This paper describes the salient features of a project wherein geogrid reinforced soil walls with a welded wire mesh supported wrapped face were used as closure and return walls for the approaches to a flyover. The walls had a height of 15.0 m for one approach and 10.0 m for the other. Indigenously manufactured knitted and PVC coated polyester geogrids were used as the soil reinforcement. A welded wire mesh supported geogrid wrapped face with random rubble backing with an inward batter of 5º was used. A relatively fine-grained Yamuna sand was the fill material. Some of the challenging aspects considered in the design like large heights, acute angle corners, and weak foundation soils are discussed.

Background

A flyover was required to be constructed on the DND-Mayur Vihar Link, which links the Trans-Yamuna area of Mayur Vihar to the DND Flyway connecting South Delhi to Noida. The approach embankments to this flyover had a maximum height of 9.0 on the DND end and 14.0 m on the Mayur Vihar End. Since there was no constraint with respect to right-of-way, the approaches consisted of normal embankments. However, retaining walls were to be constructed as closure walls behind the abutment piers and 25 m long return walls at both ends of the flyover (see figure 1).

M/s Noida Toll Bridge Company Ltd. (NTBCL) concessionaries for the project decided to use reinforced soil technology for the construction of retaining walls in view of their proven performance and cost economy. The design of the walls involved several technical difficulties and the construction had to be completed within a short time. After an evaluation of various aspects, NTBCL decided to use a geogrid reinforced soil wall with a welded wire mesh facing in view of the project and site requirements and awarded the work to Techfab India with the following scope of work:

- Detailed engineering of the reinforced soil walls and ground improvement including design, material specifications, construction drawings and construction methodology.
- Supply of knitted and PVC coated polyester geogrids, galvanized welded wire mesh panels and nonwoven geotextile
- Supervision of construction

The total wall face area was approximately 1600 sqm.

The Reinforced Soil Wall System

The Challenge

The design of the walls involved several challenges:
The maximum height of the wall was about 15.0 m on the Mayur Vihar end of the flyover.

Because the alignment of the flyover was in skew, the closure and return walls were not perpendicular to each other. There were acute angle corners with interior angle between closure wall and return wall of 42º on the DND end and 58º on the Mayur Vihar end. The design and detailing of the soil reinforcement for the acute angle corners, presents several difficulties.

The facing batter of the closure walls had to be kept as low as possible, to avoid any problems with respect to the design of approach slabs.

The upper most strata of the ground comprised a 2 to 5 m thick layer of sandy clayey silts / sandy silts with relatively loose consistency (N = 2 - 5).

The Solution

After a careful evaluation of the project requirements and site conditions a geogrid reinforced soil wall with a welded wire mesh supported wrapped face was finalized as the most optimum solution.

An indigenously manufactured knitted and PVC coated polyester geogrids were used as the soil reinforcement. These geogrids are manufactured from select grades of high tenacity polyester yarns with high molecular weight (Mn > 25,000 and low carboxyl end groups (CEG) < 30 mmol/Kg to ensure using an advanced weft insertion warp knitting process and coated with a specially formulated PVC plastisol. The high performance characteristics of these geogrids, enabled the walls as high as 15 m, to be designed safely and economically.

The facing comprised geogrid wrapped face supported by galvanized welded wire mesh panels fabricated from 8 mm diameter mild steel round bars with a mesh size of 125 x 150 mm and bent into an L shape (figure 2). The vertical leg of the L had a height equal to the geogrid reinforcement spacing which was 400 or 600 mm and the horizontal leg had a width of 500 mm. The wire mesh panels after fabrication and bending were hot-dip galvanized to a zinc coating thickness of 86 microns. Hot-dip galvanized (86 microns zinc coating thickness) steel bars of 10 mm diameter were provided as ties connecting the horizontal and vertical legs of the wire mesh panels at 500 mm horizontal spacing. A 350 mm thick random rubble packing was provided behind the wrapped face to enhance the rigidity of the facing and to contain the fill material. A nonwoven geotextile filter was used behind the rubble to retain the fill material, which was a fine sand. The overall inward batter of the facing was approximately 5º.

Ability to accommodate appreciable amounts of differential settlements was one of the major reasons for adopting this type of facing.

The fill material was a relatively fine-grained sand dredged from the Yamuna river. The design angle of shearing resistance of the compacted sand was 35º.
The ground treatment consisted of the partial excavation and removal of the upper layer of the loose sandy clayey silt / silt sand and replacement with a compacted layer of sand reinforced with a knitted and PVC coated biaxial geogrids with a tensile strength of 90 kN/m in both machine and cross-machine directions. The additional excavation required (over and above the 1.0 m embedment for the walls) was 1.5 m for wall height of 15.0 m (with 3 layers of biaxial geogrids) and 1.0 m for wall height of 10.0 m (with two layers of biaxial geogrids).

**Design**

The design of the walls was carried out using the FHWA-NHI-00-043 guidelines and comprised checks for external, internal and global stability under static and seismic conditions.

Geogrids with ultimate tensile strengths of 40 to 200 kN/m in the machine direction were used. The maximum vertical spacing of the geogrid reinforcements was limited to 600 mm. In some portions, the vertical spacing had to be limited to 400 mm because of design requirements. The minimum geogrids were wrapped back into the fill with a minimum anchorage length of 1200 mm. No secondary reinforcements were used in view of the rather stiff facing comprising the welded wire mesh panels with random rubble backing.

Special attention was given to the design and detailing of the acute angle corners. Here the same geogrid, was used to connect the opposite faces (with both ends wrapped back into the fill). If the reinforcement was axially inextensible, such an arrangement would result in at-rest earth pressures (K0 condition). Because polymer geogrids are extensible, it is doubtful whether such a case would indeed develop. Nevertheless, in view of the lack of widely accepted design procedures and the large height of the wall, a conservative approach assuming at-rest earth pressures were used in design. In this zone, the geogrid spacing was limited to 400 mm. In addition, diagonal reinforcements extending from the acute corner and tying this zone to the main body of the fill were also provided.

It has been reported that closely spaced reinforcements result in tremendous improvement in the response of reinforced soil have been reported [2]. Therefore, with such a high density of soil reinforcements, the designed reinforcement layout should ensure adequate levels of safety and serviceability.

It may be of some interest to note that, the senior author was earlier associated with the design a 12.5 m high wall with concrete panel facing with an acute angle intersection. At that time an appreciably less-conservative approach was used in design. The construction of the structure was successfully completed in 2001 and it has performed quite satisfactorily.

Detailing of acute angle corners, definitely present some challenges. However, with proper design and detailing it is possible to design and construct reinforced soil structures with satisfactory levels of safety and serviceability.

**Construction**

The construction of the wall was carried out under the supervision of Techfab India’s experienced engineer. Construction of reinforced soil structures consists of a few relatively simple and repetitive steps. The important aspects to be controlled during execution were - fixing of geogrid ensuring no slack and with correct wrap around anchorage length, alignment of wall face including careful hand-placing...
of random rubble, proper placement of geotextile filter, check on the quality of fill material especially fines content and angle of shearing resistance, use of appropriate equipments for compaction of fill material and control of relative compaction. The contractor’s workers and supervisors quickly learnt the techniques and the structure was successfully completed in December 2007, with out any difficulty. A notable feature of the wall was the excellent finish of the random rubble construction, which appreciably enhanced the aesthetics (figure 3).

A view of the completed structure is shown in figure 4.

Conclusions

Reinforced soil walls of substantial height (up to 15.0 m) and a relatively steep face (5° batter) were successfully constructed using a knitted and PVC coated polyester grids as soil reinforcement and a welded wire mesh supported wrapped face with random rubble facing. With proper design and detailing, acute angle wall intersections can be satisfactorily constructed using reinforced soil techniques.

References


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Figure 4. View of the completed structures