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IMPROVEMENT OF GYPSUM SOIL PROPERTIES USING CERAMIC POWDER AND KAOLIN CLAY ADDITIVES

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Abstract

This study investigates the effectiveness of waste ceramic powder and kaolin clay as additives to enhance the properties of gypsum soil, which is characterized by its low bearing capacity and high compressibility. The goal is to determine whether the addition of these additives can improve the qualities of gypsum soil and make it suitable for construction purposes. Vane shear test and consolidation tests were conducted on various combinations of waste ceramic (5%, 10%, and 15%) plus 2% kaolin clay to evaluate the treated soil's performance. The results showed that a synergistic effect was observed when waste ceramic and kaolin clay were combined, particularly at a ratio of 10 % ceramic and 2% kaolin clay. The treated soil exhibited improved characteristics compared to using each additive separately. The study concludes that incorporating a mixture of waste ceramic and kaolin clay can enhance the qualities of gypsum soil, thereby improving the stability and quality of foundations constructed on this type of soil.

Keywords: *Gypsum Soil, Ceramic, Kaolin Clay, Vane Shear Test, Consolidation*.

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Introduction

Gypsum soils have complex and unpredictable behavior, which makes it an anxious and unsteady soil, They can be observed in several global locations, predominantly inside arid and semi-arid geographical areas.. A total of 20 to 25 percent of Iraq's land is covered with gypsum soils. In the west desert, 30 percent of its total area was directed towards the south west. water causes gypsum soils to collapse rapidly, many structures were found to be no longer serviceable, and different parts of Iraq .(Al- Saoudi N.K.S. , A.N. 2013). Important Iraqi projects have had multiple disasters as a result of gypseous soils beneath the foundations; the majority of these structures were constructed on gypsum strata or gypseous soils (Karim 2010).

The gypseous soil, which constitutes a significant portion of the Earth's surface or near-surface soils, is characterized by its unsaturated nature. (Ahmed Abood, Mohammed Fattah 2023) . On the other hand, it is noteworthy that the generation of building and demolition waste contributes to approximately 75% of global pollution. Ceramic products constitute the majority of waste, accounting for approximately 54% of the total. The present method of disposing of ceramic waste is through landfills owing to the absence of established standards, inadequate proficiency, and a lack of protocol for utilizing ceramics in soil structures (Andrés Juan, César Medina, M. Ignacio Guerra, Julia Mª Moránb Pedro J. Aguado and Rodríguez 2014). It is crucial to recognize that each engineering production process yields residual materials and byproducts that carry substantial implications for both environmental welfare and human health. Several events happen during the initial stage, while others emerge during the transportation of materials (Chen et al. 2015). As per estimations, around 30% of the daily output of the ceramic industry is deemed unsuitable for use (Binici 2007). The process of discarding the object above leads to pollution of the surrounding soil, water, and atmosphere (Appannagari 2006). In the past few decades, there has been a notable surge in industrial and economic advancement, which has resulted in enhanced standards of living and overall welfare for the populace. It is important to acknowledge that all production systems generate by-products and waste materials that have the potential to impact the environment. The aforementioned impacts have the potential to manifest at any stage of the product's life cycle, including the procurement of raw materials, the conversion and manufacturing process, the distribution of the product, or the disposal of products that the end user no longer needs. In recent times, there has been an increase in societal awareness regarding the issue of waste management, specifically industrial waste and waste generated from the construction sector. The current issue is gaining more importance as a result of the escalating volume of industrial waste generated from construction and demolition activities. This is occurring despite the implementation of various measures by the European Community, as well as national and regional governing bodies, aimed at effectively managing and regulating waste in alignment with sustainable development policies and the Kyoto Protocol. Waste management has emerged as a critical concern in contemporary times, necessitating targeted efforts to curb waste generation. These efforts include the advocacy of resource recovery systems, such as waste-to-energy systems, recycling, and reuse, which enable the utilization of resources inherent in waste that would otherwise be lost. This approach serves to mitigate the environmental impact of waste (Juan et al. 2011) . Building materials manufacturing has improved. However, with quality systems, compliance, stricter standards, and product competition, industries will reject material inappropriate for marketing or garbage. As heat-treated clays were the first pozzolans, ceramic waste may be appropriate as pozzolanic materials. (Sánchez De Rojas et al. 2009). Theoretically, this type of refuse may be deemed inert due to its comparatively minimal level of contaminative potential. The visual impact of these structures is significant due to their substantial volume and the limited environmental regulation applied to the surrounding land. Ceramic wares are fabricated from naturally occurring substances that possess a substantial proportion of clay minerals. The activation of clay commences with dehydration at approximately 500 °C, which is succeeded by the segregation of amorphous and exceptionally reactive alumina. The peak concentration of alumina varies depending on the mineral type involved. The application of high firing temperatures during the production of ceramic materials leads to the activation of constituent minerals, thereby yielding a product that exhibits pozzolanic characteristics. Studies pertaining to ceramic waste suggest that these materials possess favorable characteristics for employment in the realm of construction, exhibiting commendable levels of efficacy and resilience (Oisés and Ojas n.d.). Several research studies have explored the feasibility of utilizing industrial waste as a viable input material during different stages of the Portland cement production process (Puertas et al. 2008).pozzolanic admixtures or alternative fuels (Goñi et al. 2001). All of these approaches assist the environment by reducing both the aesthetic impact of deposited rubbish and the mining of natural aggregates. (Navia et al. 2006) . The utilization of ceramic waste has been found to be effective in soil stabilization, particularly in the case of expansive soil. Based on the findings of the paper, it can be postulated that an increase in the concentration of ceramic waste dust is positively correlated with a corresponding There has been a notable augmentation in the unconfined compressive strength. Upon the application of a sufficient amount of ceramic dust, the stability factor exhibits a decrease, while the internal friction angle demonstrates an increase (Iravanian and Saber 2020) .Stabilization is a procedure that increases the hardness and toughness of soil, making it more suitable for construction(Divyateja Sarapu 2016). Due to the high cost of construction and the necessity to preserve biodiversity, the efficient use of waste materials for construction has been intensively investigated. (Amu, Ogunniyi, and Oladeji 2011).The final study aim this is to show that the gypsum soil properties can be improved by adding a mixture of waste ceramic and kaolin clay, hence enhancing the stability and caliber of foundations built on this type of soil. A novel attapulgite clay-based pozzolanic material reduced collapse potential by 13-90% and increased unconfined compressive strength in gypseous soil from 88 to 271 kPa by 5-40%(Safaa A. Mohamada, Hadeel Ammar Mohammed, Hanan Adnan Hassan 2022) .

noted that used 5% and 10% Magnesium Oxide without carbonation had collapse potentials 58%–89% lower than natural soil; The process of carbonation, conducted on a mixture of soil, resulted in a significant reduction in collapse potential ranging from 81% to 93% over a duration of 3 to 24 hours. (Ahmed S.A. Al-Gharbawi 2022) . The collapsibility of gypseous soil was seen to significantly decrease by 200-250% through carbonation, without the use of magnesium oxide as an additive. (A. S. A. Al-Gharbawi, Mohammed Y. Fattah 2022). Laboratory research used 10% and 15% plant fly ash to reduce landfill waste decomposition into soil heavy metals; Plant fly ash reduced soil sample specific gravity from 2.7 to 2.4 (Abdulrahman A. Salim, Zainab B. Mohammed 2022). in addition Gypsum soil improved with magnesium oxide and magnesium carbonate (A. S. A. Al-Gharbawi1,a, M. Y. Fattah,b 2021).using emulsion rubber material to improving gypsuim soil and at 1% percentage treatment the soil (Abdulrahman, Ihsan, and Sabri 2020). By adding more nano silica fume, gypseous soil has less of a chance of collapsing. The shear strength of soil samples also increased as nano silica fume quantity and cure time increased (Alaa D. Al-Murshedi, Mahdi O. Karkush 2021).

1. Methodology

the soil samples were examined using a systematic manner in the current investigation. Three distinct compositions with various ceramic clay to kaolin clay ratios have to be made in order to carry out the technique. The initial mixture had 5% ceramic and 2% kaolin clay, followed by 10% ceramic and 2% kaolin clay, and then 15% ceramic and 2% kaolin clay. Getting a collection of representative soil samples was the first stage. Each concoction was painstakingly put together and each one was painstakingly ready for testing. The samples were then subjected to a series of chemical investigations to ascertain their composition and identify any distinctive qualities. The soil samples were classified upon completion of the chemical analysis. The methodology entails the classification of specimens based on their physical and chemical attributes in order to enhance comprehension of the characteristics and behavior exhibited by said specimens series of analyses were conducted to determine the mechanical properties of the soil samples. In order to assess the soil properties settling and its compressibility, a consolidation test was performed. To ascertain the soil's shear strength, the vane shear test was carried out. After the tests were finished, a thorough analysis of the outcomes of each test was done, paying close attention to even the smallest of details. To determine the properties of the soil samples, each test's outcomes were painstakingly studied and compared. This investigation was done to find out how different ceramic and kaolin clay concentrations affected the dynamical and physical characteristics of soil. This technique made it easier to comprehend the properties of the soil samples completely. The methodical procedure ensured the completion of the thorough investigation, enabling correct analysis and trustworthy outcomes. The figure below explains the paper's mythology.

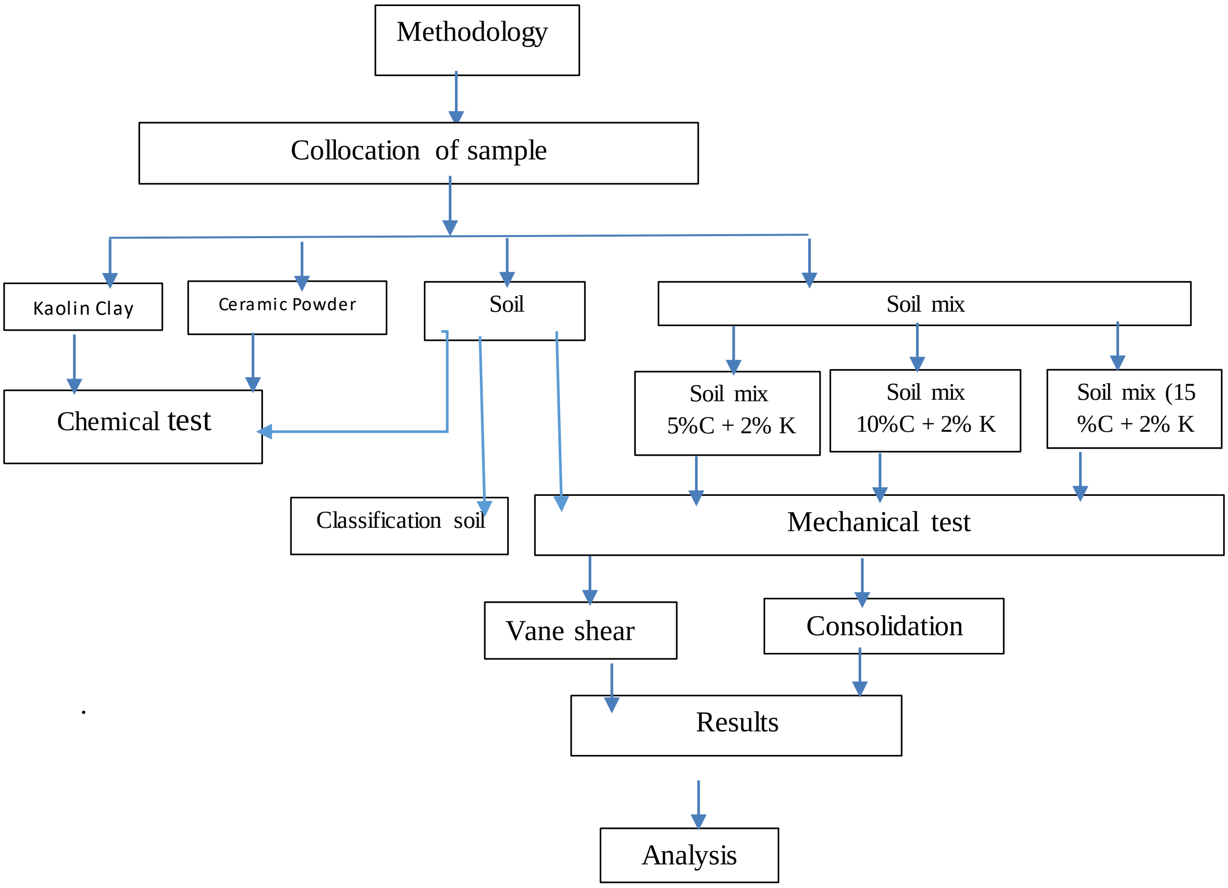

Figure 1 : Methodology diagram

2.1 Materials and Methods

2.1.1 Gypsum Soil

The samples of soil utilized in this paper were collected from a region located in the southern part of Baghdad, close to Al-Amarah City in the Maysan Governorate of southern Iraq. These samples were obtained through disturbed sampling techniques at a depth of 1.5 meters from borrow pits. The characteristics and attributes of the soft soil under study have been tabulated in Table 1. Based on the USCS system of classification [6], the soil is identified and classified as type CL .

Table 1: classification Gypsum soil

GS	**Gypsum**	**L.L**	**P.L**	**PI**	**Clay**	**Silt**	**gypsum**	**Sand**	**U.C.S. Soil type**
2.42	53	27	19	8	53	28		25	CL
(Oktavia et al. 2019)		(ASTM 2000)				(C136-06 2007)			

2.1.2 Ceramic Powder and Kaolin Clay

Kaolin clay is found in various locations throughout Iraq. Some of the known locations where kaolin deposits exist include the Sulaimaniya province in the northeast region of Iraq, the Diyala province in eastern Iraq, and the Karbala province in central Iraq. Ceramic fixtures, including bidets, washbowls, bathtubs, and lavatory pans, were sourced from sites of construction waste deposition. The objects underwent fragmentation via the application of a hammer, and subsequently underwent further reduction through a process of jaw crushing. Subsequently, the fragmented refuse underwent a process of filtration, wherein particles with a diameter less than 2 millimeters were isolated.

Table 2 : chemical Ceramic Powder and Kaolin Clay

Chemical	Ceramics	Kaolin
CaO	4.1	<0.05
SiO2	64.5	51
Al2O3	15.07	34
Fe2O3	0.65	-
MgO	2.04	0.35
K2O	2.1	1.55
P2O5	1.05	-
TiO2	0.74	0.7

3. Results and Discussion

3.1 Consolidation Test Results

Rainfall is a crucial factor in determining soil properties and behavior, especially in regions with arid and semi-arid climates. The amount and intensity of rainfall directly impact soil erosion, runoff, and infiltration, which, in turn, affect the stability and performance of engineering structures and natural slopes. Therefore, accurately measuring and predicting rainfall is vital for various fields, including agriculture, hydrology, and geotechnical engineering.

One way of obtaining reliable rainfall data is through the use of rain gauges, which are instruments designed to measure the amount of precipitation that falls over a specific area. However, installing rain gauges in remote or inaccessible locations can be challenging, and in some cases, impossible. In such situations, remote sensing techniques, such as radar and satellite-based measurements, can provide valuable data on rainfall patterns and distribution.

The collapse quantity of a soil layer is easily calculated by multiplying the layer's thickness by the collapse strain. The potential collapse severity is indicated in Table 3.

Table 1: Percentage of collapse - determinants of severity of value problems

Collapse VALUE (%)	***problem Severity***
0-1	No problem
1-5	Moderate trouble
5-10	Trouble
10-20	Severe trouble
Over 20	Very severe trouble

In this experimental setup, the rainfall data collection, and the data analysis procedures. We will then present and discuss the results obtained from the experiment, and finally, draw conclusions regarding the feasibility and effectiveness of using HYCOS for remote rainfall measurements in gypsum soil fields.

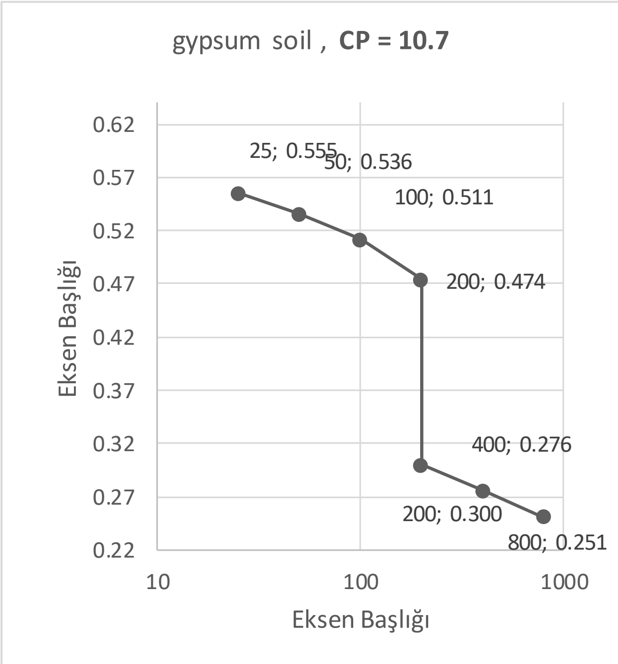

Figure 1: void ratio for gypsum soil

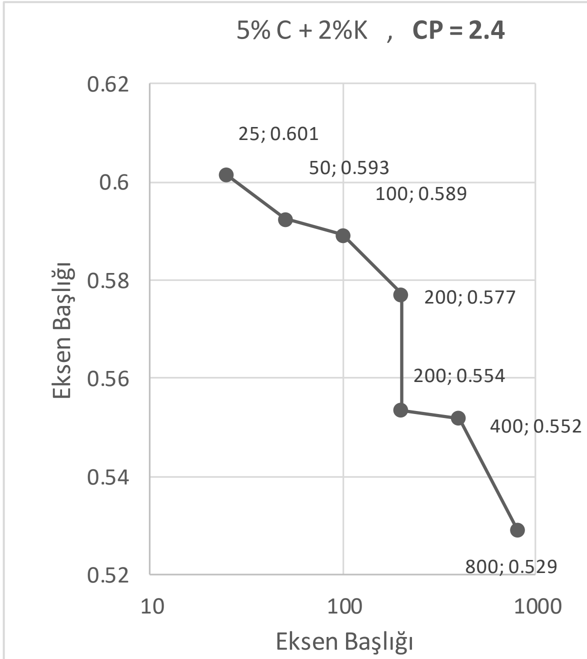

Figure 2: Impact 5 % C + 2% K on void ratio

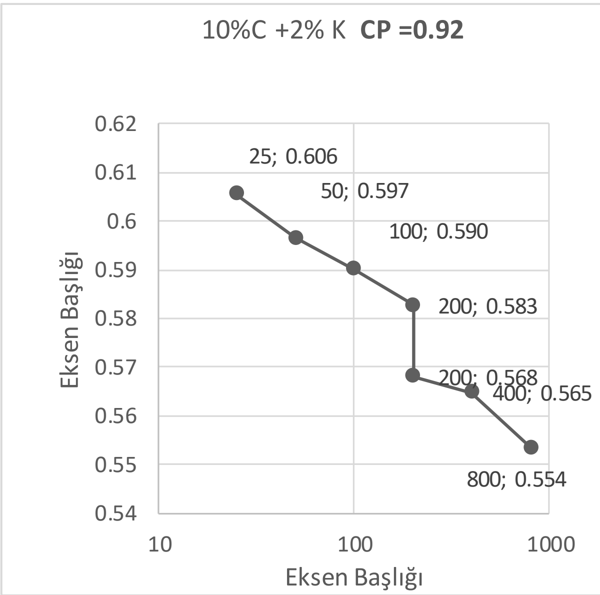

Figure 3: Impact % 10C + 2% K on void ratio

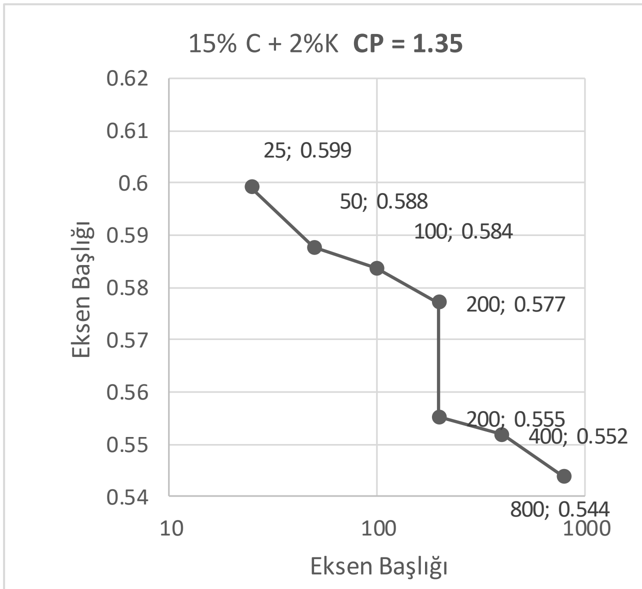

Figure 4: Impact 15% C + 2% K on void ratio

From the figure (1,2,3,and 4) , The reason why the infiltration rate of gypsum soil was 10.7, and then changed to 2.4 after adding a mixture of 5% ground ceramics and 2% kaolin clay, and then became 0.92 and 1.35 after adding a mixture of 10% and 15% ground ceramics, respectively, can be explained by the physical properties of the added materials and their effect on the soil structure.

The ground ceramics and kaolin clay act as soil amendments and can improve soil properties such as porosity, water holding capacity, and infiltration rate. When added in small amounts, such as the 5% 10% and mixture, they can increase the soil's ability to hold water and improve the infiltration rate by filling in the pores and gaps in the soil. The shear strength of soil is a fundamental mechanical characteristic that quantifies its capacity to withstand deformation when subjected to external forces. In order to enhance the shear strength of gypsum soil ,including the incorporation of additives. The shear strength of gypsum soil was assessed through vane shear tests conducted under various conditions. The study examined the impact of incorporating a composite blend of pulverized ceramics and kaolin clay on the shear strength of gypsum soil. The experimental findings offer valuable insights regarding the feasibility of utilizing additives to enhance the gypsum soil shear strength. The practical applications of this phenomenon can be observed in construction and engineering projects conducted in areas characterized by the presence of gypsum soil.

3.2 Vane Shear Test

A mechanical characteristic of soil called shear vane shear test which well it can withstand deformation in the face of external forces. Many techniques, including adding chemicals, have been investigated to increase the shear strength of gypsum soil. Gypsum soil shear strength was assessed using vane shear tests under various scenarios. The experiment looked at which adding waste of ceramics and kaolin clay affected the shear strength of the gypsum soil. The experiment's findings shed light on the possibility of employing additives to increase the shear strength of gypsum soil. In areas with gypsum soil, this may be useful for engineering and construction tasks.

Table 3: shear strength of vane shear test (Advanced unsaturated soil mechanics and engineering 2008)

Mixture percentage % plus soil	**shear strength value Cu**
Soil gypsum nature without mixture	45
Soil gypsum mixture with (5% C + 2% K)	90
Soil gypsum mixture with (10% C + 2% K)	276
Soil gypsum mixture with (15% C + 2% K)	260

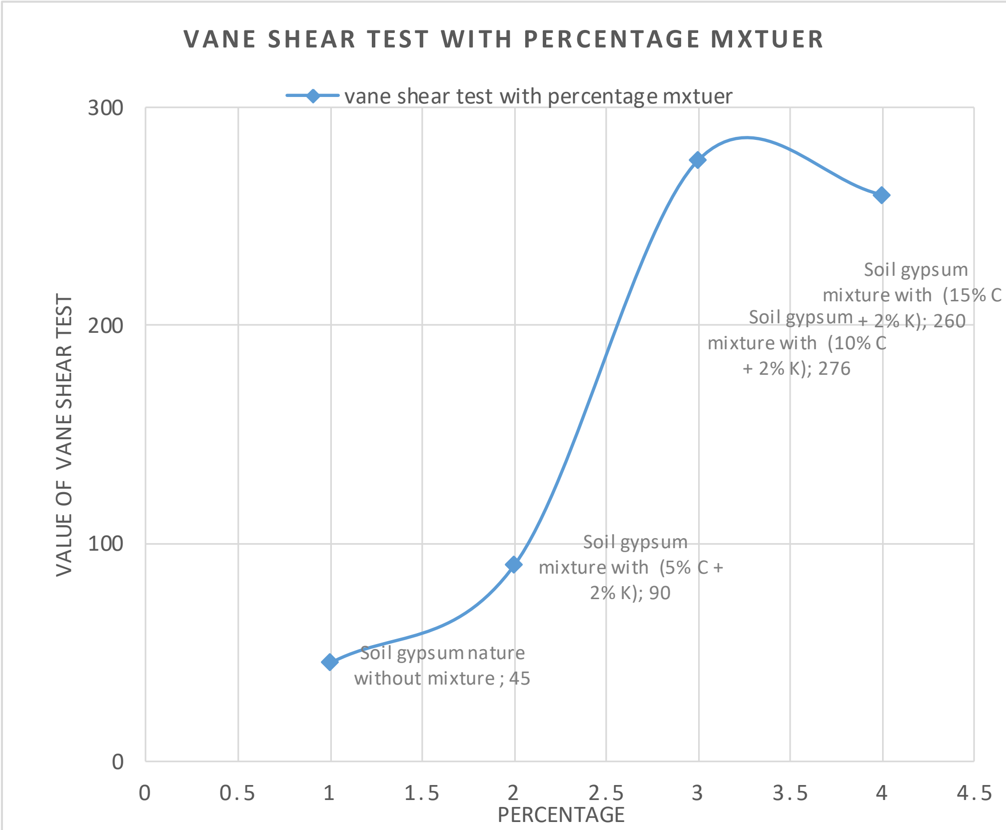

Figure 5: Vane shear test

Table 3 and figure 5 indicates that the initial shear strength of gypsum soil was 45 based on the results

of the experiment. A mixture of 5% ground ceramics and 2% kaolin clay increased the soil's shear strength to 90. Increasing the mixture to 10% resulted in a 276 shear strength. Shear strength decreased to 260 when the mixture was increased to 15%. Consequently, it can be concluded that the addition of a mixture of ground ceramics and kaolin clay enhances the shear strength of gypsum soil. The optimal ratio for improving soil's shear strength depends on the specific application and the desired level of enhancement. Nevertheless, based on the outcomes of this study, it seems that a combination of 10% ground ceramics and 2% kaolin clay yields the most significant improvement in soil's shear strength. Through a comparative analysis of our productivity in relation to prior research on the same substance, we have observed that the seramij residue exhibits favorable characteristics in terms of soil dependency and moisture reduction.

4. Conclusion

The study's findings lead to the following conclusions:

1. A significant improvement in the cohesive properties of the gypsum soil was observed when 10% ground ceramics and 2% kaolin clay were incorporated, resulting in an decrease of value of collapse from 10.7 to 0.92 according to the determinants of severity of value problems ,type problem exchange from the Trouble type of to be no problem as well as table 3(Advanced unsaturated soil mechanics and engineering 2008) . results from vane shear test indicate a notable enhancement in the shear strength of the soil when a mixture of 10% ceramics and 2% kaolin clay was used, as evidenced by the increase from 45 to 276.

2. The findings suggest that the integration of a blend of ceramic and kaolin clay can be considered as a feasible approach to enhance the shear strength of gypsum soil. Specifically, an increase in the percentage of waste ceramic dust has been found to correspond with a decrease in the liquid limit of the soil that lead to increase the strength of the soil . (Chen et al. 2015)

3. The observed phenomenon has promising practical implications for construction and engineering projects in areas characterized by gypsum soil.

4. The study concludes that the incorporation of a blend of ground ceramics and kaolin clay has a beneficial impact on the shear strength of gypsum soil. The optimal ratio for enhancing shear strength appears to be the combination of 10% ceramics and 2% kaolin clay. The present study offers significant findings for engineers and practitioners operating within the construction sector, advocating for the adoption of this methodology in endeavors pertaining to gypsum soil.

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