A comparative review on Reinforced Soil and Reinforced Soil Structures

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Abstract - *Building in layers of compacted soil and reinforcing material is an old construction method – portions of the Great Wall of China were built that way and some sections still remain today. What, is new is the reinforcing materials that are layered with the soil. Today a combination of geo-synthetics and a welded steel wire mesh form is finding success. Construction of building and other civil engineering structures on weak or soft soil is highly risky because such soil is susceptible to differential settlements, poor shear strength, and high compressibility. Various soil improvement techniques have been used to enhance the engineering properties of soil. Soil reinforcement is most popular ground improvement technique. Major advantages of soil reinforcement method are ease of construction, overall economy, time saving etc. Use of geosynthetics material in place of metal is in practice now. Form of metal reinforcement were strips, bars etc. But planar form is the traditional way of reinforcement prepared by geosynthetics.*

Key Words: Reinforced soil, Reinforced soil structure, Reinforcing Materials.

1. INTRODUCTION

Reinforced soil is a composite material formed by the association of frictional soil and tension-resistant elements in the form of sheets, strips, nets or mats of metal, synthetic fabrics, or fiber reinforced plastics and arranged in the soil mass in such a way as to reduce or suppress the tensile strain that might develop under gravity and boundary forces. By means of friction, the soil transfers to the reinforcement the forces built up in the earth mass. The reinforcement thus develops tension and the earth behaves as though, in those directions in which reinforcement has been placed, it has a cohesion, the value of which is directly proportional to the tension in the layers of reinforcement.

All civil engineering structures are constructed on the soil. Many times engineers encounters with poor or problematic soil like soft soil, swelling soil etc. In old times engineers generally avoid construction on such soil, but now a day due to limitation of land we avoid such solution. Problematic soil can be cause of serious damage of structures. So generally they are replaced by some strong soil or they are treated for better engineering properties. The techniques utilized for enhancement of the properties of those soils are known as ground improvement techniques. Ground improvement can be done by some mechanical method, through soil reinforcement or by adding some admixtures in the soil. Suitability of particular methods depends upon the site condition and economy. Among all these methods soil reinforcement technique is most popular method for ground improvement.

2. LITERATURE REVIEW

Since the beginning of civilization, man has attempted to use soil with some other materials to enable it for being used for his necessities. Typical uses include use of branches of trees etc. to support tracks over marshy land to build hutments and to support large structures. In villages mud plaster using rice puska is a popular technique to strengthen the soil. Reinforced soil was used by Babylonians more than 3000 years ago to build ziggurats with woven mats of reeds. These have also been used in parts of the Great Wall of China built about 2000 years ago. The Dutch and Romans used willow to reinforce dives and animal hides.

The recent discovery of methods of preparing high-modulus polymer materials by tensile drawing, in a sense "cold working" has raised the possibility of using such materials as reinforcement in number of civil engineering applications. Today the major function of such geogrids is in the area of the reinforcement. The key features of the geogrids is that the opening between longitudinal and transverse ribs , called the "apertures" , are large enough to allow the soil strike through from one side of the geogrid to the other. The ribs of the geogrids are quite stiff compared to the fibers of the geotextiles. Also not only rib strength is important but junction strength is also important. The reason for this is that the soil strike-through within the apertures bears against the transverse ribs, which transmit their loads to the longitudinal ribs via the junctions. The junction is the location where the longitudinal and transverse ribs are connected.

The original geogrids were first made in the United Kingdom by Netlon, Ltd. and were brought in 1982 to the U.S.by the way of Canada by the Tensar Corp. A similar product by Tenax Corporation is also available.

Textile material was perhaps first used in road construction in South Carolina in the early 1930's. The first use of a woven synthetic fabric for erosion control was in 1950's in Florida by Barett. In 1960's geotextile were extensively used for erosion control both in Europe as well as U.S.A. later in 1969, Giroud used non-woven fabrics as a filter in the upstream face of an earthen dam. In 1971 Wager initiated use of woven fabrics as reinforcement for embankments constructed on very soft foundations.

The term "Reinforced Earth" was used after a French engineer Henry Vidal, who invented this technique. Once while walking across a dry sandy beach, he noticed that mounds of dry sand could be made to stand at a steeper angle after the addition of horizontal layers of pine needles. In modem days, the success of the geotextile depends on synthetic fibres, which are resistant to degradation by the micro-organisms present in the soil. Although even today some fabrics made from natural fibers such as jute, coir etc. is also being used.

3. DIFFERENT TYPES OF REINFORCING MATERIALS

A wide range of alternatives exists in making a choice of reinforcing materials. However for the selection of reinforcement the load on the structure and the function of the structure should be considered. Moreover the cost aspect also should be kept in mind while selecting the type of reinforcement. Various types of reinforcing materials are described below.

1. Jute Fibers: The inclusion of Jute fibers constitutes an effective means of imparting cohesion to remolded and compacted soil. Due to the inclusion of fiber, impact resistance of soil can be considerably improved. The inclusion of jute fibers can be with randomly oriented. Jute fibers within 2-3 years duration disintegrate with the influence of water, heat and sun light. Hence, it recommended for temporary structures.

2. Bamboo Strips: Amongst the various types of reinforcement used in reinforced earth construction, bamboo strips have been in use for long time. They are used both as strips and mats. But, bamboo deteriorates quickly in wet conditions and is also prone to fungus and insect attacks. The bamboo reinforcements need elaborate preservative treatment before use. Bamboo, having mechanical and physical properties in comparison to geotextile or metals, can only be used in small or temporary works.

3. Coir: Coir fibers are suitable for various applications such as, soil stabilization, erosion control, slope protection, landscaping and reinforcement. Coir fibers rot due to the ecological natural cycle. Apart from this, coir fibers are highly water absorbent. Coir has the greatest tearing strength and retains this property in wet conditions, which is cost effective. The coir nets are easy to handle and install. It is a simple process and does not require skilled labour.

4. Fiber Glass: Fiber glass reinforcement has high strength and is also corrosion resistant, but it costs more and hence, is suitable only for special structures and small jobs.

5. Metal Strips: The most commonly and extensively used reinforcement in earth reinforced structures is mild steel or high tensile bars and mats. Aluminum strips have also been tried by some researchers. The steel reinforcement has excellent physical and mechanical properties. However, steel reinforcement is subjected to corrosion by chemical or electrochemical reactions depending upon the physical properties of the solid, thus necessitating corrosion protection measures like galvanization, which often renders it costlier.

6. Geosynthetics: Geosynthetic fibers are made of Polypropylene, polyethylene, and polyester. They have become increasingly popular for use as reinforcement in earth structures in recent years. They are known to be durable and have a long life. They have sufficient strength and the mechanical properties to make them suitable for reinforcement in structures.

4. REINFORCED SOIL (EARTH) STRUCTURE

4.1 Components of Reinforced Earth Structure

Reinforced earth structure consists of three main components shown in Figure 1, namely

i) Reinforcing element
ii) Soil back fill
iii) Facing element

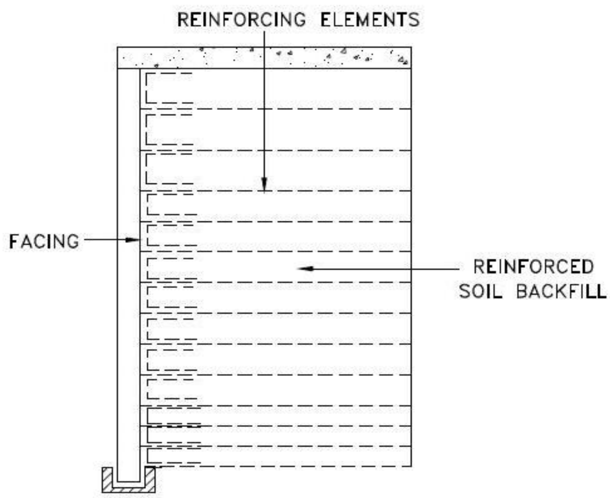

Fig -1: Components of reinforced earth structure

4.2 Description of reinforcing element:

A variety of materials can be used as reinforcing materials .Those that have been used successfully include steel, concrete, glass fibre, wood, rubber, aluminum and thermoplastics. Reinforcement may take the form of strips, grids, anchors & sheet material, chains planks, rope, vegetation and combinations of these or other material forms.

4.2.1 Types of reinforcing materials

Strips: These are flexible linear element normally having their breadth, (b) greater than their thickness, (t). Dimensions vary with application and structure, but are usually within the range t=3-5mm, b=5-100mm. The most common strips are metals. The form of stainless, galvanized or coated steel strips being either plain or having several protrusions such as ribs or gloves to increase the friction between the reinforcement and the fill. Strips can also be formed from aluminium, copper, polymers and glass fibre reinforced plastic (GRP). Reed and bamboo reinforcements are normally categorized as strips, as are chains.

Planks: Similar to strips except that their form of construction makes them stiff. Planks can be formed from timber, reinforced concrete or pre stressed concrete. The dimensions of concrete planks vary; however, reinforcements with a thickness, (t) = 100 mm and breadth, b= 200–300 mm have been used. They have to be handled with care as they can be susceptible to cracking.

Grids and Geo grids: Reinforcing elements formed from transverse and longitudinal members, in which the transverse members run parallel to the face or free edge of the structure and behave as abutments or anchors as shown in Figure 3. The main purpose is to retain the transverse members in position. Since the transverse members act as an abutment or anchor they need to be stiff relative to their length. The longitudinal members may be flexible having a high modulus of elasticity not susceptible to creep. The pitch of the longitudinal members, pL is determined by their load-carrying capacity and the stiffness of the transverse element. The pitch of the transverse elements, PT depends upon the internal stability of the structure under consideration. A surplus of longitudinal and transverse elements is of no consequence provided the soil or fill can interlock with the grid. Mono and Bi-Oriented grid as shown in Figure 2.

Fig -2: Mono and Bi-Oriented geogrid

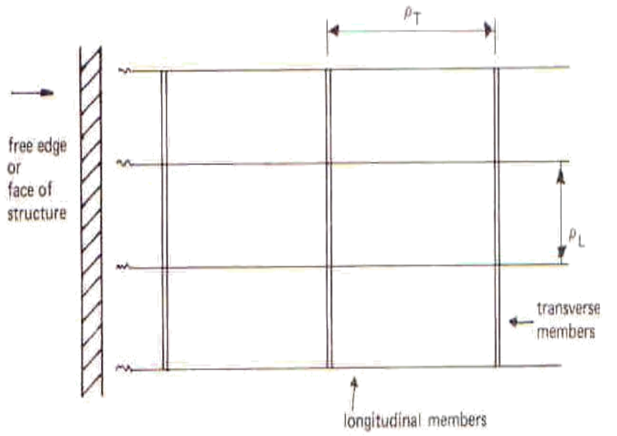

Fig -3: Movement of free face of structure

Grids can be formed from steel in the form of plain or galvanized weld-mesh, or from expanded metal. Grids formed from polymers are known as —Geo grids and are normally in the form of an expanded proprietary plastic product.

Sheet reinforcement: May be formed from metal such as galvanized steel sheet, fabric (textile) or expanded metal not meeting the criteria for a grid.

Nailing : Earth may be protected by geo synthetics with earth nailing.

Anchors: Flexible linear elements having one or more pronounced protrusions or distortions which act as abutments or anchors in the fill or soil. They may be formed from steel, rope, plastic (textile) or combinations of materials such as webbing and tyres, steel and tyres, or steel and concrete as shown in Figure 4.

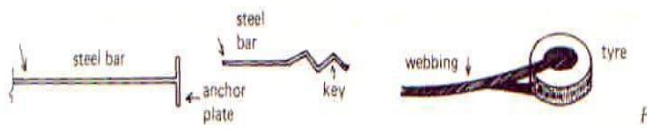

Fig -4: Different Anchors

Composite reinforcement: Reinforcement can be in the form of combinations of materials and material forms such as sheets and strips, grid and strips and anchors, depending on the requirements.

In reinforcement with polymers, polymeric joints are required. Polymeric reinforcement joints are subdivided into prefabricated joints and joints made during execution of the works. A number of different jointing systems are in use. Joints in geotextiles should normally be sewn where load transference is needed. For polymeric meshes or grid a bodkin may be employed. A Bodkin joint is an effective method of joining some polymeric grid reinforcement as shown in Figure 5.

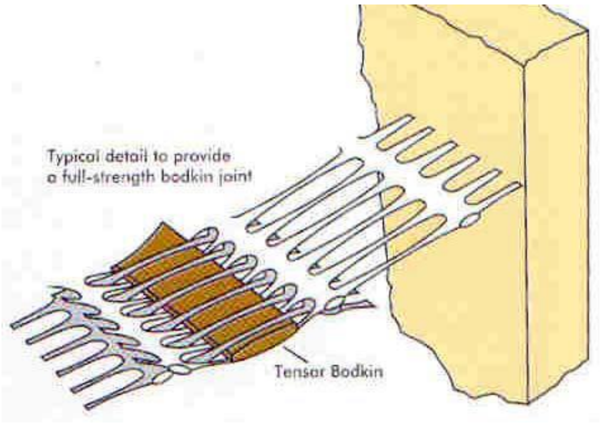

Fig -5: Bodkin Joint

Care should be taken to ensure that:

1. Bodkins have sufficient cross-sectional area and strength to avoid excessive deformation
2. Bodkins are not so large as to distort the parent material causing stress concentrations
3. Joints are pre-tensioned prior to loading, to reduce joint displacement as the components lock together.

4.3 Description of Soil Backfill

The fill material for reinforced earth structures shall be preferably cohesion less and it should have an angle of on interface friction between the compacted fill and the reinforcing element of not less than 30, measured in accordance with IS 13326 Part (I). The soil should be predominantly coarse grained; not more than 10 percent of the particles shall pass 75 micron sieve. The soil should have properties such that the salts in the soil should not react chemically or electrically with the reinforcing element in an adverse manner. A wide variety of fill types can be used with the grids including crushed rock, gravel, industrial slag, pulverized fuel ash and clay, but fill particles greater than 125 mm should be avoided.

4.4 Description of facing element

Facings may be hard or soft and are selected to retain fill material, prevent local slumping and erosion of steeply sloping faces, and to suit environmental requirements. The facing shall comprise of one of following:

- Reinforced concrete slabs
- Plain cement concrete form fill hollow block (precast)
- Masonry construction, rubble facia
- Other proprietary and patented proven system Common facing used with structure are shown in Figure 6

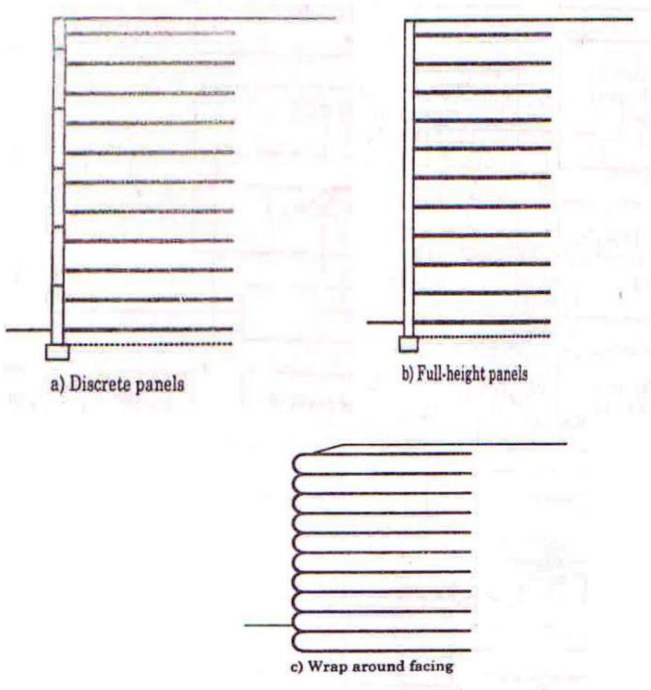

Fig -6: Common facing used with structure

4.5 Hard facings

Facing may consist of concrete, steel sheet, steel grids or mashes, timber, proprietary materials or combination of these. They should conform to the appropriate material standard and should be sized by normal design procedures using the appropriate standard. Interlocking concrete blocks, grout filled bags or Gabions can provide a substantial facing. These facing shown in Figure7.

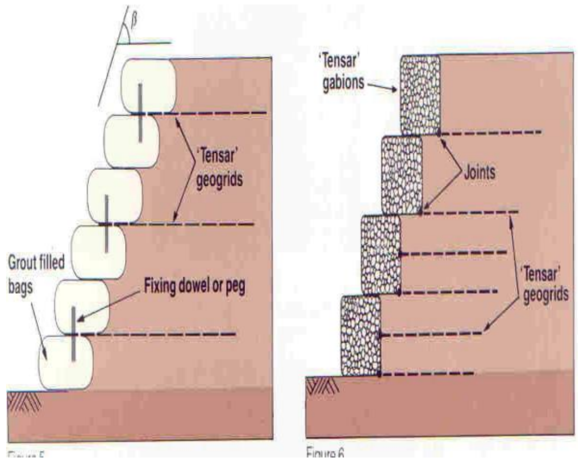

Fig -7: Hard Facing

4.6 Soft facings

Generally, external temporary formwork is erected to support the face during the construction of steep slopes (>45°). It can take the form of a light weight system of scaffold tubes and boards or consist of some form of climbing shutter. The grids are turned up the face of the framework and returned into the embankment directly below the next reinforcement layer. The two grids are connected using a high density polyethylene bodkin. The soft facing is shown in Figure 8.

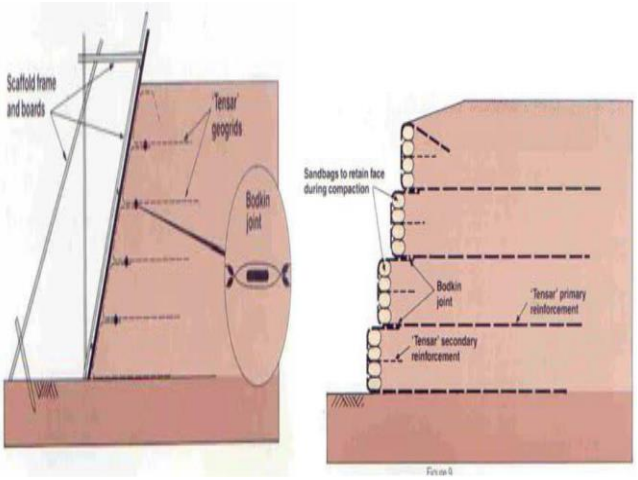

Fig -8: Scaffold frame, Sand Bags (Soft Facing)

Turf and topsoil can be placed on the fill side of the grid reinforcement as it is turned up the face of the slope to create a natural and aesthetic appearance. Where the vertical spacing of the main reinforcement is greater than 500mm, biaxial grid reinforcement is used as intermediate secondary reinforcement to provide local stability at the face of the slope.

4.7 Fasteners between the facing and reinforcing elements

Fasteners are used to make a connection between the reinforcement and the facing and take the form of dowels, rods, hexagon headed screws and nuts and bolts and may consist one of the following materials:

- Plain steel
- Coated steel
- Galvanized steel
- Stainless steel
- Polymers

The choice of material used to form the fastener should be compatible with the design life of the structure.

4.8 Drainage

If the embankment becomes waterlogged and pore water pressures increase, the magnitude of the tensile forces induced into the grid reinforcement also increases. Pore water pressures can be controlled by providing drainage layers at the back of the reinforced zone in combination with an under-drain as shown in Figure 9.

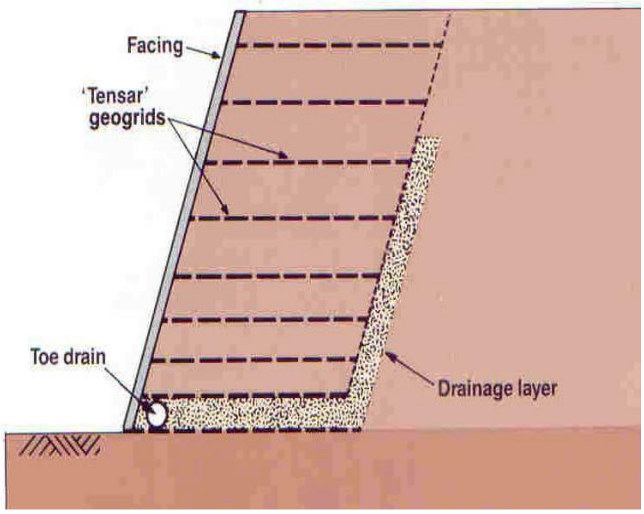

Fig -8: Facing with drainage

5. CONCLUSIONS

It can be concluded from the present review Reinforced soil is a powerful construction technique that has demonstrated its value in a wide range of practical applications, the five most important of which are described in this book. The versatility of reinforced soil and of geotextile materials is far from exhausted and new methods and materials should be expected in the coming years. Improved polymer materials can only make reinforced soil more economically attractive. The experience from the wide usage of reinforced soil will improve the knowledge and confidence in the techniques, and provide more data on the behaviour of reinforced soil structures. Additional measurements of long-term properties for polymer reinforcement materials relevant to field conditions, as well as in the laboratory, will increase our knowledge of the material behaviour. Resulting from these developments will be refinements in the limit state analysis of reinforced soil, particularly under serviceability conditions. The process of codification and standardisation in reinforced soil is underway, but a balance must be struck between preserving sufficient freedom for continued development of the technology, while capturing present best practice in widely accepted standards which will encourage further the widespread application of reinforced soil throughout the construction industry.

Reinforcement of the earth has been mostly to reduce the total and differential settlement and has improved the serviceability limit of structures founded on the soft or compressible earth. The concept has facilitated construction of the high to very high retaining walls and slopes. The reinforcement of slopes can be achieved in a variety of ways such as nailing, root piles, dowels, anchors or even as a combination of reinforcement and drainage.

The concept of reinforcing earth has also attracted the attention of the academic world, for although the concept is easily grasped the theoretical aspects involved are numerous As a result, much research and development work has been undertaken in universities and laboratories and earth reinforcing is now recognized as a separate subject in its own right in geotechnical field.

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