Geosynthetic Reinforced Soil Structures

By

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Historical Perspective
Evolution Of Soil Reinforcement

Ribbed Steel Strip – The First Engineered Soil Reinforcement
Welded Steel Ladders

Extruded HDPE Geogrid
Uniaxial Woven Geogrid

Knitted Geogrid
Polymeric Straps

Concept of Soil Reinforcement

Courtesy of Strata Geosystems
Reinforced Soil Design

Components of an Reinforced Soil Wall

- Finished Grade
- Retained Backfill
- Original Ground
- Limits of Excavation
- Drainage
- Facing
- Leveling Pad
- Reinforcements
- Foundation Soil
- Mechancially Stabilized Earth Mass
External Stability Modes

External Stability Modes
External Stability Modes

Internal Stability Modes
Pullout of the Reinforcement
Internal Stability Modes

Overstressing in the Reinforcement

Global Mode Of Failure
Geogrid – Properties & Testing

Allowable Design Strength

- Purpose - Define material properties and reduction factors for determination of allowable design strength, $T_a$:

$$T_a = \frac{T_{ult}}{RFCR \times RFDUR \times RFID \times FSUNC}$$

- Reference
  - Reinforced Soil Slopes – FHWA
  - Segmental Retaining Walls – NCMA
Required Geogrid Testing

Tensile Strength
Long-term Creep
Chemical & Biological Durability
Installation Damage

Pullout Resistance in Soil
SRW Facing Connection

Wide width Tensile Strength

Wide-Width Tensile Tests - ASTM D4595
Creep Factor

![Creep Factor Diagram](image1)

Figure No. 1: Sketch of Testing Apparatus

Reduction Factor for Installation Damage, RFID

![RFID Installation Images](image2)
Pullout Resistance in Soil
Soil Interaction Coefficient $C_i$

Connection Properties (Panel)
Connection Properties (Panel)
Geogrid Soil Retention Systems

**Segmental Block Wall** – Segmental Block faced reinforced soil wall is a composite system consisting of Block units in combination with a mass of reinforced soil stabilised by horizontal layers of Geogrid.

**Panel Faced Wall** – Panel faced wall is a reinforced concrete panel faced reinforced soil wall system of T and square shape.

**Mesh Faced Walls** – This is an environment-friendly stone facedn-faced solution, Can be of both gabion faced as well as with welded steel mesh facing.

**Stabilised Slopes** – This is an environment-friendly green-faced solution, can substantially increase the usable land for change-of-grade applications. They are further divided into stiff faced slopes from 45 to 70° and soft faced slopes less than 45°.
Schematic representation of Panel faced Reinforced Soil Wall

Panel Faced Reinforced Soil Walls
Moradabad Bareilly Expressway

Fly-ash can also be used as a reinforced backfill
ROB at Khaperkheda TPS
Fly Ash spread on the approach

Aerial view of approach
Geogrid soil reinforcement spread and pinned

Geogrid connection to panel
Heavy rolling of Fly Ash Fill

Light rolling at edges and corners
Geogrid awaiting backfill placement

Completed and capped structure
Block faced reinforced soil wall
Block Faced Walls, NH-8 Gujarat

Between Mumbai & Ahmedabad
Gabion Face Geogrid Reinforced Walls
The direction along which Geogrid has to be laid for reinforcement

Shillong Bypass Project, NHAI- Meghalaya
Gabion faced walls at Lodha Splendora, Thane
85 degree Steel Mesh Faced Wall
Steel Mesh Faced Reinforced Soil Slope – up to 70°
Soft Faced Reinforced Soil Slope

Primary Reinforcement

Intermediate Reinforcement

Slope Face (surface vegetation required)

12”-18” Typical

< 45 degrees

6 ft Maximum

4 feet

Soft Faced Reinforced Soil Slope

Geogrid Reinforced Slope
Shillong Bypass Project, NHAI- Meghalaya
Composite Structure With

A. Gabion Base and Reinforced Soil slope with Reinforced Soil Wall / Slope on the top

B. Stabilised rear cut face with Soil Nails with a Reinforced Soil front facing
Shored Reinforced Soil Walls

Figure 1. Diagram: Generic cross section of an SMSE wall system.
Composite Structure With A Gabion Base

Wadi-Umti Recharge Dam
Sultanate of Oman
UP STREAM SIDE BACKFILL

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<th>Sieve Size</th>
<th>Percent Passing</th>
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<td>0.075 mm</td>
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Note: Finer Content (No. 200 Passing) = 0% in Reinforced Backfill Soil under Submerged Conditions.
Biaxial Geogrid
Roads on Weak Soils

Penetration of coarser sub base course particles into weak subgrade on loading
Application of Biaxial geogrid

Granular material compacted over biaxial geogrids partially penetrates and projects through the apertures creating a strong and positive interlocking.
More effective load distribution enables heavier loading.
Embarkment over Soft clay usage of Biaxial Geogrid or High Strength Woven Geotextile

IRC-113-2013-Geosynthetic Reinforced Embankment on Soft Soils

Glass Fibre Geo-composite
Asphaltic Reinforcement

**Glass fiber geogrid composite is a high-strength, low strain composite of glass fibre reinforcement and a non-woven geotextile**

- Asphalt layer (overlay)
- Glass fibre geogrid
- Non-woven geotextile
- Underlying asphalt pavement

Laying of Asphaltic Reinforcement
Repairs & Rehabilitation Of Reinforced Soil Structures

Project in Gujarat

- Height of RSW was ranging from 2.0 m to 9.0 m
- Soil investigation was carried out to assess the bearing capacity of foundation soil
- Results of SPT test result showed abrupt variation from 7 to 21 indicating erratic ground condition
- Uncontrolled filled soil was encountered with depth varying from 1.5m to 3.5m
Ground Improvement

- Replacement of top layer of uncontrolled fill with well-compacted granular soil was decided.
- Wall with height up to 5.0 m was built on natural ground without any treatment after providing required embedment.
- For wall with higher height, geotextile reinforced well compacted granular soil was used.

Proposed ground improvement for wall with height ranging from 5.0m to 7.0m
Proposed ground improvement for wall with height ranging from 7.0m to 9.0m

Effect Of Severe Rains
Effect Of Severe Rains

- A stretch of 20 m of partly built wall of only 7 blocks (1.421 m) subsided with the subsidence at its highest being 550 mm.
- The reinforcing geogrid was 8.3 m long and placed in two layers as per design
- The wall face had opened up and the leveling pad exposed
- It had cracked at many places indicating subsidence
Investigation of failure

- DCPT test were conducted at the site of failure
- DCPT-values less than 4 reflect marginal to poor compaction
- DCPT-values above 6 indicate medium to better compaction

DCPT N value after replacement

DCPT – RESULT CONDUCTED TO CHECK COMPACTION STATE OF REPLACED SOIL
Solution

- DCPT value indicated that proper densification was not achieved.
- With further observation beyond 2.5 m depth, competent soil strata was identified.
- Densification of replaced fill with sand/stone pile was considered and implemented
- Proper densification was verified by DCPT test before installation of RSW

Densification with Stone Piles
DCPT value

All DCPT-value are greater than six showing proper densification.

Structures are performing satisfactorily for Ten years despite the heavy traffic load of NH-8
FINISHED PROJECT

Facing connection failure
Soil nailing at centre of panel

Connecting bolt failure
Connection details

Nailing for re-attaching facing
Bulging of panel joints
No reinforcement on top of wall

Missing top reinforcement
Repairs

Dimensional Tolerances

differential settlement

uneven unit dimension

misalignment or uneven seating

discontinuous reinforcement layer
All defects possible

Details
Improper Backfill

Large boulders
No drainage media

Geogrid exposure & vandalism
Effect of flowing water

Failure due to excess pore pressure buildup
Slide At Toe Of Wall
Global stability failure

Some Other Precautionary Measures
Levelling pad step

Foundation Too High
Direction of geogrid laying

Backfill too low
Reinforcement too low

Thank You