A Review on Clay and its Engineering Significance

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Abstract- The clay are among the world's most important soil and always a challenge for civil and geotechnical engineers. The clay minerals are important in construction where they are major constituents in brick and tiles. However, any structure constructed on clayey soil is a troublesome. It is essential to known the clay soil and its significance related to engineering applications. This paper gives a clear idea about clay minerals and their significance.

Index Terms- Clay, Clay Mineral, Shrinkage. Swell, Plasticity

I. INTRODUCTION

Expansive soils are fine grained soil or decomposed rocks that show huge volume change when exposed to the fluctuations of moisture content. They are commonly found in many arid and semiarid areas in the world such as Australia, Canada, China, India, Israel, South Africa and the United States [1]. Expansive soils generally called Black Cotton soil covers nearly twenty percent in India [2]. Many towns, cities, transport routes and buildings are founded on clay rich soils and rocks. The clays within these materials may be a significant hazard to engineering construction due to their ability to shrink or swell with change in water content [3]. When expansive soil become wet and expand, the resulting expanding pressure can cause uplift against concrete slabs and foundation footings, causing a wide variety of damages to buildings and surrounding areas. These damages may occur slowly overtime and may affect individual houses, buildings or units in a neighborhood at different times. The main objective of this paper is to critically analyze and review the definition of clay, clay minerals and their importance in civil engineering.

II. REVIEW OF LITERATURE

2.1 Clays: The term clays was assigned early to fine grained material in geological formations by Agricola in 1956 or soils by De Serres in 1600 [4] [5]. The clay is a universal material therefore it cannot be limited to one particular definition.

2.1.1 Dictionary definitions of Clay: Clay is a very fine grained soil of colloidal size consisting mainly of hydrated silicate of aluminium. It is a plastic cohesive soil which shrinks on drying, expands on wetting and when compressed gives up water. Clays are described for engineering properties by their consistency limits [6]

Clay is a fine textured, sedimentary or residual deposit. It consists of hydrated silicate of aluminium mixed with various impurities. Clay for use in the manufacture of pottery and bricks must be fine grained and sufficiently plastic to be moulded when wet, it must retain its shape when dried and sinter together forming a hard coherent mass without losing its original shape, when heated to a sufficient temperature [7].

Clay is thick, heavy soil that is soft when wet, and hard when dry or baked, used for making bricks and containers [8].

Clay is very fine-grained material that consists of hydrated aluminum silicate, quartz, and organic fragments and occurs as sedimentary rocks, soils, and other deposits. It becomes plastic when moist but hardens on heating and is used in the manufacture of bricks, cement, ceramics, etc [9].

2.1.2. Definition of Clay in various disciplines: The definition of clay in different disciplines is as follows,
Geologists consider clay as a geologic product of generalized occurrence and of fine granularity that occurs at the surface or near the surface of the Earth, and that is formed at the interfaces between the earth crust and the atmosphere, hydrosphere, and biosphere as the result of the mechanical and/or chemical alteration of rocks [10] [11].
Mineralogists consider clay as an aggregate or mixture of minerals of fine granularity, consisting principally of clay minerals, which are hydrous phyllosilicates based on Si, O, OH, H_2O, and that elements such as Al, Mg, Fe, K, Ca and Mg can participate on their composition [10] [11].

Civil and geotechnical engineers consider clay as the less than 4 μm fraction of the soil and classify clays or clayey soils as swelling or non swelling, soft or hard, that is selecting the most relevant properties that should be taken into account when the foundation of housing and public construction works is based on them [10] [11].

Based on particle size, the clay size is defined differently in different disciplines. In geology, the clay grade as material finer than about 4 microns in Wentworth scale [12]. In soil investigations, the tendency is to use 2 microns as the upper limit of the clay size grade as specified by Atterberg [13].

2.2.Clay Minerals: Research on clay minerals started in 1930s; the clay materials are basically composed of tiny crystalline substances of one or more members of a small group of minerals commonly known as clay minerals. Chemically, these minerals are hydrous alumina-silicate with other metallic ions. Their particles are very small in size, very flaky in shape and thus have considerable surface area. They can only be viewed with an electronic microscope. Clay minerals are formed from two basic structural units: tetrahedral and octahedral. On the basis of their crystalline arrangements, clay minerals are divided into three types namely, Kaolinites, Montmorillonite and Illite the properties of all three minerals are presented in Table I [14][15] [16][17][18].

Table I : Some Properties of Clay Minerals

Kaolinites	Montmorillonite	Illite
1:1 Layer	2:1 Layer	2:1 Layer
Hexagonal Flakes	Thin Flakes	Elongate
Low Base Exchange Capacity	High Base Exchange Capacity	Moderate Base Exchange Capacity
Minimal Layer Charge	High Layer Charge	Moderate Layer Charge
Low Surface Area	Very High Surface Area	High Surface Area
Largest Grain Size	Smallest Grain Size	Intermediate Grain Size
Lowest Dry Strength	Highest Dry Strength	Intermediate Dry Strength
Lowest Swelling and Shrinkage Behaviour	Largest Swelling and Shrinkage Behaviour	Intermediate Swelling and Shrinkage Behaviour

2.3 Engineering Significance of Clayey Soils: Clayey soils are common in certain regions of the country including our area (Coimbatore). Clayey soil cause damage to the structure founded in them because of their potential to react to change in moisture regime [19]. The uplift pressure due to change in volume of clay leads to foundation failure, resulting in damage to the upper floors of a building. On the other hand, clay also shrinks where they dry out, causing settlement of building. The shrinkage and swelling of clay puts repeated stress on concrete foundation. The volume change experienced by clay can cause serious damage to concrete foundation and floor slabs as well as the rooms above them. Therefore it is essential to identify the characteristics of clayey soil before any construction activities carried out. Many criteria are available, to identify and characterize expansive soils. The soil classification suggested by Chen [20], Holtz and Gibbs [21], Seed et al [22] and IS 1498 [23] are presented in Table II, Table III and Table IV.

Table II : Soil classification based on Liquid Limit

Degree of Expansion	Liquid Limit (W_L) in %	
	Chen [20]	IS 1498 [23]
Low	<30	20-35
Medium	30-40	35-50
High	40-60	50-70
Very High	>60	70-90

Table III : Soil classification based on Plasticity Index

Degree of Expansion	Plasticity Index (I_P) in %		
	Chen [20]	IS 1498 [23]	Holtz and Gibbs [21]
Low	0 – 15	<12	<12
Medium	10 – 35	12-23	12 – 34
High	20 – 55	23-32	34 – 45
Very High	>35	>32	>45

Table IV : Soil classification by other measures

Degree of Expansion	Shrinkage Limit [21]	Shrinkage Index [23]	Free Swell Index [23]	Percent expansion in Oedometer	
				[21]	[22]
Low	>18	<15	<50	<10	0-1.5
Medium	8-18	15-30	50-100	10-20	1.5-5
High	6-12	30-60	100-200	20-30	5-25
Very High	<10	>60	>200	>30	>25

III. SUMMARY AND CONCLUSION

The term " Clay Mineral" refers to phyllosilicate minerals and to minerals which impart plasticity to clay and which harden upon drying or firing as per the Nomenclature Committees of AIPEA. The behaviour of soil as a foundation material is affected both by the total amount of water and by the energy with which it is retained. Consistency, strength and density parameters are affected by water content and volume change characteristics and moisture content movements are due to engineering considerations. To overcome problems caused by moisture content and its movements, footings and foundations may be placed below the level affected by seasonal fluctuations of water content. Further, the soil affected may be replaced by a fill, soil stabilization procedures may be adopted or stiffened slabs or raft foundation may be used. Economics is a major concern in determining which option can be adopted. Hence, the clayey soils are termed as Expansive soils.

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