IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 22, Issue 2 Ser. I (Mar. –Apr. 2025), PP 76-82
www.iosrjournals.org

Properties of Deeply Weathered Residual Soils – A Review

Varma S[1]., Singh A[2]., Gupta M[3]., R. Chitra[4]

[1]Corresponding Author and Scientist 'D', Central Soil and Materials Research Station, Ministry of Jal Shakti, DoWR, RD & GR, Government of India, Olof Palme Marg, Hauz KHas, New Delhi-110016.
[2,3] Scientist 'E', [4] Director,
Central Soil and Materials Research Station, Ministry of Jal Shakti, DoWR, RD & GR, Government of India, Olof Palme Marg, Hauz Khas, New Delhi-110016.

Abstract
Unlike transported soils, residual soils originate from the in-situ weathering and decomposition of the parent rock. They are formed in-situ. The typical tropical climatic conditions provide adequate moisture and temperature conditions to transform the underlying rocks in to residual soils, faster than they can be removed by any other transporting element. As the residual soils cover a major portion of the world geography, we have to encounter with this soil in many of the engineering construction works, either in the form of foundation material or as the fill material. The main difficulty in dealing with these soils is that their characteristics are quite unpredictable. The properties of such soils are highly variant in nature and depend on various factors such as the properties of the parent rock material, climate, rainfall, topography, age of the deposits, vegetation etc. For a geotechnical engineer, to ensure the safety and quality of the material used, the knowledge about the basic properties and behaviour of such soils under different practical situations is essential. This review study is carried out to better understand the geotechnical characteristics and behaviour of residual soils.

Key Words:** **Residual Soils, Index Properties, Permeability, Compressibility, Shear Strength

I. INTRODUCTION

A residual soil is derived from the in-situ weathering and decomposition of rock, that has not been transported from its place of origin. Most of the residual soils are derived from metamorphic and igneous rocks. Based on their origin, they can be of two types, laterites and saprolites. Sandstones and granites are the most common rocks subjected to laterization, forming lateritic soils of red or yellow colour with high contents of iron. Their formation is controlled by so many factors. The optimum conditions required for the formation of laterites include: high seasonal rainfall and high temperature causing intense chemical weathering and subsequent severe leaching, strong acidic and oxidising environment, sustained long duration weathering, a chemically unstable parent rock, good internal drainage and continuous supply of freshly formed sesquioxides of iron either from the underlying parent material or from an adjacent area of similar petrological environment. Whereas the saprolites are weak, friable, chemically weathered materials, having decreased strength of the original material. They are mainly formed from sedimentary, igneous and metamorphic rocks. Saprolites are also rich in iron and aluminium, but less in silica, compared to lateritic soils. Chemical processes tend to predominate in the weathering of igneous rocks whereas physical processes dominate the weathering of sedimentary and metamorphic rocks. For a deep residual soil profile to develop, the rate at which weathering advances in to the earth's crust must exceed the rate of removal of the products of weathering by erosion.

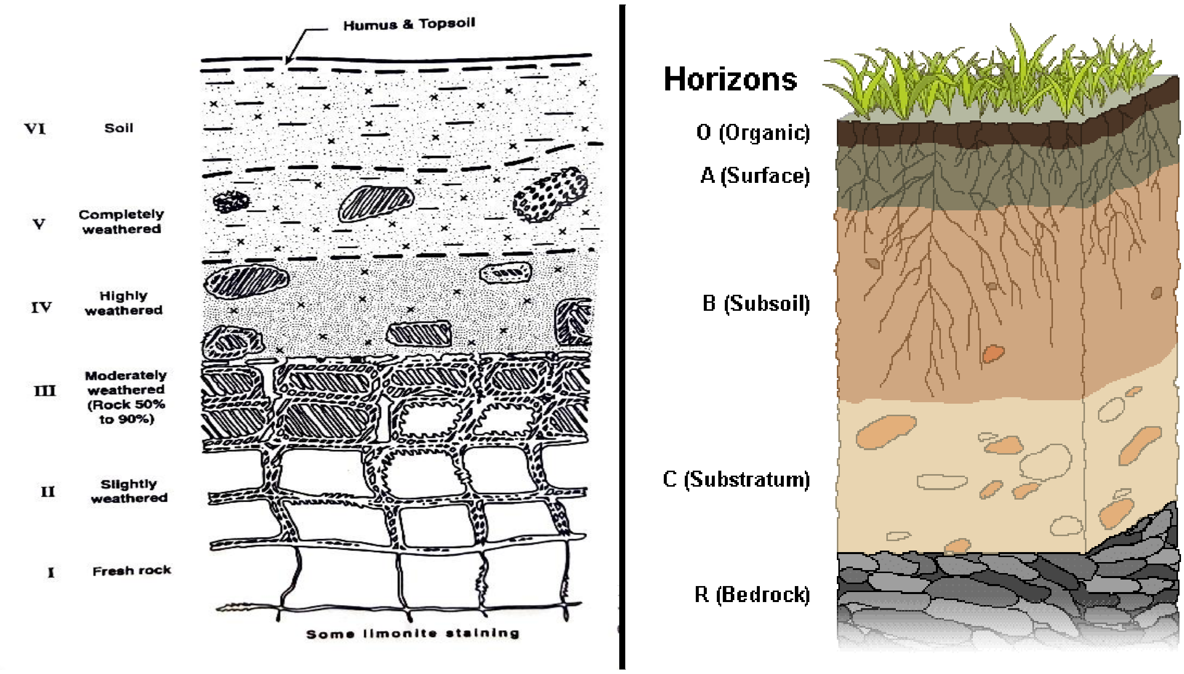

Fig 1 The Residual Soil Profile

Mineralogy is mainly responsible for the wide range of engineering properties of residual soils. The most common type of clay mineral present in lateritic soil is kaolinite. Particles of kaolinite is larger in size and less active. But smectites are found very rarely. Montmorillonite are also found less. Minerals like halloysites and allophane are also present, because of which some irreversible changes occur in such soils when dried or dessicated. But saprolites are materials that have soil-like strength and consistency, but retain modifies features of the parent rock. Hence it is very important to take care of the water content, while testing of these samples in laboratory. The widely varying complex mineral composition and the extreme climatic conditions of their native tropical regions (i.e. alternate heavy rainfall and hot conditions) make the situation quite challenging for the geotechnical engineers to arrive at the exact engineering behaviour of such soils under the working environment. Hence to find out their suitability as quality assured construction materials, it is imperative to do the testing of such soils to know the engineering behaviour of the same prior to its usage at site, the lack of which may affect the durability of the structure.

INDEX PROPERTIES OF RESIDUAL SOILS

Natural Moisture Content, Specific Gravity, In-situ Density, Plasticity characteristics and Particle Size Distribution and Compaction Characteristics:

The properties of the residual soils are affected by a change in water content. Most of the residual soils have water content varying from 25% to 40%. To remove any structural water present, air drying of the samples is carried out before its testing in the laboratory. For some residual soils, the natural moisture contents are generally high, being far above the plastic limit and in many cases it can be even above the liquid limit, but at the same time remaining in their natural undisturbed state exhibiting the solid characteristics externally, rather than of a plastic or liquid mass.

Specific gravity is controlled by the mineralogical properties. In residual soils, the specific gravity can be unusually high or low. Hence there occurs a wide range of values ranging from 2.6 to 3.6, as available from literature studies. It is essential that specific gravity has to be determined accurately in the laboratory using an accepted standard test procedure, at its natural moisture content. A greater degree of ferruginization produces a higher specific gravity soil. Also the larger the clay fraction and alumina concentration, the lower will be the specific gravity. The high specific gravity value is attributed to its high iron content. It is also observed that the iron content increases with age of formation and hence the specific gravity of residual soils also increases with age of the deposit and with degree of weathering.

The in-situ dry density of residual soils is highly variant having pretty good values, ranging from 2082 to 2563 kg/m^3 for homogeneous lateritic rocks, to as low as 320 to 961 kg/ m^3 for the volcanic red lateritic clays. As a result of leaching of materials, these soils will usually have a porous structure, which can trap air and water in their voids between the porous micro aggregations. When depth increases, the void ratio decreases, reflecting the degree of weathering. Topmost layers will have more void ratio and lesser density. As depth increases, the porosity and void ratio decreases and hence the density increases. The void ratio ranges from 0.3 to 0.7 for dense soils, 0.7 to 1.1 for medium soils and 1.1 to 1.5 for low dense soils.

Residual Soils have a good representation of both cohesive and cohesionless portions of particle sizes. Sieve analysis method can be used for cohesionless part and pipette analysis using alkaline sodium hexametaphosphate as dispersing agent can be used for finer fractions. Well graded type of soils exhibit better engineering properties.

Plasticity is an important index property of the fine grained soils, which is the ability of a soil to undergo deformation without cracking or fracturing. Liquid limit of some of the residual lateritic soils is above 50%. According to the plasticity chart, lateritic soils can fall above or below A-Line. Most of the fine grained lateritic soils fall in CH, MH or OH category. Gidigasu (1976) pointed out that the lateritic soils which fall below the A-line category needs to be well taken care of regarding their engineering properties when the soils are used for any construction purposes. The greater the plastic limit, the greater will be the compressibility and volume change, when the soil comes in contact with water.

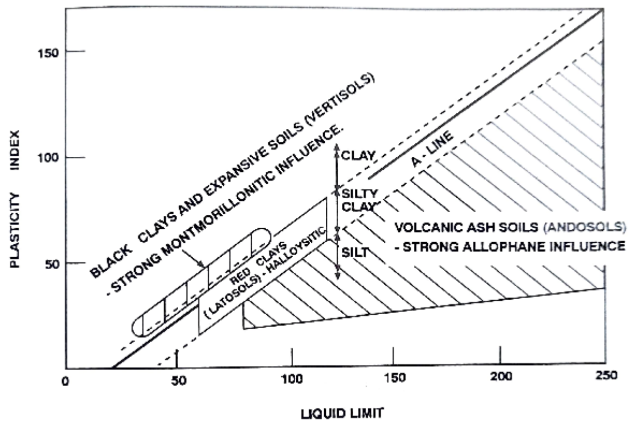

Fig 2 Plasticity Chart for Residual Soils

Compaction results in progressive break down of particles in a residual soil. The residual soils of volcanic and igneous origin often have high in-situ moisture content, meta stable clay minerals, lightly cemented soil structure, sesquioxide minerals and weathered soil particles that break down under compactive efforts. Figure illustrates compaction curves for a wide range of residual soils subjected to same method of compaction and compactive efforts.

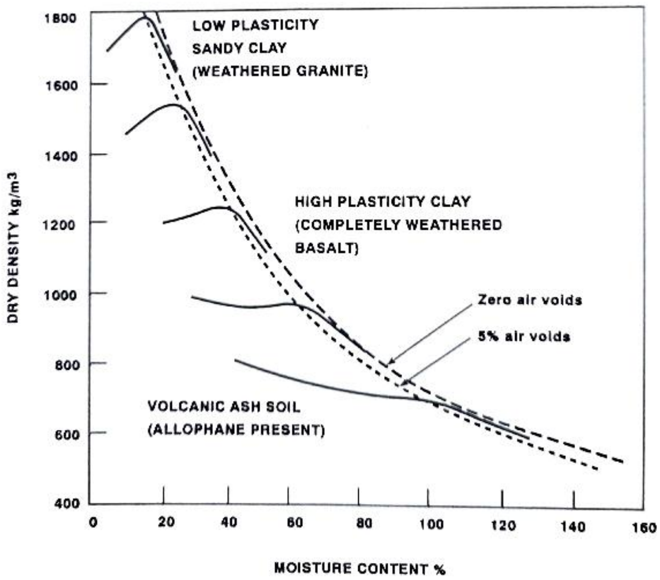

Fig 3 Compaction Curves for Residual Soils

The traits that can be observed from the compaction curves are : High strength and void content in the dry of optimum region and rapid reduction in strength in the wet of optimum region where the curve follows a line of minimum air voids. In-situ strength is often an inevitable compaction control parameter for residual soils.

The choice of compaction equipment can be made with a view to minimize earthwork costs while achieving the desired engineering properties for the compacted residual soil.

ENGINEERING PROPERTIES OF RESIDUAL SOILS:

Permeability Characteristics

The variation in the micro fabric of the weathering profile of the residual soils give rise to large variations in permeability both laterally and with depth. As the degree of weathering increases while moving down the profile, the value of coefficient of permeability decreases, due to the presence of cemented aggregates subsequent to the fines filling up the voids, leaving the soil mass less permeable for water flow. Hence it can be stated that the value of coefficient of permeability decreases when the depth increases.

The methods used to determine the permeability of residual soils in practice include both field and laboratory permeability tests, i.e. the constant head and variable head permeability tests, permeability tests infield are carried out in auger holes, bore holes and test pits. The permeability of saprolitic soils is controlled to a large extent by the relict structure of the material. Most of the flow happens along relict joints, quartz veins, termite and other biochannels. The average permeability value obtained in field permeability test of residual soils varied from 59 x 10^{-6} cm/s to 81x10^{-6} cm/s whereas the laboratory permeability value of residual soils varied from 37 x 10^{-6} cm/s to 93 x 10^{-6} cm/s.

Table 1: Relative Permeability of Residual Soils in Igneous and Metamorphic Rocks (after Deeri and Patton, 1971)

Type of residual soil/zone	Relative Permeability
Organic top soils	Medium to high
Matured residual soils	Generally medium to high in lateritic soils
Young residual soils	Medium
Saprolites	High
Weathered rock	Medium to high
Sound rock	Low to medium

Compressibility

To assess the compressibility of residual soils, a number of direct and indirect methods can be used. In-situ methods include standard penetration test, pressure meter test and plate load test. The laboratory test methods include odeometer and triaxial compression tests. All residual soils behave as if they are over consolidated and hence their compressibility is relatively low at low stress levels. But once the preconsolidation yield stress is exceeded, the compressibility increases. The compressibility of compacted lateritic soils is generally in ‘medium to low’ range and the settlement is within the elastic zone. When lateritic soil sample was tested for the compressibility characteristics, it was observed that the values of both compression index and total settlement were obtained much smaller than that for pure kaolinitic clay sample, indicating that the compressibility of lateritic kaolinite soils is much lesser than pure kaolinite. This property is attributed to the presence of the sesquioxide compounds that coat the normal scale - shaped planar kaolinitic structure, which restricts their easy bending and sliding under compressive forces. The settlement value remained same for both the standard duration test and the extra duration test, clearly indicating that these sesquioxide bonds that bind and cover the particles are not affected by soaking for a longer time, under laboratory conditions.

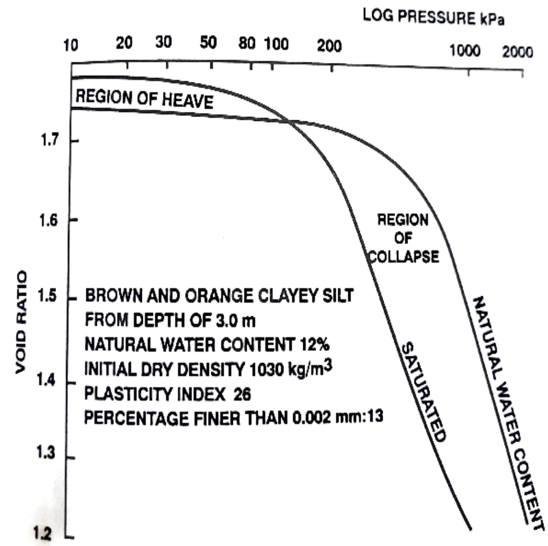

Figure 4 The Compressibility Characteristics of Residual Soils

Collapse of residual soils occur, under fully saturated conditions at high applied pressure which are compacted at dry of optimum. This is attributed to the probable loss of suction. When residual soils are compacted at dry of optimum, they deform gradually under the applied vertical pressure to some extent, till a critical pressure is reached, beyond which there occurs a rapid deformation or collapse. Although the collapse cannot be predicted on the basis of effective stress conditions, the collapsing soils behave as effective stress controlled materials both before and after the collapse take place. Depending upon the water content of the soil, the collapse may take place progressively. The amount of the collapse settlement depends on the initial void ratio of the soil and the applied stresses.. Under light foundation loads of 100 to 300 kPa, collapse settlements up to 10% to 15% of the profile depth can happen.

Shear Strength

Residual soils have a particular fabric, grain structure and particle gradation, which makes them essentially different from the transported soils. One of the main characteristics of a residual soil is the existence of bonds between particles, which represent a component of strength and stiffness that is independent of the effective stress, void ratio or density. This bonding is attributed to the cementation of particles through deposition of organic material or carbonates or hydroxides. This bonding can become stronger over time due to further chemical alterations of minerals. Within a profile, the shear strength characteristics vary considerably with the depth of the water table, nature of parent rock, topography, degree of decomposition etc.

As the lateritic soils are mainly kaolinitic in composition, they have got enough effective cohesion intercept that hold the particles together and adds up strength to the shear forces. The cementation process which is taking place among the individual soil grains by the binding action of sesquioxides, imparts more resistance additionally. It imparts good inter particle friction also. Hence l ateritic soils have relatively high to very high cohesion and internal friction angle. Well graded residual soils have good interlocking properties at the macro and micro level. With the increase in the number of wet and dry cycles, the shear strength is observed to increase. This happens because, with the increase in wetting and drying, the cementation and aggregation increases which again increases this intrinsic effective stress.

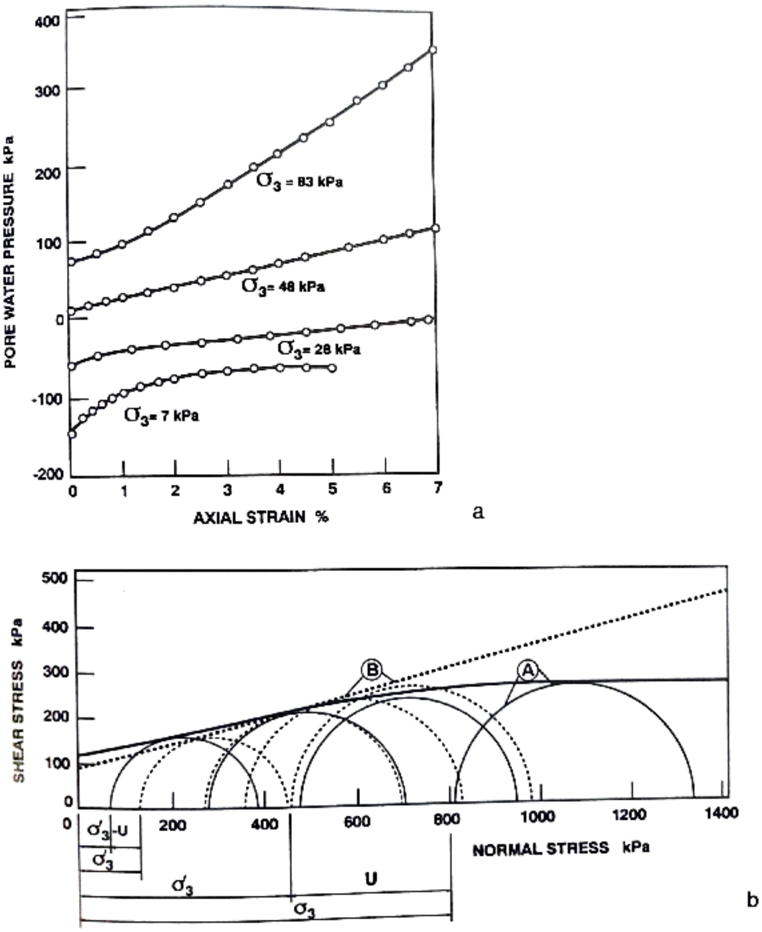

Fig 5 Shear Strength Properties for Residual Soils

II. CONCLUSION

The Residual soils have characteristics different from transported soils. The properties of different residual soils itself are highly variant in nature and depend on various factors. In this review study, the behavior and geotechnical characteristics of residual soils are analysed from available literature and inferences are abridged for better understanding of the practicing engineers.

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.

REFERENCES

[1]. Patel, H., Patel, P. and Patel, J. [2012] “Review of solar distillation methods” International Journal of Advanced Engineering Research and Studies, Vol. II, Issue I: pp.157–161.

[2]. Aginam, C. H. et.al. (2015), "Geotechnical Properties of Lateritic Soils from Anambra Central Zone, Nigeria", International Journal of Soft Computing and Engineering, Vol. 4, No. 6, pp:1-6

[3]. Aginam, C. H. et.al. (2014), "Geotechnical Properties of Lateritic Soils Northern Zone of Anambra State, Nigeria" published at International Journal of Engineering Research and Development, vol. 10, no. 12, pp:23-29

[4]. Alhassan M. et.al. (2014), “Influence of Clay Mineralogy on Plasticity of Lateritic Soils”, IOSR Journal of Mechanical and Civil Engineering, Vol. 11, No. 3, pp: 18-21

[5]. Amadi A.N. et.al. (2015), “Assessment of the Geotechnical Properties of Lateritic Soils in Minna, North Central Nigeria for Road design and Construction”, American Journal of Mining and Metallurgy, 2015, Vol. 3, No. 1, pp: 15-20

[6]. Blight G.E. (1997), "Mechanics of Residual Soils", Prepared by Technical Committee 25 for the International Society for Soil Mechanics and Foundation Engineering, Balkema Publications, Rotterdam.

[7]. Elarabi H. et.al. (2013), "Some Geological and Geotechnical Properties of Lateritic Soils from Muglad Basin Located in the South-Western Part of Sudan", Research Journal of Environmental and Earth Sciences Vol.5, No. 6, pp: 291-294

[8]. Ghosh S. and Guchhait S, K. (2015),"Characterization and Evolution of Laterites in West Bengal: Implication on the Geology of Northwest Bengal Basin", Transactions, Vol. 37, No.1, pp.94-119

[9]. Gidigasu, M.D. (1976), "Laterite Soil Engineering-Pedogenesis and Engineering Principles", Elsevier, Amsterdam, Netherlands

[10]. Hegde R.A., and Daware S.N. (2010), "Effect of Alternate Wetting and Drying on Laterite and Their Engineering Behaviour", Proceedings of the Indian Geotechnical Conference, at IIT Mumbai, December 16–18, 2010, pp: 321-324

[11]. Krishnaji, V.S. (2014), "Study of Laterites around Talmod, Maharashtra state, India", International Science Journal, Vol.1, No.2, pp: 10-14

[12]. Morin W.J. and Todor P.C. (1974), "Laterites and Lateritic Soils and Other Problem Soils of the Tropics", Instruction Manual, Vol.2, Highway Design Study for United States Agency.

[13]. Nogami, J.S. and Villibor D.F., (1991) " Use of Lateritic Fine-Grained Soils in Road Pavement Base Courses", Geotechnical and Geological Engineering, Vol.9, No.6, pp: 167-182

[14]. Sherman, G.D. (1949), "Factors Influencing the Development of Lateritic and Laterite Soils in Hawaiian Islands", Pacific Science, Vol.3, No.8, pp: 307-314

[15]. Tuncer, E. R. (1976), "Engineering Behaviour and Classification of Lateritic Soils in Relation to Soil Genesis", Thesis Report, Iowa State University Retrospective Theses and Dissertations