Potential Impact of Nanoclay on the Atterberg Limits of Clayey Soil

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Abstract – *Nanotechnology is a rapidly emerging technology with immense potential for creating new materials with unique properties and for manufacturing new and improved products for numerous applications. It plays a major role in the development of new products with improved qualities like less consumption of energy, less harmful to the environment, less consumption of resources (i.e., men, materials, money and machinery), increased safety and serviceability in construction and improvement in the geotechnical properties of soil etc. The use of nanotechnology in some talented fields such as soil improvement, seepage and grouting will offer great advantages in Geotechnology. This paper investigates on locally available weak clayey soil stabilization using montmorillonite nanoclay, an engineered nanomaterial. To evaluate the effects of nanoclay on the Atterberg Limits of clayey soil, varying fractions of nanoclay ranging from 0.2% to 3.5% by mass are added. The incorporation of nanoclay has influence on the Atterberg Limits.*

***Key Words*: Nanoparticles, Clay, Nanoclay, Atterberg Limits, Optimum, Specific surface area**

1. INTRODUCTION

The use of stabilization techniques has increased significantly in recent decades to adopt cost-effective solutions, to achieve reductions in quantities of material used and etc. Soil stabilization by adding materials such as cement, lime, bitumen etc. is one of effective methods for improving the geotechnical properties of soils. The concept of using nanoparticles fillers came with nanotechnology traced in a talk by Richard Feyman on December, 29, 1959, at the annual meeting of American Physical Society (California Institute of Technology, Pasadena, CA). Nanotechnology was then perceived as the design, characterization, production, and application of structures, devices, and systems by controlling the shape and size of material particles on a nanometer scale [11]. The applications of nanotechnology in geotechnical engineering deals with soil in two ways: 1) in studying soil structure at the nanoscale and 2) in soil manipulation at the atomic or molecular level through the addition of nanoparticles as an external factor to soil.

The physical and chemical characteristics of nanoparticles are different from conventional materials, largely due to the increase in ratio between surface area and volume of nanoparticles as well as the quantum effects caused by spatial confinement. The use of nanoparticles especially nanoclay has gained importance in various fields of interests due to ease of availability and less toxic nature. Nanoclay enhances the properties of nanocomposite materials and usually can be modified to make the clay compatible with organic monomers and polymers.

1.1 Nanoclay

Clays are used in prehistoric architecture, industry, and ag riculture. It remains one of Industry's essential minerals. Cera mists used nanoclays without knowing nanoparticles and sin ce antiquity they have improved the science of clays.Clay minerals are the basic constituents of clay raw materials the clay type, the individual layers could be composed of two, three or four sheets of either $[SiO4]^{4-}$ tetrahedra or $[AlO_3(OH)_3]^6$ octahedra. The aluminosilicate layers organize themselves over one another like pages of a book, with a regular van der Waals gap between them, called an 'interlayer'. Interlayers possess net negative charge which is due to the ionic substitutions in the sheets of clay minerals. The layer charge is neutralized by cations which occupy the inter-lamellar. These inter-lamellae cations can be easily replaced by other cations or molecules as per required surface chemistry and hence called exchangeable cations. Na^+, K^+, Mg^{2+}, and Ca^{2+}, are among common exchangeable cations present in the interlayer which are exchanged with other with other required cations [6].

2. MATERIALS

The soil considered in the study is clayey soil (Kaolinite) collected from Thonnakkal, Trivandrum. The soil was taken from a height of 10m from ground level. The obtained soil is in white powdered form. All the initial properties of the soil were done. Atterberg limits were found and classified the soil under clay of low compressibility (CL). Evaluated properties of the soil are shown in the Table-1.

Table -1: Initial Properties of Kaolinite Clay

Soil properties	Values
Colour	White
Liquid Limit (%)	32
Plastic Limit (%)	20
Plasticity Index (%)	12
Shrinkage Limit (%)	17.5
IS Classification	CL
Natural Moisture Content (%)	24.5
Optimum Moisture Content (%)	23

Maximum Dry density (g/cm^3)	1.5
Percentage of clay (%)	68.07
Percentage of silt (%)	21.93
Percentage of sand (%)	10
Specific gravity	2.62
UCC (kN/m^2) at OMC	50.32

2.1 Montmorillonite Nanoclay

The nanoclay considered for the study was Montmorillonite Nanoclay collected from Intelligent Materials Pvt Ltd., Punjab. Nanoclay is processed clay at least one of its dimension is in nanoscale. It has an aspect ratio of less than 80nm. It has light cream colour.The specification sheet of the montmorillonite nanoclay is shown in Table-2.

Table -1: Initial Properties of Kaolinite Clay

Product	Montmorillonite Nanoclay
Aspect Ratio	<80 nm
Purity	>99.9%
Form	Powder
Colour	Light Cream / Off White
pH	6-9

Chart-1 shows the figure of montmorillonite nanoclay.

Chart -1: Montmorillonite Nanoclay

3. RESULTS AND DISCUSSIONS

The application of modified montmorillonite nanoclay to clays lowered the liquid limit and plasticity index. Unlikely plastic limit increased and a significant enhancement in soil's unconfined compressive strength. Liquid limit has decreased by about 7% for 2% of nanoclay. It is shown in Chart-1.

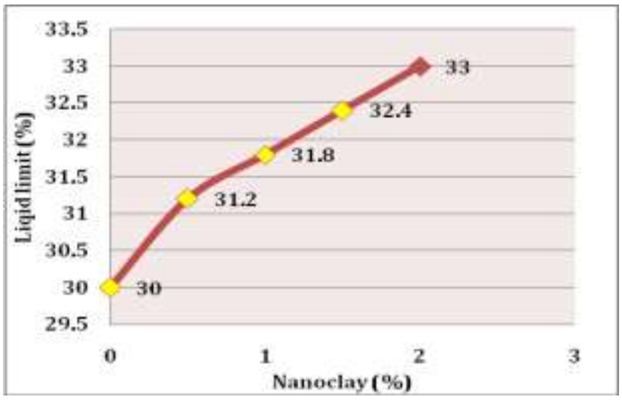

Chart – 1: Variation of liquid limit with different nanoclay percentage

Plastic limit has increased by about 4% for 2% of nanoclay. Chart-2 shows the variation of plastic limit with different percentages of nanoclay.

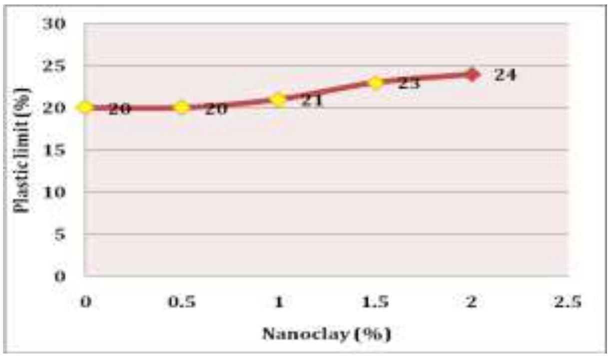

Chart - 2: Variation of liquid limit with different nanoclay percentage

Plasticity index has decreased about 11 for 2% of nanoclay. The behaviour is mainly due to the large specific surface area of the montmorillonite nanoclay particles relative to the natural clayey soil particles. Chart-3 shows the variation of plasticity index with different percentages of nanoclay.

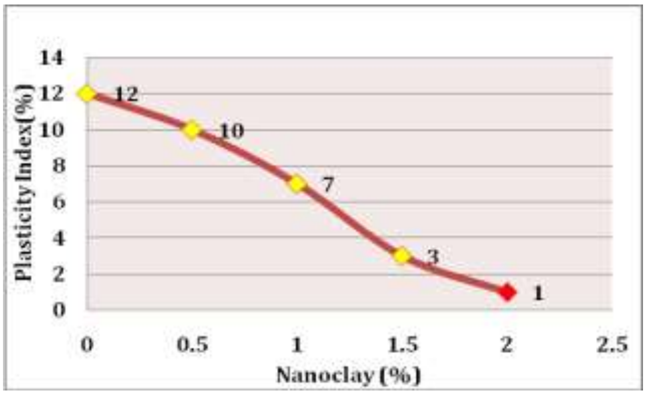

Chart - 3: Variation of Plasticity Index with different nanoclay percentage

According to implemented tests, adding nanoclay to soil causes to increase liquid limit and plastic limit of soil but plasticity index reduce (PI=LL-PL) in soil. The effect of nanomaterial in soil properties are created by area of very large specific surface and superficial loading, nanoporosity of intra-particle and micro structure of mass and compacted form. Results shown that nanoclay because of absorbing water has a considerable influence on increasing the limits of liquid and plasticity, leads to growth of interlock forces between nanoparticles in the vicinity of moisture which can cause soil stabilization by fastening the particles together and filling pores.

4. CONCLUSIONS

The introduction of nanoclays as fillers or additives in polymers for various desired effects has been of enormous interest for research and development studies. Due to nanoscale dimensions, nanoparticles hold a very high specific surface and react more actively with other particles in the soil matrix. With the addition of smaller % of nanomaterials, the soil exhibits notable effects on the Atterberg Limits. The incorporation of nanoclay results in increase of water absorption and a reduction in pores between clay particles. It is worth pointing out that the high liquid limit of soil nanoparticles does not indicate a high reactivity, due to the presence of intra-aggregate water and intraparticle water. Atterberg limits, if measured on classical clay minerals, reflect the extent of particle-particle and particle-water interactions.

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