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Soil Reinforcement Techniques

Prashant Patil*, Ipupu Mena*, Shubham Goski*, Yogesh Urs**
**Graduated B.E. Civil, N. K. Orchid College of Engineering & Technology, Solapur*
***Assistant Professor, N. K. Orchid College of Engineering & Technology, Solapur.*

ABSTRACT
In many activities concerned with the use of soil, the physical properties like Stiffness, Compressibility and Strength are some of the few important parameters to be considered. Of the many methods involved in improvement of soil properties, soil reinforcement is method concerned with increase of *strength* properties of soil. In soil *reinforcement,* the reinforcements or resisting element are of different materials and of various forms depending upon the intended use. The reinforcement can be provided permanently or temporarily to increase strength of adjacent structures. The present topic of discussion involves different materials, forms and applications of soil reinforcement
Keywords: strength, reinforcement, materials, applications.

I. HISTORY OF THE SOIL REINFORCEMENT

Basic principles of soil reinforcement already existing in nature and are demonstrated by animals, plants and birds. The modern form of the soil reinforcement was first applied by Vidal (1969). Based on the Vidal's concept the interaction between soil and the reinforcing horizontal member is solely by friction generated by gravity.

Applying this concept retaining walls were built in France in 1986. Nowadays this technique is widely used in Europe and U.S.A. This technique is yet to become popular in India, and the constraining factor being identified as the non-availability of fiber and cost of reinforcing material.

Reinforced soil is somewhat analogous to the reinforced concrete. But direct comparison between the functions of reinforcement in the two cases is not valid. The mode of action of reinforcement in soil is not one of carrying the developed tensile stresses as in reinforced concrete but of anisotropic reduction of normal strain rate.

II. MECHANISM

To understand the mechanism by which reinforcement improves the performance of soil, let us look at two laboratory scale experiments. In the first case, a tank ABCD as shown in figure is filled with dry sand. When we remove side AB of the container, the vertical face of the sand does not remain stable and the soil mass rearranges itself as a sloping surface. We now repeat the same experiment by using geotextile material as reinforcement in soil mass. The geotextile is the flexible material that resembles a strong or thick sheet of cloth. This material is placed in horizontal layers when the sand is filled in the tank and it is folded at the ends as shown in figure. After removing the side AB, the vertical side does not collapse. We may observe some bulging but the face remains vertical and stable. This is so because, when the soil particles in the failure zone begin to collapse, the geotextile reinforcement prevents their movement

1. During the shearing stage, prior to failure, the reinforced soil sample shows lower radial and axial strain under the same deviator stress as compared to unreinforced sample.
2. At failure, the deviator stress of the reinforced sample is significantly larger than that of sample without reinforcement indicating higher shear strength of the former

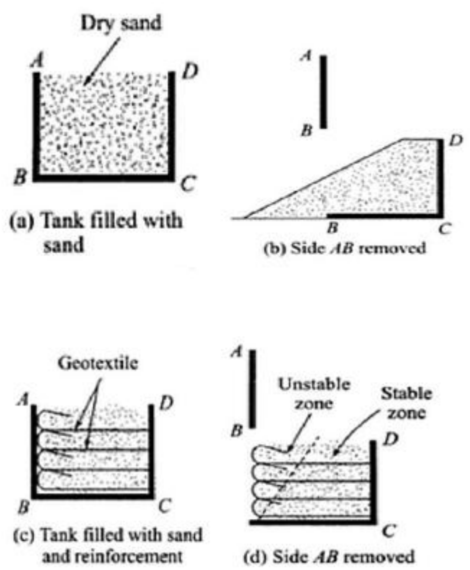


Figure 2.1

If we take two samples of medium-dense sand, one reinforced and the other not reinforced and test them in the triaxial apparatus under consolidated drained conditions. The reinforcement is introduced in one of the soil sample in the form of four discs of thin aluminium foil placed horizontally in the sample. Two important observations can be made from these tests:

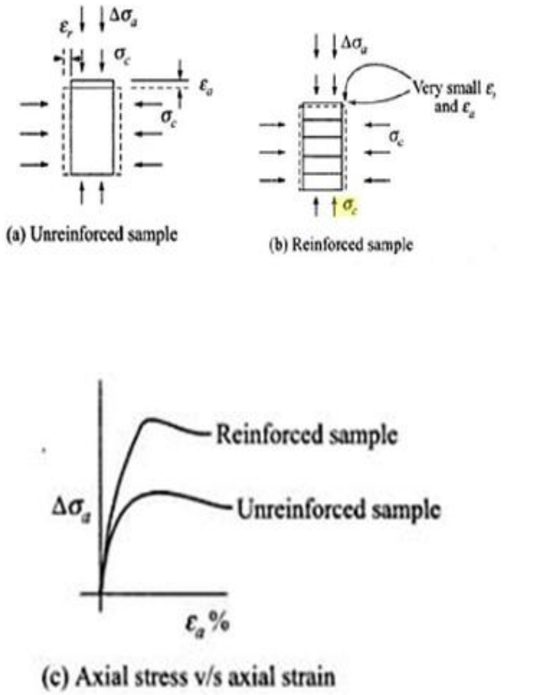


Figure 2.2

III. MATERIALS

There are two basic materials used in the construction of reinforced soil.

- Soil or fill matrix
- Reinforcement or anchor system

There used to be adequate inter-relationship between the materials used. Based on the design strength and availability, the materials are selected. We will discuss one by one, the materials that are being used.

Soil or fill matrix

The shear properties of soil can be improved as theoretically any soil could be used to form earth reinforced structure. In long term conventional structures the soil used is the well graded cohesionless soil or a good cohesive frictional fill although pure cohesive soils have been used with success. The advantages of cohesionless soil are that they are stable, free draining, not susceptible to frost and relatively non-corrosive to reinforcing elements.

The only disadvantage is its cost. As a convenient compromise between the technical benefits from cohesionless soil and economic benefits from cohesive soil, cohesive frictional may be preferred.

Sometimes the use of waste material as fill for reinforced soil structures is attractive from an environmental as well as economic view point. Mine wastes and pulverized fuel ash are the wastes usually employed

Reinforcement

A variety of material including steel, concrete, glass, fiber, wood, rubber, aluminium and thermoplastics can be used as reinforcing material. Reinforcement can have the form of strips, grids, anchors and sheet material chain, planks, rope, vegetation and combinations of these or other material forms.

- Strips are flexible linear elements having their breadth greater than their thickness. Strips are formed from aluminium, copper, polymers and glass fiber reinforced plastic and bamboos. The forms of stainless galvanized or coated steel strips are either plain or with projections such as to increase the friction between reinforcement and fill.

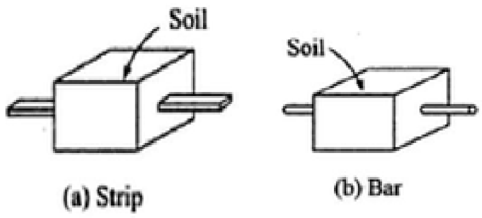


Figure 3.1

- Grids or are also used as reinforcement. Grids are formed from steel in the form of plain or galvanized weld mesh or from expanded metal.

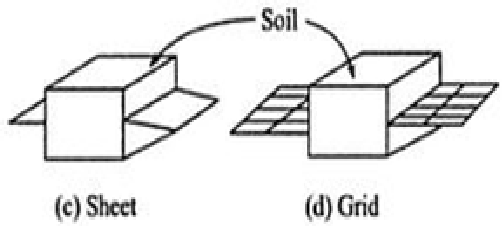


Figure 3.2

- Sheet reinforcement may be formed from metal such as galvanized steel sheet, fabric or expanded metal not meeting the criteria for a grid

Flexible linear elements having one or more pronounced distortions which act as abutments or anchors in the fill or soil. They may be made from materials like steel, rope, plastic or combination of materials such as webbing and tyres, steel and tyres etc.

Composite reinforcements can be formed by combining different materials and materials forms such as sheets and strips, grids and strips and anchors, depending on the field problem requirement.

The principal requirements of reinforcing materials are strength, the stability (low tendency to creep), and durability, case of handling, a high coefficient of friction, and/or adherence with the soil, together with low cost and ready availability.

Geosynthetics

Geosynthetics are manmade products. They are flexible and planar (sheet-like). They are manufactured from synthetic polymeric materials and sometimes from natural materials. They find use in Geotechnical engineering as a separator, filters, drains, reinforcement, hydraulic barriers, protectors and erosion control system.

I. Geotextiles are porous geosynthetics that resemble a thick strong cloth or blanket with its strands and fiber visible. They are planar permeable, polymeric material that are usually made from polypropylene and sometimes from polyester, polyethylene or from natural fibers such as jute .they can be woven, non-woven or knitted. Woven geotextiles are produced by weaving or interlacing, usually at right angles of two or more set of fibers. Non-woven geotextiles are produced by mechanical bonding or needle punching of randomly oriented fiber. Geotextiles can be 0.25 to 7.5 mm thick and have a mass/unit area of 150 to 2000 gm/mm^2

Fig 1. Woven Geotextile Fig 2. Non-woven Geotextile

Figure 3.3

II. Geogrids are mesh like or grid like geosynthetics with square or rectangular openings that are larger than the thickness of the ribs. the rib thickness ranges from 5 to 15mm and the mass /unit area lies between 200 to 1500 gms

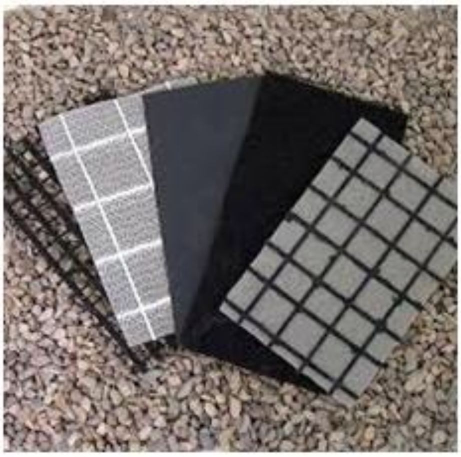


Figure 3.4

III. Geonets are similar to geogrids but have thinner member sand angular apertures ,not square or rectangular but resembling parallelograms

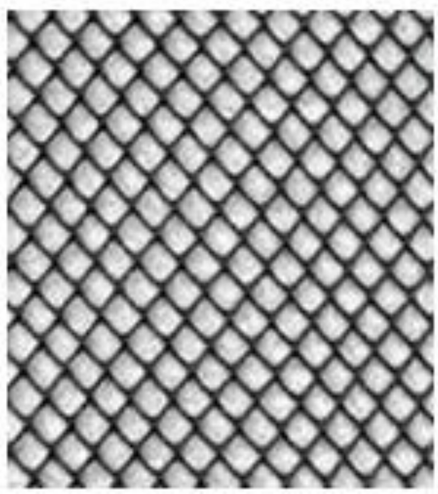


Figure 3.5

IV. SOIL REINFORCEMENT TECHNIQUES

Soil reinforcement techniques can be divided into two major categories

1. Insitu soil reinforcement
2. Constructed soil reinforcement

In the insitu reinforcement technique the reinforcement is placed in an undisturbed soil to form a reinforced soil structure. This includes the technique of soil nailing and soil dowelling. The reinforcement used for insitu structures is usually linear owing to the method of installation.

1. Open excavation using soil nails:

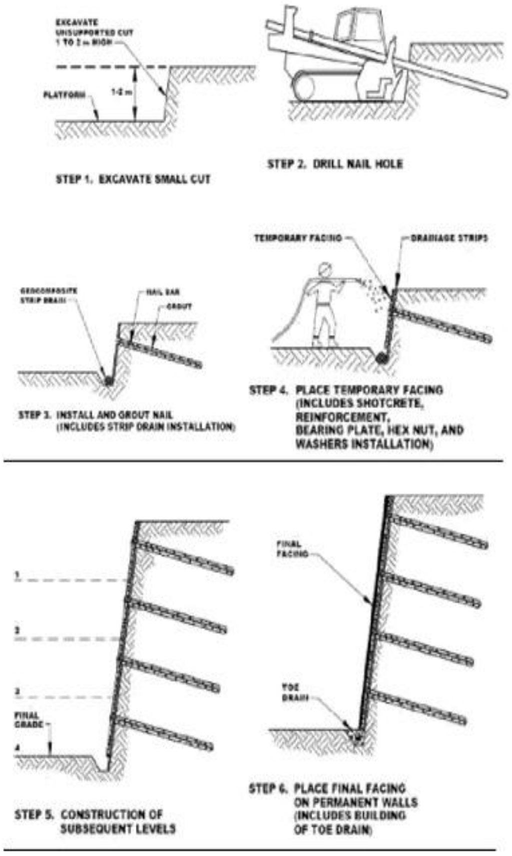


Figure 4.1

Vertical or steeply inclined cuts can be made for open excavation using rigid soil nails as reinforcements. Such cuts are also referred to as nailed soil walls. Unlike reinforced soil walls are constructed from bottom to top, nailed soil walls are constructed from top to bottom. The facing of such walls is usually in the form of a wire-mesh reinforced shot Crete panels, although metal plates and other types of panels have also been used. Soil nails are installed at an inclination of 20 to 25 degrees to the horizontal near the ground surface so as to avoid intercepting underground utilities and the inclination is reduced to 10 to 15 degrees as we go deeper into the cut.

2. Constructed soil reinforcement technique:-

1. Reinforced soil structures with vertical face:-

The facing usually comprises of prefabricated concrete or steel panels joined together by an interlocking arrangement. The soil used as backfill in such cases is granular soil with less than 15% fines to enable development of large friction between the reinforcement and soil. The most often used reinforcement is steel strips since they have large tensile strength as well as low extensibility. Construction takes place from bottom upwards and the reinforcement is placed sequentially as layers of soil are compacted, one after the other.

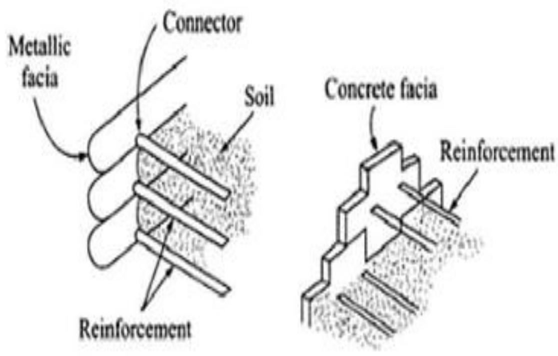


Figure 4.2

The constructed soil reinforcement technique describes the technique where the reinforcement is placed at the same time as an imported and remolded soil. Such technique are often called as bottom up process as they involve the placement of a fill and reinforcement simultaneously, these include structures such as reinforced soil embankments and bridge abutments. The reinforcement used for the constructed category is in the form of strips, mats or grids.

V. APPLICATIONS OF SOIL REINFORCEMENT

1. Slope failure repairs

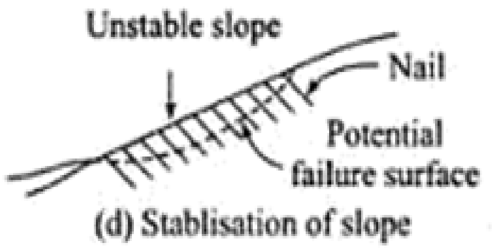


Figure 5.1

Large and small landslides and failures of natural slopes often occur in areas where the value of the environment (for technical or economical or touristic or artistic reasons) call for the repair of the slope to the original (or as close as possible to the original) geometry. Geogrids allow using the same soil of the landslide to reinstate the slopes thus achieving fundamental savings over the solution of importing a soil with better mechanical characteristics. The geogrid reinforced slope can be easily vegetated with the local essences, in order to obtain the best integration with the surrounding environment.

2. Slope cutting repairs

The installation of pipelines and other underground structures often requires cutting a slope in protected or valuable areas where the Authority imposes to repair the cutting to the original situation. This may produce geotechnical problems due to the fact that the excavated soil results in lower mechanical characteristics than the original soil in the slope. Geogrids allow improving the stability of the soil: the slope can be rebuilt without using expensive consolidation techniques.

3. Steep slopes embankments and bunds

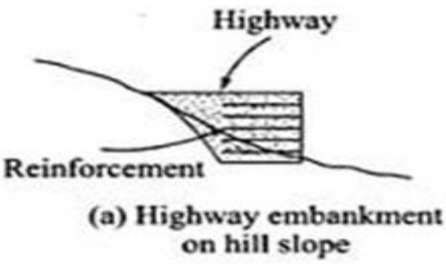


Figure 5.2

There are many situations where the shortage of space or fill material calls for the construction of embankments and bunds with very steep slopes, greatly in excess of the naturally stable angle.

Geogrid reinforced soil structure provide a safe, sound and economical solution which can be used for some of these applications:

- Noise protection bunds along highways, railways and airport taxiways
- Blast protection embankments
- Increase of the available volume in exhausted landfills
- Construction of embankment dams for solid or liquid impoundments.

In all these applications, the inherent flexibility, the ease of construction, and the use of any locally available fill soil are the technical and economic advantages of geogrid reinforced soil structures.

4. Widening of slope crest.

There are different cases where a rather flat slope has to be converted to a sub-vertical wall enlargement of parking areas, smoothing of sharp road bends, land reclamation projects and housing developments are just examples of them. In most of these cases the toe of the slope cannot be moved forward, due to the right-of-way limits or natural boundaries (rivers, roads, etc.). Therefore the crest of the slope shall be widened, making the slope steeper or even vertical. Geogrids allow building steep slopes and walls with almost any locally available fill soil. The face can be built with a vegetated or concrete finishing different solutions can be easily implemented at design and construction stages to meet technical, architectural, environmental requirements. The original slope has usually to be cut at the bottom to yield enough space for placing the reinforcing geogrids. All the operations can be performed with standard earth-moving machinery and easily available tools, even by unskilled labourers. And, very important, the traffic and the activities in front of the slope are not disturbed by the construction operation.

5. Bridge abutments and wing walls

Bridge abutments and wing walls are often the earth retaining structures that support the highest loads. Besides the high vertical and horizontal loads directly applied by the bridge deck, dynamic loads from heavy traffic, and sometimes seismic loads, challenge the design engineer. Soft foundation soils, high water table, environmental impact regulations often provide further problem. Geogrid reinforced soil structures provide strong, yet flexible, retaining structures. Bridge abutments and wing walls can be designed and built to resist all the anticipated loads with the required Factors of Safety, even with low quality fill soil. Soft soil stabilization and drainage problems can be solved with geogrids and geocomposites. The face can be designed to fulfill any requirement regarding visual and environmental impact.

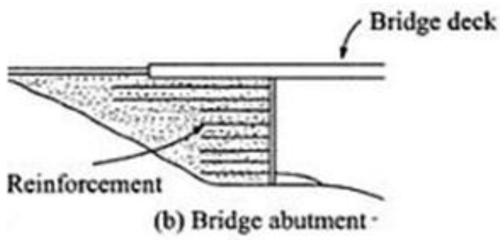


Figure 5.3

6. Soil retaining structures

Soil retaining structures can be divided into:

- FACE WALLS which are usually designed to cover a steep rock slope or a cliff, for environmental and safety reasons. This kind of wall usually has only small or no horizontal pressures from the backfill, but has to resist the internal outward pressure of the fill soil.
- COUNTERSCARP WALLS which must support the constant load of a sloping terrain

on the top. The soil pressures to be resisted are usually much higher than for a face wall.

- RETAINING WALLS which are usually designed to support both static and dynamic loads. The design and construction of face walls, retaining walls and counterscarp walls may have to deal with technical, practical and economical problems due to availability of the fill soil, access to the job site with operating machines, speed of construction, aesthetics, and overall cost and so on. The Technical Authorities and the client often require specific solutions, sometimes with a vegetated face, while sometimes a concrete face or another type of "rigid" face is preferred.

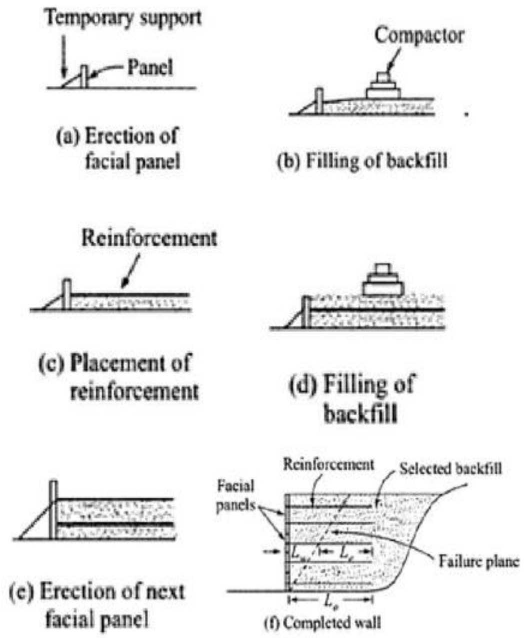


Figure 5.4

Geogrid reinforced walls can be designed and built to fulfill the most varied requirements in terms of load support and face finishing geogrids reinforced soil structures provide a cheap and diversified solution to wall construction problems the experience of engineers can help to find the proper solution, either with a vegetated or concrete face or new solutions can be developed for the face finishing as well as for the construction method and all the ancillary design details.

7. Road and Railway embankments

Road and railway embankments are usually large and high earth structures, which require considerable quantities of fill soil and land.

The cost of the fill soil and its transport from the quarries, as well as the value of the land, may be so high that some alternatives may be considered, such as designing steeper slopes or using lower quality fill soil. Geogrids allow the slope to be built at any inclination with the required Factors of Safety. The specific surcharge loads, as well as the dynamic or seismic loads, can be incorporated into the design to provide safe construction to the Client, the Engineer and the Contractor. Almost any locally available soil can be used for the geogrid reinforced embankment: this facility can produce very large savings in both costs and construction time.

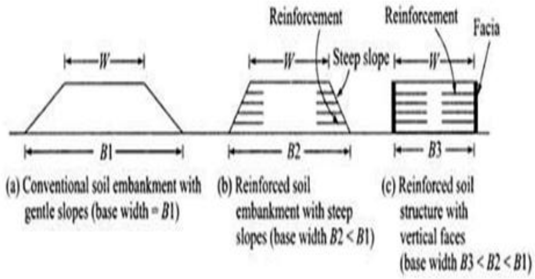


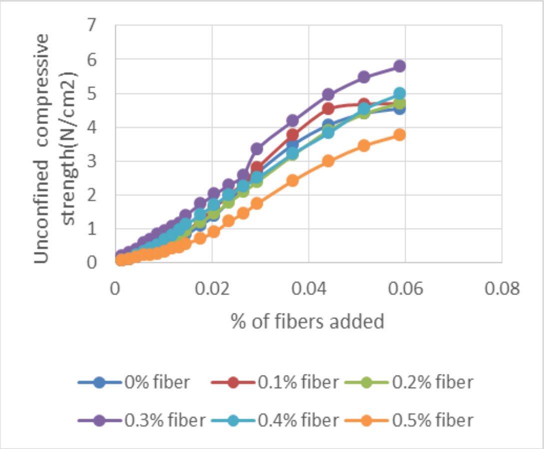
Figure 4.5

VI. TEST RESULTS

The locally available black cotton soil was used for the experiment. The properties of soil used are as follows

1. % of soil passing 75 micron – 54.95%
2. Liquid limit of soil –61.25%
3. Plastic limit of soil –31.15%
4. Shrinkage limit of soil –15.02%
5. Soil classification –Highly cohesive clayey soil
6. Specific gravity – 3.09
7. Maximum dry density –1.35gram/cubic cm
8. Optimum moisture content –27%

Unconfined compressive strength test has been carried out for locally available soil with different percentages of the glass fibers. The strength variation for different percentages of fibers can be given graphically as follows



The results are as follows

Sr. No	% of fibers added	Unconfined compressive strength(N/cm^2)
1	0%	4.676614383
2	0.1%	4.690550575
3	0.2%	4.704426486
4	0.3%	6.090866115
5	0.4%	5.787868872
6	0.5%	4.594023642

VII. CONCLUSION

The use of reinforcement and its effect in increasing soil strength has been discussed. The different material techniques used and its application area have been discussed. In addition to this economical aspect of reinforced soil with unreinforced soil and traditional structure has been discussed and soil reinforced structure is found to be economical.

According to the results, the strength of soil increases on addition of fibers but up to certain limits. Further increase in percentage of fiber results in decrease in the strength. This may be caused because of balling action of fibers, which may result in poor compaction of soil. In this study we observed 0.3% was optimum percentage of fibers causing increase in strength.

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