EFFECT OF COMPACTION ENERGY ON CLAYEY SOIL STABILIZED WITH ADDITIVES

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ABSTRACT

Clayey soils are normally accompanied by volumetric changes when subjected to change in moisture content. Also, the majority of our land consists of soft soil. These soils need to be compacted or improved to reduce settlement and to improve bearing capacity. Also fits in the base of the load bearing structure. Surrounding the world different ground improvement techniques have been used. Some are through mechanical stabilization, or some are undertaking admixtures. This research investigates the results of compaction energy on geotechnical characteristics for improvement of natural soil by adopting admixture. Here cement & sand were used as the admixture. Cement at a fixed percentage (7%) and sand varying percentage (10%, 20%, 30%, 40%, 50%, 60%) by weight were used in this study. Also, four different compaction energy was used where all were standard proctor level of compaction only changed in no of layers & no of blows. For this purpose laboratory experiments were conducted on both unstabilized and stabilized soils. Test were standard proctor compaction at four different energies and unconfined compressive strength. An arrangement of test was undertaken to develop relationships between compaction parameters, mechanical properties etc. The natural soil was used in this study were inorganic clay with intermediate plasticity. Findings show that the maximum dry density of both unstabilized & stabilized soil rises with a rise in compaction energy whereas the declination of optimum water content. For natural soil MDD rises from 18.20 kN/m^3 to 19.70 kN/m^3 wheres OMC declines 18.5% to 14.29% due to the results of compaction energy 594 to 2219 kNm/m^3. Maximum value of MDD & minimum value of OMC was found at 60% sand content with 2219 kNm/m^3 compaction energy 22.0 kN/m^3 & 10.2% respectively. Up to 40% of the sand content, better results found in terms of MDD & OMC. The unconfined compressive strength improves with increment in compaction energy. The maximum value of UCS was found 370.55 kN/m^2 at 30% sand content in 2219 kNm/m^3 compaction energy. Soil using any project these types of stabilization have a positive effect. Throughout any type of earthwork construction, sand-cement stabilization with a high compaction can be very useful to improve weak soil.

Keywords: *Compaction energy, MDD, OMC, stabilization, Unconfined Compression Strength.*

1. INTRODUCTION

Compaction is a process to improve the existing soil to increase the resistance, decrease deformation capacity and provides a stable base to support against external loads which requires mechanical energy. Also, to decrease permeability it is a prerequisite. Fine grained soil also known as problematic soil is subjected to improving their mechanical conditions. For any construction works of soil, existing soil should meet the requirements of their geotechnical properties and should fit the technical description of the works. For infrastructure development of most of the countries, it is prerequisite to reduce long term settlement of the structure and provide a sufficient cost effective base for bearing the load of the infrastructure. In case if there exits the soft soil at the base of the foundation can occur excessive settlement, starting un-drained failure of the superstructure if adequate ground improvement is not taken out (Buddhima et. al., 2013). In order to increase the bearing capacity and reduce intolerable excessive and differential settlement, appropriate ground improvement techniques can be selected to build foundations at low cost (Basack et. al., 2018). One of the ways is to stabilize these soil according to require demand. The objective of this research is to investigate the results of energy of compaction on geotechnical characteristics of soil using different admixture as a partial replacement of natural soil.

Existing literature shows a remarkable soil improvement has been achieved by using sand as a stabilizing agent. The addition of sand is capable of reducing the swelling action (Loaufi and Bahar, 2012). Sand has a greater bearing capacity than clay and do not change their properties to change in moisture content (Farooq and Virk, 2009). There was an impact of compaction energy on geotechnical characteristics of soil such as Maximum Dry Density (MDD), Optimum Water Content (OMC) and Unconfined Compressive Strength (UCS). It shows that considerable behaviour changes in soil due to the variations in compaction energy (Drew, 2005). The previous study found a significant effect of compaction energy on MDD, OMC, UCS, CBR and swell%. MDD, UCS and CBR increased and OMC decreased with increase in compaction energy (Basack et. al., 2021, Sadek, et. al., 2022, & Vinod et. al., 2015). Moreover, when the existing soil requires to improve to meet the design criteria, adding of cement soil has become an exciting technique. Soil stabilized with cement hardened because cement crystal takes up the free spaces of the soil (Mousavi, 2017). Generally cement stabilized the soil by hydration of cement particles which results in high compressive strength due to cement crystal develops an interlock among soil particle with one another (Afrin, 2017). Again it was investigated that for greater than 7% of cement, the maximum density almost remain constant and soil structure can be destroyed by cement if its amount greater than 8% (Pongsivasathit, 2019). It was also found that up to 7-9 % of cement content, an improvement of MDD and corresponding drop of OMC. With further increment in cement content MDD will remain same (Eskedil, 2014). Considering the above background, sand with varying percentage and cement fixed percentage (7%) is used as an additive in this study. Also the results of several energies of compaction on this improved technique are studied out.

2. METHODOLOGY

2.1 Research Materials Collection

The natural soil sample used in this research was brought from Karnai, Dinajpur which is located near HSTU campus. It was a disturbed sample collected at 5-6 ft depth from the ground surface. The sand used for this study was bought from Domar. Portland cement was collected from Dinajpur City. The soil samples collected in the study were dried in the oven and to make dust crushed manually.

2.2 Characterization of collected material

Different physical properties were found out in order to identification of soil sample. All the properties measured by following ASTM test standards. Their properties are given below in Table 1. According to the USCS classification system, the soil is inorganic clay with intermediate plasticity.

Table 1: Basic properties of natural soil

Properties	Results
Plastic limit, PL (%)	25.69
Liquid limit, LL (%)	41.81
Plasticity index, PI (%)	16.12
Specific gravity , G_s (soil)	2.71
Sand: clay & silt (%)	56.91 : 43.01
Soil colour	Brown
Soil type	CI

2.3 Investigation on the effect of compaction & compaction energy

To investigate the effect of compaction & compaction energy, at first natural soil sample was compacted at four different compaction energies shown in Table 2. All four are standard proctor level only variation in no. of blows per layer & no. of the layer. Then soil mixed with admixture such as cement, 7% and sand 10%, 20%, 30%, 40%, 50% & 60% with partial replacement of natural soil and compacted of that four energy level. After that UCS value were determined by untreated & treated soil applying OMC and MDD obtained at each level of compaction. UCS were determined after 24 hours of making specimen.

Table 2: Different energy level of compaction applied in the laboratory compaction

Compaction energy level	Weight of Hammer (N)	No. of blows/Layer	No. of layer	Height of drop (m)	Volume of the mold (cm^3)	Compaction energy level
E1	24.525	25	3	0.305	944	594.29
E2	24.525	25	5	0.305	944	990.48
E3	24.525	56	3	0.305	944	1331.21
E4	24.525	56	5	0.305	944	2218.68

There are six mix proportions used in this study shown in Table 3. Detailed working procedure was shown in Figure 1.

Table 3: Different Mix proportions

Sample	**Description**
Mix A	Soil 90% + Sand 10% + Cement 7%
Mix B	Soil 80% + Sand 20% + Cement 7%
Mix C	Soil 70% + Sand 30% + Cement 7%
Mix D	Soil 60% + Sand 40% + Cement 7%
Mix E	Soil 50% + Sand 50% + Cement 7%
Mix F	Soil 40% + Sand 60% + Cement 7%

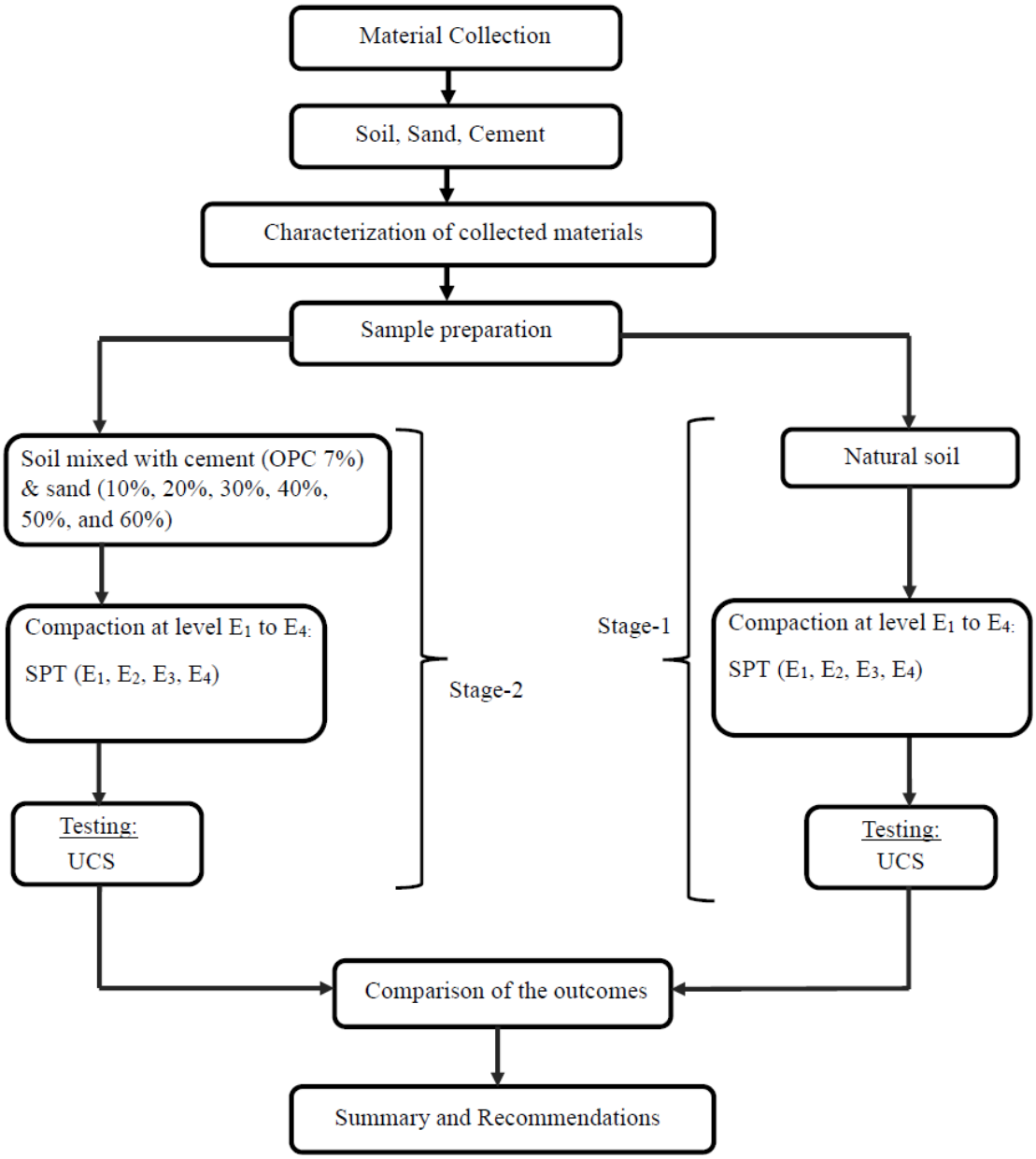

Figure 1: Detailed working procedure

3. RESULTS & DISCUSSIONS

3.1 Soil Stabilized with Sand & Cement

In this research work, the addition of cement at a fixed percentage (7%) and sand (10% to 60%) of the dry mass of the soil sample was investigated. All the materials were mixed homogeneously before testing. Then proctor test was conducted on the both treated and untreated soils with the relevant compaction level shown in table previously. Figure 2 to Figure 8 shows the relationship between dry density vs. water content of natural soil & different mixed proportions. The MDD & OMC change with different mix proportions. For natural soil OMC reduced 23%, where MDD increases 8% approximately due to the effects of compaction energy variation E1 to E4. Similarly for Mix A, Mix

B, Mix C, Mix D, Mix E, Mix F declination of OMC & increment of MDD for the results of compaction energy are approximately 21% & 8%, 18% & 6%, 17% & 6%, 15% & 4%, 12% & 3%, 14% & 4% respectively. The maximum value of MDD was found 22.0 kN/m^3 and minimum value of OMC was 10.2% of the E4 energy level of 60% of sand content.

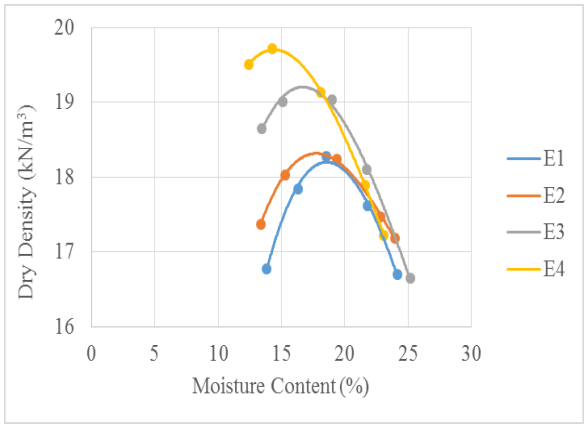

Figure 2: Moisture-density relationship for Natural soil

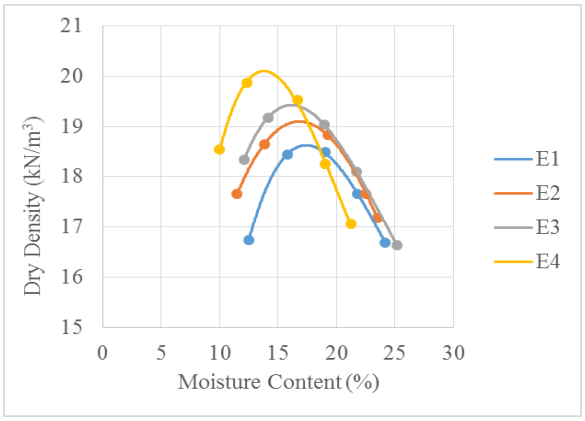

Figure 3: Moisture-density relationship for Mix A

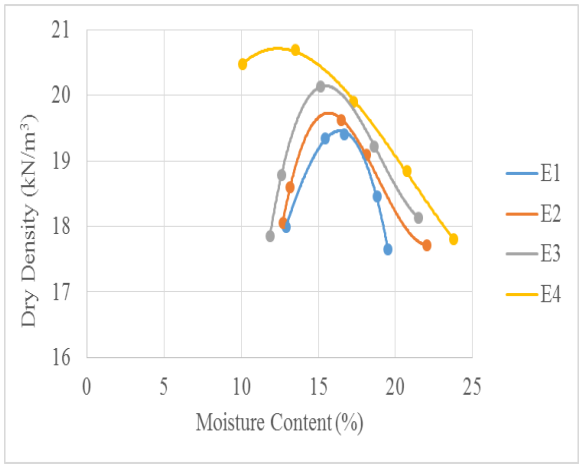

Figure 4: Moisture-density relationship for Mix B

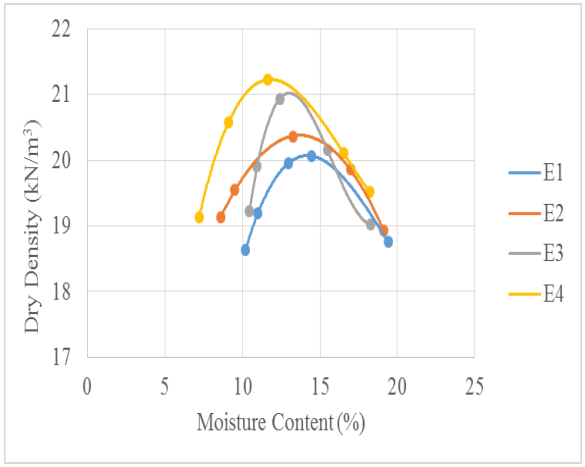

Figure 5: Moisture-density relationship for Mix C

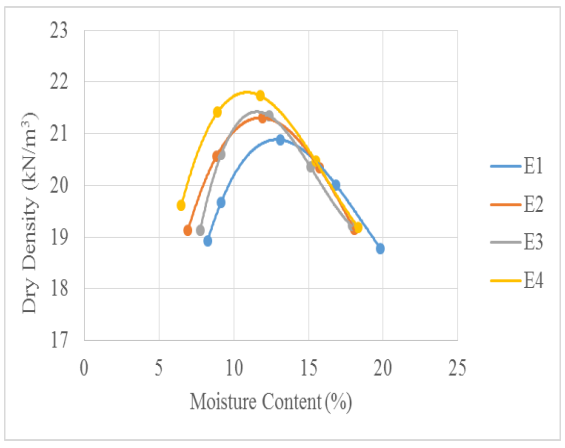

Figure 6: Moisture-density relationship for Mix D

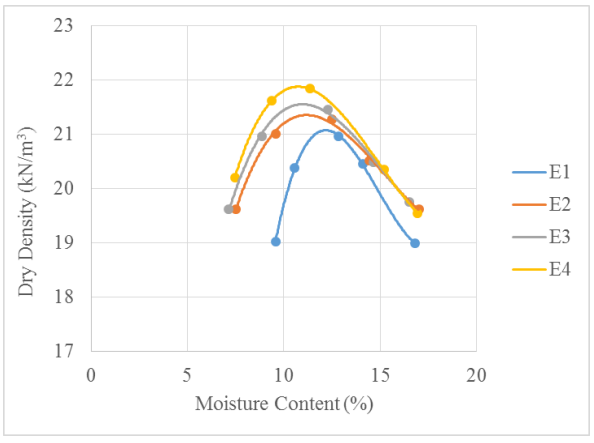

Figure 7: Moisture-density relationship for Mix E

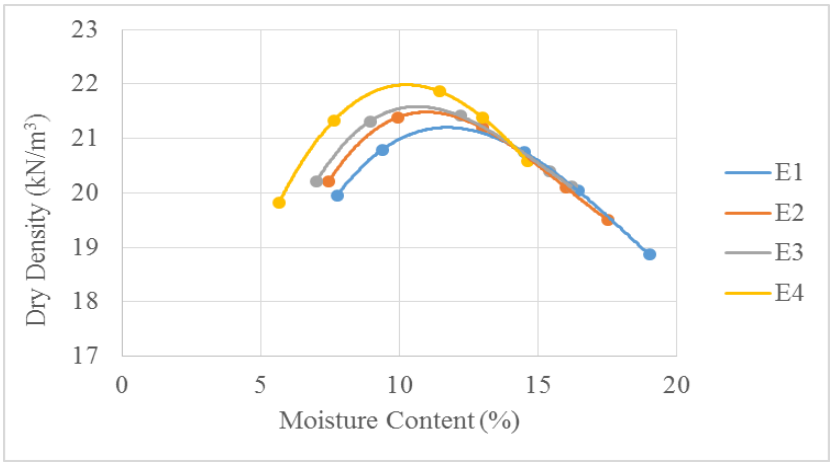

Figure 8: Moisture-density relationship for Mix F

Figure 9 shows the relationship between MDD with compaction energy. The maximum dry density rises with a rise in sand content. The sand particle size is larger than natural soil. Because of compaction, particles distribute in such a way that solid volume per unit of total volume is increased. Hence, the amount of void reduced whereas dry density rises with rising in sand content which is similar to the results Found by the Alkroosh *et. al*., (2021). There was a decrement of OMC with the increment in compaction energy shown in Figure 10. This decrements because Surface area of the particle is reduced, when sand is added to the clay. So less amount of water is required to lubricate the particle and create friction among particle.

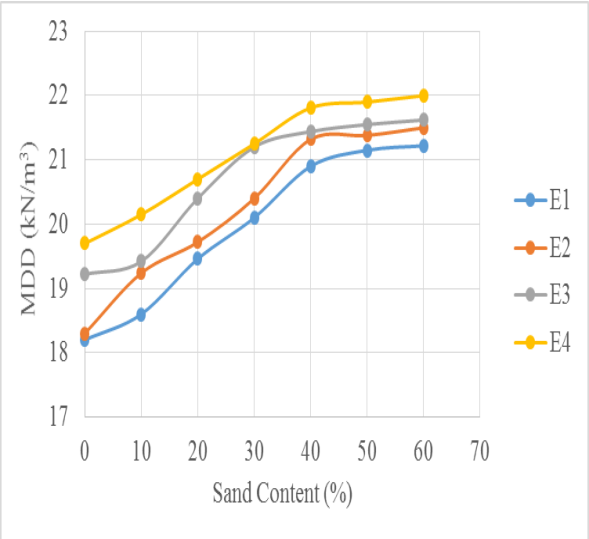

Figure 9: Variation of MDD with sand Content

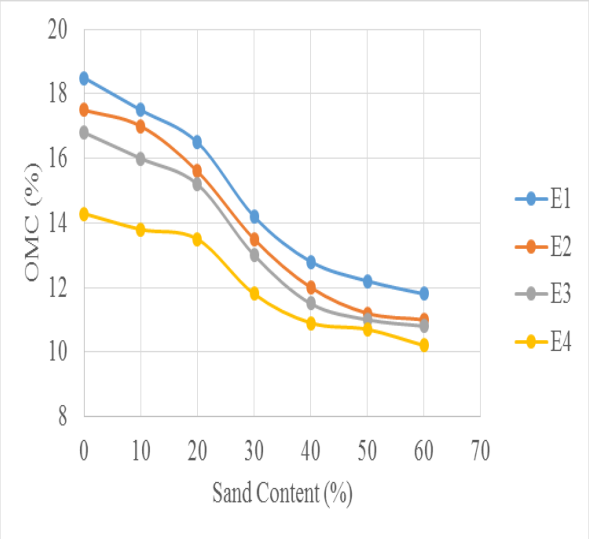

Figure 10: Variation of OMC with sand content

The variation of UCS value with the percentage of sand content is shown in Figure 11. At first UCS value increases with increase in sand percentage. If sand is added to soil-cement, sand acts as an aggregate. Thus, the soil particle made a stable structure. So strength is increasing. After that UCS value fall to increase in sand content. If large particle size is more, then there generates a gap between the mix. So strength decreases. Similar result was found by Yao *et. al.*, (2019).

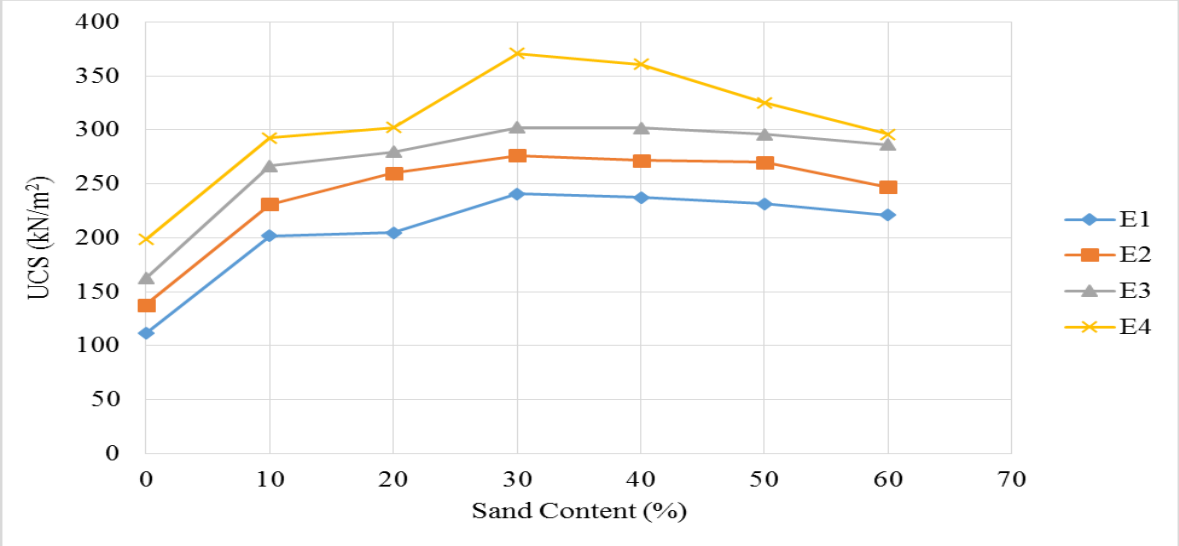

Figure 11: Variation of UCS with sand content

3.2 Compaction Energy Effect on Soil Stabilization

It was shown from the Figure 12 that the OMC varies inversely with compaction energy. There is a reduction in optimum moisture content with a rise in compaction energy for both untreated and treated soils. Water content reduces due to reduction of void spaces among the soil masses. So water accumulation for the voids is less available. Also, Figure 13 shown that The MDD variation with energy level increase proportionally, because of soil grain tightened together. As a result, it falls in porosity and improve in compactness. With the increment of compaction energy, UCS value also rises was shown in Figure 14. Compressive strength of soil is dependent on the packing of soil density & moisture content. More density is provided by flocculated structure than scattered (Hussain, 2017). For natural soil, the value is rising from 111.32 kN/m^2 to 198.28 kN/m^2, when compaction energy increased from 594 kNm/m^3 to 2219 kNm/m^3. The maximum value of UCS was found 370.55 kN/m^2 for 30% sand content at E4 compaction level.

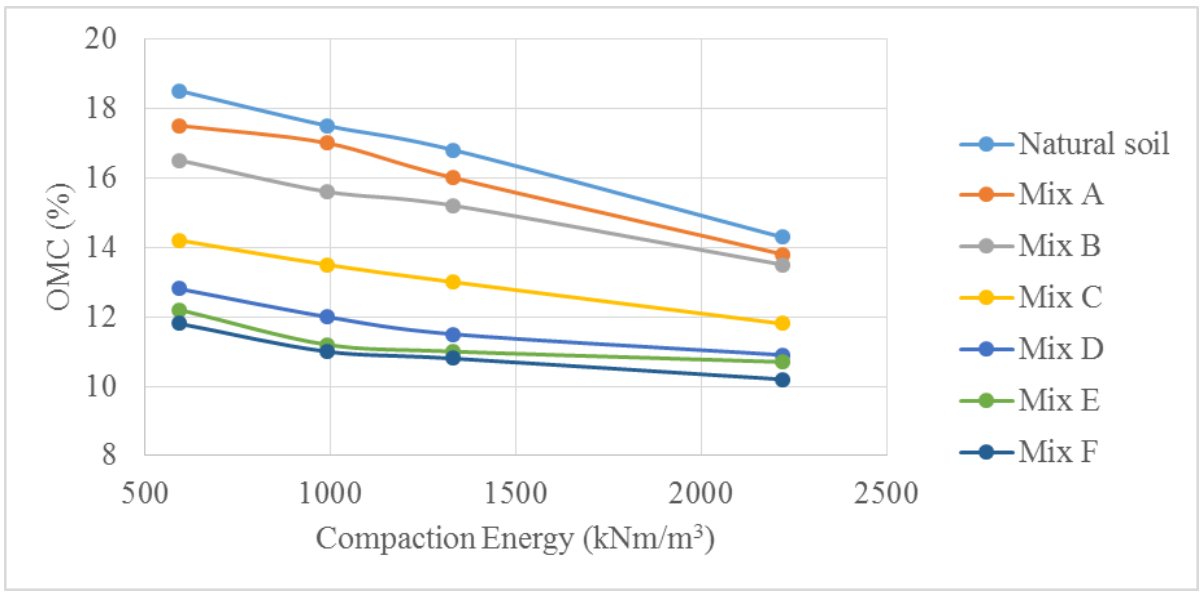

Figure 12: Variation of OMC with compaction Energy

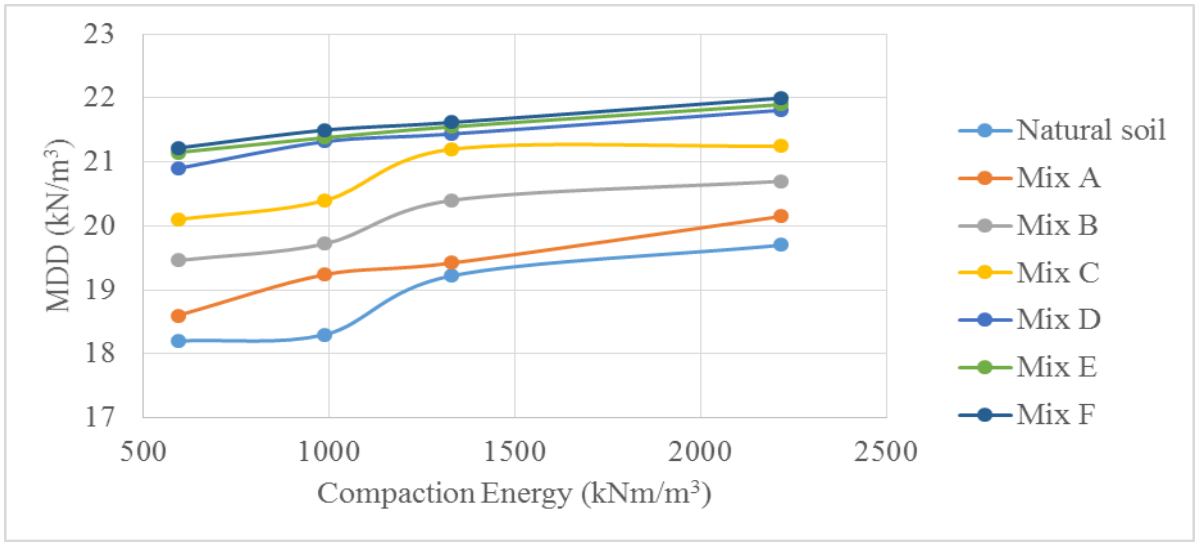

Figure 13: Variation of MDD with compaction energy

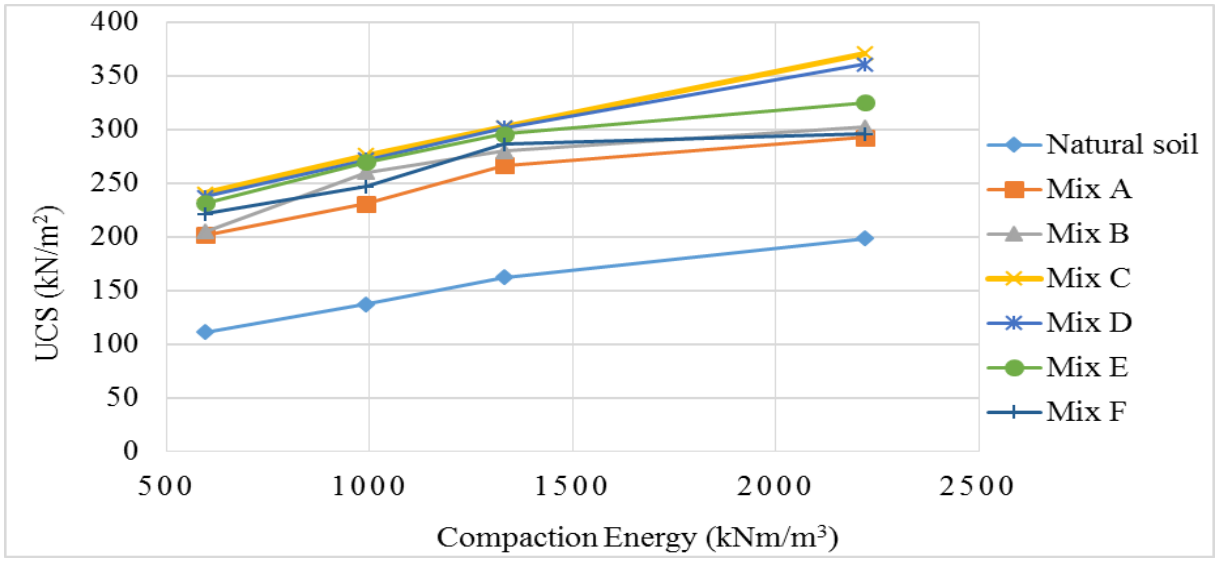

FIGURE 14: VARIATION OF UCS WITH COMPACTION ENERGY

4. CONCLUSIONS

This research was conducted to find out the impact of compaction energy and admixture on the improvement of natural soil. According to the USCS classification system, this soil is intermediate plasticity inorganic clay. Due to the increments of compaction energy, the MDD increases & OMC decreases both treated & untreated soils. Maximum MDD & minimum OMC value was found at maximum energy level (E4) in all cases. Also increments in percentages of sand, there was an increment in MDD & fall in the OMC. Up to 40% of sand content, the increments were better. UCS value also increases with increment in compaction energy. Up to 30% of sand content, there was an increment of UCS value. After that UCS value decreases with increase in sand content. The maximum value of UCS was found 370.55 kN/m^2 at E4 compaction level. At last it can be said that these improvement combinations are an efficient technique to stabilize the soils using any load bearing base while avoiding an additional budget.

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