Chapter 4

RESEARCH METHODOLOGY

4.1 GENERAL

Reinforced soil is a composite material in which the strength of the soil is enhanced by the addition of strong tensile reinforcement. It is one of the most promising areas, where different materials have been used in the last forty years as soil reinforcement materials. Intensive research has been carried out in finding the alternative construction materials to offset the increasing cost of traditional materials. Large application of reinforced earth has been seen in ground slabs, foundations, embankments and retaining walls.

In this study nylon rope was considered for using as soil reinforcement in the form of grid at 6 x 6 inches spacing. Nylon is cheaper than the traditional materials, e.g. steel, polymeric materials (geo-grid, geotextiles). Therefore in this hypothesis it was considered to use nylon as soil reinforcement in temporary works and also for moderate height embankments. To determine the resistance of the nylon ropes under different normal stresses pullout test were performed. The apparatus for pullout test was fabricated. The resistance offered by the nylon ropes was measured with the help of proving ring. Test was conducted on Risalpur soil. Laboratory tests were carried out to determine the index properties of soil. The test was run on assuming different water contents, i.e. dry of optimum and the wet of optimum. Following methodology was adopted in order to carry out this research.

4.2 DESK STUDY

In desk study, the primary objective is to go through the available literature on the subject. Keeping this in view, the collection of available information/literature was carried out to understand the mechanism and theories involved in the soil reinforcement.

4.3 FIELD RECONNAISSANCE

The purpose of field reconnaissance was to select an appropriate site for conducting the pullout tests. Site at the back of soil laboratory at Military college of

Engineering Risalpur was found to be feasible for conducting the pullout tests. Concrete box at back of the laboratory served the purpose of the test with slight modification. Holes were drilled on both the sides of the concrete box for pulling out the ropes with the help jack and clamp arrangement.

4.4 LABORATORY TESTS

4.4.1 General

The laboratory tests were performed for the determination of engineering properties of the soil samples collected from the field. The laboratory test results enabled us to the determination of material properties and the classification of the soil. These results were used as input parameters in the design example (Chapter 5) in which the unsupported embankment height was calculated and also the heights with reinforcement were calculated. All laboratory tests have been performed as per the ASTM standards.

The details about the laboratory tests performed on the samples collected form the test pit and bulk samples from the Risalpur soil are given below:

a. Classification Test

For the classification of the soil samples, grain size analysis and hydrometer tests were performed. The classification of soil was done as per the Unified Soil Classification Systems. The samples for the tests were collected from the test pits excavated at the backside of National Institute of Transportation building. Three sets of samples were collected and tested in a laboratory. For the hydrometer test performed on the particle size less than 0.075 mm (passing sieve no 200), H 152 hydrometer and sodium hexametaphosphate (dispersing agent) were used.

b. Density/Unit Weight

Density/unit weight tests were conducted as per ASTM D2937. For this test, three samples were collected from selected site using tubes (4 X 6 inches). The test was performed with the help of weight volume relationship. Special measures were taken to preserve the in-situ moisture content of the samples and also from the sample disturbance. The density/unit weights were determined through weight volume relationships from bulk soil samples collected through tubes. The values of unit weights were subsequently used as inputs in the design example in next chapter, to calculate embankment heights.

c. Moisture Content

Moisture content tests were carried out with great care because it's important to retain the moisture, which is there in the field conditions. This test was conducted as per ASTM D2216. For this, test samples were collected from the field and determined at the laboratory. The samples were brought to the laboratory in packing, which could minimize sample disturbance. Moisture contents were taken so as to find the in-situ conditions and subsequently evaluating the soil behavior under low and high moisture conditions.

d. Atterberg Limits

Atterberg limits tests were conducted as per ASTM D4318. Liquid limit and plastic limit was carried out on the 4 samples collected from the site. Liquid limit is defined as the water content, which produces a groove closure of 12.7mm for 25 blows in liquid limit apparatus. And the plastic limit has been arbitrarily defined as that water content at which a soil thread just crumbles when it is rolled down to a diameter of approximately 3 mm. Figure 4.1 is showing the laboratory test samples. The liquid limit and plastic limits are used internationally for the soil identification, classification and for strength correlations. The potential volume change can often be detected from liquid and plastic limit tests.

e. Direct Shear Test

The direct shear test was performed as per the reference ASTM D3080. The undisturbed samples were obtained from the field using Shelby tubes. The specimen for the direct shear test were prepared in the specified ring dimensions of 63.5 × 63.5 × 20 mm. The ring containing the specimen was placed in the testing machine and the specified load was applied through the loading yoke. Normal loads of 5, 10, and 15 kg on the specimen were used for three consecutive tests. After the consolidation of the specimen was over under the applied normal stress, it was sheared at the strain rate of 1.2

mm/m. Loads, horizontal and vertical displacements of the specimen were recorded during the course of the test. Stress-strain curves were plotted for three tests. Finally the strength parameters, c and ϕ were computed from direct shear test.

FIG.4.1. Liquid Limit and Plastic Limit Tests

f. Standard Compaction Test

The standard compaction test was conducted in laboratory as per reference ASTM D1557. The purpose of this test was to obtain the moisture-unit weight relationship for a given compactive effort on the particular soil. Compaction achieves soil stabilization through the input of energy into the soil by:

- An increase in shear strength since this is a function of unit weight (the other variables are structure, ϕ and c).
- An increase in swell potential.
- An increase in unit weight.
- A decrease in shrinkage.
- A decrease in permeability.
- A decrease in compressibility.

g. Elongation Test

Elongation test was done on the nylon in the soil laboratory. The purpose of this test was to check the short-term elongation in nylon. As there was no standardized apparatus available in the laboratory for elongation test, following method was adopted to see the behavior of nylon under a constant load. Loads equivalent to 612 psi, 1836 psi and 4000 psi were hanged on one side of the nylon specimen of length 12 inches and the other end was tied to a fixed support as shown in Figure 4.2. After allowing the initial elongation reading were taken after every 1 hour until the elongation becomes constant. Finally the graph was plotted between the elongation and days.

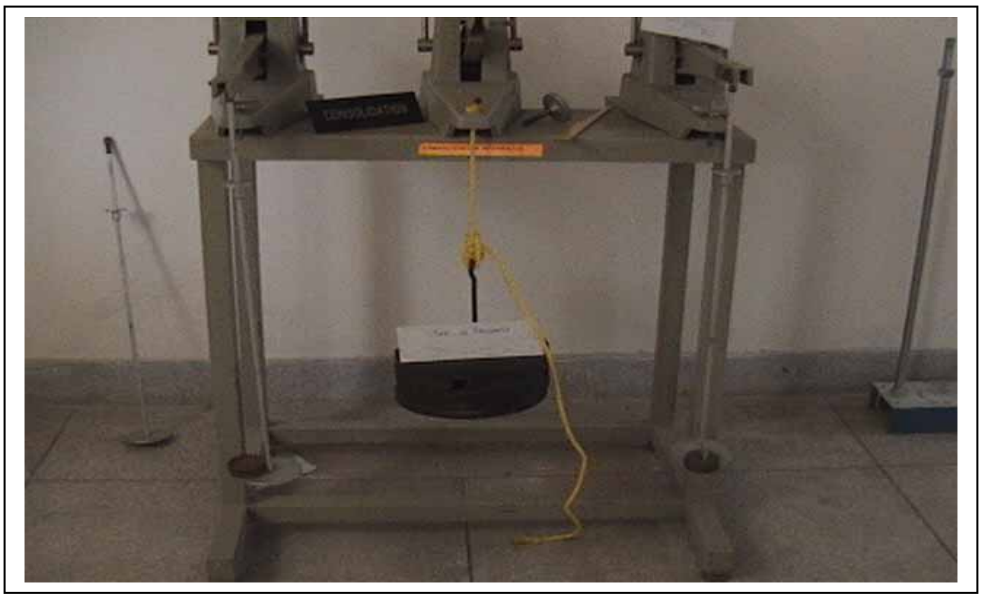

FIG. 4.2. Elongation Test on Nylon

h. Specific Gravity Test

The specific gravity test was carried out in laboratory as per reference ASTM D854. The value of specific gravity is necessary to compute the void ratio of the soil; it is used in the hydrometer analysis, and also to predict the unit weight of the soil. Occasionally, the specific gravity may be useful in the soil mineral classification; e.g., iron minerals have larger values of specific gravity than silica.

The specific gravity of any substance is defined as the unit weight of the material divided by the unit weight of distilled water at 4 C^o.

$$G_s = \frac{\gamma_{material}}{\gamma_{water}\, at 4C^o}$$

i. Tensile Strength Test

The purpose of this test was to determine the ultimate tensile strength of nylon with the help of universal testing machine. This test was done in the strength of materials laboratory. A specimen of nylon rope of length 8 inches was tested under tensile loading at constant rate as shown in Figure 4.3. The speed of the universal testing machine was kept at 5mm/min. The tensile load was measured with the help of dial gauges and the elongation in the nylon was also measured.

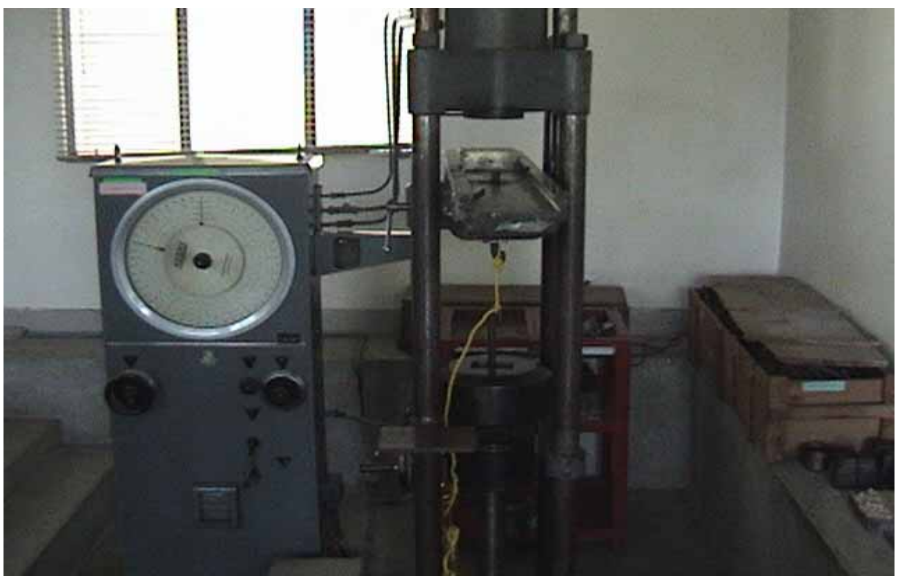

FIG. 4.3. Tensile Strength Test

4.5 Pullout Test

4.5.1 Development of Apparatus

Pullout test apparatus was fabricated to determine the pullout resistance of soil-nylon composite. Nylon grid of 6 X 6 inches was used as soil reinforcement in Risalpur soil. Five longitudinal members of nylon ropes were pulled out of the soil composite with the help of jacks, the displacement of the nylon grid and settlement of the soil-nylon composite under the applied load was measured with the help of proving ring. The apparatus comprised of following ingredients.

a. Apparatus

b. Soil sample

c. Testing Box

d. Pullout test procedure

a. Apparatus

The apparatus consisted of hydraulic Jacks (manual and motorized), nylon rope, steel plate, iron frame, clamp, electric motor, proving ring and dial gauges. Each apparatus is discussed below

I. Hydraulic Jacks

Two Hydraulic Jacks were used in the test.

(i) Manual Hydraulic Jack.

(ii) Motorized Hydraulic Jack.

(i) Manual Hydraulic Jack

Manually operated hydraulic jack of max 5ton capacity was selected for applying the load in four stages from minimum of 0.75 tons to a maximum of 3 tons. A proving ring with a dial gauge was attached to jack for measuring the load.

(ii) Motorized Hydraulic Jack

A motorized hydraulic jack was used to apply a uniform pulling stress on the nylon grid, which was attached to a clamp. The time required to pullout the clamp with motorized jack was found to more than the manual jack. Both manual and motorized jacks were used in the test to check the difference between the two jacks. But no major difference in operation was noticed during the test. The arrangement of motorized jack is shown in Figure 4.4.

FIG.4.4. Motorized Jack for Pulling the Ropes

II. Steel Plate

A steel pate of 22 inches by 34 inches leaving inch free on each side of the test pit to cater for the friction with the walls of the test pit. The purpose of the plate was to distribute the vertical load uniformly over the entire soil area.

III. Iron Frame

An iron frame of height 3 feet and top width of 3 feet 4 inches was fabricated to give reaction to the hydraulic jack applying the normal load from the top. The frame was bolted fixed to the sides of the concrete box with the help of two bolts 12 inches long and ½ inches diameter.

IV. Nylon Rope

A nylon rope of 1/4 inches diameter was selected for making a nylon grid to be used as soil reinforcement for the soil selected for testing. Nylon grid consisted of 6 inches by 6 inches grid spacing, covering 3 feet by 2 feet of the test pit. One end of the nylon grid was free to measure its displacement while the other end was held tightly with the help of a clamp. Iron frame and the nylon grid is depicted in Figure 4.5.

FIG. 4.5. Nylon Grid and the Iron Frame

V. Clamp

An Iron clamp was manufactured for the practical to serve the purpose of holding the nylon ropes of the geo-grid at one end and apply a constant pulling stress. It consisted of 5 holes, each to grip each nylon thread. The width of the clamp was 2feet equal to the width of test pit.

VI. Electric Motor

An electric motor was attached with the hydraulic jack for applying the pullout force to the nylon grid.

VII. Proving Rings

Two proving rings were used in the test for measuring the force, one with the hydraulic jack applying vertical load and second with the hydraulic jack applying the horizontal pullout force.

VIII. Dial Gauges

Three dial gauges were used in the test, two were attached with vertical and horizontal proving rings respectively, to indicate the horizontal and vertical loads and third one was attached with the clamp to indicate the horizontal displacement. The arrangement of clamp, proving ring and dial gauges is shown in Figure 4.6.

FIG. 4.6. Clamp, Proving Ring and Dial Gauges Arrangement

b. Soil Sample

The soil used for the test was Risalpur soil. The sample was taken from the site situated at the back of NIT building. The soil was classified as CL-ML according to Unified classification system. The strength parameters and index properties of the soil were determined in the laboratory.

c. Test Box

A concrete box of 3 feet height, 2 feet wide and 2 feet depth was used for the pullout test. It was already built at the backside of Soil Laboratory in Military College of Engineering, Risalpur Cantt**.** The concrete box with 6-inch thick walls and it served the requirement of the test with slight modifications. Five holes were drilled on the two faces of the box for pulling out the longitudinal members of nylon ropes. Displacement of the nylon grid was measured with the help of steel bars, which were fastened on the joints of the gird.

FIG. 4.7. Concrete Test Box and Jack Arrangement for Vertical Loading

d. Pullout Test procedure

First of all the undisturbed and disturbed soil samples were taken from the mentioned site for laboratory testing and preliminary soil testing was done which are as follows. All the laboratory tests were performed according to ASTM standards.

a. Moisture content.
b. Standard Proctor test.
c. Sieve Analysis.
d. Hydrometric Analysis.
e. Atterberg Limits (LL, PL).
f. Specific gravity test.
g. Elongation test.
h. Tensile strength test of Nylon rope.

After conducting the laboratory testing, the apparatus for pullout test was placed in the concrete box for testing. Plastic sheet was placed inside the concrete box and grease was applied on the four sides to minimize the friction between soil and the walls. Then soil was filled in 6-inch thick layers, each layer was compacted using mechanical compactor until the drilled holes, which were at 1-foot height from the bottom of the box. Then the nylon grid was laid above the soil and the ends of the ropes were passed through the holes on both the sides. The ropes were then fixed into the clamp on one side to measure the pullout resistance offered by the nylon gird under different normal stresses, while on the other side, the rope ends remained free. A thin metallic wire was tied to the joint of the nylon grid to determine the displacement at the free end.

Then the remaining portion of the concrete box was filled with the soil in layers. After the soil is completely filled in the box, a steel plate is placed at the top of the test pit for uniform distribution of load over the entire concrete box.

A hydraulic jack with proving ring and dial gauge was also placed at the top of the plate to apply a vertical uniformly distributed load.

Finally the normal load was applied simulating the different heights of embankments i.e. 2 ft, 4 ft, 6 ft, and 8 ft and for each normal load horizontal pullout resistance was noted. The vertical loading was applied in four steps with varying over burden as described below:

Step 1

The vertical loading was equal to an over burden of 2 feet high embankment.

$$P = \gamma * h$$
$$= 120 * 2$$
$$= 240 \text{ Psf}$$
$$\text{Load} = 240 * 6$$
$$= 1440 \text{ lbs}$$
$$= 0.72 \text{ ton}$$

Step2

The vertical loading was equal to an over burden of 4 feet high embankment.

$$P = \gamma * h$$

$= 120 * 4$

$= 480$ Psf

Load $= 480 * 6$

$= 2880$ lbs

$= 1.44$ ton

Step 3

The vertical loading was equal to an over burden of 6 feet high embankment.

$P = \gamma * h$

$= 120 * 6$

$= 720$ Psf

Load $= 720 * 6$

$= 4320$ lbs

$= 2.16$ ton

Step 4

The vertical loading was equal to an over burden of 8 feet high embankment.

$P = \gamma * h$

$= 120 * 8$

$= 960$ Psf

Load $= 960 * 6$

$= 5760$ lbs

$= 2.88$ ton

The horizontal displacement and the deformation were measured for each step of loading. Finally graphs were plotted between pullout resistance and normal load. After each step nylon grid was examined and was replaced for the next stage. The pullout tests were conducted on dry side of optimum and also on the wet side of optimum to check the behavior of nylon gird with varying water contents. The results of the all the tests are discussed in the next chapter.