SOFT SOIL STABILIZATION USING ADMIXTURES FROM VARIOUS SOLID WASTE MATERIALS

Subhadeep Mondal[1], Sudip Basack[2], Hadi Khabbaz[3], Joyanta Maity[4] and Subha Sankar Chowdhury[5]

[1] *Regent Education & Research Foundation Group of Institutions, Maulana Abul Kalam Azad University of Technology, Kolkata, India;* [2] *Graphic Era Deemed to be University, Dehradun, Uttarakhand, India;* [3] *University of Technology Sydney, Australia;* [4] *Techno International Batanagar, West Bengal, India;* [5] *Heritage Institute of Technology, Kolkata, India*

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ABSTRACT

Foundations for civil infrastructure built on soft and compressible soils are prone to failure owing to either undrained shear failure or excessive settlement. Therefore, it is essential to improve soft soils by increasing their bearing capacity and reducing their compressibility. Amongst various techniques, addition of specific admixtures to the soft soil is one of the most effective and convenient methods of stabilization. This paper presents a series of experimental studies conducted for soft soil improvement using various admixtures like nylon cord fibers, banana fibers, and plastic waste materials. A comparative analysis of the enhancement of compaction and penetration properties of the treated soil was conducted. It was observed that the values of optimum moisture content, maximum dry density, and California Bearing Ratio of the soil were altered significantly by the addition of admixtures wherein China nylon cord fiber was most effective. An array of concluding remarks were derived from the overall study.

1 INTRODUCTION

Failure of foundations for infrastructure constructed upon soft and compressible soil is evidenced either by undrained shear failure of the supporting soil or excessive settlement (Chang et al., 2008). Therefore, providing a cost-effective foundation for civil infrastructure with the required factor of safety against bearing failure and an acceptable magnitude of settlement is imperative for long-term safety and serviceability (Sánchez-Garrido et al., 2022). Subsoil existing in significant regions worldwide consists of soft alluvial clay or soft marine clay deposits in coastal areas (Basack et al., 2023). Consequently, it is vital to augment the strength and stiffness of the soft soil; this technique is termed as 'ground improvement' (Basack et al., 2022a). Various types of ground improvement techniques adopted around the world have been primarily classified as mechanical stabilization, consolidation, and chemical stabilization (Basack et al., 2022b).

In the case of mechanical stabilization, soft soil is subjected to external impact energy such as compaction or blasting, blending, or replacing the poor soil with better quality materials or soil reinforcement, where stiffer materials such as compacted fine or coarse aggregates are used to strengthen the soft soil (Afrin, 2017). The consolidation technique is specifically applicable to soft clay, which includes the application of preloading on the ground surface and allowing the clay layer to consolidate. To accelerate the consolidation process, a series of vertical drains are often used to assist radial consolidation. Stone columns, sand compaction piles, and prefabricated vertical drains are included in this category of soft ground improvement techniques (Basack et al., 2022). The use of chemical additives or admixtures to enhance soft soil performance is termed chemical soil stabilization. Among the particular techniques of chemical soil stabilization are stabilization by cement, lime, and bituminous emulsion (Cabezas et al., 2019).

Using certain admixtures for soft soil has often been considered as a combination of mechanical and chemical stabilization. Apart from acting as stiffening materials to improve the overall strength and rigidity of soft dirt, admixtures often undergo chemical reactions with soil particles to alter their geotechnical properties. The application of bagasse ash, stone dust, or other similar materials used as admixtures has been a few examples of this category (Basack et al., 2021).

2 LITERATURE REVIEW

A brief overview of the concepts and field applications of soil stabilization by admixtures has been discussed by Puppala et al. (2015). The authors described a diverse array of admixture treatment techniques, encompassing the formulation of stabilizers and their respective dosages, together with experimental mix design procedures, field building practices, and quality control evaluations.

A laboratory-based investigation on the influence of fly ash and lime used as admixtures on the geotechnical properties of expansive soil was performed by Ji-ru and Xing (2002). The stabilization was visualized by alteration in soil texture, Atterberg limits, compaction parameters, and CBR. Choobbasti et al. (2010) studied the influence of rice husk ash and lime as admixtures for controlling the swelling potential of soft clay. The method was found to assist in the effective chemical reaction between the admixtures and clay particles and in the enhancement of the geotechnical qualities of soft ground.

Another technique of applying sawdust ash as admixture to increase strength of unstable soil was performed by Butt et al. (2016). This industrial waste material was observed to be a cost-effective and suitable strengthening ingredient for base and sub-base course in flexible pavement construction. Jalal et al. (2020) performed an extensive review regarding the utilization of calcium-based admixtures for expansive soil stabilization. The authors provided an in-depth analysis of the effects of calcium-based stabilizers on the physicochemical attributes of soft soils.

Renjith et al. (2021) studied the improvement of fly-ash-based soil stabilization techniques for highway building. They found that the application of enzymes as an additive improved the strength of the fly ash-treated soil. The utilization of specific industrial waste materials including steel slag, blast furnace slag, and phosphor-gypsum for treating construction residue soil was conducted by Chen et al. (2024). This research examined the engineering features of construction residual soil treated with a specific admixture, studying how organic matter concentration, dose, and curing age affect unconfined compressive strength. The long-term performance was also studied in wet–dry cycle and water stability tests.

It is an innovative approach to address plastic pollution by incorporating solid plastic waste into the subgrade pavement layers. Plastic waste can be used as a sustainable alternative in road construction, thereby reducing environmental pollution and improving waste management practices. By repurposing plastic waste in this manner, this practice contributes to circular economy principles and provides a practical solution for reducing plastic accumulation in landfills and oceans (Amena, 2022).

The application of leftover plastic materials to improve soft soils is an emerging trend. Small-sized strips or pieces derived from waste plastic bottles or other materials, used as admixtures to virgin soil, were found to provide satisfactory results in soil stabilization (Singh and Mittal, 2019; Gangwar and Tiwari, 2021). Attempts have also been made to use strips of plastic-mesh textile bags in combination with fly ash treated soil, which indicated significant increment in shear strength properties of soft clay (Bitar et al., 2024). Other recent techniques include the use of banana fiber reinforcements derived from banana trees and cut into small strips (Gobinath et al., 2020; Bawadi et al., 2020) and China nylon cord obtained from waste rubber tyres (Jafari and Esna-ashari, 2012).

3 MOTIVATION AND RESEARCH METHODOLOGY

Waste plastic materials in various forms are widely used by citizens and are available everywhere in communities (Pilapitiya and Ratnayake, 2024). A similar situation also exists for waste rubber tyres obtained from vehicles (Tian et al., 2024). In addition, banana trees exist in approximately 135 countries around the world (Li et al., 2024). Although waste plastic materials, banana trees, and waste tyres are widely available, their applications for soil stabilization are still not thoroughly investigated. An in-depth investigation of the utilization of large volumes of these waste materials as admixtures for soft soil stabilization is yet to be conducted, although the use of various conventional materials in ground improvement has been studied in detail.

This study seeks to address this research gap. This particular research has aimed to bridge this gap through a set of comprehensive laboratory tests and comparative analyses. The research methodology includes extensive experimental investigation in a geotechnical engineering laboratory with the objective of studying the effectiveness of the above-mentioned waste materials as admixtures for stabilizing soft soil. Various materials were collected in appropriate quantities, including soft soil, waste plastics, banana tree branches, and China nylon cord. Disturbed soil samples were tested to determine their engineering properties. In the next step, various admixtures were cut to the desired shapes and sizes, intimately mixed with the soil samples, and subjected to laboratory testing to observe alterations in the geotechnical parameters of the treated soils. Thereafter, in-depth analyses and interpretations of the test results were obtained, followed by a comparative study.

4 MATERIALS

4.1 SOIL

Disturbed soft soil sample in bulk volume has been collected by auger boring (ASTM, 2024) from a pit of 1 m × 1 m × 1 m dug in a suitable rural site near the city of Midnapore of West Bengal, India (Global coordinates: 22.24ºN; 87.65ºE). The soil was air-dried under sunlight for 30 days and thereafter oven-dried for 24 hours. The dry samples were finely ground and tested in the geotechnical laboratory. Particle size distribution derived from sieve analysis and hydrometer tests (ASTM, 2017) revealed 30% clay, 32% silt, and 38% sand. Figure 1 depicts the relevant curve for particle size distribution.

The geotechnical attributes of the disturbed soil sample were assessed using procedures standardized by (ASTM, 2018), as detailed in Table 1. From the unified classification system (ASTM, 2000), the soil is categorized as CL.

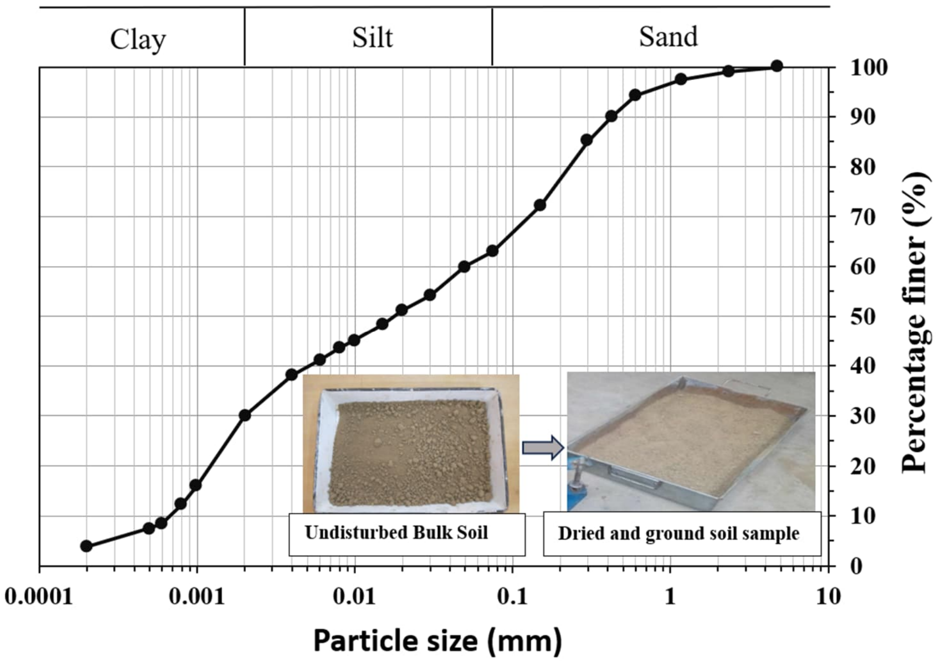


Figure 1: Particle size distribution of soil

Table 1: Geotechnical properties of soil

Parameters			**Values**
Particle size distribution	Clay		32%
	Silt		30%
	Sand		38%
Atterberg limits [a]	Liquid limit		26 ± 1%
	Plastic limit		20 ± 1%
	Plasticity index		6 ± 2%
Specific gravity of solid particles (G_s) [b]			2.5
Standard Proctor compaction test [c]	Optimum moisture content, w_o		12.1%
	Maximum dry density, $\gamma_{d_{max}}$		17.8 kN/m^3
California Bearing Ratio (CBR) [d]	Penetration [e]	2.5 mm	Un-soaked: 9.7% Soaked (4 day): 6.7%
		5.0 mm	Un-soaked: 10.2% Soaked (4 day): 7.3%
The test procedures followed [a] (ASTM 2018), [b] (ASTM 2014), [c] (ASTM 2007), and [d] (ASTM 2021). Note: [e] Considering the higher values, CBR => Unsoaked:10.2%; Soaked (4 day): 7.3%.			

The compaction curve obtained from the standard Proctor test and the load-penetration curve derived from the CBR test data are shown in Figures 2 and 3, respectively.

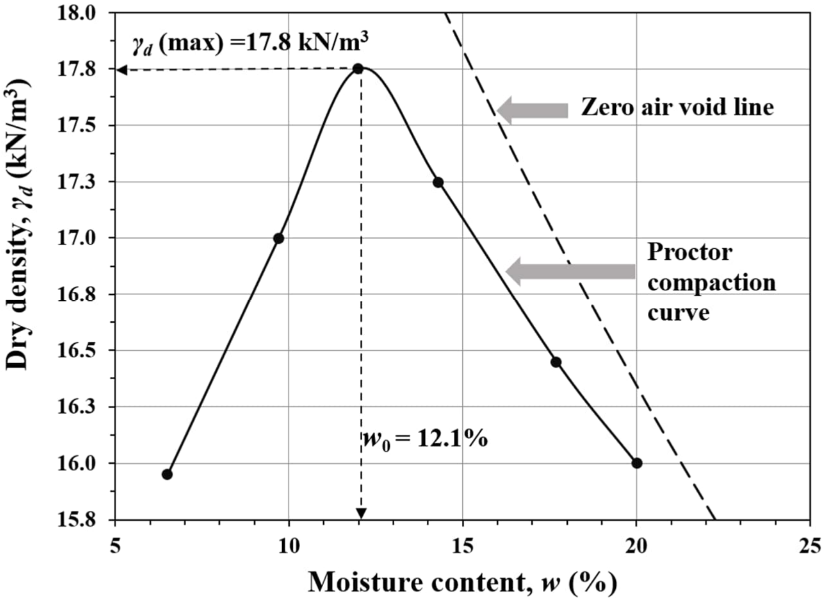


Figure 2: Proctor compaction test results

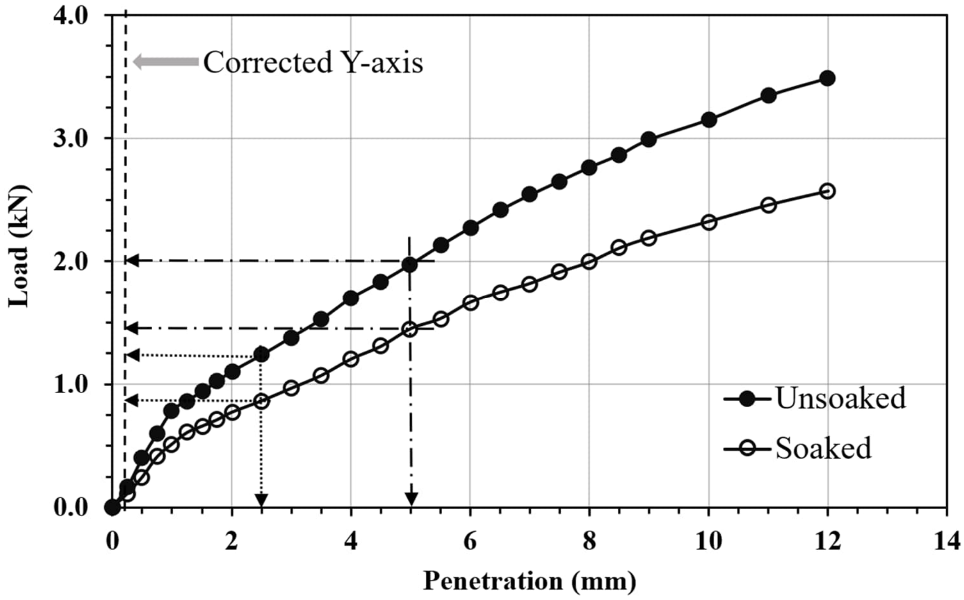


Figure 3: Load-penetration curves for CBR tests

4.2 ADMIXTURES

The admixtures used were derived from: (i) waste plastic bottles, cut to desired shapes and sizes or grounded in powder form, (ii) fibers derived from China nylon cord obtained from waste rubber tyres of vehicles, and (iii) fibers obtained from branches of banana trees, cut to desired sizes. Photographic views of the admixtures are portrayed in Figure 4.

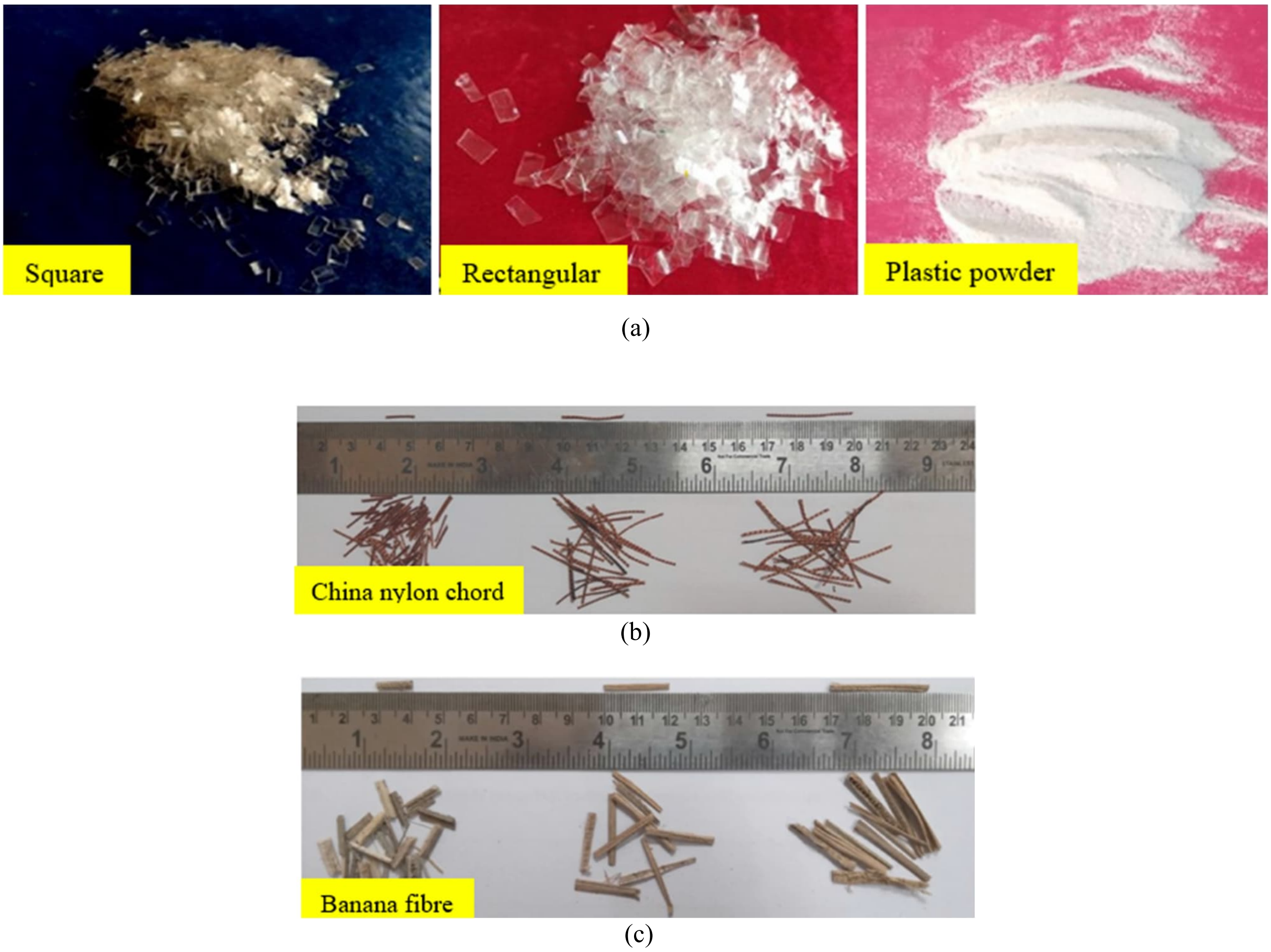


Figure 4: Photographic views of different admixtures: (a) Plastic materials, (b) China nylon cord, and (c) Banana fibers

The specific gravity of each admixture was ascertained using the pycnometric method (ASTM, 2014). In addition, plastic, nylon cord, and banana fibers were cut into wires of specified sizes and tested in the laboratory to determine the Young's modulus following a standard procedure (ASTM, 2020). The characteristics of these substances are presented in Table 2.

Table 2: Engineering properties of admixtures

Properties	Materials	Values
Specific gravity	Plastic waste	1.42
	China nylon cord	1.38
	Banana fiber	1.35
Young's modulus	Plastic waste (square/rectangular)	2.92 GPa
	China nylon cord	0.06 GPa
	Banana fiber	19.4 GPa

4.2.1 Plastic Wastes

The admixtures derived from waste plastic bottles are used in three different specifications:

- Square, having size 5 mm × 5 mm
- Rectangular, having size 10 mm × 5 mm
- Finely ground to powder using a high-speed blender, with the particle sizes ranging from 75 µm to 1.18 mm

4.2.2 China Nylon Cord

The synthetic nylon cord obtained from waste vehicle tyres was cut to various sizes having diameter of 1.0 mm and lengths of 10, 20, and 30 mm. Attempts have also been made to use finely ground powder derived by blending cords, but the same was unsuccessful. Owing to its soft and brittle nature, blending in bulk volume was difficult, which affected the workability. A similar problem was found in a few previous studies (Wealthy Waste, 2024).

4.2.3 Banana Fiber

The banana fibers are derived from the stems of banana trees in bulk quantities, each fiber having a diameter of 1.5 mm and lengths of 10, 20, and 30 mm. Similar to the nylon cord, as explained above, the fibers were not used in powdered form.

5 EXPERIMENTAL PROGRAM, RESULTS AND DISCUSSION

The primary aim of the experimentation was to determine the compaction and penetration characteristics of the soil treated with the different admixtures described above at specified quantities. The details of the test arrangement are listed in Table 3. The outcomes derived from laboratory experimentations are given in Table 4 and their analyses and interpretations are presented as well.

Table 3: Test program

Particulars				Tests [b]
Admixture	Shape	Size	Mix proportion (%) [a]	
Untreated soil	-	-	-	P, C_{US}, C_S
Plastic waste materials	Square	-	1, 2, 3, 4	P, C_{US}, C_S
	Rectangle	-	1, 2, 3, 4	P, C_{US}, C_S
	Powder	-	1, 2, 3, 4	P, C_{US}, C_S
China nylon cord	-	Length: 10mm, 20 mm, 30 mm	0.5, 1, 1.5, 2	P, C_{US}, C_S
Banana fiber	-	Length: 10mm, 20 mm, 30 mm	0.5, 1, 1.5, 2	P, C_{US}, C_S

Notes: (1) Total number of test sets: 37. (2) For each test set, 3 individual tests were conducted to minimize the error. (3) [a] Quantities are measured by weight of soil. (4) [b] P: Standard Proctor compaction test; C_{US}: CBR test un-soaked; C_S: CBR test soaked.

Table 4: Standard Proctor Compaction and California Bearing Ratio test results

Admixture	Shape	Size	Mix Proportion (%)	w_0 (%)	$\gamma_{d_{max}}$ (kN/m^3)	Unsoaked CBR (%)	4 Day Soaked CBR (%)
None	-	-	-	12.1	17.8	10.2	7.3
Plastic wastes	Square	-	1	11.9	17.3	10.9	8.0
		-	2	11.3	16.9	11.8	8.6
		-	3	10.8	16.5	11.3	8.5
		-	4	10.3	15.9	10.9	8.4
	Rectangular	-	1	11.5	17.5	10.9	8.1
		-	2	10.9	17.1	11.4	8.4
		-	3	10.3	16.9	11.2	8.3
		-	4	9.6	16.3	11.1	8.1
	Powdered	-	1	11.8	17.1	11.6	8.9
		-	2	11.1	16.7	12.4	9.0
		-	3	10.6	16.3	12.2	8.8
		-	4	9.9	15.6	11.8	8.6

China Nylon Cord	-	Length = 10 mm	0.5	11.6	17.2	12.0	9.3
			1.0	11.5	16.8	12.9	9.9
			1.5	11.2	15.9	12.6	9.7
			2.0	10.6	15.5	12.1	9.5
		Length = 20 mm	0.5	11.8	17.3	12.2	10.2
			1.0	11.7	17.1	13.2	11.0
			1.5	11.3	16.5	13.0	9.9
			2.0	10.8	16.0	12.4	9.6
		Length = 30 mm	0.5	11.9	17.3	12.2	10.0
			1.0	11.8	17.2	12.7	10.2
			1.5	11.6	16.6	12.4	9.9
			2.0	11.1	16.2	12.3	9.8
Banana Fiber	-	Length = 10 mm	0.5	12.9	17.3	11.4	9.1
			1.0	14.0	16.3	12.2	9.7
			1.5	15.5	15.7	11.9	9.1
			2.0	16.8	15.2	11.4	8.9
		Length = 20 mm	0.5	13.4	16.5	11.8	9.0
			1.0	14.9	16.2	12.4	10.2
			1.5	16.5	15.3	12.2	9.4
			2.0	17.3	14.8	11.9	9.0
		Length = 30 mm	0.5	14.7	16.2	11.7	8.8
			1.0	15.7	15.8	12.1	10.0
			1.5	17.2	15.0	12.0	9.5
			2.0	18.4	14.6	11.6	9.0

5.1 COMPACTION

Figure 5 depicts a few representative proctor curves obtained from standard Proctor compaction tests (ASTM, 2007). The trends of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the treated soils with different admixtures in various proportions and lengths are illustrated in Figures 6, 7 & 8.

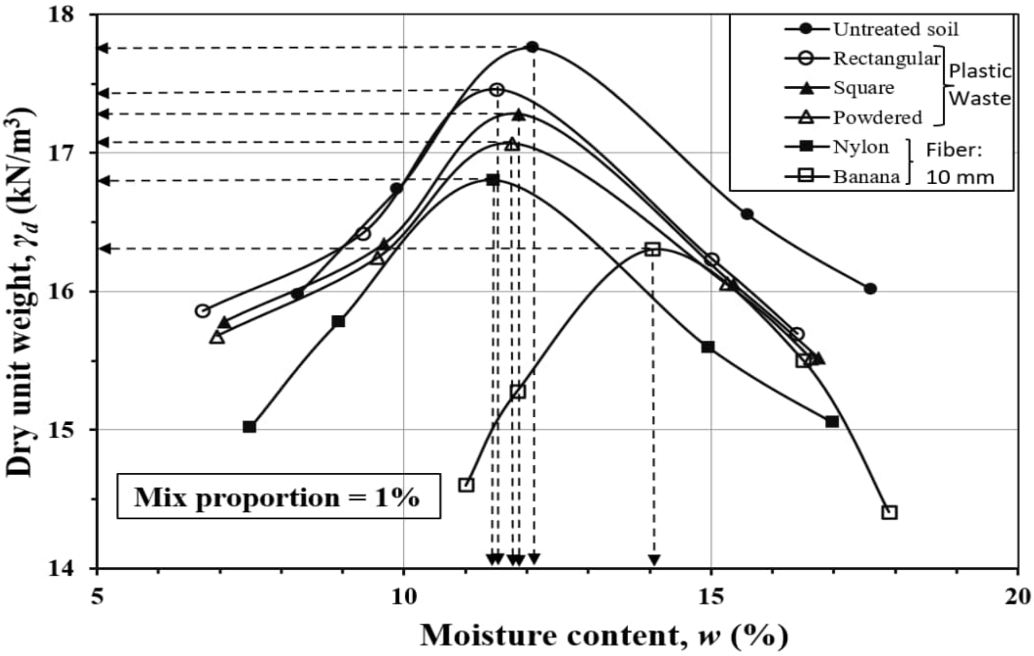


Figure 5: Standard Proctor compaction curves for representative samples

The variation in the compaction properties of treated soil has been studied by a group of non-dimensional parameters (Basack et al., 2021) given as follows:

$$\alpha_o = \frac{(w_o)_t}{(w_o)_u} \tag{1}$$

$$\alpha_d = \frac{(\gamma_{d_{max}})_t}{(\gamma_{d_{max}})_u} \tag{2}$$

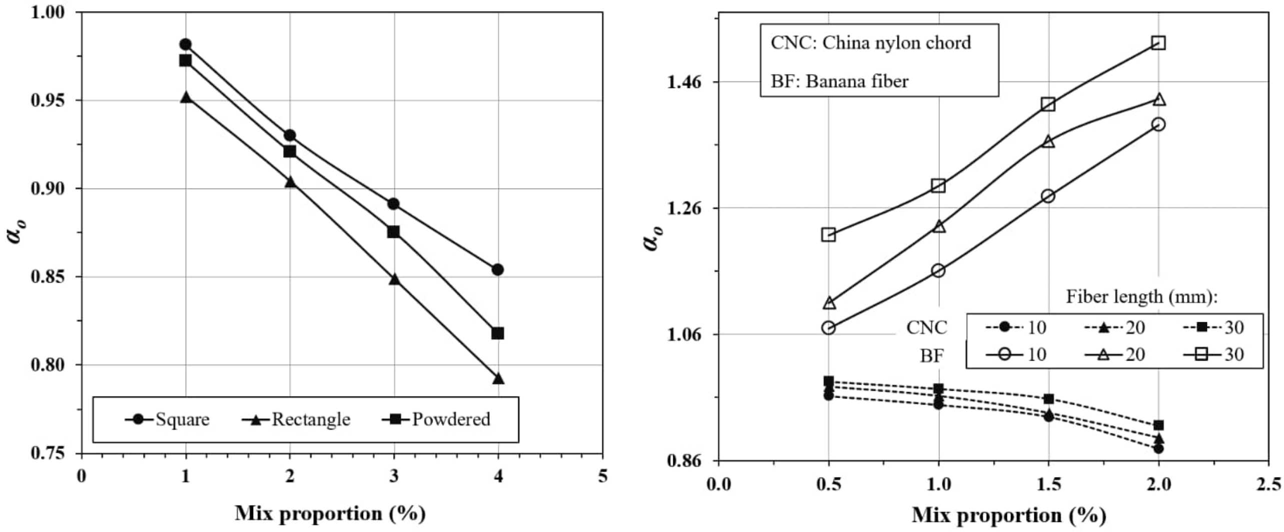
where, α_o and α_d are the normalized values of optimum moisture content and maximum dry density, w_0 and $\gamma_{d_{max}}$ are the optimum moisture content and the maximum dry density and the suffixes t and u referred to the values relevant to treated and untreated soils, respectively.

The variation of α_o and α_d with mix proportion for plastic waste, China nylon cord, and banana fiber are portrayed in Figures 6 and 7, respectively.

The ranges of variation of the values of α_o and α_d were $0.79 \leq \alpha_o \leq 0.98$, $0.88 \leq \alpha_o \leq 0.99$, $1.07 \leq \alpha_o \leq 1.52$, $0.88 \leq \alpha_d \leq 0.98$, $0.87 \leq \alpha_d \leq 0.98$, and $0.82 \leq \alpha_d \leq 0.97$ for plastic waste, nylon, and banana fibers, respectively. As observed from Figures 6 and 7, the values of both parameters α_o and α_d decreased with increasing mix proportion for plastic waste and nylon. In the case of banana fiber, the parameters α_o and α_d were observed to increase and decrease, respectively, with the mix proportion.

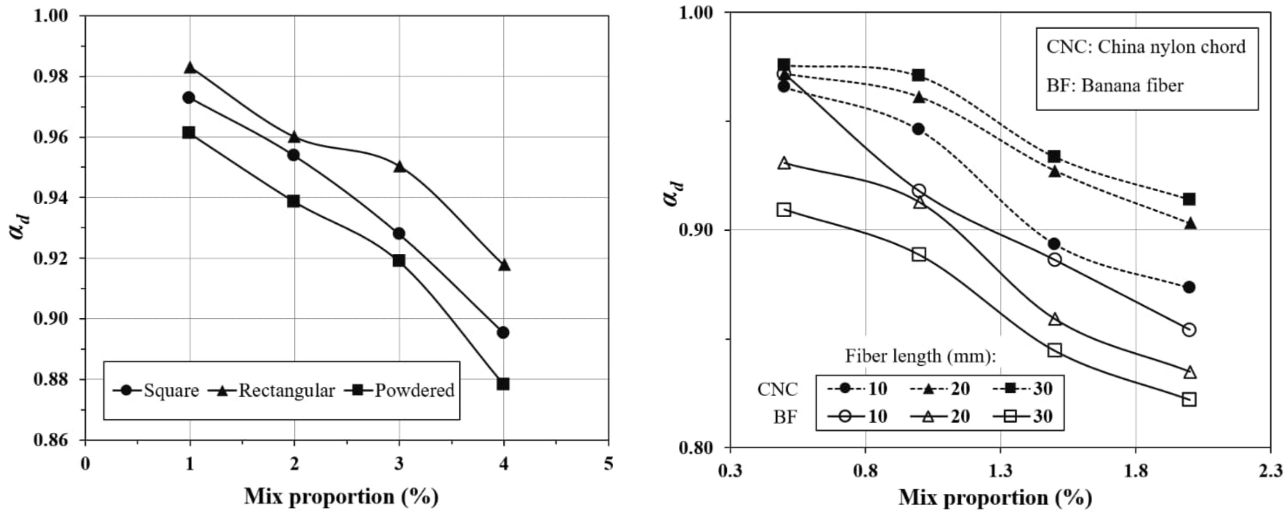
Both plastic wastes and nylon are chemically inert with soil mass, with negligible water retention capacity. In addition, their specific gravity is less than that of soil particles. These factors may have significantly reduced OMC and MDD of the treated soil. The incorporation of banana fibers into the soil can influence its physical properties owing to their high water retention capacity. Unlike plastics and nylon, the water retention capability of banana fibers can increase the OMC because they hold more moisture within the soil matrix. This addition tends to decrease the MDD as it changes the overall density distribution of the soil (Maqbool et al., 2023; Patil and Pusadkar, 2020).

The variation of α_o and α_d with the lengths of the nylon and banana fibers is depicted in Figure 8. Both parameters α_o and α_d were found to increase with the length of the nylon fiber. The observed pattern can be justified by the fact that the ascending length of the fiber possibly initiated a rearrangement and realignment of soil elements, thus enhancing the OMC and MDD of the treated soil (Owino and Hossain, 2023). In addition, nylon fibers being chemically inert with soil mass produced insignificant variations in the values of α_o and α_d (Zafar et al., 2023). Conversely, for Banana fiber, the parameters α_o and α_d were observed to increase and decrease with length, respectively. However, no specific pattern of variation could be seen. The rate of increment was observed to be sharper for banana fiber compared to nylon.



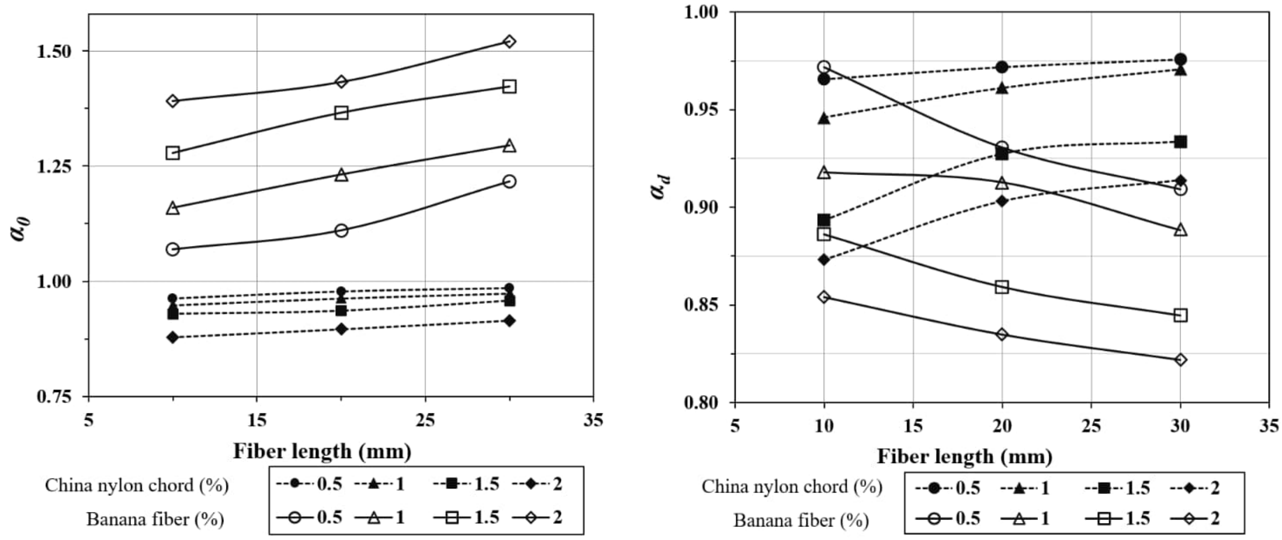
(a) (b)

Figure 6: Variation of α_0 with mix proportion in case of: (a) plastic waste, and (b) China nylon cord and banana fiber.



(a) (b)

Figure 7: Variation of α_d with mix proportion in case of: (a) plastic waste, and (b) China nylon cord and banana fiber



(a) (b)

Figure 8: Variation of normalized parameters: (a) α_0 with fiber length (b) α_d with fiber length

5.2 PENETRATION

The penetration characteristics of the stabilized soil were characterized through CBR tests wherein both the unsoaked and soaked (4 day) soils were tested in accordance with ASTM, 2021. The variation in CBR strength for the various soil-admixture combinations is graphically represented in Figures 9 and 10.

For comparison, the CBR values were normalized with respect to the untreated soil (Basack et al., 2021) given as follows:

$$\alpha_c = \frac{CBR_t}{CBR_u} \quad (3)$$

where, α_c is the normalized CBR, and CBR_t and CBR_u are the values of CBR for treated and untreated soils, respectively.

The variation of α_c with mix proportion for different admixtures have been plotted in Figure 9. As observed from the plot, the patterns of variation have been curvilinear. With the chosen mix proportion, the normalized values of un-soaked and soaked CBR were found to vary between the ranges of 1.07 $\leq \alpha_c \leq$ 1.22 and 1.09 $\leq \alpha_c \leq$ 1.23 for plastic wastes, while 1.18 $\leq \alpha_c \leq$ 1.30, 1.28 $\leq \alpha_c \leq$ 1.50, 1.12$\leq \alpha_c \leq$ 1.22, and 1.20 $\leq \alpha_c \leq$ 1.40 in the cases of nylon and banana fibers, respectively. Also, with ascending mix proportion of the additives, the parameter α_c initially increased, attained peak values and thereafter decreased, for all the additives. The peak values were observed to occur in mix proportions of 2% - 2.2% and 1% - 1.2% for plastic wastes and fiber admixtures, respectively.

Based on the observed variation in α_c with the fiber length (Figure 10), the peak values of α_c were attained for a fiber length of 20 mm for both fiber types.

The penetration behavior of the stabilized soil was evaluated by CBR testing. Keep in mind that the CBR test is well known for its intrinsic variability and limited repeatability, as demonstrated by the research background for the DCP-DN design method for LVSR (Paige-Green and Zyl 2019). Given the documented exposure levels on test repeatability, CBR values in this study have been rounded to a single decimal place so that the analysis produces a realistic order of engineering accuracy and does not over-fit the experimental data.

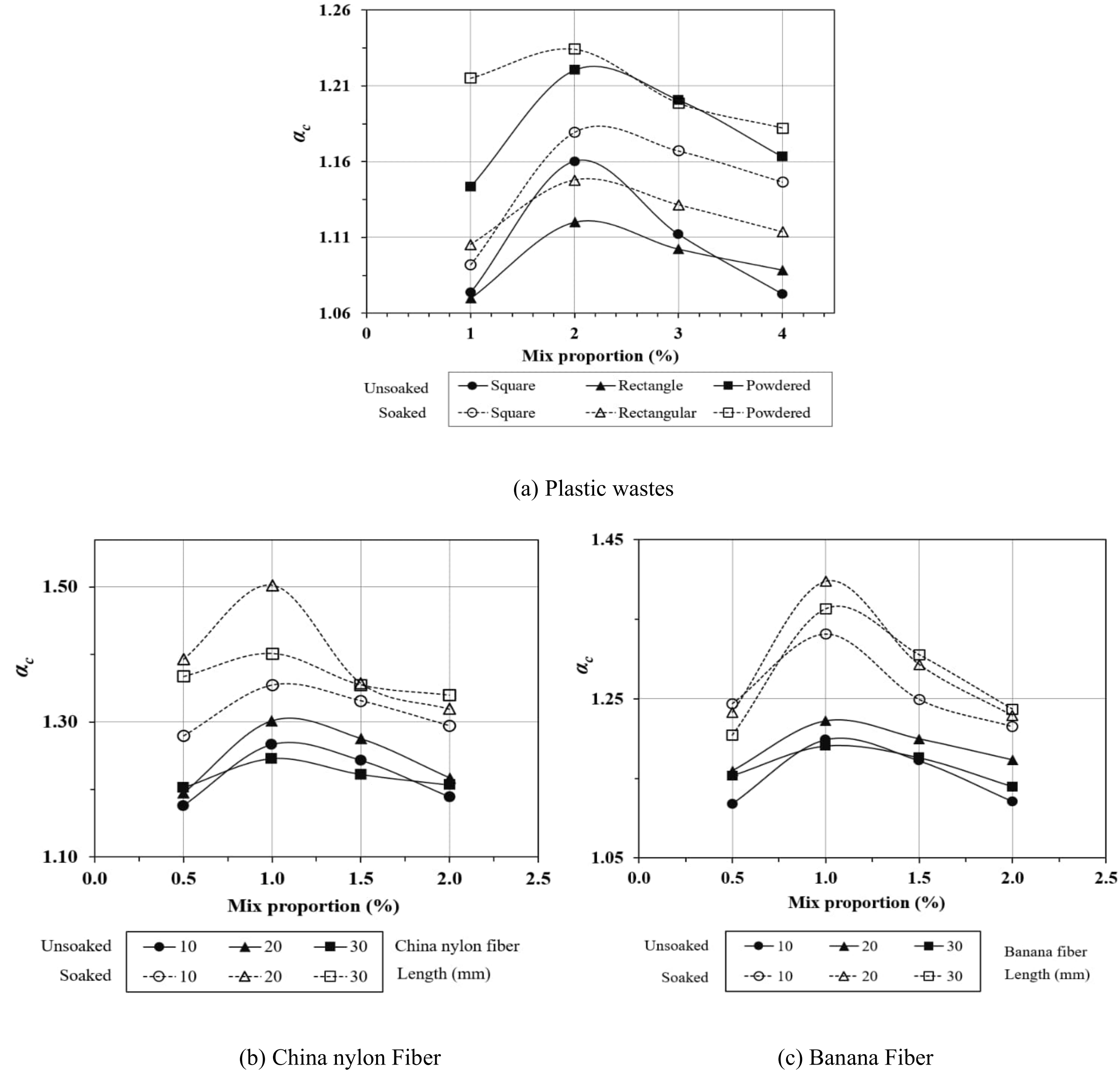
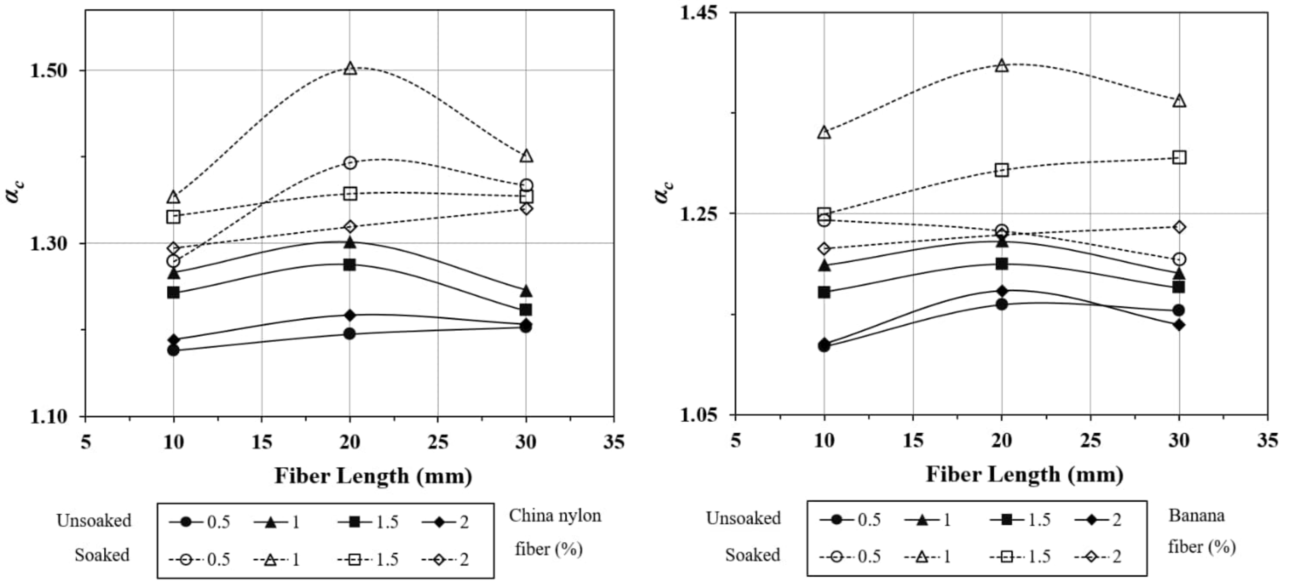


Figure 9: Variation of α_c with mix proportion



(a) China nylon Fiber

(b) Banana Fiber

Figure 10: Variation of α_c with fiber length

The above observations may be explained by the possibility that an increase in admixture proportion initially enhances the soil stiffness due to the reinforcing effect until the peak value is attained, whereas a further increase in additive content subsequently reduces the resistance to penetration owing to the excessive admixture content (Kassa et al., 2020). Similar observations were also reported by several previous studies (Badiger et al., 2019; Nezhad et al., 2021; Ahmed et al., 2024).

Using plastic waste as admixtures enhances the CBR of unstable soil primarily due to tensile reinforcement of discrete plastic admixtures randomly distributed in the soil mass, initiating reduced swelling, enhanced frictional resistance and filling voids. The soaked CBR tests simulate the worst-case scenario for subgrade, when the soil is fully saturated, for example during monsoon or high water table conditions. In the current study, it is observed that the required admixture contents and sizes for optimal values of soaked CBR are more than those for unsoaked tests, possibly due to counteracting the weakening effects of water saturation (Gangadhara and Vivek 2016; Boobalan et al. 2023).

6 ANALYSIS AND INTERPRETATION

The above experimental findings reveal that both the plastic wastes and nylon fibers, being chemically inert with soil mass, OMC and MDD descended with ascending admixture content. This implies a reduced volume of water required for field compaction and a reduction in the effective overburden pressures in the deeper soil layers. Conversely, the variance pattern differed for banana fiber due to an increase in OMC and a decrease in MDD. Similar observations were found in few recent studies as well (Çelik et al., 2025; Akıllı et al., 2025; Özdemir et al., 2024).

Furthermore, chemically inactive admixtures eliminate the possibility of biodegradation and subsequent alteration in the treated soil properties. Besides the direct mechanical effects of using solid waste materials, their influence on the environmental background for soil should also be taken into account. Although the chemical inertness of nylon and plastic waste would resist a rapid biodegradation which is desired to maintain the enhanced geotechnical properties, their long-term physical existence presents concerns regarding microplastic accumulation. During long engineering lifecycles, it is conceivable that environmental stress factors might result in the fiber breaking up. But in the case of ground improvement, these materials are intimately mixed and encapsulated in a compacted soil. This burial effectively protects the admixtures from ultra-viiolet radiation and significant mechanical abrasion, the two principal drivers of plastic degradation in surface environments (Vincenzini et al. 2021; Amena 2022; Kalita et al. 2025; 2026). As a result, the potential of microplastic leaching toward the surrounding environment reduces with time, thus indicating that these waste-derived admixtures might serve as long-lasting and environmentally-friendly solution for stabilizing soft soils. Thus, considering the enormous efforts in cutting the bulk volume of square- or rectangular-shaped plastic waste, as well as powdered plastic waste, nylon fibers appear to be a preferable option. Moreover, from the CBR test results, the mix proportion relevant to the peak value is preferable.

7 CONCLUSIONS

A comparative experimental study was performed to investigate the effectiveness of selected types of admixtures applied to improve the compaction and penetration characteristics of soft clayey soil. Plastic waste materials derived from waste bottles and cut into the shapes of square, rectangular and powdered form, China nylon fibers derived from waste rubber tyres, and banana fibers cut from banana stems, were intimately mixed with saturated soft clay to stabilize the soft soil.

The main focus of the current work is to conduct an in-depth comparative study on the influence of plastic wastes, natural and synthetic fibers on soil stabilization in terms of compaction and penetration characteristics. The specific effects of admixture content and their sizes on the compaction parameters (OMC and MDD) and CBR (unsoaked and soaked) were analysed through non-dimensionalized parameters α_o, α_d and α_c and the relevant conclusions are drawn.

Standard Proctor compaction and California Bearing Ratio (CBR) tests were conducted on both untreated and treated soil samples. This study revealed that both the compaction and penetration characteristics of the soil were significantly influenced by the addition of admixtures. The values of both optimum moisture content (OMC) and maximum dry density (MDD) decreased with the increase of waste plastic and nylon contents. The values of both parameters α_o and α_d descended with ascending mix proportion for plastic waste and nylon. In the case of banana fiber, the parameters α_o and α_d were observed to increase and decrease, respectively, with the mix proportion. Both parameters α_o and α_d were found to increase with the length of the nylon fiber. Both plastic waste and nylon are chemically inert relative to soil mass and possess minimal water retention capability. Their specific gravities are lower than those of the soil particles. These effects likely contributed to the reduction of OMC and MDD of the treated soil to a considerable extent.

However, banana fiber exhibits superior water retention capabilities, and its specific gravity is less than that of soil particles. These effects likely increased OMC and decreased MDD of the treated soil significantly. For banana fiber, the parameters α_o and α_d increased and decreased, respectively, with the mix proportion. In contrast, for banana fiber, the metrics α_o and α_d were noted to increase and decrease with length, respectively. No clear pattern of variation could be identified. The rate of increment was observed to be more pronounced for banana fiber, compared with nylon.

As far as the CBR tests are concerned, the values of both the unsoaked and 4 day soaked CBR varied nonlinearly with the admixture quantity and fiber length. With increasing quantity of admixture, the CBR initially increased, attained peak values, and thereafter decreased. The peak values occurred at mix proportions of 2.0%–2.2% and 1.0%–1.2% for plastic wastes and fiber admixtures, respectively. In the case of the fibers, the peak value of CBR was attained for a fiber length of 20 mm.

Overall, this investigation demonstrated that China nylon cord acted as the most effective admixture, optimizing the compaction and penetration characteristics of soft soil.

For a more comprehensive study, it is desired to carry out field based investigation and a comparative cost analysis, so as to develop appropriate design recommendations with appropriate charts and curves.

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CRediT authorship contribution statement

Subhadeep Mondal: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing-original draft, Writing-review & editing. **Sudip Basack:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing-original draft, Writing-review & editing. **Hadi Khabbaz:** Conceptualization, Methodology, Resources, Supervision, Validation, Writing-review & editing. **Joyanta Maity:** Data curation, Investigation, visualization, Writing-review & editing. **Subha Sankar Chowdhury:** Resources, Writing-review & editing.

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