Geocell mattress for high embankments on black cotton soil

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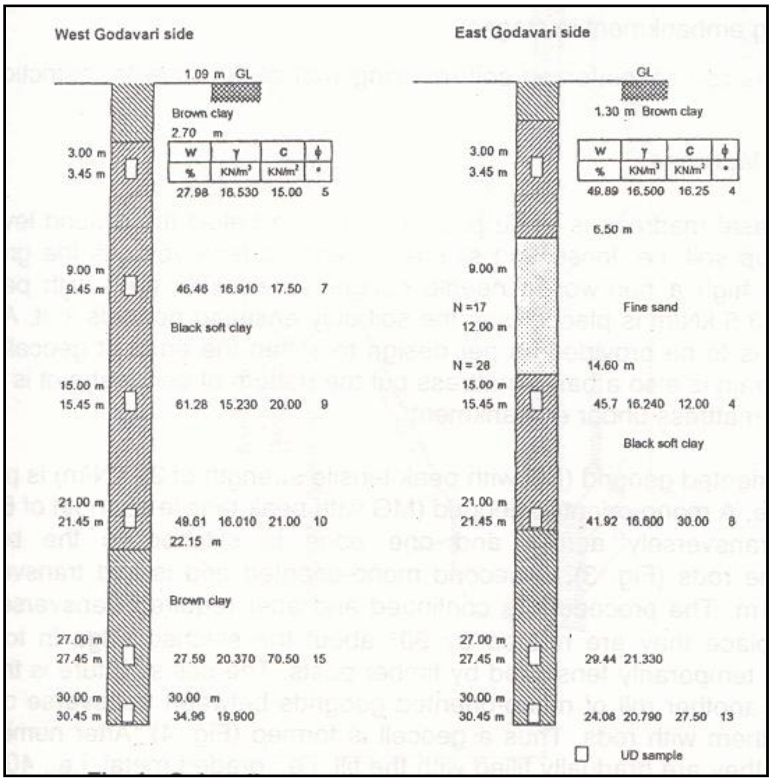
ABSTRACT: Construction of embankments on soft and swelling soils often pose problems for engineers. The paper describes a major case history of construction highlights of a 12 m high embankment on 30 m thick black cotton soil founded on a basal geocell mattress.

1 INTRODUCTION

The maximum embankment height in the bridge approach for a bridge across Vasista branch of the Godavari river in Andhra Pradesh was 12 m with a longitudinal gradient of 1 in 35. The embankment was to be formed on weak black cotton soil extending up to 30 m depth (Table 1).

Table 1 Subsoil Profile



The foundation soil was highly plastic and swelling type with very poor bearing capacity. The conventional pre-loading with sand drains or prefabricated vertical drains were considered ineffective and time consuming because of the swelling nature of the soil. After studying various alternatives it was decided to adopt a basal mattress foundation as a measure to improve the bearing capacity of the weak soil.

2 DESIGN PHILOSOPHY

The embankment runs for about 350 m length on each side, i.e., West Godavari side and East Godavari side of the bridge across Vasista River. The typical cross-section is shown at Figure 1. The height of embankment varies from 2 m to 12 m. The proposal consisted of:

1. Construction of geocell mattress of 1.0 m thick with end restraint from 8 m to 12 m height of embankment. Figure 2. shows the longitudinal section. The design has been done as per BS 8006 -1995.
2. Construction of geocell mattress of 0.50 m thick for 5 m to 8 m height embankment. Figure 3 shows geocell details.
3. Raising embankment in stages.
4. Construction of reinforced soil retaining wall at toe (due to restriction of base width).

3 CONSTRUCTION OF GEOCELL MATTRESS

The basal mattress was to be placed at 0.50 m below the ground level. Before laying, the top soil, i.e., loose and slushy material was removed. As the groundwater level was very high a non-woven needle punched geotextile (GT) with peak tensile strength of 13.5 kN/m was placed over the soil duly ensuring no folds in it. A 4 m wide end restrain was to be provided as per design to stiffen the ends of geocell mattress. The end restrain was also a basal mattress but the bottom of end restraint is 1 m below the principal mattress under embankment.

A biaxial geogrid (BG, with peak tensile strength of 20 kN/m) was placed over the geotextile. A uniaxial geogrid (MG, with peak tensile strength of 60 kN/m) was then laid transversely across and one edge was stitched to the base using polypropylene rods. A second mono-oriented grid was laid transversely at a spacing of 1m. The procedure was continued and after required transverse grids were stitched in place they were rotated by 90° about the stitched edge in to a vertical position and temporarily tensioned by timber posts. The cell structure was then formed by unrolling another roll of mono-oriented geogrids between transverse diaphragms connecting them with rods. Thus a geocell was formed. After numbers of cells were formed, they were gradually filled with the fill, i.e., graded metal, i.e., 40 to 75 mm. The filling was commenced from one boundary. The cells were filled in this manner to avoid distortion of the mattress, i.e., no cell was filled to full height before the adjacent cell was at least half filled. As it may be impractical to compact the fill in the cells, overfilling by 100 to 150 mm was done to cater for compaction settlements and to allow for construction plant to operate on the mattresses without damaging diaphragms.

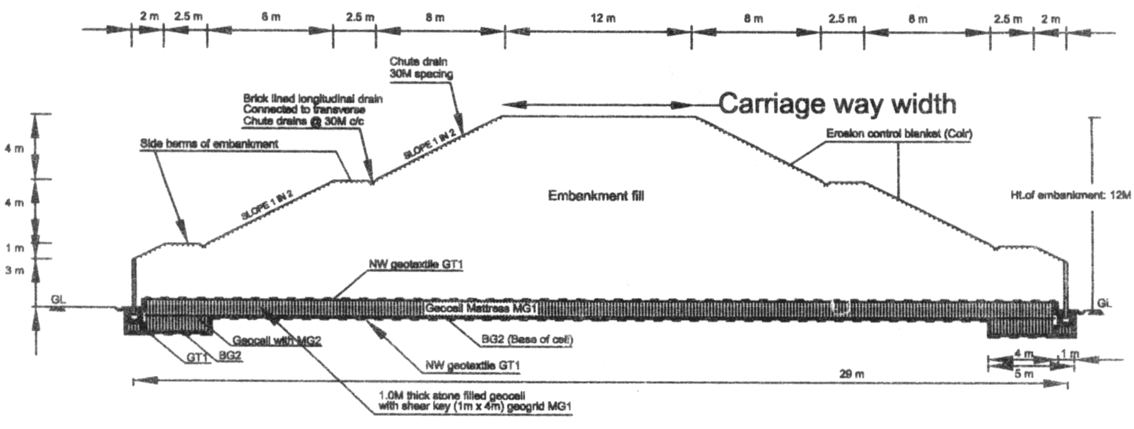


Figure 1. Typical cross section of embankment

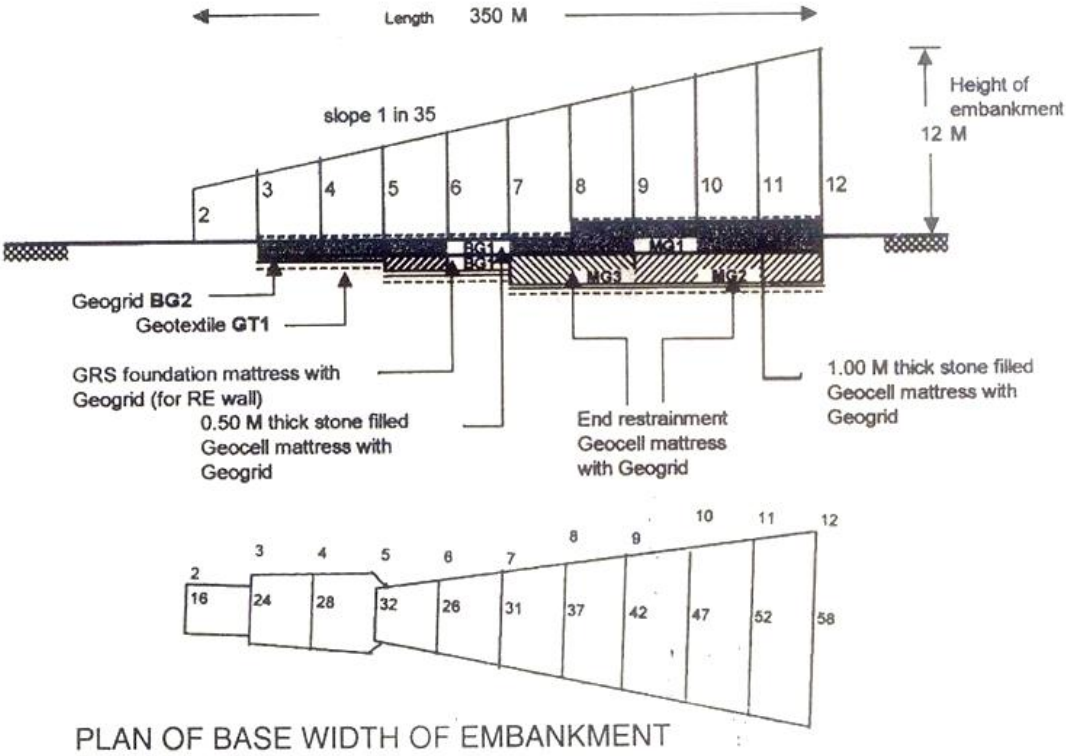


Figure 2. Longitudinal section of the embankment

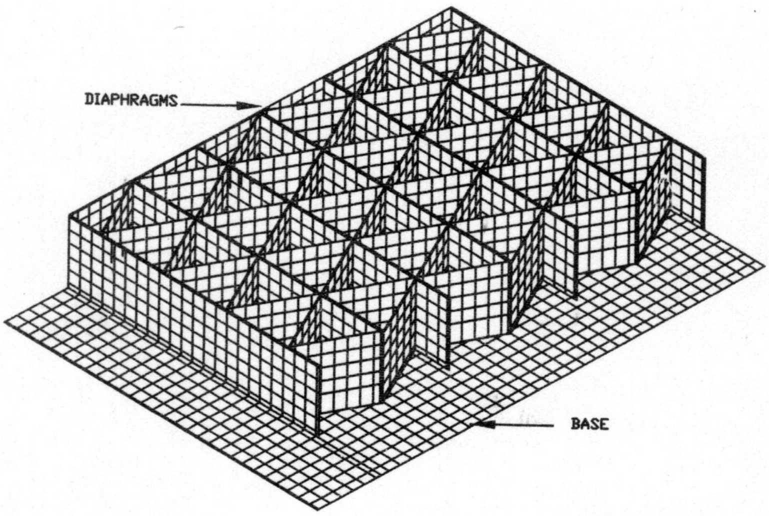


Figure 3. Arrangement of geocell

The mattress formation was commenced from 5 m height embankment and at a time about 30 m to 35 m length of mattress was tackled. The base widths were varying from 21 m to 58 m. After completing the principal mattress, the end restraint was taken up. In a similar manner to the principal mattress the end restrain was formed. A 4 m x 1 m deep excavation was done and a geotextile was placed on the soil. 1 m thick geocell was formed as noted above and the top of this cell was to coincide with the bottom of the principal cell. Once this additional cell was over the principal cell was extended over the ends. The top and bottom cells were jointed with Polypropylene rods. The strength of uniaxial geogrid used for end restraint was 100 kN/m, which was higher than the grid used for principal mattress, i.e., 60 kN/m. After filling the geocells with boulders another layer of non-woven geotextile was placed over the fill to act as a separator between embankment fill soil and stone fill in the geocell mattress. Figures 4 to 7 depict the construction sequence.

Figure 4. A view of the 1 m high geocell mattress prepared

Figure 5. A view of filling the cells with stones

Figure 6. A view of the non wovengeotextile enveloping the geocell mattress

Figure 7. A completed view with erosion control blanket

The embankment was raised in 2 m intervals in layers with each layer of 200 to 300 mm thick. The fill used was sand and silty sand. The compaction was achieved by using vibratory rollers. The embankment was raised by first filling in the centre of cross-section and then extending to ends. After attaining 4 m to 5 m height of embankment it was allowed to settle for 15 days and then the end reinforced soil retaining walls using concrete facia and geogrid reinforcement (tensile strength 45 kN/m) were taken up. The height of wall was 3 m and after laying backfill behind wall, the full embankment was raised. The top 4 m height was raised in 4 months with observation period of 1 month after 1 m raising. The construction was done in phased manner to allow initial settlement to occur during construction period.

After completion of the embankment, it was covered with Rolled erosion control blanket , and seelings of local grass were planted, as shown in Figure 7 and after a season of monsoon, the profuse growth of turfing is evident from Figure 8.

Figure 8 The embankment of a monsoon season, with profuse growth of turfing.

Important points to be noted :

- No excavation and minimal site preparation
-No trips required for disposal of unsuitable excavated material
- No difficulty working at or below the water table
- Initial training to familiarize the workforce with construction is required.
- Supervision and strict pattern of working required.
- In order to maintain the rigidity of the mattress during construction and infilling, a large degree of tensioning of the transverse vertical diaphragms is necessary.

The work was completed by 2001 and traffic is plying since then satisfactorily

4 CONCLUSIONS

The geosynthetic reinforced structures with basal mattress were very effective in mobilizing the maximum shear strength and in increasing the bearing capacity of soft soil. All the structures constructed in the last two decades in many parts of Andhra Pradesh have been performing well.

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