



Role and Effect of Geotechnical Properties in Pavement Design

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Abstract: *This essay discusses several soil geotechnical characteristics and how they affect pavement design. The kind of soil is determined by the type of rock, the minerals that make up that rock, and the local climate [1]. The strength of the subgrade soil that will support the pavement is a major factor in its design. Subgrade strength is also influenced by the fundamental characteristics of the soil [2]. Hence Because they affect the stability of the pavement, geotechnical properties of the soil are crucial for pavement design. This essay discusses a number of geotechnical characteristics of soil, including specific gravity, density index, consistency limit, particle size analysis, compaction, consolidation permeability, and shear strength.*

Key Words: geotechnical properties, Pavement design, Sub grade strength

1. INTRODUCTION

According to Woods and Adcox (2006), a pavement section is commonly thought of as the structural material positioned above the sub-grade layer. The three distinct layers of surface, base, and sub-base are represented by a particular pavement's structure, whilst the geotechnical features of the soil bed upon which the complete pavement system is supported are represented by a particular pavement (Mcgee, 2010). , It is usually required to have knowledge of its qualities in order to properly assess the soil's viability as a foundation and as building material. [3]. Local soil is not only the cheapest but also the most adaptable road material for building and maintaining country roads for low traffic volumes. Structures must be designed with knowledge of surface and subsurface elements, also, for organizing building methods [1] The geotechnical challenges in pavement design may be divided into two groups: (1) general issues that determine the design's overall direction, such as whether to use a new or rehabilitation design, and (2) particular technical concerns, such as determining the stiffness and strength of the subgrade.[6]. Based on its engineering, soil should be evaluated for appropriateness for a certain usage. One of the main contributors to traffic accidents is poor pavement, which is typically brought on by construction companies using the inappropriate building materials, particularly laterite as a foundation and sub-base material [4].

rather than on surface appearance or apparent resemblance to other soils. The crucial elements that aid an engineer in understanding the plasticity or consistency of clay are the plasticity index and liquid limit. Although shearing strength changes for all clays at plastic limits, it remains constant at liquid limits [9]. Because it is one of the crucial parameters for analyzing and resolving stability issues (calculating earth pressure, the bearing capacity of footings and foundations, slope stability, or stability of embankments and earth dams), shear strength of soils is particularly relevant among geotechnical soil properties [8]. The kind of soil determines how much weight it can support. In general, fine-grained soils are less capable of supporting a load than coarse-grained soils [7]. In this study, interactions between various geotechnical features and their effects on have been addressed.

GEOTECHNICAL PROPERTIES OF SOIL

Specific gravity of soil- The ratio of the mass of soil solids to the quantity of water in an equivalent volume is known as specific gravity. According to their investigation, Roy and Dass [14] discovered that a rise in specific gravity can result in an increase in the shear strength indicators (cohesion and angle of shearing resistance). It is helpful in classifying soil minerals and is somewhat significant in terms of the qualitative behaviour of the soil. For instance, iron minerals have a higher specific gravity than silica minerals [11]. At a 1% level of significance, correlations are statistically significant and show that particular gravity affects CBR. It provides insight into the viability of the soil as a building material; greater specific gravity results in stronger roads and foundations. He also noted that the strength of the subgrade materials utilised in road building increased along with a rise in specific gravity, or California bearing ratio. Roy [10]

Table -1: Typical values of specific gravity (Bowles, 2012)

Sr.No	Type of soil	Specific gravity
01	Sand	2.65-2.67
02	Silty sand	2.67-2.70

03	Inorganic clay	2.70-2.80
04	Soil with mica or iron	2.75-3.00
05	Organic soil	1.00-2.60

Density Index - The density index, which is represented in percent, is calculated as the ratio of the difference between the void ratio of cohesion-less soil in the loosest state and any specific void ratio to the difference between its void ratios in the loosest and the densest states. [12]. Fine-grained soil compaction is measured in proportion to the maximal dry density for a certain compaction effort, such as 90% of light compaction density or proctor density. For coarse-grained soils, however, a different type of index is utilised to measure compaction. The two extreme states of compaction for coarse-grained soils, namely the loosest and densest states, might persist depending on the size, shape, and gradation of the soil grains. With the use of a measure known as relative density, or density index[1], any intermediate condition of compaction may be contrasted to these two extreme states. Relative density of a sandy deposit is arbitrary, according to Apparao and Rao [13]. It really reflects the ratio of the volume of voids that have actually decreased in a sandy soil to the volume of voids that have decreased to their lowest conceivable level, or how much more densification the sand under study is capable of undergoing than its current condition. In measuring the safe bearing capacity of sandy soils and compacting coarse-grained soils, its results are useful.

Table 2. Characteristics of soils based on relative density

Relative density (%)	Soil compactness	Angle of shearing resistance (0)
0-15	Very loose	<28
15-35	Loose	28-30
35-65	Medium	30-36
65-85	Dense	36-41
85-100	Very dense	>41

Consistency limit The water content corresponding to transition from one state to next are known as liquid limit, the plastic limit and the shrinkage limit [19]. Large numbers of studies were done by the previous researchers to find out different physical and

engineering behavior of different soils. According to an assessment of the physical and engineering characteristics of several soils by Nath and Dalal (2004), when the liquid limit rises, the soil's flexibility index rises and the frictional angle falls [3].

Earth roads are easily used at a plastic limit water content, and excavation work is also simply accomplished. The soil is considered to be in the plastic range when the water content is between the liquid limit and the plastic limit. Table 3 (Atterberg's classification of the soil) demonstrates the relationships between the plasticity index, soil type, degree of plasticity, and degree of cohesiveness.[16]

The water content of a soil during the transition between the liquid and plastic stages of consistency is referred to as the liquid limit and is stated as a percentage of the weight of oven-dried soil [22]. The shear strength of the soil is quite low. The term "plastic limit" refers to the water content as a percentage of the weight of oven-dried soil during the transition between semi-solid and plastic soil consistency stages.

Table3. Types of soils based on plasticity index

Plasticity Index (%)	Soil type	Degree of plasticity	Degree of cohesiveness
0	Sand	Non-plastic	Non-cohesive
< 7	Silt	Low plastic	Partly cohesive
7-17	Silt clay	Medium plastic	Cohesive
>17	Clay	High plastic	cohesive

For the preparation of very fine clayey soils, consistency is a crucial and practical measurement. The cohesiveness and workability of the soils are reflected in their plasticity. The construction of the clay core in an earth fill dam, the creation of a layer of low permeability covering a deposit of polluted material, the design of foundations, retaining walls, and slab bridges, as well as determining the stability of the soil on a slope all depend on these soil properties.

The soil mass was initially created from remoulded soil, and the shrinkage limit is the highest water content, given as a percentage of oven-dried weight, at which any further drop in water content would not result in a decrease in the volume of the soil mass [15]. More shrinking is seen in the soil's finer soil particles. In soil containing the clay mineral montmorillonite, more shrinkage is seen.

Particle size analysis- Particle size analysis: Sieve analysis is used to quantify the proportion of soil particles of various sizes larger than 75, whereas hydrometer analysis is used to quantify those less than 75. Based on the particle size study, distribution curves for particle sizes are plotted. It is possible to determine if a soil is well-graded or poorly-graded, hence the concept of the gradation of the soil is gained.

According to Apparao and Rao [13], the examination of grain size is frequently used to categorize soils. The information on grain size distribution curves is used to plan filters for earth dams and assess the quality of soil for building roads and airfields. Particle-size is one of the suitability parameters for soils for highways, airfields, levees, and other structures.

Particle-size has been identified by Bowles [11] as one of the soil suitability requirements for the construction of highways, airfields, levees, dams, and other embankments. Unless they are suitably enclosed by a filter consisting of appropriately graded granular materials, very fine soil particles are easily transported in suspension by percolating soil water, and drainage systems are quickly clogged with sediments. The appropriate gradation of this filter material is predicted by the particle-size analysis. In order for the filter pores to allow water to pass through while collecting the smaller soil particles from suspension, the filter material's particle size must be greater than the soil being protected.

According to Dafalla [17], the form of the sand—whether spherical, surrounding, or angular—will have an impact on the soil's shearing strength. Angular grains offer more interlock and enhanced shear resistance. Sand size and gradation have an impact on shear resistance. Compared to poorly graded materials, well-graded materials offer increased grain to grain area contact. When considering clay and sand mixes, porosity and the space available for the clay within the sand are crucial factors.

Compaction-

The method for improving the earth is soil compaction. The soil grains are more tightly organized as a result of the soil being subjected to compactive force. Compaction makes soil more tensile and weakens its permeability and compressibility [19, 21]. According to Prakash and Jain [16], compaction of soils decreases void ratio, porosity, permeability, and settlements while increasing density, shear strength, and bearing capacity. The outcomes are helpful in ensuring the stability of field issues such as earthen dams, embankments, roadways, and airports. The value of the optimal moisture content obtained by the laboratory proctor compaction test controls the moisture content at which the soils are compacted in the field. The maximum dry density measured in the laboratory also influences the compaction energy employed in the field.

Consolidation- The primary goal of a consolidation test, according to Prakash and Jain [16], is to gather soil data that is used to forecast the pace and quantity of settlement of a structure built on clay, which is predominantly due to clay volume change. The following settlements may happen: (i) total foundation settlement under any given load; (ii) total settlement due to primary consolidation; (iii) settlement for any given time and load; (iv) any percentage of total

settlement or consolidation; and (v) pressure resulting from previously compressed or consolidated soil. When the soil layer is under compressive stress from building operations, the soil layer compresses. Compression is brought on by the crushing of particles, water seepage, particle rearrangement, and elastic distortions. Three factors are considered while analysing a structure's settlement: the structure's appearance, its function, and any structural damage. When there are fractures or the building tilts owing to settling, the visual appeal of the structure may be harmed. Cranes, sewers, pumps, electrical lines, and other utilities may be damaged as a result of a structure's settlement. A structure's structural integrity may be compromised by further settling and may collapse. Settlement is the result of combining time-dependent (also known as consolidation) with time-independent compression, such as quick compression. [14]

Permeability- Given that groundwater conditions are regularly encountered on building projects, the engineer should be familiar with fluid flow concepts. The water table is the point at which the pressure is atmospheric, and water pressure is always measured in relation to atmospheric pressure. Because pore pressure dissipation is governed by a soil's permeability, shear strength of the soil is also indirectly influenced by permeability. According to the U.S. Bureau of Reclamation, soils are categorized as either (i) impervious (coefficient of permeability) less than 10^{-6} cm/sec, or (ii) permeable (coefficient of permeability greater than 10^{-6} cm/sec). Semi pervious is defined as k between 10^{-6} and 10^{-4} cm/sec, while pervious is k larger than 10^{-4} cm/sec. The characteristics and behaviour of soil are significantly influenced by the quantity, distribution, and flow of water inside the soil. When seen in relation to the water table, soil mass is separated into two zones:

The two zones are (i) just below the water table (referred to as the capillary zone with degree of saturation 100%) and (ii) just above the water table (a saturated zone with 100% degree of saturation). The stability of foundations, seepage loss via reservoir embankments, drainage of subgrades, excavation of open cuttings in water-bearing sand, and rate of water flow into wells are all significantly impacted by soil permeability [9]. According to Prakash and Jain [16], seepage pressures caused by water eroding soil have a direct impact on the security of hydraulic systems. The permeability of a compressible clay layer determines how quickly it settles under stress

Shear Strength- The strength and shear parameter of the subgrade material heavily influences the characteristics of the roads or runways. During the design, building, and servicing phases of the road pavement, it is crucial to assess the subgrade strength [23]. For foundation design, earth and rockfill dam design, highway and airport construction, stability of slopes and cuttings, and lateral earth pressure issues, the shear strength of a soil is crucial. Because it is one of the crucial parameters for analyzing and resolving stability issues (calculating earth pressure, the bearing capacity of footings and foundations, slope stability, or stability of embankments and earth dams), shear strength of soils is particularly relevant among geotechnical soil properties [8]. According to several studies, a soil's shear strength determines whether it can hold a load from a building, carry its overburden, or maintain an equilibrium slope.

According to Akayuli et al. [35], a sandy soil has a higher friction angle than cohesiveness, while a clayey soil has the opposite.[21] Shear strength values for unconsolidated undrained or consolidated undrained situations are employed for slopes, foundations, and dams' short-term stability, whereas shear parameters for consolidated drained conditions provide more accurate findings for long-term stability

Concluding Remark-

[Researchers found that from the perspective of civil engineering construction, all of the soil's geotechnical qualities have a significant influence. Roads are a crucial part of the transportation system since they have a direct and significant impact on the economy of the nation. A greater value of specific gravity delivers additional strength for roads and foundations; it also provides information about the appropriateness of the soil as a building material. Additionally, it has been noted that an increase in specific gravity enhances the California bearing ratio, or the strength of the subgrade materials used in road building. Determining density index is useful for compacting coarse-grained soils and determining safe bearing capability, particularly for sandy soils. The examination of grain size is frequently used to categorize soils. The information on grain size distribution curves is used to plan filters for earth dams and assess the quality of soil for building roads and airfields. Particle size is regarded as one of the soil suitability parameters for the building of highways, airfields, levees, dams, and other embankments. The density, shear strength, and bearing capacity of soils are all increased by compaction, while their void ratio, porosity, permeability, and settlements are all decreased. The outcomes are helpful in ensuring the stability of field issues such earthen dams, embankments, roadways, and airports. An important goal of a consolidation test is to gather soil information that will be used to estimate how much and how quickly a structure built mostly of clay would settle. When soil is permeable, water seeps through with significant pressures that directly affect the stability of buildings. So, the minimum permeability for a road should be. The strength and shear parameter of the subgrade material have a major impact on the characteristics of the roads or runways. For the road pavement during the design, construction, and service phases, subgrade strength must be evaluated.

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