# GEOGRID REINFORCED SOIL WALLS - FACINGS, MATERIALS AND CONSTRUCTION

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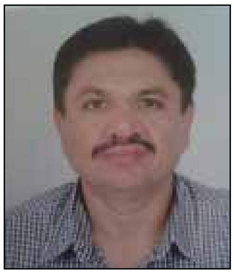

Saurabh D Vyas, 1973 born, completed B.E.Civil from the BVM Engineering College, Vidhyanagar, Received Post graduation degree from CEPT, Ahmedabad. His work experience includes 11 years with Netlon India and Techfab India Industries Ltd., for design and implementation of Geosynthetics and reinforced soil applications.

## Summary

Geogrid Reinforced Soil Wall (RSW) has wide acceptance now in India. There are various facings options are available for aesthetic as well as technical consideration. RSW private projects are also executed with marginal fill materials with due provisions, in and outside India. Further study is needed for the adaptability of the fill other than the standard provisions. There are construction issues, which needs to address for the betterment of the Reinforced Soil Wall structures and for their satisfactory performance, during their design life. Geogrid RSW is indeed a proven solution due to their cost effectiveness as the Geogrid materials are available indigenously.

**Keywords:** RSW – Reinforced Soil Wall, Geotextiles, Geogrids, Backfill Materials.

## 1. Introduction

Reinforced Soil Wall has an emerging market in developing countries like India. Polymeric (mostly PVC) coated polyester Geogrids are one of the most widely used soil reinforcement for Reinforced soil wall application. Reinforced Soil walls with different facings and fill materials conforming to design standards are executed on a large scale in our country. The performance of RSW has been found to be generally satisfactory, except for some isolated cases related to foundation, backfill material consistency and/or execution.

Facings and material selection plays an important role for Geogrid Reinforced soil wall. Apart from technical requirements, facings selection is influenced by customer preferences. There are standard guidelines to use of backfill material for Reinforced Soil wall application, which are part of tender document for compliances. Some less critical applications like site development and landscaping for private commercial projects, are executed with relaxation in standard design guidelines, for backfill materials (use of locally available backfill materials), with additional design provisions and with more emphasis on the aesthetic appearance of facing are also performed well.

To ensure good performance of the Reinforced Soil Wall, it is important to have a proper design, using specified backfill with proper compaction, provision of adequate drainage measures and proper execution with good control on horizontal and vertical alignment.

## 2. Geogrid Reinforced Soil Wall – Facings

Reinforced Soil Walls require a facing to perform various functions - formwork for the backfill during placement and compaction, to assist the reinforcement to function as tie-backs, to protect the reinforcement, to protect the fill against raveling and erosion, and to present a suitable aesthetic appearance. The selection of the facing is based on, design consideration, batter requirement, space constraint and architectural finish as per the customer requirement.

One of major advantages of Geogrids is that it can be used with various types of facings, such as, precast concrete panels, modular concrete blocks, weld mesh facings, gabion facing and wrap-around. Based on facing selection, designs are checked for connections.

### 2.1 RSW Precast concrete Panels:

Precast concrete panels are used widely as Geogrid Reinforced soil wall application. Area of panels is 2.25 to 3.2 Sqm, either square or cruciform in shape with thickness of 160mm to 200mm. Panels are designed structurally for all vertical loads, earth pressure and connection. For aesthetic requirement, special architectural finishes are provided at front face as shown in Fig.1. Connection to connect the Geogrid with panels, are designed for the Geogrid tension, for the design life of the structure. Wider & Narrow width Geogrids are used, considering the coverage for design, for Geogrid Reinforced Soil Wall. Please refer case study-1.

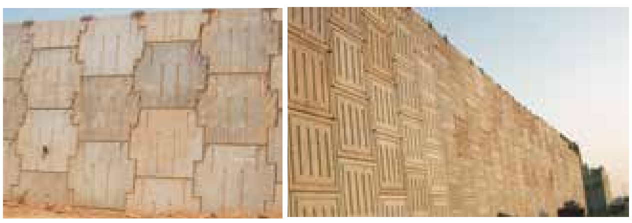

*Fig.1: Geogrid RSW with panel*

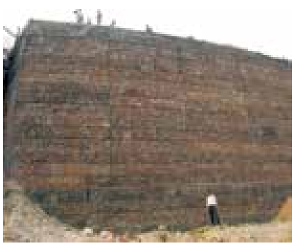

*Fig.2: Geogrid RSW with Block*

*Fig.3: Geogrid RSW with welded wire mesh*

### 2.2 RSW Precast concrete Block facing:

Precast block of size 450mm wide, 300mm deep and 200mm thick are used with straight and curve face with Geogrid. Blocks are small in size are

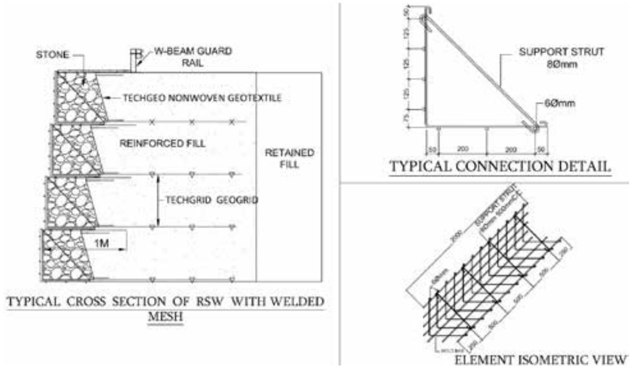


*Fig.4: Geogrid RSW with Welded wire mesh facing*

best fit for the walls with acute horizontal curve. Geogrid coverage for Block is 100% (butting each other) and the connection for Geogrid - Blocks is based on friction. Figure 2 shows the photograph of 15 m high block wall at Hyderabad Outer Ring Road.

### 2.3 RSW Weld mesh facing:

When there are some constraints in the use of concrete facings, welded wire mesh with stone backing can be used as an alternative. As a geogrid wrap-back detail is used, no separate connection fixtures are required (figure 3 and 4). 100 % geogrid coverage is provided. Relatively tall walls with a steep face can be constructed using this technique.

Figure 3 shows photograph of the 15 m high wall for the DND Flyover at New Delhi.

### 2.4 RSW Wrap-around facing:

As an alternative to hard facings like concrete or stone, soft wrap-around facing were the geogrid reinforcements are turned along the wall face and anchored back into the fill, may be used (figure 5). The typical anchorage length is 1.0 to 1.5 m. The wall face is vegetated to protect the soil from erosion and also to protect the geogrids from weathering. The difficulties in establishing and sustaining the vegetative cover increases as the wall face becomes steeper and requires special attention. The system may not be suitable in locations with a hot and dry climate.

### 2.5 Gabion facing:

Gabions are factory made boxes of required sizes, made from hexagonal mesh, supplied in

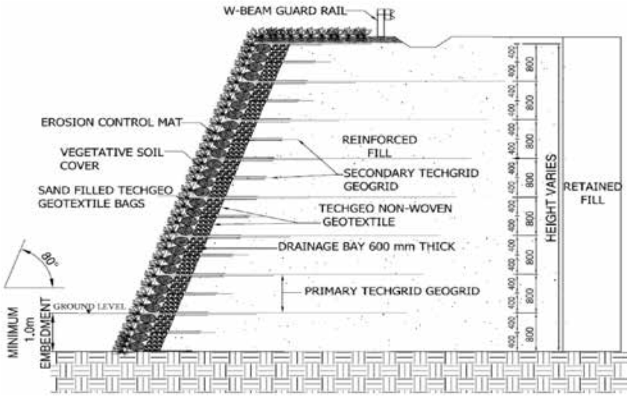


*Fig.5: Typical C/S of RSW with Wrap Around (BAG WORK)*

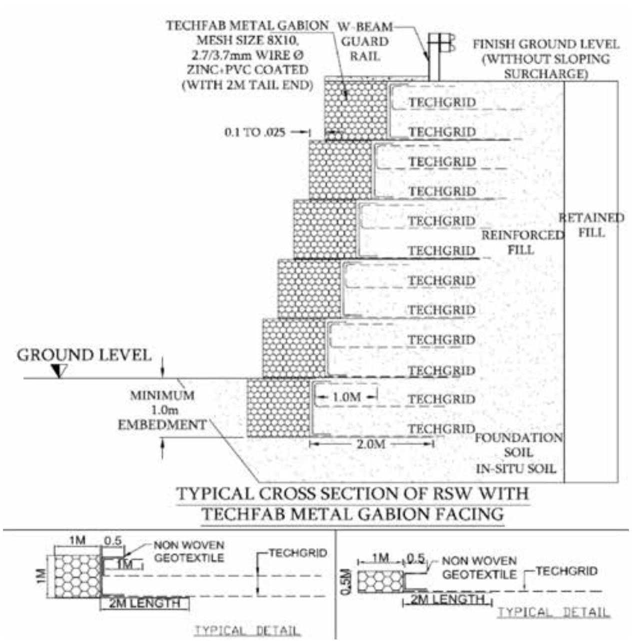


*Fig.6: Typical C/S of RSW with Metal Gabion*

collapsed from, and assembled at site to make a box. Gabions are filled with boulders and used as gravity structure also. For Geogrid Reinforced Soil Wall, Gabions are used for front facing with tail end of 2 meter to hold it in position as shown in Figure 6. Geogrids are used as soil reinforcement, as per design spacing.

## 3. Geogrid Reinforced Soil Wall - Materials

Reinforced soil wall consists of reinforcing material-Geogrid, facing unit, backfill and filter media for drainage. Typical cross-section for Geogrid RSW arrangement is shown as Figure 7 below:

### *3.1 Geogrids for Soil Reinforcement*

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.

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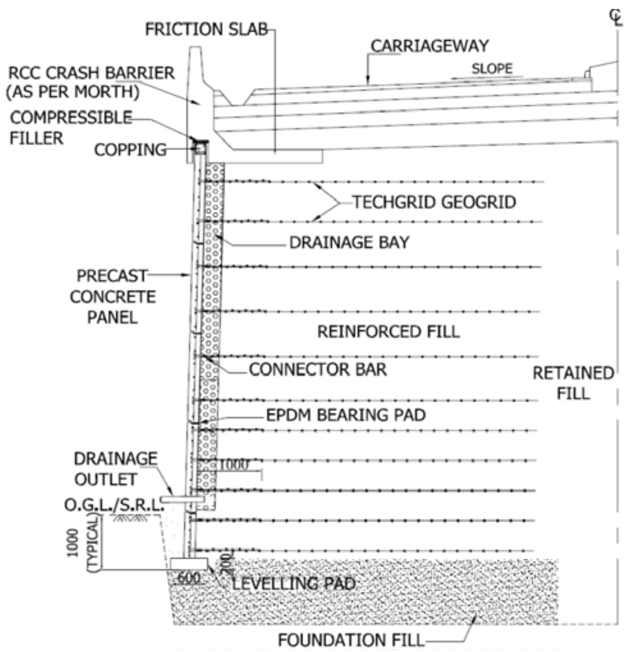


*Fig.7: Typical C/S of Geogrid RSW*

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 compound, was introduced in the mid 1980's. Today a large number of companies worldwide manufacture coated polyester geogrids.

Inclusion of geogrid 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.

## *3.3 Backfill material*

### *3.3.1 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.

Fill parameters are to be well defined, effective cohesion (c´), normally taken as zero for most soils, Peak effective angle of shearing resistance, Particle size and gradation, Unit weight, Compaction characteristics and Chemical properties.

Generally a free-draining granular fill without excessive fines having high angle of shearing resistance and free-from organic and other deleterious materials is ideal for use as reinforced fill. Reinforced fill is selected granular material, with fines (75 micron passing) restricted to 10 to 15%, plasticity Index less than 6, Co-efficient of uniformity is equal to or more than 4.

Apart from granular soil such as sand, Fly ash are also used as backfill materials as backfill. Fly ash are non plastic with higher shearing resistance and used successfully with Geogrid reinforced soil wall. Please see below the case study with Fly ash with Polyester Geogrid.

### *3.3.2 Retained fill*

Retained fill is the fill provided behind the reinforced fill, which exerts earth pressure over the reinforced mass. Retained fill parameters are to be well defined and as per the standard for design consideration. Retained fill is also free from organic and any other deleterious materials.

### *3.3.3 Drainage*

Adequate arrangements should be made to drain away any water entering into the reinforced or retained soil zones, 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. Adequate filter media shall be provided behind the wall for drainage consideration. Generally the thickness for filter media shall be 600mm.

Considering the intensity of rainfall down take pipe at certain distance, for full height wall and side drain with down take pipe for partial height wall (RSW with sloping surcharge) to be provided.

For the reinforced fill with higher fines (e.g. Flyash), provision for Nonwoven geotextile for full height (In between the filter media and reinforced fill) shall be provided. There is an additional provision for impervious layer of soil or liner, is recommended, to prevent the infiltration of water at top, in case of partial height wall. Care to be given for the wall constructed with existing false free slope, by providing benching and drain, wherever required.

# 4. Geogrid RSW Construction Guidelines:

For RSW, Execution is crucial and important for long term performance and for aesthetic reason. Proper care has been taken for casting of facing, adequate foundation depth, batter of wall, placement of facing, laying of Geogrid, connection, placement of drainage bay, placement of fill and compaction of fill material.

### 4.1 Casting of facing material:

Casting of facing material either for Block and panel shall be carried out with minimum of M35 concrete. Block shall be design with consideration of key for self batter and dry casting is carried out at hydraulic press with specially made moulds.

Different shape of panels with tongue & groove arrangement are designed and accordingly casting has been done with metal or fiber mould. Connection for the Geogrid is embedded within the concrete of panel, at the time of casting. Proper curing is required before placement of the Block & Panel.

### *4.2 Foundation Depth:*

With reference to the MORT&H guidelines, minimum 1 meter of embedment depth is required. Embedment depth is to be considering either from Ground level or Service Road Level. Foundation soil shall be verified and unsuitable soil to be replaced with good quality soil, considering Bearing capacity and settlement requirement.

### *4.3 Batter for RSW:*

Batter is required for wall to avoid leaning of wall out ward. Blocks are designed with self batter and after placement wall will be inside with designed batter. For panels, considering the fill material characteristic, initial batter of 2 to 3 degree shall be provided and after compaction wall shall be inside with at least 1 degree batter.

### *4.4 Placement of facing:*

For proper placement of facing at bottom, considering designed final batter (generally 1 degree), centerline is marked at an offset of distance between center of coping and center of leveling pad. Leveling pad is cast, with reference to marked centerline for facing placement. Leveling pad of minimum M15 grade of concrete is to be provided at bottom. Bottom most panel are fixed in final batter position with wooden block or mortar concrete. At each layer after compaction batter to be checked and it should not be excessive inside or outside.

### *4.5 Laying of Geogrid:*

Geogrid are cut and laid as per the design consideration with sufficient overlap for connection. Geogrid are to be laid in line and level, without wrinkles in full taut conditions, over well compacted surface. No direct vehicle movement over laid Geogrid is allowed, unless until minimum 200mm thick soil layer is placed over it. Geogrid are laid with main ribs (Higher tensile strength ribs – Machine direction) perpendicular to panel.

### *4.6 Connection:*

Blocks are designed with frictional connection, and test at various normal pressure with different types of Geogrid to be performed at laboratory to derive the connection strength. For panel, connections are made by inserting hooks or connector rod inside the panel during casting. Designed connection shall be test at laboratory for their connection capacity, which shall be more than the Geogrid tensile strength.

### *4.7 Placement of Drainage bay:*

Drainage bay shall be provided behind the RSW, to have the filter criteria. Minimum 600mm of filter media is recommended for RSW. For the reinforced fill with higher fine content, provision such as chimney drain, base drain, nonwoven geotextile in between filter media and backfill are to be made.

Proper Drainage design is to be implemented, to avoid the ingress of water and to release of pore water pressure, by providing longitudinal and down take pipe, along with other provisions.

### *4.8 Fill material placement:*

Reinforced fill as per the design consideration, are laid in 200mm of layer thickness. Compaction with 10T roller is carried out to achieve 95% Procter density, at least 1.0 to 1.5 meter away from the face of the facing. Near facing compaction are to be done with 1T baby roller and plate compactor. Fill material parameters such as internal friction, gradation, are checked as per the frequency specified. Considering the fill material various tests are recommended to ensure the compliance with design consideration. Pullout resistance is utmost important parameter to match the design consideration. For the backfill such as Fly ash, site pullout test is recommended. Please find below the details for the site pullout carried out at site:

## 4.9 Field Pullout Tests to Determine the Interface Friction Angle between Geogrid and Fill

### 4.9.1 Objectives and Significance

Pullout tests are carried out to determine the interface friction angle between the geogrid reinforcement and fill material.

Pullout resistance of the reinforcement (F) is calculated as follows:

$F = 2 L_e B \sigma_v' C_i \tan \phi_i$ - Equation (1)

Where,

2 stands for top and bottom surface of geogrid in contact with soil

$L_e$ : Embedment of geogrid

B : Width of geogrid

$\sigma'_v$ : Normal stress on geogrid

$C_i$ : Coefficient of interaction defined as the ratio of the tangent of Interface friction angle between geogrid and soil to the tangent of Peak effective angle of shearing resistance of soil

$\phi_i$ : Interface friction angle between geogrid and soil = $\tan^{-1}$ (Ci tan $\phi$)

$\phi$ : Peak effective angle of shearing resistance of soil = 32 degree (In design)

On rearranging the above equation,

$$\varphi_i = \tan^{-1}\left(\frac{F}{2LeB\sigma'_v}\right)$$ - Equation (2)

### 4.9.2 Example of Field Pullout Tests

Recently, field pullout test on geogrid was conducted for the reinforced soil walls constructed for the Six laning of Chennai Tada section of NH-5 from km 11+000 to 54+400 in the state of Tamilnadu.

The pullout force is the maximum load recorded during the test. From this the interface friction angle is calculated using Equation (2). The value of the interface friction angle determined from the test is compared with value considered in design.

The design value of interface friction = $C_i \tan\phi$, where $C_i$ (equal to 0.85 in design) is the coefficient of interaction and $\phi$ = 32 degree, is the design angle of shearing resistance of the fill.

Based on the above, the design value of interface friction angle between Geogrid and fill is,

tan-1(Ci tan $\phi$) = $\tan^{-1}$ (0.85 tan 32) = $\tan^{-1}$ (0.531) = 27.97 degree.

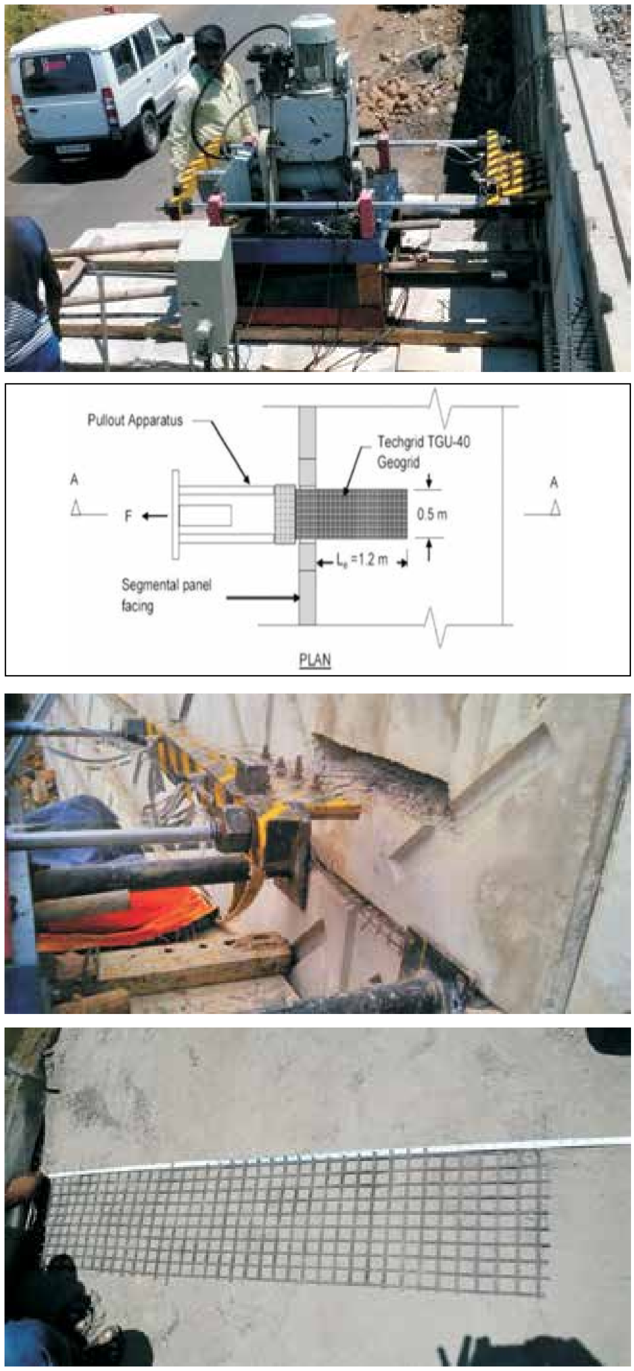


*Fig.8: Details for field pullout test for RSW*

## Field pullout results:

| | |
|---|---|
| Type of Geogrid | : TGU60 |
| Embedded length of Geogrid test specimen (Le) | : 150 CM |
| Width of Geogrid test specimen (B) | : 30 CM |
| Average height of fill on the test specimen (H) | : 50 CM |
| Bulk unit weight of fill ( $\gamma$) | : 1.16 GM/CC |
| Diameter of the hydraulic ram (d) | : 6 CM |
| Area of the hydraulic ram (A) = $\pi$ d2/4 | : 28.274 $CM^2$ |
| Maximum pressure recorded during the test (p) | : 20 $KG/CM^2$ |
| Pullout resistance (F) = p A | : 565.48 KG |
| Coefficient of interface friction measured in pullout test ($\mu$i (test)) = F/ (2LeB$\gamma$H) | : 1.083 |
| Coefficient of interaction considered in design (Ci) | : 0.85 |
| Design angle of shearing resistance of fill ($\Phi$) | : 32 degree |
| Design coefficient of interface friction ( $\mu$i (design)) | : 0.531 (0.85 tan$32^0$) |

Filed coefficient of interface friction = 1.083 (above), which is more than 0.531 (Design)

## 5. RSW Case Studies:

### 5.1 *RSW with Fly ash as backfill for Nagpur bypass:*

#### *5.1.1 Project details:*

| | |
|---|---|
| **Name of project:** | Fourlaning of MP/Maharastra border to Nagpur including Kamtee-Kanhan and Nagpur bypasses |
| **Client:** | National Highway Authority of India |
| **Consultant:** | L.R Kadiyali & Associates |
| **Contractor:** | Oriental structural Engineers Pvt. Ltd. |
| **Technology Provider:** | Techfab India Industries LTd. |

#### *5.1.2 Challenge:*

There are several RSW approaches along the Nagpur bypass, such as Grade separators, Rail over bridges and Flyovers. The major challenges to execute the RSW at this stretch are weak foundation soil and scarcity of selected backfill for Reinforced soil wall application.

#### *5.1.3 Solution:*

Detailed soil investigation was carried out to have clarity for foundation soil stratum. Soil investigation report clearly mentioned the presence of expansive soil, up to the depth of 3 to 4 meter form existing ground level. Various ground improvement techniques, such as stone column, PVD and soil replacement are designs and checks for cost effectiveness. Finally it has been decided to replace the expansive soil either with available yellow earth or Fly ash. To address the settlement, it has been decided to use square panel (size 1.5m x 1.5m), with continuous vertical joint with Geogrid reinforcements are discontinued at every fourth panel so the relative movement of the panels are taken care off.

*Fig.8: RSW for Nagpur Bypass with Fly ash*

Apart from the ground improvements, the selected backfill for RSW is not available in vicinity and to bring it with long distance is not viable solution. Another alternate material available nearby is Fly ash. Fly ash is having good internal friction value, but it has higher fines (passing 75 micron), up to 35%. Special provision for Nonwoven geotextile is considered in between the filter media and reinforced fill, to prevent the erosion of Fly ash particles. Work has been completed in 2011-2012.

## 5.2 RSW with Fly ash as backfill for Chennai-Tada Road Project:

### 5.2.1 Project details:

Name of project: Six laning of Chennai to Tada section of NH-5 from Km. 11.00 to Km 54.40

| | |
|---|---|
| **Client:** | National Highway Authority of India |
| **Consultant:** | SNC-Lavalin / Aarvee Associates JV |
| **Contractor:** | L&T ECC / L&T IDPL. |
| **Technology Provider:** | Techfab India Industries LTd. |

### 5.2.2 Challenge:

Reinforced soil wall for the package was earlier designed with the granular fill and work has been started at one location. Design was carried out with the panel of size 1250mm x 600mm x 210mm, frictional connection. After completion of 1 to 2 meter of wall height, Contractor was not getting the material and requested to technology provider for alterative solution, as work was held up for almost a year. As the Fly ash is available, all the necessary checks (Shear parameters, PH value, gradation etc.) are carried out and proposal with Fly ash as backfill was submitted to consultant for approval. At first instance they were hesitate to adopt the proposal and insisted more tests.

### 5.2.3 Solution:

Frictional angle and PH values are well within the acceptable criteria. Considering the higher fines and drainage consideration use of Nonwoven geotextile in between to filter media and backfill was recommended. Also a layer of drainage with Nonwoven geotextile was proposed at leveling pad level, as shown in the figure below. Also the pullout test was carried out with fly ash at IIT-Madras and they have recommended the co-efficient for pullout resistance as 0.85 for design consideration. Although the consultant has asked for the site pullout test and for that the special panel with groove was casted and the Geogrid to be laid at that level with one end fixed with the testing equipment, outside the panel, pass through the groove as shown in the field pullout test results (clause 4.8.1) above. The failure of the grid was noted as rupture not pull out and the co-efficient at for site pullout was measured and calculated more than 1.0. Out of four structures, three structures were completed in mid 2014.

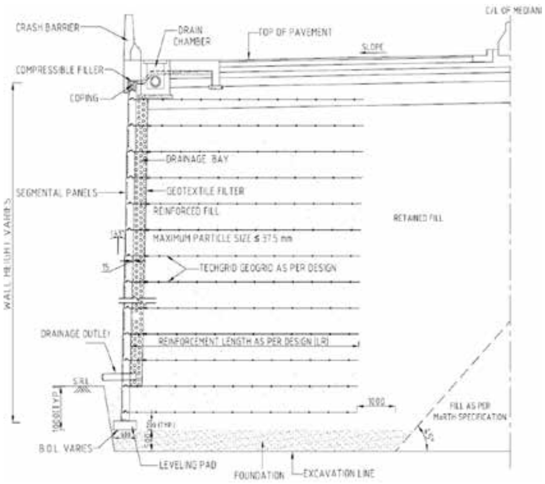


Fig: 10 RSW Cross-section with Fly ash

## 5.3 RSW with locally available backfill for Private Project:

### 5.3.1 Project details:

Name of project: Reinforced Soil Wall for Monsoon Palace, Aamby Valley.

| | |
|---|---|
| Contractor : | M/s Spectrum Engineers, Vadodara. |
| Architect : | M/s Prabhakar B Bhagwat, Landscape Architects & Environmental Planners, Ahmedabad. |

### 5.3.2 Challenge

Monsoon Palace is being built in Half Acre Area, at Village-Devgar, Taluka-Mulshi, North Lake at Aamby Valley City, Lonawala, District -Pune.

The Palace is surrounded by hilly terrain and running streams. Due to high embankments and steep slopes of basically murrum soil, it was necessary to have a retaining wall for reinstatement purposes. Since these walls were outer walls surrounding the monsoon palace, the client and architect was willing to have an aesthetic and viable solution compared to the conventional solution of RCC wall.

With consideration of locally available soil with other drainage provisions, Reinforced Soil Wall is proposed to consultant.

*5.3.3 Solution*

TechFab (India) Industries Ltd suggested the use of TechGrid Uniaxial Geogrid TGU of Ultimate Tensile Strength varying from 40 KN/m to 250 KN/m. These Polyester Uniaxial Knitted Geogrids are used as primary reinforcements to the existing steep slopes. Geomembrane was provided below the top drain to prevent any ingress of precipitation or runoff water. Design of Reinforced Soil Wall was done by considering the maximum possible vehicular load and other surcharge loads. ReSSA 3.0 Software was used to carry out the Global Stability Check for the designed Rein forced Soil Wall.

*Fig: 11 RSW for Monsoon Palace*

By giving this solution of Reinforced Soil Wall, client has developed extra land of around 2 acres.

## 6. Conclusion:

Polymeric geogrids are one of the most widely used soil reinforcement materials for the construction of reinforced soil walls. It can be combined with a wide range of facings – precise concrete discrete panels, modular concrete blocks, gabions, welded wire mesh and vegetated wrap-around face - to construct reinforced soil walls for different applications.

If the requirements for materials, design and construction as specified in the standards and codes are followed, satisfactory performance and durability of reinforced soil walls can be ensured.

Sometimes, it is difficult to get high quality granular fill material for RSW execution and use of quarry sourced material may be rather costly. In some of the less critical applications like site developmet and landscaping walls for private residential or commercial developments, use of locally available soils with the necessary additional precautions in design and construction could be considered.

Many projects are executed with the fly ash as backfill material and performing well without any issues. Latest MORT&H fifth revision also allow using the Fly ash as backfill material for Reinforced Soil Wall application. Now-a-days field pullout tests are mandatory in many projects and especially for the backfill with lower density. With good quality control during construction, high interface friction is developed between fly ash and geogrid. In one of our project, mentioned above as case study, wherein geogrid was used to reinforce fly ash, during field pullout test, value of interface friction recorded was almost twice the designed consideration of interface friction. Which proves higher interface friction are available with geogrid, used to reinforce selected soil, as well with fly ash.

## 7. References:

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[2] BS8006-1:2010. Code of practice for strengthened/reinforced soils and other fills.