GEOTECHNICAL PROPERTIES OF EXPANSIVE SOIL IMPROVED WTTH ALKALI ACTIVATED BRICK DUST

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Final Year Project titled

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for the undergraduate degree

in

CIVIL ENGINEERING

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DEDICATION

We dedicate our project to our parents for their constant support throughout our lives.

We sincerely thank our supervisor Dr Arshad Ullah for his guidance and mentorship throughout the project.

Also, we would like to thank the Military College of Engineering (MCE) for providing us with the requisite knowledge, tools, and resources to complete this endeavor.

DECLARATION

This report is a presentation of our assigned project work. Wherever commitments of others are included, each exertion is made to demonstrate this obviously, with due reference to the writing, and affirmation of communitarian project and exchanges. The work is carried out under the supervision of Dr. Arshad Ullah at Military College of Engineering, Rislapur, NUST.

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We are thankful to the All-Mighty Allah, whose help guided us in the accomplishment of this task.

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LIST OF ABBREVIATIONS AND SYMBOLS

AABD	Alkali Activated Brick Dust
AASHTO	American Association of Soil for Highway and Transportation
BCS-FA	Black Cotton Soil- Fly Ash
BD	Brick Dust
CaO	Calcium Oxide
EDP	Entrepreneurship Development Program
F	Force
Fe_2O_3	Di Iron Tri-Oxide
FOS	Factory of Safety
KOH	Potassium Hydroxide
LL	Liquid Limit
M	Momentum
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
OPC	Ordinary Portland Cement
PC	Portland Concrete
PI	Plasticity Index
SEM	Scanning Electron Microscopy
SH	Sodium Hydroxide
Si-O-Al	Aluminum Silicates
SiO_2	Silicon Dioxide
SOM	Soil Organic Matter
SPT	Standard Penetration Test
SSI	Soil Structure Interface

T	Time Period
UCS	Unconfined Compressive Strength
USCS	Unified Soil Classification System
V	Velocity
Al	Aluminum
C	Carbon
c	Cohesion
Ca	Calcium
d	Diameter
Dl	Deformation in length
έ	Strain
f	Force
gm	grams
kN	Kilonewton
kPa	Kilopascal
L	Length
ΔL	Change in length
lbs	pounds
M_2	wet soil in grams
M_3	dry soil in grams
Mg	Magnesium
m	mass
N	Number of blows
Φ	Angle of internal friction
Si	Silicon
t	Tim

ABSTRACT

Expansive soils have susceptibility to shrinking and swelling with the change in moisture content. These soils are worldwide problem and possess challenges for geotechnical engineers. The most common and economical technique for improving the properties of these soils is utilizing admixtures. In this study, the effect of alkali-activated brick dust on the geotechnical properties of expensive soil was examined. The brick dust was activated with Potassium Hydroxide (KOH) and added to the soil at 30%, 40% and 50% by weight. Sieve analysis, Atterberg limits, compaction test, swelling index and unconfined compressive strength were carried out for the untreated and alkali-activated treated expensive soil. The liquid limit and shrinkage limit of untreated soil and soil treated with 30%, 40% and 50% alkali-activated brick dust are 39,33,30 and 29 respectively. Furthermore, the unconfined compressive strength of 231Kpa, 348Kpa , 464Kpa and 510 Kpa were achieved for the untreated and soil treated with 30%, 40% and 50% alkali-activated brick dust respectively. Based on the findings of the study, increasing the percentage of alkali-activated brick dust with soil tends to reduce the liquid limit and swelling index and increase the compressive strength. The improvement in soil properties was more prominent for the expensive soil treated with 40% alkali-activated brick dust. It can be concluded from the results that expensive soil can be improved successfully by alkali-activated brick dust. The utilization of brick dust in soil improvement can reduce project costs, solve dumping issues, and will bring sustainability to ground improvement.

CHAPTER 1

INTRODUCTION

1.1. Background

Expansive soils and swelling soils are those soil which have susceptibility to shrink and swell with the change in moisture content. As a result of which significant affect in the property soil occurs, causing substantial damage to the overlaying structure. During raining season these soils absorb water and become soft and their capability to hold water decreases, while in rice season this soil shrink and become stiff because of evaporation of water. These kinds of soil usually exist an arid and semi-arid region of the world and are being considered as a potential natural hazard, which if not stabilized or improved will can trigger extensive damage not only to the structure but can also result in human loss. Montomorollite soil exhibit these properties (Shahzada, K. et al 2017). However, many engineering structures especially geotechnical and geo-environmental ones are designed by altering their properties. Geotechnical engineers opt either to excavate and replace the entire soil or to improve the geotechnical properties of the soil to attuned to the potential problem rather than trying to change the whole system. Different soil additives such as cement(Zhang et al., 2022),lime((Malekpoor & Toufigh, 2010) ,rice husk((Fattah, Rahil, & Al-Soudany, 2013) and fly ash((Bhuvaneshwari, Robinson, & Gandhi, 2005) has been usually used to improve the geotechnical properties of poor construction materials like expansive soils.(Ene& Okaglue,2009).Moreover , brick dust can be utilized as an additive in order to enhance the properties of expansive soils. During the manufacturing of brick, brick dust is generated which is shown in Fig 1.1.

Expansive soils also called as Black soils or Black cotton soils are usually found in Pakistan. Based on seismic zoning map, Pakistan has been divided into 5 zones. Islamabad is located in Zone (2B) which is shown in fig 1.2. In October 2005, the collapse of Margalla towers occurred and resulted into substantial uncertainty in

Geotechnical Engineering. Because other buildings in the amenity were remain intact structurally. Based on the geotechnical reports of Margallo towers the soil was classified as silty and clayey soil as per AASHTO and USCS soil classification system. The investigation reported that Geotechnical aspect was ignored during the design phase (K. Mahmood et al. 2016).

Figure. 1.1 Brick Dust

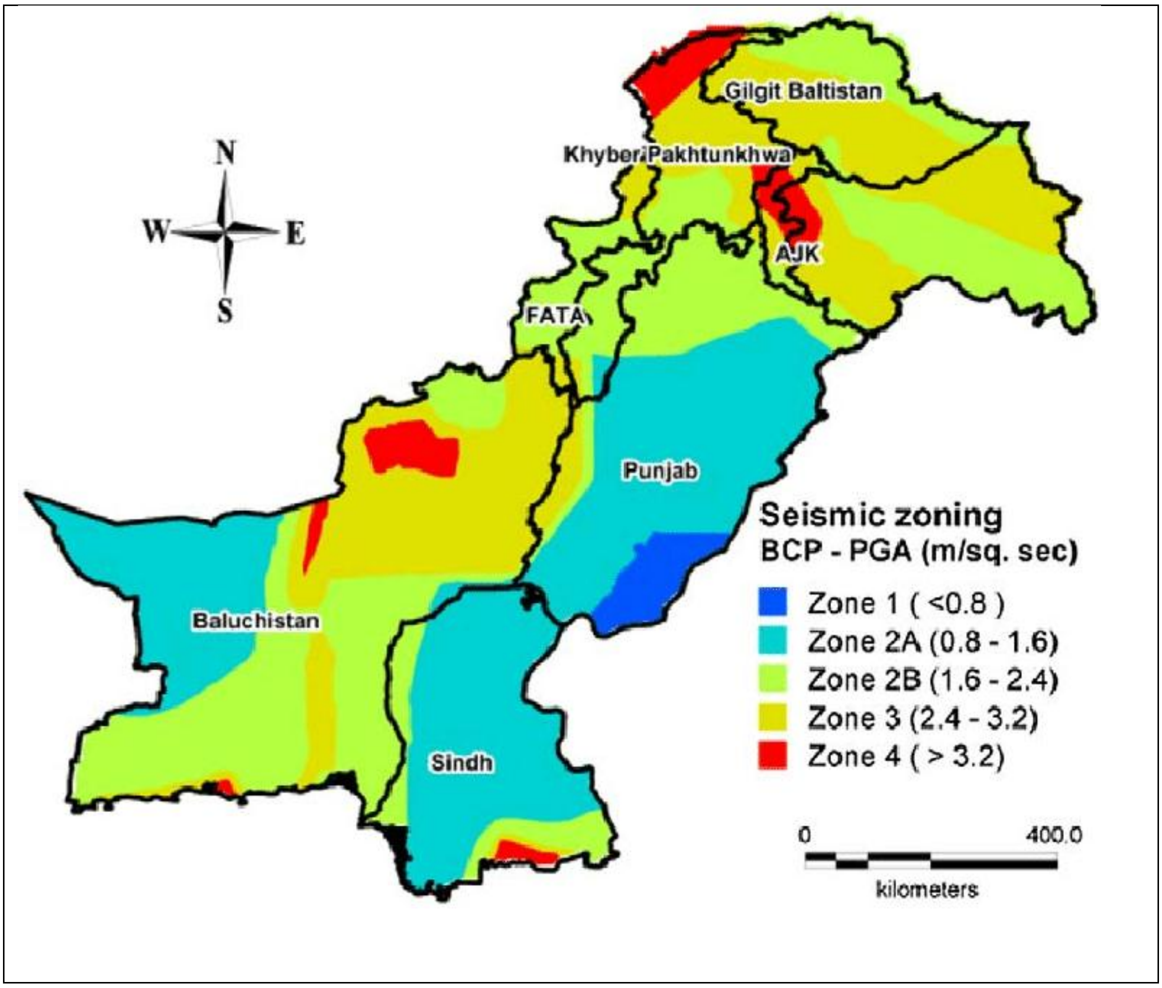


Figure. 1.2 Seismic zoning Map of Pakistan

According to Roosevelt et al (1933), the nation that destroys its soil, destroys itself. Soil improvement techniques are introduced in the modern world, as demand for land for development purposes increases, where construction was impossible due to soil related problems. (M.R. TAHA 2009). Pakistan has many active tectonic plates due to which geotechnical engineering problems occur. The correlation between factor of safety (FOS) and standard penetration test (SPT) in accordance with earthquake magnitude can be vital for making safe subsoil profile. (Xiao-Wei Tang et al 2018). The Margalla Towers in Islamabad collapsed while no other nearby building collapsed, but they all have soil profile, but soil beneath Margalla Towers was clay and it was neglected during foundation design. (Alam 2012; Tesfamariam and Saatcioglu 2008). The conduct of the whole structure relies upon the structure itself, the soil beneath earth, and the continuum interface between them. The structure and the soil offer together against the outside loadings. This process is known as the soil structure interaction (SSI), which is commonly dismissed in the plan codes of common structures. Nonetheless, for structures and structures laying on expansive soils, the impact of the soil structure interaction turns into a critical factor. (Salah Khalfallah et al 2015).

The act of added substances is advantageous on the grounds that one of the fundamental pre-requisites for structural designing activities is that it must be reasonable. On occasion, land to be better-quality covers an enormous region and furthermore including huge separations (for instance expressways) (M.R. Taha 2009). The adding of lime (as admixture) and concrete to responsive fine-grained soil has important impact on their designing properties, remembering decrease for versatility, swell potential, upgraded functionality, improved quality, firmness, and higher solidness (S. Riaz et al 2014). The act of utilized tire-chips blended in with clayey soils as a fill material is conceivable. The combinations up to 20% coarse grained tire-chips and 30% fine grained tire-chips can be utilized over the ground water tables where low weight, and penetrability and high quality are needed in fills, for example, highway embankments, bridges and backfilling behind holding structures particularly when they are to be built on feeble establishment soils with low bearing capacity and high settlement issues. (Mustafa Fener et al 2006). Nanotechnology and Nanoparticles in Geotechnical Engineering is the main topic for engineers today as it enhances the soil properties, for instance, the behavior of soil is studied while mixing it with nano soil and it was concluded that it increases plastic limit and liquid limit due to which water content decreases which is a major concern for geotechnical engineers during construction. (M.R. Taha 2009). The use of brick dust as an admixture in concrete can be a vital replacement of cement. It was experimented that use of brick dust instead of cement gives same strength of concrete, reduces heat of hydration and it’s reddish colour looks more aesthetic. (M. Kamal Uddin 2004).

1.2. Project Motivation and Problem Statement

The construction of buildings on expansive soil with low strength is increasing due to rapid growth in infrastructural development. The construction on expansive soil is extremely challenging job for geo-technical engineer due to excessive settlement and probable bearing failure. However, different methods are applied to improve the properties of these soils, one of the methods is chemical stabilization by using cement, lime and flyash to improve the expansive soil.

Expansive soil is usually found in Pakistan. Different improving techniques are used to improve the expansive soil but most of them are focusing by using the traditional stabilizers such as cement and lime. However, growing awareness towards sustainable development in soil improvement is leading to a larger desire to utilize recycled material as stabilizers. Brick dust is a byproduct generated during manufacturing of bricks. In Pakistan, the brick dusts are discarded as a waste in landfill. Therefore, a study is needed to utilize the brick dust in improving the expensive soil properties. The utilization of brick dust as a soil additive will help to solve the dumping problem, decrease the project cost and will bring sustainability in soil improvement.

1.2.1. Project Questions

Soil investigation is compulsory before the start of any construction of a structure. With the use of admixture, soil properties can be enhanced.

1.3. Aims and Objectives

The aim of this study is to investigate the geotechnical properties of expansive soil improved with alkali activated brick dust. This study will focus on the following objectives to be achieved.

a) To examine the geotechnical properties of soil collected from the proposed site.
b) To determine the unconfined compressive strength, swelling index and compaction parameter for the soil stabilized with different proportion of alkali activated brick dust
c) To recommend the optimum percentage of Alkali Activated Brick Dust and soil mixture.
d) To show the importance of using improved expansive soil before starting any construction

1.4. Scope of Work and Study Limitations

The extent of work includes leading point of interest observation review, geotechnical examination, research center testing, information investigation and finish of safe bearing limit with respect to the proposed work. All examination incorporates visual inspection of the site, lab testing, assurance of soil boundaries, investigation of field and Laboratory information, showing up at the definitive choice on establishment framework to be embraced in the current case utilizing our designing judgment, in view of the flow practice. The laboratory tests for the example will be gathered for the grain size distribution, Atterberg limits, swelling index and unconsolidated compressive strength.

1.4.1. Rationale Behind Variable Selection

The major logic behind using expansive soil is that it had caused great damages to structures and had costed around billions worldwide due to its swelling and shrinking problem. Expansive soil is widely present in Pakistan at different locations. Using BD with Alkali activated can overcome its swelling and shrinking problem. Since, BD is a waste material at brick kilns that's why utilizing it also take our project sustainable development.

KOH as an alkali is being used in the project because it is easily available in the market and available at less expensive value in the market.

1.5. Project Significance and Project Implementation

The physical and mechanical properties of expansive soil have been enhanced by using alkali activated like potassium hydroxide with brick dust through laboratory tests. The swelling index of expansive soil has been improved by using alkali activated brick dust for any type of construction.

1.6. Project Report Layout

Expansive soil has been a problem for engineers to deal with because of swelling problem in monsoon season. The industrial wastes are affecting our environment and its only solution is using those wastes in beneficial way. So that's why, brick dust is being utilized with potassium hydroxide (KOH) to overcome the problem of swelling index and increase the compressive strength of expensive soil.

CHAPTER 2

LITERATURE REVIEW

2.1. Background

The vast majority of the challenges brought about by expansive soils in structural designing structures were surely known by architects and scientists the world over. Expansive soils swelled essentially and showed low shear quality when in wet conditions such soils shrink and the other way around (J.M. Kate,. 2005). Most financially savvy and current technique for balancing out expansive soils was utilizing additives substances that do changes in volume. By and large, modern deposits cause the greater part of the climate issues. In this way, usage of modern waste in development industry is the most ideal approach to arrange it (J.M. Kate,. 2005).

The chance of utilizing consumed brick dust as settling added substance in expansive soil is evaluated for the improving designing properties of expansive soil. The laboratory testing's have been performed on three extents 30%, 40%, and half with expansive soil. The directed tests result shows critical decrease in swelling of expansive soil. With expanding measure of stabilizer swelling decreases (Sachin N. Bhavsar et al 2014).

2.2 Soft Soil

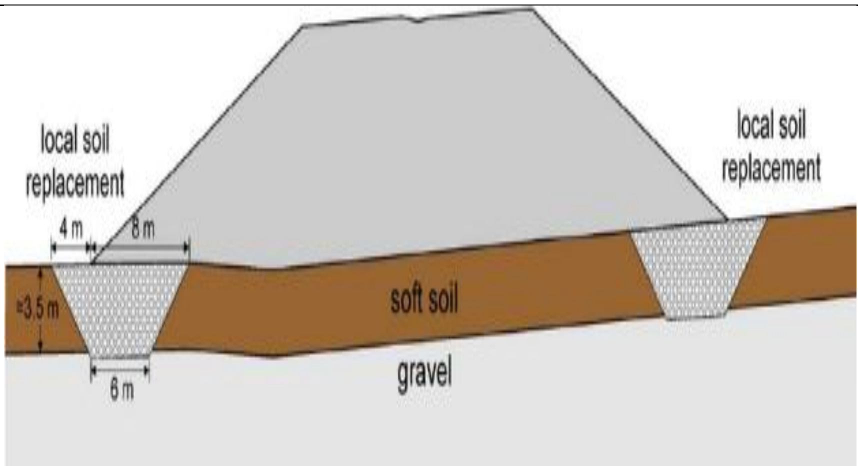
Bjerrum (1973) classify soft clays based on their engineering geological history and emphasizing the change in properties which have occurred since their deposition as normally consolidated young clays, normally consolidated aged clays, over consolidated clays, weathered clays in upper crust, quick clay deposits and cemented clays. , the term "soft soil" is defined as clay or silty clay soil which is geologically young, and come to an equilibrium under its own weight but has not undergone significant secondary or delayed consolidation since its formation. It is characterized by the fact that it is just capable of carrying the overburden weight of the soil, and any additional load will result in relatively large deformation.

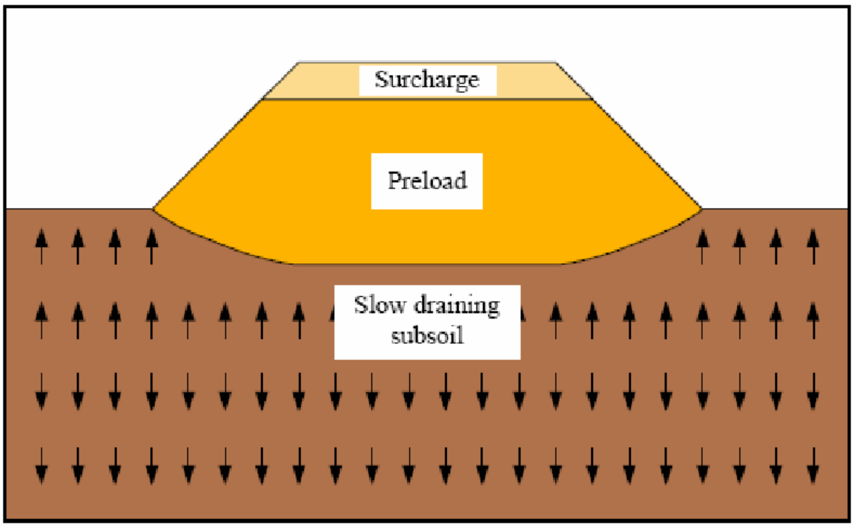
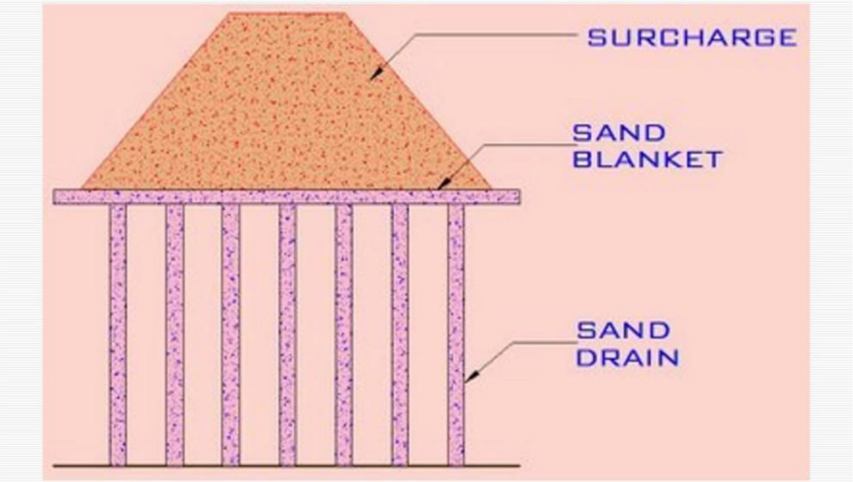
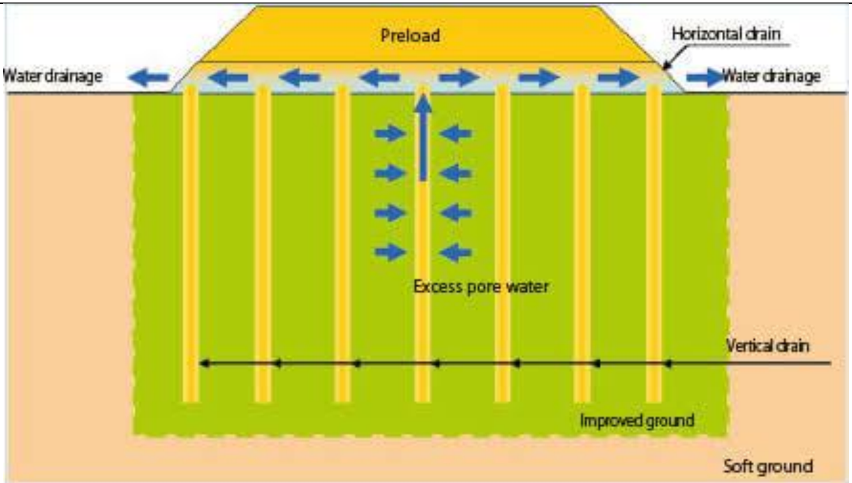
2.2 Soil Improvement Techniques

Geotechnical engineers generally face the issue of structures on soft soil and need to modify the soil properties according to project demand (Ashour, 2016). In a poor soil situation Mitchell and Jardine (2002) four possibilities besides continuing the project :

1. Change the soft soil with the most suitable material.
2. Avoid construction on soft soil or provide deep foundations.
3. Enhance the site condition of the poor ground in order to improve the soil properties according to the project demands.
4. Redesign the structure according to project demands.

The increase in cost and a better knowledge of the upcoming effect related with the construction on the environment becoming the main contributors to expanding the utilization of soil improvement techniques (Fattah et. Al 2016). Soil improvement techniques generally intend to modify certain properties of soil to satisfy the needs of construction works. Different soil improvement methods are used to improve the soil properties. Some of the improvement methods are shown in fig 2.1

Soil replacement	

Pre compression-loading	
Sand drains	
Vertical drains	

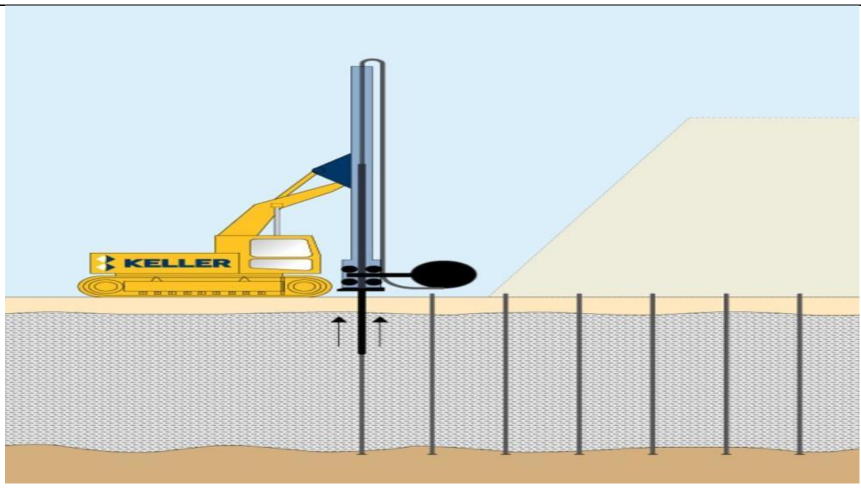
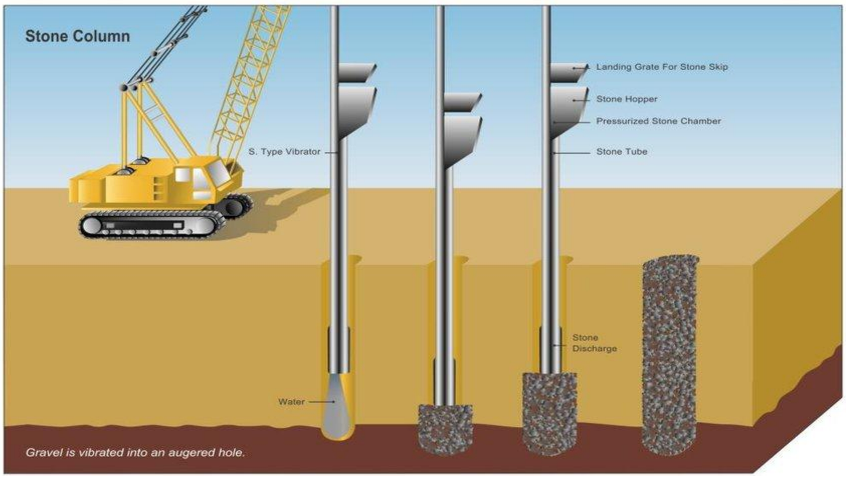
Prefab vertical drains (PVD)	
Stone columns	

FIGURE 2.1

2.2 Chemical stabilization

Chemical stabilization is one of the methods usually used to increase the strength and reduce the compressibility. In this method different chemicals are applied to stabilize the soft soil.

Under this category, soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect.

For a successful stabilization, a laboratory tests followed by field tests may be required in order to determine the engineering and environmental properties. Laboratory tests although may produce higher strength than corresponding material from the field, but will help to assess the effectiveness of stabilized materials in the field. Results from the laboratory tests, will enhance the knowledge on the choice of binders and amounts (EuroSoilStab, 2002).

Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties. A clay soil compared to others has a large surface area due to flat and elongated particle shapes (Sherwood, 1993).

2.2.1.1 Stabilizing Agents

These are hydraulic (primary binders) or non-hydraulic (secondary binders) materials that when in contact with water or in the presence of pozzolanic minerals reacts with water to form cementitious composite materials. The commonly used binders are:

1. Cement
2. Lime
3. Fly ash
4. Blast furnace slag

2.2.1.2 Cement

As primary stabilizing agent or hydraulic binder because it can be used alone to bring about the stabilizing action required (Sherwood, 1993)&(EuroSoilStab, 2002). Cement reaction is not dependent on soil minerals, and the key role is its reaction with water that may be available in any soil (EuroSoilStab, 2002). This can be the reason why cement is used to stabilize a wide range of soils. Numerous types of cement are available in the market; these are ordinary Portland cement, blast furnace cement, sulfate resistant cement and high alumina cement. Usually the choice of cement depends on type of soil to be treated and desired final strength. Cement stabilized soils have the following improved properties:

- Decreased cohesiveness (Plasticity)
- Decreased volume expansion or compressibility
- Increased strength (PCA-IS 411, 2003).

2.2.1.3 Lime

Lime provides an economical way of soil stabilization. Lime modification describes an increase in strength brought by cation exchange capacity rather than cementing effect brought by pozzolanic reaction (Sherwood, 1993). In soil modification, as clay particles flocculate, transforms natural plate like clays particles into needle like interlocking metallic structures. Clay soils turn drier and less susceptible to water content changes (Roger et al, 1993). Lime stabilization may refer to pozzolanic reaction in which pozzolana materials reacts with lime in presence of water to produce cementitious compounds (Sherwood, 1993, EuroSoilStab, 2002). The effect can be brought by either quicklime, CaO or hydrated lime, Ca (OH)2. Slurry lime also can be used in dry soils conditions where water may be required to achieve effective compaction (Hicks, 2002).

Quicklime when mixed with wet soils, immediately takes up to 32% of its own weight of water from the surrounding soil to form hydrated lime; the generated heat accompanied by this reaction will further cause loss of water due to evaporation which in turn results into increased plastic limit of soil i.e. drying out and absorption (EuroSoilStab, 2002; Sherwood, 1993). Sherwood (1993) investigated the decrease in plasticity as brought about in first instance by cation exchange in which cations of sodium and hydrogen are replaced by calcium ions for which the clay mineral has a greater water affinity. Even in soils (e.g., calcareous soils) where, clay may be saturated with calcium ions, addition of lime will increase pH and hence increase the exchange capacity. Like cement, lime when reacts with wet clay minerals result into increased pH which favors solubility of siliceous and aluminous compounds. These compounds react with calcium to form calcium silica and calcium alumina hydrates, a cementitious product similar to those of cement paste. Natural pozzolanic materials containing silica and alumina (e.g. clay minerals, pulverized fly ash, PFA, blast furnace slag) have great potential to react with lime.

2.2.1.4 Fly ash

Fly ash is a byproduct generated during combustion of coal in coal fired power station; it has little cementitious properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementitious compound that contributes to enhanced strength of soft soil. Fly ashes are readily available, cheaper and environment friendly. The reduction of swell potential achieved in fly ashes treated soil relates to mechanical bonding rather than ionic exchange with clay minerals (Mickiewicz and Ferguson, 2005). However, soil fly ash stabilization has the following limitations (White, 2005)

1. Soil to be stabilized shall have less moisture content; therefore, dewatering may be
   required.
2. Soil-fly ash mixture cured below zero and then soaked in water are highly
   susceptible to slaking and strength loss
3. Sulfur contents can form expansive minerals in soil-fly ash mixture, which reduces
   the long-term strength and durability.

2.2.1.5 Blast Furnace Slags

These are the by-product in pig iron production. The chemical compositions are similar to that of cement. It is however, not cementitious compound by itself, but it possesses latent hydraulic properties which upon addition of lime or alkaline material the hydraulic properties can develop (Sherwood, 1993; Åhnberg et al, 2003). Depending on cooling system, Sherwood (1993) classified slag into three forms, namely:

- Air-cooled slag
- Granulated (merit 5000) or Pelletized slag
- Expanded slag

Under certain conditions, steam produced during cooling of hot slag may give rise to expanded slag

Over the latest forty years, there has been a slight assortment toward the use of ground improvement as a countermeasure as opposed to the danger of liquefaction. It is reasonable that objections with improved soil persevere through less ground distorting and subsidence than adjoining, unaltered zones. The field case narratives cover a wide extent of progress procedures, from standard densification strategies like sand compaction heaps to more surprising parallel safe based methods, for instance, sheet heaps dividers or profound soil blending matrices. The assembled data shows that dirt of improved quality generally performed well (Nicholar Sitar et al 2001).

2.3 Brick Debris

Brick is very important building materials, also, it is perhaps the greatest part of waste created from both development and smoothing. Reuse of this waste would diminish the natural and social impacts of development. One potential mass utilization of such waste is as a solidifying specialist for soil adjustment is shown in table 2.2

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	H_2O	LOI
63.89	25.49	7.73	0.29	0.04	0.2	0.2	0	1.33	0.95

Table 1.2: Chemical composition of crushed clay

2.3.1 Brick Debris as a Soil Stabilizer

Chemical stabilization can also be sorted to improve the strength and durability of expansive soil for construction. Keeping this in view, cement and lime have been used effectively to improve geotechnical properties of expansive soil. (Nadgouda and Hegde, 2010). However, there are many environmental and energy issues in the production of lime and cement. While, a considerable amount of waste produced from various industries i.e., fertilizer production, power generation, metal extraction & processing and agriculture sectors remains unused in lagoons and landfills (Pappu et al., 2007). Hence, many of the researchers have done their investigations to replace the conventional stabilizing materials like lime and cement with the wastes generated from different industries (Murmu and Patel, 2018; Pappu et al., 2007). Whereas many researchers investigated the use of waste materials on stabilization of soil and some have used it to manufacture building materials. It is encouraged to use these waste products all over the world so that harmful effects of greenhouse gases can be reduced along with large amount of energy consumption.

Soil due to large amount of moisture content that decreases the bearing capacity of soil and it becomes permeable soil . to counter this, brick debris is mixed in the soil with the alkaline compounds which may enhance the structure strength, resist the thrust or drift force acting on the soil and interlocking between the particles remain same no change in between the particles due to the slight drifting of particles like in roads, not a hair cracking occurs having an admixture of brick debris in an expansive soil.

Figure 2.3: Brick Debris

2.2.3. Reported Improvement Soil Behavior

In this examination, the utilization of consumed brick dust as additive substance to expansive soil is evaluated for improving geotechnical properties of expansive soil. The test includes swelling index, linear shrinkage, Atterberg's cutoff points, and compaction trial of expansive soil in its characteristic state just as when blended in with differing extent of consumed brick dust (from 30 to half). The analyses have been performed on three proportions 30%, 40%, and 50% of brick and soil. The exploration result shows critical decrease in swelling of expansive soil. With expanding measure of stabilizer swelling declines. Greatest reduction in expanding has been seen in half of substitution of soil by brick dust. Greatest abatement in shrinkage has been seen in half substitution of soil by stabilizer. Most extreme dry thickness of soil is improving, and ideal moisture content is diminishing with expanding balancing out substance. For expanding substance of balancing out specialist brick dust Atterberg's cutoff esteems are likewise declining (Sachin N. Bhavsar et al 2014).

Compaction is a broadly utilized technique for expansive soil treatment. It utilizes a mechanical method for removal of air voids inside the soil mass along these lines the soil can tolerate loading accordingly minus any additional quick pressure, which is not quite the same as those started by long haul union of clayey muds. Thusly, it is vital for acquiring the dampness thickness relationship of soils, in which the optimum moisture content (OMC) is gotten at a comparing most maximum dry density (MDD). In any case, sometimes, the soil could be ideally compacted nearby OMC, contingent upon the site-explicit conditions and the point of the compaction cycle. Soil-subordinate factors that essentially impact the OMC and MDD incorporate grain size dispersion, state of the soil grains, specific gravity, and sum and sort of mud minerals present in the soil (Das, 2002).

2.3.3 Stabilized Soil with Brick Dust

Different application and uses of recycled brick waste were presented in the works of researchers. Some of the researchers used the brick waste in the form of aggregates, while the others described the using of dust form of this waste material. The effect of brick aggregate on the properties of expansive soil stabilized. The study findings suggested that after a curing period of 28 days' improvement of soil achieved the durability and strength to be used as a base course in the pavement. It was observed that the cost is less than conventional base course materials. Katti and Sankar (2013), investigated the behavior of bearing ratio and strength characteristic of expansive soil mixed with lime and brick aggregates. The results determined that California bearing ratio, shear strength parameters (cohesion (c) and angle of internal friction (Ø)) of soil mixes with additives, generally, increased. While decreasing in swelling, consolidation settlement, soil plasticity and compaction maximum density have been recorded. Sachin et al(2015), performed a laboratory study on engineering properties of expansive soil treated with burnt brick dust and noticed a significant improvement in these properties (Atterberg's limits, linear shrinkage, compaction characteristics, and swelling properties). It was noted that the optimum brick dust content 50%.The results indicated that with increase in brick dust, a significant decrease in consistency limits, optimum moisture content, swelling potentials, and shrinkage was recorded. On the other hand, the maximum dry density of stabilized soil was increased on the increment of brick dust. In overall, it was concluded the improvement of expansive soils using brick dust has positive impacts on the soil, such material is environmentally friendly and cost effective (Ali Al-Baidhani,2019).

Alkali activated brick dust has captured the attention of researchers to improve the soft soil. Previously, sodium hydroxide as alkali activator with brick dust to stabilize expansive soil.

As the utilization of alkali activated brick dust showed to enhance the properties of expansive soil and can be applied successfully for soil improvement. However, another alkali activator such as Potassium hydroxide is sorted to activate the brick dust to improve the expansive soil. The use of alkali activator will reduce project cost, solve dumping issues, and will bring sustainability to ground improvement.

2.4 Summary

After having an in-depth view of several research, a conclusion is derived that a lot of work has been done on brick kiln dust. In addition, the NaOH has been used to activate the brick Kiln dust before mixing with soi. However, a research is need to investigate the behavior of expansive soil improved with KOH active brick dust. Using both the materials on the expansive soil and how it turns out be studied and should be given an in-depth view that how both things work with each other in stabilizing the soil. This is significant as it may reduce the environmental impacts associated with the inappropriate disposal of this residue. The curing temperature was found to have a strong influence on resistance; hence, improved performance can be expected in warm climates. This approach offers a route for utilizing a form of waste that is abundant in cities wherein brick is the basis of construction. Since it does not require a considerably fine grain size, our approach should be economically attractive in industrial applications.

CHAPTER 3

METHODOLOGY

3.1. Introduction

Soil provides the base for all types of construction. For sustainable construction, soil has to be prevented by the component which may affect the soils bearing capacity and tends towards the failure of the structure. Soil has pore water pressure, it is good in absorption of water which may increase the Atterberg limits, decreases bearing capacity, reduce the soil lifted structures durability. In the testing matrix we add brick dust in it and is compared to the basic sample and check the unconfining stresses of soil may not be disturbed, whenever the drifting of soil is act on it, or applied on it. Most important here we have to check the unconfined compression strength of soil at different combination with certain amount of brick dust. A far-reaching test program with respect to the utilization of reused totals delivered from destruction of brick structures is introduced. The brick squanders were squashed, arranged and ordered into coarse and fine totals just as powder.

3.2. Raw Materials

First of all there is a need to understand the meaning of raw material that it is an unprocessed material. It is used to produce stocks, products in their complete finished state, or midway materials that are co-products for future completed products. There are different stample used in this project like brick dust, expansive soil from selected site and potassium hydroxide as an alkali. One thing should be kept in mind any type of dust particles in these raw materials can cause significant changes in the result and can lead our project to wrong way by giving wrong results.

3.2.1. Brick Dust

Brick dust is generated during the heating of bricks in the kilns. It is a waste material which causes environmental problem as well as dangerous to human health. The place of origin of brick dust is mostly in brick kiln, construction sites and during movement of bricks from one place to another. Clean and unused brick dust is used from the brick kiln located in Phambali, Rawat, Punjab in the expansive soil and performing our laboratory tests. Comparison of expansive soil sample with alkali-activated brick dust and the other one without this additive is made. Addition of different proportions of powdered brick dust of soil is used in the respective tests. Brick Dust will be sieved first from sieve #200 and then it is used in laboratory testing.

3.2.2. Expansive Soil

A 50 kg sample of expansive soil was collected from the Bahria Town overseas block Phase VIII which was used for laboratory testing.

Expansive soils and swelling soils are those soil which have susceptibility to shrink and swell when the moisture content variates. This variation in the moisture content of the soil causes fluctuations in the soil properties and considerable amount of damage to the structure on the surface of the soil. Every year it is estimated that expansive soil cause damage to structures more than $2 billion which is more than twice the damage caused from all the natural hazards in the world together. Physical characteristics of expansive soil is shown in table 3.1.

Physical Characteristics of Expansive Soil

Properties	Amount
Coarse Sand %	0.3
Medium Sand %	3.02
Fine Sand %	24.34
Silt and Clay %	72.34
Liquid Limit	39
Plastic Limit	14.34
Plasticity Index %	24.66
Maximum Dry Density g/cc	1.85
Optimum Moisture Content %	15.57
Free swelling Index	High
UCS (kPa)	232

3.2.3. Alkali

Alkali is basic earth metal which dissolve in water. The solution has a pH value greater than 7. Variety of alkali metal are available in the market, but Potassium hydroxide is preferred being the cheapest. Solution is to be made in case of Atterberg limits in the laboratory with all precautionary measures. We are adding 2 % of potassium hydroxide per liter of water in the soil.

a) Brick Dust b) Expansive Soil c) KOH

Figure 3.1: Collection of raw materials from respective sites

3.3. Soil Improvement Steps

Expansive soil has created problems in the past due to expansion. That’s why in this project soil has been improved by using waste material from kiln brick dust and alkali as potassium hydroxide. First of all, all laboratory tests such as sieve analysis, Atterberg limits, Proctor Test and UCS were performed on expansive soil and then all these tests were performed by using three different proportion of alkali activated brick dust in soil. Soil improvement of expansive soil is carried out in two steps by adding three proportions of alkali activated brick dust.

3.3.1. Treatment of Brick Dust with Alkali

Brick Dust was collected from the brick kiln in raw form without impurities. Alkali activator such as Potassium Hydroxide is being used because of its cheapness and availability in the market. Brick Dust was passed through sieve and then it is mixed with Potassium Hydroxide. (20 grams per liter).

3.3.2. Improvement of Expansive Soil

Expansive soil was improved through laboratory testing by adding admixture of alkali activated brick dust.

3.3.3. Testing Matrix

Firstly, all mentioned tests were conducted with untreated expansive soil. Then by adding 30 % alkali activated brick dust in the expansive soil, soil was tested. Same process was repeated by adding 40% alkali activated brick dust in expansive soil. Finally, all tests were again conducted using 50% alkali activated brick dust in expansive soil

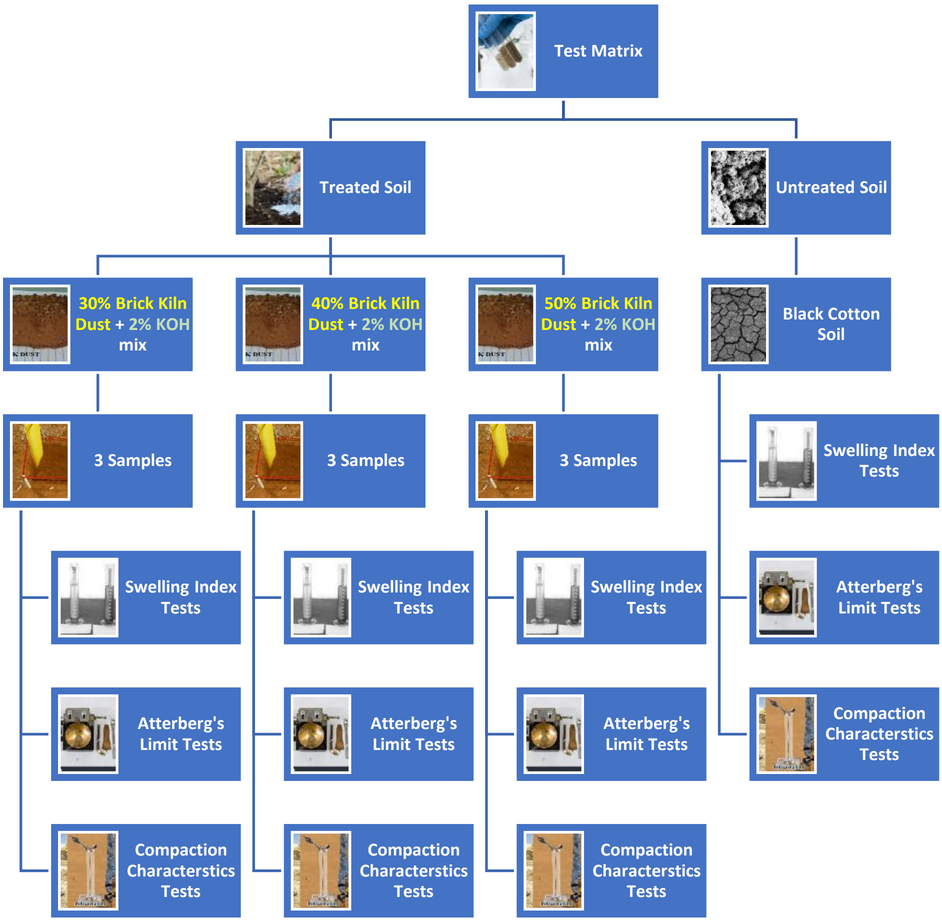


Figure 3.3: Testing Matrix

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3.4. Basic Testing

Sieve Analysis, Treatment of Brick Dust with Alkali (KOH), Atterberg Limits, Moisture content, swelling index and Unconfined Compressive Strength are conducted in the laboratory according to the ASTM standards. Each test was conducted with and without alkali activated brick dust.

It should be noted that all these experiments were first performed on expansive soil following the procedure mentioned below and then same experiments were performed using 30%, 40% and 50% brick dust along with different proportions of potassium hydroxide in expansive soil. Then in the results, we are going to compare all these results to check at which proportion our swelling potential is declined.

3.4.1. Sieve Analysis Test

This test was conducted according to the (ASTM D422-63). Each test is done on two samples, one with alkali activated brick dust in expansive soil and other one without it but same procedure will be followed for both samples.

Following is the procedure:

We are using 500 grams of expansive soil. Brick Dust is passed through sieve number 40 and then it is used in soil and then grain sieve analysis must perform. The weight of the given dry expansive soil sample is written as well. All the sieves are placed in the order depending on the sieve size. The pan is placed at the bottom. The soil is poured and shake well with the mechanical shaker. The weight of soil on each sieve is noted.

3.4.2. Atterberg Limit Test

This test is conducted through (ASTM D4318-00). Three samples are prepared. First liquid limit and then plastic limit procedure is mentioned below:

Liquid Limit:

Note down the mass of three moisture cans. A dry soil weighing 250 gm passed through no. 40 sieve along with brick dust mixed with 2 grams of KOH is collected in evaporating dish. A uniform paste is formed by adding water. A part of paste is placed in

Casagrande apparatus. The surface is then levelled with spatula while keeping the depth of 8mm. Grooving tool is used to give a cut in the center of the soil placed in Casagrande apparatus. Blows are then given at about 2 revolutions per second. Keeping the no. of blows(N) between 25 to 35, the groove in the soil is closed to a distance of half inch. Specimen is collected in the moisture cap. The weight of the can and moist soil was determined. The same process was repeated for blows between 20 to 25 and the weight was determined again.

Plastic Limit

Take 20 g of dry soil and pass it through sieve No. 40, Similarly, take brick dust passing through sieve no 40 and 20 grams of KOH is put into a porcelain evaporating dish, then it is mixed with water thoroughly. Weigh the moisture of the soil sample. It is then squeezed with fingers and as a result ellipsoidal-shaped soil is prepared. With the help of palms of hands soil sample is rolled on a glass plate giving 80 to 90 strokes per minute. When the soil sample is reduced to⅛ in (3.18 mm) after the rolling motion of palms it is further reduced into pieces. Pieces of sample is squeezed between the fingers to form an spheroidal mass again. Weight of the mould and wet soil was determined and it is placed in the oven for 24 hours. After 24 hours mould is taken out of oven and weight of dry soil and mould was determined in grams. Through liquid limits and plastic limits, classification of soil from the site was carried out.

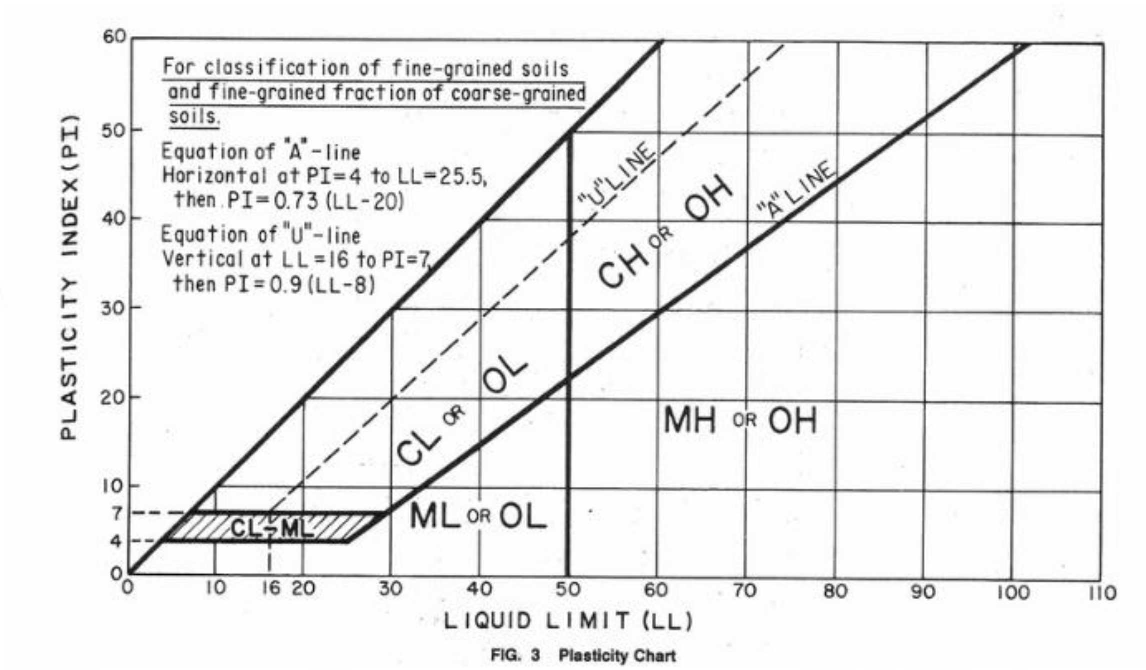


Figure. 1 Plasticity Chart

3.4.3. Unconfined Compressive Strength Test

The unconfined compressive strength (UCS) test is carried out by (ASTM D2166/2166M-13). Same two samples are prepared.

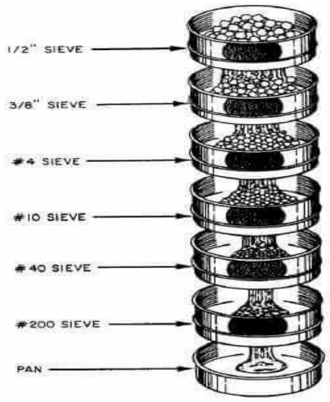
The soil sample from Shelby tube sampler is extruded. A soil specimen is cut so that the ratio (L/d) is approximately 2. Where L and d are the length and diameter of soil specimen, respectively. The exact diameter of the top of the specimen is measured at three locations 120° apart, and the same measurements is made on the bottom of the specimen. Average the measurements and the average as the diameter on the data sheet is recorded. The exact length of the specimen is measured at three locations 120° apart, and average the measurements and the average as the length on the data sheet is recorded. The deformation (ΔL) corresponding to 15% strain (ε) is calculated. The specimen is placed carefully in the compression device and center it on the bottom plate. The device is adjusted so that the upper plate just makes contact with the specimen and the load is set and deformation dials to zero. The load is applied so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and the load and deformation dial readings are recorded on the data sheet at every 20 to 50 divisions on deformation the dial. The load was applied to keep until the load (load dial) decreases on the specimen significantly, the load holds constant for at least four deformation dial readings, or the deformation significantly pass the 15% strain that was determined in step 5.A sketch is to draw to depict the sample failure. The sample is removed from the compression device and it obtains a sample for water content determination.

3.4.4. Proctor Test

This test is conducted through (ASTM D698-12 and ASTM 1557-12). Two samples were going to made, one with expansive soil and one with different proportions of alkali activated brick dust in expansive soil.

Following procedure was adopted for the test:

Depending on the type of mold using sufficient quantity of air-dried soil in large mixing pan. For the 4-inch mold take approximately 10 lbs, and for the 6-inch mold take roughly 15lbs. The soil is pulverized and passed it through the # 4 sieve. The weight of the soil sample was determined as well as the weight of the compaction mold with its base (without the collar) by using the balance and the weights is recorded. Compute the amount of initial water to add by the following method: (a) Assume water content for the first test to be 8 percent. The water was measured, it is added to the soil, and then it was mixed thoroughly into the soil using the trowel until the soil gets a uniform color. The compaction mold to the base was assembled, some soil in the mold was placed and the soil in the 3 number of equal layers is compacted specified by the type of compaction method employed. The number of drops of the rammer per layer is also dependent upon the type of mold and test. The drops should be applied at a uniform rate not exceedingly around 1.5 seconds per drop, and the rammer should provide uniform coverage of the specimen surface. The soil should completely fill the cylinder and the last compacted layer must extend slightly above the collar joint. If the soil below the collar joint at the completion of the drops, the test point must be repeated. (Note: For the last layer, watch carefully, and add more soil after about 10 drops if the collar was removed carefully and trim off the compacted soil so that it is completely even with the top of the mold using the trowel. Small bits of soil were replaced that may fall out during the trimming process. The compacted soil was weighed while it's in the mold and to the base, and the mass was recorded. The wet mass of the soil is determined by subtracting the weight of the mold and base. The soil was removed from the mold using a mechanical extruder and soil moisture content samples from the top is taken and bottom of the specimen were taken and filled with soil and the water content is determined. The soil specimen is placed in the large tray and break up the soil until it appears visually as if it will pass through the # 4 sieve, add 2 percent more water based on the original sample mass, and re-mix as instep 4. Steps 5 through 9 until was repeated, based on wet mass, a peak value is reached followed by two slightly lesser compacted soil masses.



a) Sieve Analysis b) Casagranda Apparatus

c) UCT apparatus d) Proctor Test Apparatus

Figure 3.4: Apparatuses for Laboutory Tests

3.6. Sustainability aspect exploration

In this design project the waste of the brick is being used that makes it the sustainable because during the construction many of the bricks wasted and its dust that is going to use in the soil which is also sustainable for the future use. Different forms of brick waste have been used in various civil engineering applications include crushed aggregates, dust form, and brick powder form.

3.7. Summary

The applications and uses of brick waste in geotechnical and civil engineering have been studied in this research. Brick waste, in different forms, has been used in many civil engineering applications, it used as aggregate materials, pavement subbase material, filter material in permeable pavements, filling material, as filler in filled pozzolanic cement, as a fine and coarse aggregates in concrete production, and as a soil stabilizer. Different forms of brick waste have been used in various civil engineering applications include crushed aggregates, dust form, and brick powder form. The best stabilization effect of brick waste can be obtained at the optimum content, this content, in general, varied from 40% to 50%., actually, a lower brick content is required as an optimum content when brick waste applied to soil stabilized with other material like cement, lime, or fly ash. However, the efficiency and content of brick waste are dependent on factors like soil type, initial soil condition, soil composition and its mineralogy, and etc. Application of brick waste in the stabilization of soil provides good results when compared to other stabilizers like lime, fly ash and cement. From an economic point of view, such application provides a cheaper alternative to conventional materials. Environmentally, using a vast amount of brick waste in soil stabilization and other civil engineering applications is lead to greener construction material and help in reducing wastes in the environment.

CHAPTER 4

RESULTS AND ANALYSIS

4.1. Background

This chapter discuss the experimental results obtained from different tests. The results of the index property test (grain size analysis and Atterberg's limits tests), the strength tests (compaction and UCT) are hereby discussed. Through graphs and tables different proportions of alkali activated brick dust has been compared. And better results have been achieved through higher proportion of alkali activated brick dust.

4.2. Basic Results

The results of the index property test (grain size analysis and Atterberg's limits tests), the strength test (compaction and UCT) hereby discussed through different graphs, comparing results at different proportions addition of admixture. The basic results of the performed tests have been achieved to check whether the alkali activated brick dust is useful or not in the soil.

4.2.1. Sieve Analysis

The soil samples were collected from Overseas Block Bahria Town Phase VIII. The soil consists of mostly fine-grained clayey soil with high swelling potential from the initial observation. The results of Particle Sieve Analysis are given in Fig. 4.1 Here one point should be noted that Sieve Analysis was performed for untreated expansive soil only. A particle size distribution curve gives us an idea about the type and the gradation of the soil. Grain Size Distribution indicates if a material is well graded, poorly graded, uniformly graded, fine or coarse.

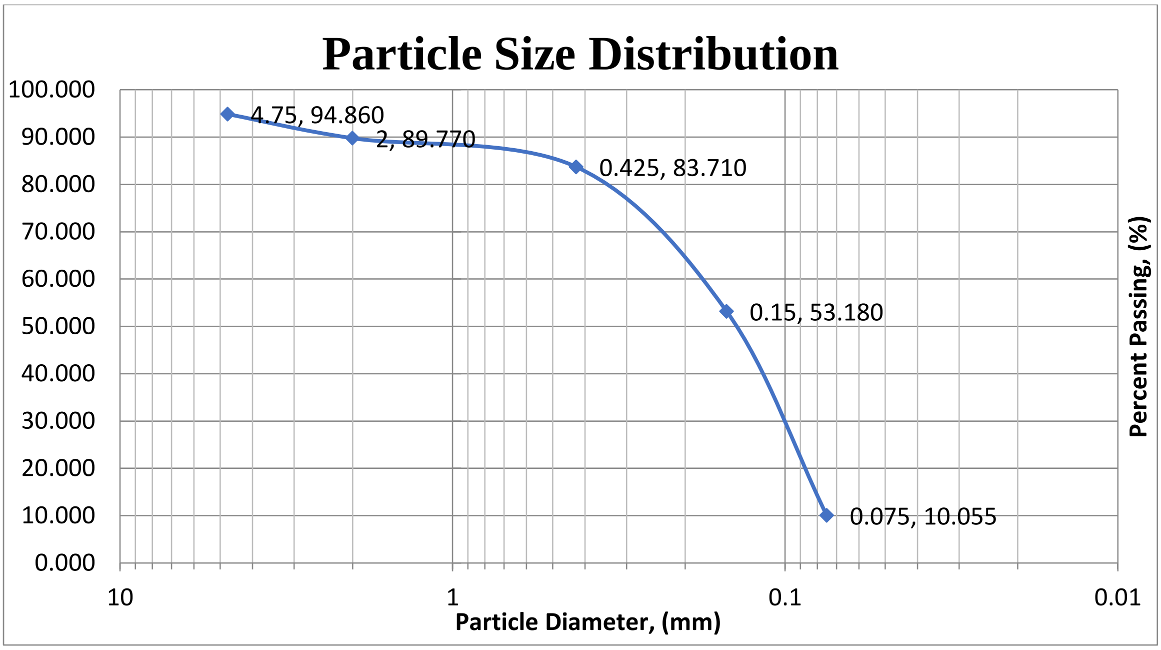


Figure 4.1: Gradation Curve of the Used Soil

4.2.2. Atterberg's Limits

Atterberg Limits play an important role in soil identification and classification. Table 4.1 shows the result of Atterberg's Limit for the untreated soil and activated brick dust improved soil. The liquid limit values for 30% replacement are nearly equal to 33 which 18% less than the virgin soil value. As same for 40% replacement liquid limits value decrease by 30% and for 50% burnt brick dust it reduced by 34%. The immediate and long-term effects combine together to bring out the beneficial changes in the plasticity characteristics. As same reduction is identified in plastic limit and plasticity index. Reduction in plastic limit value for 30, 40, 50 % burnt brick dust are respectively 14.39, 12.37, & 11.96 %. As same reduction in plasticity index for 30, 40, 50 % brick dust are respectively 19.98, 17.63, & 17.04%. This maximum reduction obtained with the least amount of stabilizer. Plasticity Index varies directly with liquid limit, plastic limit, linear shrinkage and varies inversely with shrinkage limit. It is known by the results mentioned below that addition of alkali activated brick dust has reduced the thickness of diffuse double layer clay particles, caused flocculation of clay particles, and increased the coarser particles content by substitute finer soil particles with brick dust. By the replacement of black cotton soil from the burnt brick dust it is identified that the values of

Atterberg's limits are decreasing with increasing the stabilizing content is shown in table 4.2

Description	Expansive Soil	30% BD	40% BD	50% BD
Liquid Limit	39	33	30	29
Plastic Limit	14.34	13.02	12.37	11.96
Plasticity Index	24.66	19.98	17.63	17.04

Table 4.2 : Atterberg's limit values for mix proportions of soil & brick dust

Figure 4.3 shows the plasticity chart for the classification of expansive soil. According to the unified soil classification system plasticity chart, the expansive soil is classified as CL (low-plasticity clay).

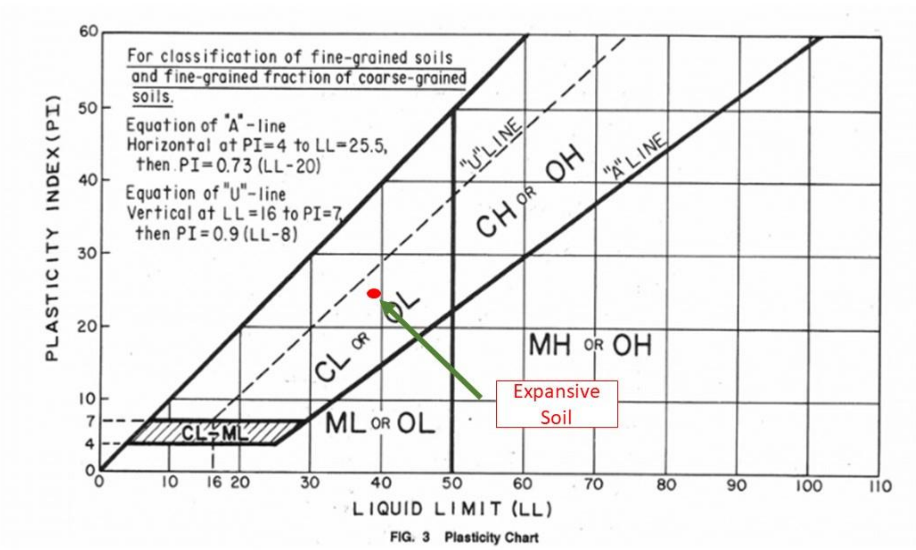


Figure 4.3 Plasticity Chart

4.2.3. Unconfined Compressive Strength

The unconfined compressive strength variation with AABD additive is graphically presented as shown in Figure 4.4. It is observed that alkali activated brick dust demonstrated significant improvement in unconfined compressive strength. The increment of strength depends on the amount of BD added. When 30 % ,40 % & 50% AABD added to the expansive soil, the unconfined compression strength increases from 231 KPa(untreated) to 347Kpa ,464Kpa & 510 KPa respectively.

Stress–strain graphs of the Unconfined Compression Strength Test showed that although alkali activated brick dust caused increase in strength, maximum stress for improved samples has yielded in greater strains however improved samples with brick dust have deformed softly after yielding. While brick dust caused a brittle behavior and samples showed a sudden deformation. In order to investigate on the UCS of treated soils, the test samples were prepared with different percentages additives and mixed with soil. A summary of the UCS results is tabulated in Table 4.3. The results showed that the UCS increased by increasing the additive percentage. In the case of using brick dust as a stabilizer. Figure 4.4 shows changes in UCS for the improved soil by brick dust at curing times of 14 days.

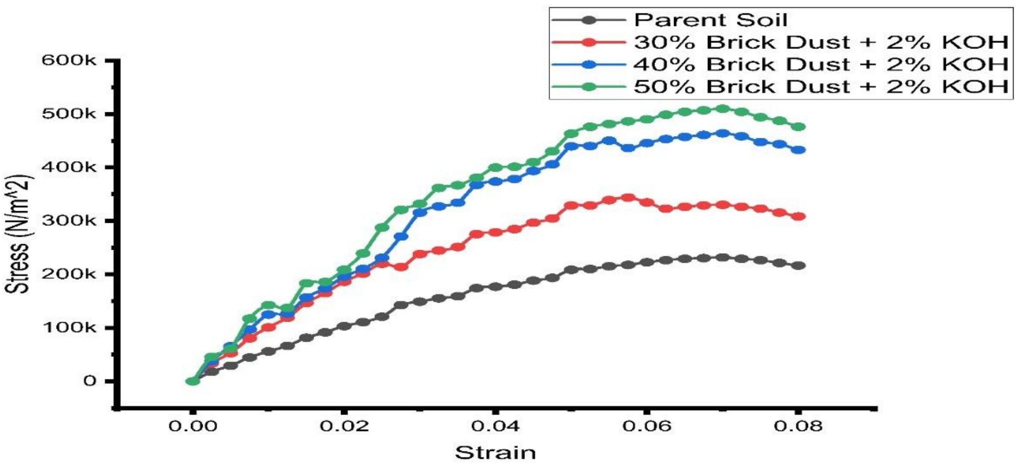


Figure 4.4: Influence of Brick Dust on Unconfined Compression Strength of the Soil

4.2.4. Modified Proctor

Table 4.5 is showing how the soil is improved with adding this admixture through Modified Proctor Test.

	Expansive Soil	30% BD	40% BD	50% BD
MDD (g/cm^3)	1.85	1.97	2.04	2.12
OMC (%)	15.57	14.78	13.69	12.98

Figure 4.5 shows the impact of brick dust on maximum dry density and optimum moisture content. From the Figure 4.5 it is concluded that with the increased amount of Brick Dust by percentage weight of expansive soil, dry density has increased, and optimum moisture content has decreased. Brick dust was less sensitive to variation in moisture content than soils. This could be explained by the higher air void content of brick dust. Soils normally have air void content ranging between 1% and 5% at maximum dry density, whereas brick dust contains 5% to 15%. The higher void content could tend to limit the buildup of pore pressures during compaction, thus allowing the brick dust to be compacted over a larger range of water content. Modified proctor compaction test was carried out on the brick dust treated soils. The effect of the brick dust treatment on the maximum dry unit weight and optimum water content for the soils are shown in Figure 4.3. There is a clear tendency that the maximum dry unit weight increases at 50% brick dust content and then decreases whereas the optimum moisture content decreases gradually with increase in brick dust content. The cause for the reduction in the optimum water content when increasing the brick dust content can be explained as follows:

a. The cation exchange between additives and expansive soil decreases the thickness of electric double layer and promotes the flocculation. The flocculation of the solid particles implies that the water-additives–soil mixtures can be compacted with lower water content, and the optimum water content is reduced.
b. The decrease in the optimum water content indicates that expansive soil can be stabilized by adding brick dust even for soils with low water content.

c. The decrease of the maximum dry unit weight with the increase of the percentage of brick dust is mainly due to the lower specific gravity of the brick dust and compared with expansive soil, and the immediate formation of cemented products which reduce the density of the treated soil. The reduced dry density therefore reduces the swell shrinkage properties of the compacted expansive soils.

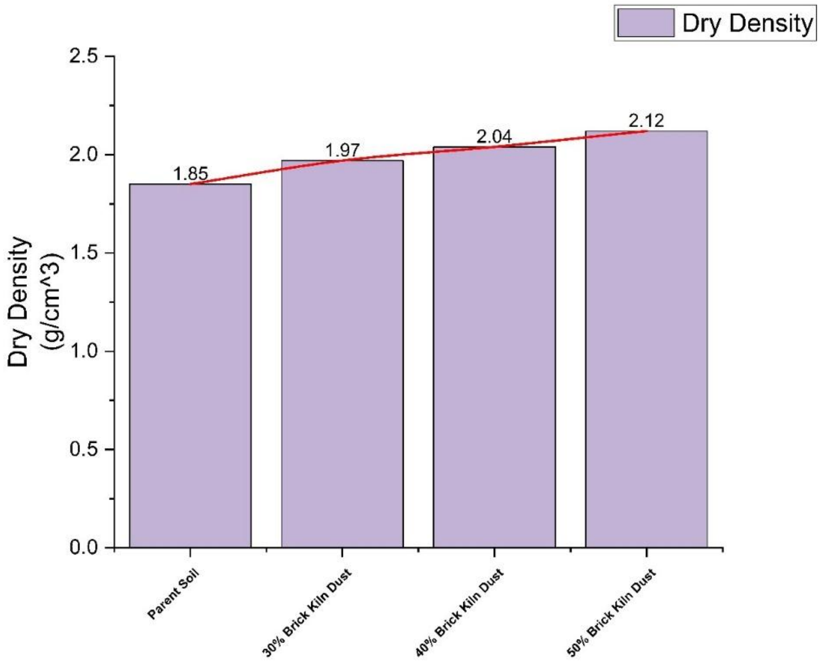


Figure 4.5(a): Maximum Dry Density for Mix Proportions Soil & Brick Dust

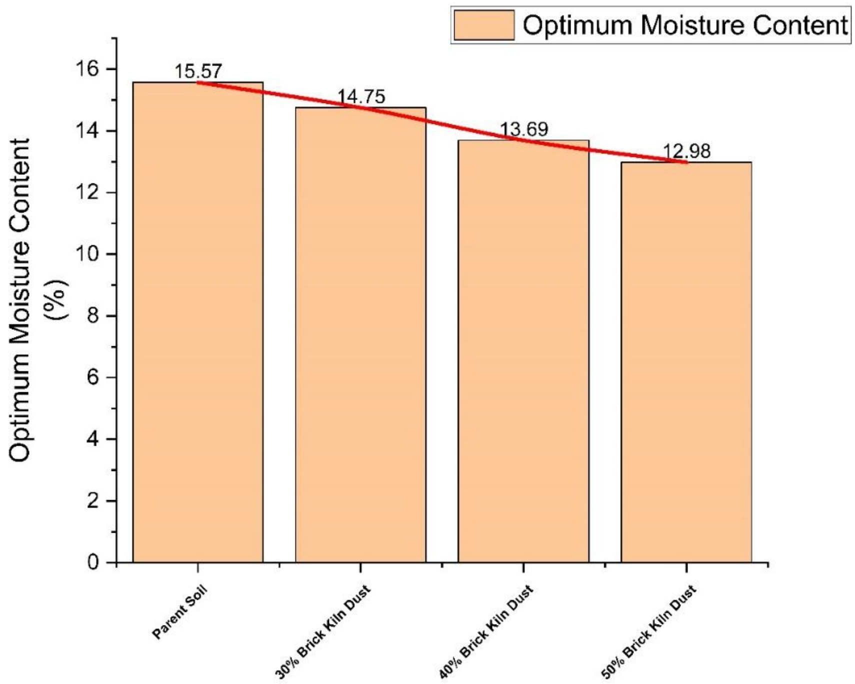


Figure 4.5(b): OMC & Brick Dust

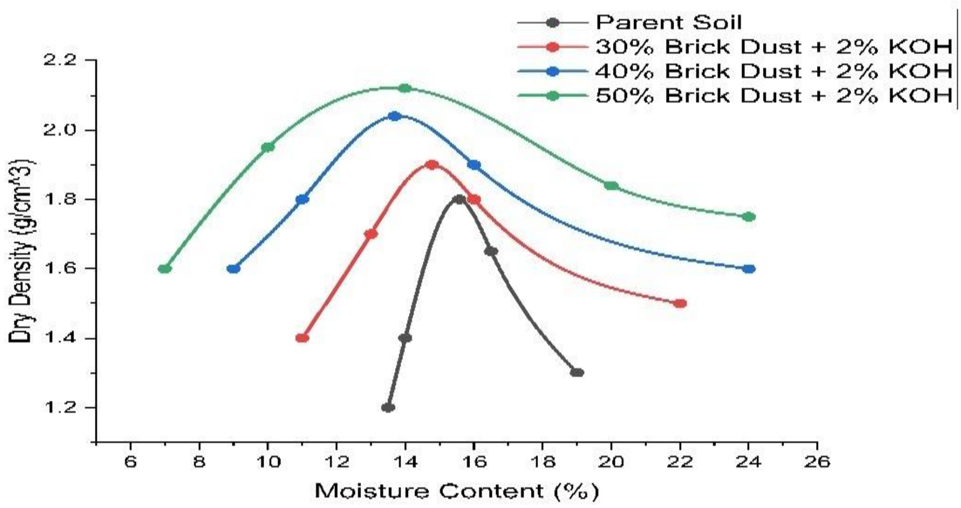


Figure 4.5(c): OMC & DD

4.3.2. Determination of Swelling Index from Plasticity Index

Our main purpose of the project has been achieved through decreasing the value of free swell index by increasing the percentage of admixture.

According to Elbadry, H. (2017), Empirical relation b/w swell potential and plasticity index. The relation ship between plasticity index and swelling index is shown in table 4.6

$$SP = \left(2.16 \times 10^{-3}\right) \times P.I^{2.44}$$

Plasticity Index	Shrinkage Index	Potential Swell Index
<12	<15	Low
12-23	15-30	Medium
23-32	30-40	High
>32	>40	Very High

Table 4.6 shows that Potential Swelling Index of untreated expansive soil lies in high zone however it can be clearly seen by addition AABD the plasticity of the soil has decreased and effected the potential swelling index. The soil treated with AABD lies in Medium Potential Swelling Index Zone.

	Expansive Soil	**30% BD**	**40% BD**	**50% BD**
Plasticity Index	24.66	19.98	17.63	17.04
Free Swell Index	High	Medium	Medium	Medium

Table 4.6: Free Swell Index

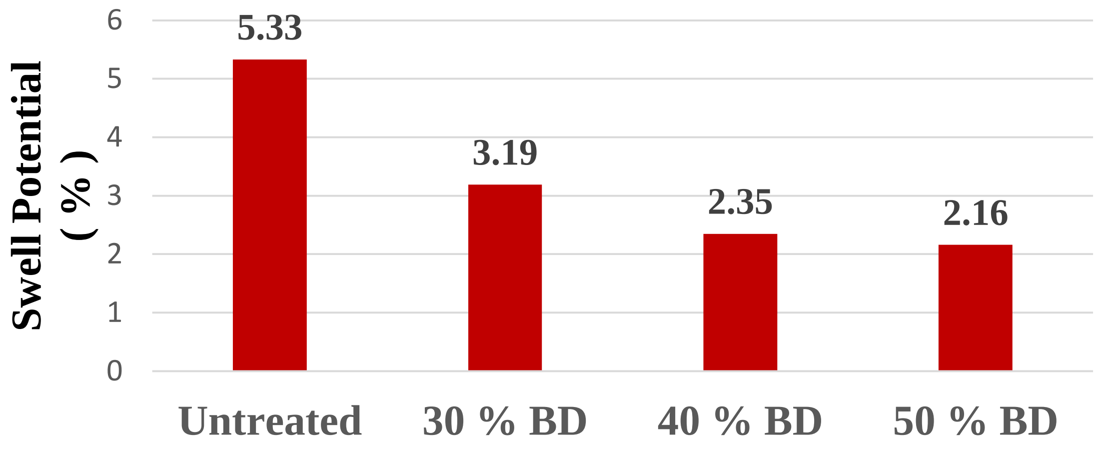


Figure 4.7 : Free Swell Index

4.4. Summary

It can clearly see in all the results and discussions that soil is being improved by adding AABD in expansive soil and notice that at 50% addition soil is mostly improved. An evaluation of the expansive soil stabilized with brick dust systems are presented. The results of swelling measurement tests proved the treatment of soil with brick dust used has significant impact on reducing swelling potential and pressure. On the other hand, adding 50% brick dust caused a significant increase in the shear strength parameters of improved soil samples. Considering changes in the shear stress versus changes in lateral deformations, the treated soil showed more deformation values when compared to the brick dust-treated samples. In addition, the result of compaction tests indicated that addition of brick dust could cause an increasing in maximum dry unit weight and also reducing soil optimum moisture content. The results of the Atterberg limits tests also showed the presence of waste on the Atterberg limits was significant. The UCS results indicated that curing time had a significant effect on increasing the bearing capacity of improved soil samples.

CHAPTER 5

ANALYSIS AND DISCUSSION

5.1 Background

Above results has shown some incredible figures by adding three different proportions of alkali activated brick dust. This can be a game changing for engineers to overcome the problem of expansive soil in the future. For civil engineers, these results are really significant. As it will really help them to overcome the problem of expansive soil and decline the overall cost of the project. Industry can use this alkali activated brick dust in soil to improve soil and decreases the cost of the project.

5.2 Percentage improvement with Alkali Activated Brick Dust

Above performed experiments are compared below and clearly showing that soil is improved by using AABD at 50% in expansive soil. All parameter of the soil being calculated and interpreted to obtain desired results. The above observations and calculations can lead us to as an effective method to utilize brick dust in the stabilization of expansive soil. The conclusions are based on the tests carried out on various clay-brick dust mixes selected for the same. The addition of brick dust reduces the plasticity characteristics of expansive soil. The liquid limit, plastic limit, plasticity index, linear shrinkage decreased drastically and shrinkage limit increased with the addition of brick dust. The free swell Index value and swelling pressure is found to decrease with increase in fly ash content. The maximum dry density increases up to 50% brick dust mix, and then gradually decreases whereas the optimum moisture content decreased with increase in brick dust content. Maximum Unconfined compressive strength was obtained at 50% brick dust mix with clay and further addition of brick dust reduces the strength.

Alkali Activated Brick Dust has good potential for use in geotechnical applications. The relatively low unit weight of brick dust makes it well suited for placement over soft or low bearing strength soils. Its low specific gravity, freely draining nature, ease of compaction, insensitiveness to changes in moisture content, good frictional properties, etc. can be gainfully exploited in the construction of embankments, roads, reclamation of low-lying areas, fill behind retaining structures, etc.

DISCRIPTION	Expansive Soil	30% BD	40% BD	50% BD
Liquid Limit (%)	39	33	30	29
Plastic Limit (%)	14.34	13.02	12.37	11.96
Swelling Index	High	Medium	Medium	Medium
Proctor Test OMC (%)	15.57	14.78	13.69	12.98
Unconfined Compressive Strength(kPa)	231	347	464	510
Plasticity Index (%)	24.66	19.98	17.63	17.04

Table 5.1 Geotechnical Results of the Treated Samples

5.3. Sustainable use of Improved Soil

By using industrial waste as in the form of Brick Dust, our soil has been improved and can be used locally in any construction projects. By using industrial waste as in the form of Brick Dust, our soil has been improved and can be used locally in any construction projects. An ideal or native soil could be used as a reference to evaluate a soil in question assuming that the reference soil contained the ideal characteristics. This approach might work in tilled soils derived under native grassland using virgin sites, if available, as a reference. Soil quality characteristics from the reference soils could then be used to evaluate those soils in question. This approach would have to assume that native soils possessed ideal soil characteristics and that agricultural practices degrade soil; however, there are examples where sound agriculture practices can enhance soil quality through improvement of nutrient status, drainage, and physical characteristics. Using an ideal or native soil as a reference would not be possible for soils derived under forest vegetation and now under cultivation as the soil profile characteristics would have been changed considerably.

A more commonly accepted working definition of soil quality is based on its capacity to perform productivity, environmental, and health functions. They have defined soil quality as "the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health." Thus, the definition involves more than the capacity of soil to produce crops. The relation of soil quality to crop productivity is probably the best understood of the soil quality components. Most soil scientists agree that soil organic matter is a key desirable component in all three performance categories. Yet, it alone is not an adequate indicator of soil quality or health (Doran et al 1994).

5.4. Guidelines for practical engineers and designers

- For the practical implementation, it should be kept in mind that expansive soil should be classified and lie in CL category.
- 1 liter of KOH per 20 grams should be added in expansive soil.
- All tests should be conducted according to the ASTM Standards.
- All materials used in this project should be in raw form without any impurities.

5.5. Summary

It is concluded that by adding 50% AABD in the expansive soil, soil shows incredible result for us. Atterberg’s Limits decreases and UCS also declines. Soil gains more strength against all kind of forces. From the results of the present study, brick dust can be said to be a good stabilizer of expansive clay soil. There is reduction in soil plasticity and linear shrinkage when blended with brick dust. The brick dust coats and binds the clay clasts together and fills the voids in the clay. This brings an increase in soil aggregation, alteration of the effect of clay minerals and reduction in water absorption, hence improvement in swelling properties and in the workability of the soil. Compaction results show that both maximum dry density increased and optimum water content decreased with increased brick dust content. This is attributed to aggregation and flocculation of particles resulting from reactions between brick dust and clay. There is substantial improvement in the shear strength of the clay soil as brick dust content increases.

In Pakistan where these brick dusts are produced in very large quantities, their use as soil stabilizer in highway construction is surely a positive welcome development. In addition to already being available in large quantities, and being considerably less expensive than Portland cement and lime, their use will eliminate the unaesthetic sight of their heaps and reduce the environmental hazards posed by those heaps.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A series of laboratory tests were carried out to investigate the influence of AABD admixture on the characteristics of expansive soils. The conclusions can be summarized as follows:

1. The experimental results of untreated expansive soil indicated a liquid limit and plastic limit of 39% and 24% respectively. Based on the Unified Soil Classification Plasticity Chart, the expansive soil is classified as CL. The samples show the Unconfined Compressive Strength of 350 kPa, while the Max Dry density and the Optimum moisture content are 1.85 and 15.57 respectively.
2. The findings achieved from the experiments show the liquid limit of 34%, 30% and 29% for the soil improved with 30%, 40% and 50% AABD respectively. The swelling index of the improved soil with 30%, 40% and 50% are 24.2 ,19.6 and 16.2 respectively. The Unconfined Compressive Strength for the 30% ,40% and 50% is 347kPa, 464 kPa and510 kPa respectively. The result show that increasing the percentage of AABD tend to enhance the mechanical strength and reduce the liquid limit and swelling index of expansive soil.
3. Based on the results achieved for the compressive strength and swelling index, the improvement is more pronounced in the range of 30% to 40%. Furthermore, the utilization of AABD beyond 40% resulted in less improvement. Hence the study suggests an optimum value of AABD of 40% for improvement of expansive soil.
4. The usage of AABD have successfully improved the geotechnical properties of expansive soil hence AABD can be applied as a additive for soil improvement rather than discarded as landfill. The utilization of brick dust as a soil additive will help to

solve the dumping problem, decrease the project cost and will bring sustainability in soil improvement.

6.2 Recommendations

The conclusions can be summarized as follows:

1. From the results it is concluded that the impact of brick dust on black cotton soil is positive. By replacing soil by 40% of its dry weight by brick dust it gives optimum improvement in the engineering properties of black cotton soil. So, use of brick dust is preferable for stabilization because it gives positive results as stabilizer and also it is a waste utilization.
2. The results show improvement in geotechnical properties of soil by using AABD as a soil stabiliser. By keeping the quantity of Potassium Hydroxide constant (KOH) (2%) and variation in Brick Dust improvement in the soil is achieved, A variation in the quantity of KOH solution is recommended for further research.
3. Due to scarcity of time Cost Analysis of the study is not addressed, it is recommended to study the economical aspect of the study for industrial.

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