Guide to Reinforced Fill Structure and Slope Design

Introductory Course (Lecture 1)

Geotechnical Engineering Office
Civil Engineering Department
The Government of the Hong Kong Special Administrative Region
Reinforced fill is an established technology dating back to 4/5 BC.

Examples include the Great Wall of China.
First Reinforced Fill Wall in Hong Kong 1981
Historical Development in Hong Kong

- First used in 1981
- Currently over 100 structures built
North West Tsing Yi - 40m Reinforced Fill Wall
Scope

Geoguide 6 is a companion to Geoguide 1 – Guide to Retaining Wall Design (1993)

Presents a recommended standard of good practice for
- design
- construction supervision of new permanent structures

Included are:
- Walls and slopes
- bridge abutments
- segmental block walls

(Does not cover soil nailing, reinforced fill dams, maritime structures or embankments on soft ground)
Classification of Common Earth Retention Systems
(Fig 13, P.145)
Areas of Application

- Transportation
- Housing
- Slope stabilisation and landslide mitigation
- Others (industrial works, river walls)
The Use of Reinforcement Fill in Highway and Railway Application (Fig 2, P.134)
Highway Bridge Abutment

- Bridge Desk
- Approach Embankment
- Bearing
- Facing Panels
- Zone of Reinforced Fill
- Levelling Strip
Retaining Wall and Embankment for Railway
The Use of Reinforced Fill in Housing Development (Fig 3, P.135)
Segmental Block Facing
Other Common Usage
(Fig 5, P.137)
Examples of Reinforced Fill Structures
Reinforced Fill Blast Wall

Zone of Reinforced Fill
Rationale for the Use of Reinforced Fill

- Reinforced fill structures can offer technical and economic advantages over conventional forms of construction
- Savings of 20-50% of initial capital cost are possible
- Particularly suited to sloping terrain
- Largely immune to earthquake
- Compatible with the concept of sustainable development
Examples of Economic and Technical Advantages of Reinforced Fill (Fig 6, P.138)
Tsing Yi North Coastal Road
Cyber Port Development
Ecological Parameters for a 6m High Reinforced Fill Structure and an Equivalent Reinforced Concrete Structure (Fig 7, P.139)
Reinforced Fill Wall

Conventional Concrete Retaining Wall
## Embodied Energy (EE) of Construction Materials

### Definition
Energy used to extract and transport raw materials, refine and manufacture them, package, deliver and install them on site.

<table>
<thead>
<tr>
<th>Conventional RC Retaining Wall</th>
<th>Reinforced Fill Retaining Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (ready mix) = 1.3 GJ/ton</td>
<td>Concrete (precast) = 2.0 GJ/ton</td>
</tr>
<tr>
<td>Steel (virgin) = 32.0 GJ/ton</td>
<td>Steel (galvanised) = 35.0 GJ/ton</td>
</tr>
<tr>
<td>Fill = Nil</td>
<td>Fill = 0.2 GJ/ton</td>
</tr>
<tr>
<td>Formwork = 19.0 GJ/ton</td>
<td></td>
</tr>
</tbody>
</table>
Energy used by RF wall and RC wall

for a 4 m High Wall

for a 12 m High Wall

Construction Materials

- Green: RC Wall
- Pink: RF Wall
Quantity of Concrete used by RF wall and RC wall

- Wall Height (m)
- Tons per m

GEOGUIDE 6
Quantity of Steel used by RF wall and RC wall

Tons per m vs Wall Height (m)

RC Wall
RF Wall
Quantity of Fill used by RF wall and RC wall

Wall Height (m) vs. Tons per m

- RF Wall
- RC Wall
Energy used by RF wall and RC wall

- **Energy per m (GJ/m)**: The energy consumption is plotted against the wall height (m).
- **Wall Height (m)**: The wall height is measured in meters.

### Graph Details:
- **Energy per m (GJ/m)**: The graph shows the increase in energy consumption per meter as the wall height increases.
- **Wall Height (m)**: The horizontal axis represents the wall height in meters.
- **Graph Legend**:
  - **RC Wall**: Represented by a blue line.
  - **RF Wall**: Represented by a yellow line.

The graph illustrates the relationship between wall height and energy consumption for both RC and RF walls, showing a linear increase in energy usage with increasing wall height.
Reinforced Fill Systems

- Elemental
- Full height
- Anchored earth
- Wrap-around
- Segmental blocks (hybrid)
Reinforced Fill Systems: Elemental

(Fig 8, P.140)
Forms of Reinforcement
Reinforced Fill Systems: Full Height

(Fig 9, P.141)
Reinforced Fill Systems: Anchored Earth
(Fig 12, P.144)
Reinforced Fill Systems: Wrap-around

(Fig 10, P.142)
Reinforced Fill Systems: Segmental Blocks

(Fig 11, P.143)
Selection of Systems

- Depends upon
  - Use of the structure or slope
  - Nature and size
  - Life of structure
  - Economy
  - Available fill
  - Aesthetics
Selection of Systems: Elemental

Applications
- Bridge abutments
- Walls
- Construction on slopes
- Industrial structures
- Containment dykes
- Building platforms
Selection of Systems: Elemental

- **Advantages**
  - Proven technology
  - Used with wide range of reinforcement
  - Good aesthetics

- **Limitations**
  - Initial cost of shuttering for new units high
  - Need to test new units
Selection of Systems: Full Height

- Applications
  - Bridge abutments
  - Retaining walls
  - River training works
  - Industrial structures
Selection of Systems: Full Height

**Advantages**
- Rapid construction
- Very robust
- Eliminates failure through the facing
- Good finishes (pretensioned concrete)

**Limitations**
- Limited to 10m height
- Needs propping
- Good compaction required
Selection of Systems: Wrap-around

- Applications
  - Steep slopes
  - Slope repairs
  - Tall embankments
  - Blast walls
  - Rock fall protection
Selection of Systems: Wrap-around

- Advantages
  - Use of indigenous fill
  - Economic
  - Green structures
  - Composite reinforcement/drainage used with fine fill

- Limitations
  - Facing susceptible to fire/vandalism
  - Must protect against UV light
Selection of Systems: Anchored Earth

- Applications
  - Bridge abutments
  - Walls
  - Slope repairs
  - Noise barriers
  - Blast barriers
Selection of Systems: Anchored Earth

- Advantages
  - Improved pullout
  - Use of waste materials (tyres) produces economic structures

- Limitations
  - Not used with wrap-around systems
Selection of Systems: Segmental Block

- Housing
- Low/medium walls
- Bridge abutments
- Superimposed structures
Selection of Systems: Segmental Block

- Advantages
  - Proven technology
  - Rapid construction
  - Minimal construction plant
  - (Used with indigenous fill)
  - Wide range of facings

- Limitations
  - Usually no provision for differential settlement between facing/fill
  - Little adaptability to differential settlement
Proprietary Systems and Products

- Proprietary products/systems often restricted to specific applications
- Some proprietary products only suitable for use with proprietary systems
- Some systems are covered by Patents
Certification of Reinforcing Products

Objectives of Certification

- Ensure safe long-term design strength
- Ensure adequate quality assurance of products
- Eliminate repetitive checking
Certification Procedure

- Manufacturer submits product details to GEO
- Reinforced Fill Advisory Panel (RFAP) assesses the submission
- RFAP submits draft certificate to Endorsement Committee for review and agreement
- Director of Civil Engineering (DCE) signs the certificate
Certification of Reinforcing Products

Types of Reinforcing Products

- Metallic reinforcing products do not require certification
- Reinforcing products, the strength and stress-strain characteristics are temperature and time dependent require certification
(Fig 23, P.155)

Strips/bars

Woven or knitted polyester grid or grid formed by welding/knitting individual strips/bars

Drawn polymer sheet containing holes

Ribbed polyolefin casing

Polyester or polyaramid bands
Viscoelastic Behaviour of Polymer

Load (kN/m) vs. Strain (%) for different Strain Rates.

- Strain Rate (%/min.): 23.23, 11.62, 2.32, 1.16, 0.23, 0.12, 1.05 x 10^{-2}, 2.1 x 10^{-2}, 232 x 10^{-2}, 1.85 x 10^{-4}

△: Rupture
Viscoelastic Behaviour of Polymer

Temperature vs. Load and Strain

- Temp. °C
- Load (kN/m)
- Strain (%)

Rupture indicated by 'V'
Viscoelastic Behaviour of Polymer

Increasing Temperature

(Peak Load)/(Index Value) x 100% vs. Strain Rate (%/min)
Certification of Reinforcing Products

Assessment Details

- Creep and stress rupture
Sustained Load Creep Test
Interpretation of Sustained Load Creep Test

Creep Curves

![Graph showing creep curves for Polyethylene grid at 20°C. The graph plots strain (%) on the y-axis and time (hr) on the x-axis. The load (kN/m) is indicated at various points along the graph, with a breaking load of 80 kN/m.]
Interpretation of Sustained Load Creep Test

Isochronous Curves

Load (kN/m) vs. Strain (%)

- 1hr.
- 10hr.
- 4000hr.
- 8000hr.
- 100hr.
- 1000hr.

\(10^6\) hr. (predicted from extrapolation)
Certification of Reinforcing Products

Assessment Details

- Creep and stress rupture
- Oxidation and hydrolysis
- Installation damage

CED Homepage (www.info.gov.hk/ced) provides details of the certification system and submission requirements
END OF LECTURE 1