ISSN: 2278-0181
NCETEMS-2015 Conference Proceedings

Mechanically Reinforced Earth Walls

Naveen Kumar[1], Manoj Lakra[2], Pankaj Yadav[3]
[1,2,3]Department of Civil Engineering,
Ganga Institute Of Technology & Management,
Kablana, Jhajjar, Haryana, India

Abstract: **this paper will investigate the basic principles of the reinforced erath and gravity wall. At present, the mechanically stabilized earth and gravity walls are probably the most used-particularly for roadwork where deep cuts or hill side road locations require retaining walls to hold the earth in place. These walls eliminate the need for using natural slopes and result in savings in both right of way costs and fill requirements. Most retaining structures are vertical or nearly so; however, if the 'α' angle in the coulomb earth-pressure coefficient is larger than 90°, there is a reduction in lateral pressure that can be of substantial importance where the wall is high and a wall tilt into the backfill is acceptable.**

I. INTRODUCTION:

The mechanically reinforced earth wall of Fig. 1-1 uses the principle of placing reinforcing into the backfill using devices such as metal strips and rods, geotextile strips and sheets and grids, or wire grids. There is little conceptual difference in reinforcing soil or concrete masses—reinforcement carries the tension stresses developed by the applied loads for either material. Bond stresses resist rebar pullout in concrete: soil relies on friction stresses developed based on the angle of friction δ between soil and reinforcement or a combination of friction and passive resistance with geo- and wire grids.

The principle of reinforced earth is not new. Straw, bamboo rods, and similar alternative materials have long been used in technologically unsophisticated cultures to reinforce mud bricks and mud walls. Nevertheless, in spite of this long usage French Architect H. Vidal was able to obtain a patent (ca. mid- 1960s) on the general configuration of Fig. 1-1, which he termed "reinforced earth."

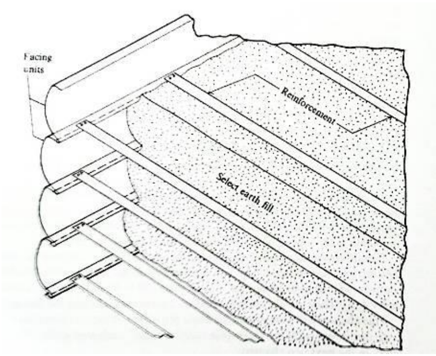

Figure 1 The Reinforced Earth Concept

We see three basic components in this figure:

1. The earth fill---usually select granular material with less than 1 percent passing the No. 200 sieve.
2. Reinforcement---strips or rods of metal, strips or sheets of geotextiles, wire grids, or chain link fencing or geo grids (grids made from plastic) fastened to the fencing unit and extending into the backfill some distance. Vidal used only metal strips.
3. Facing unit---not necessary but usually used to maintain appearance and to avoid soil erosion between the reinforcements.

These three components are combined to form a wall whose side view is shown in fig.1-2 the facing units may be curved or flat metal plates or precast concrete strips or plates .where geotextiles are used the sheet may lap,fig. 1-3, to produce the facing unit When wire mesh or other reinforcement with discontinuities (grid voids) is used ,a portion may be bent, similar to the sheet of fig.1-3, to form a facing unit. Grid type reinforcements strengthen the soil through a combination of friction and passive pressure pullout resistance. The bent-up portion used as a facing piece provides some erosion control until the wall is completed.

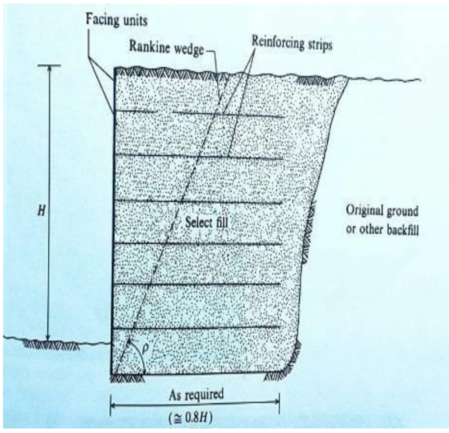

Fig 2 reinforced earth walls

The exposed reinforcements are usually sprayed with concrete mortar or gunite (material similar to mortar) in lifts to produce a thickness on the order of 150 to 200mm. This is both to improve the appearance and to control erosion. For metals this covering also helps control rust, and for geotextiles it provides protection from the ultraviolet rays in sunlight and discourages vandalism.

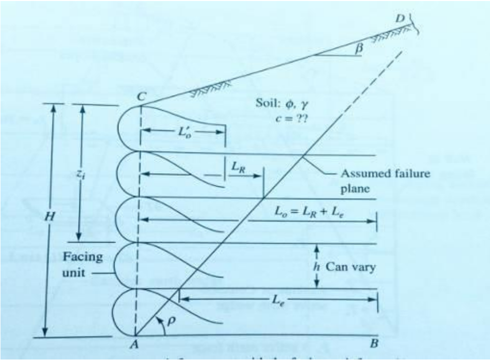

Figure 3; Using Geotextile sheets for reinforcement with the facing unit formed by lapping the sheet as shown. Critical Dimensions are L_e, L_0. Distances L_e and L_0 are variable but for this wall produce a constant length $L_{con} = L_0 + L_e$. The Rankine p not equal to 45° + φ/2 for backfill β as shown.

The basic principle of reinforced earth is shown in fig 1.4 where we see a wall acted on by either the Rankine or Coulomb active earth wedge. Full-scale tests have verified that the earth force developed from the active earth wedge at any depth z is carried by reinforcing strip tension.

Strip tension is developed in the zone outside the active earth wedge from the friction angle δ between strip and soil and the vertical earth pressure left to be carried by the wall facings they can be quite thin and flexible with the principal functions of erosion control and appearance.

II. DESIGN CONSIDERATION

The following several factors enter into the design of reinforced earth wall:

1. Backfill soil is usually specified to be granular; however, recent research indicates that we can use cohesive soil if a porous geotextile is used for reinforcement to allow backfill drainage. This allows one to use the drained friction angle φ' to calculate friction between the soil and reinforcing.

2. Backfill soil should be compacted, taking care not to get component too close to the facing unit, so that it is not pulled from the reinforcement.

   It is also necessary to exercise care with geotextile fabrics not to tear the fabric in the direction parallel to the wall. A partial tear of this type would reduce the amount of tension the fabric can carry.

3. Tests with experimental walls indicate that the ranking wedge adequetly defines the "soil wedge" this angle should be routinely checked using the trial wedges method for large backfill angles.

4. The wall should be sufficiently flexible that the active earth pressure wedge forms and any settlement/subsidence do not tear the facing unit from the reinforcement.

5. It is usually the assume all the tension stress are in the reinforcement outside the assumed soil wedge zone – typically the distance L of fig 1-5.

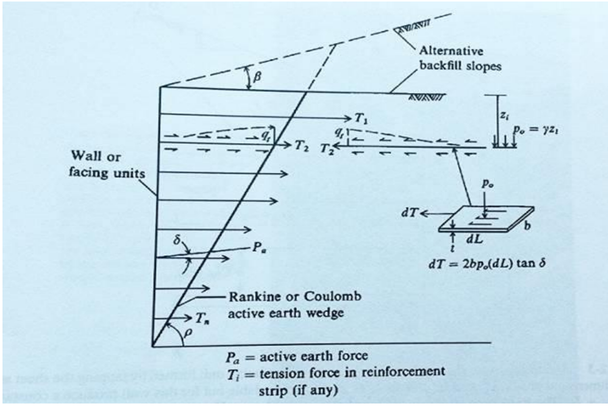

Figure 1.4; The General Concept of reinforced earth is that $\Sigma T_i = P_a \cos\delta$, so the earth force against the wall =0

6. The wall failure will occur in one of three ways

a. Tension in the reinforcements.
b. Bearing capacity failure of the base soil supporting the wall along the base line AB of fig 1-3 and 1-6.
c. Sliding of the full block (ABCD of fig 1-6) along base AB.

7. Surcharges (as in fig 1-6) are allowed on the backfill. These requires analysis to ascertain whether they are permanent (such as a roadway) or temporary and where located for example

   a. Temporary surcharges within the reinforcement zone will increase the lateral pressure which in turn increases the tension in the reinforcements but does not contribute reinforcement stability.
   b. Permanent surcharges within the reinforcement zone will increase the lateral pressure and tension in the reinforcements and will contribute additional vertical pressure for the reinforcement friction.
   c. Temporary or permanent surcharges outside the reinforcement zone contribute a lateral pressure, which overturn the wall.

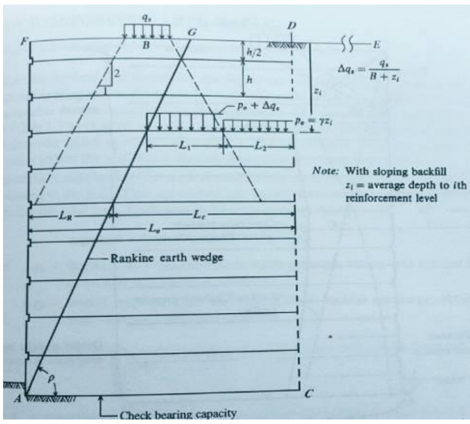

Figure 1.5; Length of Reinforcements L0 = Lr +Le as required bus must extend beyond Rankine/Coulomb Earth-Pressure wedge

In most cases the lateral pressure from the backfill surcharge can be estimated using the Theory of Elasticity equation [Eq. (11-20)]. One can also use the Bossiness equation for vertical pressure, but it will may be sufficiently accurate to use the 2:1 method [Eq.(5-2)] adjusted for plane strain to give q_v= Q/B+Z

Where Q=Bqo for the strip width(side view) and average contact pressure produced by the surcharge ; for point loads use either a unit width(0.3m or 1 ft) or Eq. (5-3). Since these two methods give greatly differing vertical pressures (the 2:1 is the high and Eq (5-3) is very low) yo may have to use some judgement in what to use –perhaps an average of two methods.

B= strip width; you implicitly using L=1 unit of width.

where

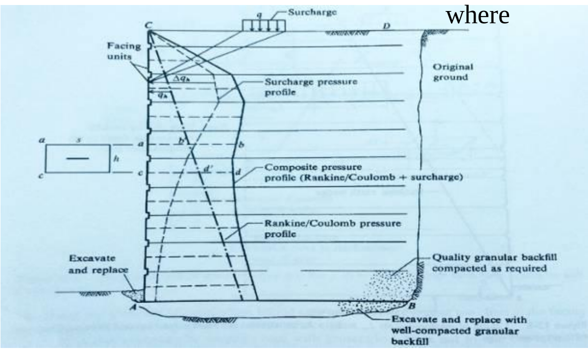

Figure 1.6; General wall case with surcharge on backfill as from a road or other construction.

Linearizing the surcharge pressure profile as shown is sufficiently accurate, Laba and Kennedy (1986) used the 2:1 vertical pressure method [Eq. (5.2)] as shown in Fig. 1-5 with reasonably good results. In this figure Eq. (5.2) is being used to get a pressure increase in the zone L_1 so that the friction resistance F_R for the effective lengths ($L_e = L_1 + L_2$) is

$$Fr = \tan \delta\ [(\gamma z + \Delta q)\ L_1 + \gamma z L_2]$$

Where terms are identified in Fig. 1.5

8. Corrosion may be a factor where metal reinforcements are used. It is common to increase the theoretical strip thickness somewhat to allow for possible corrosion within the design period, which may be on the order of 50 to 100 years.

9. Where aesthetics is critical, a number of concrete facing unit configurations are available in a wide range of architecturally pleasing facades, which can either outline the wall or blend it into the landscape

10. There will be two safety factors SF involved. One SF is used to reduce the ultimate strength of the reinforcements to a "design" value. The other SF is used to increase the computed length L_e required to allow for any uncertainty in the backfill properties and soil-to-reinforcement friction angle δ.

<u>DESIGN OF REINFORCED EARTH WALLS:</u>

The design of a reinforced earth wall proceeds basically as follows:

1. Estimate the vertical and horizontal spacing of the reinforcement strips as in Fig. 1-7. Horizontal spacing *s* is meaningless for both wire grids and geotextile sheets but one must find a suitable vertical spacing *h* for those materials. The vertical spacing may range from about 0.2 to 1.5 (8 to 60in.). The lateral-earth-pressure diagram is based on a unit width of the wall but is directly proportional to horizontal spacing *s*.
2. Compute the tensile loads of the several reinforcements as the area of the pressure diagram contributing to the strip. This calculation can usually be done with sufficient accuracy by computing the total lateral pressure at the strip (see Fig. 1-6) level,

$$q_{h,I} = q_h + \Delta q_h \qquad (1\text{-}1)$$

q_h = Rankine or Coulomb lateral earth pressure, taking into account backfill slope and any uniform surcharge
Δq_h = lateral pressure from any concentrated backfill surcharge; obtain using your computer program SMBLP1
With the average pressure obtained from Eq. (1-1), the strip tensile force can be computed as

$$T_i = A c q_{h,I} \qquad (1\text{-}1a)$$

Where A_c = contributory area, computed (Including the Horizontal spacing s) as

$$A_c = (h_1 + h_1 + 1)s/2$$

Only should routinely make a computational check:

$$\sum T_i = S\ X\ (P_{ah} + \text{area of } \Delta q \text{ diagram})$$

That is the sum of the several tensile reinforcement forces should equal the lateral-earth-pressure diagram rationed from a unit width to the actual reinforcement spacing s.

3. Compute the strip lengths L_e of fig 1.5 that are required to develop a friction resistance
$F_r = T_i$ X SF (or $L_{e,\ Computed}$ X SF). From these lengths and the Rankine wedge zone we can then determine the overall strip length L_o to use. It is common to use a single length for the full wall height so that the assembly crew does not have to be concerned with using an incorrect length is based on soil to strip friction of f= tanδ, where δ = some fraction of φ such as 1.0, 0.8, 0.6φ. What to use depends on the roughness of the strip. For rough materials use δ =φ; for smooth metal strips use δ = 20° to 25°.

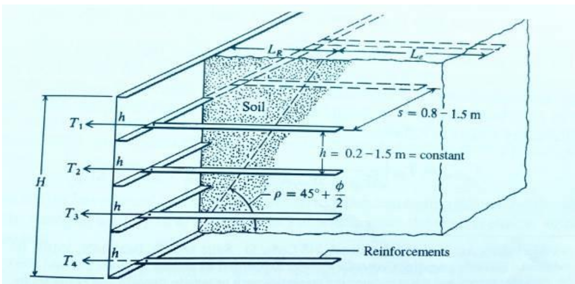

Figure 1.7; Typical range in reinforcement spacing for reinforced earth walls.

For strips of b x L_e geotextile sheets of base width $L_{e,}$ both sides resist in friction. For round bars the perimeter resists friction. In both cases friction is the product of X normal pressure on the reinforcement. Using consistent units, this approach gives the following reinforcements:

Strip: $Fr= 2(yz_i)\ (b\ X\ L_e)\ \tan\delta > T_i\ X\ SF$

Rod : $Fr= 2\pi\ (yz_i)\ L_e \tan\delta > T_i\ X\ SF$

Sheet : $Fr= 2(yz_i)\ (1\ X\ L_e)\ \tan\delta > T_i\ X\ SF$

Where b= strip width, D = Rod diameter, and 1= unit sheet width

4. Next compute the reinforcement area for strips b X t and for rods with bar diameter D. for wire and geotextile grids, obtain the tension force per some unit of width. For geotextile sheets look in the manufacturer's catalog to find a fabric with a suitable strength.
For these materials a suitable SF must be used to reduce the ultimate tensile strength of metal strips and bars to a design value or the geotextile strength. To a design value, for metals it is common to use some SF such as 1.5 to 1.67; however, for both metals and geotextiles we can compute an SF based on partial safety factors as follows:

$$T_{allow} = T_{ult}\left(\frac{1}{SF_{id}\ X\ SF_{cr}\ X\ SF_{cd}\ X\ SF_{bd}\ X\ SF_{if}\ X\ SF_{\varphi}}\right) \quad (1.3)$$

Where T_{allow} = Allowable Tensile Stress
T_{ult} = Ultimate Tensile Stress
SF_{id} = Installation damage factor, 1.1 to 1.5 for geotextiles; 1 for metal
SF_{cr} = Creep Factor (1.0 to 3.0 for geotextiles; 1 for metal)
SF_{cd} = Factor for chemical damage or corrosion (1.0 to 1.5 for Geotextiles; 1.0 to 1.2 for metal)
SF_{bd} = Factor for biological degradation (1.0 to 1.3 for Geotextiles; 1.0 to 1.2 for metal)
SF_{if} = Imprtance factor (1.0 to 1.5)
SF_{φ} = Genral Factor; (1.0 for Geotextiles; 1.3 to 1.4 for metal)

Let us compute an allowable tensile stress fa for steel strip based on 350 MPa steel (factors not shown are 1.0) as

Fa = (350x1)/ (1.1x1.2x1.3) = 350/ 1.716 = 204 ~ 200MPa

Let us now consider a geotextile example. From the 1995 specifier's guide we find an Amoco 2044 woven (W) geotextile with a wide-width tensile strength, using the ASTMD 4595 method, of 70.05 kN/M in both the MD (along the roll) directions. The Allowable tensile strength is computed using Eq.(1.3). Substituting some estimated values, we obtain

T_{allow} = (70.05x1)/ (1.5x2.0x1.2x1.1x1.1x1.0)= 70.05/4.356= 16.08 ~ 16.0 kN/m

III. GENERAL COMMENTS

1. Between manufacturers.
2. With fabric type and grade. For Example, woven fabric is usually stronger than film fabric and additionally has a larger coefficient of friction.
3. With direction. The MD direction (Machine Direction, also warp; that is, with the roll) is stronger than (or as strong as) the XD direction (cross-machine, or fill; that is, across the roll-transverse to the the roll length). Sometimes the strength difference is on the order of XD~ 0.5MD. This means that attention to th strength direction during placing may be Critical.

REFERANCES

1. Foundation Analysis and Design (Fifth Edition) by Joseph E. Bowles