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REINFORCED EARTH AND ITS POTENTIAL APPLICATION IN NEPAL

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ABSTRACT

Although totally new in Nepal the technique of Reinforced Earth has many application areas such as support of carriageways in hill roads, slope stablization, flood protection work, bridge abutments, embankment, industrial structures etc. An attempt has been made through this article to familarize practioners, engineers with this technique. The article includes basic mechanism of Reinforced Earth, materials, construction methods and its application in Nepal. Also some recommendations for the construction of Reinforced Earth in mountaineous environment of Nepal have been given.

INTRODUCTION

The Reinforced Earth is a construction system as shown in Fig. 1, in which reinforcing elements are used to import tensile strength to a soil mass which would otherwise have little or no tensile strength. The reinforcing effect is achieved by frictional adherence between the reinforcing elements and the soil. The technique of Reinforced Earth has achieved a lot of development and wide scope throughout the world because of so many favourable reasons such as simpler construction methods, non-expensive foundations, small formation width, rapid rate of construction, lower maintenance cost etc.

BASIC MECHANISM OF REINFORCED EARTH

State of Stress in a Reinforced Earth Structure

The basic mechanism of Reinforced Earth is illustrated in simplified form in Fig. 2. As shown in Fig. 2 (a) an axial load on a sample of granular material will result in lateral expansion in dense materials. Because of dilation, the lateral strain, e_h will be more than one half the axial strain, e_v. But if extensible horizontal reinforcing elements are placed within the soil mass, as shown in Fig. 2 (b), these reinforcements will prevent lateral strain because of friction between the reinforcing elements and the soil, and the behaviour will be as if a lateral restraining force had been imposed on the element.

The equivalent lateral load on the fill matrix is equal to the earth pressure at rest (K_o V_v) in which K_o and V_v are coefficient of earth pressure at rest and insitu vertical stress. Each element of the soil mass is acted upon by a lateral stress equal to K_h V_h in which V_v is the insitu lateral stress. Thus, as the normal stresses increase, the horizontal or lateral stresses also increase in direct proportion. Therefore, for any value of the angle of internal friction, normally associated with granular soils, the Mohr Circle lies well below the rupture curve at all points, as shown in Fig. 2 (c) in which V_v and V_h are principle stresses in vertical and lateral directions. Failure can occur only, by loss of friction between the soil and the reinforcements, or by tensile failure of the reinforcing elements.

Friction between Soil and Reinforcements

Three factors which influence the friction between soil and reinforcements are: (a) density of fill matrix, (b) nature of the surface of the reinforcing element (smooth or ribbed) and (c) the overburden pressure. Several types of tests are used to measure the value of coefficient of friction between the soil and the reinforcements. These include: (i) Direct shear test between soil and the reinforcement, (ii) Pull-out tests carried out on actual reinforcing elements in reinforced earth walls and on strips in reduced scale models.

Of all the testing procedure used, the direct shear test is the one most available to practising engineers for the evaluation of design parameters. Other testing proceedures require more specialised equipment, and generally involve higher cost which may not be justified by either the size of the project or the economic gain that may result from more refined and extensive data.

MATERIALS

There are three basic material composites required in the construction of any reinforced soil structure. They are:

(a) Soil or Fill matrix
(b) Reinforcement or anchor system
(c) Facing

Soil or Fill matrix

The choice of the soil or fill material depends upon the technical requirements of the structure in question and also upon the basic economics associated with the scheme. For practical purposes, only a limited range of soils are likely to be used, particularly in vertically faced reinforced soil structures such as retaining walls and abutment structures, although marginal material may be used in sloping soil structures like embankments.

Granular soils compacted to densities that result in volumetric expansion during shear are ideally suited for use in Reinforced Earth structures, especially where these soils are well-drained, effective normal stress transfer between the strips and soil backfill will be immediate as each lift of backfill is placed and shear strength increase will not lag behind vertical loading. In the range of loading normally associated with Reinforced Earth structures, granular soils behave as elastic materials. Therefore, for structures designed at working stress levels, no post construction movement associated with internal yielding or readjustments should be anticipated.

On the other hand, fine grained materials are not especially suitable for Reinforced Earth structures. They are normally poorly drained, and effective stress transfer will not be immediate, thus requiring a greatly slowed construction schedule or an unacceptable low factor of safety in the construction phase. Fine grained materials often exhibit elastoplastic or plastic behaviour, which gives the possibility of post-construction mevements. Table 1 gives the minimum specification for select backfill adopted by Federal Highway Administration (FHWA, 1978).

Reinforcement

A variety of materials can be used as reinforcing materials. The most common type is galvanized steel. Each reinforcing element is a thin strip of metal, typically 50 - 100 mm wide and upto 9 mm thick, and several metres in length. Reinforcement may take both plane and ribbed surface, (Fig. 3). Other type of metals from which reinforcement strips have been prepared include stainless steel, aluminium, aluminium alloy and copper. Plastic materials show promise for the future. Two main types of plastic materials are presently available - fibre reinforced plastic and Paraweb.

Facing

At a free boundary of a reinforced structure it is necessary to provide some form of barrier so that the soil is contained. This facing can be either flexible or stiff but it must be strong enough to hold back the soil and to allow fastenings for the reinforcement to be attached.

The facing is usually prefabricated form units which are small and light enough to be handled for quick and easy construction. The units are generally made from reinforced concrete, steel, aluminium or plastic, but mostly used are reinforced concrete precast panels. A common form of reinforced concrete facing unit is shown in Fig. 4. The facing units require a small foundation from which they can be built.

CONSTRUCTION

Methods of Construction

In the construction of Reinforced Earth structures, constructional techniques compatible with the use of soil as a constructional material are required. The use of soil, deposited in layers to form the structure, results in settlements within the soil mass caused by gravitational forces. These settlements within the soil result in the reinforcing elements positioned on discrete panels moving together as the layers of soil separating the planes of reinforcement are compressed. Thus construction techniques should be capable to accomodate the internal compaction within the soil fill. The three widely used techniques for the construction of Reinforced Earth structures are briefly described below.

Concertina Method

This method developed by Vidal (1966) is shown in Fig. 5 (a). Differential settlement within the mass is achieved by the facing of the structure. Since the facing must be capable of deformation, a flexible hoop shaped unit made from steel or aluminium is normally used. Fabric and geogrids when used as reinforcements provide their own facing. This method is often used with temporary structure when the distortion of the facing is allowed.

Telescope Method

In the telescope method of construction developed by Vidal (1978) the settlement within the soil mass is achieved by the facing panels closing an equivalent amount to the internal settlement. This is made possible by supporting the facing panels by the reinforcing elements and leaving a discrete horizontal gap between each facing panel. The horizontal gap between the facing panels may be produced by the use of compressible gaskets employed to hold the panels apart during the placing of the soil fill. The closure between the panels will vary from application to application depending upon the geometry of the structure, quality of fill material, size of facing panels and degree of compaction achieved during construction. Findley (1978) reported vertical closures of 5 to 15 mm for facing panels 1.5 m high. The shape and form of the facing panel must be compatible with the procedure adopted, and reinforced concrete cruciform or tee-shaped panels covering 1 to 4 sqm and 150 to 200 mm thick are typical. The telescope method is show in Fig. 5 (b).

Sliding Method

In the sliding method of construction developed by Jones (1978), differential settlement within the fill can be accomodated by permitting the reinforcing member to slide relative to the facing. Slideable attachments can be provided by the use of grooves, slots, vertical poles or bolts. If vertical poles are used these may form the structural elements of the facing and the facing may become non-structural providing only a covering. The vertical poles will protect the completed structure from the elements and prevent erosion. If a structural facing is used, the connecting element, the vertical pole, may be reduced in size to an approximate form. The facing my be rigid or semi-rigid; up to a height of approximately 10 m a rigid facing may be used, for heights above 10 m an elemental form of facing is approximated. The sliding method is shown in Fig 5 (c).

The choice of the most suitable construction technique for any particular project depends upon various factors such as geotechnical parameters of the site and fill material, geometry of the structure, type of structure whether temporary or permanent, site conditions, etc.

Labour and Plant

Labour and plant requirements for the construction of Reinforced Soil structure are minimal, and no specialist equipment or skills are required. Erection of a normal vertically faced structure of 500 - 1000 sqm. exposed area is undertaken usually by a small construction team of 5-6 men deployed to cover the main construction elements, namely erecting the face, placing and compacting the fill, and placing and fixing the reinforcement. A comparison in labour requirements for different forms of retaining walls has been given by Leece in Table 2. An additional 20 to 35% to this is recommended for Nepal depending upon various geographical locations.

The plant requirements during construction normally include aids to the placing and compaction of fill, and some form of small crane or lifting device, although the latter is not required when a non-structural facing is used. The compaction plant used within 2 m of the facing consists normally of the following forms:

(a) Vibrotempers
(b) Vibrating plate compactors with a mass less than 10,000 kg.
(c) Vibrating rollers with a mass/metre width less than 1,300 kg. and a mass less than 1,000 kg.

Rate of Construction

Construction of reinforced soil structures is normally rapid. Construction rates for vertically faced structures of 40 m - 100 sqm. per day may be expected and usually the speed of erection is determined by the rate of placing and compacting the fill. Construction is normally unaffected by weather except in extreme situations.

Damage and Corrosion

Care must be taken that facing elements and reinforcing members are not damaged during construction. Vehicles and tracked plant must not run on top of reinforcement; a depth of fill of minimum 150 mm above the reinforcement is frequently specified before the plant can be used. Reinforcement should be stored in a safe dry environment.

Compaction

Good compaction reduces internal differential movements, while uniform compaction provides the most stable environmental conditions which are important for durability. Uniform compaction of the fill is achieved by placing the fill in layers varying in depth 100-300mm, and compacting the soil using a suitable plant moving parallel to the facing or edge of the structure.

APPLICATION IN NEPAL

In Nepal Reinforced Earth has many application areas. In many situations Reinforced Earth structures can be used as an effective substitute of classical solutions based on rigid retaining structures. The major areas of application are the construction of hill road carraige ways support, slope stabilization works potential bridge abutments bank protection works in a river training scheme, and the construction of embankments, foundations structures etc.

In hill roads of Nepal the conventinal type of structures in use for supporting carriageways and slope protection are rigid reinforced and masonry retaining walls and rather flexible type gabion walls. The main disadvantages of rigid type of retaining structures are the facts that they require expensive foundations, larger ground widths because of large wall thickness and the difficulty to repair. On the other hand, the gabion structures are heavy and require large supporting ground widths. So they do not always prove effective especially at those sites where access is minimum and formation widths are small. The Reinforced Earth structures do not require any expensive foundation and can be constructed with ease even at places of small formation widths just sufficient for carriageway. These are the main advantages of Reinforced Earth structures over others types of conventional structures. Some other advantages are ease of construction, faster rate of construction, easy maintenance etc. The in-situ availability of suitable fill materials for construction of Reinforced Earth structures adds further benefits in their use in mountaineous environment of Nepal.

RECOMMENDATIONS FOR MOUNTAINEOUS REGIONS OF NEPAL

To make the best use of these structures in hill roads of Nepal, following recommendations are made for their design.

1 (a) Minimize the volume of excavations and ensure their short term stability (i,e. stability during construction): this is possible with little embedment and short strips.

(b) Improve the general stability: the failure surface will be deeper, and more favourable, if the wall has an important embedment and long strips.

A good conception must enable to find, very early in the project, an equilibrium between these two imperatives.

2 Geometric alternatives for the Reinforced Earth wall.

Most of the Reinforced Earth walls have a rectangular shape with embedment equal to 0.1 times its height, and a strip length equal to 0.7 or 0.8 times its height. On the slope, it is possible to design a wall with strips shorter in the lower part than in the upper part. This shape will allow more limited excavations. Moreover one may design a retaining structure with two or more superimposed walls saving important volume of cutting. But it is also equally important to analyse the stablities of different shapes of the walls.

3 Long term stability of the work.

It is always important to perform complete computations of stability for the slope with the retaining structure. Computer calculations involving Bishop's and other's methods are very useful to estimate the stability in case of complicated works, especially with several walls.

4 Short term stability of the excavation.

It is equally important to ensure sufficient stability of the excavations during construction of the structure. When it may be assumed that this stability is sufficient for some days or weeks, the work can be done, if necessary by building the Reinforced Earth wall by plots in such a way that the excavations have a length approximately equal to twice their height. But if the situation is such that short term stability of the excavation is not possible then the cutting has to be stabilized by some suitable methods such as injection, grouting, soil nailing or root piling, etc.

The adequate solution has to be found, with the geotechnical engineer, by choosing a good laying out of the highway in relation with the slope and the soils.

CONCLUSION

The good overall deformability without any loss of serviceability of structure is the main reason for the frequent choice of these structures. A good overall conception of the works includes taking into account all the parameters, such as geotechnical data, fill material, durability of reinforcing elements, geometry of Reinforced Earth structures, proper design and stability evaluations. A well drained granular material, compacted to a field density that results in dilation during shear, will result in an extremely safe structure with a long and highly predicable service life. As backfill materials become more fine-grained, caution must be exercised in selecting design parameters and factors of safety to allow for the more complex shear strength and corrosion characteristics of these finer grained materials. To overcome corrosion of reinforcing elements a proper allowance in thickness of reinforcement for corrosion attack should be incorporated in design. The choice of construction methods has to be made based on type of structures i.e., whether permanent or temporary and the site conditions.

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Table - 1

Table 1 Specification for Selection of Backfill for Reinforced Earth (after FHA, 1978)

Size	Percent Passing
150 mm	100
75 mm	75 - 100
No 200	0 - 25
and PI < 6	

Table - 2

Comparison of Labour Requirement for Different Types of Retaining Walls (after LEECE, 1979)

Type of Wall	Labour Requirement (man hours/sqm)
Reinforced Earth structure - without traffic barrier	4.1
Reinforced Earth structure - with traffic barrier	4.7
Mass concrete	11.2
Reinforced concrete	11.5
Crib Walling	13.3

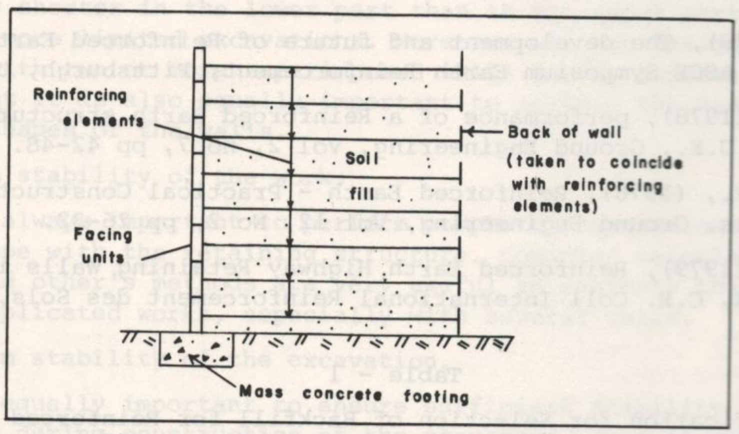

Fig. 1. Reinforced Earth system

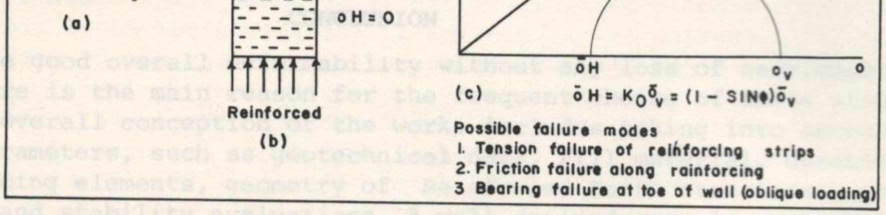

Fig. 2. Basic mechanism of Reinforced Earth

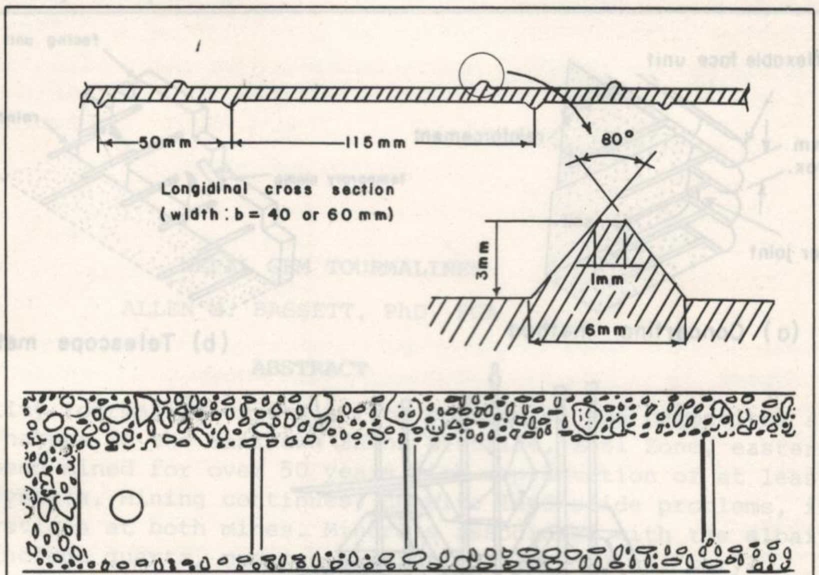

Fig. 3. Ribbed reinforcement stripe

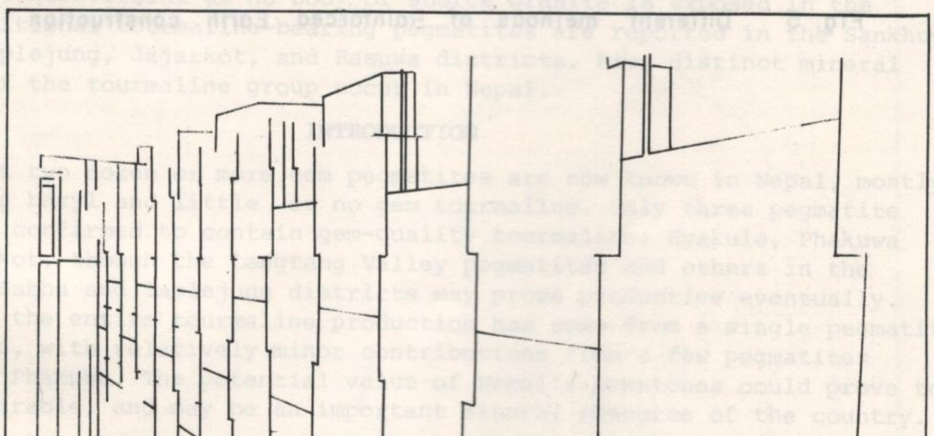

Fig. 4. Precast concrete Facing unit

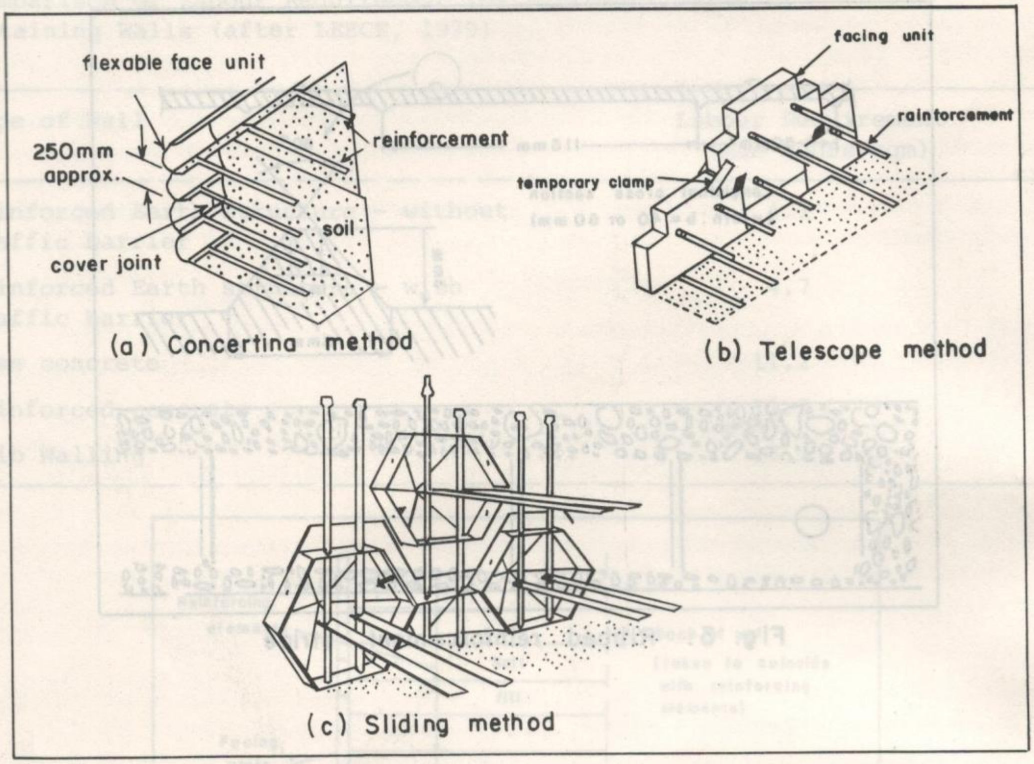

Fig. 5 Different methods of Rainforced Earth construction