# Alamo Cenotaph

## Investigation & Restoration


**Texas Historical Commission Update**
SAL Permit #HS 1120

July 26, 2024

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ALAMO TRUST INC.

Project: Alamo Cenotaph
Location: San Antonio, TX
Phase: Investigation & Restoration
Date: July 26, 2024

# Agenda

- Previous Investigation Summary
- Additional Investigation Results
- Restoration Recommendations
- Cleaning and Restoration Mockups
- Schedule

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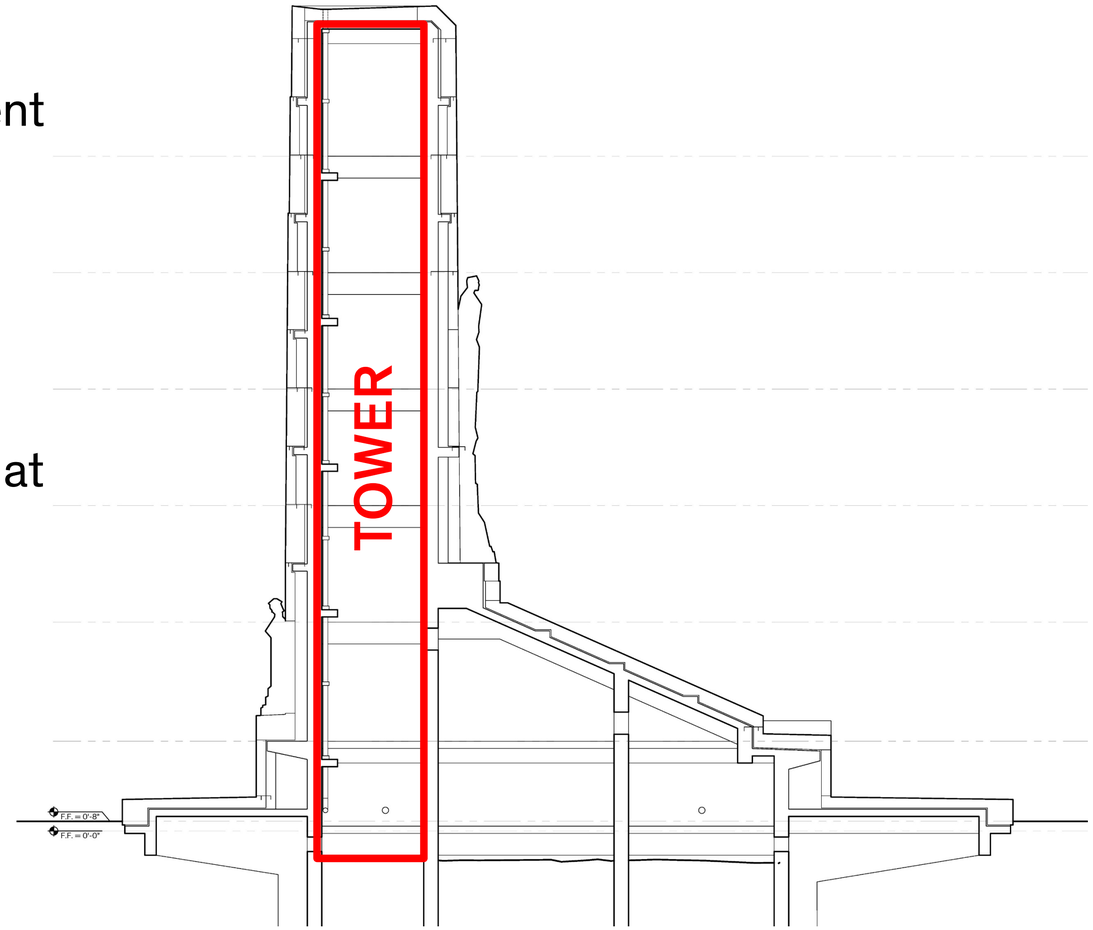
# Previous Investigation

**Findings:**

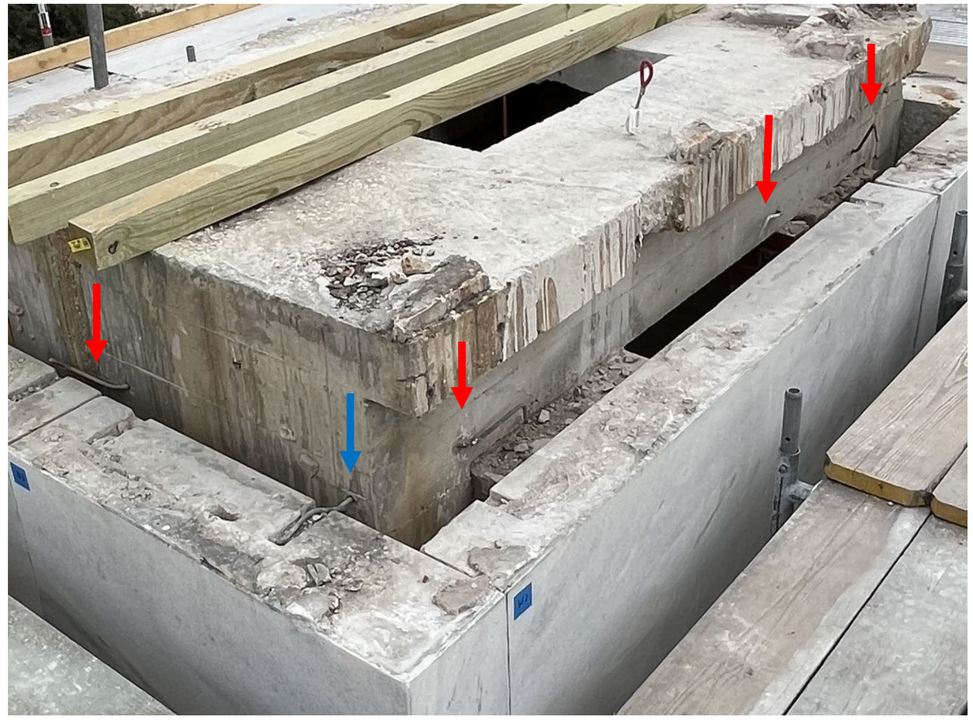
- Low concrete cover depth, exposed reinforcement
- Concrete carbonation
    - Concrete pH = 5 (12 is typical)
    - Carbonation depth of 1.5” from both sides at south wall
- Interior atmospheric conditions
    - Visible water infiltration
    - Insufficient air flow



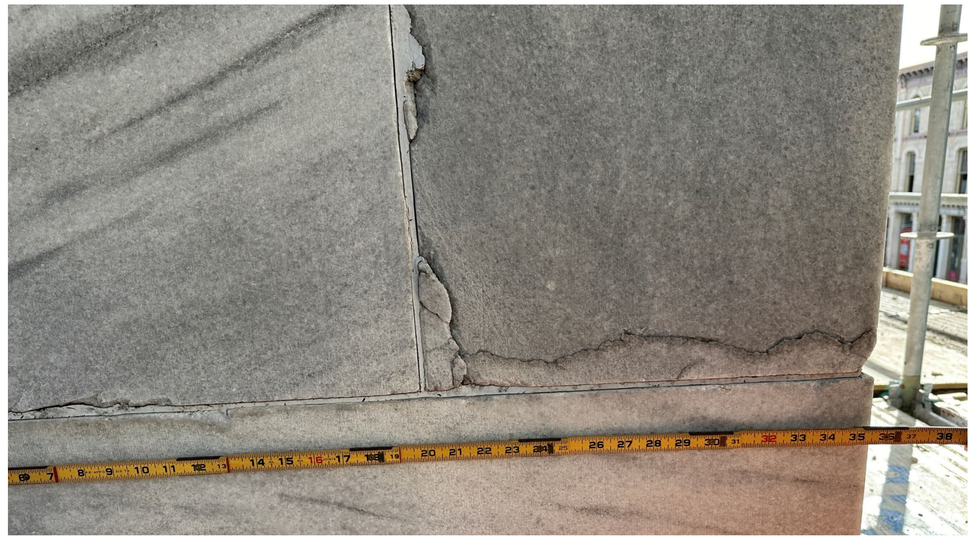

*Initial investigation area*

# Previous Investigation

- Stone anchors
    - Missing and improperly attached stone anchors
- Exterior marble condition
    - Displacement
    - Spalling, cracking, joint damage
    - Soiling



*Stone anchors*

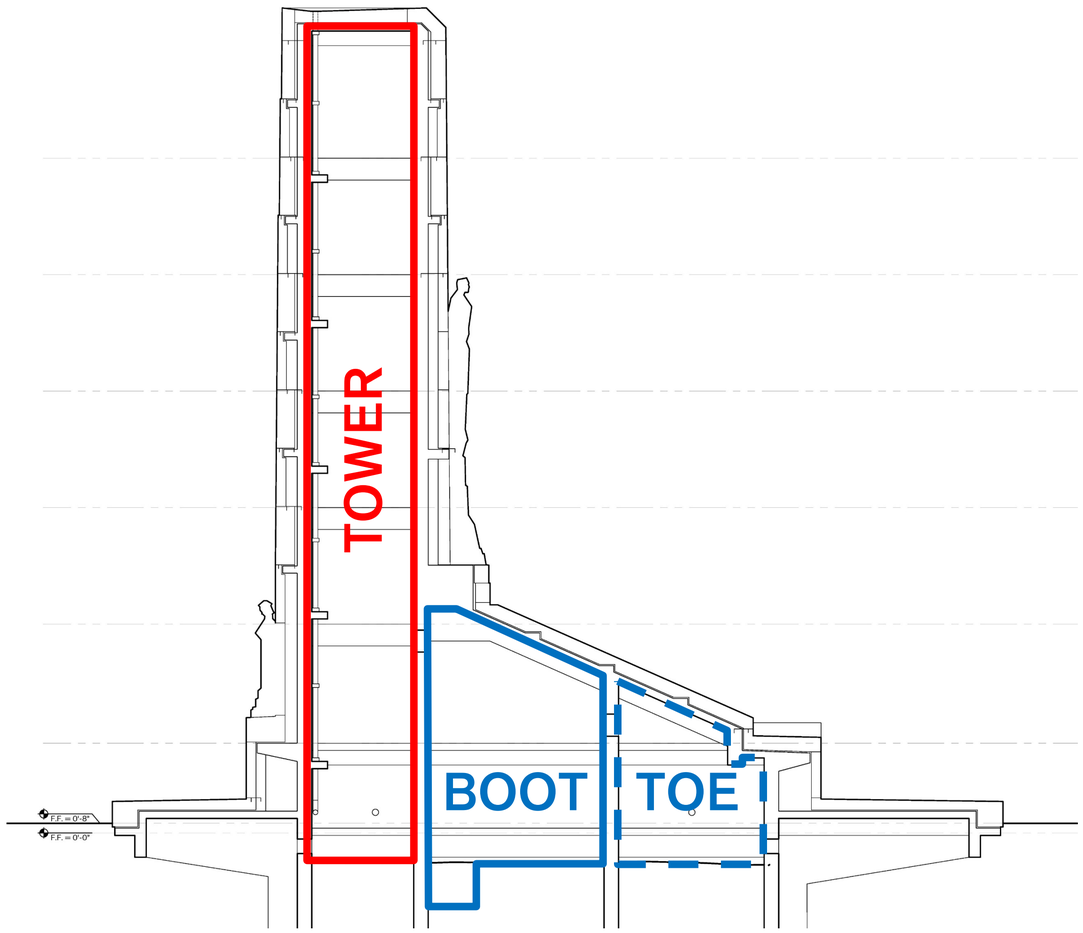


*Marble damage at joints*

# Additional Investigation

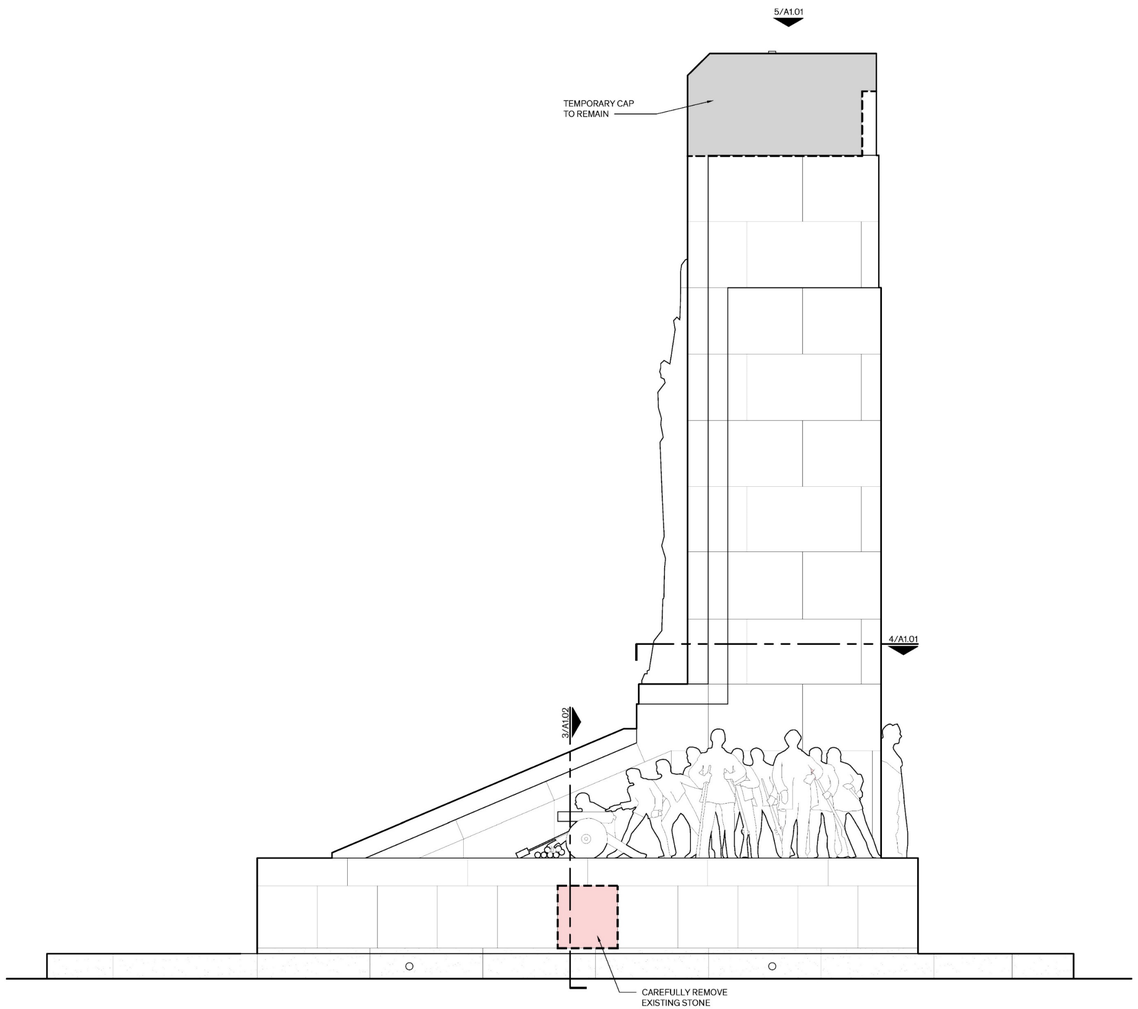
**Scope:**

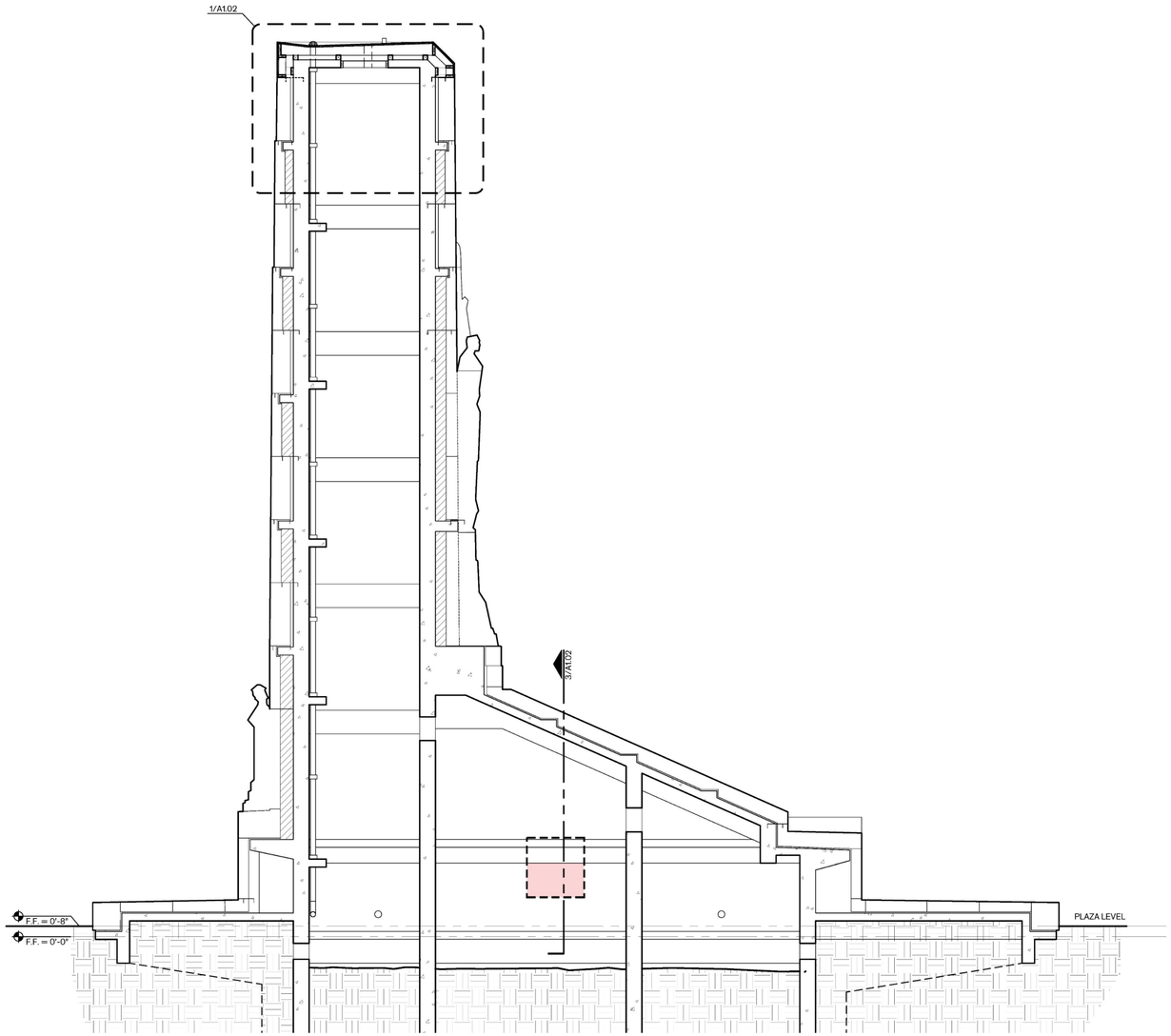
- Access to interior of boot area
- Partial visual access into toe area
- Interior test pit
- Installation of temperature, relative humidity, and $CO_2$ sensors at tower
- Installation of concrete moisture sensors at boot




*Red = initial investigation, blue = additional investigation*

# Additional Investigation Stone Removal

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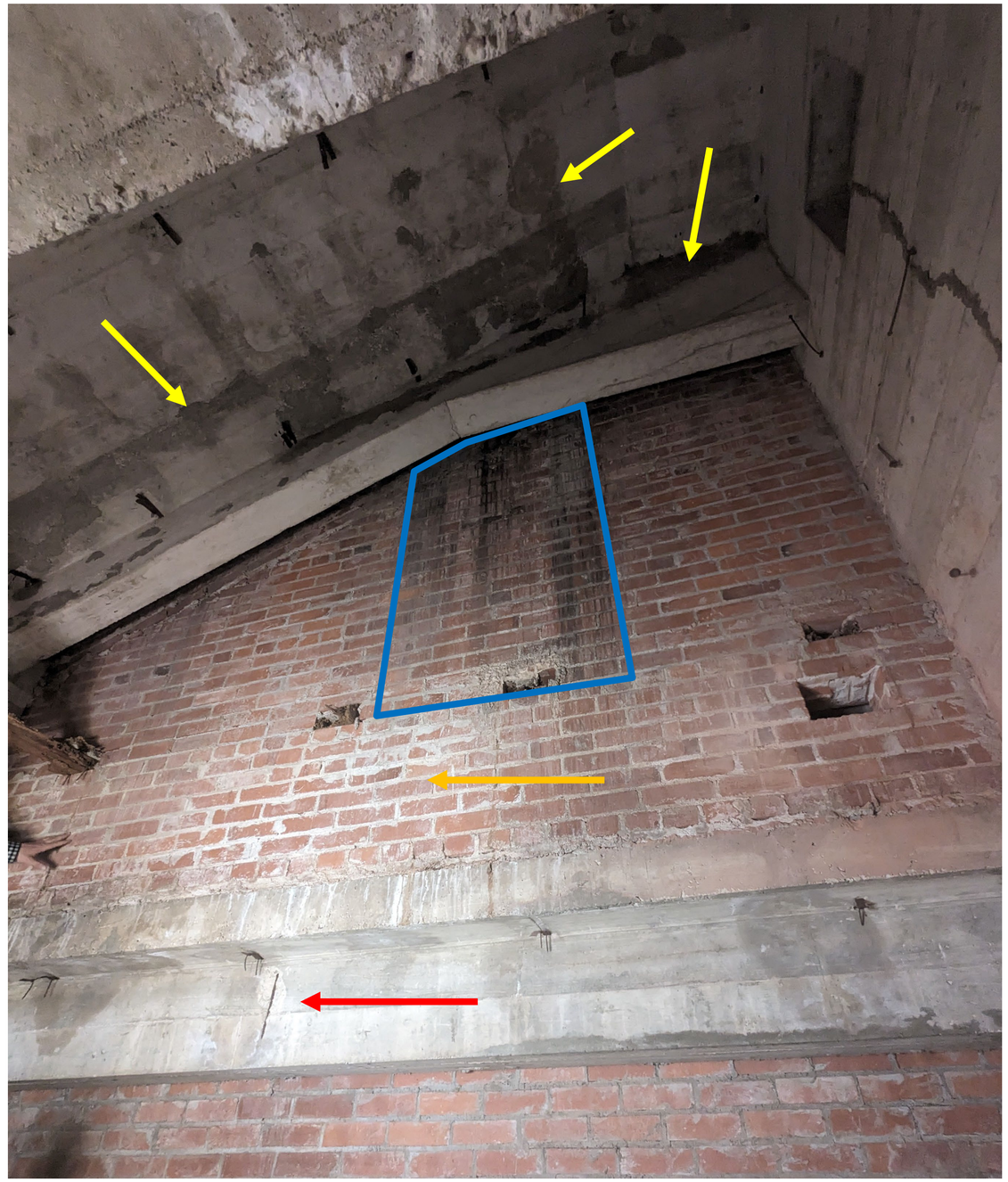
# Additional Investigation

*3D scanning*



*West interior wall*

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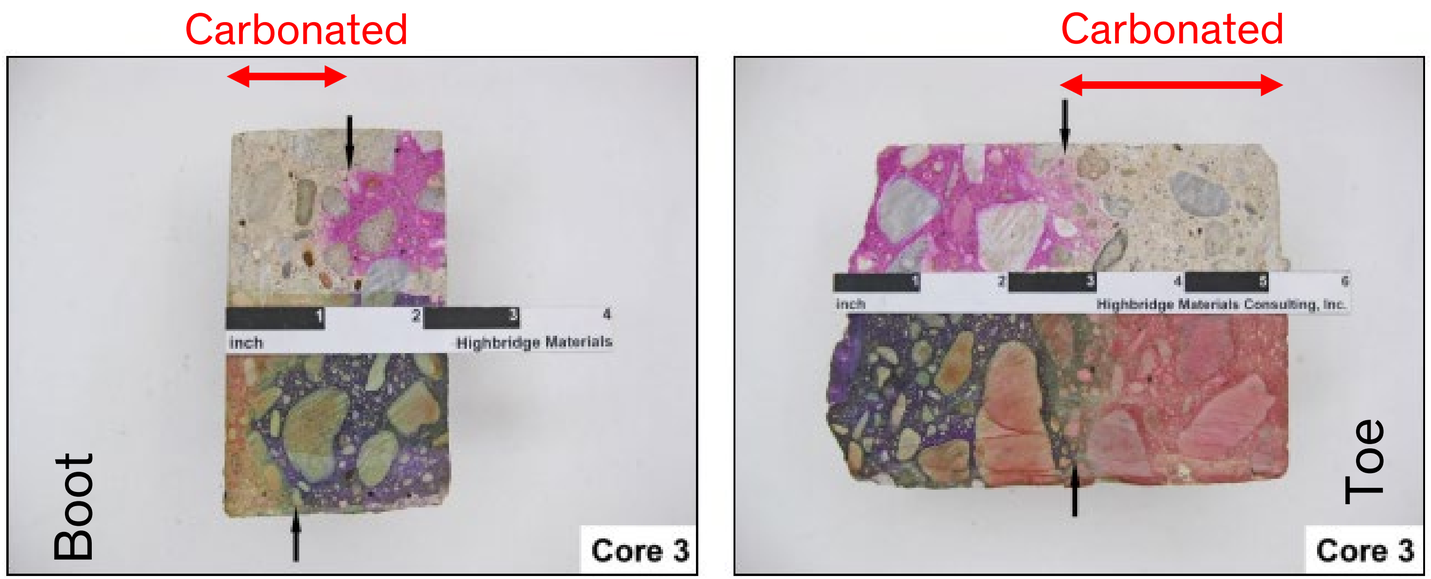
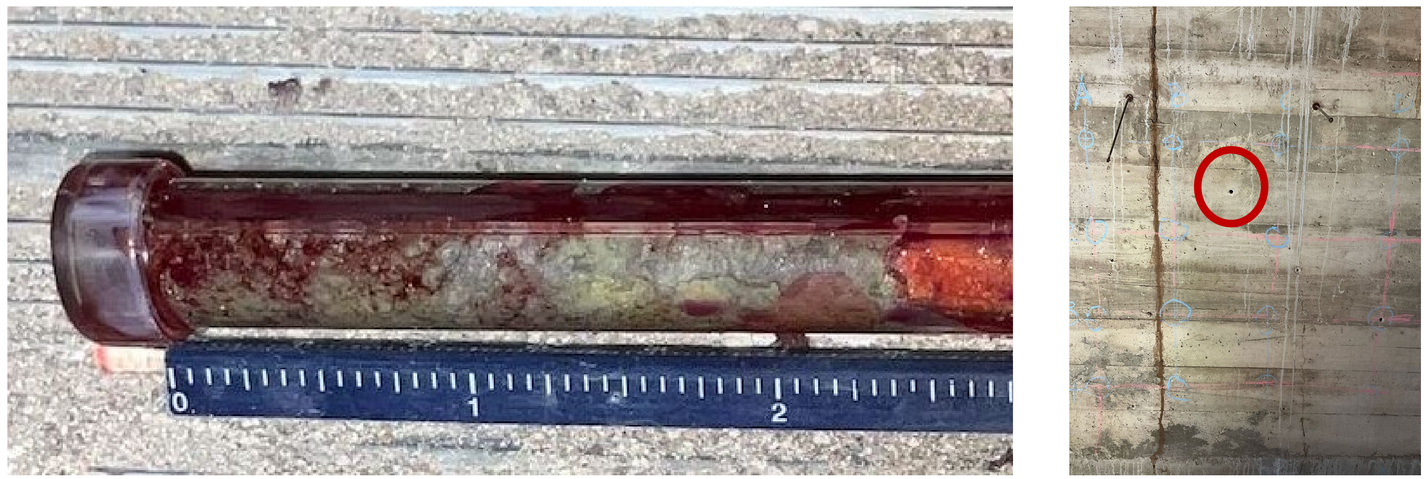
# Additional Investigation – Concrete Carbonation

**On-site and laboratory testing:**

- Depth of carbonation ranges from 1” – 2.5”
- Concrete pH = 8-10 (12 is typical)
- Concrete below grade has negligible carbonation



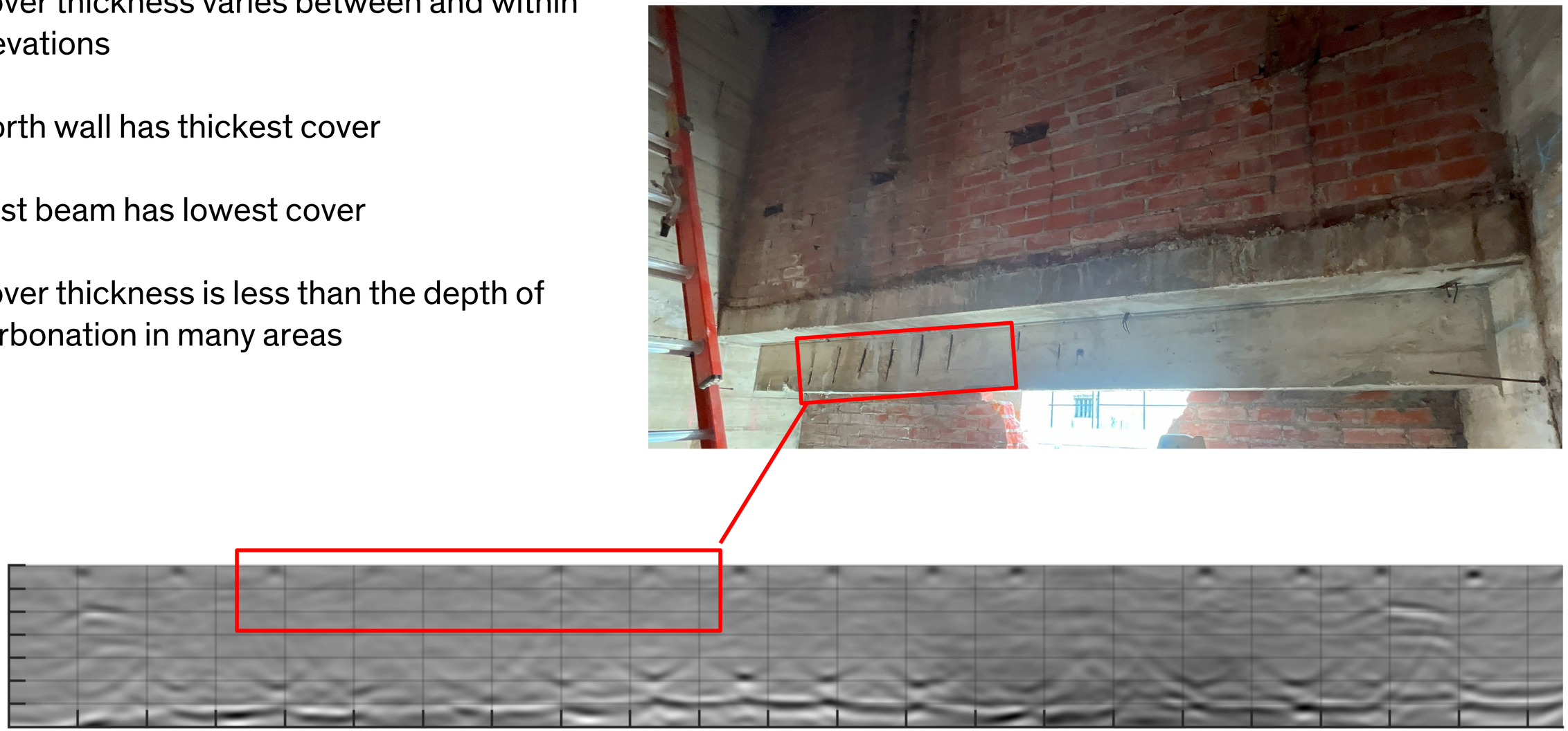

*Above grade concrete core at south boot wall*




*On-site carbonation testing*

# Additional Investigation – Concrete Cover

- Cover thickness varies between and within elevations
- North wall has thickest cover
- East beam has lowest cover
- Cover thickness is less than the depth of carbonation in many areas

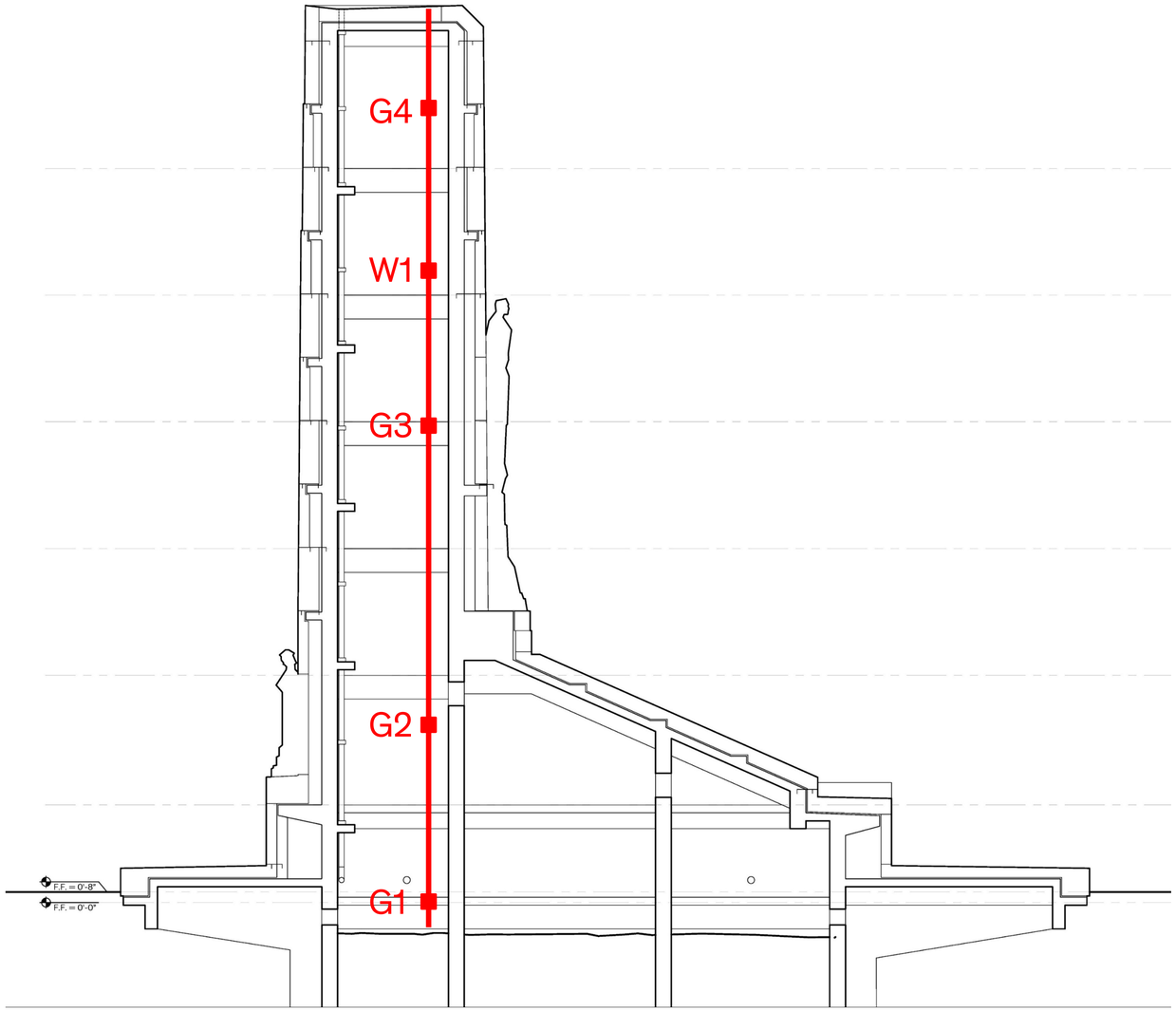


*Ground penetrating radar scan*

# Additional Investigation – Interior Atmosphere

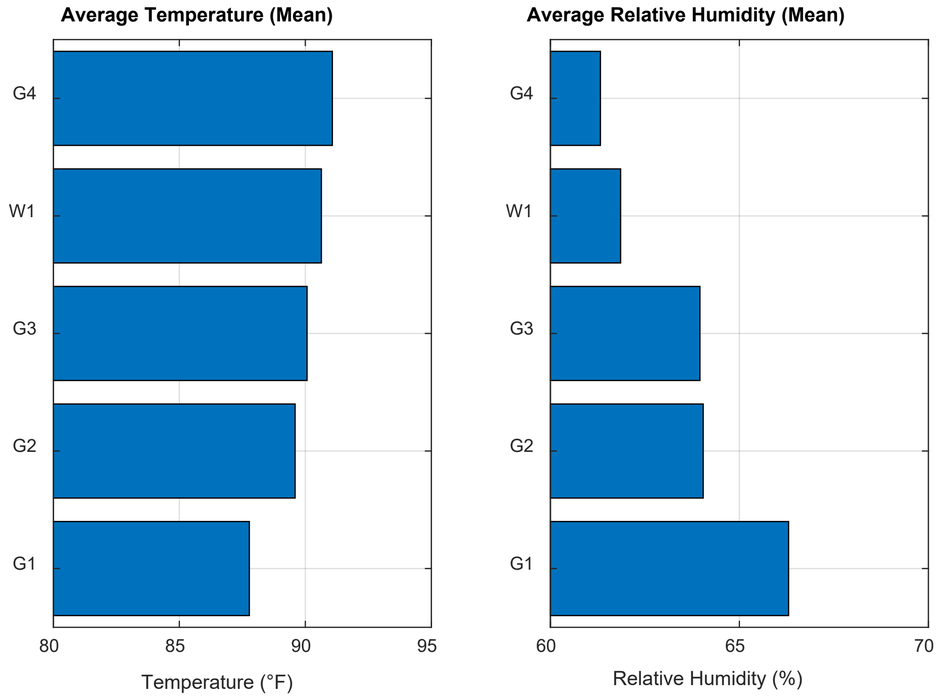
**Sensor Data:**

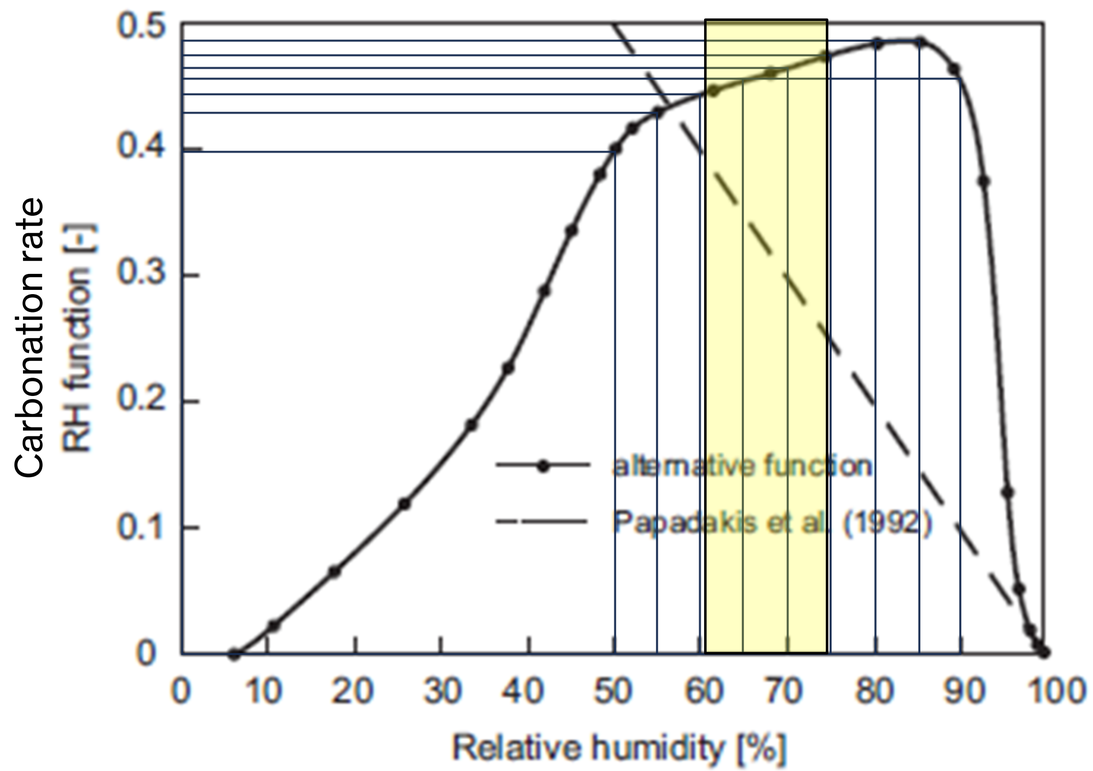
- Temperature and RH fluctuates daily (more fluctuation on top and bottom of tower)
- Higher average temperature at top of tower
- Higher relative humidity at bottom of tower
- Interior $CO_2$ level higher than average exterior level




*Approximate sensor locations*

# Additional Investigation – Interior Atmosphere



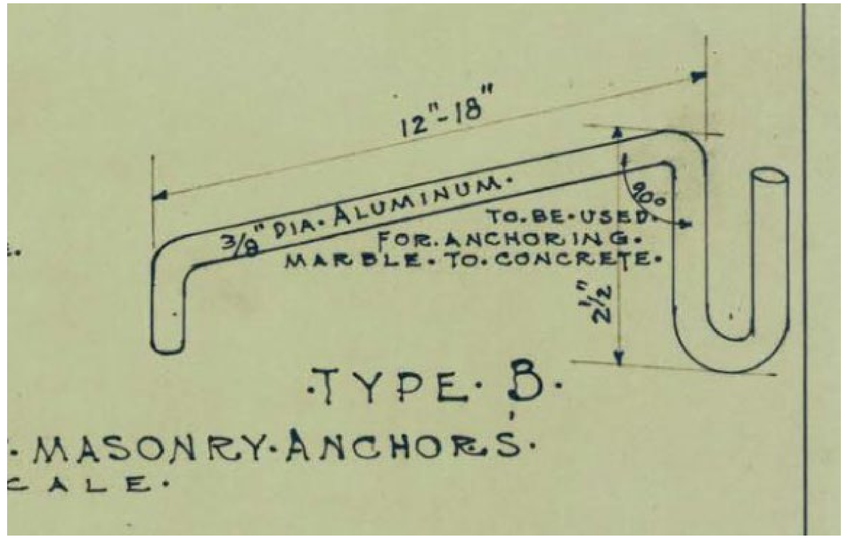

*Carbonation rate model*

| Height from ground (ft) | Sensor ID | Temperature, mean (F) | Temperature, Stdv. (F) | RH, mean (%) | RH, Stdv. (%) |
|---|---|---|---|---|---|
| 52 | G4 | 90.3 | 2.3 | 64.1 | 8.1 |
| 42 | W1 | 89.7 | 2.4 | 65.9 | 9.0 |
| 32 | G3 | 89.2 | 2.2 | 67.8 | 9.2 |
| 12 | G2 | 88.3 | 2.6 | 69.3 | 10.8 |
| 2 | G1 | 87.0 | 2.1 | 70.0 | 8.9 |

*Sensor data*

# Additional Investigation - Other Laboratory Testing

- Aluminum stone anchors
    - 95% aluminum
    - 4% copper
    - .5% iron
    - .5% magnesium
    - Alloy is safe to remain embedded in concrete



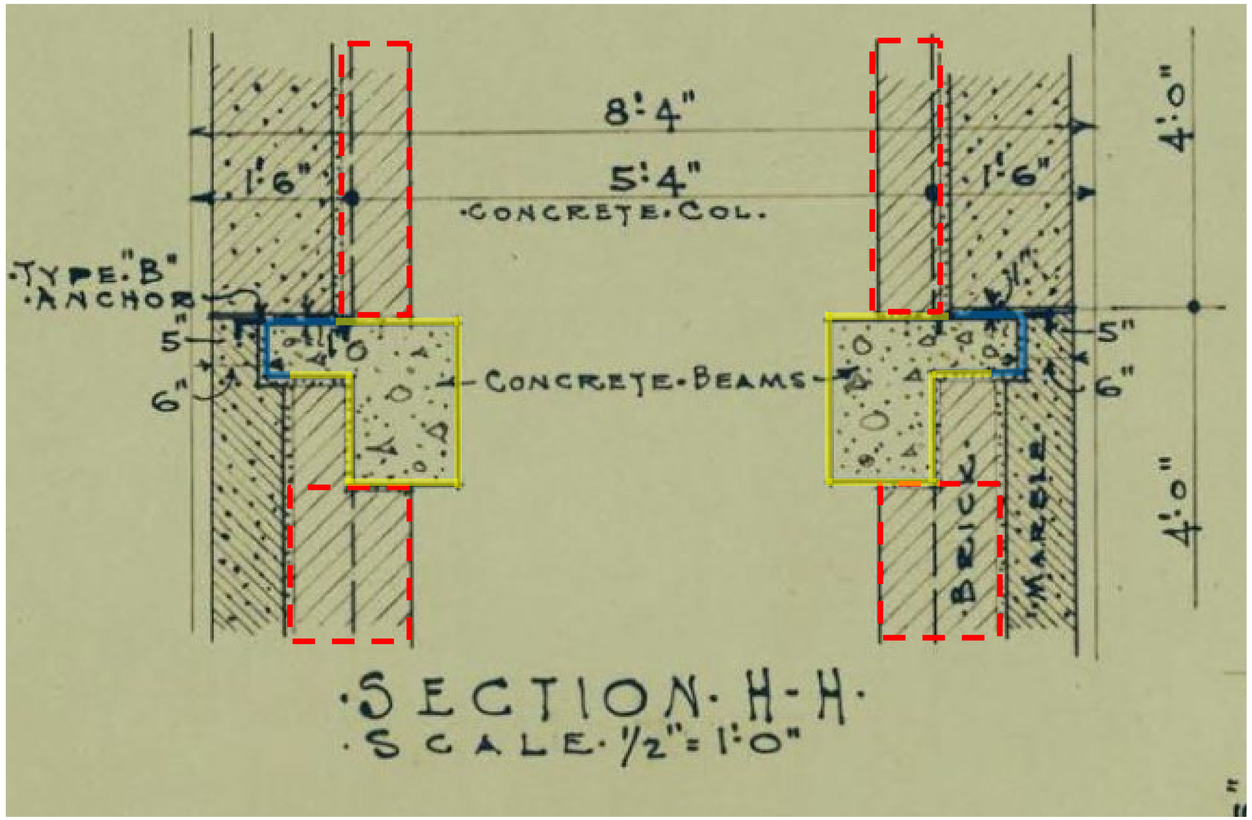

*Historic anchor drawing*

- Brick and mortar: sulfate contamination
    - In bricks: 0.3% - 0.7%
    - In mortar (20% Portland Cement): 0.8% -1.4%


*Bricks from Cenotaph interior*

# Restoration Recommendations

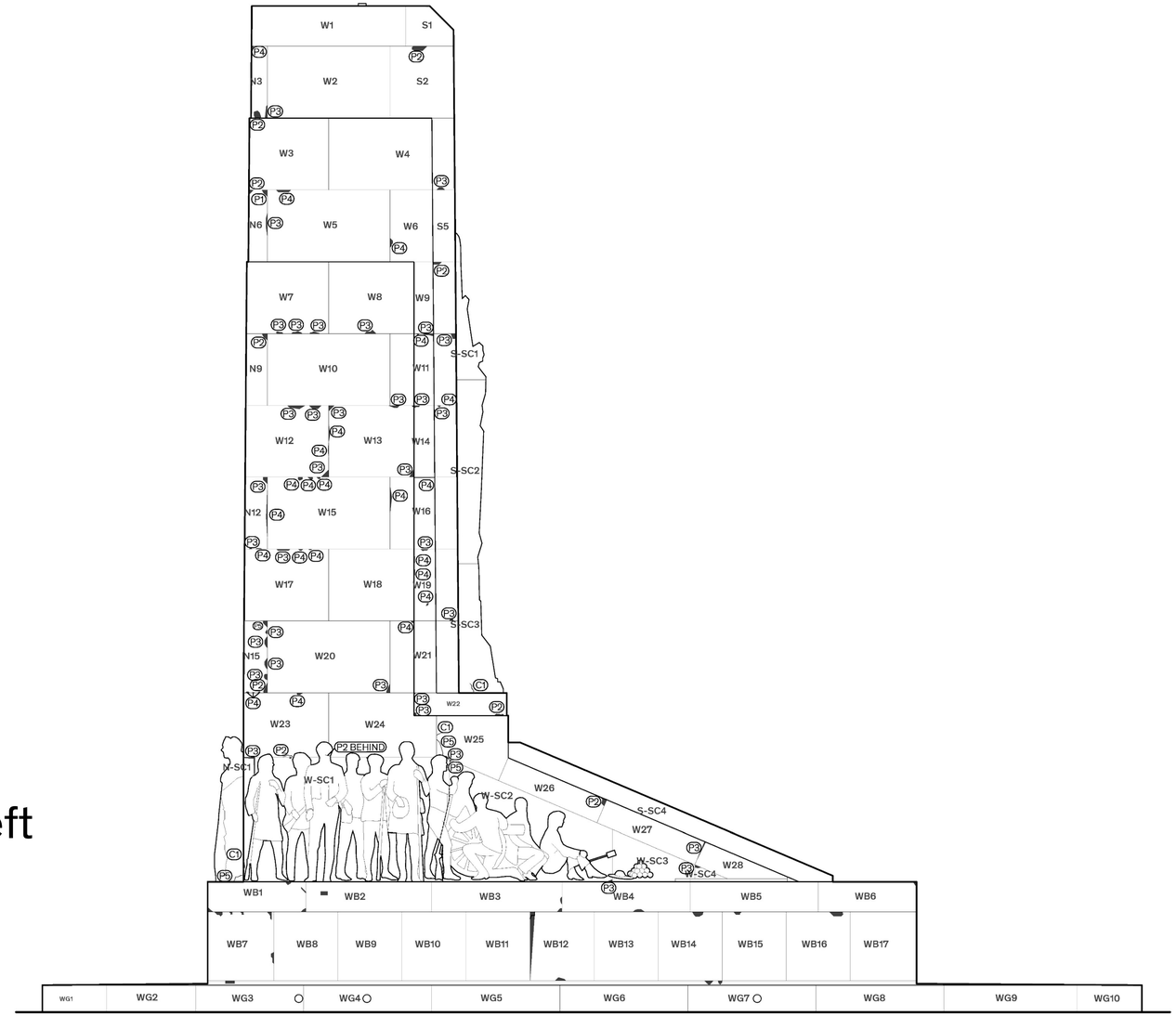
- Removal and replacement of brick infill
- Realkalization treatment of carbonated concrete
    - All beams require realkalization
    - North and south walls to be considered for realkalization
    - Realkalization area will depend on how much marble cladding is removed
    - Expose 1 foot of concrete structure below grade for treatment
- Apply protective anti-carbonation coating to all accessible concrete surfaces




*East-west section detail at beams*

# Restoration Recommendations

- Environmental control measures
    - Increase interior ventilation
    - Long-term monitoring
- Restoration of marble
    - Complete cleaning
    - Complete marble restoration
    - Reinstall marble with correct anchoring
    - Existing aluminum anchors can be cut and left embedded in concrete as required




*Restoration construction drawing*

# Marble Cleaning

## Chemical Cleaning

- Three products tested March 7


*Before chemical cleaning*


*After chemical cleaning*

# Marble Cleaning

## Laser Cleaning

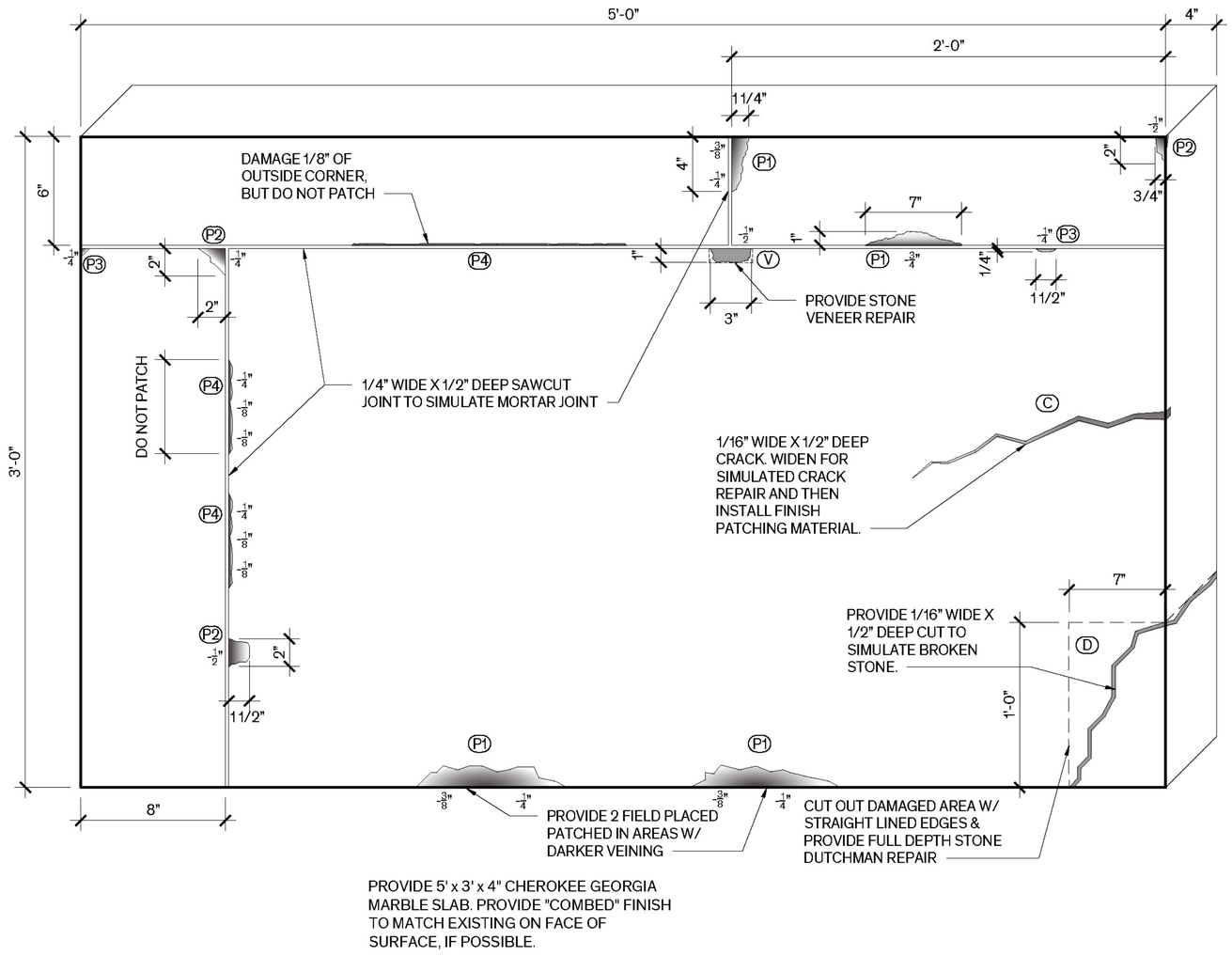
- Mockup completed June 24


*Before laser cleaning*


*After laser cleaning*

# Marble Restoration

- Marble slab procured from quarry in Georgia that sourced original stone
- Mockup slab will be deliberately damaged and then repaired per restoration recommendations




*Repair mockup construction drawing*

# Schedule

- Summer 2024: Restoration Construction Documents in progress

- Fall 2024
  - Bidding
  - Stone repair mockup

- Late Fall 2024: Construction mobilization

- June 2025: Restoration complete

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# Questions?


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