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LESSONS LEARNED IN GEOTECHNICAL ENGINEERING

2ND ANNUAL GEO-INSTITUTE CONFERENCE

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

By Jose N. Gomez, PE, MSc
Principal Engineer
ECS Mid-Atlantic, LLC

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

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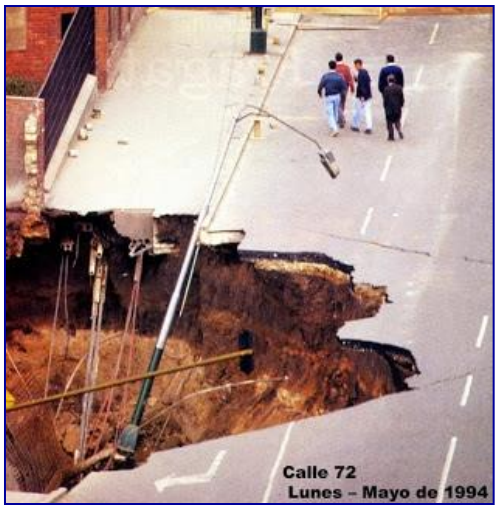
Introduction



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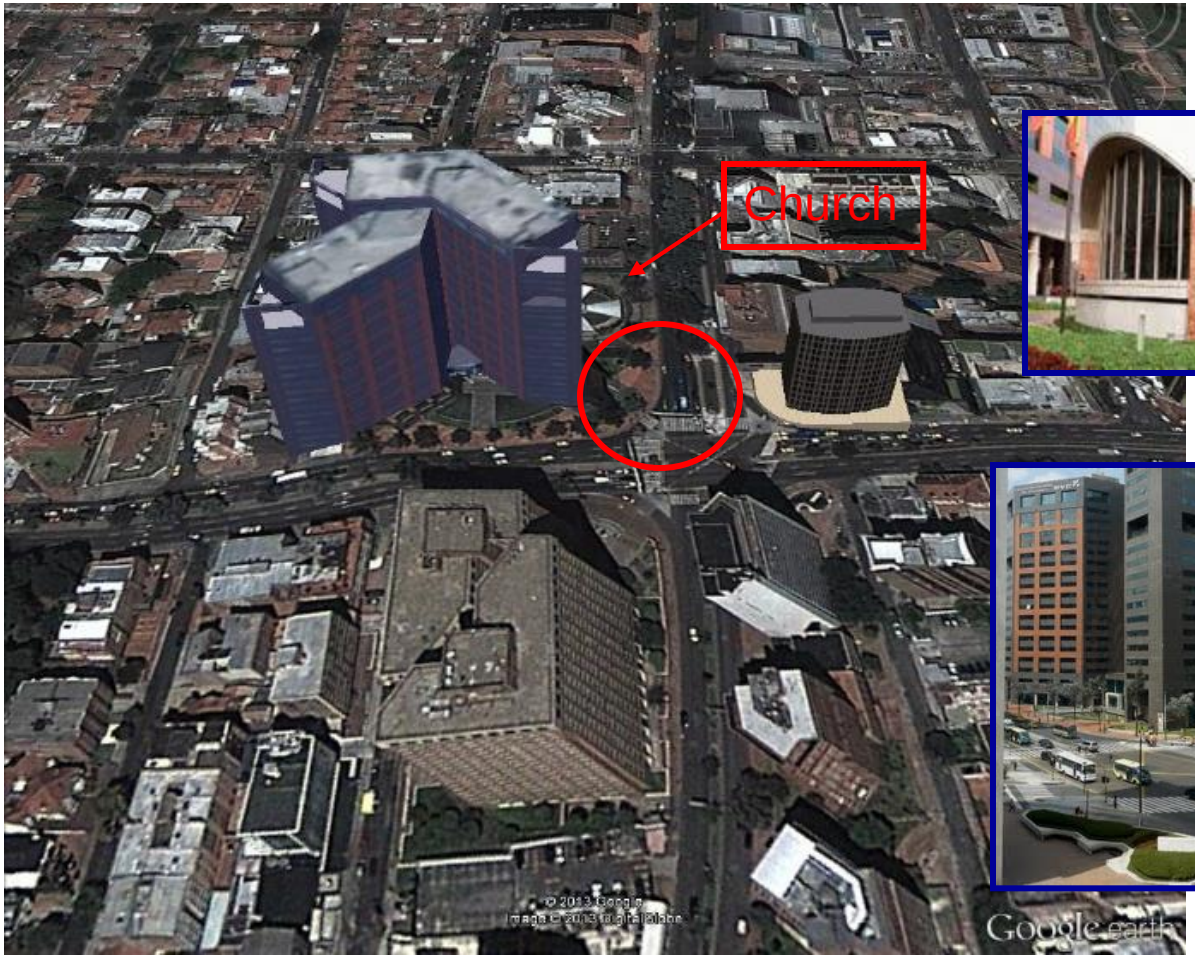
Geotechnical Minute….

Slide Location – Aerial View
Within the City Financial Center

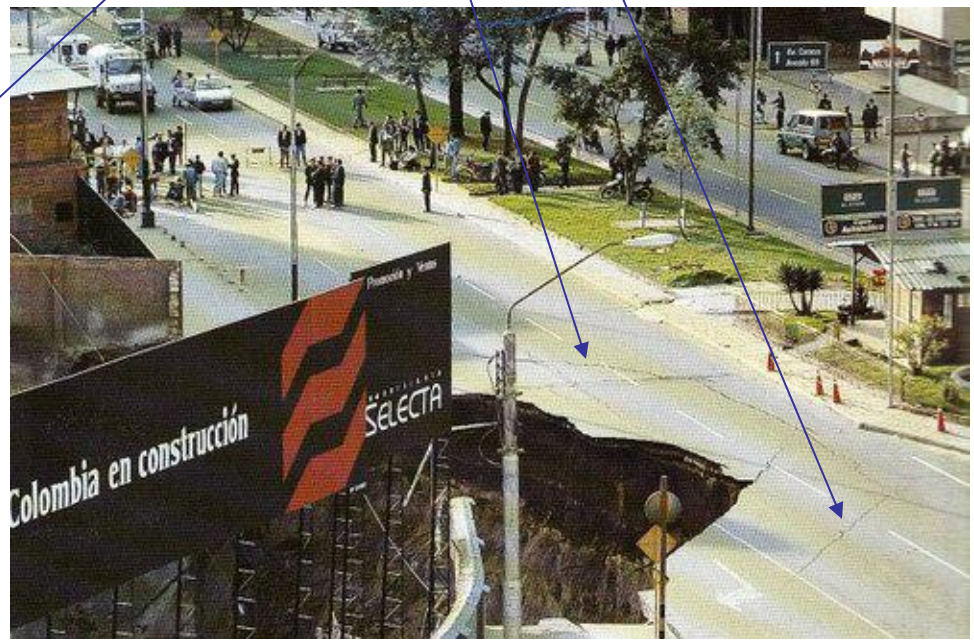


8,000 + VPD

Bldg:
100,000 SF Lot
1M SF Total
19 Stories
4 Bsmts (then 5)

Breaking News…
May 9, 1994

Tension Cracks



Slide Cross Section

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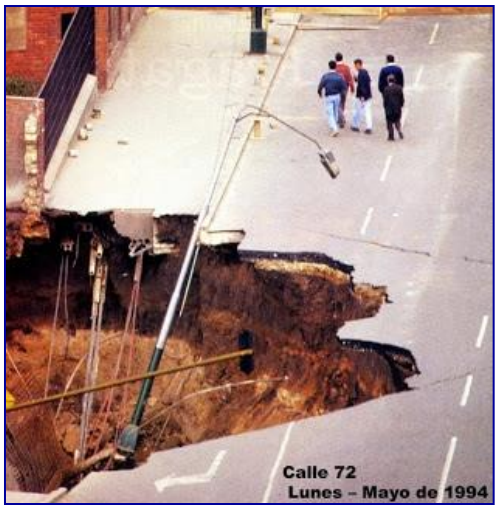
Soil Profile and Temporal Support System



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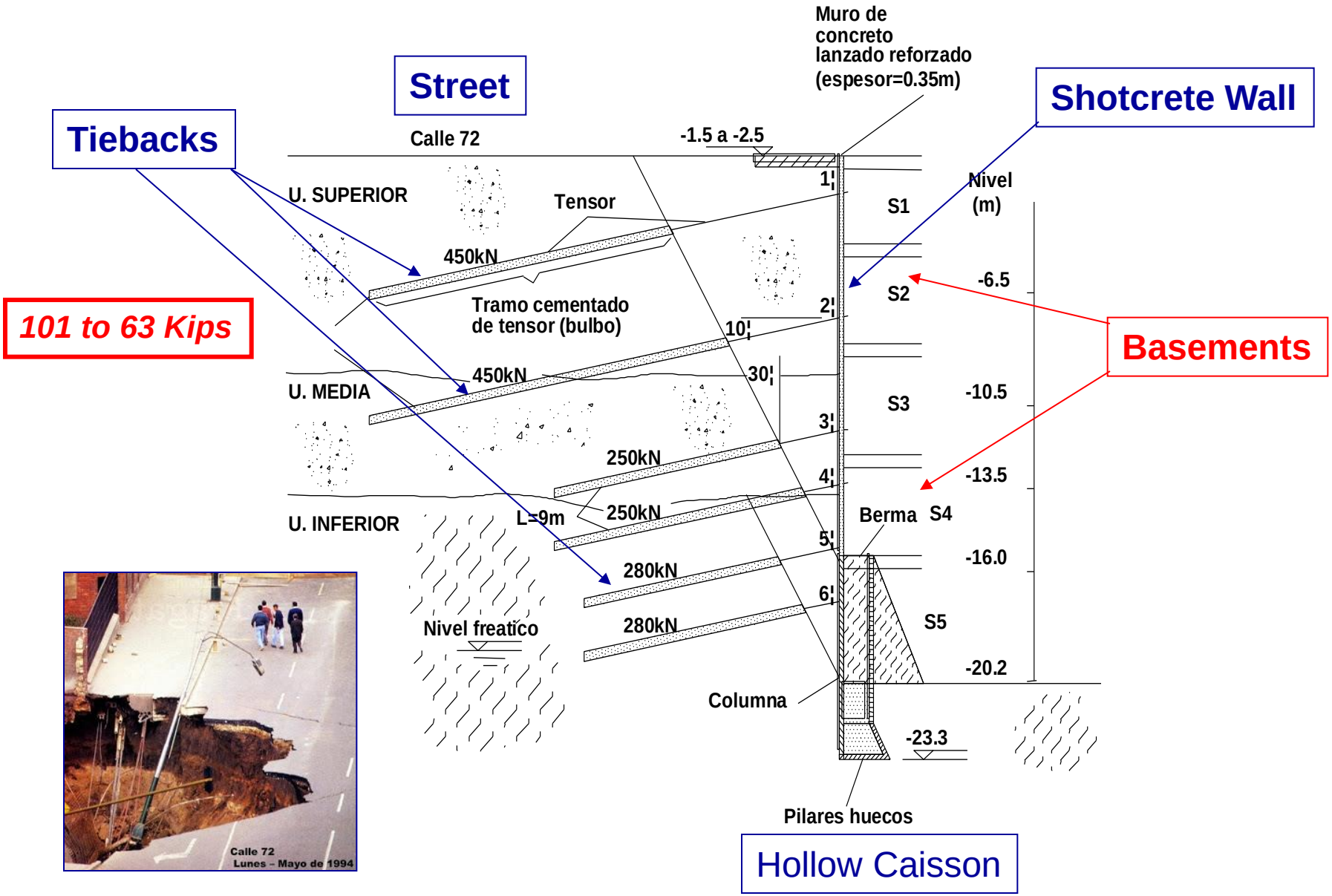
Temporal Support System

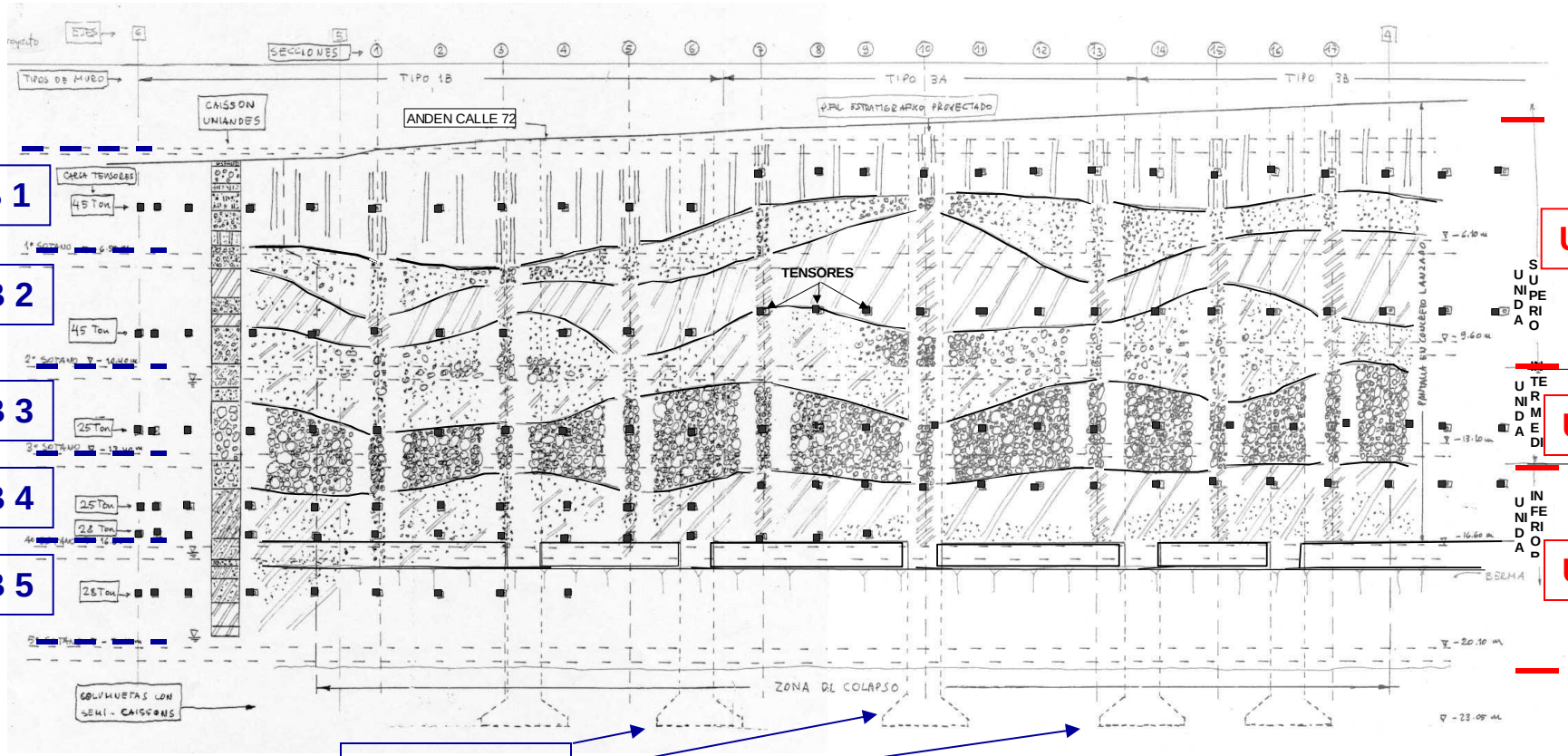


"Detailed" Soil Profile

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

Collapsed Sector

125 ft



From SCI

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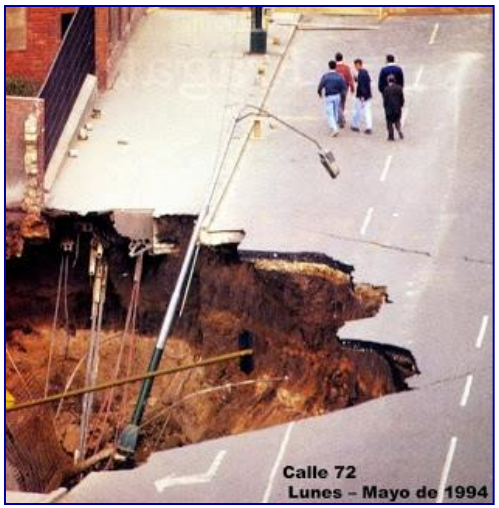
Cause of the Earth Slide



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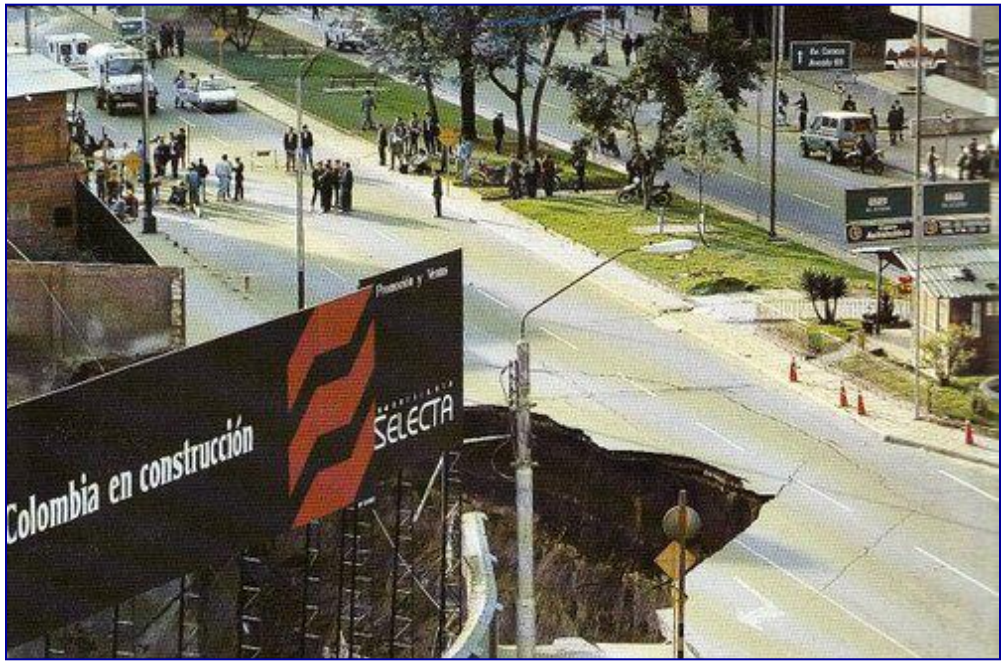
What Was Going On??



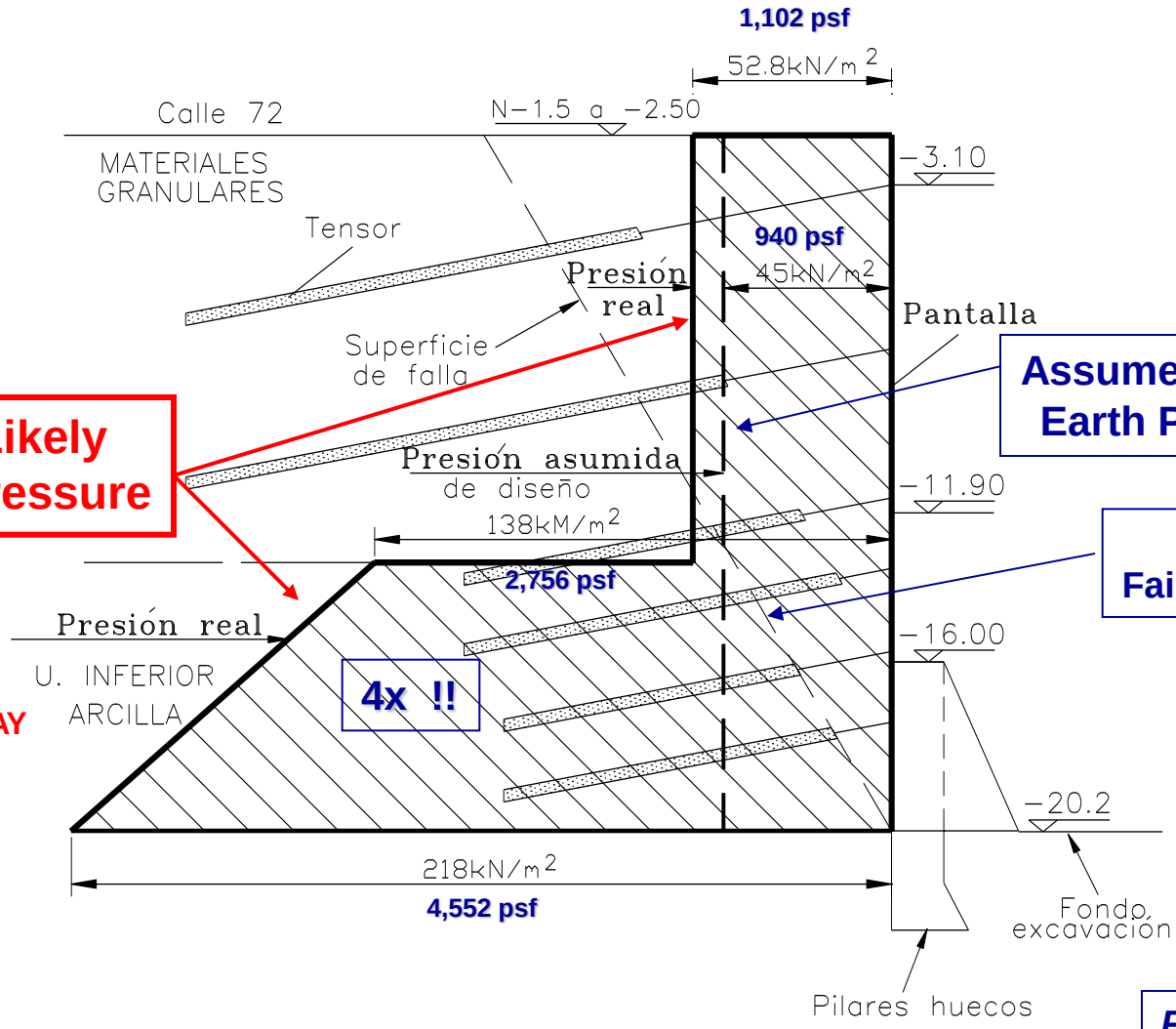
The Buzz:
A Water Pipe Broke…
Water Pressure Built Up… and
Then… Everything Slid Down..

The Truth:
Earth Moved.. And Then,
Water Pipe Broke…

Cause of the Earth Slide

Lateral Earth Pressure Diagrams

Flexible Walls



U 1 and **U 2**

Granular/Coarse Soils

More Likely Earth Pressure

Assumed Lateral Earth Pressure

Rankine Failure Surface

U 3 **Silty-sandy CLAY**

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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

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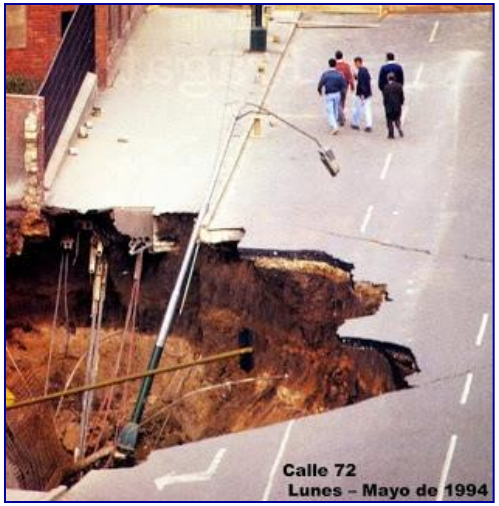
Rehabilitation Alternatives



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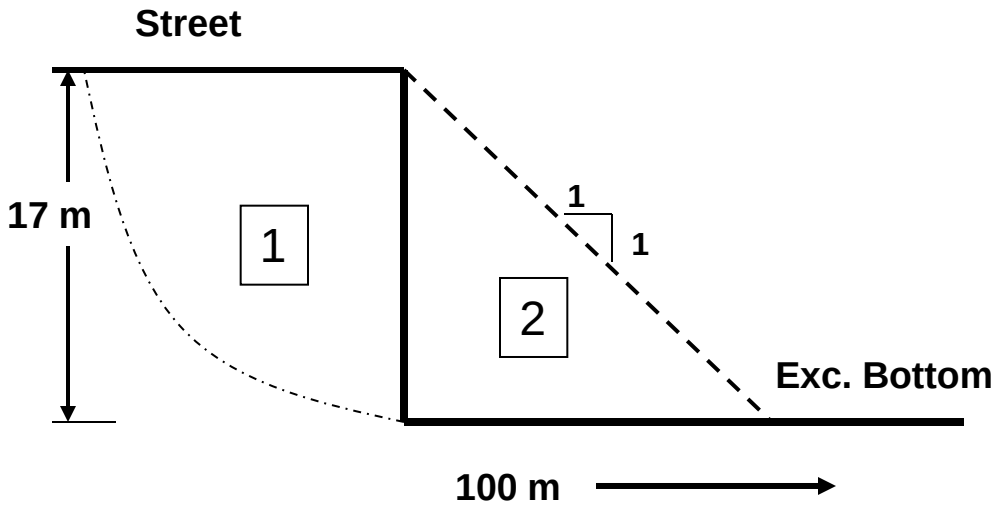
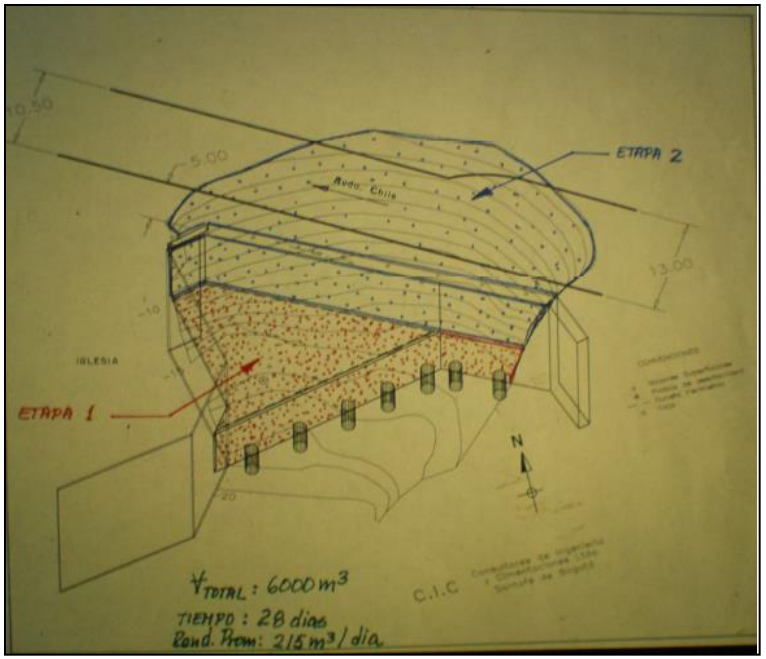
Rehabilitation Alternatives

Purposes:

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

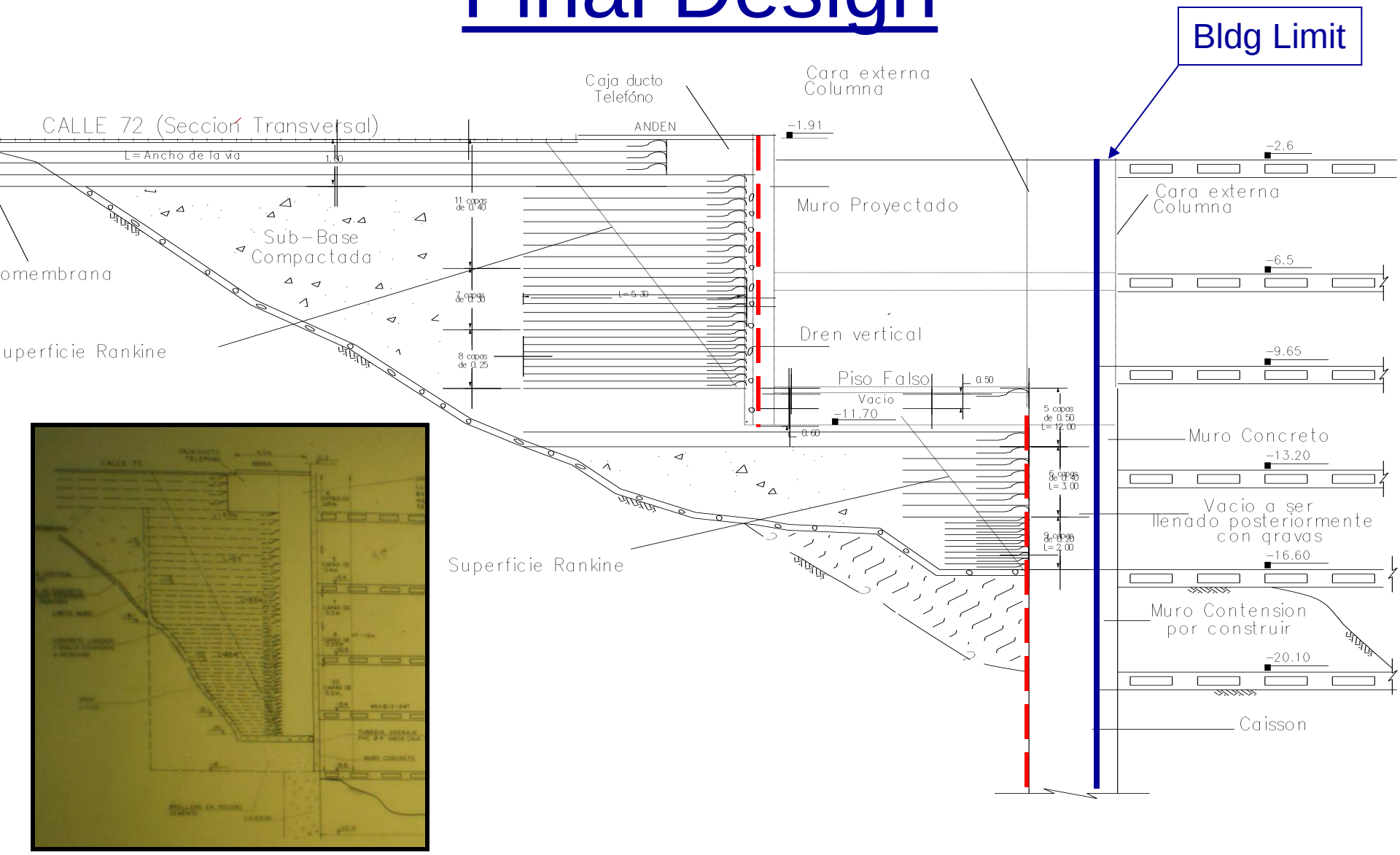
Rehabilitation Alternatives





Excavation footprint taken by 2 : 17% or 40.1% of total bldg area

Final Design



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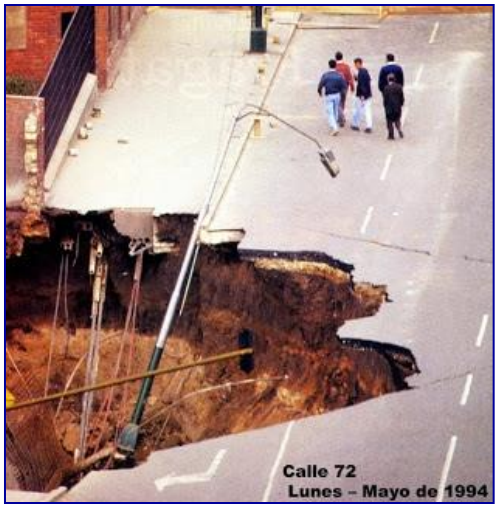
Reinforced Earth Fill Design Considerations – Fill Properties



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Reinforced Earth Fill Design Considerations

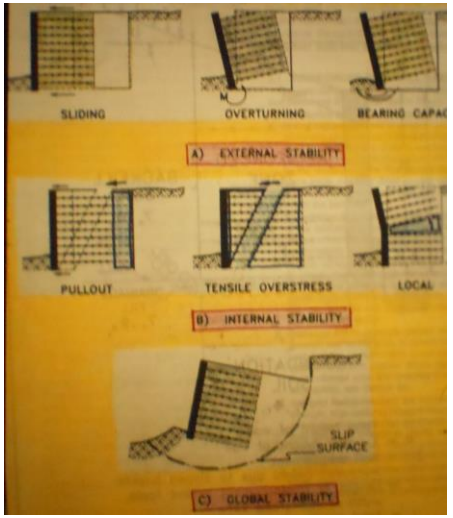
- Internal Stability

  -Material Properties (Geotextiles and Fill)

  -Pullout

  -Tensile Overstress

  -Local

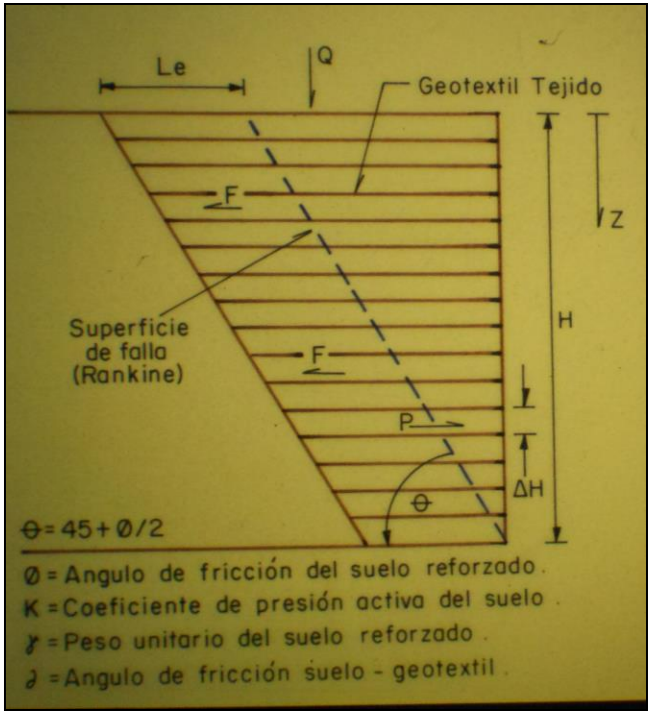


- External Stability

  -Bearing Capacity

  -Slope Stability (Rigid Block Sliding)

Internal Stability



- Presión de la tierra

$p = K \gamma Z$

Lateral Earth Pressure

- Empuje de Tierra

$P = p \times \Delta H$

Earth Thrust

- Fuerza de Tensión (Geotextil)

$F = 2L \gamma Z \tan \partial$

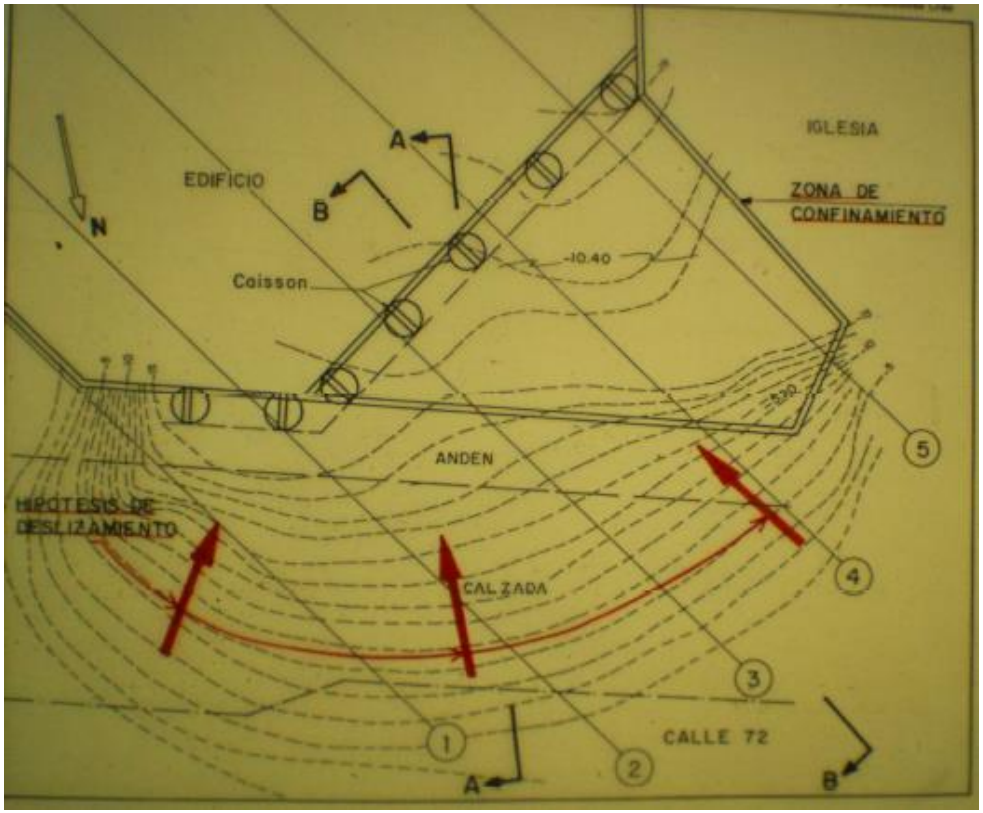
Tension Force

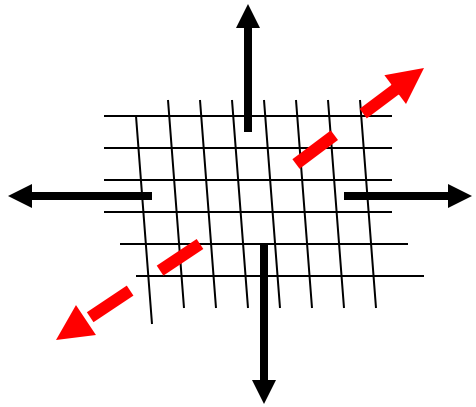
$Le = \frac{K \Delta H (F.S)}{2 \tan \partial}$

Equivalent Length

After G. F. Sowers

Failure Hypothesis
3D rather than a 2D Failure Mechanism



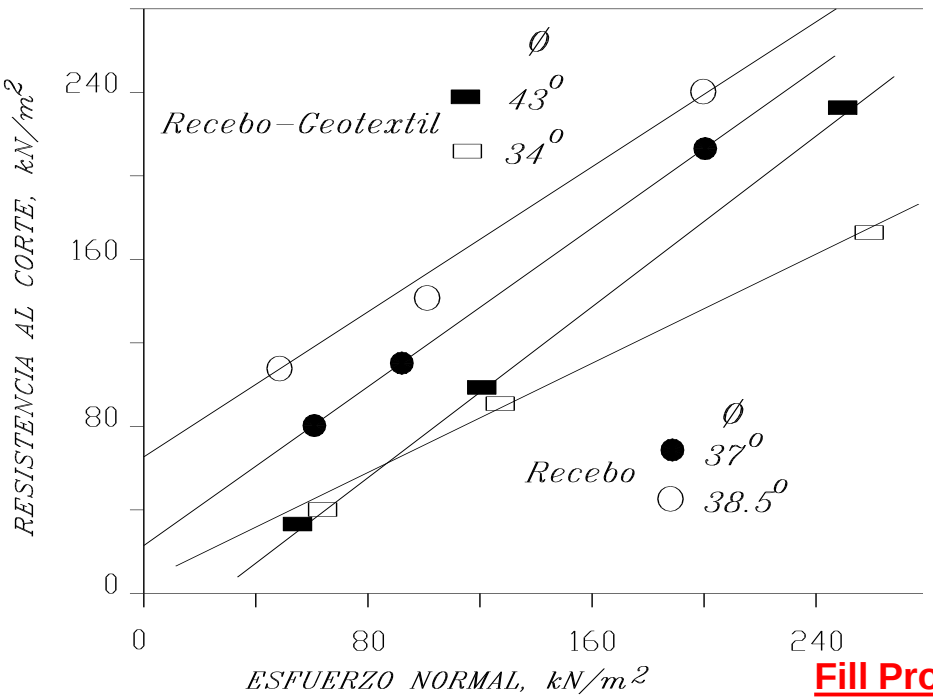


W Geotextile

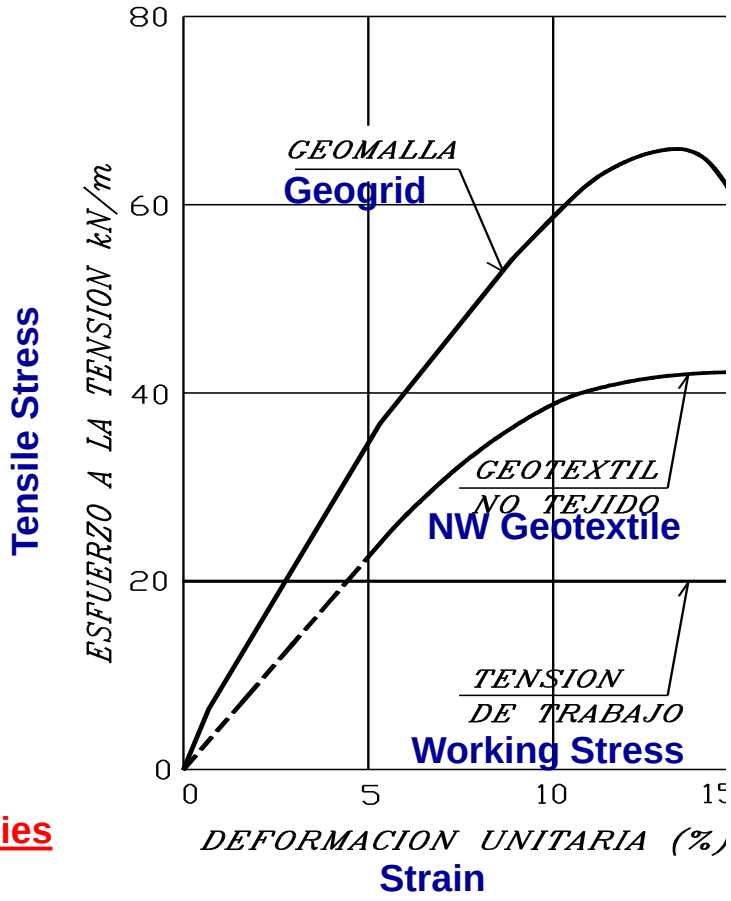
NW Geotextile was selected

Material Properties

Earth Fill



Geosynthetics



Fill Properties

Type : GC

PI : 16%

S200: 19%

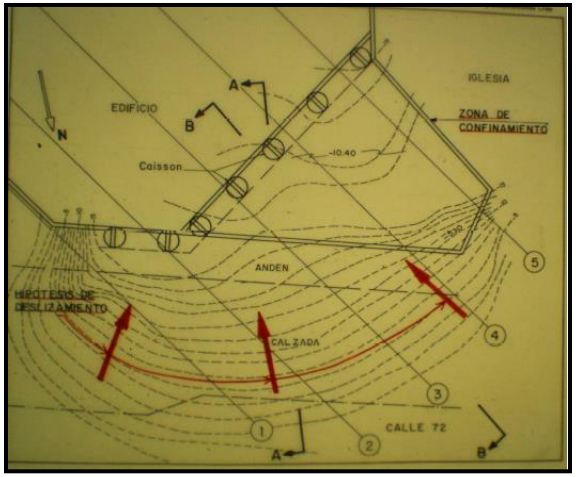
UW_{dry} : 1.86 Tn/m3 (116 pcf)

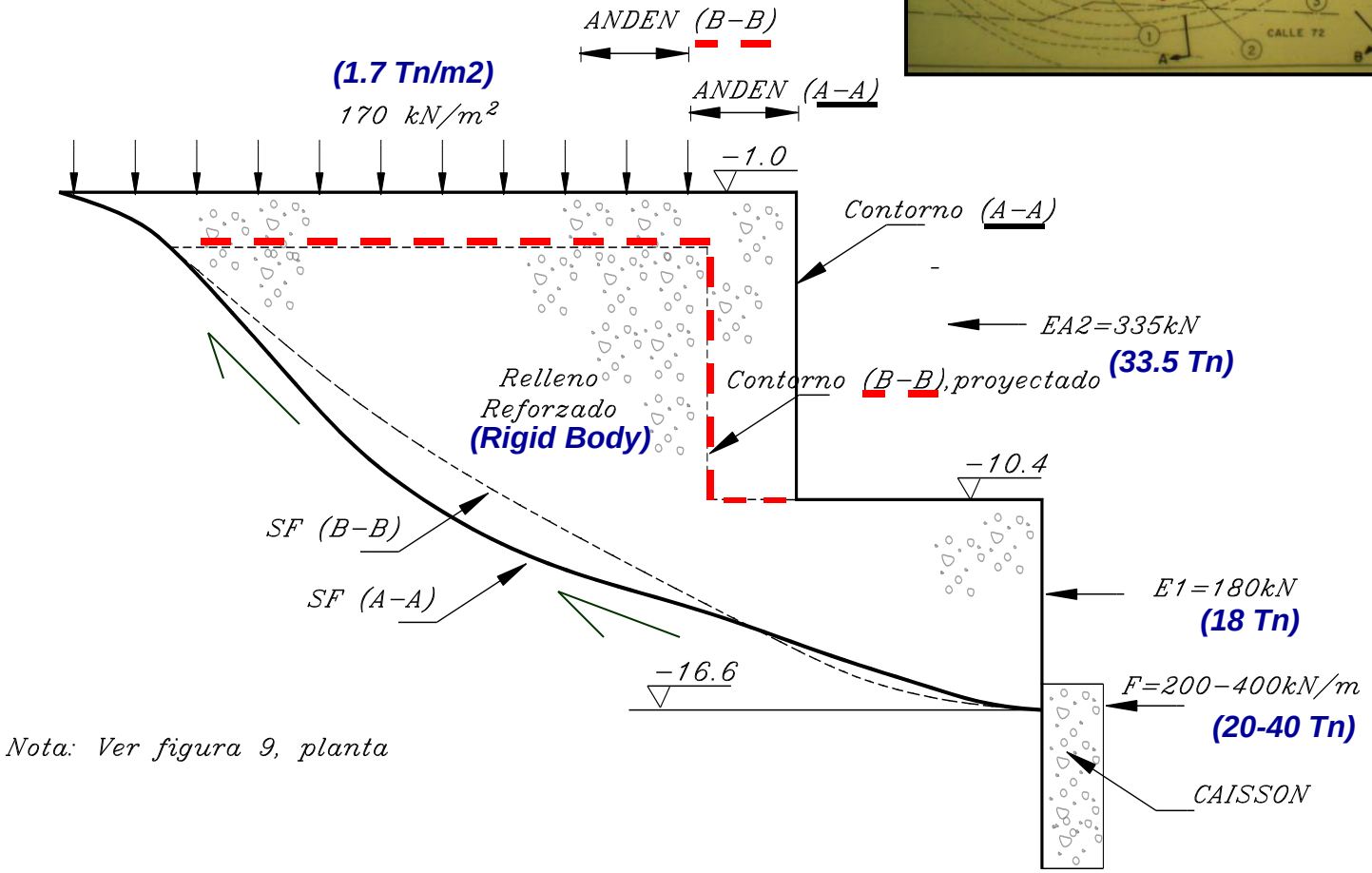
w : 11.1%

External Stability

Stability Analysis Parameters

Material	γ (kN/m³)	ϕ (o)	C (kN/m²)
Reinforced Fill	21.9	35	0 – 200
Failure Surface	-	30	0 – 200



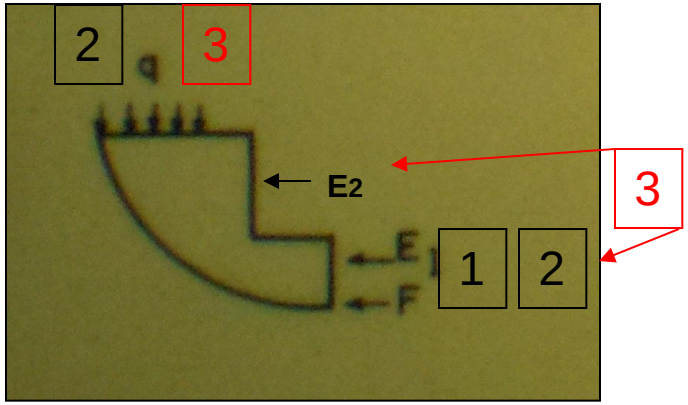


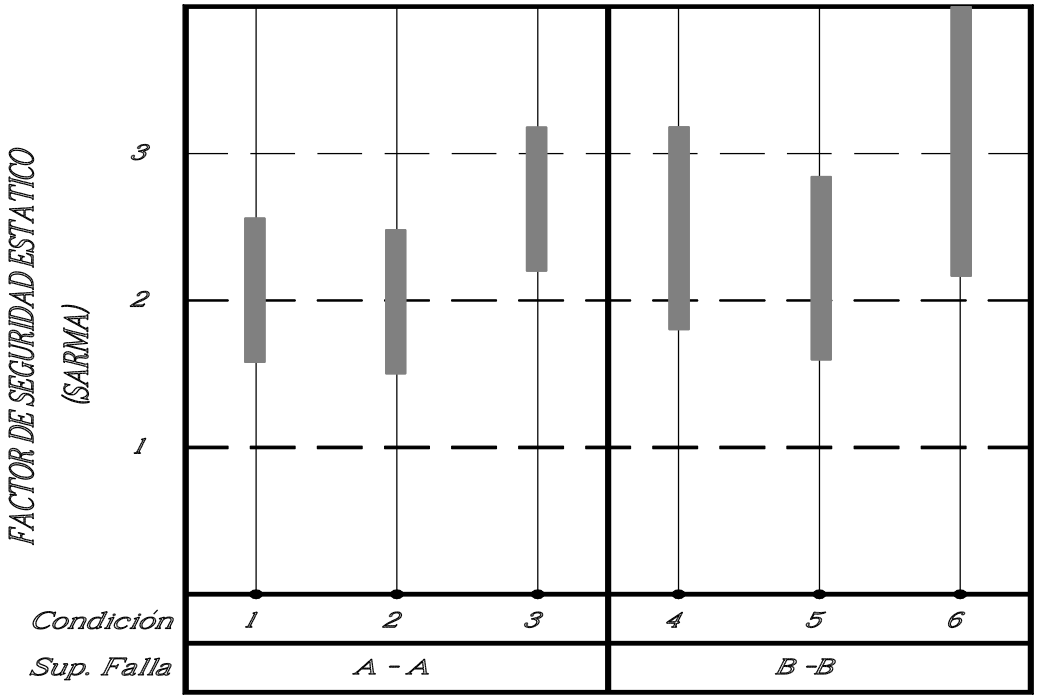
External Stability-Load Considerations

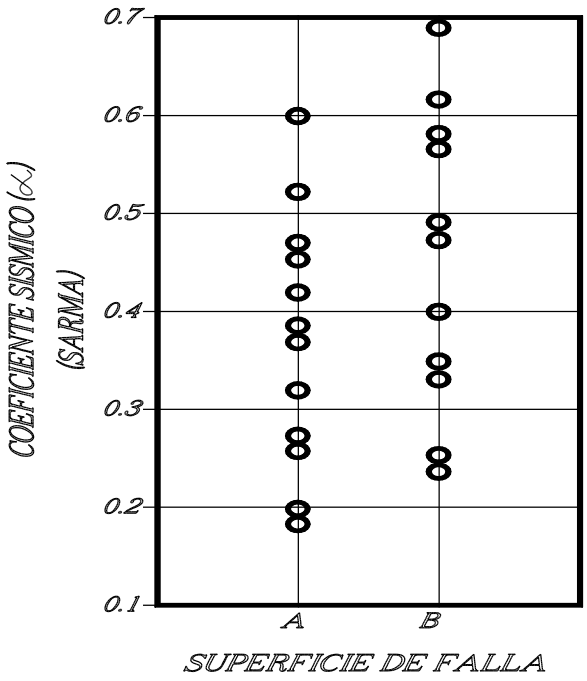
1 **Initial Stability: Bottom Support; No Traffic**

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

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







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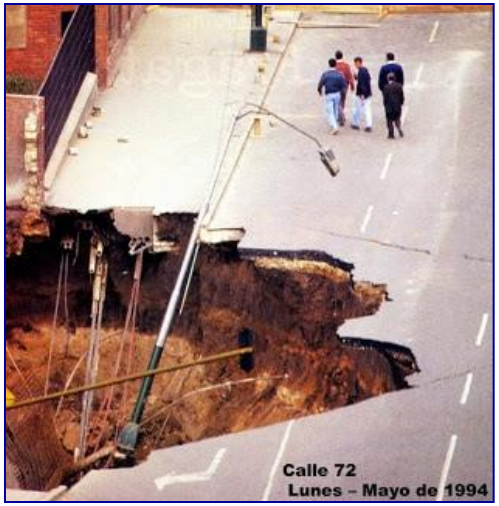
Construction Experiences and Behavior



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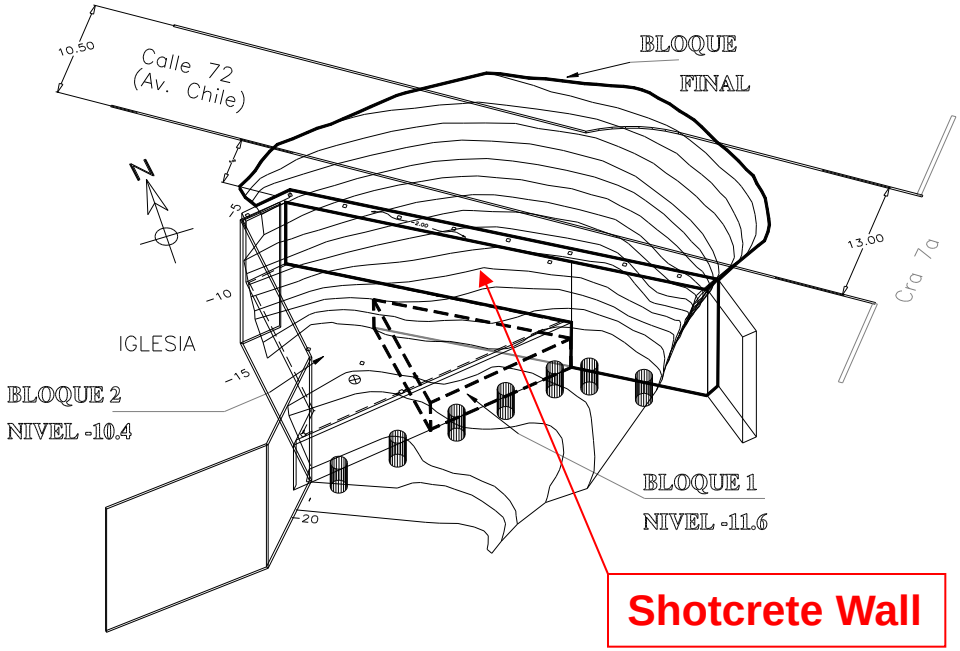
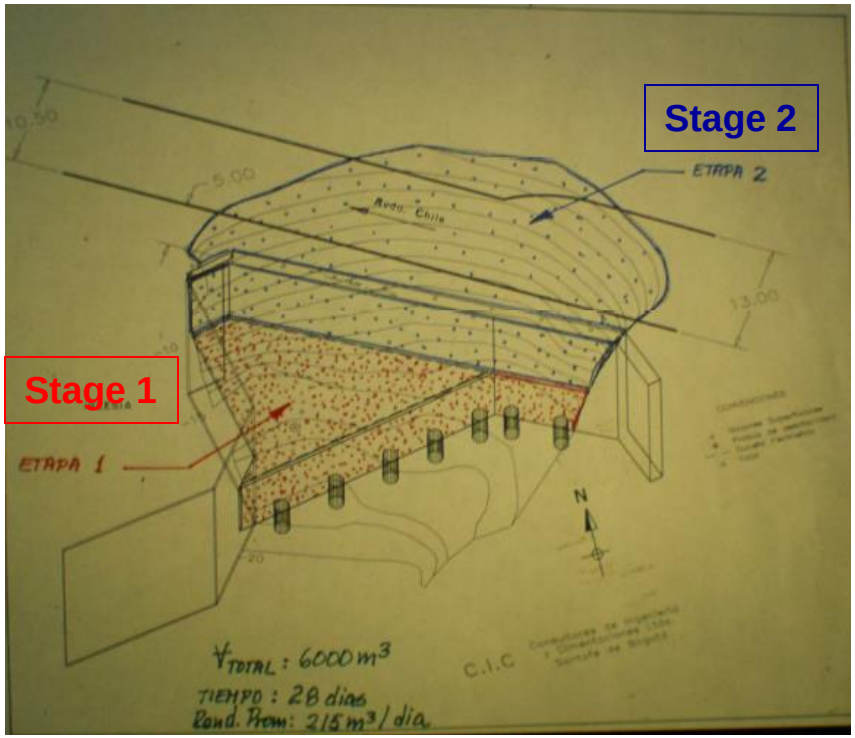
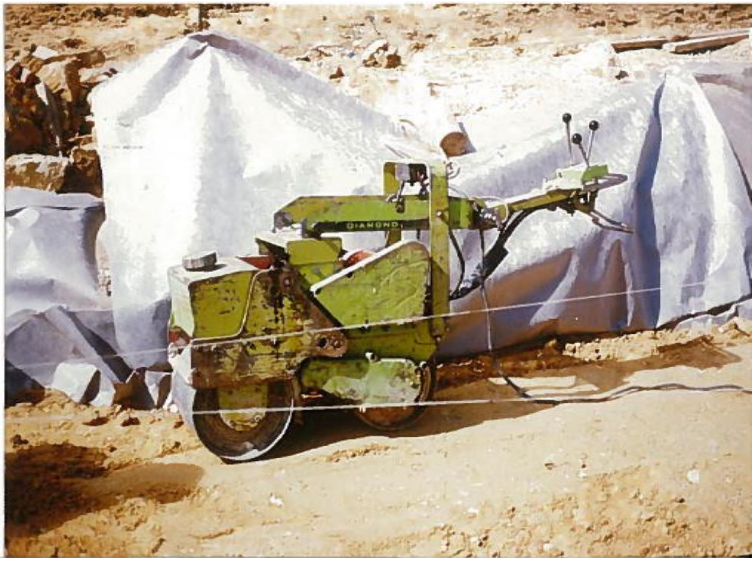
Construction Stages





Reinforced Fill – Clayey Gravel

Compactors

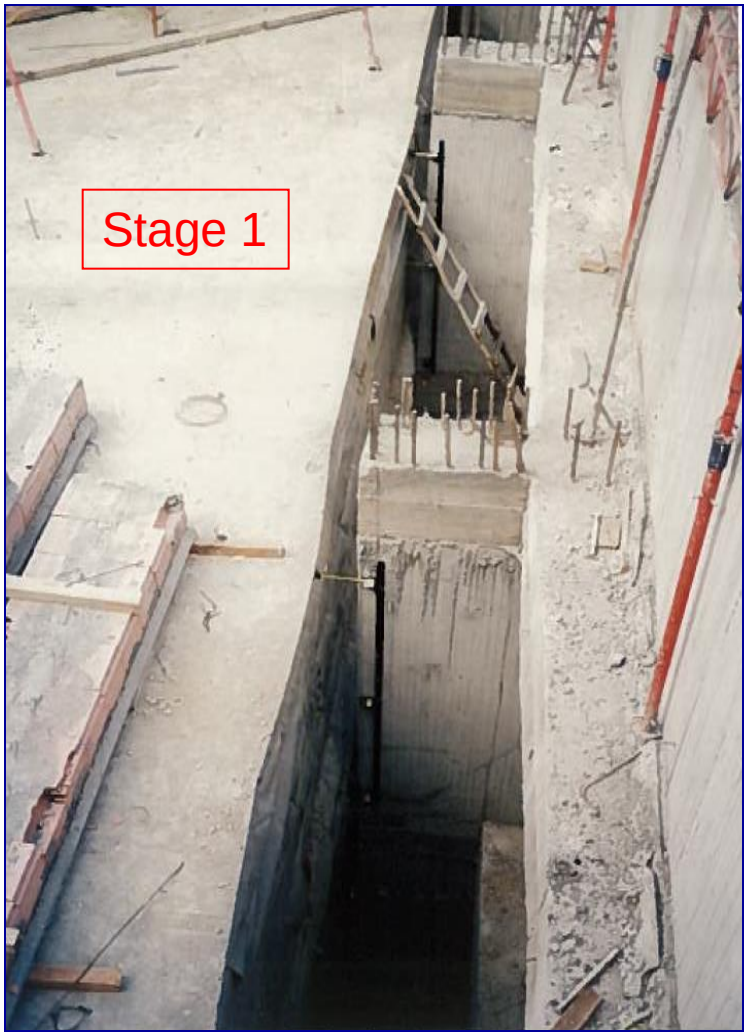


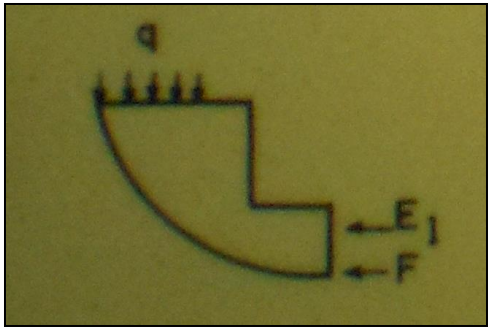
95% Mod. Proctor
Thin Lifts

Bottom Corner

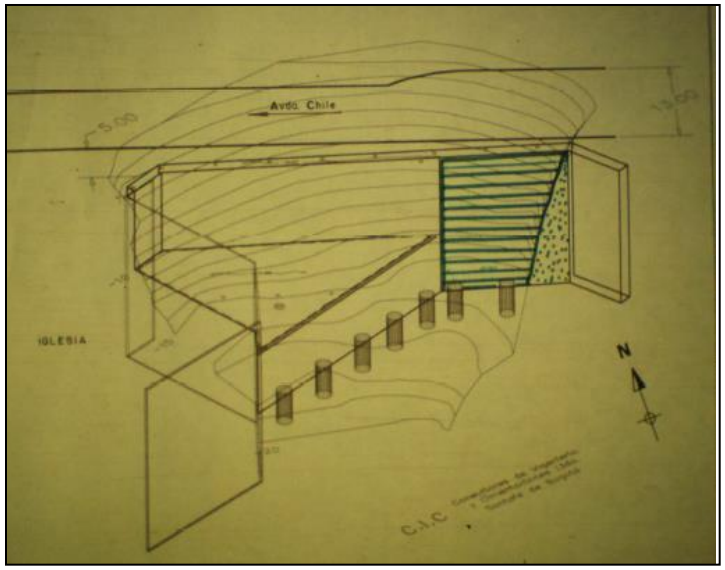
Removing Shotcrete

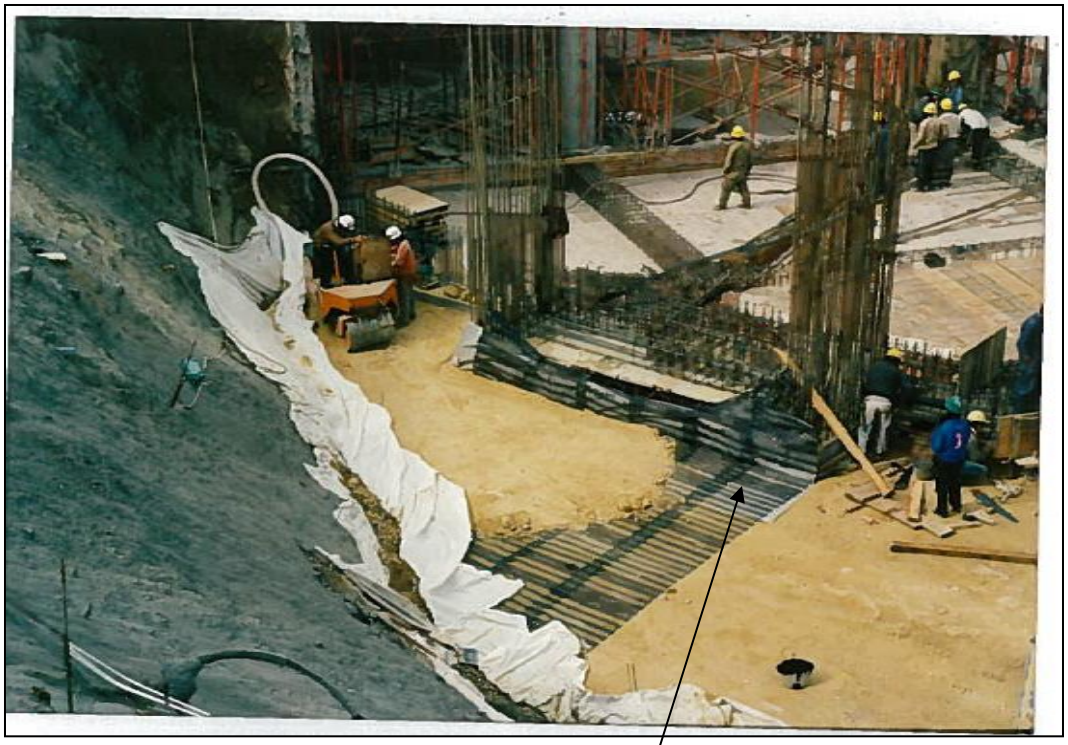
Intermediate Supports





Tallest Face

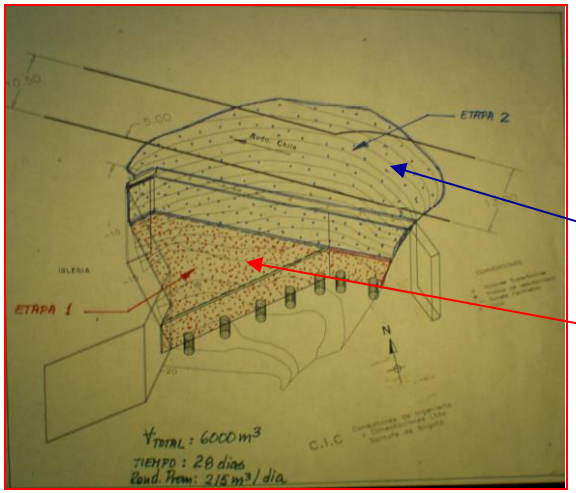


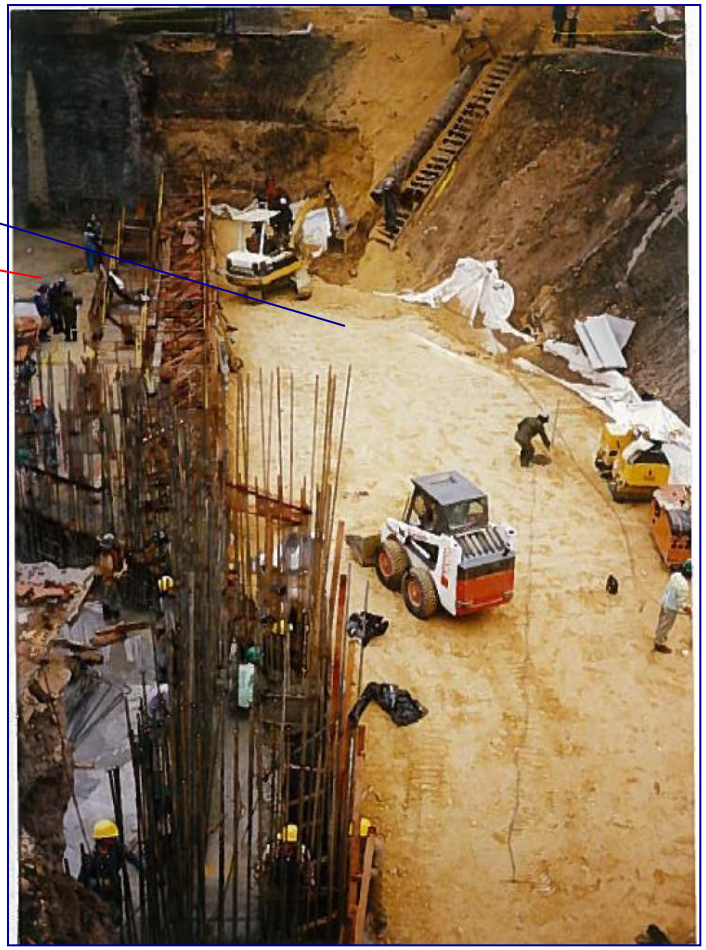


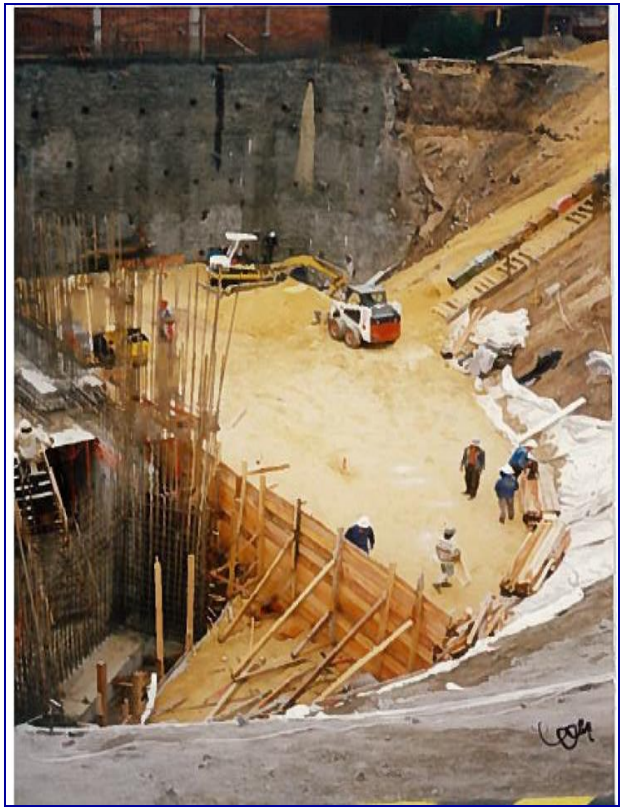
Geotextile and Geogrid

Tide Work Conditions-Tallest Face

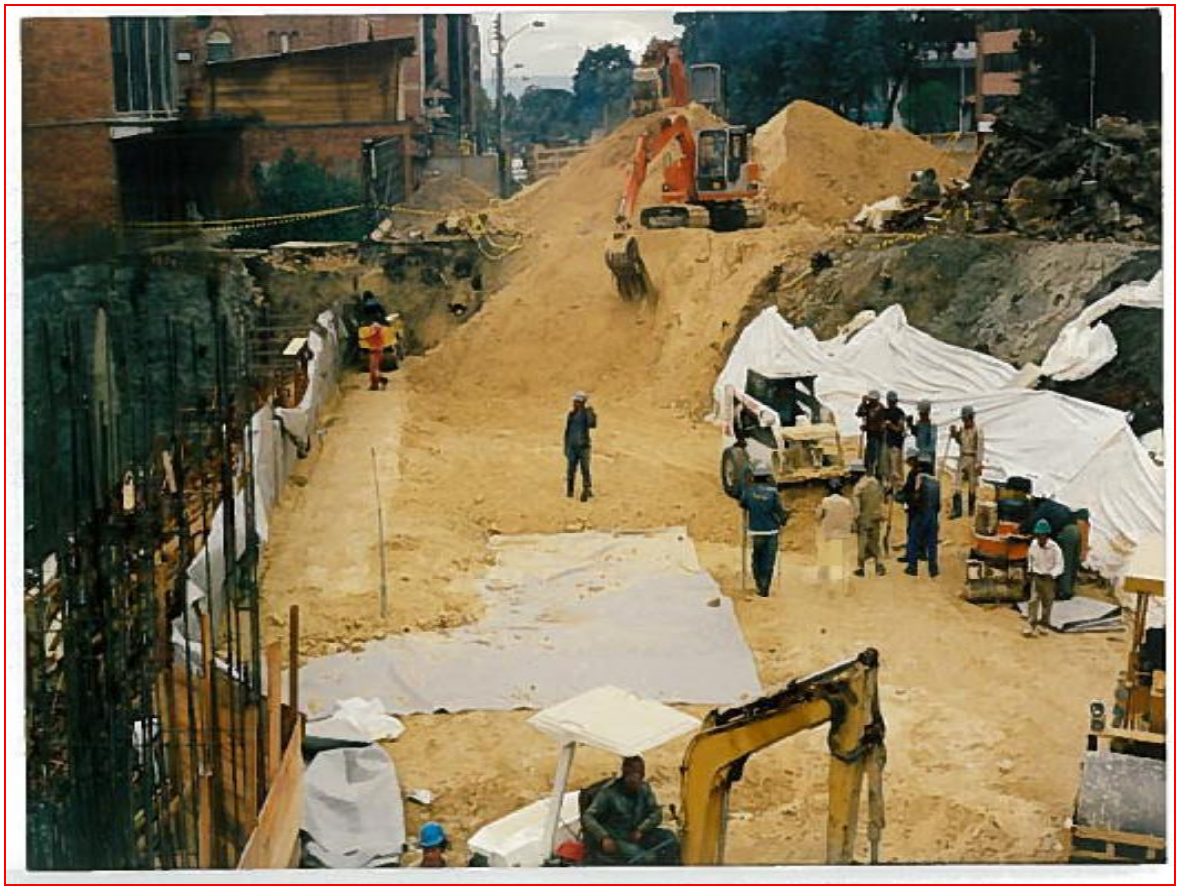
Construction Stages





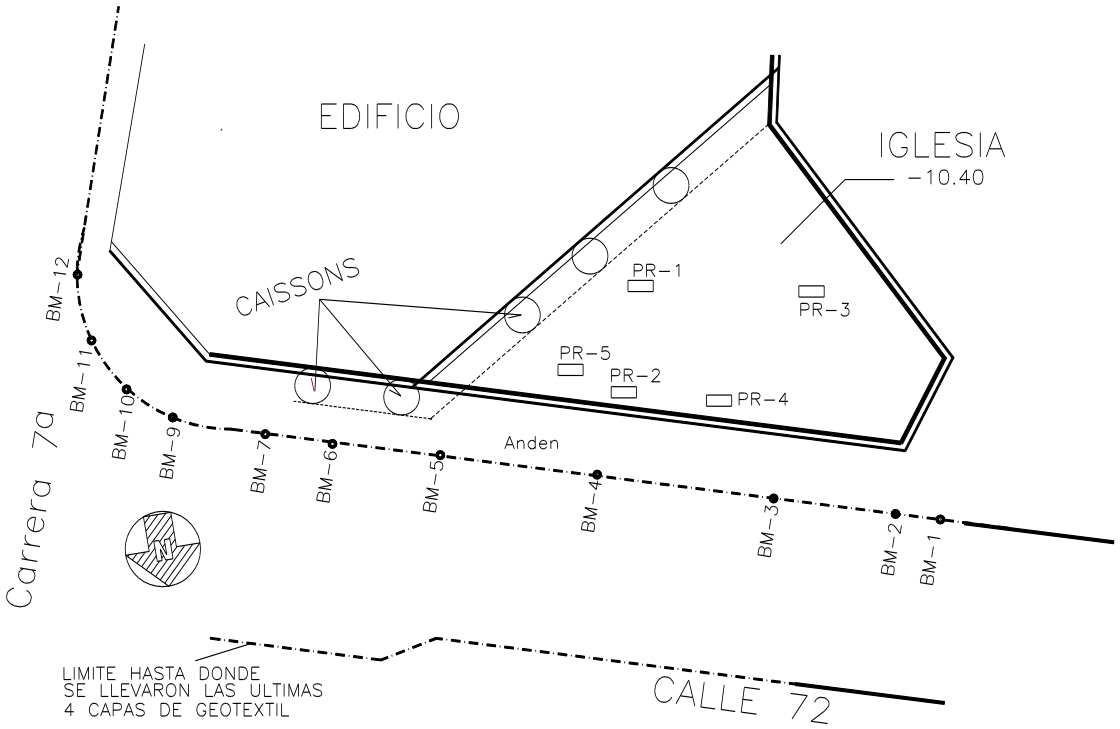


Few Meters Away From Top



Near To The Top

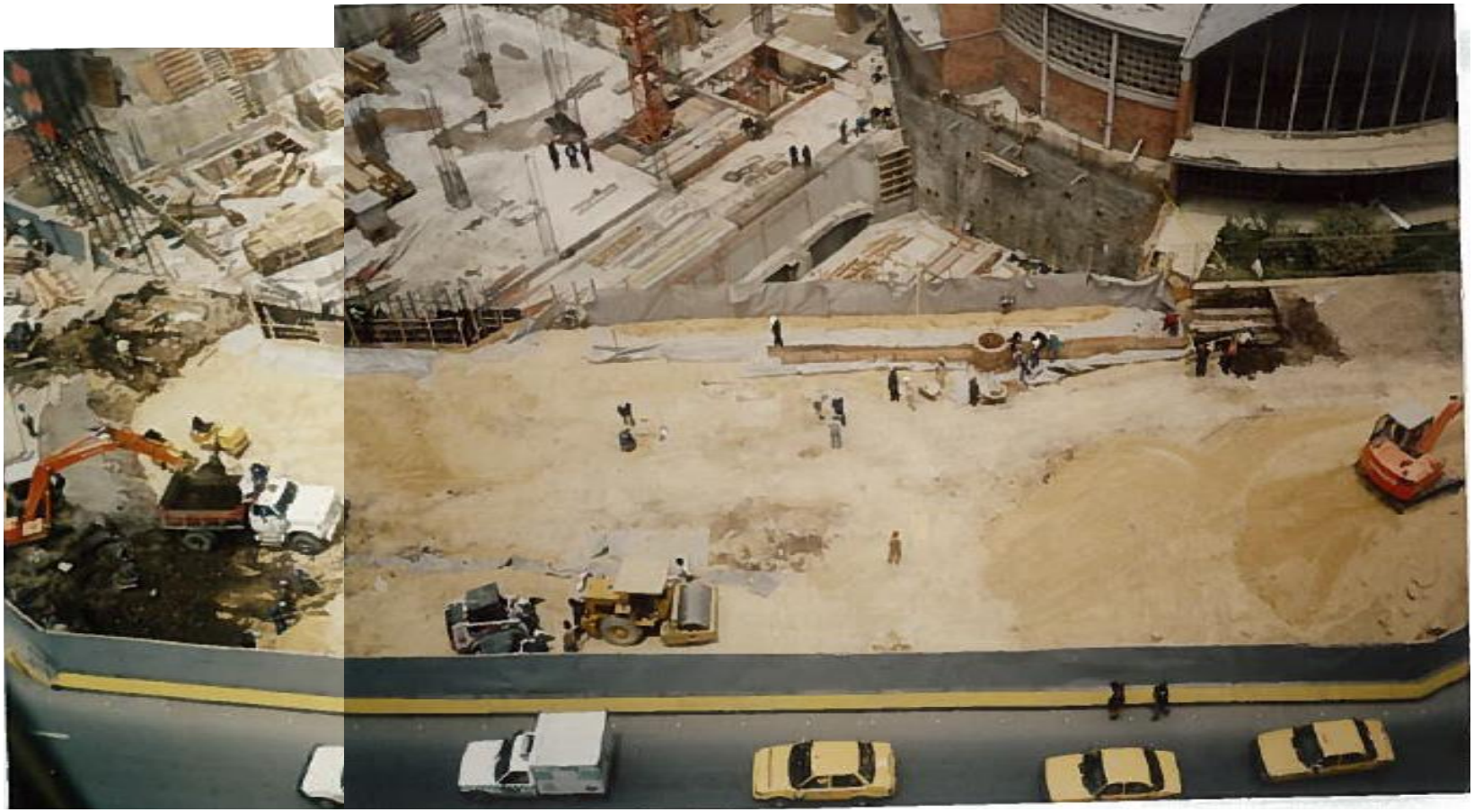
Instrumentation



PR Settlement Plates
BM Monuments

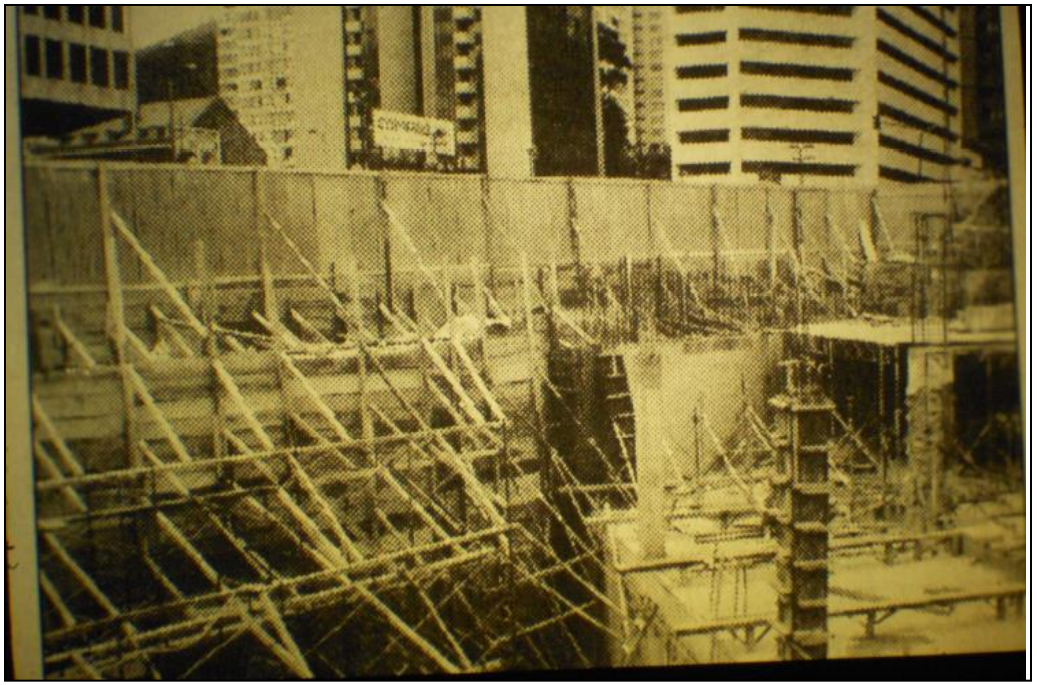
Making It Watertight

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!!

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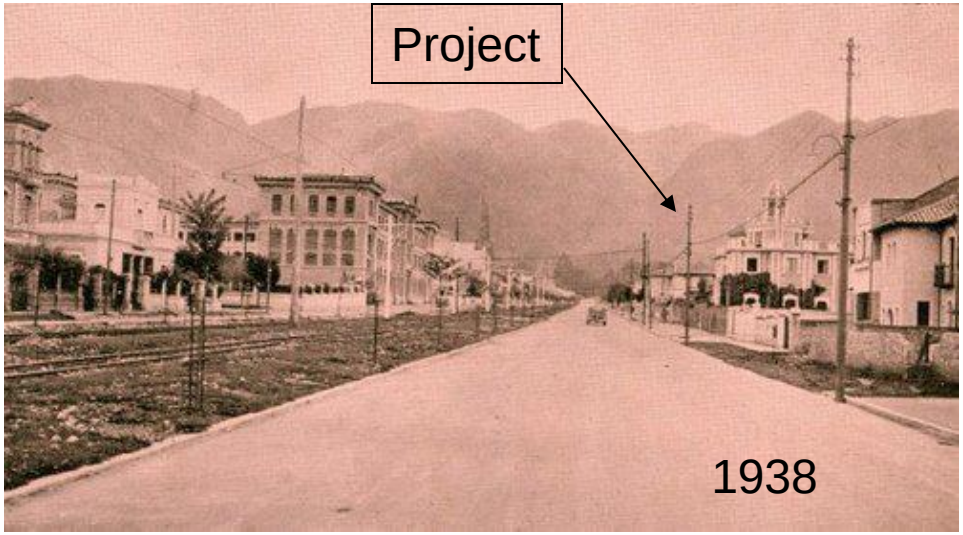
Thank You ! !!



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