Effects of Mechanical Stabilization on Expansive Soil using Ambo Sand Stone as Subgrade Material

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Abstract
Expansive soil is a clay soil that changes its volume depending on the seasonal variation of the moisture. These types of soil create serious problems to the civil engineering structures. To improve this different researchers found different method, among this mechanical stabilization using locally available materials are the one. Therefore these study was done on the stabilizing the expansive properties of soil of Ambo city by locally available material.To perform this study soil was taken from five (5) pits, on 15km under construction road in Ambo city and Ambo sand stone from Sankale Faris. This study was done by mechanically mixing the ambo sand stone with expansive soil by percent. The mix ratio was prepared by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% for ambo sandstone of mass of soil and the engineering properties of pure expansive soil and mixed soil with sand stone were done accordingly.The lab result indicates that as sand stone increases in the mixes, the liquid limits, plastic limits, shrinkage and free swell of treated soil decreases, the CBR increases. The UCS increase as the sand stone percentage increases to 60% and then decreases. Hence, the addition of this stabilizer decreases the plasticity properties of the treated soil. Therefore, the optimum mix ratio was attained at 60% ambo sand stone to stabilize the soil. The mixes of ambo sandstone changes the geotechnical properties of the natural soil and makes this soil to be suitable for subgrade construction.
Keywords: Geotechnical properties, Sand Stone, Stabilization, Subgrade, Swelling
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1. Introduction

Expansive soil is a clay soil that exhibit significant volume changes as a result of soil moisture variation. This type of soil, upon wetting and drying, causes severe damages to pavement constructed on such soil. It has many effects on the life and economy of the country throughout the world. Those problems were conducted by different researchers likes (Gobena and Suppia, 2019A) in the USA, (Gobena et al., 2021) in India, (Gobena and Lollo, 2016) in some European countries constructing a road on inadequate and soft soil and replacing this soil with strong soil. This soil costs billions of dollars in real property damage to structures in the United States each year (Gobena and Suppia, 2019B). Expansive soils are costing a lot worldwide, most of these damages occur to transportation facilities such as highways, railroads, runways, canals, pedestrian walkways among others.

The swelling potential of expansive clay can be minimized or completely eliminated either by pre-wetting, compaction, soil replacement, chemical stabilization or isolation of the clay from moisture. The current highway practice in resolving expansive soil problem is the removal of the undesirable soil and replacement with non-expansive soil. Chemical stabilization and geo-membranes are also in use extensively in countries such as USA, Canada, India and China (Gobena, 2016). Stabilization of the sub-grade material will allow for the design of a thinner overall pavement or alternatively extended life and reduction in required maintenance.

Expansive soils have a great effect also in Ethiopia since the major soil group of Ethiopia is expansive soil. The road sector in Ethiopia is suffering from the high shrink-swell behavior of this expansive soil. Many damages occur each year and road construction over such expansive soil creates serious problems including increasing cost of construction and maintenance (Gobena, 2021)

Although the extent and range of distribution of this problematic soil have not been studied thoroughly: the southern, south-east, and south-west part of the city of Addis Ababa areas and central part of Ethiopia following the major trunk roads like Addis-Ambo, Addis-Woliso, Addis-Debre Berhan, Addis-Gohatsion, Addis- Modjo are some of the areas covered by expansive soils. Areas like some parts of Mekele, Gondor, Bahirdar, Debreberihan, and Gambela are also known to be partly covered by expansive soils (Atahu et al., 2019). The other problem of expansive soil is its susceptibility to erosion.

The soil of Ambo city is heavy clay soil as prior researchers conducted. This is highly an expansive soil (Butt et al., 2019); (craig, 2004) and (Chen, 2004). An expansive soil has the potential for damaging the properties constructed on it due to shrinking or swelling depending on changes in moisture content. To overcome this problem there is a different method to increase the strength of the subgrade materials like borrowing good soil and replacing with soft soil, using chemical stabilization, mechanical stabilization, etc. are some methods to overcome this problem but those methods are not adequate and satisfactory results gained so far. To achieve a compressive solution site-specific condition is required. In this regard, use of locally available material reduces construction cost. Mechanical Stabilization of expansive soil in case of Ambo town where ambo sandstone is locally abundantly available and it is essential to conduct scientific research to use those materials. In this study, Ambo sandstone was used as the effectiveness of mix and efficiency in improving engineering properties of expansive soil.

2. Materials and Method

The study was conducted in Ambo town, which is found in the Oromia region about 110km west of Addis Ababa. The latitude and longitude of Ambo town are 8°59′N 37°51′E / 8.983°N 37.850°E respectively and an elevation of 2101 meters above mean sea levels. The samples were taken from the field purposively to conduct the research. Firstly, samples of soils was taken from the field and stabilizer (Sandstone) from the quarry site. Then, before laboratory tests, the soil taken from the field was air-dried and mixed with ambo sandstone in percentage. After the specimen was prepared, Atterberg limit, shrinkage limit, free swell, proctor test, UCS, CBR, and Swell tests were conducted according to the standard AASHTO, ASTM, ERA, and IS manuals. The mix proportion were 10%, 20%, 30%, 40%, 50%, 60%,70%,80%, 90%, and 100% for ambo sandstone.

3. Results and Discussion

3.1 Properties of Materials

3.1.1 Soil Properties

The relevant engineering property of the soil is evaluated both for natural and stabilized soil samples separately. The tests include; Atterberg limits, compaction, unconfined compressive strength (UCS), and California bearing ratio (CBR) for both soaked and un-soaked samples.

The result of the test conducted and the determination of the properties of the soil before adding the sand were presented in figure 4. The grain size analysis of all soil samples were analyzed and it contains gravel, sand, clay, and silt. Those soil samples are found highly expansive with a range of liquid limit (LL) 76.79-102.61%, plastic limit (PL) 23.05-36.66% and free swell of about 101.33-114.33%. Therefore, according to AASHTO, the soil of the study area (all pits) falls under the A-7-5 soil class and CH as the USCS soil classification system. Soils under this class are classified generally as a material of poor engineering property and not to be used as a sub-grade material.

3.1.2 Determination of Stabilizers Percentage

To determine the percentage of ambo sandstone added to the soil for stabilizing the expansive soil, the atterberg limit, proctor test, CBR%, and UCS of expansive soil and stabilized soil were determined. As the percent of ambo sandstone increases, the liquid limit, plastic limit, plasticity index, moisture content of the soil decreases, and the relative density of the stabilized soil, CBR percentage of stabilized soil increases, and the UCS firstly increased for up to the ambo sandstone increment 60% of the soil mass then decreases linearly. The unconfined compression strength increases for all pits of the soil up to 60% ambo sandstone as shown on figure 4.6 and then linearly decreases. These indicate that a decrease in strength values could be due to less cohesion between the particles in the mixture that means the bonding between the soil and ambo sandstone decreases. For these reasons, it can be concluded that 60% ambo sandstone mixed with a soil mass was an optimum value for soil stabilization.

3.1.2 Effect of Ambo Sand Stone on Atterberg Limit of Soil

The liquid limit of both soil and soil-ambo sandstone mixtures (passing the No. 40 sieve) was used by the Casagrande method. The liquid limit values decreased with the addition of ambo sandstone. The same is true for the plastic limit values; though the rate was, slow than that of LL. The decrease in plasticity index values is mainly due to the decrease of LL values. The variation in Atterberg limits with the addition of sand in various proportions are shown in Figures 5 and 6 respectively. The sample treated with ambo sandstone has a lower liquid limit, plastic limit, and plasticity index than the native soil samples. Therefore, the ambo sandstone changes the properties of Atterberg limits of the native soils. Similar findings were reported in other experimental works on soil stabilization with sand (Eberemu, & Sada, 2013); (Udoeyo and P. U, 2002).

3.1.3 Effect of Ambo Sand Stone on Moisture Density relationship of the Soil

The values of maximum dry density (MDD) of soil treated with ambo sandstone slightly increased for increasing ambo sandstone percentage to the soil samples as shown in figure 7 and the optimum moisture contents continuously decreased for all pits of soils as shown in figure 8. A continuous increase in MDD has been noted mainly because of the higher specific weight of the admixture material. Therefore, the ambo sandstone changes the properties of the moisture density relationship of the natural soil have in its nature.

3.1.4 Effect of Ambo Sand Stone on California Bearing Ratio (CBR) of the Soil
The bearing capacity of study area soils from all pits are between 0.79-1.30. This value shows that soils have a very low bearing value less than the permissible limit for subgrade material as per Ethiopia Road Authority Manuals, Volume I Flexible Pavements and Gravel Roads – 2002 page (3-7). As the percentage of ambo sandstone increases, the value of soaked and un-soaked California Bearing Ratio (CBR) increase for all pits from 0.79-6.25. Figure 9 shows that, as the ambo sandstone percent increased from 10%-60% the values of soaked CBR% increased linearly and then slightly increased above 60%. This increase of the values of CBR% indicates that the addition of the ambo sandstone percent can increase the load-bearing capacity of the subgrade soil and also meets the minimum CBR% provided by the ERA design manual.
3.1.5 Effect of Ambo Sand Stone on Free Swell of the Soil
Some soils, especially heavy clays, are likely to swell during soaking and excessive swelling may indicate that the soil is unsuitable for use as a sub-grade. The addition of ambo sandstone also decreases the swell percent of the natural soil as shown in figure 10 below. The addition of ambo sandstone on native soil can increase the bearing capacity of the soil and makes the expansive soil meet the minimum ERA design standard manual for the subgrade soil. Therefore, the swell properties of treated soil with ambo sandstone decreases and meet the criteria to be used as subgrade materials as per the ERA manuals.
3.1.6 Effect of Ambo Sand Stone on Unconfined Compressive Strength of the Soil
The unconfined compressive strength increases for all pits of the soils with increase in ambo sandstone up to 60% and then decreases as shown in figure 11. These indicate that decrease in strength values could be due to less cohesion between the particles in the mixture. It can be concluded that 60% sand mixed with soil was optimum for soil stabilization.

In general, the maximum dry density increased and optimum moisture content decreased the compaction characteristics enhanced with the addition of sand as the moisture-density curves have been shifted left and upper. These properties support to conclude that the strength gain reached 95.22-105.76% with the addition of sand 60% by soil weight. The demand for water to achieve the desired field density values is lower.

4. CONCLUSION

Based on the result of laboratory investigation the following conclusions and recommendations may be drawn;

- ✓ The laboratory test result of the natural soil showed that the engineering properties of the expansive clay under the study are not meet the standard of the ERA manual therefore, the soil of the study area was not suitable to be used as a subgrade and or embankment fill material unless it’s undesirable properties are improved.
- ✓ The Experimental results showed that the stabilized soil with the Ambo sandstone; Atterberg limits changed in a decreasing mode with ascending percentages of ambo sandstone. Initially, the liquid limit decreases with the addition of sand. The plastic limit showed slight reduction with increasing the sand content. The lower PI values could be mainly attributed to the decrease of LL values. The California bearing ratio (CBR) increases as sand percent increase. The Unconfined compressive test of soil increased up to 60% of ambo sandstone and later slightly decreased with increased the percent of ambo sandstone. Therefore, the optimum value to stabilize expansive clay with ambo sandstone is 60%.
- ✓ The laboratory result shows that the additions of ambo sandstone to the expansive soil decreases the free swell and swell potential. This shows that the properties of expansive soil decrease with the addition of sand and decrease the shrinkage properties of the soil. Hence, the strength of this soil increases with the addition of ambo sandstone.

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Figure 1. Soil Sample

Figure 2. Ambo Sand Stone

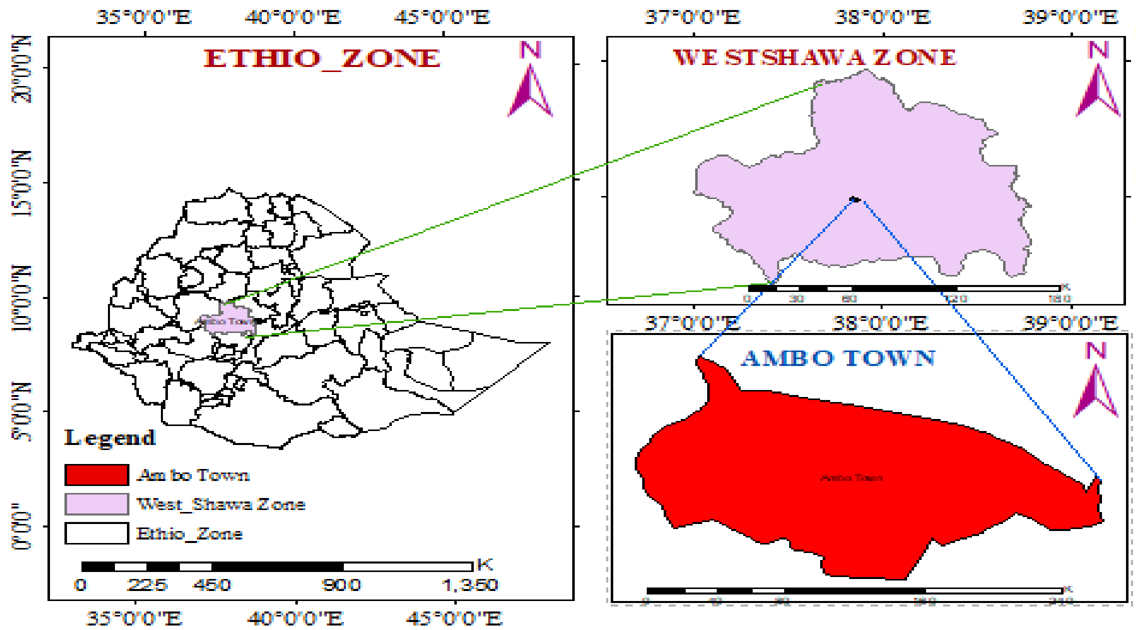

Figure 3. Map of Ambo Town

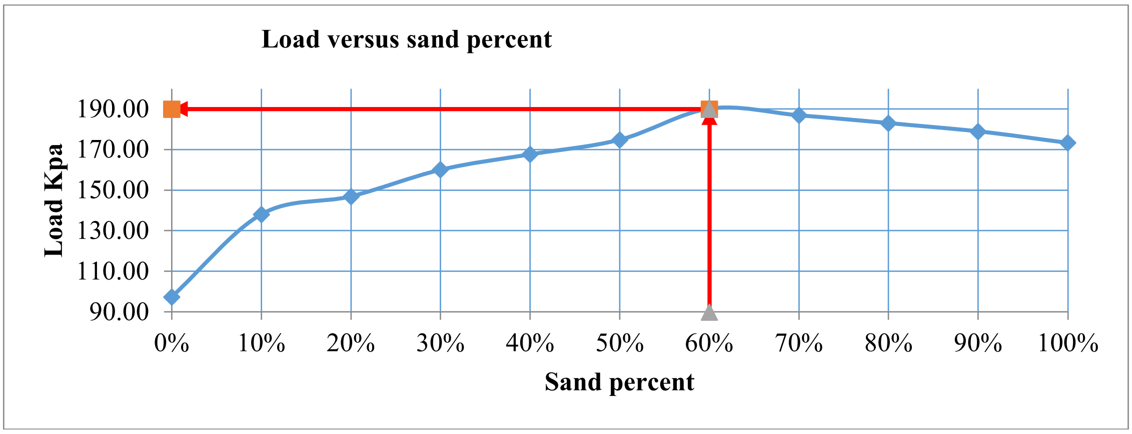

Figure 4. Graph of load for soil mixed with varying sand percent

Table 1. Properties of the soil

Geotechnical property	Pit No.				
	1	2	3	4	5
Initial moisture content %	48.53	51.02	53.06	51.39	40.67
Specific gravity	2.75	2.75	2.71	2.78	2.73
No. Passing 200 sieve	98.80	99.20	99.87	99.92	99.91
LL	76.79	78.30	102.61	89.51	89.21
PL	23.05	31.20	36.66	32.63	35.95
PI	53.75	47.10	65.95	56.88	53.26
Liner shrinkage	17.27	16.4	17.14	16.7	15.71
Free swell	107.33	114.33	103.67	104.00	101.33
USCS	CH	CH	CH	CH	CH
AASHTO	A-7-5	A-7-5	A-7-5	A-7-5	A-7-5
MDD (g/cm^3)	1.47	1.50	1.49	1.49	1.50
OMC %	27.13	26.89	26.15	26.69	27.14
soaked CBR %	0.79	0.75	0.75	0.74	0.76
Un soaked CBR%	0.84	0.85	0.86	0.89	0.92
Swell potential %	3.353	3.496	3.676	3.652	3.627

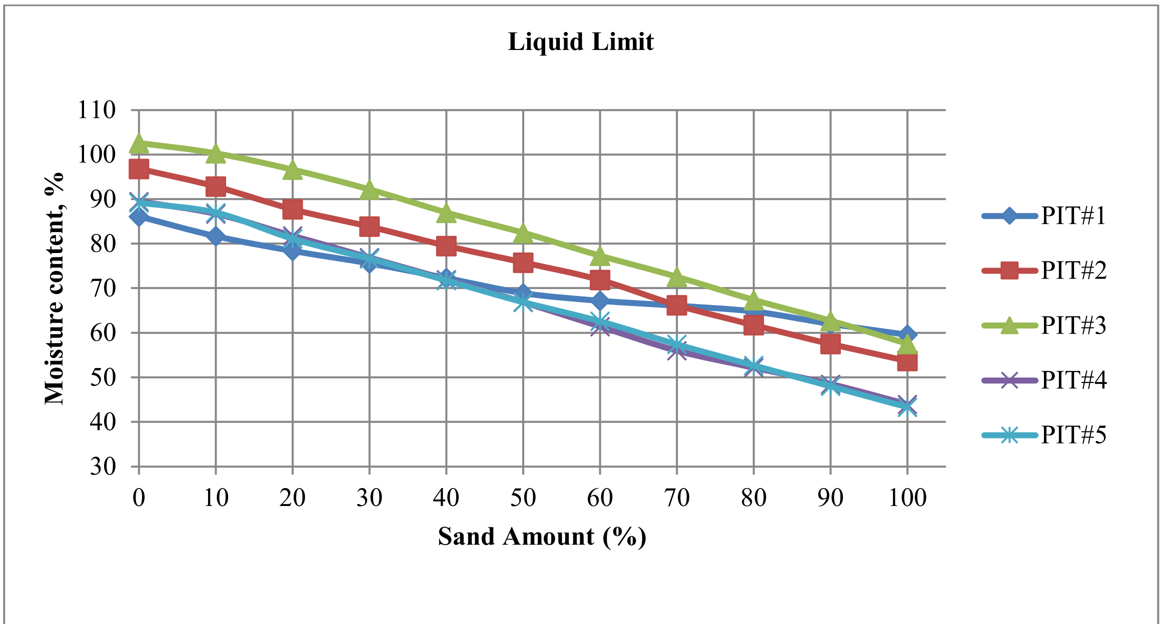

Figure 5. Liquid limits for soil mixed with varying sand content

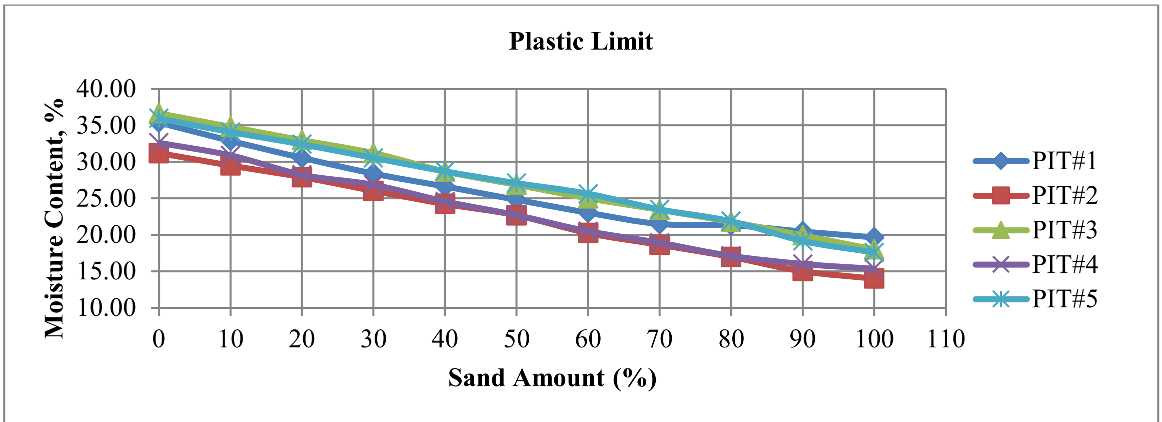

Figure 6. Plastic limits for soil mixed with varying sand content

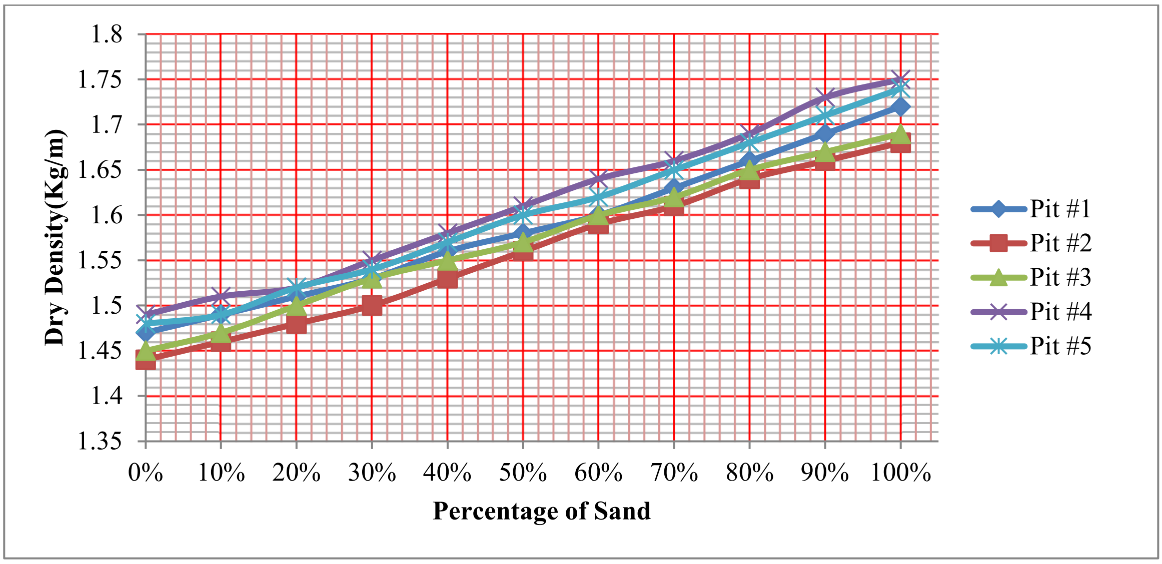

Figure 7. Maximum dry densities for soil mixed with varying sand content

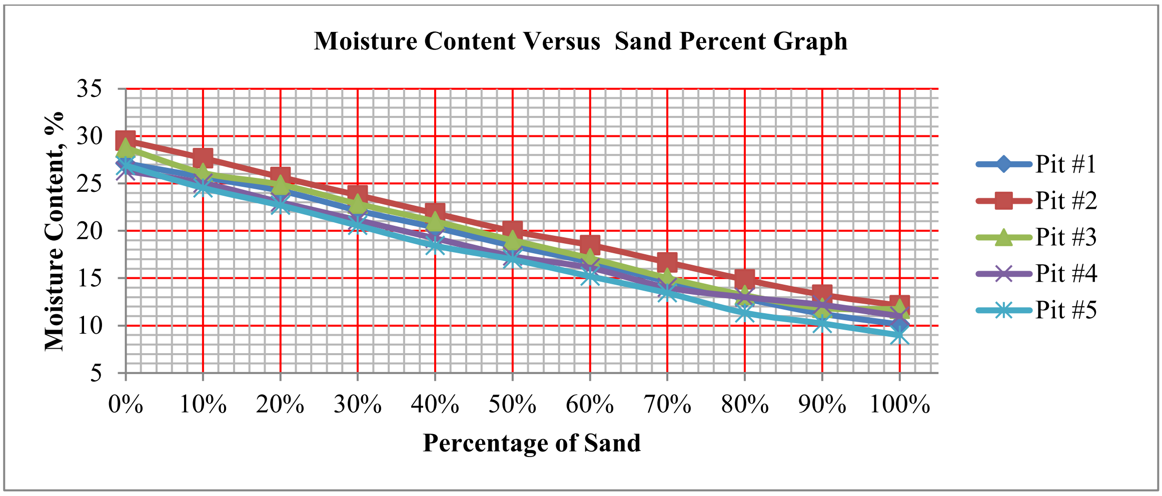

Figure 8. Moisture Contents for soil mixed with varying sand content

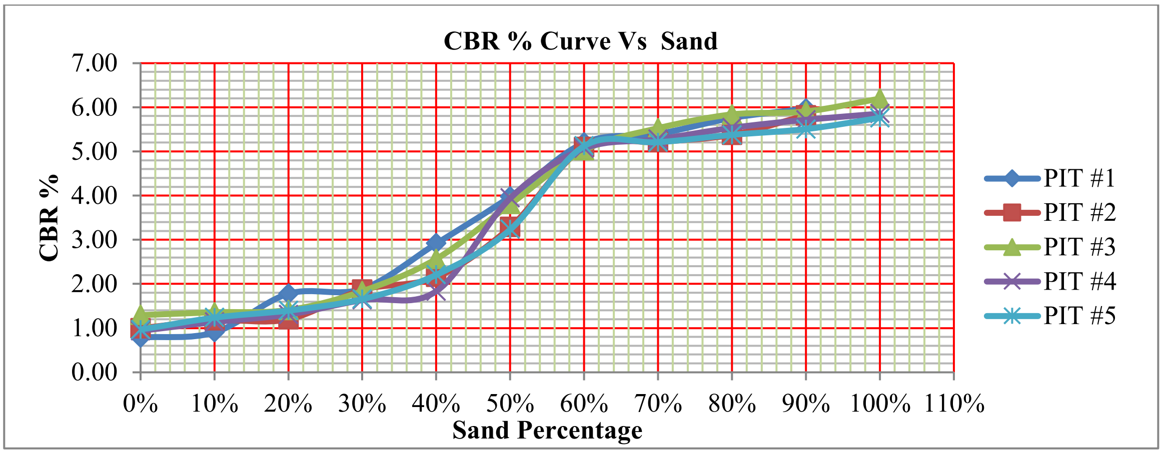

Figure 9. Graph of CBR percentage for soil mixed with varying sand content

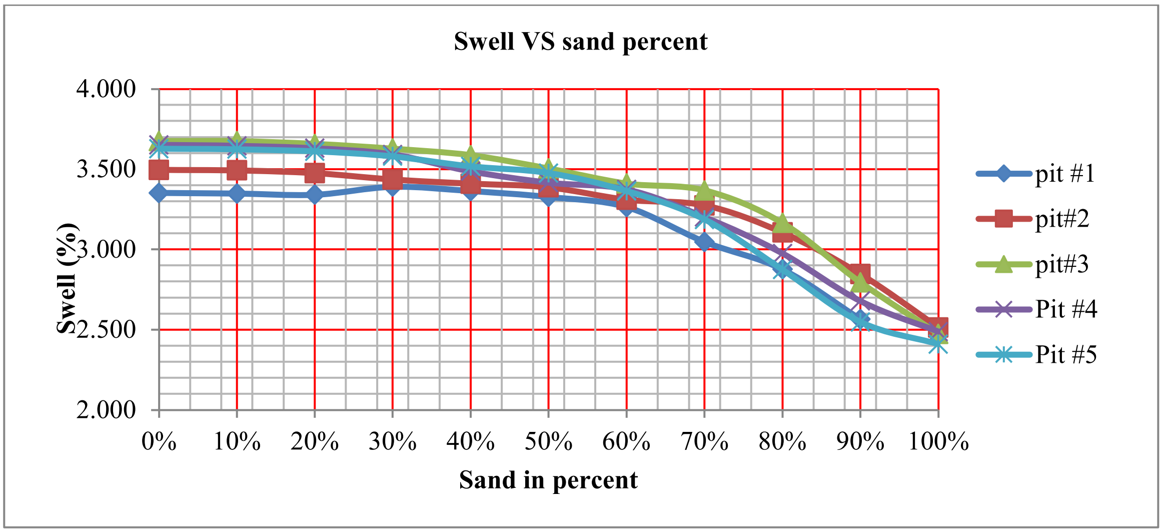

Figure 10. Graph of Swell percentage for soil mixed with varying sand content

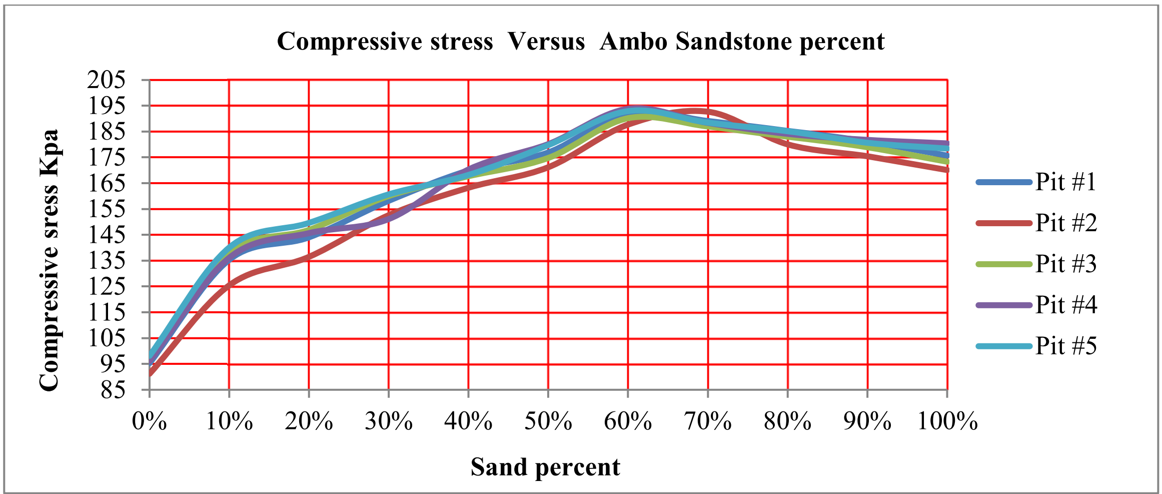

Figure 11. UCS for soil mixed with varying sand content