ANALYSIS AND DESIGN OF MECHANICALLY STABILIZED REINFORCED EARTH WALL

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Abstract-- Soil confinement systems are very important elements for every highway design. Different types of soil reinforced wall have evolved over the last past 20 years. For many years retaining structures were made of reinforced concrete. The cost of conventional retaining walls increases rapidly with increase in height of wall. Reinforced earth walls are cost effective soil retaining structures and can tolerate large settlements than conventional concrete retaining wall. Due to this reason Reinforced earth technology has completely replaced conventional concrete retaining structures. Geo-grid reinforced earth wall retaining structures have gained wide acceptance. Present research deals with analysis, design and construction of back to back RE wall. At present observations were done during construction of RE wall carried by TECHFAB INDIA LTD for ensuring knowledge of designing the RE wall. Analysis and design of RE wall was done based on following FHWA – 043 code and BS: 8006. Similarly steel strips reinforced earth wall and concrete retaining wall are designed. Cost comparison is made which shows that Geo-grid reinforced earth walls are more economical than concrete retaining walls. Cost calculation of Geo-grid reinforced earth wall is done by varying angle of internal friction of reinforced soil.

Keywords Fly ash; Geo-Grid; Direct shear test; Tensile strength; Internal and external stability

1. INTRODUCTION

For efficient and vast highway infrastructures, construction of highways through various terrains is required. Many a times, the highways pass through soft compressible strata e.g. marshy land or through backwaters. Construction of highways on such strata by conventional methods results in huge dumping of expensive granular fill sinking progressively till a working platform emerges. In such cases Reinforced earth walls are used. Reinforced earth consists of a compacted soil mass within which reinforcing elements or membranes, usually in the form of horizontal strips of metal, rods of metals, wire grids, fiber glass, bamboos or geotextile, embedded. The essential feature of the reinforced earth is that friction develops between compacted layers of the earth and the reinforcing elements. [10]Due to this reason Reinforced earth technology has completely replaced conventional concrete retaining structures. Geo-grid reinforced earth wall retaining structures have gained wide acceptance. Present project deals with analysis, design and construction of back to back RE wall. At present observations were done during construction of RE wall carried by TECHFAB INDIA LTD for ensuring knowledge of designing the RE wall. Analysis and design of RE wall was done based on following FHWA – 043 code and BS: 8006. Similarly steel strips reinforced earth wall and concrete retaining wall are designed. Cost comparison is made which shows that Geo-grid reinforced earth walls are more economical than concrete retaining walls. Cost calculation of Geo-grid reinforced earth wall is done by varying angle of internal friction of reinforced soil.
There are various types of reinforced earth walls which are used for different types of transportations as follows,

1. Classical gravity retaining walls
2. Reinforced concrete types
3. Buttressed and counterfort
4. MSE with metal reinforcement
5. MSE with geosynthetic.

Reinforced earth is the technique where tensile elements are placed in the soil to improve stability and control deformation. To be effective, the reinforcements must intersect potential failure surfaces in the soil mass. Strains in the soil mass generate strains in the reinforcements, which in turn, generate tensile loads in the reinforcements. These tensile loads act to restrict soil movements and thus impart additional shear strength. This results in the composite soil/reinforcement system having significantly greater shear strength than the soil mass alone. The basic principle involved in reinforced earth technique is simple to grasp and have been used by man for centuries. Recognition and the interest in the subject have gained impetus because of the technical and commercial success that has been demonstrated by the practitioner like Henri Vidal.
C. Sub soil data

The available soil information consists of two numbers bore holes carried out at the proposed fly over. Considerable variation in strata encountered as well as in the properties of the existing soil may be noticed in the information available from the bore holes. However, generally the sub soil consists of black cotton soil up to 2m from EGL, loose to medium dense slope plastic silt or silty clay from 2m above EGL up to the depth of 4 to 5m and med dense to dense slope plastic silt or silty clay below that depth. SPT ‘N’ does not exceed about 5 within the top 5m and is exceeding 5 below that depth. Computations show that the safe bearing capacity of existing ground may not exceed 65 KN/m2. Details of bore holes and test results are included in design calculations. Since the safe bearing capacity of existing ground does not exceed 65 KN/m², it may be readily recognized that ground improvement of the overlying loose to medium dense silt or clay stratum is necessary to achieve the required safe bearing capacity for the proposed fly over approach embankments for walls of all height. The required safe bearing capacity computed for the RE wall structures are as follows.

Table 1: Required safe bearing capacity KN/M²

| Design RE wall height m | Required safe bearing capacity KN/M² |
|-------------------------|-------------------------------------|
| 4                       | 150                                 |
| 4.5                     | 165                                 |
| 5                       | 172                                 |
| 5.5                     | 180                                 |
| 6                       | 203                                 |
| 6.5                     | 220                                 |
| 7                       | 235                                 |
| 8                       | 263                                 |
2. METHOD OF GROUND IMPROVEMENT

The black cotton soil at site which exists up to 2m depth shall completely be removed and replaced with proposed back fill. The loose silt or clay at the site which exists from 2m below EGL to 5m depth need to be improved to achieve much higher safe Bearing capacity required to support the proposed RE walls for the project. After considering various alternatives such as dynamic compaction, dynamic replacement, geo-grid reinforced sand mattress etc., we propose the best method of ground improvement to suit requirements and site conditions. The system of ground improvement proposed consist geo grid reinforced sand mattress at the bottom of reinforced soil wall.

![Fig. 5: Ground improvement using geo grid](image)

3. MATERIALS USED

A. Fly ash

It is an industrial by product from thermal power plants is proven suitable for variety cement, concrete, mortar bricks, etc. Fly ash as a building material has many advantages like cost effectiveness, environmental friendly increases strength and conservation of other natural resources and materials.

B. Geo grid

A geo-grid is a geo-synthetic material used to enhance the soil and other materials. Geo grids are commonly used to reinforce retaining walls, as well as sub bases or subsoil below pavements or structures. Geo grids are mesh like or grid like geo synthetics with square or rectangular aperture that resemble plastic meshes often seen as garden fence. They are planar polymeric materials consisting of regular open network of connecting polyester. [4] The % open area of geo grids lies between 40 – 95 % with the width of the openings being typically 10 – 100 mm. The rib thickness ranges from 5-15 mm and the mass per unit area lies between 200 – 1500 GSM.

C. Geo textile

Geo textiles are permeable fabric geo synthetics that resemble a thick strong cloth or blanket with its strands or fibers visible. They are planar, permeable, polymeric materials that are usually made from polypropylene and sometimes from polyester, polyethylene or from natural fibers such as jute. [9] They can be woven, non-woven or knitted. Geo textiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, drain. Woven geo textiles are produced by weaving or inter lacing, usually at right angles, of two or more sets of fibers or yarns. Non-woven geo textiles are produced by mechanical bonding or needle punching of randomly oriented fibers, i.e.; in a manner similar to that used in making blankets. In some cases non-woven fibers may be bonded thermally or chemically.
D. Facial block

The wall facing elements are provided at the free boundary of a reinforced earth structure, to provide some form of barrier so that the soil mass is contained. These elements, usually known as skin, may be either flexible or stiff; it should be strong enough to hold back the soil and should allow fastening to attach reinforced elements. [6] The facing units are usually pre-fabricated units which are small and light enough for transportation for quick and easy construction. The wall facing elements or units are generally made from steel, aluminum, plastic, fiber, glass or reinforced concrete. The facing units require a small foundation of concrete from which they can be built.

4. DESIGN OF REINFORCED EARTH WALL

It includes following steps

- Defining wall geometry, loading soil and geo-grid properties
- Initial Dimensioning of the Structure
- Depth of embedment Minimum length of reinforcement

External stability analysis
- Check for sliding along base
- Check for overturning
- Check for bearing capacity

Internal stability analysis
- Check for pullout resistance
- Check for tension

A. Design of concrete retaining wall

Defining wall geometry, loading, soil properties,

a. Initial dimensioning of structure
b. Designing base, stem, toe and heel of wall
c. Check for shear
d. Check against sliding
e. Estimation of cost of geo-grid, steel strips reinforced earth wall & concrete retaining wall
f. Estimation of cost of geo-grid reinforced earth wall by varying material

5. DESIGN OF REINFORCED EARTH WALL

A typical urban highway retaining wall design with inextensible steel linear reinforcement and precast concrete panels will be designed.

STEP 1: Establish design height, external loads.

Total design height \( H \) = 7.8 m, to gutter grade
Required panel height = 7.5 m vertical
Traffic surcharge and barrier required. Barrier will be cast integrally to the concrete pavement
Traffic surcharge = 9.4 KN/m2
Seismic coefficient = 0.05 g

STEP 2: Establish Engineering properties of foundation soils.
Angular internal friction Φ = 30° (clayey sand, dense)
Allowable bearing capacity = 300 kpa
Differential settlements on the order of 1/300 are estimated.

STEP 3: Establish Engineering properties of retained and reinforced backfill.
Unit weight of retained fill ϒ = 18.8 kn/m3
Angular internal friction Φ = 34°
Factor of safety = 2

STEP 4: Establish design factory of safety.
External stability FS
Sliding = 1.5
Maximum foundation pressure < allowable bearing capacity
Eccentricity < L/6
Global stability > 1.3
Internal stability FS
Pullout > 1.5
Allowable stress – 0.55Fy
Design life = 75 years

STEP 5: Establish Preliminary length for reinforcing strips.
For horizontal backfill slopes, L = 0.7H
L = 0.7H = 0.7 * 7.8 = 5.5 m

STEP 6: Check external stability for L = 5.5 m
Compute Ka for retained the fill, with Φ = 30 degree
\[
Ka = \tan^2(45 - \Phi/2) = 0.33
\]

Computing sliding FS at base:
Factory of safety = \frac{v_1 + \tan \theta}{\Sigma PH} = \frac{806.5 + \tan 30}{212.90} = 2.19 > 1.5

Compute eccentricity at base = \frac{L}{2} - \left( \frac{\Sigma MR - \Sigma MQ}{\Sigma V} \right) = 0.73 < L/6 = 0.92 m

Compute bearing pressure at base
\[ \sigma_v = \frac{L - 2e}{L - 2e} \left( \frac{v_1 + v_2}{L + 2e} \right) \]
\[ \sigma_v = \frac{858.8}{5.5 - (2.72)} = 212 kpa < 300 \]

These results will show the depth of reinforcement for each layer.

6. CONCLUSION

The following in conclusion can be drawn present study

1. Reinforced earth wall are provided to be cost effective bridge approaches in view of rapid construction.
2. It is noticed that present RE WALLS are comes under category of back to back reinforced earth wall
3. The entire length of bridge approach is 150 m and having viable height is varying from 8.5m to 4.5 at different chainages.
4. The back fill is used in the construction is fly ash. Fly ash is an industrial waste and its disposal is a major problem for thermal power plants.
5. Fly ash is used in this study because its having less unit weight And high angle of internal friction.
6. It is felt that proper drainage is important as any construction since main failure of REWALL is due to development of pore water pressure within the backfill.

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