Ahmad Hamid PhD PE
e: ahmadahamid16@gmail.com

Michael Schuller PE
e: mschuller@ana-usa.com New York: 917 647 9530
Boulder: 303 444 3620

Assessment and Retrofit of Masonry Structures

Case Studies

College of Continuing and Professional Studies
Structural Engineering Webinar
March 7, 2023

Case Studies

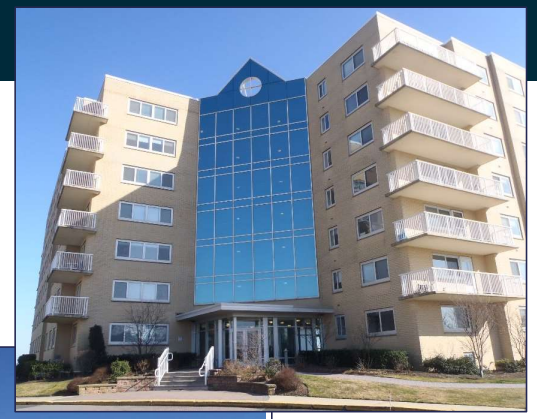
- The process
  - Evaluation/diagnostics
  - Design
  - Implementation
  - Quality assurance
- Lessons learned

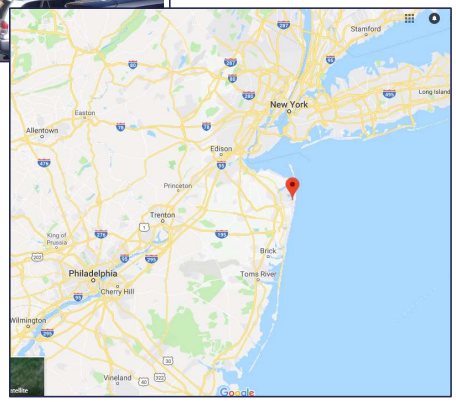
1963 - New Jersey coast
"Architectural" maintenance

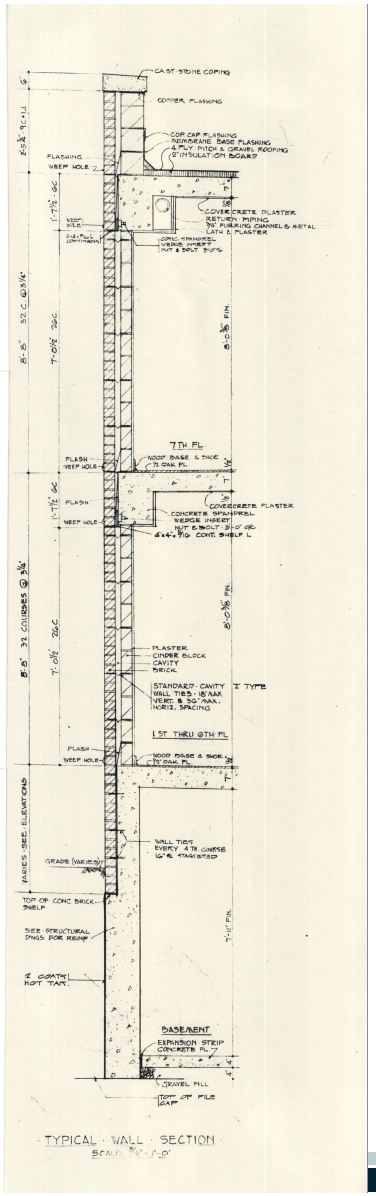
1889 - New Orleans
Structural strengthening

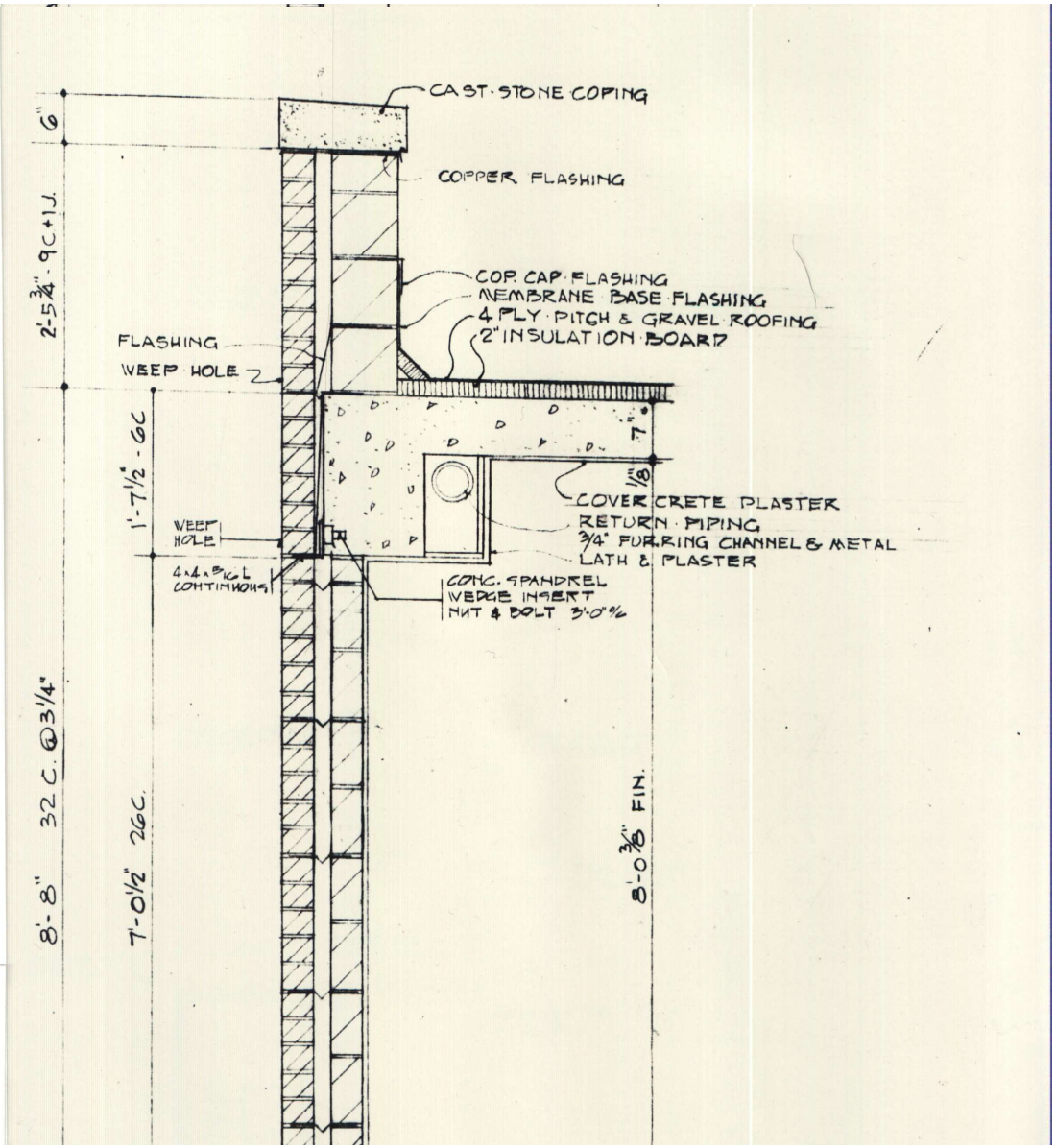
Brick veneer cavity wall

- 7-story apartment building
- 1960's construction
  - 4" brick veneer
  - 4" CMU backup
  - 1" drainage cavity
- Reinforced concrete frame
  - Steel shelf angles each floor

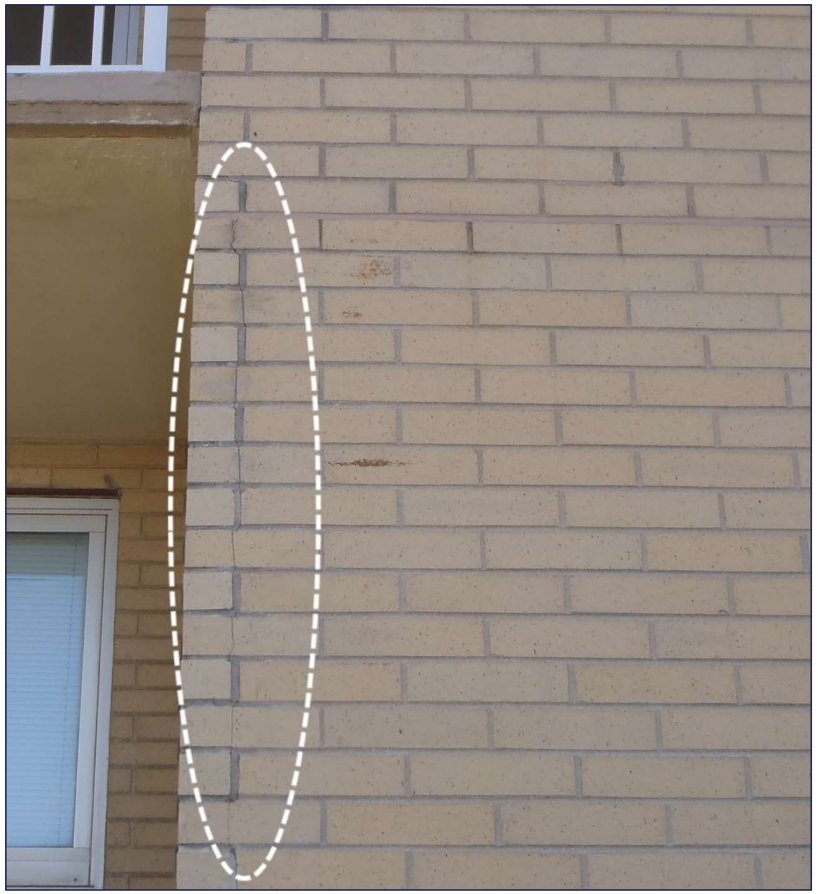





CAST STONE COPING
COPPER FLASHING
COP. CAP FLASHING
MEMBRANE BASE FLASHING
4 PLY PITCH & GRAVEL ROOFING
(2" INSULATION BOARD)
FLASHING
WEEP HOLE
COVERCRETE PLASTER
RETURN PIPING
3/4" FURRING CHANNEL & METAL
LATH & PLASTER
CONC. SPANDREL
WEDGE INSERT
NUT & BOLT 3'-0" OC
7TH FL.
WOOD BASE & SHOE
(75 OAK FL.)
FLASH
WEEP HOLE
4x4x5/16 CONT. SHELF L
PLASTER
CINDER BLOCK
CAVITY
BRICK
STANDARD CAVITY WALL TIES - 18 AAX VERT. & 30" MAX. HORIZ. SPACING
I TYPE
1 ST THRU 6TH FL
WALL TIES EVERY 4TH COURSE G & STAGGERED
GRADE (VARIES)
TOP OF CONC BRICK SHELF
SEE STRUCTURAL DWGS FOR REINF.
2 COATS HOT TAR
BASEMENT
EXPANSION STRIP
CONCRETE FL.
GRAVEL FILL
TOP OF PILE CAP
8'-8" 32 C. @3 1/4"
T-0 1/2" 26G.
8'-0 3/8" FIN.
1'-7 1/2" GC
2'-5 3/4" 9C+1J.
6"
8'-6" 32 COURSES @ 3 1/4"
VARIES - SEE ELEVATIONS
TYPICAL WALL SECTION
SCALE 3/4"-1'-0"

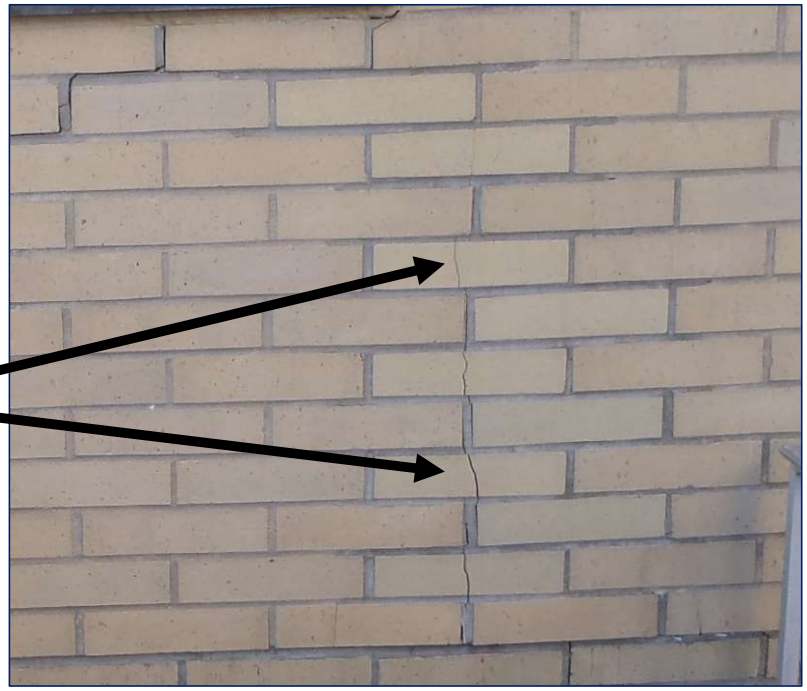

CAST STONE COPING
6"
COPPER FLASHING
2'-5 3/4" 9C+1J.
COP. CAP FLASHING
MEMBRANE BASE FLASHING
4 PLY PITCH & GRAVEL ROOFING
2" INSULATION BOARD
FLASHING
WEEP HOLE
1'-7 1/2" GC
WEEP HOLE
4x4x5/16 L CONTINUOUS
COVERCRETE PLASTER
RETURN PIPING
3/4" FURRING CHANNEL & METAL
LATH & PLASTER
CONC. SPANDREL
WEDGE INSERT
NUT & BOLT 3'-0" %
8'-8" 32 C. @3 1/4"
T-0 1/2" 26G.
8'-0 3/8" FIN.

- Masonry – 50 years old, in great shape!
- Mortar – mostly OK
- Sealant failure
- Localized cracks at building corners



- Ongoing maintenance
  - 1990's:window, sealant replacement
  - Crack repair
  - Stains - cleaning

Bricks replaced – cracked again!



Existing conditions

- No movement joints



Rust-jacking

- Steel shelf angles at each floor line
- Steel corrosion
  - Oxidation byproducts occupy a larger volume than original metal
  - Expansion: up to 7x

Displacement: parapet movement

- 2014: superstorm Sandy
  - Parapet rocking back and forth
  - Permanent displacement

Investigation

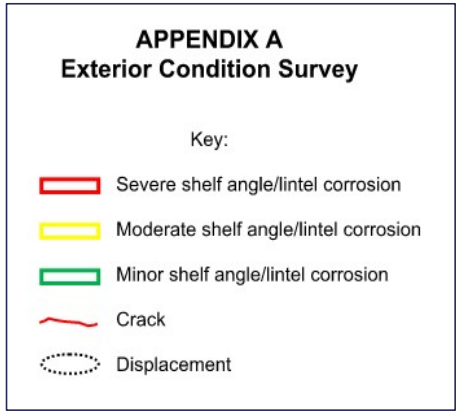
- Document review, interviews
  - Prior reports, repairs
- NDE: anchor location, videoscope

Diagnostics: flashing and shelf angles

- Probe openings
- Flashing
  - PVC type
  - Still flexible!
- Shelf angle corrosion
  - Minor: visible surface oxidation
  - Moderate: surface pitting
  - Severe: flaking, section loss

Visual Condition Survey

- Severity
- Prioritize repairs
  - Emergency



East elevation

West elevation

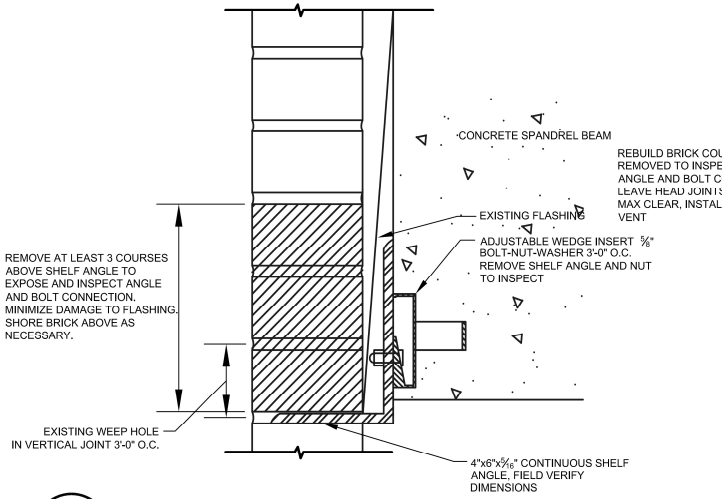
Prioritizing repairs

Corrosion, cracks, sealants, staining

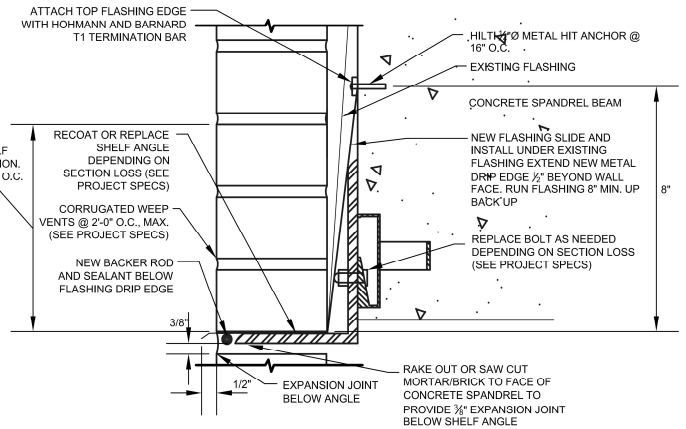
- High priority: life safety implications
  - Shelf angle repairs: severe corrosion, displaced brick
  - Veneer movement at parapet
- Medium priority repairs: moderate distress
  - Shelf angle repairs: moderate corrosion
  - Cracks and displacement
  - Veneer expansion joints
  - Parapet displacement
- Maintenance-level repairs
  - Flexible sealant replacement
  - Cleaning: stains

Solutions

- Shelf angle replacement



1/S8 MASONRY DEMOLITION AT SHELF ANGLE
WALL SECTION 3" = 1'-0"



2/S8 SHELF ANGLE REPAIR
WALL SECTION 3" = 1'-0"

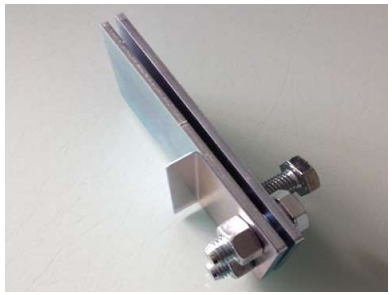
3/S8

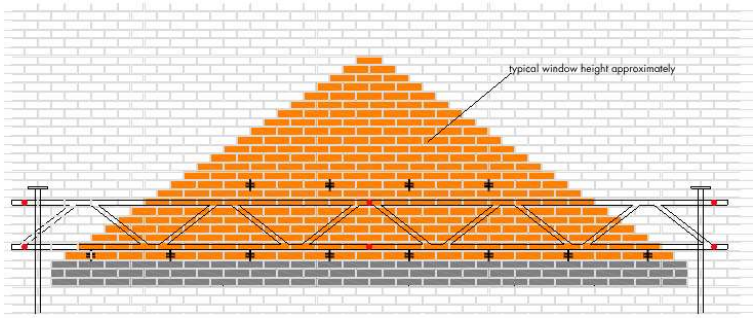
Brick shoring

Wood blocking

Shear pins

Brick bracing

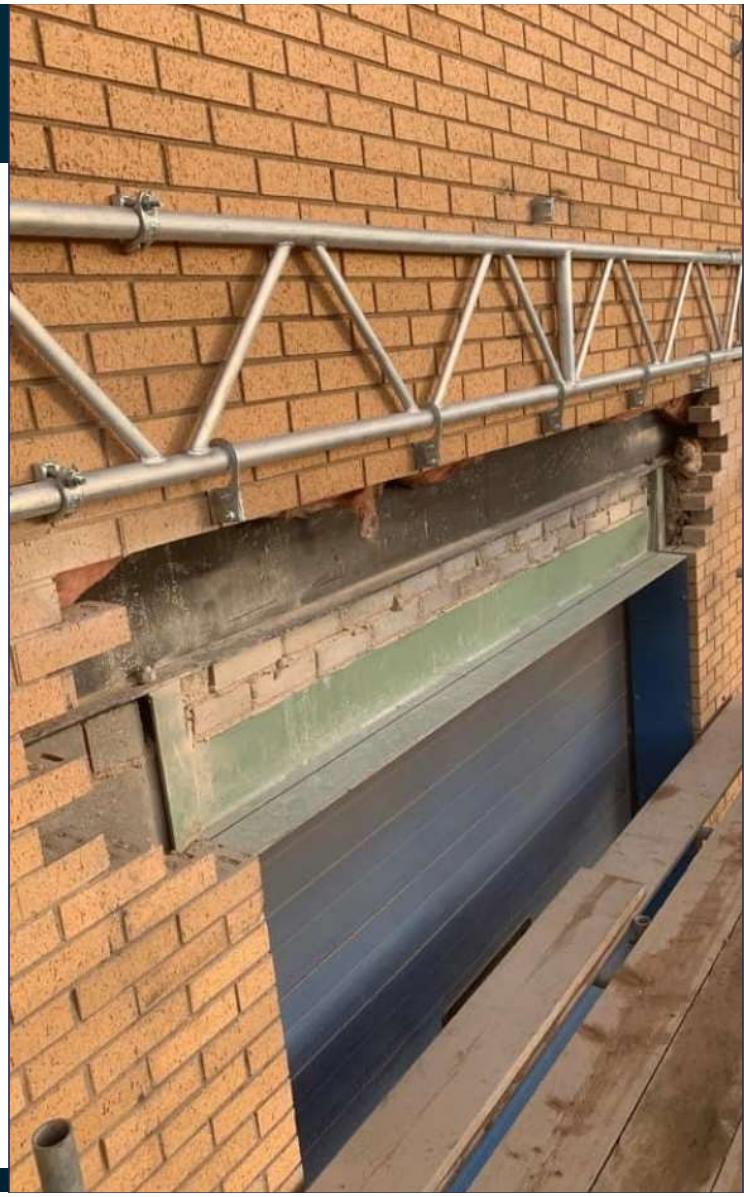




5400mm opening (24 brick)

Brick wall - Stretcher Bond

Brickbrace.com



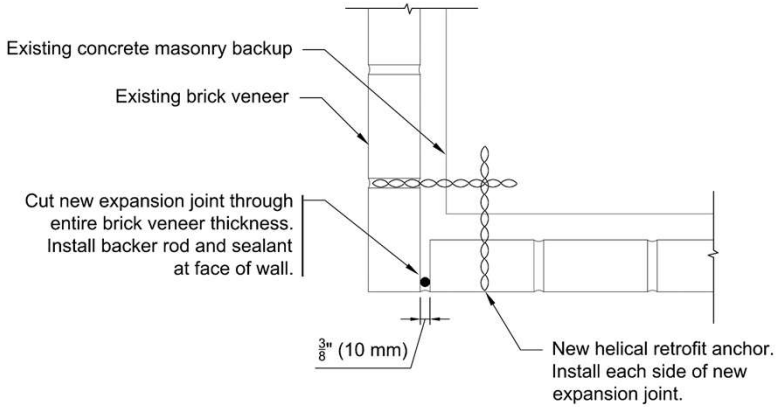
Corrosion – the actual conditions

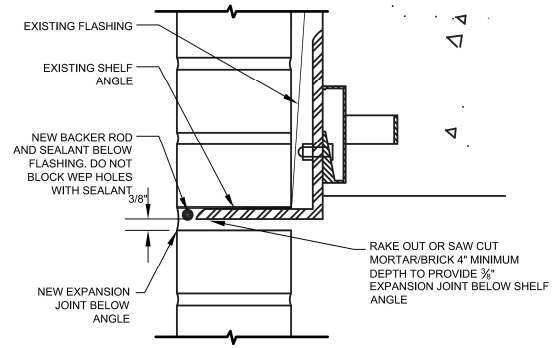
- Veneer anchors
  - Minor – moderate corrosion

- Shelf angles
  - Much worse than expected!

Solutions

- Expansion joints needed
  - Vertical
    - At building corners
  - Horizontal
    - Beneath shelf angles

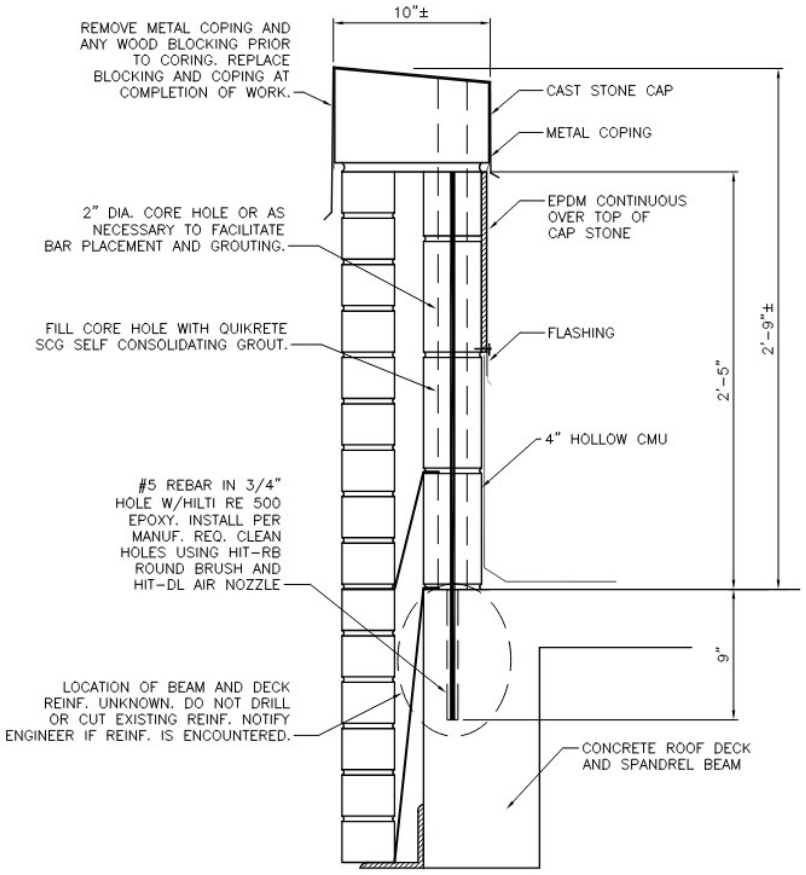




5/S8 NEW EXPANSION JOINT – SHELF ANGLE WALL SECTION 3" = 1'–0"

Parapet repair

- Strengthening or rebuild?



Lessons learned

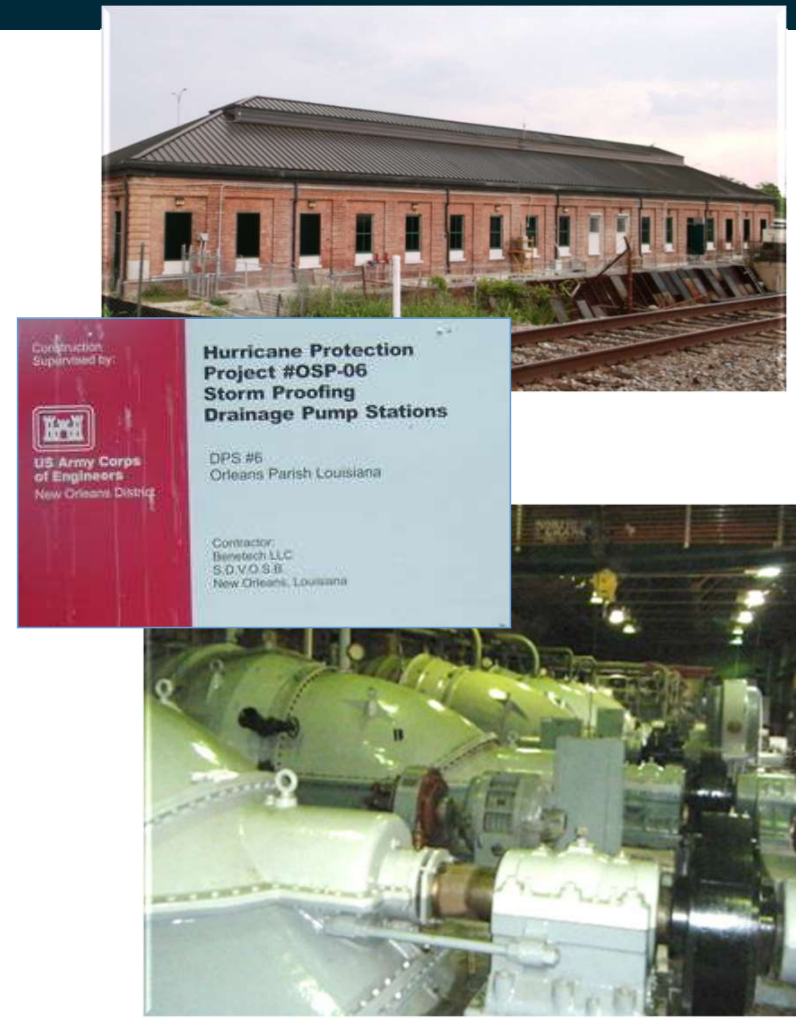
- Good maintenance records
  - Nice to have
  - Saved $10,000 in diagnostics?
- Masonry construction needs movement joints
- What's cheaper?
  - Localized repairs or re-cladding building
- Repairs are expensive
  and materials are a small part of the total cost
  - Long-lasting sealants
  - Corrosion protection
    - Hot-dipped galvanizing
    - Epoxy coating
    - Stainless steel
- You can find a replacement brick…

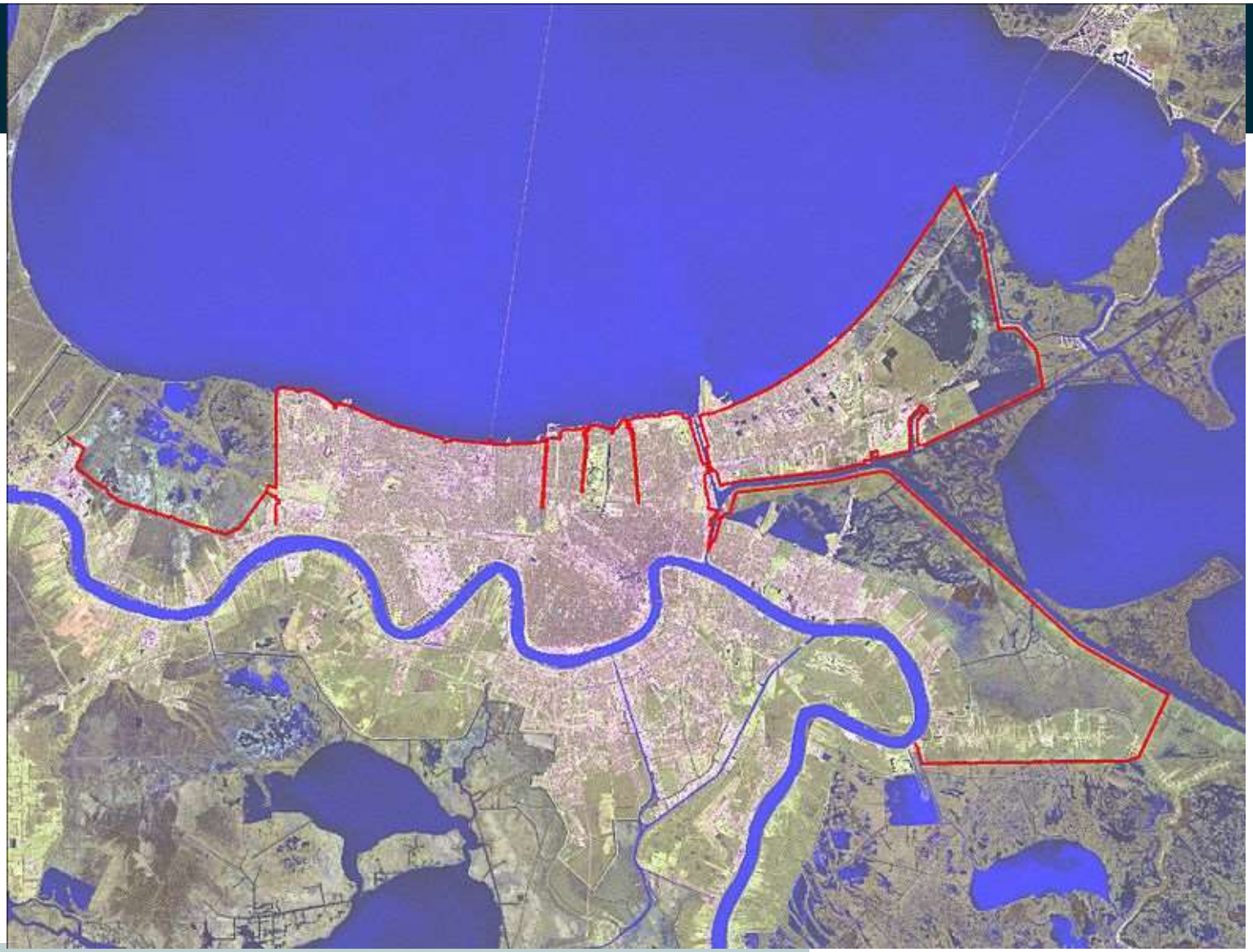
Veneer Maintenance and Repair

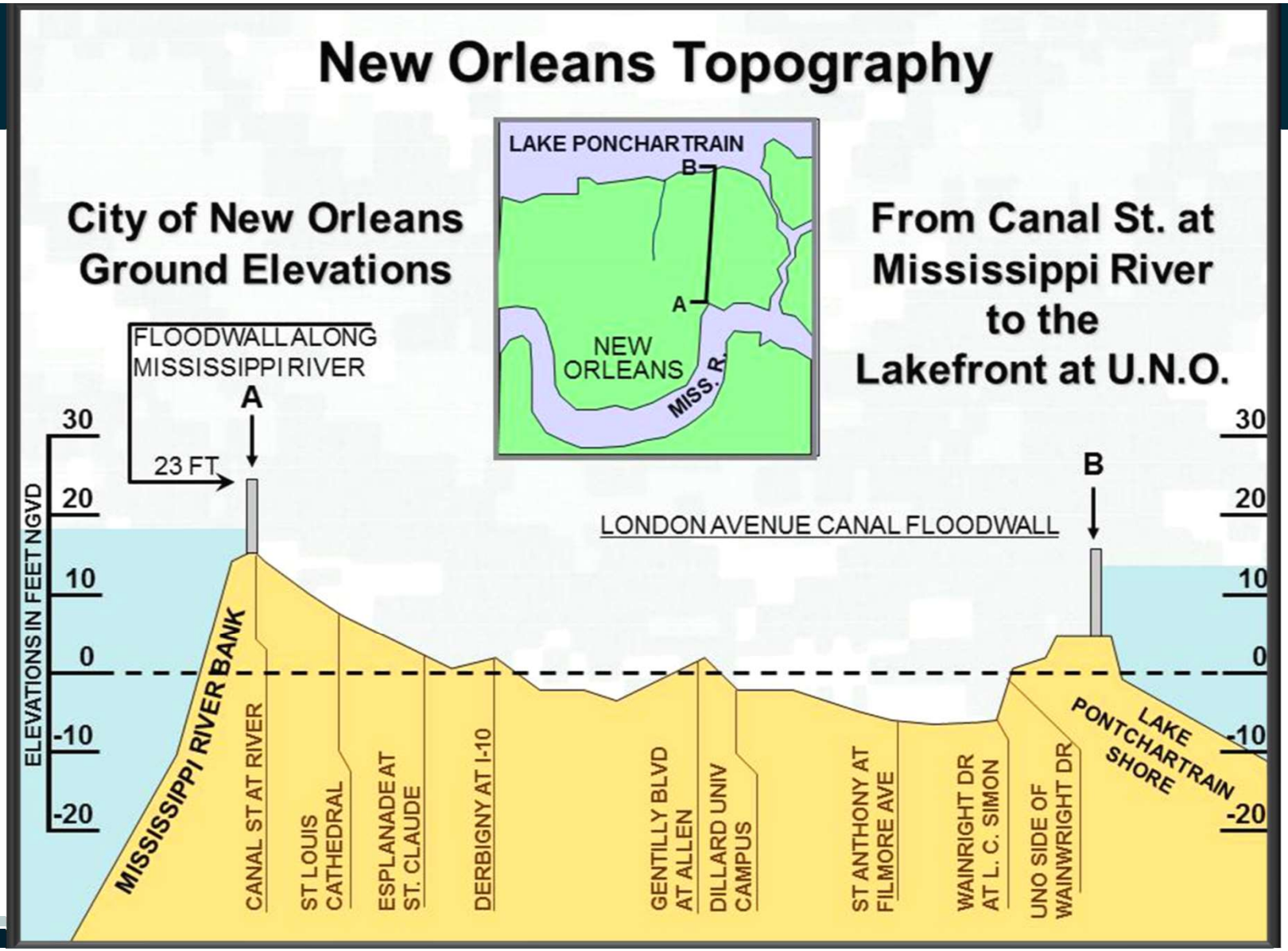
- Lessons learned
  - It's hard to find a good brick match

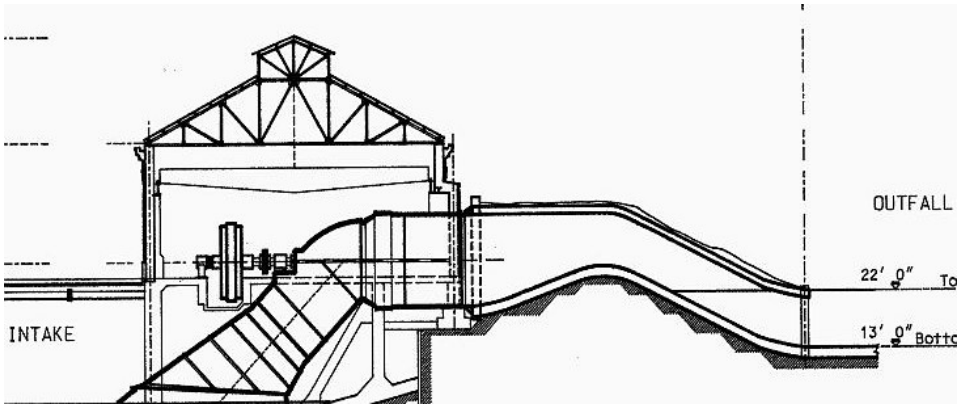
Case Study: Strengthening Historic Masonry

- Diagnostics
  - NDE, in situ tests
  - Laboratory
- Stabilization
  - Helical anchors
  - Injection
- Strengthening
  - Vertical reinf.
  - Horizontal reinf.






New Orleans Topography
City of New Orleans Ground Elevations
From Canal St. at Mississippi River to the Lakefront at U.N.O.
LAKE PONCHARTRAIN
B
A
NEW ORLEANS
MISS. R.
FLOODWALL ALONG MISSISSIPPI RIVER
A
23 FT
B
LONDON AVENUE CANAL FLOODWALL
ELEVATIONS IN FEET NGVD
30
20
10
0
-10
-20
MISSISSIPPI RIVER BANK
CANAL ST AT RIVER
ST LOUIS CATHEDRAL
ESPLANADE AT ST. CLAUDE
DERBIGNY AT I-10
GENTILLY BLVD AT ALLEN
DILLARD UNIV CAMPUS
ST ANTHONY AT FILMORE AVE
WAINRIGHT DR AT L. C. SIMON
UNO SIDE OF WAINWRIGHT DR
LAKE PONTCHARTRAIN SHORE


OUTFALL
22' 0"
13' 0"
INTAKE

August 29, 2005:

Hurricane Katrina

Retrofit Design Requirements

- USACE Design Requirements
  - Full-strength category 4 hurricane
    - Wind 156 mph (251 km/h)
    - Flood loading to 5 ft. (1.5 m)
    - Risk Category IV (Additional 15%)
  - Large out-of-plane loads

⇨Strengthening required

Operational Challenges

- Stations house large, tightly spaced pumps
- Many pipes and utilities directly adjacent to wall interior

MUST REMAIN IN OPERATION THROUGHOUT CONSTRUCTION

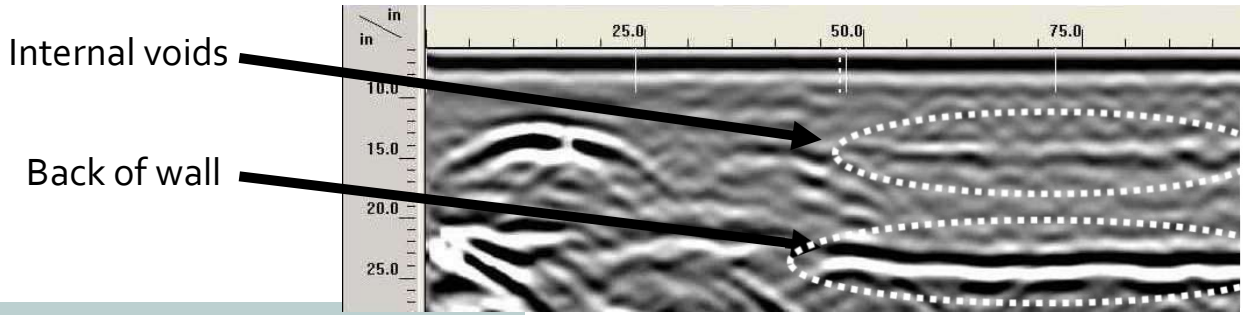
➔ *Internal strengthening methods*

The first step:
Condition and material evaluation

- ASCE 41: Seismic Evaluation and Retrofit of Existing Buildings
- International Existing Building Code (IEBC)
  - Evaluation methodology
  - Number of tests, where
  - Interpretation and use

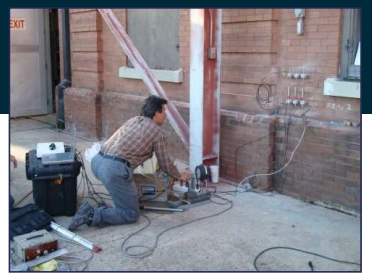
Evaluation and Testing

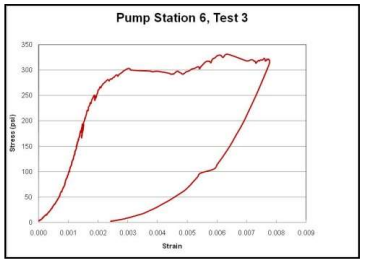
- Condition survey
  - Cracks, deterioration
  - Microwave radar: interior voids, metals
  - Borescope: interior voids
  - Pachometer: metals
  - Typical wall sections
  - Typical conditions: roof anchors, steel lintels



Evaluation and testing

- In situ tests
  - Exterior face wythe
  - Interior common brick wythes
  - Flatjack (compression): ASTM C1197
  - Shear: ASTM C1531
  - Flexural bond: ASTM C1072
  - Anchor tension: ASTM E488
  - Anchor shear: ASTM E488





Engineering recommendations

- Diagnostic information used to design strengthening

Table 9. Engineering Design Values: Construction Typology 1, Multi-Wythe Brick Masonry, No Visible Header Courses, Construction Era 1898 – 1930's

Property	Average Load/Strength		Conservative Design Load/Stress	
	Common Wythe	Face Wythe	Common Wythe	Face Wythe
Masonry compressive strength f'_m (psi)	260	390	240	290
Masonry compression modulus E_m (psi)	86,000	1,000,000	N/A	N/A
Masonry flexural tensile strength, normal to bed joints (psi)	7	9	4	6
Masonry shear strength (psi)	25	64	20	43
Anchor tensile strength (lb)	3,340		835[1]	
Anchor shear strength (lb)	2,140		535[1]	

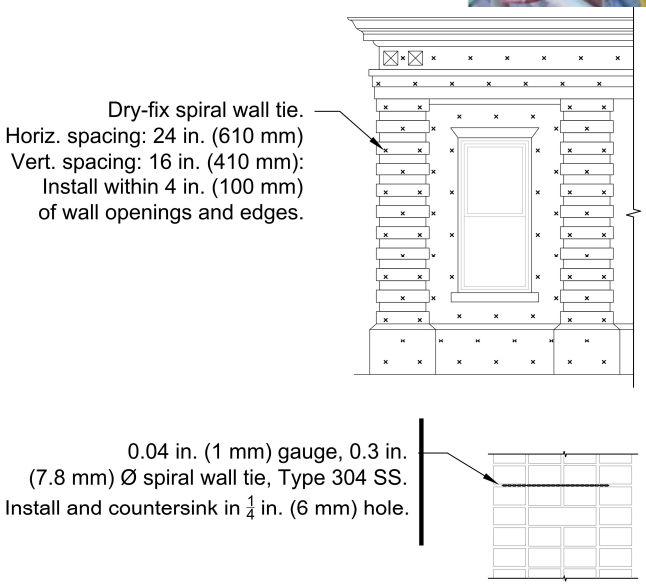
[1]Factor of safety of 4 applied to average ultimate load values.

Retrofit Methodology

- Components
  - *Compatible Injected Fill:* CIF grout injection
  - Helical wall ties
  - Enhancement rods – hollow stainless steel reinforcing
    - Placed in holes, cored vertically and horizontally
    - Tapered anchor conditions at wall base

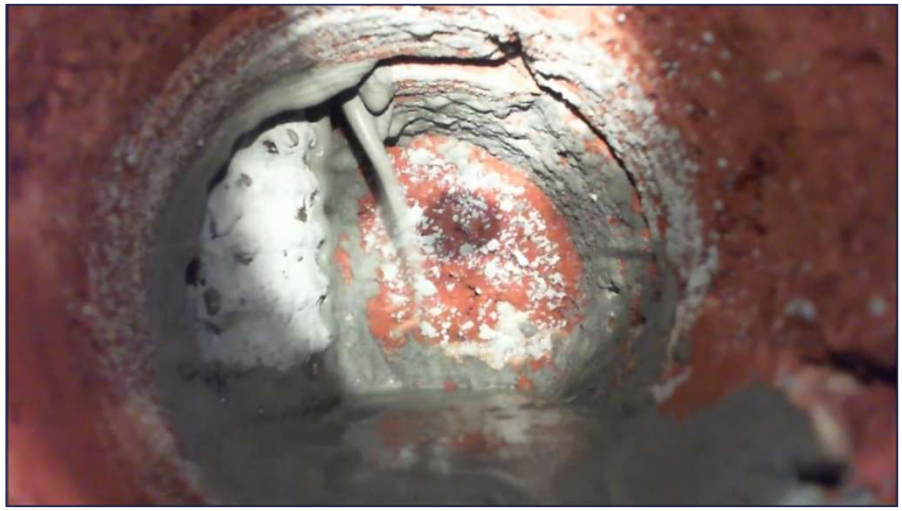
Dry-fix helical anchors

- Easy
- Adequate capacity
- Cheap?

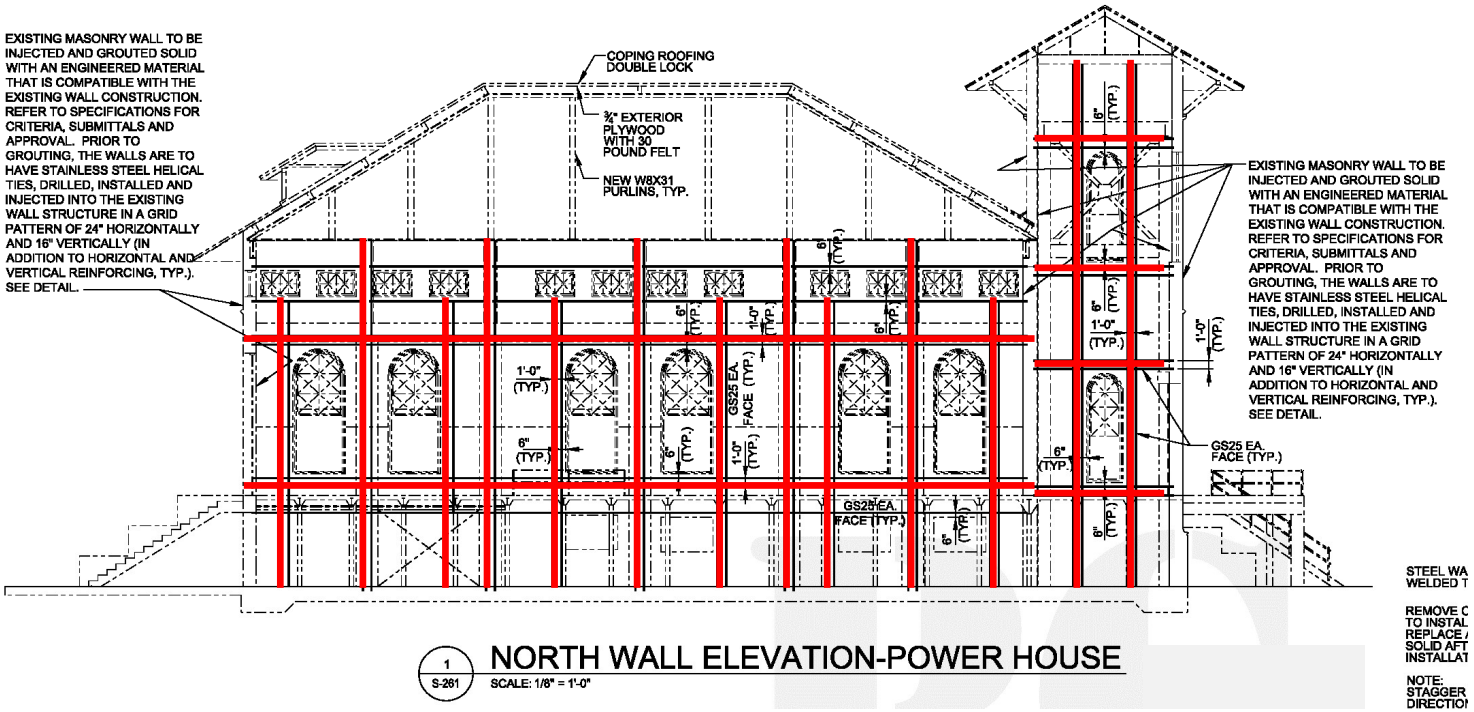


Masonry Stabilization

- Injection procedures
  - Compatible Injected Fill: CIF
  - Low pressure injection
  - Small-diameter holes



Internal reinforcement scheme



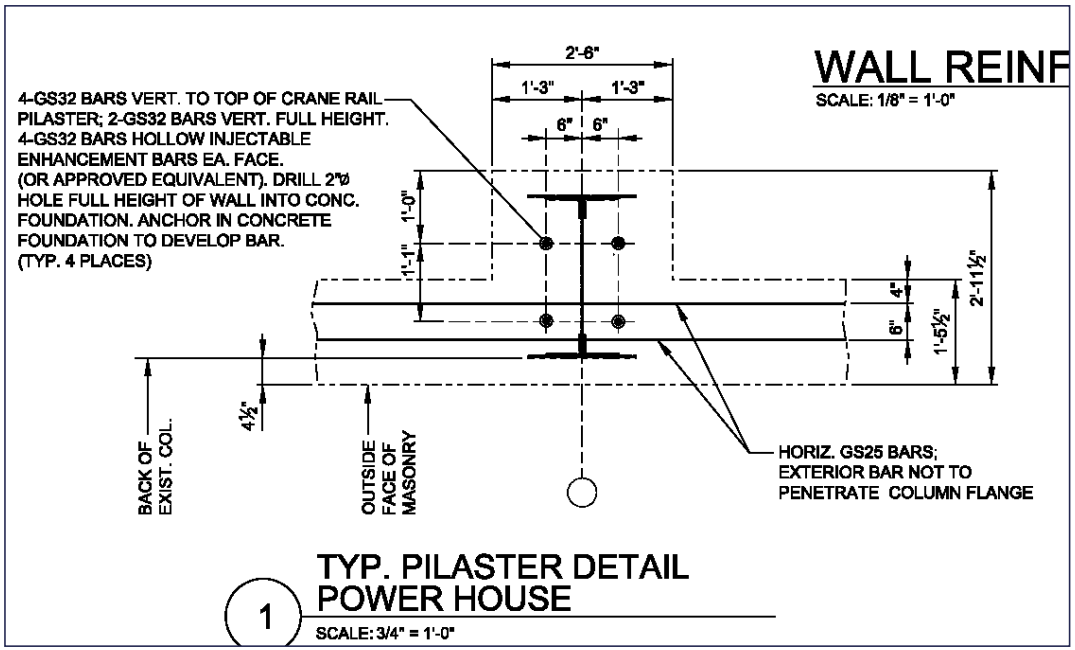
Enhancement rods

- Cold rolled stainless steel
- Hollow
- Socked

Coring through fragile historic fabric

Dry coring – no water involved

Typical pilaster details



Project summary

- Over 85,000 sq. ft. (1050 m^2) of wall area
- Over 1200 US tons CIF grout injected
- Approx. 8 % of wall volume was void
- Over 30,000 linear ft. (9,200 m) of stainless steel reinforcing bars

  - No visible change to structure
  - No service interruption

Ahmad Hamid PhD PE
e: ahmadahamid16@gmail.com

Michael Schuller PE
e: mschuller@ana-usa.com New York: 917 647 9530
Boulder: 303 444 3620

Assessment and Retrofit of Masonry Structures

College of Continuing and Professional Studies
Structural Engineering Webinar
March 7, 2023

University of Minnesota
Driven to Discover®