Slide Stabilization with a 17-Meter Tall Reinforced Earth Fill: Lessons Learned

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Williamsburg, October 1, 2013
Presentation Content

- Introduction
- Soil Profile and Temporal Support System
- Cause of the Earth Slide
- Rehabilitation Alternatives
- Reinforced Earth Fill Design Considerations
  Fill Properties
- Construction Experiences and Behavior
- Lessons Learned
Introduction
Geotechnical Minute....
Slide Location – Aerial View
Within the City Financial Center

8,000 + VPD

Bldg:
100,000 SF Lot
1M SF Total
19 Stories
4 Bsmts (then 5)
Breaking News…
May 9, 1994

Tension Cracks
Slide Cross Section

-17 meters
Soil Profile and Temporal Support System

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“Detailed” Soil Profile

Collapsed Sector

125 ft

U 1 Medium Gravel, clayey-sandy matrix
U 2 Coarse Gravel, sandy-silty matrix
U 3 Silty-sandy Clay

Caissons

From SCI
Cause of the Earth Slide

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What Was Going On??

The Buzz:
A Water Pipe Broke…
Water Pressure Built Up… and Then… Everything Slid Down..

The Truth:
Earth Moved.. And Then, Water Pipe Broke…
Cause of the Earth Slide

Lateral Earth Pressure Diagrams

Flexible Walls

From SCI

**U 3** Silty-sandy CLAY

**U 1** and **U 2** Granular/Coarse Soils

More Likely Earth Pressure

**1,102 psf**

Assumed Lateral Earth Pressure

Rankine Failure Surface

1,102 psf

940 psf

4,552 psf

2,756 psf

4x !!
Lessons Learned-Lateral Earth Pressure

BIG Lessons Learned:

• CALL Geotech Eng. to Make decisions Involving Soil Issues

• Complete/Additional Geotechnical Exploration

• Do not Assume Soil Profile because Everything is All Right…

• Verify Changes in Soil Conditions
Rehabilitation Alternatives

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Rehabilitation Alternatives

Purposes:

• Fast Track (Traffic Problem – 8,000 VPD)
• Quick Design Turn Around
• Do Not Reduce Bldg Footprint!
• Safe
• Economical
Rehabilitation Alternatives

Excavation footprint taken by 2: 17% or 40.1% of total bldg area
Reinforced Earth Fill Design Considerations – Fill Properties

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Reinforced Earth Fill
Design Considerations

- **Internal Stability**
  - Material Properties (Geotextiles and Fill)
  - Pullout
  - Tensile Overstress
  - Local

- **External Stability**
  - Bearing Capacity
  - Slope Stability (Rigid Block Sliding)
Internal Stability

After G. F. Sowers

Lateral Earth Pressure
Earth Thrust
Tension Force
Equivalent Length
Failure Hypothesis
3D rather than a 2D Failure Mechanism

W Geotextile

NW Geotextile was selected
Material Properties

Earth Fill

**Fill Properties**
- Type: GC
- PI: 16%
- S200: 19%
- UW<sub>dry</sub>: 1.86 Tn/m³ (116 pcf)
- w: 11.1%

**Properties**
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**Geosynthetics**
- Geogrid
- NW Geotextile
- Geomalla

**Graphs**
- Shear Stress vs. Normal Stress
- Tensile Stress vs. Strain
- Working Stress vs. Strain
## Stability Analysis Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>$\gamma$ (kN/m³)</th>
<th>$\phi$ (°)</th>
<th>$C$ (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Fill</td>
<td>21.9</td>
<td>35</td>
<td>0 – 200</td>
</tr>
<tr>
<td>Failure Surface</td>
<td>-</td>
<td>30</td>
<td>0 – 200</td>
</tr>
</tbody>
</table>

**External Stability**

*Nota: Ver figura 9, planta*
External Stability-Load Considerations

1. Initial Stability: Bottom Support; **No Traffic**

2. Intermediate Stability: Bottom Support; **Traffic**

3. Final Stability: Bottom/Top support; **Traffic**

![Graph showing stability conditions]
Construction Experiences and Behavior
Construction Stages

Shotcrete Wall

Stage 1

Stage 2
Reinforced Fill – Clayey Gravel
Compactors

95% Mod. Proctor Thin Lifts
Bottom Corner
Removing Shotcrete
Intermediate Supports

Stage 1
Tallest Face

Geotextile and Geogrid
Tide Work Conditions - Tallest Face
Construction Stages
Few Meters Away From Top
Near To The Top
Instrumentation

**PR** Settlement Plates
**BM** Monuments
Making It Watertight
Works Never Stopped

After 25 Days of Ground Zero
Psychological Support
Lessons Learned-Design & Construction

- Geotechnical involvement must be continuous, from beginning to end
- If things are working, do not assume they will continue to do so: get the facts
- Working along limited spaces requires patience and sharp approach
- Do Not Forget To Drill Those Borings!!
Thank You ! !!

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