International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 3 [March. 2025] PP: 132-136

Shrinkage Behaviour of Tropical Red Soils – A Comparative Study

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Abstract
When fine grained soils lose moisture content, shrinkage happens which will adversely affect their engineering properties and performance. Red soils, of lateritic origin, being commonly available in tropical and subtropical regions, are widely used in engineering construction works. Suitability of red soils for any engineering work depends on their geotechnical characteristics, as they vary widely depending upon their origin and many other factors. Shrinkage characteristics come in to role, when the soil is exposed to alternate dry and wet weather conditions prevailing in warm humid climatic regions. When used in earthen embankments or exterior of earthen dams, the shrinkage cracks developed on outer slopes can affect the hydraulic conductivity and stability of the structure. In this study, the shrinkage characteristics of different red soils are analysed.
***Key words**: Tropical Red soils, shrinkage characteristics, clay fraction, plasticity index, optimum moisture content, maximum dry density*

I. INTRODUCTION

Soil when used as a construction material or foundation material, all the engineering properties, that define its suitability for any practical application, are related to the water content. As the name indicates, the word shrinkage means the reduction in volume, due to the change in water content. In case of soils, this happens when plastic soils are met with a loss in their water content due to a reduction in water content i.e. by drying. This variation in natural water content can be caused by natural or anthropogenic conditions. Shrinkage behaviour of soils has been a subject of interest for many researchers and much research has happened associated with soil shrinkage and its effects on the soil and associated structures. The shrinkage behaviour is unique for each type of soil. Large volumetric shrinkage will lead to differential settlement or subsidence of the soil mass, which will affect the stability of the engineering structures founded on it. The shrinkage will also lead to cracking and will destroy the integrity of the soil structure, thereby reducing the strength and bearing capacity of the soil, leading to structural instability.

Tropical red soils are believed to be the most highly weathered soils.As this soil is formed in the climate characterized by alternate wet and dry weathers i.e. the warm humid climatic condition, they are highly sensitive to moisture changes and hence are responsible for numerous geotechnical problems like slope failures upon sudden exposure to heavy rainfalls and sub-surface cracking leading to pavement failures and stability issues in earthen embankments. The plasticity characteristics of the red soils depend upon the percentage fines contained, the nature of the clay aggregates, the porosity between these clay aggregates, the intra and inter aggregate bonding etc., and their geotechnical characteristics vary to higher extent. Therefore in order to better understand the shrinkage behaviour of red soils, seven different red soils are selected for this study and their shrinkage behaviour is analysed.

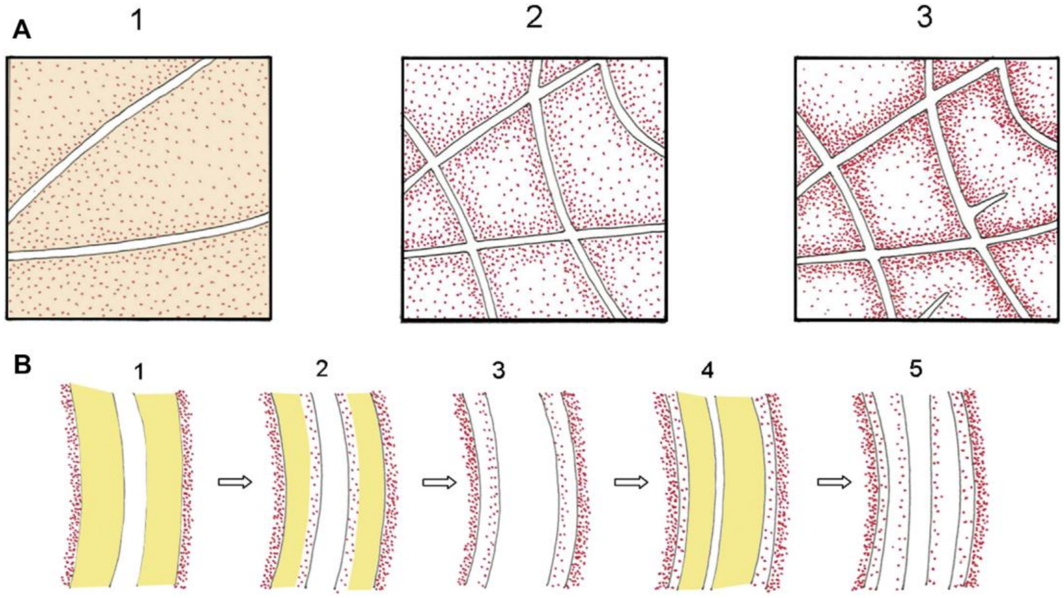

Fig 1. The formation of residual red soils due to weathering from parent rock

Red soils with higher clay content can retain a greater volume of water and thus are more susceptible to large volumetric shrinkage strains upon drying. The parent rock compositionalso defines the characteristics of red soils. The sesquioxides of iron and aluminium formed and deposited during the process of laterization, cause the physical cementation of soil aggregates and form the specific granular structure.The behaviour of soil structure during the process of shrinkage is quite complex and depends on so many factors like soil structure, composition, density, previous stress history, water content etc. When water content within the soil mass decreases, there will be a subsequent increase in suction and a reduction in volume. When soils shrink, cracks are created which act as channels for moisture migration and ultimately affects the engineering properties like hydraulic conductivity and shear strength of the soil mass. Therefore it is very important to understand the shrinkage behaviour of sols.

II. OBJECTIVES

Redsoils are encountered in many parts of the world, especially in tropical regions. The seasonal variations in rainfall and temperature cause variation in water content of the soil matrix, thereby leading to volumetric shrinkage and soil cracking. The main objectives of this study is to analyse theshrinkage behaviour of red soils. Seven different red soils are selected for this study and their shrinkage behaviour is analysed from shrinkage properties. Correlation studies were carried out between the shinkage parameters like linear shrinkage, volumetric shrinkage with other important soil properties like clay content and maximum dry density.

III. MATERIALS AND METHODS

The red soils selected for this study are serially numbered as S1, S2, S3, S4, S5, S6 and S7. The shrinkage properties were tested using the standard mercury displacement method, with prepared dry pat, as explained in IS 2720: Part 6, 1972,was used to determine the shrinkage properties like shrinkage limit, shrinkage ratio, volumetric shrinkage, and linear shrinkage etc. The shrinkage characteristics were correlated with the selected soil properties, i.e. percentage clay fraction and the maximum dry density.

IV. RESULTS AND DISCUSSION

The basic index tests were carried out on the sample and the values obtained are tabulated in Table 1 as below: The specific gravity of the selected soils ranged from 2.65 to 2.71. The plasticity index values of the selected samples ranged from 23.2 to 33.4. The percentage clay fraction varied from 29.0 to 60.1. The shrinkage limit varied from 13.1 to 18.2. The optimum moisture content obtained from Standard Proctor compactor ranged from 15.6 to 25.8 %. The value of maximum dry density ranged from 1.61 to 1.75.

Table 1: Results of the index properties test and compaction characteristics of selected samples

Property tested	S1	S2	S3	S4	S5	S6	S7
Specific Gravity	2.66	2.65	2.66	2.71	2.65	2.69	2.67
Liquid Limit	54.5	50.6	55.8	56.2	50.7	53.7	55.2
Plastic Limit	21.1	25.8	25.8	28.7	25.1	30.5	28.8
Plasticity Index (%)	33.4	24.8	30.0	27.5	25.6	23.2	26.4
Gravel(%)	Nil	Nil	Nil	Nil	16.5	Nil	Nil
Sand (%)	36.6	31.9	29.4	19.8	29.6	49.0	21.8
Silt (%)	30.5	39.1	29.5	43.0	18.7	9.6	18.1
Clay (%)	32.9	29.0	41.1	37.2	35.2	41.4	60.1
Optimum Moisture Content (%)	15.6	18.2	19.2	25.8	19.8	20.8	19.9
Maximum Dry Density (g/cc)	1.75	1.71	1.68	1.61	1.64	1.68	1.61
Shrinkage Limit (%)	16.6	18.2	15.1	16.0	17.9	14.4	13.1
Shrinkage Ratio	1.79	1.69	1.90	1.88	1.74	1.93	1.97
Linear Shrinkage (%)	12.1	11.6	14.1	12.9	12.0	14.9	18.9
Volumetric Shrinkage (%)	57.5	52.3	62.7	60.5	54.4	67.8	77.8

Correlation Analysis

The correlation analyses were carried out between the selected shrinkage characteristics like linear shrinkage and volumetric shrinkage with percentage clay fraction and maximum dry density. The graphs obtained are given below in figures respectively.

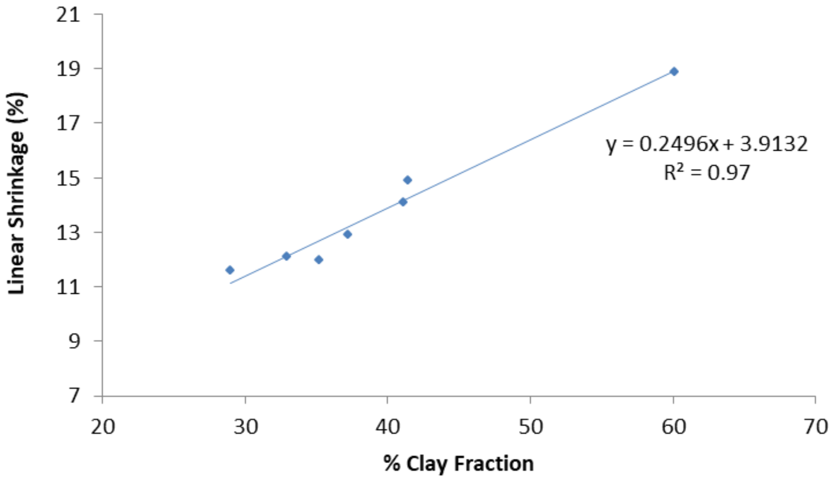

Figure 2. Variation of Linear Shrinkage with % Clay Fraction

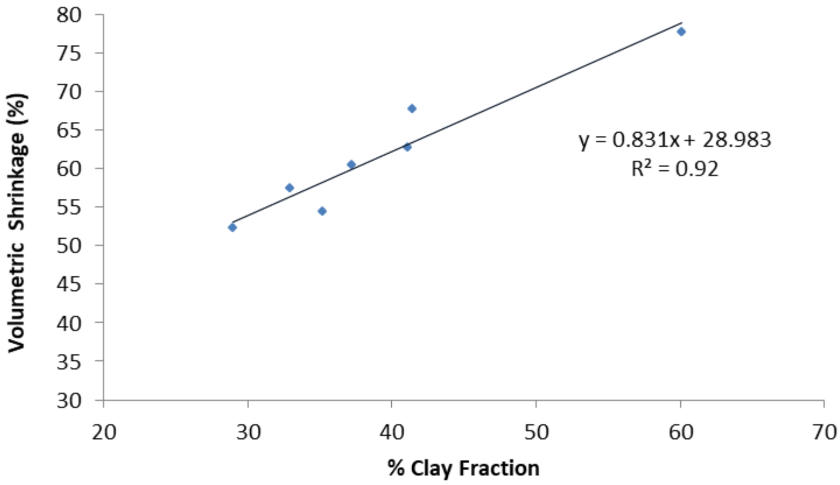

Fig 3 Variation of Volumetric Shrinkage with % Clay Fraction

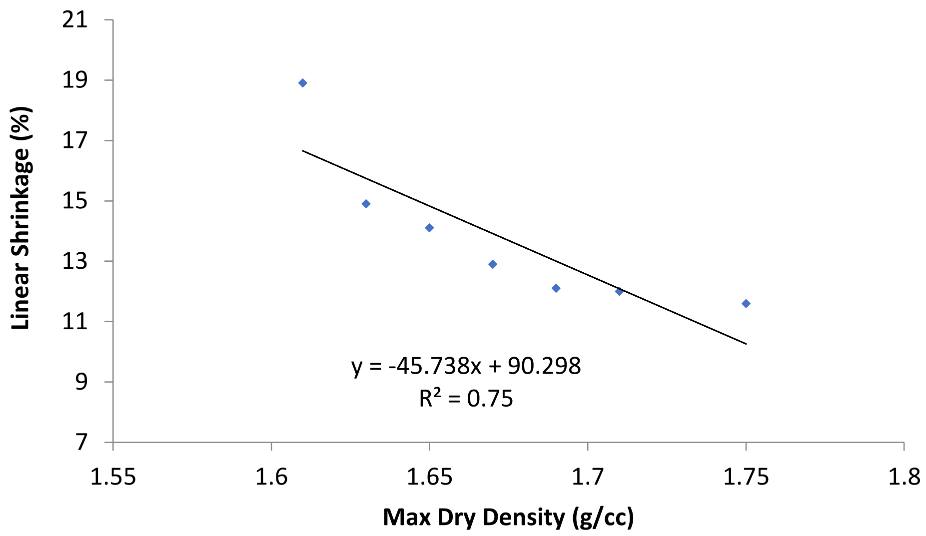

Fig 4 Variation of Linear Shrinkage with Maximum Dry Density

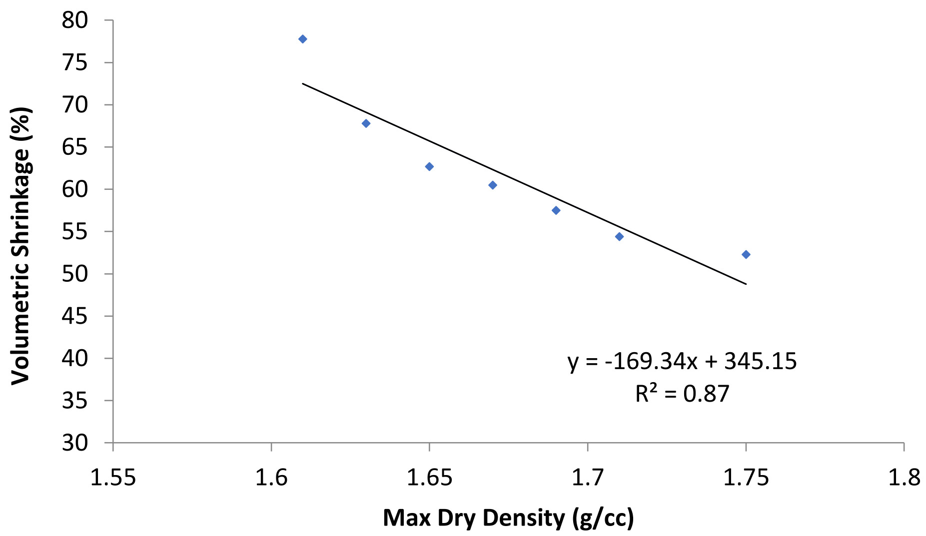

Fig 5 Variation of Volumetric Shrinkage with Mximum dry density

V. CONCLUSIONS

The knowledge of the shrinkage properties is very important and is a measure of the ability to resist the drying stresses. The following conclusions are drawn from the present study:

- Red soils with higher clay content can retain a greater volume of water and thus are more susceptible to volume changes.
- The presence of sand and silt in the soil reduces the shrinkage as they occupy the pore spaces for water.
- When there is an increase in the soil density, there is a decrease in the volume of voids, resulting in reduced volumetric shrinkage thereby reducing the chances of shrinkage cracking in the soil.
- In the correlation study the correlation obtained between the linear shrinkage and % clay fractions is 0.97 and the correlation obtained between volumetric shrinkage and % clay fractions is 0.92 respectively.
- The correlation obtained between the linear shrinkage and maximum dry density is 0.75 and the correlation obtained between volumetric shrinkage and maximum dry density is 0.87 respectively.

ACKNOWLEDGEMENT

The authors are immensely acknowledged to Dr. R. Chitra, Director, Central Soil and Materials Research Station (CSMRS), for the continuous motivational support and valuable technical guidance during this work, to make this attempt fruitful.

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