TECHFAB INDIA

TECHGRID GEOGRID
REINFORCED SOIL
WALLS
INTRODUCTION

Reinforced Soil

Reinforced Soil structures may be defined as a composite earth structure wherein soils (or other suitable fills) are internally stabilized by the inclusion of discrete layers of reinforcement materials which are generally placed horizontally, between successive lifts of fill during construction. Structures with faces steeper that 70° are generally considered as reinforced soil walls (RSW) (or mechanically stabilized earth walls) and structures with face inclinations < 70° are considered to be reinforced soil slopes (RSS). Some kind of facing will be required for walls and slopes steeper that 45°.

Rudimentary examples of this concept are found in nature - stabilization of hill slopes by tree-root reinforcement and beaver dams. Several ancient civilizations made practical use of soil reinforcement by combining locally available earth materials and reinforcing elements of plant origin for the construction of monumental structures (Ziggurats), building materials (adobe bricks) etc.

The modern era of reinforced soil technology began with the invention of Reinforced Earth by Henry Vidal in the early 1960’s in France. Since then reinforced soil has evolved into an advanced construction technology used all over the world for a wide range of applications. Today different forms of soil reinforcement (steel strips, bar mats, welded mesh, geogrids, geotextiles etc.) are combined with different types of facings (full-height panels, discrete panels, segmental panels, modular blocks, gabions, wrap-around etc.) for the construction of an amazing variety of reinforced soil walls and steep slopes. Thus reinforced soil is a proven and mature technology which is almost forty years old and requirements for successful practice are well-understood and established in several codes of practice.

Geogrids

Geogrids are planar, polymeric structures consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing, whose openings are larger than the constituents, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications.

The first geogrid was produced in the early 1980’s by extruding a sheet of polyethylene or polypropylene, punching a regular pattern of holes and then stretching the sheets. Such extruded and oriented geogrids are called as stiff geogrids. Another class of geogrids - the flexible or textile grids - comprising a woven or knitted structure of high tenacity polyester filament yarn coated with a polymeric (mostly PVC) compound, were introduced in the mid 1980’s. Today a large number of companies worldwide manufacture coated polyester geogrids. Thus PVC coated polyester geogrids have a successful history of almost 25 years.
TechGrid - the First Indian Geogrid

TechGrid geogrids are knitted and PVC coated polyester geogrids manufactured at Techfab India's ISO 9001:2000 certified state-of-the-art facility at Silvassa, Dadra & Nagar Haveli. Manufactured from superior quality materials using highly advanced technologies and tested to stringent international standards, TechGrid geogrids are engineered for demanding soil reinforcement applications.

Superior grades of high tenacity, high molecular weight (> 25000) and low carboxyl end group (< 30) polyester yarns are formed into a grid structure using a highly sophisticated warp-knitting process and is then precision coated with a specially formulated polymeric compound to produce a strong, flexible, tough, dimensionally stable and durable geogrid. The product is ideal for the reinforcement of soils and other granular materials for a variety of applications including reinforced soil retaining walls.

TechGrid geogrids are manufactured using state of the art computerized warping and knitting machines from Karl Meyer of Germany and coating machines from Karl Menzel of Germany. Quality control testing is carried out on a regular basis at our in-house test facility with a 50 kN capacity material testing machine with a laser extensometer for accurate measurement of elongation. TechGrid geogrids are tested at TRI/Environmental Inc., USA an internationally renowned accredited independent laboratory. Additional tests have also been carried out at NABL accredited laboratories like BTRA and SASMIRA.

COMPONENTS OF REINFORCED SOIL WALL

TechGrid Geogrids for Soil Reinforcement

Inclusion of TechGrid geogrids transforms a compacted fill into a coherent composite material. When the soil strains in response to applied loads, tensile forces are generated in the geogrid because of the excellent interaction between the geogrid and soil. The tensile forces developed in the reinforcement keeps the reinforced soil mass in stable equilibrium.

Long-term Design Strength

Design of the geogrid reinforcement is based on the long-term design strength, i.e., the minimum assured strength of the reinforcement at the end of the design life of the structure.

The long-term design strength ($T_D$) is calculated as follows:

$$T_D = \frac{T_{ult}}{R_{Fcr} R_{Fld} R_{Fd}}$$
Where:
Tult = Peak ultimate tensile strength (MARV) as per ASTM D 6637
RFcr = Reduction factor for creep
RF = Reduction factor for installation damage id
RFD = Reduction factor for durability

The values of Tult, reduction factors and long-term design strength for TechGrid geogrids are as follows:

<table>
<thead>
<tr>
<th></th>
<th>TG U-40</th>
<th>TG U-60</th>
<th>TG U-80</th>
<th>TG U-100</th>
<th>TG U-120</th>
<th>TG U-150</th>
<th>TG U-200</th>
<th>TG U-250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tult (marv - MD) (kN/m)</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>150</td>
<td>200</td>
<td>250</td>
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<tr>
<td>RFcr (120 years design life)</td>
<td>1.55</td>
<td>1.55</td>
<td>1.55</td>
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<td>1.55</td>
<td>1.55</td>
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<tr>
<td>RFd (sand / silt / clay)</td>
<td>1.10</td>
<td>1.05</td>
<td>1.05</td>
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<td>1.05</td>
<td>1.05</td>
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<tr>
<td>RFID (Dmax 37.5mm)</td>
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<tr>
<td>FRD</td>
<td>1.15</td>
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<td>1.15</td>
<td>1.15</td>
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</tr>
<tr>
<td>Td  (sand/silt/clay), KN/m</td>
<td>21.4</td>
<td>32.0</td>
<td>42.7</td>
<td>53.4</td>
<td>64.1</td>
<td>80.1</td>
<td>106.8</td>
<td>133.5</td>
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<tr>
<td>Td  (Dmax 37.5mm), KN/m</td>
<td>19.5</td>
<td>29.3</td>
<td>39.0</td>
<td>48.8</td>
<td>58.5</td>
<td>73.2</td>
<td>97.5</td>
<td>121.9</td>
</tr>
</tbody>
</table>

**Interaction Factors**
The coefficient of interaction for direct sliding and pullout for TechGrid geogrids may be taken as:
- Gravel / sandy gravel / sand : 0.90
- Silty sand : 0.80

**Facing Systems**
The facing of an RSW performs the following functions:
- Imparts local stability to the external surface of the reinforced soil - prevents raveling, erosion etc.
- Protects the reinforcement from the elements, fire, act of vandalism etc.
- Enables the reinforcement to function as a tie-back
- Acts as temporary form work during the placement and compaction of the fill
- Provides an attractive appearance to the wall.

The choice of the most suitable facing for a specific project would depend on the following aspects:
- Type, function, location and importance of the structure
- Wall height
- The magnitude of differential settlements the structure is expected to undergo
- Maximum permissible facing batter
- Site access, operating space etc.
- Type of architectural finish / treatment required
- Cost

TechGrid geogrids can be used with almost all types of facings - precast concrete panels, segmental concrete panels, modular blocks, gabions, wrap-around etc.
Precast Concrete Discrete Panels

Discrete panels can be of different shapes - square, hexagonal, T, diamond, cruciform etc. and sizes - width and heights varying from 600 mm to 2000 mm and thickness varying from 140 mm to 220 mm. It is possible to use TechGrid geogrids with different types of discrete facing panels.

One of the simplest types of panels is the square panels. Standard size panels will have nominal dimensions of 1500mm x 1500mm (actual dimension of the panel will be 1480 x 1480 mm; a 20 mm gap is maintained at vertical and horizontal joints; the nominal dimension of panel is taken as from the c/c distance between joints). In the bottom most row of panels, standard panels and half-height panels will be used alternately. Reduced width panels may be required at wall returns, movement joints and wall ends. At the top and bottom of the wall, to accommodate changes in elevation, non-standard height panels may be required. Panels will normally have a thickness of 180 mm and concrete of grade M will be used. Nominal reinforcement consisting of 8mm dia. HYSD bars will be provided both ways at the center.

Panels should be able to undergo some movements to accommodate foundation settlements. Hence a nominal joint width of 20 mm is provided between adjacent panels. On the horizontal bedding joints elastomeric bearing pads will be used to prevent concrete to concrete contact so as to avoid excessive stresses leading to cracking of the concrete. The relatively compressible bearing pads also permit some vertical movement of the panels, thereby reducing the axial stiffness of the facing. This will ensure that the panels are not subjected to excessive vertical stresses induced by deformation of reinforcement strips and frictional forces at the back of the facing. Closed cell polyurethane foam may be used as filler material for the vertical joint. Alternatively geotextile strips may be placed behind the panel to prevent loss of soil through the joints.

Typical details of square discrete panels are shown in figure 1. Appearance of the exposed wall face of an approach is shown in figure 2. A typical cross section of the wall is illustrated in figure 3. Details of the connection between geogrid reinforcement and panel are shown in figure 4.

Modular Concrete Blocks

Another popular form of facing is the segmental or modular concrete blocks. These are solid/hollow pre-cast concrete blocks of different designs (some of which may be proprietary) having different sizes and shapes. Typical dimensions of segmental blocks are in the range of length 300 - 600 mm, depth 200 - 500 mm and height 150 - 300 mm. Most segmental blocks employ a frictional connection between the geogrid reinforcement and the block, although some designs may also have mechanical devises to ensure a positive connection.

TechGrid geogrids are suitable for use with a wide range of segmental blocks. Appearance of the exposed face of a segmental retaining wall is shown in figure 5. A typical cross-section of the wall and details of the segmental blocks are shown in figure 6.
Segmental Concrete Panels

Segmental panels are in between the range of discrete panel and blocks in terms of size. Segmental concrete panel size is 1.0m to 1.25m (width), 0.4m to 0.6m (height) and 0.2m to 0.25m (thickness). Most segmental panels employ a frictional and tongue & groove connection between the geogrid reinforcement and the panel.

TechGrid geogrids are suitable for use with a wide range of segmental panels. Appearance of the exposed face of a segmental panel retaining wall is shown in figure 7. A typical cross-section of the wall and details of the segmental panels are shown in figure 8.

Reinforced Fill

Reinforced soil retaining walls are internally stabilized systems wherein the fill reinforced with multiple layers of reinforcement behaves as a coherent composite mass and resists earth pressures from the retained fill and other externally imposed loads.

Hence the fill material plays an equally important role as the reinforcement and due care has to be exercised in the selection of appropriate type of fill and determination of the properties for design.

The following properties of fill are important:

- Effective cohesion \( (c^' ) \) : Normally taken as zero for most soils
- Peak effective angle of shearing resistance
- Particle size and gradation
- Unit weight
- Compaction characteristics
- Chemical properties

Generally a free-draining granular fill without excessive fines and having high angle of shearing resistance and free-from organic and other deleterious materials is ideal for use as reinforced fill.

Leveling Pad

The function of leveling pad is to provide a firm, level and flat surface on which the facing units can be erected to the correct line and level. For most discrete panel and segmental block type facings, a plain cement concrete (grade M15) footing of 600 mm width and 200 mm thickness would be adequate.
Drainage

Adequate arrangements should be made to drain away any water entering into the reinforced or retained soil zones, so as to prevent buildup of excessive pore-pressures and hydrostatic pressures. The design of the drainage system will be project specific considering the type and dimensions of the wall, type of facing, permeability of reinforced and retained fill, amount of rainfall and infiltration etc. Granular or geosynthetic materials may be used for drainage.

Coping

A cast in-situ coping may be required at the top of the wall to achieve the desired longitudinal vertical profile of the wall. M20 grade concrete may be used and nominal reinforcement should be provided.

DESIGN METHODOLOGY

Codes of Practice

The following codes / guidelines are available for the design of TechGrid geogrid reinforced soil retaining walls

1. BS 8006 : 1995 Code of practice for strengthened/reinforced soils and other fills
2. FHWA-NHI-00-043 Mechanically stabilized earth walls and reinforced soil slopes design and construction guidelines
3. Design manual for segmental retaining walls, National Concrete Masonry Association

Design Procedure

In general design involves the following steps:

Define wall geometry, loading, soil and geogrid properties

- Wall geometry: height, facing batter, slope of ground surface in front of wall, back slope at top of wall etc.
- External loads: Dead load surcharge, live load surcharge, strip loads etc.
- Soil properties: Effective cohesion, angle of shearing resistance and unit weight for reinforced fill, retained fill and foundation soil; pore pressure parameter; depth of ground water table; undrained shear strength of foundation soil (where short term undrained bearing capacity analysis is to be performed); consolidation parameters of foundation soil for settlement analysis.
- Geogrid characteristics: long-term design strength, coefficient of interaction
- Seismic parameters: peak ground acceleration
Initial Dimensioning of the Structure

- Depth of embedment
- Minimum length of reinforcement

External Stability Analysis (static and seismic)
- Check for sliding along base
- Check for bearing capacity
- Check for eccentricity/overturning (not applicable for BS 8006:1995)
- Global stability

Internal Stability Analysis (static and seismic)
- Check for internal sliding
- Check for rupture of reinforcement
- Check for adherence/pull-out of reinforcement
- Check for stability of facing
- Check for serviceability
- Horizontal deformations
- Vertical deformations (settlement)

CONSTRUCTION METHODOLOGY

Construction of reinforced soil structures involves a repetitive sequence of fairly simple operations which can be easily and quickly mastered in a short time. Nevertheless it is important to take all necessary precautions and checks at each stage to ensure that the construction is strictly in accordance with the approved design and drawings.

Excavation and site preparation:

The foundation for the wall shall be excavated to the lines and grades as shown in the drawings and graded level for a width equal to the length of the reinforcement plus 300 mm or as shown on the drawings. Any foundation soils found to be unsuitable shall be removed and replaced with approved fill. Before the start of wall construction, the foundation (except in the case of rocks) shall be compacted with a smooth wheel vibratory roll.

Casting of Foundation leveling pad

Mark the center-line of the facing at the founding level, excavate trench of required dimensions, place side forms and cast foundation leveling pad to the lines and grades as shown on the drawings. The leveling pad should be finished to a tolerance of ± 3 mm and cured for 24 hours prior to commencement of placement of facing units.
Erection of facing units

The first row of facing panels will normally consist of an alternating sequence of full and half-height panels (or special bottom panels appropriate height to accommodate grade differences in leveling pad due to ground level variations), set to the required batter to compensate for panel rotations during fill placement and compaction. It will be required to prop the first row of panels. Subsequent rows of panels are fixed to the lower raw using clamps. A uniform vertical gap of 20 mm (or as shown on the drawings) is maintained between adjacent panels. Geotextile strips fixed to the rear face of the panels or polyurethane foam inserted to the joints are used to prevent loss of fill through the joints.

Segmental blocks are placed in a running bond configuration, with any hollow cavities or spaces in between filled with crushed stone / granular drainage media as per specifications.

Placement and compaction of fill to the first layer of reinforcement

Fill should be placed and compacted in lifts with appropriate thickness consistent with vertical spacing of reinforcement and compaction requirements. The uniform loose lift thickness of reinforced fill should not exceed 300 mm. The fill should be compacted to the specified density - 95% of maximum Proctor density for normal fill, 98% for pavement subgrades and 100% for fill supporting structural footings.

No plant or equipment with a weight more than 1500 Kg, should not be permitted to operate within a distance of 1.5m from the facing. A light weight (< 1500 kg) walk behind vibratory roller or vibratory plate compactor may be used in this zone. Beyond a distance of 1.5 m from the facing, static/vibratory rollers of 8 - 10 T weight may be used for compaction.

Placement of the first layer of Geogrid reinforcements

Geogrid reinforcement of the required strength and length are installed at the levels shown in the drawings. The geogrid shall be laid with its principal strength direction (normally the machine direction) perpendicular to the wall face. The geogrid shall be connected to the facing elements (panels, blocks etc.) as shown on the drawings. The geogrid shall be laid smooth without folds and wrinkles. A light tension is applied to the geogrid to remove any slackness and it is held in this position by driving U-pins or placing small heaps of fill. Adjacent panels/sheets of geogrid are simply but-jointed without any overlap.

Placement of next and subsequent lifts of fill

No equipment shall be allowed to operate directly on the geogrid. It is recommended to maintain a minimum loose lift thickness of 200 mm between geogrid and the wheels/tracks of any construction plant. Fill should be dumped near the rear or middle of the geogrid and bladed towards the front face. Fill placement behind the reinforced zone should also proceed simultaneously. Compaction of the fill should be carried out as described above.
Erection of subsequent rows of facing units and reinforcements

Top of the installed facing units should be cleaned of any debris, gravel, fill etc.

In the case of discrete panels bearing pads should be provided on the horizontal bedding joints. Erect the next row of panels to the required batter using wooden wedges and fix to the lower row of panels with wooden clamps. Fix geotextile/foam strips.

Segmental block units are normally placed in running bond configuration. Blocks normally have a built in arrangement in the form of locator pins/lips/down-stand etc. which automatically ensures the correct setback between successive courses of units. Ensure that each unit is pushes forward to engage the shear key / pins etc. of the course below.

At each level ensure that the horizontal and vertical alignment of the facing and bedding between successive rows/courses of panels/blocks are correct and as per the drawings and any deviations within the permissible limits.

Install geogrid reinforcements of the required strength and length at the required levels.

Placement of drainage layer

Install the drainage system, simultaneously with the placing and compaction of fill. The drainage fill should be brought up at the same rate as reinforced and retained fill, taking care to prevent any mixing with other soils. Any perforated collection pipes should be installed with the required slope as shown on the drawings.

Coping

At the top of the wall, provide cast in-situ coping to achieve the required longitudinal profile.
Figure 1. Example of discrete panel
Project: Construction of Flyover at Nanavarachha

Facade: Discrete Panel

Client: Surat Municipal Corporation


Contractor: Raj Kamal Builders Infrastructure Private Ltd.

Max. Height: 9.0 m
Figure 7
Project: Forming, providing wet mix macadam & black topping to master plan road in between Brahmani & Indu project at IT SEZ Hardware park, RR Dist.

Facia: Modular Block

Client: Andhra Pradesh Industrial Infrastructure Corporation Ltd.

Consultant: Shree Lakshmi Metal Industries & Constructions

Contractor: Shree Lakshmi Metal Industries & Constructions

Max. Height: 15.0 m
REINFORCED SOIL WALL WITH SEGMENTAL PANEL FACING FOR APPROACHES

Figure 9

TYPICAL CROSS SECTION OF REINFORCED SOIL WALL WITH SEGMENTAL PANEL FACING

Figure 10
Project: Construction of Flyover at Palanpur - Swaroopganj Road Project on NH-14
(km 264.00 to km 340.00)

Facia: Segmental Panel

Client: National Highway Authority of India Ltd.


Contractor: Larsen & Toubro Ltd., ECC Division, Chennai.

Max. Height: 12.0 m