

MILWAUKEE CITY HALL

Evaluation of Distressed Terra Cotta



Scope of Investigation

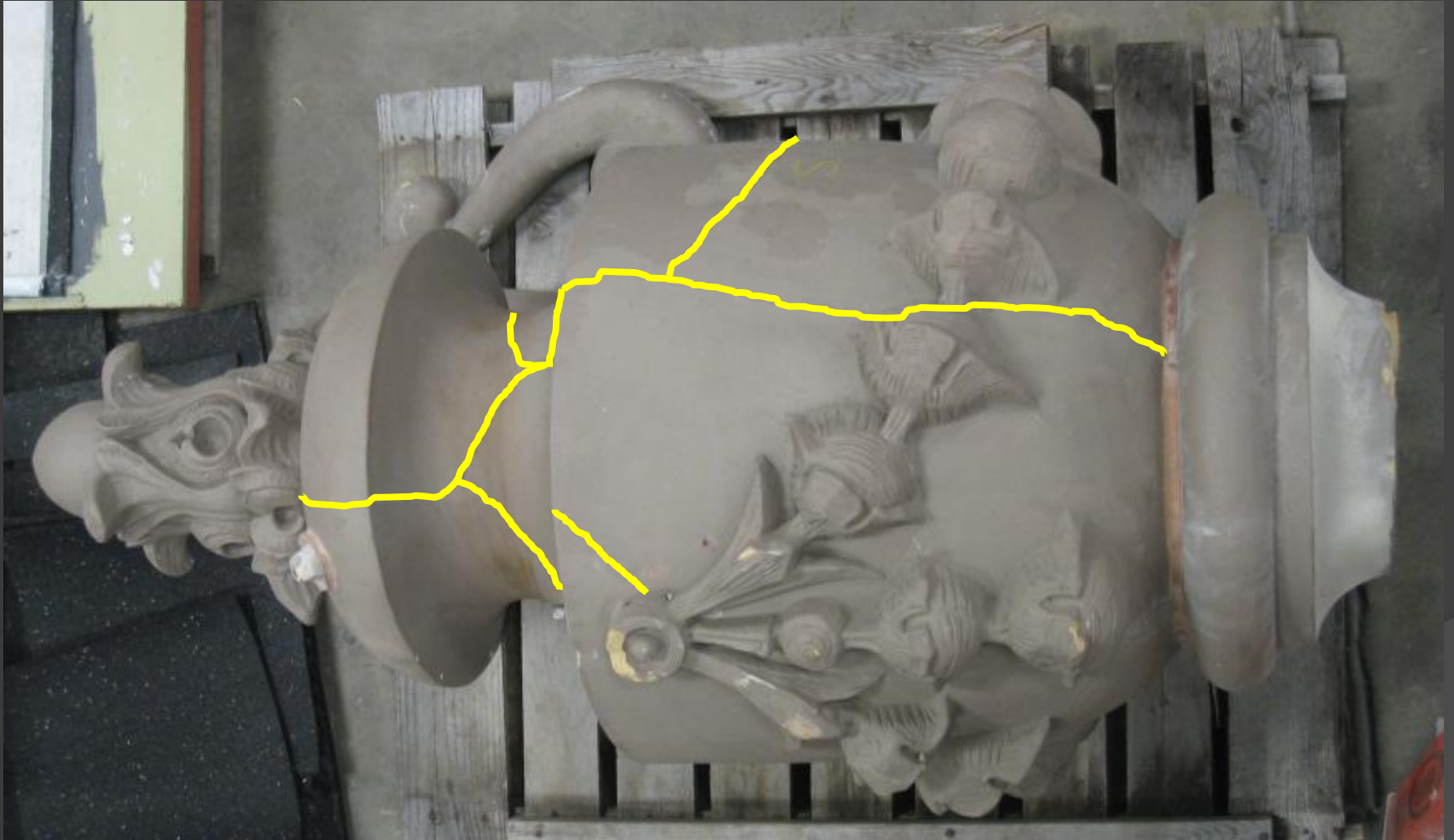
- ⦿ Document Review
- ⦿ Field Inspections (3 total)
- ⦿ Laboratory Testing
 - Grout
 - Terra cotta
 - Mortar
 - Assembly/Mockup
- ⦿ Field Monitoring



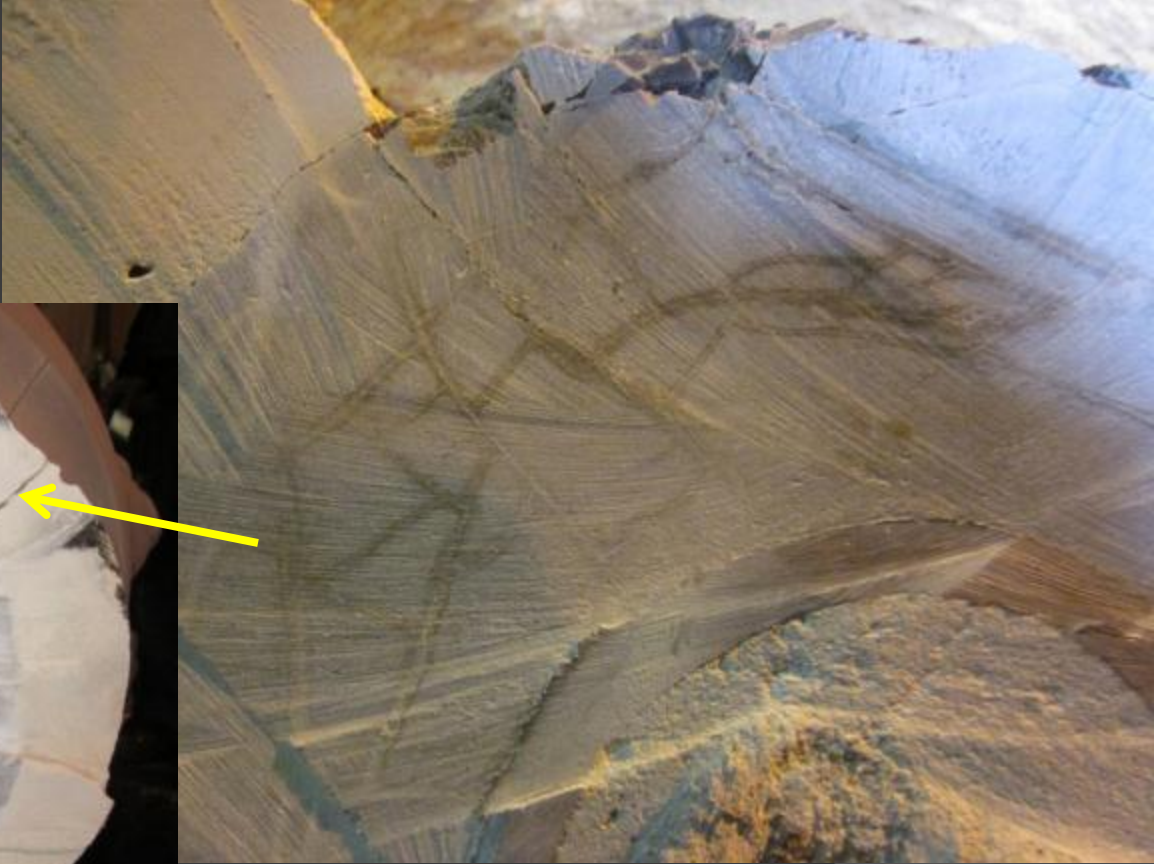
Urn Removal



Urn Distress



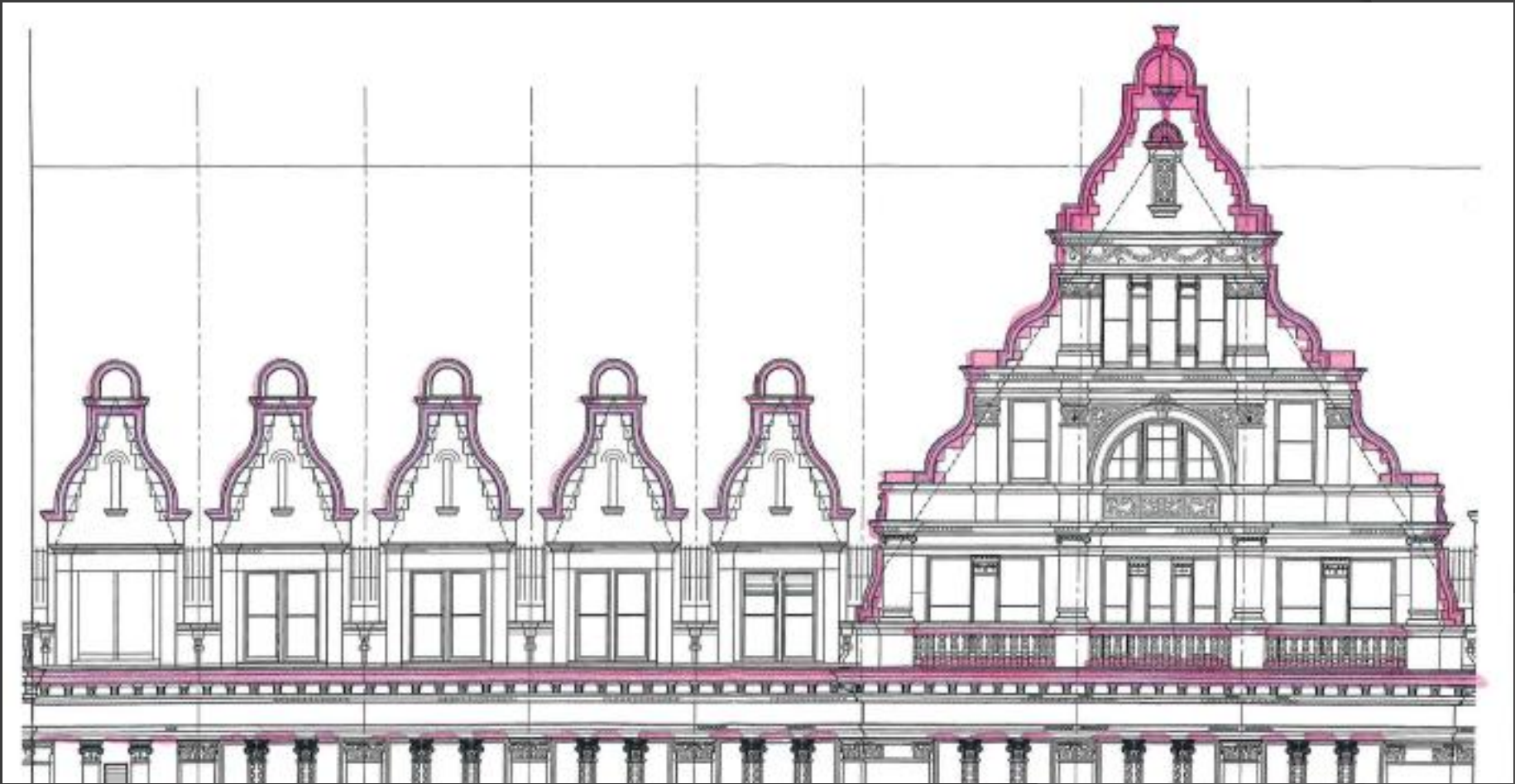
Observations - Urns

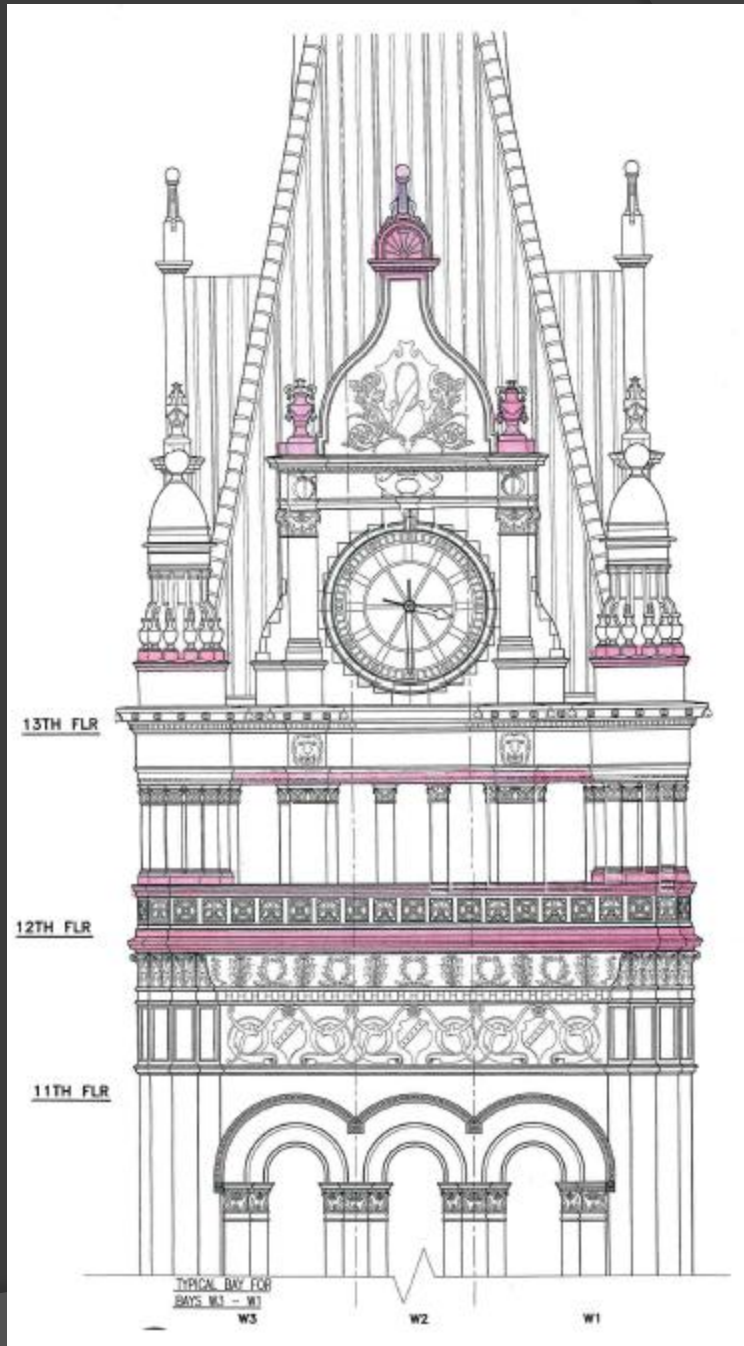
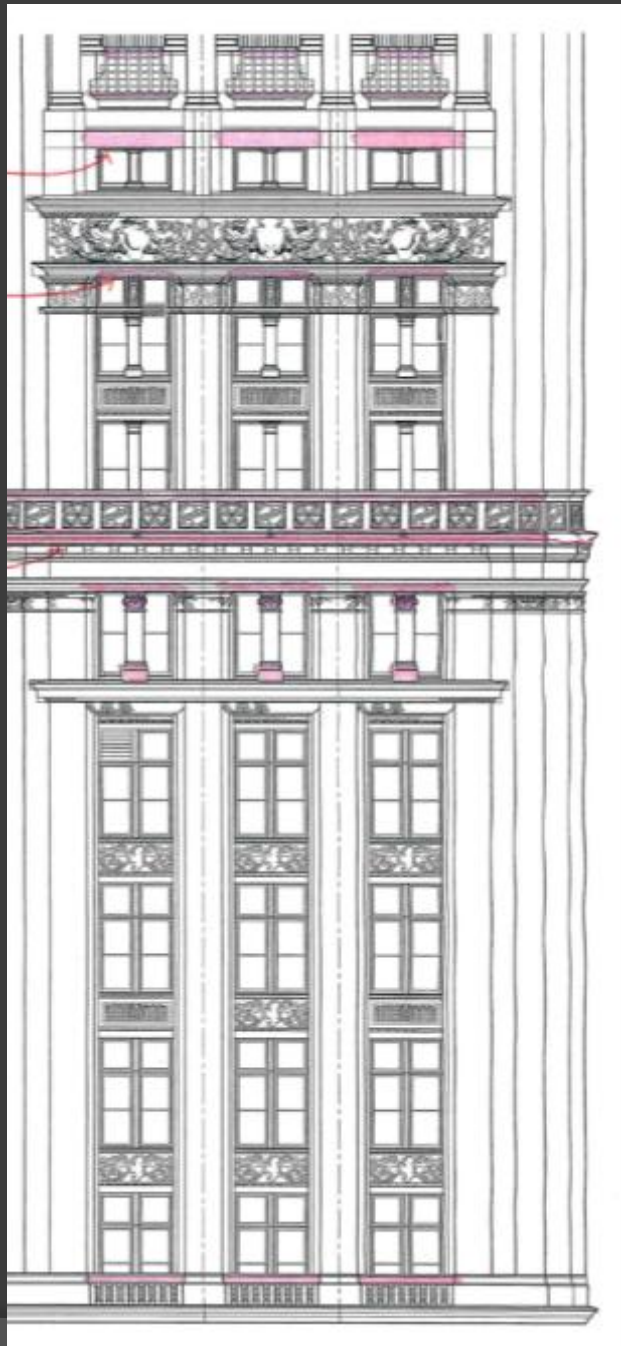


Observations - Urns



Grouted Terra Cotta Units





New Terra Cotta

- Approximately 13,400 new terra cotta units were installed
- Approximately 4,000 units are grouted solid
 - South Tower- 1950 units
 - North facade- 300 units
 - South facade- 550 units
 - East facade- 550 units
 - West facade- 550 units
 - North Facade- 350 units
 - East Facade- 850 units
 - West Facade- 850 units
- Approximately 2,500 units are partially grouted

Inspection(s)



Observations Base Building



Dormer & cross
gable copings

Observations Base Building



Dormer and cross
gable copings

Observations Base Building



8th floor water table

Observations South Tower



12th floor balustrade

Observations South Tower



12th floor balustrade

Observations South Tower



12th floor balustrade

Observations South Tower



Turret urn bases

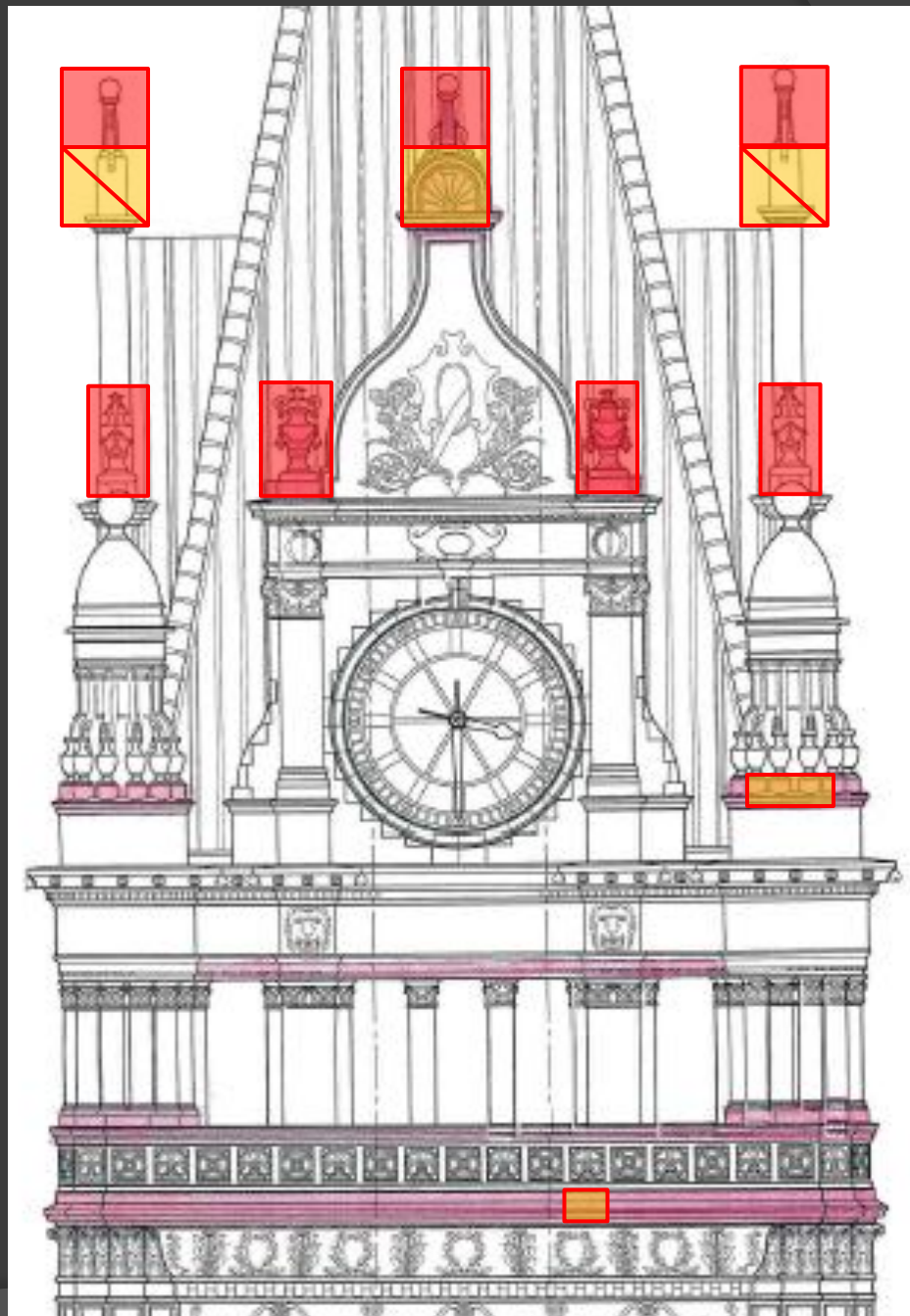
Observations South Tower



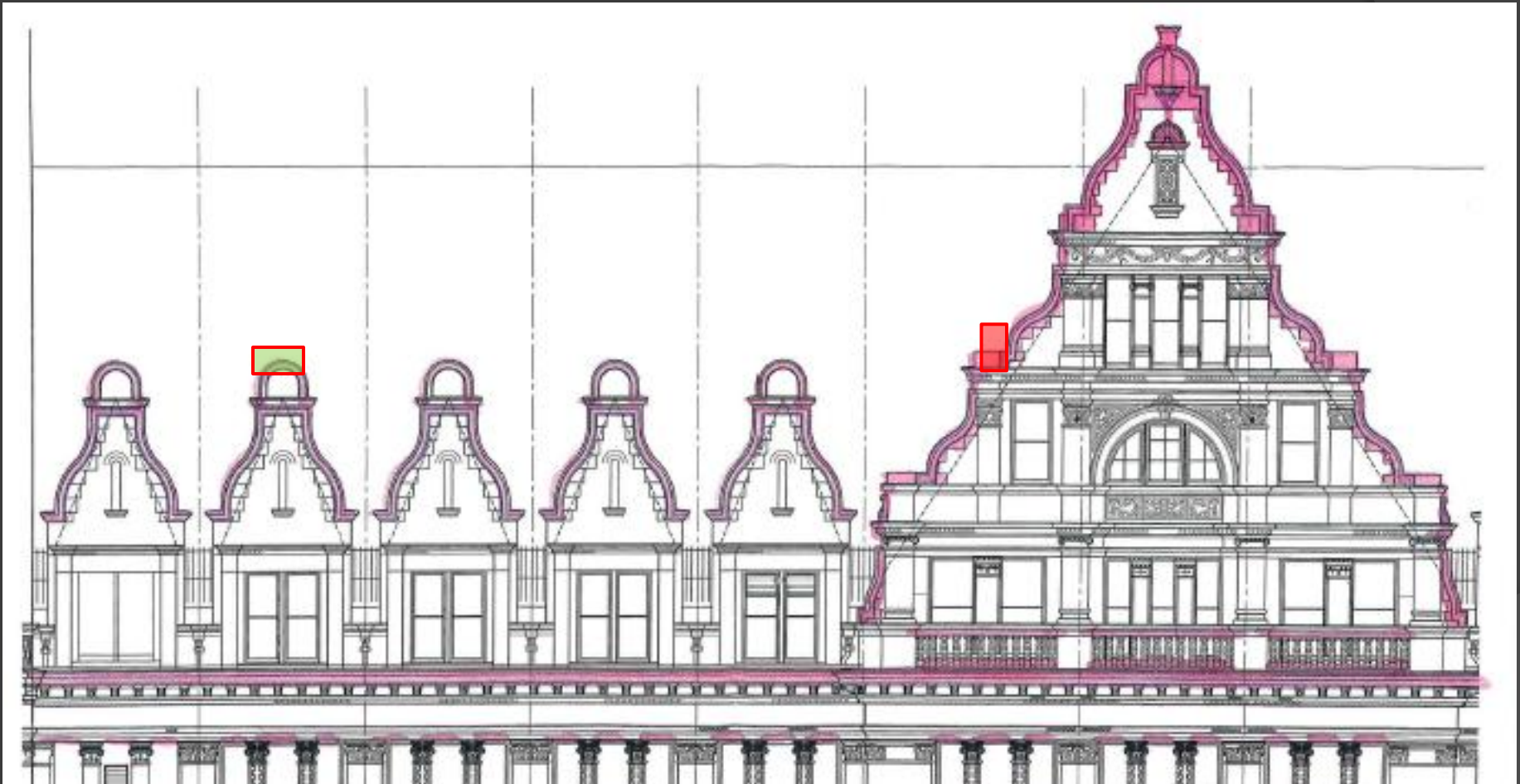
Finial bases

Removal or Stabilize

-  March 2011 (removal)
-  May 2011 (stabilize)
-  May 2011 (removal)
-  December 2011



Removals



Inspection: Summary

- ⦿ Cracking of grouted terra cotta units
 - Urns and finials (removed)
 - Gable, dormer copings and turret finial bases
- ⦿ Glaze spalling of grouted terra cotta units
 - Southern exposure more predominant than northern exposure
 - Primarily 'upward' facing surfaces
- ⦿ Efflorescence at cracks and mortar joints
- ⦿ Failing of upward facing mortar joints
- ⦿ Spalling of terra cotta at watertable 'corners'
- ⦿ Spalling terra cotta below coping flashings

Terra Cotta

- 654 (16%) grouted units show signs of distress.

Cracks- 165 units

South Tower- 72 units

North Facade- 10 units

East Facade- 37 units

West Facade- 46 units

Spalls and/or Efflorescence- 489 units

South Tower- 188 units

North Facade- 19 units

East Facade- 144 units

West Facade- 138 units

Preliminary Test Program

	ASTM Standard	Grout	Mortar	Terra cotta
Petrography	C1324/C856*	X	X	X
Porosity		X	X	X
Permeability		X	X	X
Moisture content	C780*	X	X	X
Compression strength	C67*			X
Coefficient of thermal expansion		X		X
Moisture expansion				X
Glaze adhesion	C1167 / AIA no. 9			X
Glaze permeability	C1167			X
Craze resistance	C126 / AIA no. 9			X
Air content	C780*	X	X	
Modulus of rupture	C67*			X
Modulus of elasticity	C1352*			X
Absorption (24hr and 5 hr)	C1084*/C67	X		X
Saturation coefficient	C67			X
Freeze-thaw resistance	C67	X	X	X
Efflorescence	C67			X
Imperviousness	C126			X
Chemical resistance	C126 / AIA no. 9			X
Drying index		X		

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Grout Testing

- Mix 1 - Grout mixed according to manufacturer's recommendations
- Mix 2 - Grout mixed with water cement ratio similar to installed grout (slump greater than 10 in.—can't correlate directly to w/c ratio)
- Mix 3 – Grout mixed with slump consistent with specifications (8 to 10 in.)

F-T Testing



Free Water



Free Water



Free Water



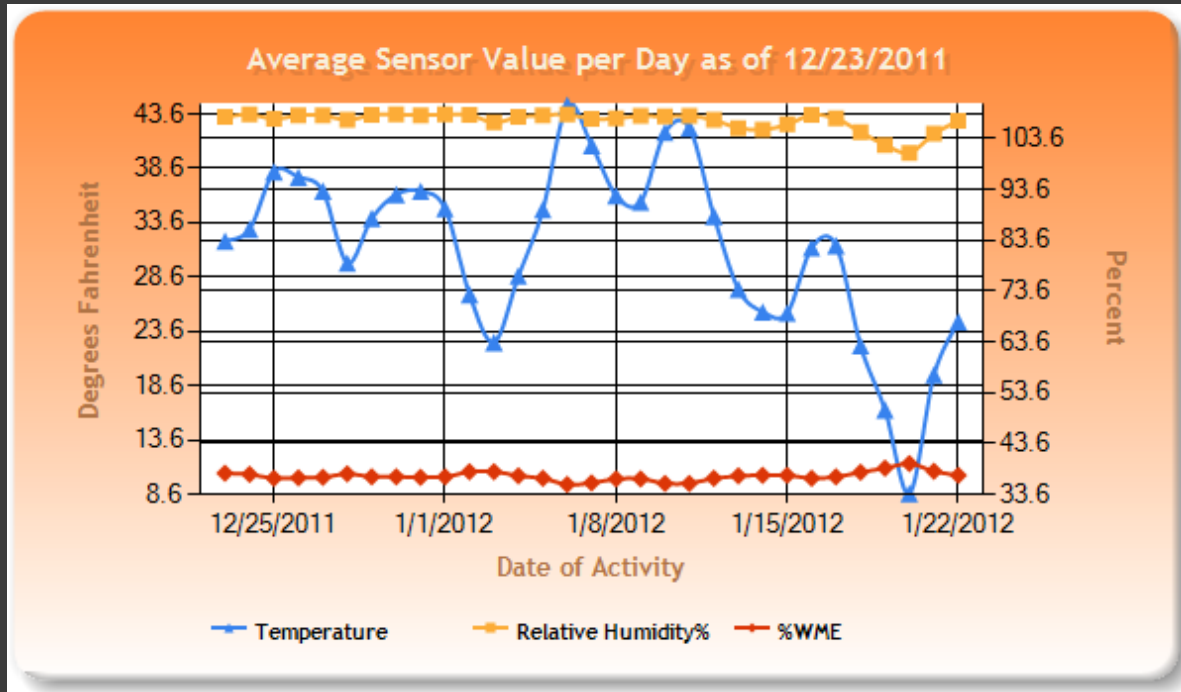
Mock-ups

- Obtain 'Closed' units replicating urn mechanism.
- Place mockup(s) in weathering chamber at representative cure duration as original construction
- Monitor
 - grout drying rate
 - terra cotta cracking
 - Circumferential strain

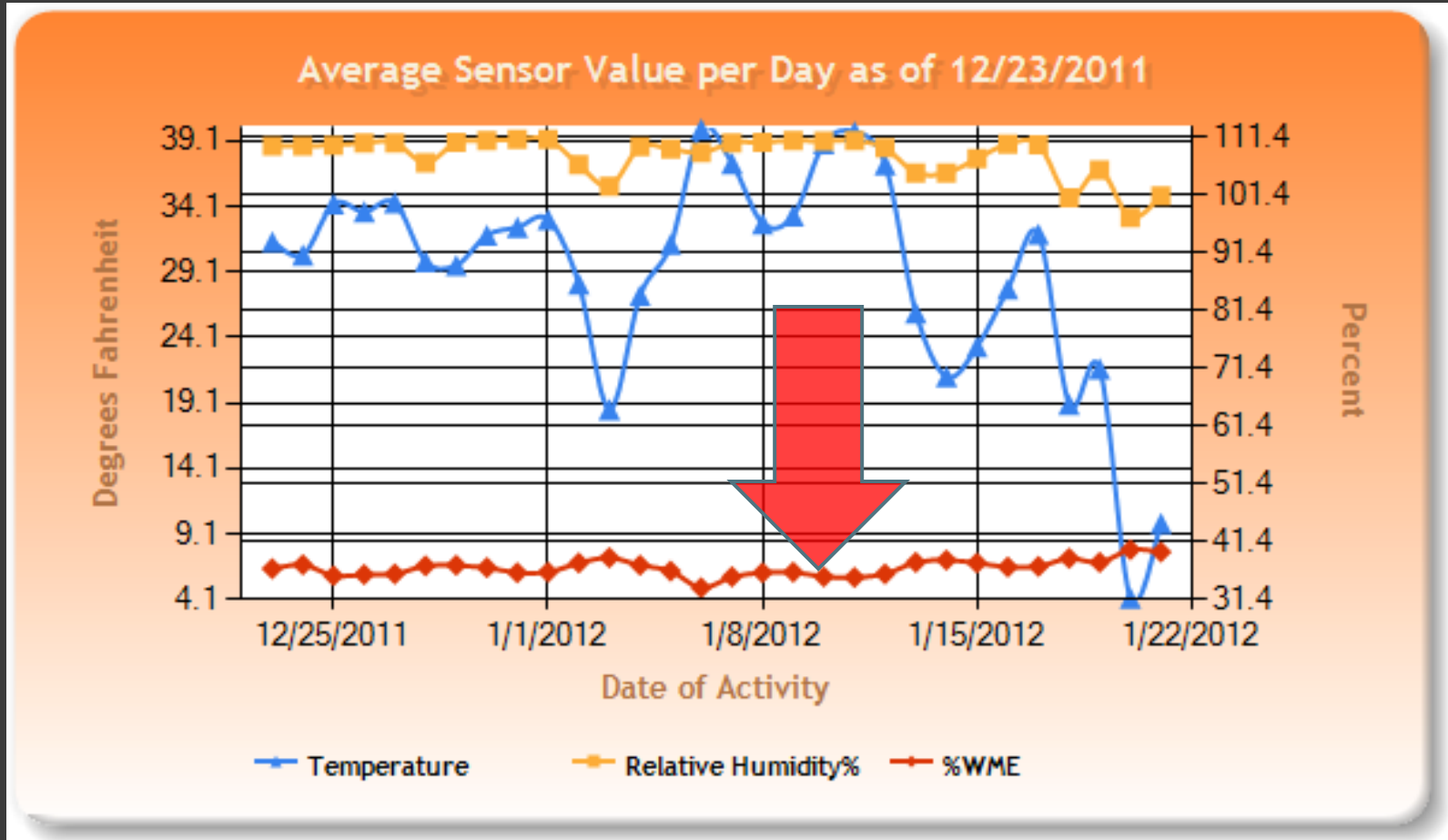
Mockup



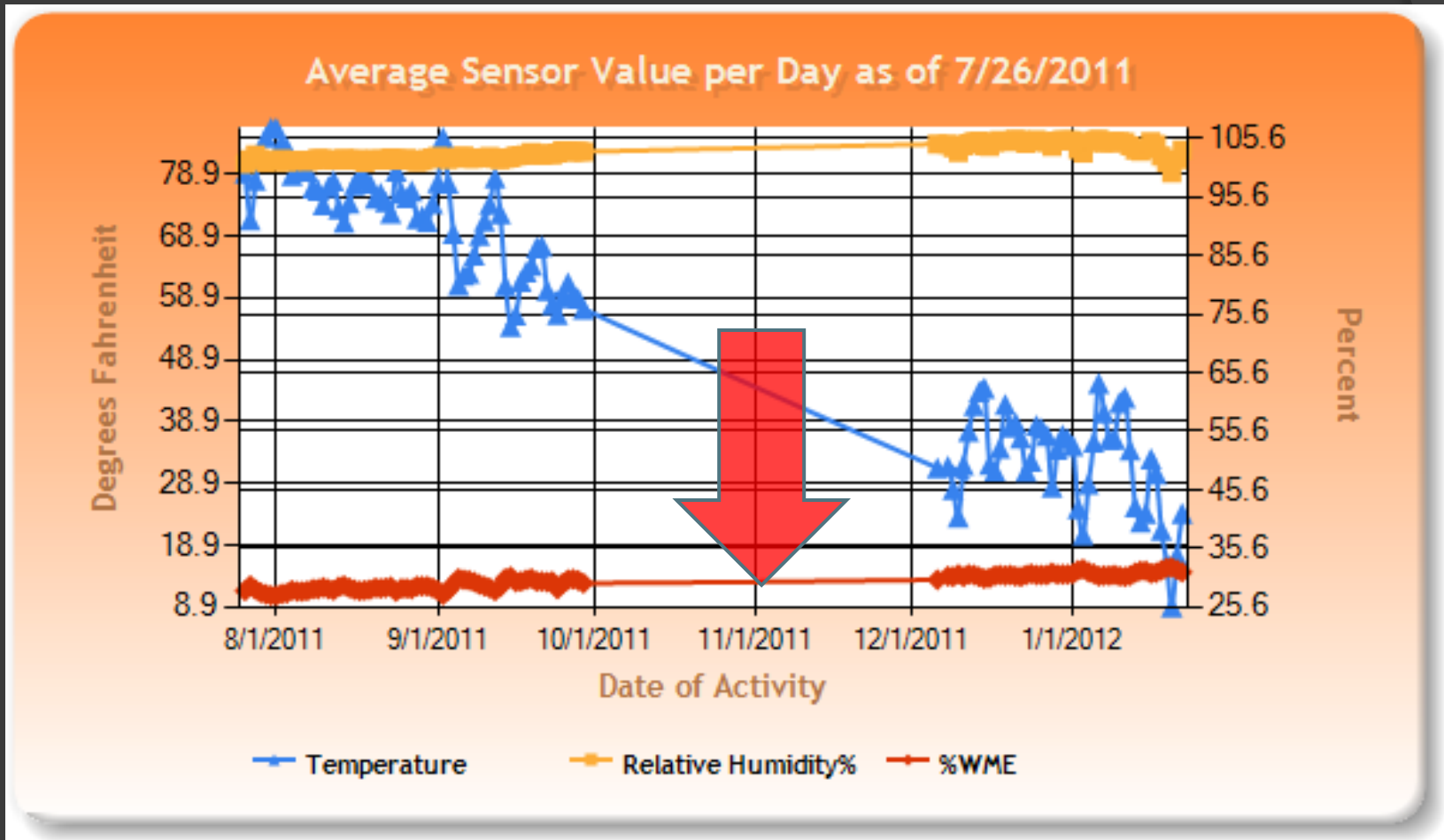
In-situ Monitor



In-situ Monitor (Tower West)









In-situ Monitor (Base East)



Conclusions

- Distress limited to grouted units
- Grout consistency (water content) varies
- Distress has continued to develop

Repair Options

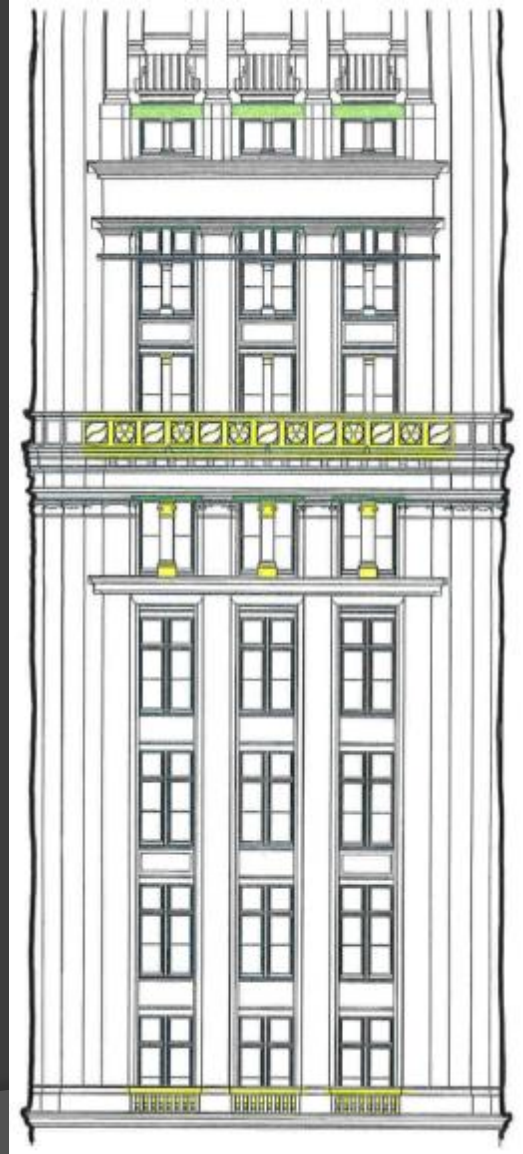
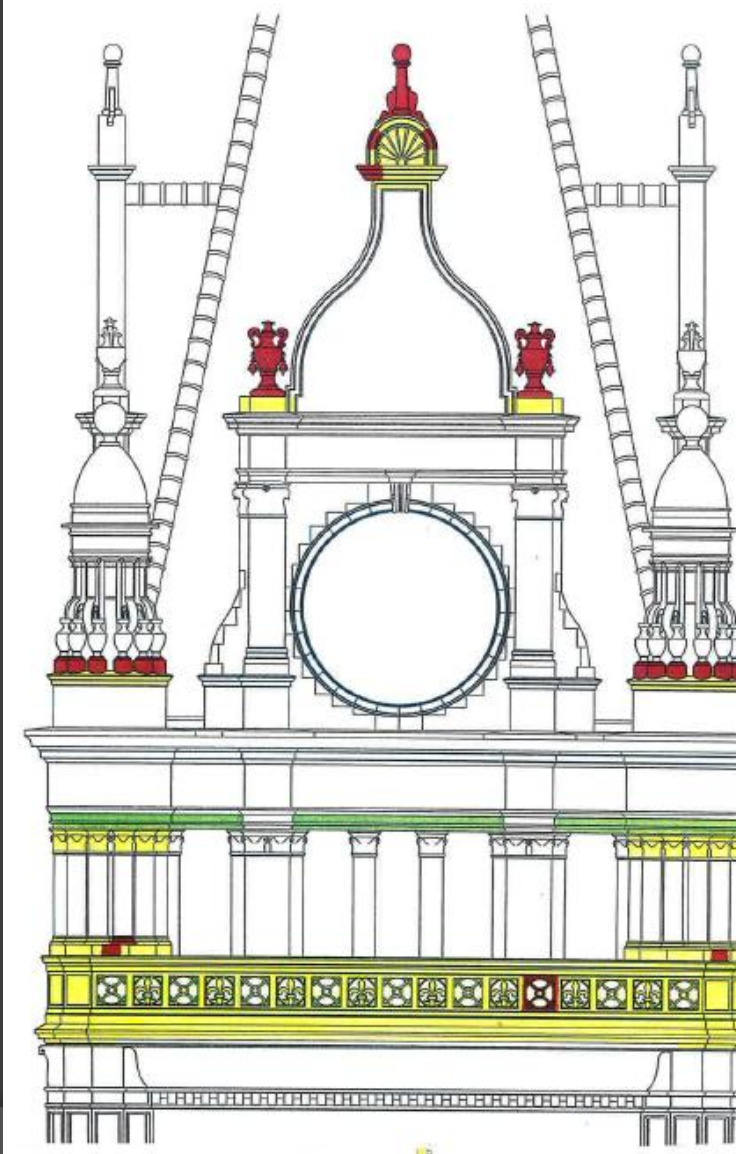
- ① Replace all fully and partially grouted units (~6,500 units)   
 - no follow-up inspection required except for City mandated inspections (5 years)
- ② Replace grouted units types exhibiting distress (~3,500 units)  
 - w/less frequent regular inspections
- ③ Replace only distressed units (~500 units)
 - w/regular inspections 

Repair Options- Cost Estimate

- ◎ Replace all fully and partially grouted units (~6,500 units)
 - ~ \$15,500,000 (per JPC)
- ◎ Replace grouted units types exhibiting distress (~3,500 units)
 - ~ \$11,000,000* (per WJE)
- ◎ Replace only distressed units (~500 units)
 - ~ \$9,000,000* (per WJE)

*First cost only. Does not include subsequent inspections

Repair Options- Tower



Repair Option- Base, lower floors



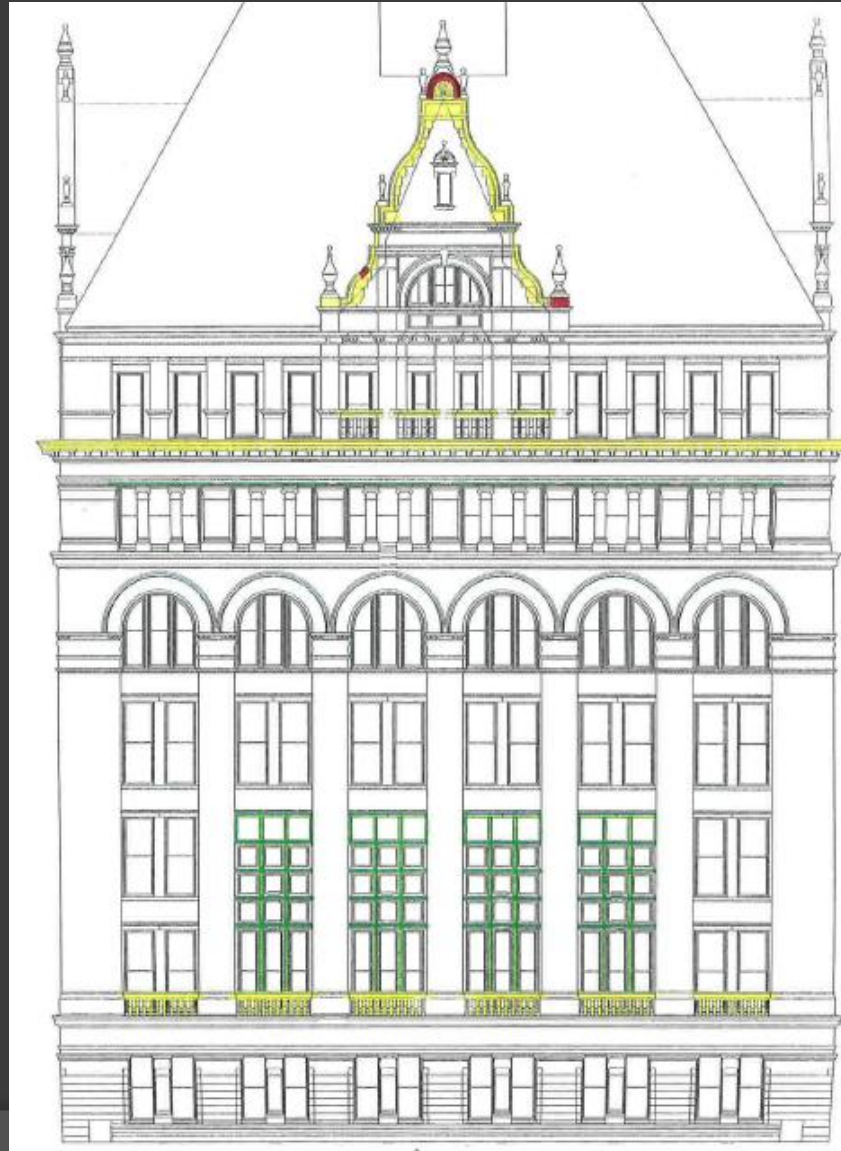
Repair Options- Base, roof area



Repair Options- Base, roof area



Repair Options- Base



Questions