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Research Article

NSF (Nylon Synthetic Fiber) Effectiveness in Stabilizing Weak Subgrade Soil: An Experimental Investigation

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Improvement in subgrade soil has always been an area of concern for highway and geotechnical engineers. Weak subgrade soil results in a greater thickness of the pavement layer, which increases the cost of pavement construction. It further leads to large deformations, which in turn cause continuous deterioration of the paved surface. To solve this problem, various engineering solutions and soil improvement mechanisms were previously proposed. This study was designed to investigate the stabilization of weak subgrade soil with nylon synthetic fiber (NSF) in a compromising combination. Previously, some investigations used a lower fiber content with a higher fiber length, whereas others used a lower fiber length with a higher fiber content. However, this investigation was uniquely designed to stabilize weak subgrade soil with the consideration of appropriate fiber length (10 mm and 20 mm) and content (0.5%, 1%, 1.5%, and 2.5%). The engineering properties of the soil, the effect of NSF on weak subgrade soil, various fiber content and aspect ratios, and the optimum content and critical fiber aspect ratio were investigated in a laboratory. The effect of fibers on compaction, CBR values, and CBR swell values has also been studied. Laboratory results on the modified compaction tests showed that maximum dry density (MDD) was increased with the increment of fiber content, whereas optimum moisture content (OMC) remained constant. The soaked CBR and CBR swell values of natural soil were 1.80% and 8.95%, respectively. Due to reinforcement, the percentage increase in soaked CBR value at the optimum NSF content is 265.3, 310.0, 282.8, and 342.2 for aspect ratios of 33.33, 66.67, 25, and 50, respectively, with reference to natural soil. Also, the percentage decrease in swelling is 34.7, 52.75, 43.55, and 36.9, respectively. Moreover, the CBR value increases with the increase in aspect ratio by keeping the diameter constant and decreases with the increase in aspect ratio by keeping the length constant. It was also observed that increasing the length and diameter of NSF further increased the CBR value of reinforced soil. This increment was substantial at a fiber content of 1.5% for an aspect ratio of 50 (length = 20 mm, diameter = 0.4 mm). There was also a decrease in the CBR swelling value with an increase in fiber content. Finally, this investigation concluded that the use of NSF is a solution to weak soils with regard to moisture and performance problems.

1. Introduction

Building a pavement on weak or soft soil poses a serious risk because it has low shear strength, is highly compressible, and is prone to settlement [1]. For sustainable development in developing nations such as Ethiopia, transportation infrastructure is crucial. However, a better performance of the agricultural sector, in particular, would be achieved by an upgrade of the basic infrastructure, as Ethiopia's economic growth is strongly dependent on it, as would be the sustainable economic growth of the country at large. As a result, it has been determined that the country's road network is a significant obstacle to its economic growth. Huge areas of Ethiopia are covered in vast soil. The majority of the country's built and proposed roadways, as well as a sizable portion of the most recent railway plans, run through the country's enormous soils [2]. Weak subgrade soil is frequently a problem while building highways since the roads built on them frequently fail after a few months or even a year or two after they are finished. Researchers and geotechnical engineers are currently concerned with such soil types [3].

Improvement of the soil might be considered one of many mechanisms for resolving the issue of weak soils [4, 5]. The term soil improvement is used for the techniques that improve the index properties and other engineering characteristics of weak and soft soils [6]. The main method of stabilization includes mixing the soil with soil of higher strength or binding materials such as limestone, low carbon limestone calcined clay cement (LC3) [7, 8], cement, bentonite [9], or calcium [10], or reinforcing with suitable elements such as COVID-19 face mask [11, 12] or fiber [13, 14]. Soil reinforcement improves soil strength, bearing capacity, ductility, and inhibits deformation. Soil can also be reinforced by the inclusion of high-strength metal strips or wire [15], a waste byproduct of paper/wood industry [16] and relatively low-modulus natural and/or synthetic fibers [17]. In order to improve the geotechnical qualities of problematic soil and address the issue of waste disposal [18, 19], various mixing proportions of fine steel slag aggregate (FSSA) and glass fiber in soil modification were employed. The effects of fibers on swell and unconfined compressive tests were clearly examined. With regard to Standard Proctor, Static Triaxial Test, and California Bearing Ratio (CBR) tests, [20] studied the behavior of soft soil stabilized with varied amounts of coir pith (0–3%) and coir fiber (0-1%) and found promising results. During the last few decades, much work has been done to improve the engineering properties of weak soil, and it has been established that the addition of fiber is an efficient way to enhance the overall engineering performance of soil. Fiber-reinforced soil is effective in all types of soils (i.e., sand, silt, and clay) [17, 21]. It is estimated that Ethiopia has 24.7 million acres of expansive soils overall [22, 23]. Moreover, the soil in Jimma town was reported to have a high value of liquid limit and a small value of CBR [24, 25]. Hence, soil modification is an important engineering practice.

Natural fibers come straight from living things, whereas synthetic fibers are created by humans through chemical synthesis. The latter are the product of in-depth scientific investigation to enhance naturally occurring animal and plant fibers [26]. In general, synthetic or artificial fibers are manufactured by extruding fiber-forming ingredients via spinnerets. Synthetic fibers are produced through the process of polymerization, which includes joining monomers to form a lengthy polymer or chain [27]. The Greek prefix "poly" (which means "many") and the suffix "mer" (which means "single units") are the origins of the word "polymer." (Note: A monomer is a single unit of a polymer.) Without synthetic fibers, the modern textile business is inconceivable today. Silk-like synthetic fibers have traditionally been highly prized for their gloss and fineness. Rayon, nylon, and polyester are a few examples of synthetic fibers.

Many studies have been conducted relating to the behavior of soil reinforced with different types of fiber. A series of direct shear tests [28] on dry sand reinforced with different synthetic, natural, and metallic fibers to investigate the effects of parameters carried out such as fiber orientation, fiber content, fiber area ratios, and fiber stiffness on their contribution to shear strength [29]. Based on the test results, an increase in shear strength was directly proportional to the fiber area ratios, and shear strength envelopes for fiber-reinforced sand clearly showed the existence of a threshold confining stress below which the fiber tries to slip or pull out. The application of jute fiber in the improvement of subgrade characteristics reduced the maximum dry density and increased the optimum moisture content of the subgrade soil. The experimental results showed that the stress-strain behavior of soil was improved by the inclusion of coir fiber into the soil, and jute sheets improved the California Bearing Ratio (CBR) value of fly ash significantly. They further concluded that the deviator stress at failure was increased up to 3.5 times over the plain soil.

The problem of weak soil was a point of concern for researchers. Various reinforcing materials with various dosages were previously adopted. For instance, CBR values of 5.76% (aspect ratio = 3.75, length = 15 mm, diameter = 4 mm) and 6.30% (aspect ratio = 1.875, length = 15 mm, diameter = 8 mm) were obtained when the soil was reinforced with jute fiber at fiber content of 0.3%, which indicates the effect of fiber length on CBR value [17]. This study initiated other investigators to use coir, jute, bamboo, and sisal fibers as reinforcing materials with diameters in the range of 0.1–1.5 mm. The coir was cut into pieces of length 15 mm to 20 mm [30]. Polyester fibers of length 70 mm were mixed in soil according to [28] and used as random reinforcement in amounts of 0.5%, 1.0%, and 1.5%. On the other hand [31], the influence of natural fibers as well as synthetic polyester (PET) fibers on the strength behavior of clayey soil was experimentally investigated with various fiber contents (0.5%, 1%, and 2%) and lengths of 2.5 mm, 5 mm, and 7.5 mm.

Generally, some researchers used a higher fiber length (such as 70 mm) [28], and some others used a lower length (2.5 mm–7.5 mm and 15 mm) [17, 31]. To fill those gaps, this investigation was uniquely designed to stabilize the weak subgrade soil with NSF in different aspect ratios and dosages. In this study, fiber lengths of (10 mm and 20 mm) and fiber content of (0.5%, 1%, 1.5%, and 2.5%) were used, which makes this investigation unique from others with regard to knowledge and practical gaps. Moreover, this research is designed with the following specific objectives: to assess NSF on the performance improvement of weak subgrade soil that could be implemented in road construction projects; to determine the optimum fiber contents by weight for the improvement of weak subgrade soil; to determine the critical fiber aspect ratios on the engineering properties of weak subgrade soil; and to recommend remedial measures in order to improve the performance of weak subgrade soil.

2. Materials and Experimental Methods

2.1. Study Area Description. According to the WGS 84 coordinate reference system, which is the latest revision of the World Geodetic System, Jimma is geographically located between 7°38′52″ and 7°43′14″N latitude and between

36°48′00″ and 36°53′24″E longitude, as shown in Figure 1 below. The town is located in an area with an altitude of 1718–2000 m above sea level. The specific geographical locations of the study area were 7°40′22″N latitude and 36°50′4″E longitude.

2.2. Weak Subgrade Soil. The soil for this study was collected from Jimma town (Merkato near Woma Hotel), specifically, 7°40′22″N latitude and 36°50′4″E longitude. The disturbed sample was picked along the soil profile at a depth of 2 meters to avoid the inclusion of organic matter. Preliminary checks indicated that the soil was grayish-black in color and highly cracking and plastic in nature, as shown in Figure 2.

2.3. Nylon Synthetic Fiber. Fibers used in this study were collected from Tays PLC Synthetic Fiber Company at Addis Ababa, Merkato branch (refer to Figure 3). Then, the fibers were cut into two different lengths, which were 10 mm and 20 mm. The fiber content used in this study by dry weight percentage was 0.5%, 1%, 1.5%, and 2.5%, as demonstrated on Figure 4.

2.4. Sampling Techniques, Sample Size, and Preparation. This study followed a purposive sampling and selection process. For the purpose of sampling and description, pits were dug to at least 50 cm below the expected subgrade level [32]. In the case of a new alignment, the depth from the natural ground surface should not be less than 2 m [33], unless a rock stratum is encountered. In bore pits, the number of samples is determined by the heterogeneity of the subsurface and the characteristics of the soil [34]. At least one sample should be taken per test pit or trench. In this study, there was no observable major change in material properties. Hence, three representative sample locations were selected for field and laboratory tests from Jimma town, Merkato, near the Woma Hotel.

Soil weighing about 600 kg (200 kg per sample location) of disturbed, weak subgrade soil was brought from the site to the Jimma Institute of Technology geotechnical laboratory so as to have sufficient samples to carry out each type of test, while the undisturbed soil sample was being taken using the tube sampler. After taking the undisturbed sample, immediately cover it with plastic at the tip of the tube to control the moisture. The undisturbed sample was taken for the natural moisture content, unconfined compressive strength test, and field density test of the natural soil, whereas the disturbed sample was taken for the other remaining tests incorporated in this investigation.

Once the required amounts of samples are taken, the next step should be sample preparation. Soil samples were prepared based on the method described in ASTM D 421. After collecting the samples from the study area, air-dried soil was mixed with stabilizers in their corresponding percentages. The proportion of the mix was by dry weight. The percentage values of NSF used for the preparation of samples to conduct the entire required laboratory test are described in detail in Table 1, and during preparation, it looks like Figure 5. After preparing the samples, the required tests are conducted on a calibrated instrument (Figure 6 above shows the CBR and unconfined compression tests).

The overall activity and research process in the study include problem identification associated with weak subgrade soil in the study area, material collection and preparation of the sample for laboratory testing, trimming the fibers, preparing for testing, and conducting laboratory tests for subgrade with different aspect ratios of NSF to select the optimum percent required, which is summarized in Figure 7 below.

2.5. Laboratory Investigation. This section reveals the results of laboratory and experimental procedures, the recording of data in a proper format, which is an input for the analytical analysis, and the outputs of the findings.

Soil densification is an important mechanism for improving soil properties such as strength, unit weight, permeability, and compressibility [35–37]. Tests such as compaction and the California Bearing Ratio are conducted to determine the performances of hybrid materials (i.e., soil and nylon synthetic fiber), as shown in Table 2.

3. Results and Discussions

3.1. Properties of Weak Subgrade Soil. The thickness of the subgrade material has a significant impact on the pavement design [38, 39]. Natural subgrade materials can occasionally be of poor quality. In order to determine if a certain soil may be used as subgrade material or not in its natural condition [40, 41], the natural state of the soil has to be examined.

The soil in the study area was identified as gray soil. The average unconfined compressive strength of 61.4 kPa was obtained, which was in the range of 50–100 kPa; hence, the soil was medium-soft in terms of consistency. The lab result for the mechanical wet sieve analysis test showed that subgrade soil was fine-grained. It contains 89.48 percent fine-grained soil (about 5.37% are clay particles and 84.11% are silt particles) and 10.52% coarse-grained soil (about 10.4% are coarse-grained soil and 0.12% are sandy soil) out of the 1 kilograms of soil. The percent passing of each test is not only used to categorize soils as coarse-grained or fine-grained but it is also helpful to determine the soil classifications together with Atterberg's limits. Both the mechanical wet sieve analysis and the hydrometer tests are combined and drawn, as shown in Figure 8. According to the laboratory result provided in Table 3, the general properties of the soil before any stabilization indicated that the soil of the study area was weak or expansive [40]. The expansiveness properties of soil can be determined from its Atterberg's limit [42], in addition to other properties such as CBR values. For this particular investigation, the plastic index of the soil was about 22%, which indicates the soil has swelling potential. Moreover, it was stated that soil possessing a plastic index in the range of 20–40 was grouped as high plastic [33]. Hence, the soil identified in this study area was classified as expansive soil by combining the results obtained from Atterberg's and the CBR value.

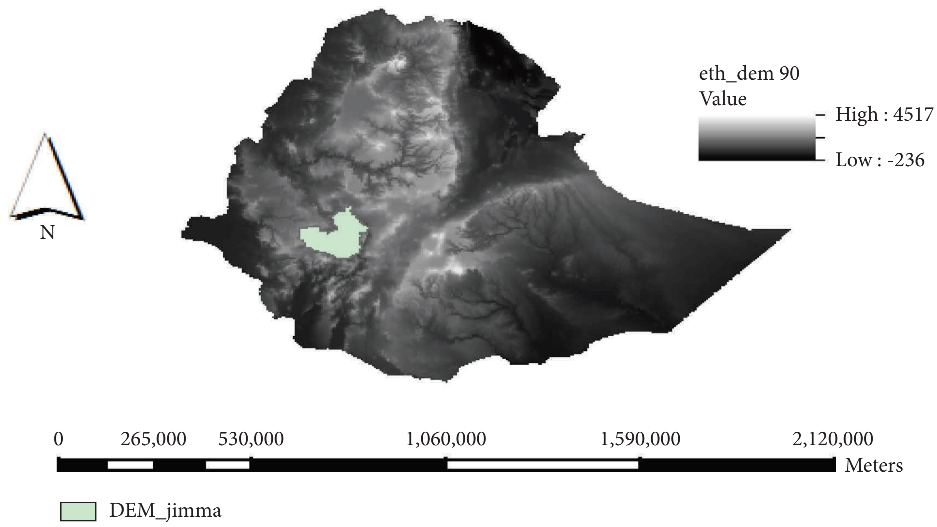

Figure 1: Location of study area (source: generated from GIS software).

Figure 2: Image of sampling pits (source: the researchers).

Figure 3: Nylon synthetic fiber collected from market (source: the researchers).

Figure 4: Nylon synthetic fiber after trimmed in to 10 and 20 mm lengths (source: the researchers).

Table 1: Percentages of NSF used in the study.

Diameter of NSF (mm)	Length of NSF (mm)	Aspect ratio (L/D)	% of NSF by dry weight (%)
0.3	10	33.33	0.5
			1
			1.5
			2.5
	20	66.67	0.5
			1
			1.5
			2.5
0.4	10	25	0.5
			1
			1.5
			2.5
	20	50	0.5
			1
			1.5
			2.5

Figure 5: Material preparations and mixing (source: the researchers).

Figure 6: Photograph for CBR and unconfined compression test (source: the researchers).

The lab result for the hydrometer test shows that the sample soil contains 94% silt particles and 6% clay particles out of the 50 grams of soil, (i.e. 89.48% ∗ 94/100 = 84.11% silt particles and 89.48% ∗ 6/100 = 5.37% clay particles). Hence, these values were used for soil classification in Figure 8.

Based on the gradation and Atterberg's limit of the sample, the soil is classified as **CL** as per the USCS system and **A-7-6 (21) as** per the AASHTO classification system. According to AASHTO classification system, a lower group index value of (0) indicates better performance of the

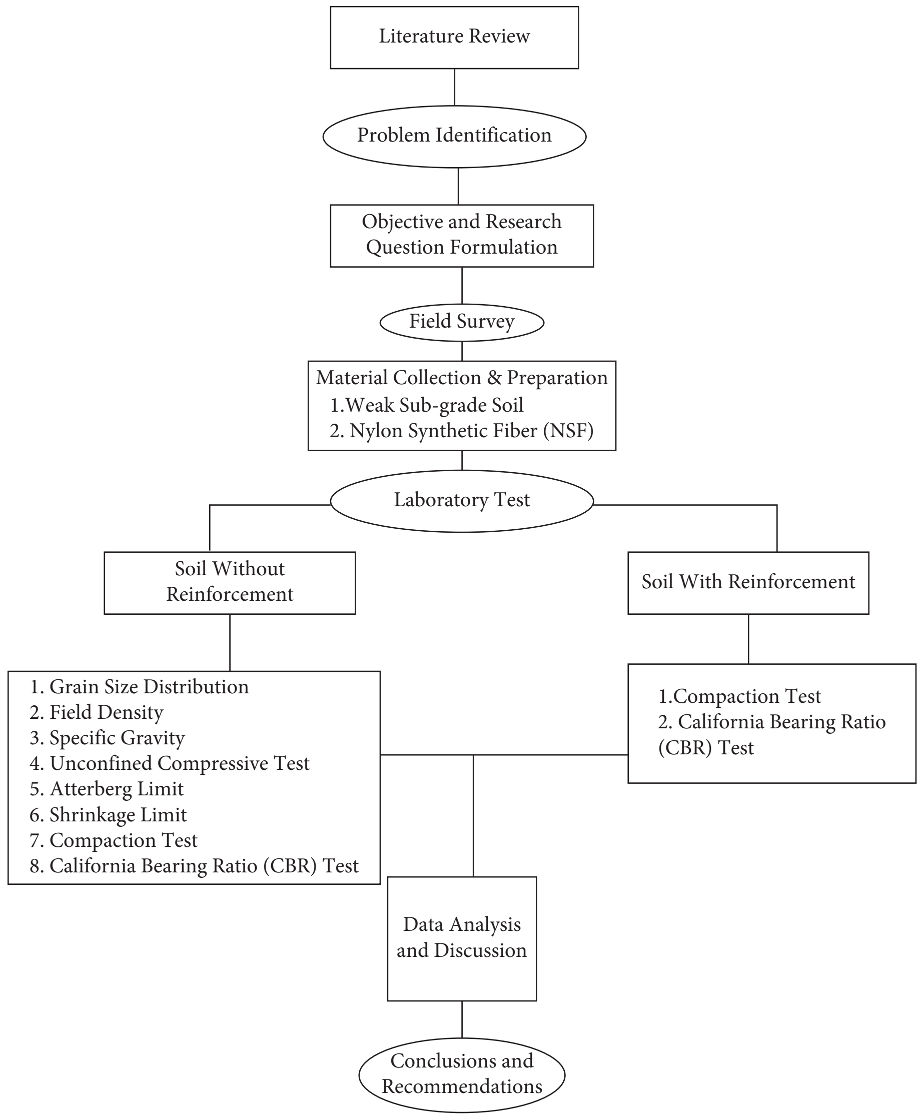

Figure 7: Study design frame of the research.

Table 2: Summary of soil tests, method, and manual used.

Conducted tests	Method used	Manuals
Natural moisture content	Oven dry method	ASTM D 2216
Field density	Sand replacement method	ASTM D 4914
Unconfined compressive strength	Unconfined compressive test	ASTM D 1556
Grain size analysis	Sieve analysis and hydrometer test	ASTM D 422-63
Atterberg's limit	Atterberg's limit test	ASTM D 4318
Specific gravity	Pycnometer method	ASTM D 854
Free swell index	Free swell test	ASTM D 4546
Compaction	Modified compaction test	ASTM D 1557
California Bearing Ratio	Standardized penetration test	ASTM D 1883

material, whereas one with a higher group index (of 20 or above) is considered extremely poor. So, the soil in this study is classified as unsuitable subgrade material with regard to the group index, as shown in Table 3 (which is about 21).

3.2. Soil Compaction and CBR Values. Compaction is the process of increasing a soil's strength and density. It is a quality-control device at the construction site that reduces expansive soils' swelling, settling, and moisture

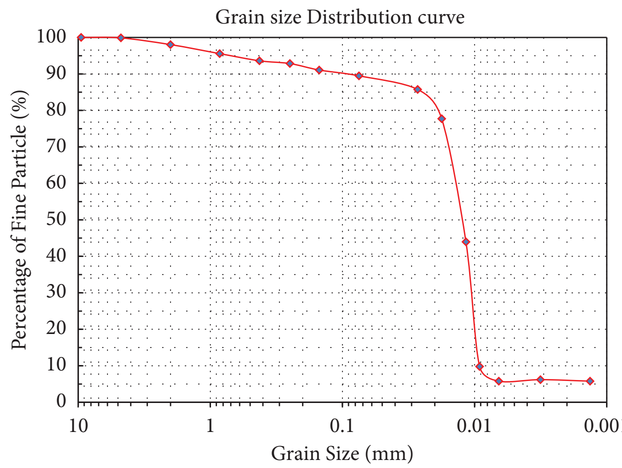

Figure 8: Grain size distribution curve result.

Table 3: A summary of the geotechnical properties of natural/unreinforced soil.

S. no.	Properties	Values/laboratory result
1	Percentage of passing sieve no. 200 (%)	89.48
2	Natural moisture content (%)	39.27
3	Field dry density (g/cm^3)	1.23
4	Liquid limit (%)	43
5	Plastic limit (%)	21
6	Plastic index (%)	22
7	Linear shrinkage limit (%)	6.77
8	AASHTO classification system	A-7-6 (21) very poor subgrade
9	Unified Soil Classification System (USCS)	CL
10	Specific gravity	2.63
11	Optimum moisture content (%)	17.02
12	Maximum dry density (g/cm^3)	1.51
13	Unconfined compressive strength (qu) (kPa)	61.4
14	Soaked CBR value (%)	1.80
15	CBR swell (%)	8.95
16	Color	Gray

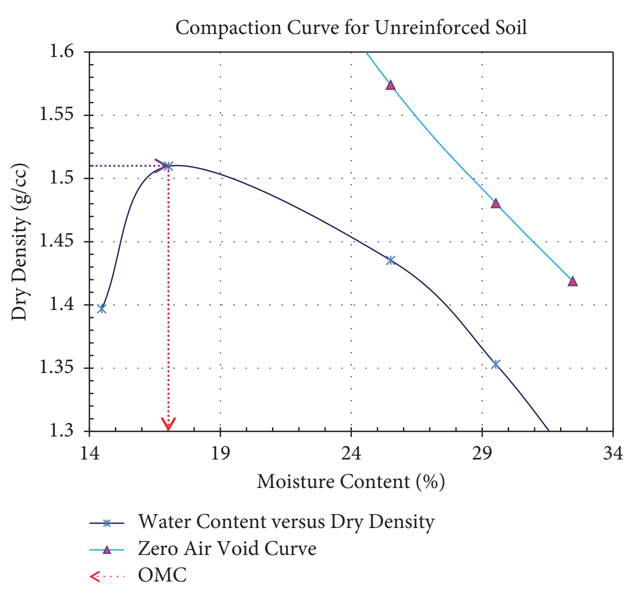

Figure 9: Compaction curve for natural soil.

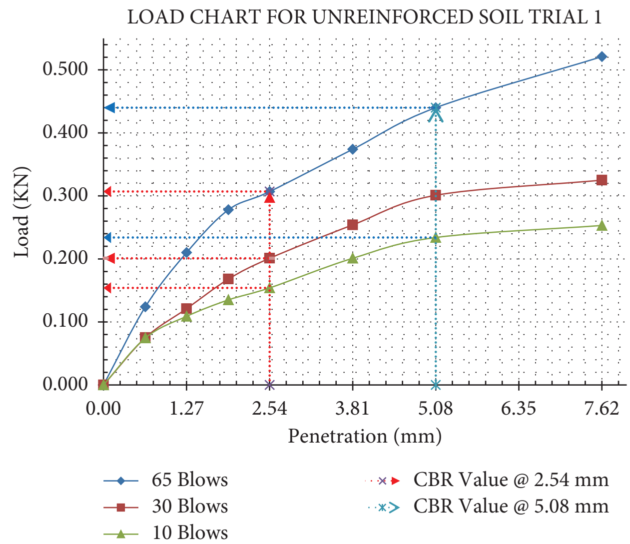

Figure 10: Load versus penetration graph for CBR determination of natural soil-trial 1.

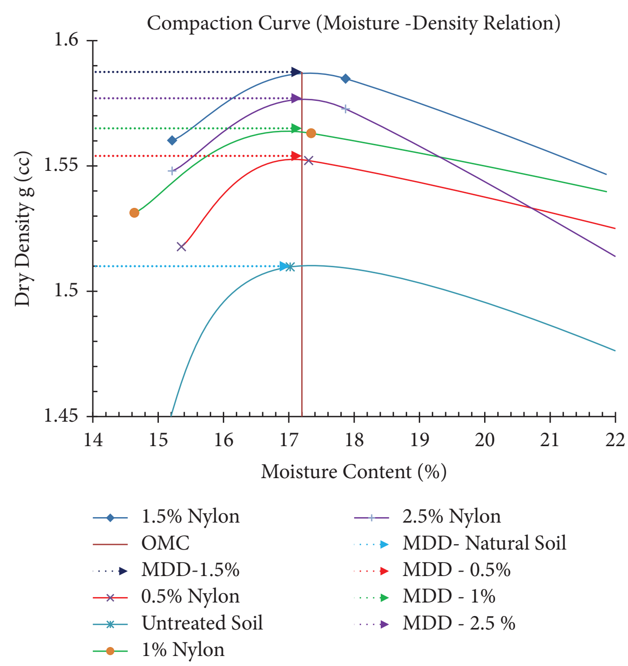

Figure 11: Effects of nylon synthetic fibers on moisture and density.

sensitivity [43, 44]. A modified proctor compaction test was conducted for the soils under consideration to determine the optimum moisture content and maximum dry density of the soils. The optimum moisture content is the moisture content corresponding to the maximum dry density of soils obtained from the compaction curve. The moisture added to the soil prepared for CBR is the OMC obtained from the compaction test. The optimum moisture content obtained from this compaction test is used as input data to prepare the CBR specimen to test the soaked CBR values. The dry density and optimum moisture content of the sample were determined according to the modified proctor test as per ASTM D1557, as concluded in Table 2. Material preparation was carried out according to Method C. Accordingly, the MDD and OMC of the sample of natural soil were 1.51 g/cm^3 and 17.02%, respectively, as shown in Figure 9.

After samples were soaked for 96 hours, CBR and CBR swell were determined as per the ASTM standard. The sample under study possessed CBR and CBR swell values of 1.80% and 8.95%, respectively. Based on the CBR value, the soil was classified as poor subgrade material [45].

Table 4: Percentage increase in CBR values due to reinforcement of fibers.

Fiber length (L (mm))	Percentage of fiber by dry weight of soil	Fiber diameter = 0.3 mm				Fiber diameter = 0.4 mm			
		AR = (L/D)	CBR value (%)	% increase in CBR value	Soaked CBR swell (%)	AR = (L/D)	CBR value (%)	% increase in CBR value	Soaked CBR swell (%)
	0		**1.80**	—	**8.95**		**1.80**	—	**8.95**
10	0.5	33.33	5.03	179.4	8.22	25	5.21	189.4	6.19
	1		5.83	223.9	7.09		6.39	255.0	6.03
	1.5		6.575	265.3	5.84		6.89	282.8	5.06
	2.5		6.52	262.2	3.87		6.81	278.3	4.11
	0	—	**1.80**	—	**8.95**		**1.80**	—	**8.95**
20	0.5	66.67	5.45	202.8	8	50	6.01	233.9	6.07
	1		6.2	244.4	6.13		6.87	281.7	5.66
	1.5		7.38	310.0	4.23		7.96	342.2	5.65
	2.5		7.3	305.6	3.87		8.02	345.6	5.5

Making these values bold is just to see the CBR value of the natural (unreinforced) soil and compare it with other percentages of reinforcement.

Table 5: Effect of nylon synthetic fiber on CBR.

S. no	Fiber diameter (D (mm))	Fiber length (L (mm))	Aspect ratio (AR) = L/D	% wt. of fibers	CBR value (%)	Soaked CBR swell (%)
	Weak subgrade soil + nylon synthetic fiber thread					
1	0.3	10	33.33	0.5	5.03	8.22
				1	5.83	7.09
				1.5	6.575	5.84
				2.5	6.52	3.87
		20	66.67	0.5	5.45	8
				1	6.2	6.13
				1.5	7.38	4.23
				2.5	7.3	3.87
2	0.4	10	25.00	0.5	5.21	6.19
				1	6.39	6.03
				1.5	6.89	5.06
				2.5	6.81	4.11
		20	50.00	0.5	6.01	6.07
				1	6.87	5.66
				1.5	7.96	5.65
				2.5	8.02	5.5

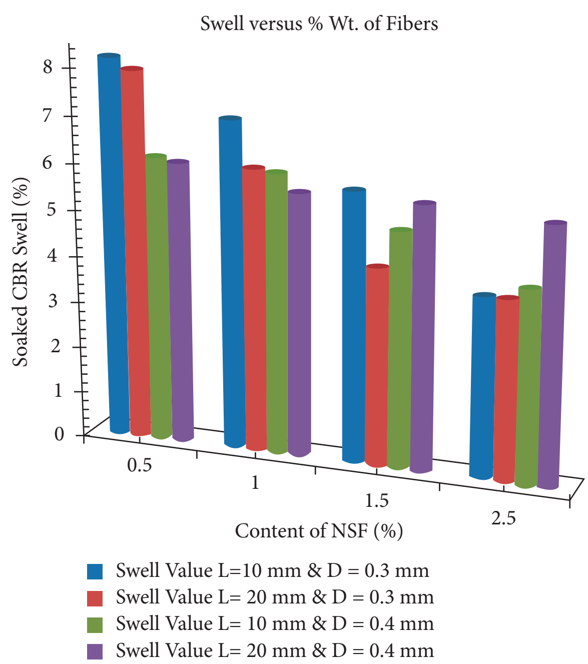

Figure 12: Effects of nylon synthetic fibers on CBR swell.

The lab result showed that the soil had weak strength and a high plasticity index, which deviates from the standard requirement for subgrade for highway construction. Therefore, the soil requires initial treatment and stabilization [46] to improve its engineering properties.

The relationship between load and penetration of the natural (unreinforced) soils during the first trial of the CBR test is shown in Figure 10.

3.3. Effect of NSF on the Performance of Weak Subgrade Soil

3.3.1. Effect of Nylon Synthetics Fiber on Moisture Density Relation. The moisture density relations are determined based on ASTM D1557 Method A, as shown in Table 2 above. Tests were conducted with different percentages (0.5%, 1%, 1.5%, and 2.5%) of Nylon Fiber added to the weak subgrade soil. The moisture content versus dry density were plotted to determine the values of MDD and OMC, as shown in Figure 11. As shown in the figure, the optimum moisture content almost remained constant with the increment of nylon synthetic fiber (NSF) content, whereas the maximum dry density increased with the increment of NSF content which is an almost tolerable result according to [47]. However, [17, 48] observed that the optimum moisture content was increased and the maximum dry density was decreased with the increment in jute fiber and fly ash and

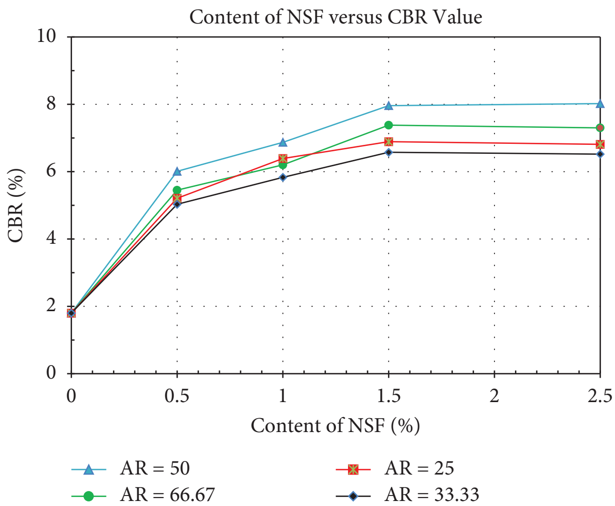

Figure 13: Summary of CBR test result for different aspect ratios (ARs).

nylon synthetic fiber content for each length and diameter. This is probable due to the material and fiber content variations used in the tests.

3.3.2. Effect of Nylon Synthetic Fiber on CBR and CBR Swell. The CBR test was conducted by taking an air-dried sample according to ASTM 1557 with the standard modified Proctor method, A. A sample of soil passing through sieve No. 4 (4.75 mm) was mixed with different percents of NSF (0.5%, 1%, 1.5%, and 2.5%) for compaction. The CBR value was determined by the three-point CBR method through modified compaction with five layers of tamping or compaction. All samples were soaked for 96 hours. CBR swells were conducted with different percents of NSF threads added to the soil. The effects of NSF were determined by changing its percentages and aspect ratios. The summary of the results is shown below.

The CBR values increase with the increase in aspect ratio of NSF by keeping the diameter constant and decrease with the decrease in aspect ratio by keeping the length constant. It was also observed that increasing the length and diameter of NSF further increased the CBR value of reinforced soil, and the same conclusions were indicated by the studies [10, 39–41], and this increase is substantial at a fiber content of 1.5% for an aspect ratio of 50 (length = 20 mm, diameter = 0.4 mm; refer to Table 4).

As shown in Table 5 and Figure 12, the swelling of the soil decreases as the percentage of fibers increases, but the degree of minimizing the swell is not sufficient.

The CBR value was increased by increasing both the length and diameter of the fibers, as shown in Figure 13 and Table 4, and it is supported by other studies [42, 43].

4. Conclusions

As the challenges of weak subgrade soil are high and attention is needed, this investigation was conducted for the performance improvement of weak subgrade soil by nylon synthetic fiber. The literature reviewed, detailed laboratory investigations on weak subgrade soil with NSF threads as reinforcing material, graphs plotted between various soil properties, and various physical parameters (aspect ratio and percentage weight of fibers) of the reinforcing material were analyzed according to the objectives of the study with national and international standards, and the following findings were drawn:

(1) Various aspect ratios such as 33.33, 66.67, 25.00, and 50.00 were adopted in this investigation. The aspect ratios of NSF were identified to affect the CBR values of weak subgrade soil in all cases. Hence, this investigation concluded that the CBR value of weak soil can be increased with the increase in aspect ratio of NSF by keeping the diameter constant and decrease with the increase in aspect ratio by keeping the length constant.

(2) The effect of NSF on weak subgrade soil was clearly shown in this particular investigation. Increasing the content of NSF further increases the CBR values of reinforced soil, and this increase was substantial at a fiber content of 1.5%. The optimum moisture content almost remains constant with the increase in NSF content. However, the maximum dry density increases with an increase in NSF content. Hence, the incremental relation between CBR value and MDD was observed and concluded with this investigation.

(3) The aspect ratio of 50 (length = 20 mm, diameter = 0.4 mm) is the critical value that gives the largest CBR value out of all the other aspect ratios in this study. This aspect ratio can be used for weak subgrade soil stabilization in the field.

(4) The soaking CBR and swell values of natural soil were 1.81% and 8.95%, respectively. Due to reinforcement, the percentage increase in soaked CBR value at the optimum NSF content is 265.3%, 310.0%, 282.8%, and 342.2% for aspect ratios of 33.33, 66.67, 25, and 50, respectively, with reference to natural soil. Also, the percentage decrease in swelling is 34.7%, 52.7%, 43.5%, and 36.9%, respectively. Therefore, from this study, it can be concluded that reinforcing weak subgrade soil with nylon synthetic fiber can improve the value of CBR and decrease the swell value.

(5) The swelling of the soil decreases as the percentage of fibers increases, but the potential for a decrease is not sufficient.

(6) Hence, reinforcing weak subgrade soil with NSF can solve the problems of weak subgrade soil in the road construction industry with regard to performance and swelling problems. Finally, as the percentage of fibers increases, the soil's tendency to inflate reduces, although the possibility of a drop is insufficient.

Therefore, it is open for researchers in the future to combine NSF with other materials, such as lime or others, to lessen the swelling so that comparisons can be made for economic analysis. Moreover, the field suitability of the laboratory result can also be a further research area for concerned experts.

Data Availability

The data that support the findings of this study are available from the corresponding author and in the Jimma University online system [49] upon reasonable request. It can be accessed from the system with this link, https://repository.ju.edu.et//handle/123456789/6813.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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