GEOSYNTHETICS AND REINFORCED SOIL STRUCTURES

Case Study of the Construction of Very High Reinforced Soil Retaining Walls in India

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Brief history of MSE Walls in India

- First MSE wall in mid-1980’s at Ludhiana
- Most RoBs on NHAI projects built using this techniques
- Very common to see MSE wall heights more than 10m
- Geosynthetics and steel ladders, steel strips, plymeric strips, anchor systems used as RE materials
- Soil and fly ash used as backfill material
- Till date maximum height of RE wall in India ≈45 m
- One project currently underway in Sikkim with height more than 100 m
Different Types of RE Walls built in India

- Full-height walls
- Modular block walls
- Panel walls
- Steel mesh reinforcement
- Steel strips with anchor
- Gabion facings
- Geogrid reinforcement
- Polymeric strip reinforcement
Construction of Ghat road at Kanakadurga Temple Vijayawada

22m high wall

44m high wall
Narrow stretch on the Ghat road
Objectives of the Construction

- Widening of the approach road
- Creation of a large parking space for vehicles at the top of the hill

Extra space gained

Existing hillock

Proposed Soil fill

Height varying from 20 to 44 m
Different Options Considered

• Blasting of hill to create additional space – ruled out because of fragile nature of the rock, high built up area around the hill.
• Reinforced concrete walls – ruled out because of uneconomical designs – very difficult to even bring the fresh concrete because of insufficient access
• Long columns with a reinforced concrete slabs – too expensive
• Panel supported reinforced soil walls – not possible because cranes cannot be operated at such great heights
Anticipated problems

- Limited access to construction site
- Heavy rain fall
- Large surface run-off from upper reaches
- Limited space for mobility of equipments
- Large height of walls of this kind
- Hill slopes with disintegrated rock with several joints/fissures
- Frequent boulder falls
Narrow access to the construction site at ground level
Reinforced soil wall construction does not disturb the existing hillock which is already fairly fragile,

• Reinforced soil wall provides an additional 20 m wide space over existing 3 m wide road,

• Geosynthetic reinforced segmental retaining wall is economical and fast, and

• does not require heavy machinery for construction.
Site Conditions

• Average annual precipitation ≈ 1500 mm
• Good bearing stratum at shallow depths (rock strata)
• Gravelly soil with 30% fines available at a distance of 25 to 30 km from site
• gravel 39%, coarse sand 5%, medium sand 12%, fine sand 8% and silt and clay 36%.
• Mixed with coarse river sand in 50:50 ratio to reduce the fines to less than 20%
• Plasticity index of gravel soil less than 6%.
Adopted System

• Modular block facing because of ease of handling – each unit weighs around 30 kg only

• Tiered soil retaining walls with geosynthetic reinforcement layers

• Tiers help in increasing the stability, provides staging space for construction of upper tiers, aesthetics.
Reinforcement Used

• Proposed to use a high strength polymeric composite which has excellent strength and drainage properties

• Reinforcement made of polyester fibres having tensile strengths from 50 kN/m to 200 kN/m

• Geotextile backing is made of needle punched nonwoven polypropylene
Design

• Based on BS8006 for static loads
• Based on FHWA for seismic loads
• Connections checked using NCMA (National Concrete Masonry Association, USA) guidelines
Piggy-back walls

\[ D \leq \frac{H_1 + H_2}{20} \]

\[ \frac{H_1 + H_2}{20} < D \leq H_2 \tan(45^\circ - \frac{\phi_r}{2}) \]

\[ D' = 2D \frac{H_1}{H_1 + H_2} \quad R_0 = \frac{\phi - \phi_r}{90^\circ - \phi_r} \]

\[ D > H_2 \tan(45^\circ - \frac{\phi_r}{2}) \]

a) **MAXIMUM TENSION LINES**

--- INEXTENSIBLE

-------------------- EXTENSIBLE
CASE 1  \( D \leq H_2 \tan (45^\circ - \frac{\Phi_f}{2}) \)
\( \sigma_l = \gamma H_1 \)

CASE 3  \( D > H_2 \tan (90^\circ - \Phi_f) \)
\( \sigma_l = 0 \)

CASE 2  \( H_2 \tan (45^\circ - \frac{\Phi_f}{2}) < D \leq H_2 \tan (90^\circ - \Phi_f) \)
\( \sigma_f = \frac{\gamma H_1 - \gamma \frac{3_1}{3_2 - 3_1} H_2}{3_2 - 3_1} \)

\( 3_1 = Dt \tan \Phi_f \)
\( 3_2 = Dt \tan (45^\circ + \frac{\Phi_f}{2}) \)

b) **ADDITIONAL VERTICAL STRESS**

Additional stress on the bottom wall as per FHWA guidelines
Level difference between ground surface and ghat road
Modular facing block – Rockwood type – made of M35 grade concrete by cold pressing process
Length of reinforcement
Bottom tier – 10.5m
Upper Tier: 7.4m
No. of layers
Bottom tier – 29
Upper tier 18
Vertical Spacing of reinforcement layers
(in multiples of 200 mm – height of each block)

Bottom tiers (PEC 200 – 200 kN/m index strength):

• Elevation 0 1.6m  200 mm
• Elevation 1.6 m to  6.8m  400 mm
• Elevation: 6.8 m to 12 m  600 mm

Upper Tier (all layers at 600 mm vertical spacing)

• PEC 200   12.2 m to 12.8 m
• PEC 150   12.8 m to 15.8 m
• PEC 100   15.8 m to 17.6 m
• PEC 075   17.6 m to 20.0 m
• PEC 050   20.0 m to 22.4 m
First layer of modular blocks placed – notice the drains and bottom drainage layer
Typical block used – notice the shear key

Placing of the modular blocks
Light weight vibro-roller used at site – unable to bring in standard 10 Ton vibro-roller
Plan views of the wall under construction
Notice the chimney drain around the wall
Construction aspects

Soil and aggregate dumped from hill road by trucks

Dumping of fill materials from ghat road
Monitoring of compaction quality
Compacted soil covered with polythene sheets during rains.
Close-up view of chimney drain
Wall at 3m height

Wall at 19 m height with 5 m berm
Wall during construction
Wall during construction – notice the close proximity of existing buildings
COMPLETED TWO TIER WALL
View of 2-tier Wall from Krishna River
Top view of the finished 22 m high wall with wide space for road
Another view of the road on the completed wall
Global stability analysis of 2-tier retaining wall
Global stability analysis of 4-tier wall
Global stability analysis of 4-tier retaining wall
Excavation for the 4-tier wall
ALIGNMENT OF TIER 1 FOR 4 TIER WALL
Top view of the completed 4-tier wall -
View of the bottom most tier – perfectly straight alignment – no visible signs of bulging
Bulging of wall next to hill junction – excessive nailing
subsidence at hill top due to compression of soil fill
Local subsidence at 3rd tier level
View of the entire wall from ground level
Another view of the entire height of wall
Vertical cracks due to differential settlement between different parts of the wall – vertical joint would have avoided the crack
View of the additional parking space gained at the top of the hill
a. sectional view of apparatus

loading frame

hydraulic jack to apply vertical load on bricks

blocks

load cell

jack to pull geogrid

to pull geogrid

giogrid
b. plan view
Laboratory testing of connection strength between blocks and geocomposite
### Table 1. Typical data from connection tests

<table>
<thead>
<tr>
<th>Normal load (kN/m)</th>
<th>Approx. wall height (m)</th>
<th>Load at 20 mm displacement (kN/m)</th>
<th>Peak load (kN/m)</th>
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</thead>
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<td>10</td>
<td>1.90</td>
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<td>20.7</td>
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<tr>
<td>50</td>
<td>9.35</td>
<td>23.4</td>
<td>28.8</td>
</tr>
</tbody>
</table>

Data from connection tests on PEC 75 textile
Rock fall protection works
Rockfall protection works
Conclusions

- Reinforced soil wall technology is widely used in India.
- Applications include approach roads, bridge abutments, coastal erosion protection, etc.
- Even small companies in India are able to take up these works.
- RE Wall at Vijayawada has saved considerable time and money.
- Created large usable space for traffic and parking at hill top.