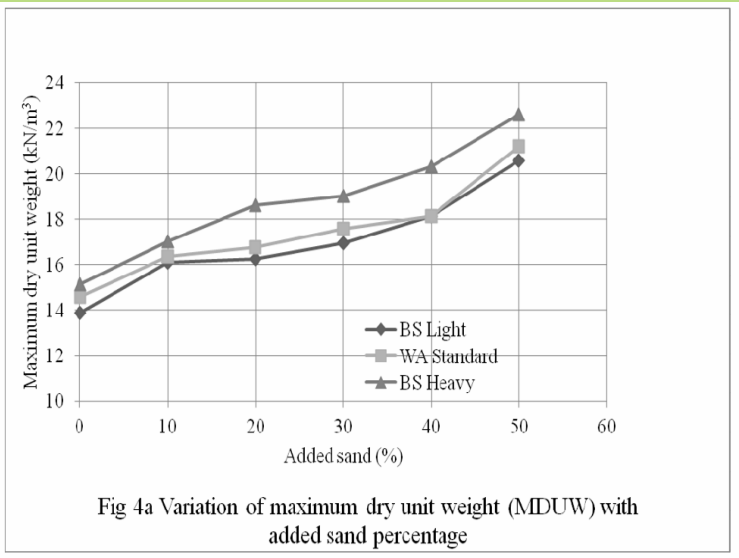

Fig 4a Variation of maximum dry unit weight (MDUW) with added sand percentage

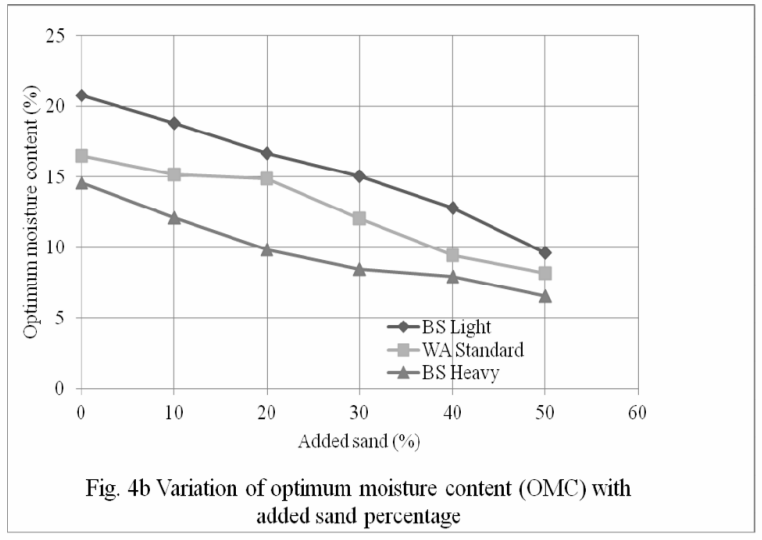

Fig. 4b Variation of optimum moisture content (OMC) with added sand percentage

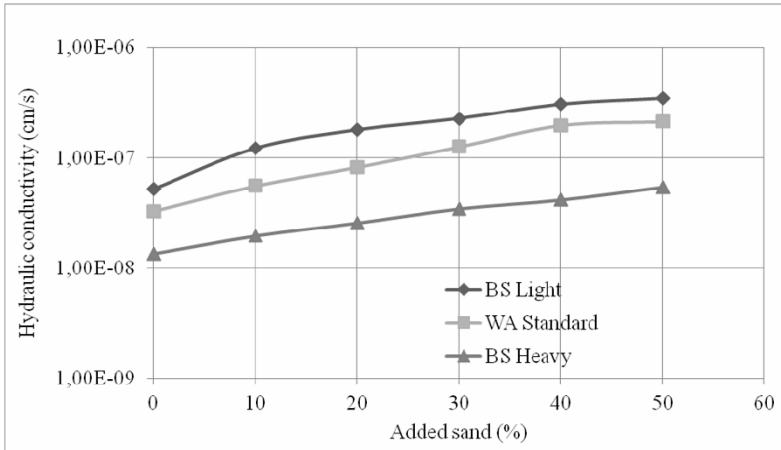

Fig. 5 Variation of hydraulic conductivity with added sand percentage

3.3. Volumetric Shrinkage Strain

% BRS	0	10	20	30	40	50
BSL	15.9	17.6	9.6	6.8	6.4	8.7
WAS	10.9	5.7	6.5	5.0	2.8	7.0
BSH	-	10	7.8	3.2	2.0	-

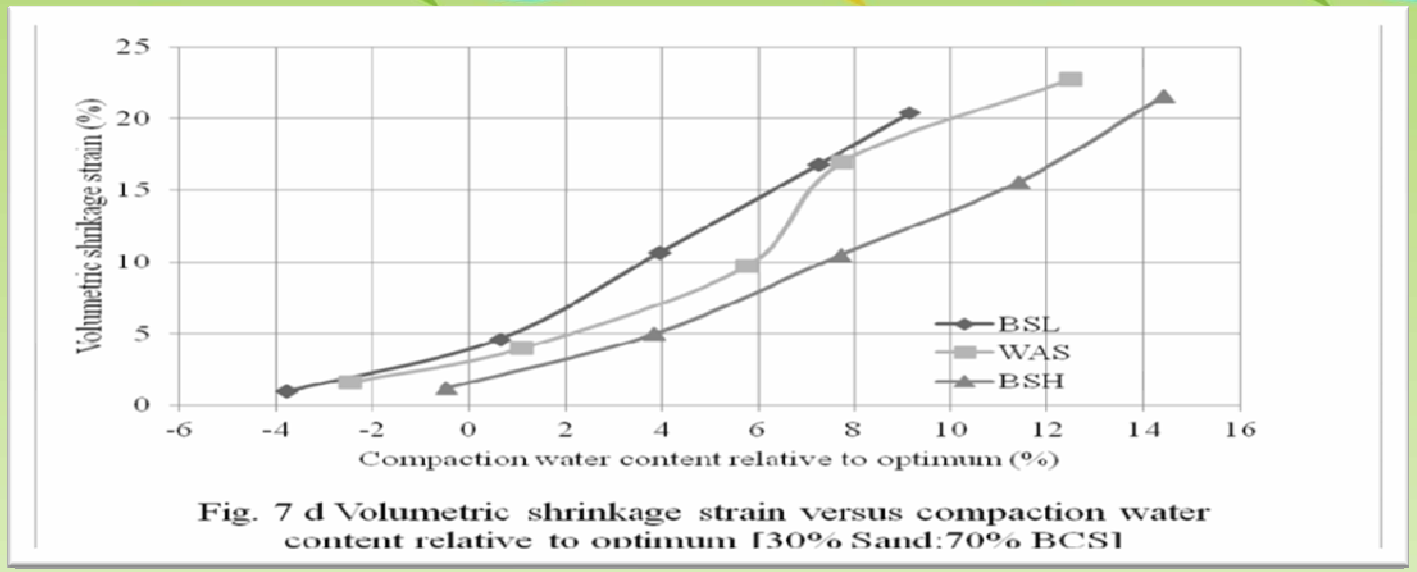

Fig. 7 d Volumetric shrinkage strain versus compaction water content relative to optimum [30% Sand:70% BCS]

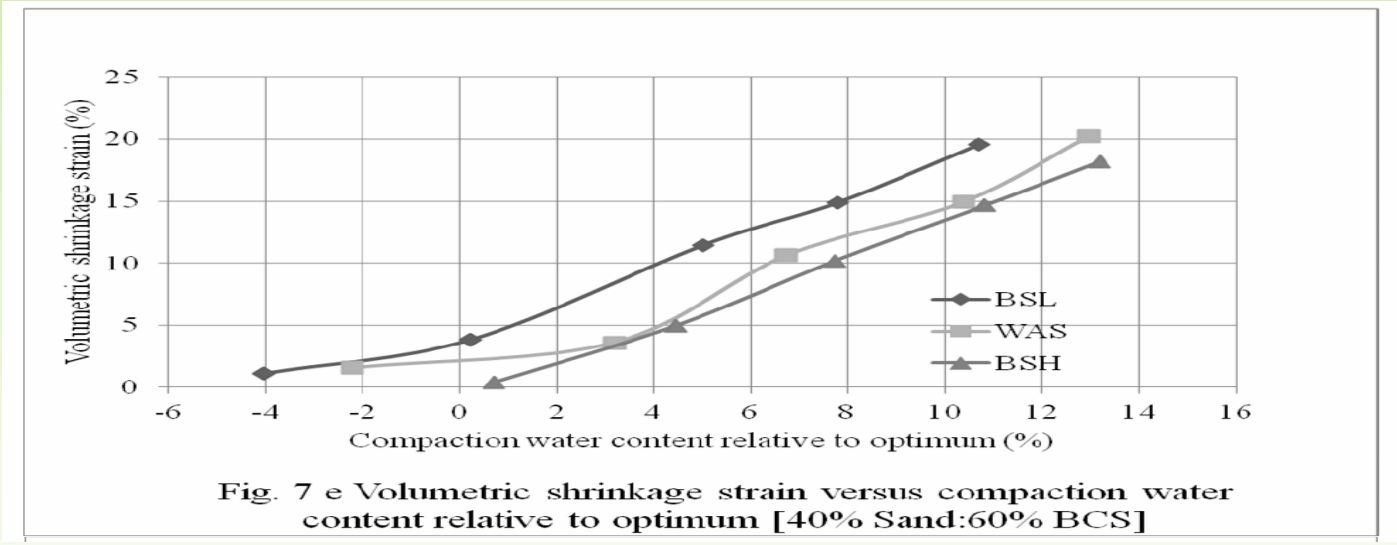

Fig. 7 e Volumetric shrinkage strain versus compaction water content relative to optimum [40% Sand:60% BCS]

4. CONCLUSION

The hydraulic conductivity at 2% points wet of optimum and volumetric shrinkage strains of sand-black cotton soil mixtures have been investigated in this study. Hydraulic conductivities obtained from three compactive efforts were less than 1×10^{-6} cm/s for all percentages of added sand. The value of 1×10^{-6} cm/s is the maximum hydraulic conductivity required for earth cores in rockfill dams. However, in tropical regions especially in the arid and semi-arid areas, shrinkage of compacted soil mixtures needs to be considered. It is possible to use soil mixtures containing 30% sand and 70% black cotton soil or 40% sand and 60% black cotton soil as earth-cores in rockfill dams as they satisfy both hydraulic conductivity and volumetric shrinkage requirements.

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