INVESTIGATING THE IMPACT OF CEMENT CONTENT ON THE GEOTECHNICAL PROPERTIES OF CLAY-BASED MIXTURES

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ABSTRACT

Soft clay deposits are highly plastic, normally consolidated fine grained soils characterized by their low inherent shear strength. The mixing of soft clays with cement as a chemical stabilizer has become a well-known stabilization technique. The resulting strength of the clay–cement mix is controlled by different factors, but mainly the water to cement ratio, the cement content, and the curing conditions. It is crucial to develop a clear under-standing of the changes in engineering behaviour of the clay–cement mix that result from changes in controlling factors. A phase diagram was established to define the initial conditions of the mass–volume relationships of air, cement, clay, and water of a typical clay–cement mix. This phase diagram was then used to determine the total dry density, void ratio, and specific gravity of the clay–cement mix as a function of the cement content and water to cement ratio. The main objective of this work was to develop generalized trends for the geotechnical properties of clay–cement mixes. These trends were evaluated based on unconfined compressive strength as well as consistency tests carried out on soft clay samples before and after mixing with cement and at different curing times. The reduction in the PI of the clay–cement mix was found to be an efficient tool to represent the improvement in the strength of the clay after mixing with cement

Key words: *Soft clay, Clay cement mix, Curing time, Unconfined compressive strength, Soil stabilization.*

INTRODUCTION

For past several decades, mixing sand with an adequate amount of clay/ ntonite has been a common practice for creating mixtures as construction materials used in a variety of engineering applications, such as hydraulic and waste containment. The combination of mixing sand and bentonite can be able to provide a very low permeability because of the ability of bentonite to swell and then fill the voids between sand particles. Another benefit of the mixture is low compressibility which is provided by the sand framework. Furthermore, the mixture has less susceptible to frost damage comparing with natural clays , with low shrinkage potential in terms of wetting or drying processes, which lead to better volume stability and higher strength. The sandbentonite mixture seems to be an economical solution for the geo-environmental applications in places which are covered mostly by sandy soils. The behaviour of compacted clay-sand and clay-gravel mixtures was studied by conducting untrained triaxial tests. They suggested critical sand/gravel contents, below which the shear strength and secant deformation modulus, of the mixed soil (as compared to those of the pure clay) remain almost unchanged, and beyond which they increase considerably. Also, the results revealed that adding sand/gravel to the clay increases pore water pressures during monotonic shearing. The clay-gravel mixtures, as opposed to the clay-sand mixtures, showed a slightly higher strength and lower pore water pressure during shearing

Soil stability is the process of enhancing a soil's engineering characteristics on where it is located. Large amounts of silt or clay cause the geophysical characteristics of soils to change over time. These soils compress when dry, swell when exposed to snow, and become plastic when there is rainwater nearby. When constructing on soils like this, construction traffic is a critical and tough subject. In simple terms, it's frequently challenging, if not impossible, to find other uses for these materials. Such soil can be utilized to build foundations or beneath the surface of structures after being stabilized with wheat straw ash and lime, avoiding costly excavation work and transport. Utilizing wheat straw ash and lime considerably modifies a soil's properties to provide for a long-time durability and toughness, especially with regard to the effects of water and snow. The soils' mineralogical characteristics will affect how reactive they are to wheat straw ash and lime as well asthe long-term strength that the stabilized coatings will develop.

LITERATURE REVIEW

Thao Ba Vu [2023] The compressive strength of cement-treated soil is known as the most crucial factor, which governs the quality of cement-treated soils. Indeed, many factors affect the compressive strength of cement-treated soils, including cement types and contents, water/cement ratio, soil types, as well as curing conditions, etc. In which, curing conditions, cement types, and soil types are the most important factors that govern the compressive and durability of cement-treated clay. Three cement types and two types of clay were used to prepare the specimens of cement-treated clay with three cement dosages The specimens of cement-treated clay were cured under two conditions (sealed and drying). The results showed that drying conditions significantly increased the unconfined compressive strength of cement-treated soils regardless of cement types, cement contents, soil types, and ages as compared to those under sealed conditions.

Alemineh Sorsa [2022] This study was to evaluate the engineering properties of cement stabilized expansive clay soils. This study considered an experimental program to determine Atterberg limits, free swell index, compaction characteristics, California Bearing Ratio (CBR), and swell of the mixtures. The collected expansive soils were stabilized using 10, 12, 14, and 16 % of cement by weight. The laboratory results showed that the soils have low shear strength and high swelling potential, which indicates the soils are weak for subgrade without improvement. The analysis results indicated that 14 % cement stabilization is very effective for the improvement of expansive soil strength.

Sadegh Ghavami [2021] An experimental study was conducted to determine the effect of cement kiln dust (CKD) and fly ash (FA) on compaction and strength characteristics of the high-plasticity clay obtained from a forest road in North of Iran. Accordingly, the soil was mixed with 15% CKD by dry weight the soil, and a partial replacement of the CKD with 10, 20, and 30% FA was applied to produce mixtures. The unconfined compressive strength tests were performed on specimens after a curing time 7 and 28 days. Also, the microstructures of untreated and treated specimens were examined using a scanning electron microscope (SEM). It was found that incorporation of CKD and FA leads to a decrease in the volume of pores in the soil matrix, which is due to the formation of calcium silicate hydrates and calcium aluminate hydrates gels. These cementitious compounds in the mixtures were presumed to be the significant factor contributing to strength improvements.

Roman Jaskulski [2020] alcined clays are the only potential materials available in large quantities to meet the requirements of eco-efficient cement-based materials by reducing the clinker content in blended cements or reducing the cement content in concrete. More than 200 recent research papers on the idea of replacing Portland cement with large amounts of calcined clay are presented and discussed in detail. First, the fundamental information about the properties and structure of clay minerals is described. Then, the process of activation and hydration of clays is discussed, including the methods of pozzolanic activity assessment. Additionally, various testing methods of clays from different worldwide deposits are presented. The application of calcined clay in cement and concrete technology is then introduced.

Clay Mixing

A small mixing device was used to blend the ingredients. Everything needed to be put into the mixer by h&. To start, put the coarse aggregates at the bottom of the mixing drum. Then, on top of it, put the fine aggregates. In the middle part, you'll introduce the dangerous substance, clay in particular. After that, pour the cement on top, & lastly, sprinkle some more coarse aggregate. Before turning on the mixing equipment, the pre-mixed component was added to the water & then moved to the mixing drum. After two minutes of mixing, the concrete was mixed again until it reached the desired consistency.

Clay Soils

Naturally occurring solids known as clay soils consist of clay minerals that have been ground to a fine powder. Clay soils are naturally porous & may be worked into many shapes while wet, but as they dry out, they become harder & less pliable. Expansive soils, which are mostly clay-based, undergo large volumetric changes when the moisture level varies. Soils that are rich in clay tend to be located in arid parts of the globe. In the realm of architecture & construction, clay has several applications. Some potential applications include making sewage & drainage system components, wall tiles, & pottery. Due to its exceptional absorption properties, this material finds widespread use in foundry operations, particularly in the manufacture of mouldings &s for metal casting &mould facing.

Laboratory investigations and mix designs

The geotechnical properties of clay soils and their mixtures with lime (LM) and waste marble powder (WMP) were assessed using established protocols under ambient temperature conditions (22–31°C). The clay soil underwent drying before being manually mixed with LM and WMP at varying percentages until achieving a homogeneous color. Sixteen repetitions involved increasing doses of LM and WMP in clay soil, followed by fixed doses for specific gravity, compaction, direct shear, compression strength, oedometric, and EDX microstructure tests. Significant enhancements in the clay soil properties were observed, confirming the positive impact of LM and WMP.

Clay structure & physiochemical characteristics

For any given amount of liquid, the clay will undergo a series of push-pull curves that are proportional to the distance between them. In response to an applied force, the clay minerals' particles combine to form a single cohesive mass. "Flocculation" describes this process. When a net force applies pressure to displace particles, the phenomenon is known as dispersion. Clay behaviour is heavily influenced by its geological history & structural features, making particle interactions an important factor to address. Soil engineering properties are sensitive to changes in fine-grained soil structure. Soil formation is made possible by geological processes that are fundamentally influenced by the organisation of soil. The main focus of geotechnical engineering is to analyse the physical & mechanical properties of structures that are supported by soil, as well as the relationships between soil characteristics, texture, & overall performance.

Stabilization of Clay Soil with Cement

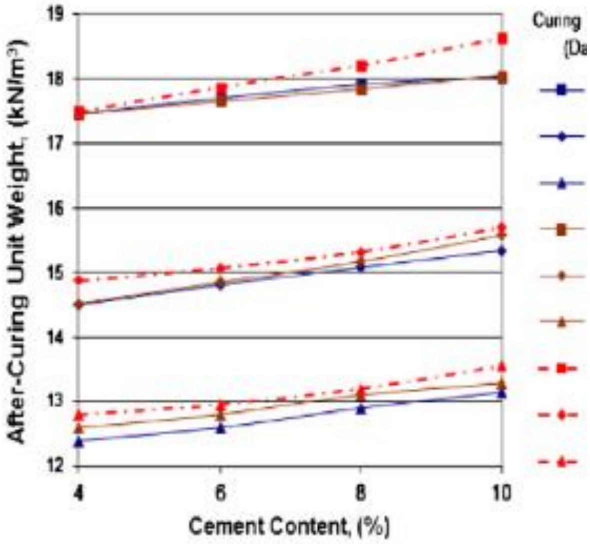
Soil stabilisation refers to the process of treating soils in a way that increases their strength & durability, which in turn increases the variety of uses for such soils. When soaked, clay soils exp& substantially, & when dried, they compress substantially. Civil engineering projects sited on expansive & shrinkable soils are very prone to failure; hence, stabilising the soil should be the first priority before work begins. Much study has focused on the stabilisation of clayey soil using lime, coal bottom ash (fly ash), natural gypsum, & high-density polyethylene, among other elements. The clayey soil's physical qualities have been greatly enhanced by the addition of these chemicals

METHODOLOGY

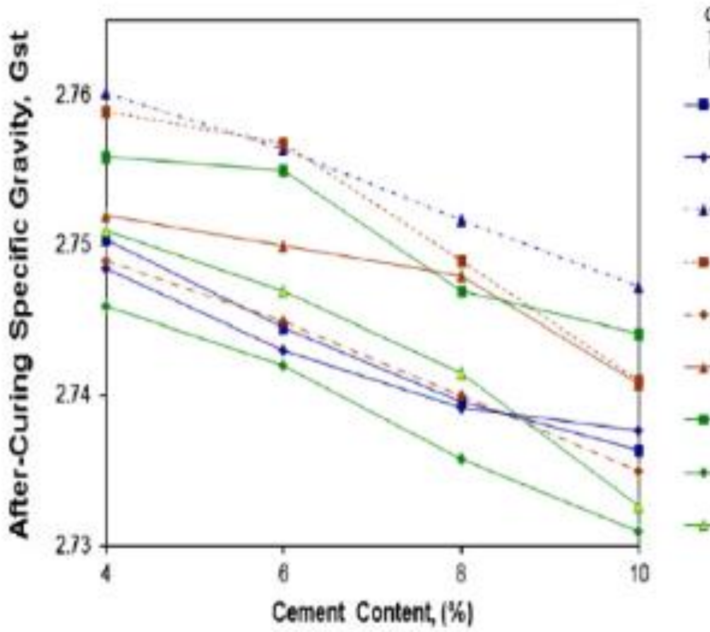
Investigation of the geotechnical properties of coarse-fine mixtures (CFM) and interaction of these intermediate, The materials used for this research includes clay soil, cement, ceramic waste dust and distilled water transitional soils with geogrid in direct shear testing requires parameter-controlled experimentation. Mixtures were prepared having certain gradation, fines content and plasticity index values that relate to the sandgravel, silt-clay boundaries of the commonly used soil classification systems, and the upper and lower limits of soil index properties defined in different design codes for appropriate backfill material criteria. Seven different commercially available soil products were used to obtain ten different soil mixtures for this purpose. In this section, the selection and geotechnical properties of the soil products and soil mixture preparation methodology are discussed in detail. In addition to the soil materials to be tested, the physical and mechanical characteristics of the geogrids used and all specimen preparation and test procedures in the scope of the study are described.

RESULTS AND DISCUSSION

The plot of after curing unit weight versus cement content at varying magnitudes of remolding water content and curing time is shown in graph. 1. The unit weight increased with increasing cement content and curing time. Little effect of curing time on the unit weight of specimens. The reason for the increase in the unit weight with the cement content and curing time could be the shrinkage of the samples during the curing process. More shrinkage occurred for samples with higher cement content and curing time.



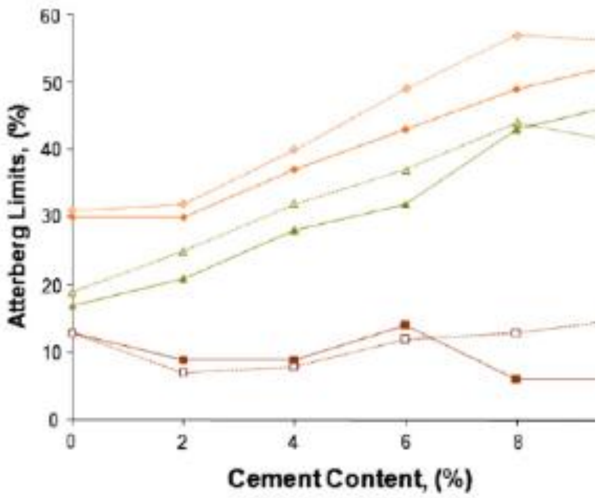
Graph 1 Increase in unit weight with cement, at different water contents and curing times



Graph: 2 The decrease of specific gravity with cement content and curing time

In graph.2 the plot of after curing specific gravity of solids (Gst), against cement content at different remolding water contents and curing time is shown. The value of the treated samples then decreased with an increasing cement content and curing time. The reason for the increase in the specific gravity of solids after curing may be due to high the specific gravity of Portland cement and the reason for the decrease in G stwith cement content and curing time may be due to the aggregated nature of particles of soil–cement. This means that the single solid soil particles of natural clay were transformed into the aggregated particles of soil–cement consisting of several single solid particles connected together with secondary cement bonding with voids. These aggregated soil–cement particles with secondary cement bonding with voids are then bonded together by primary cement bonds to form the macrostructure of cement-treated soil after curing.

Graph . 3 shows the results of the Atterberg limit tests on cement-treated soil samples prepared according to the abovementioned procedures. In general, the liquid limit of the treated samples increased with the cement content .One possible reason for the increase in the Atterberg limits, especially the liquid limit of the treated soil, may be the micro porous nature of the aggregated particles of the material that trap the water within intra-aggregate pores. For the Mexico City natural soft clay, with porous diatoms particles, the porous nature of particles had a more significant effect on the plastic limit.



Graph: 3 The increase in Atterberg limits with cement content (initial remolding water content= 70%)

CONCLUSION

Soft clay soils consist of normally consolidated clays and are generally identified by low shear strength. This paper was intended to provide a quick estimation of the role of curing time and cement content on the geotechnical properties of a clay–cement mix Experiments suggested that the overall geotechnical index properties of clay–cement mixes were controlled by the water to cement ratio, as well as the cement content. Therefore, a phase diagram was developed to present the geotechnical index properties, such as dry density, specific gravity, and void ratio of a typical clay–cement mix. This phase diagram showed that increasing the cement content of the clay–cement mix resulted in an increased void ratio and decreased total dry density for the same water to cement ratio. Therefore, higher compaction efforts may be needed to achieve the same dry density with increased cement content. The clay–cement mix had a greater strength than the natural soft clay. The unconfined compressive strengths of clay–cement mixes increased significantly with increasing cement content and followed linear relationships at different curing times.

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