Brindley Engineering

2018 ICRI Spring Convention
Seismic Solutions

Industrial Structure Column Repair

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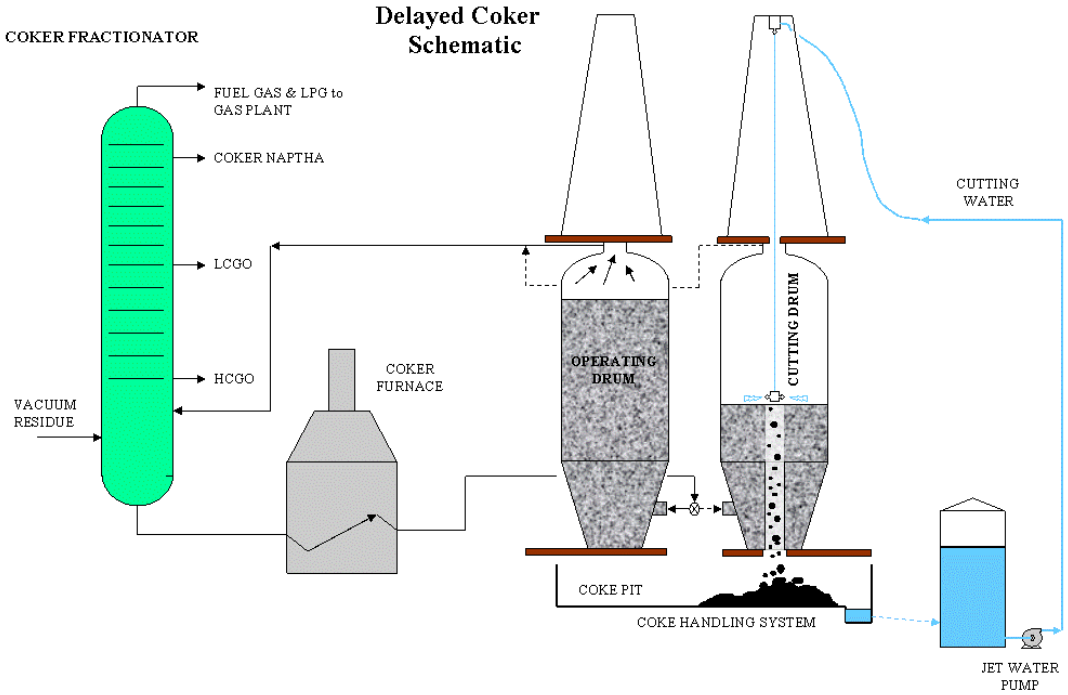
Presentation Outline

- Project Background
- Deterioration Mechanism
- Repair Strategy
- Seismic Design Challenges
- Constructability Challenges
- Results

Coker Operation

Structural Loads:

- Extremely heavy Operating Loads (full drums, proof loads)
- Comparatively light Dead Loads
- Resulted in full perimeter column repairs (instead of phased approach)



Coker Unit at a Midwest Refinery

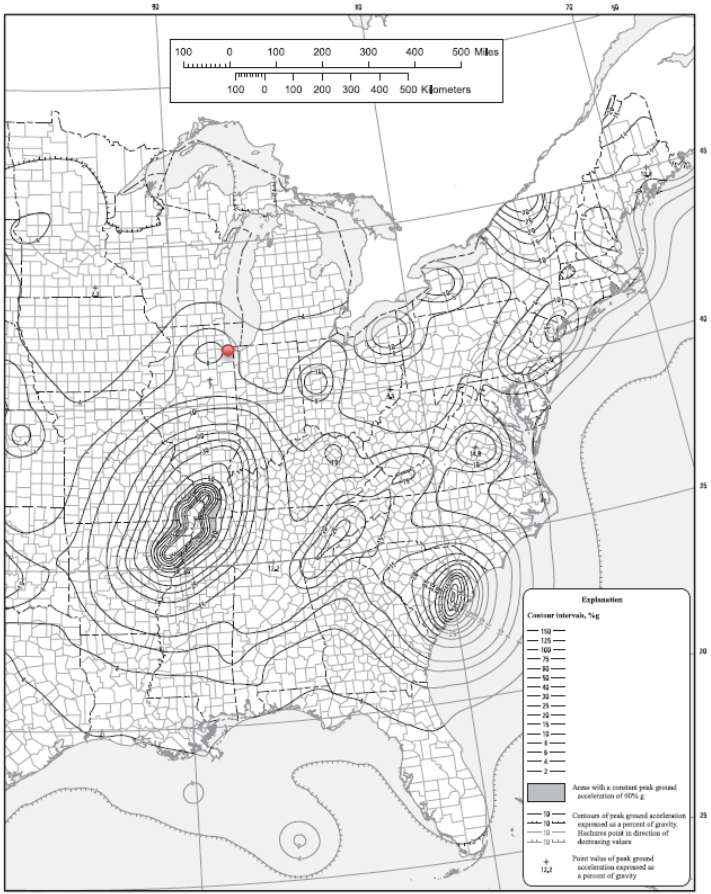
- 3 Steel Derrick Structures
- 6 Coke Drums (2 per Derrick)
- 3 Concrete Decks
- Concrete Chute
- Coke Pit
- Overhead Crane

Project Timeline:

1. Repair accessible Columns prior to unit outage (phased)
2. Remove Top Derricks
   (Max 700,000 lbs)
3. Remove Old Drums
   (Max 480,000 lbs)
4. Repair Concrete Structure
   (45’ tall)
5. Install New Drums
   (Max 550,000 lbs)
6. Re-install Top Derricks
7. 47 days

Design Parameters

- Determine Extent of Concrete Damage
- Design for Additional Loads of New Drum
- Determine Loading During Construction
- Seismic Considerations
  - Category B
  - ACI 318-11 Chapter 21 Section 21.3.3.2
  - Stirrup Spacing reduced from 18” to 6”



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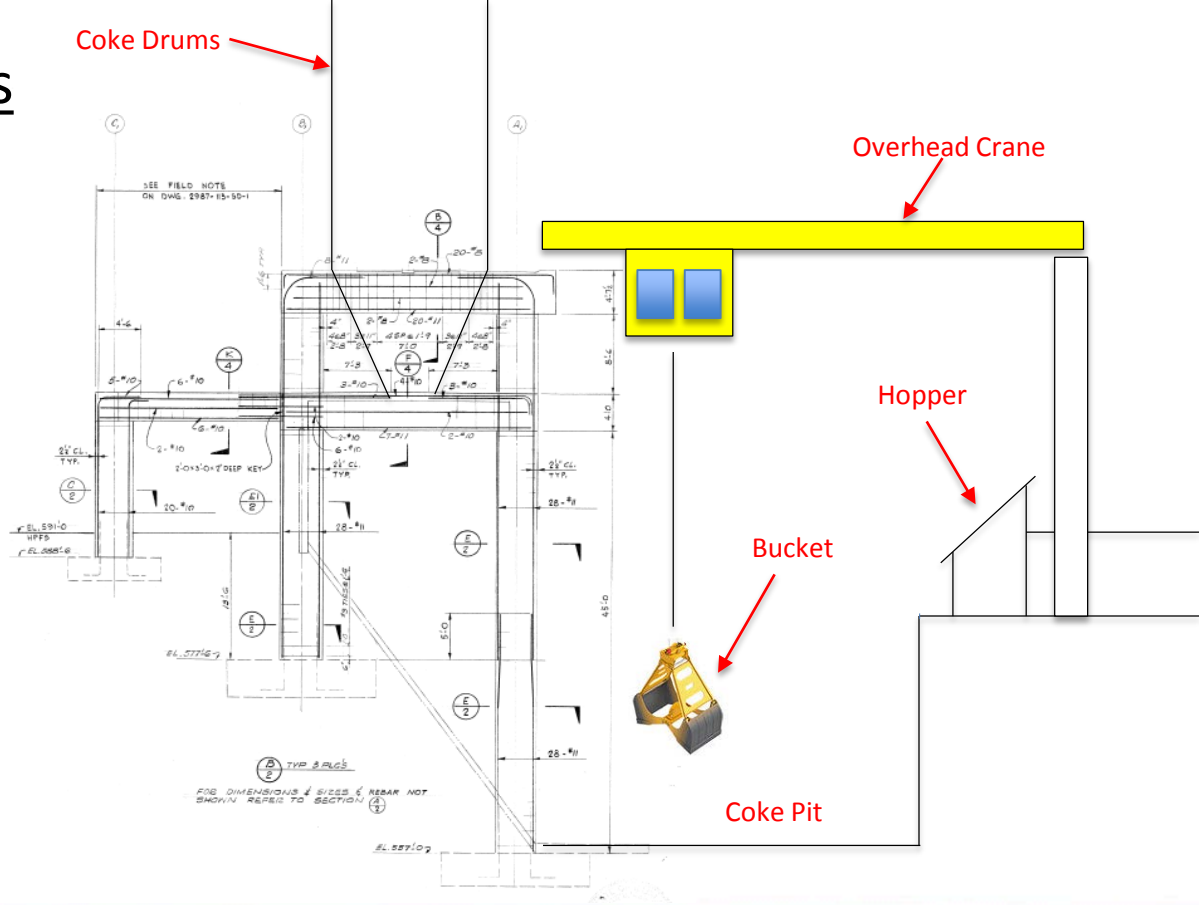
Deterioration Mechanisms

- Mechanical and impact damage
- Water and moisture cycles
- Freeze / thaw cycle
- Temperature differences
- Vibrations from equipment



Deterioration

- #3 Stirrup spacing at 18” (many were damaged)
- Structure vulnerable to brittle column failure in seismic event
- Code requires 6”
- Heavy deterioration
- No concrete cover in many spots

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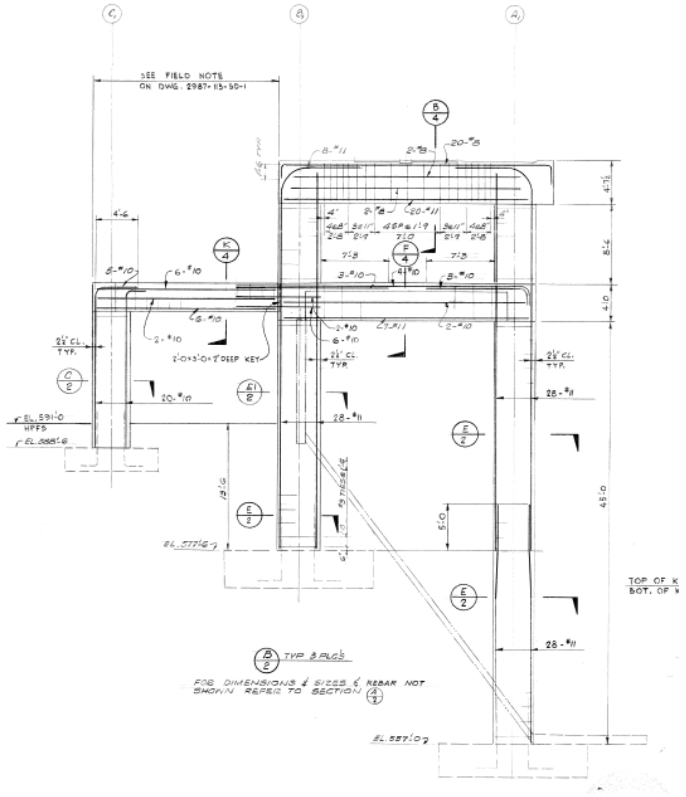
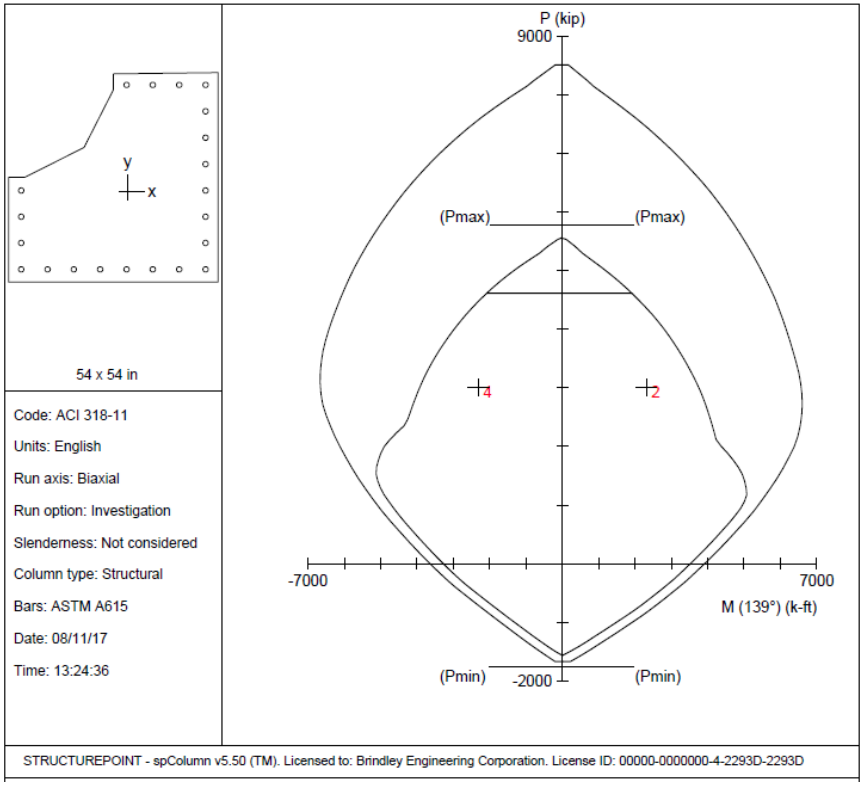
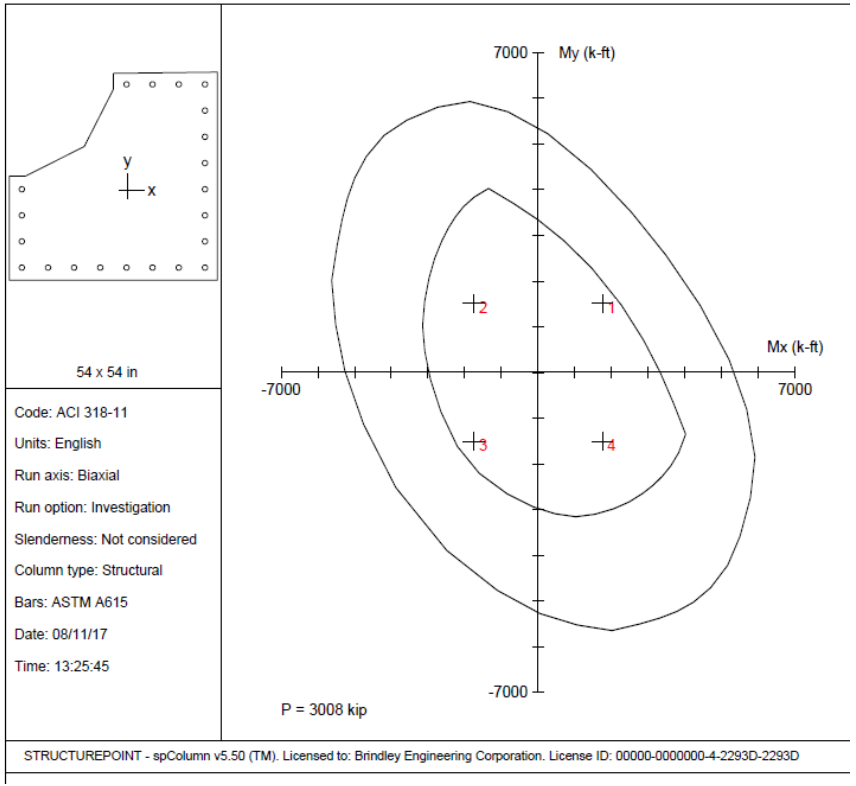
Repair strategy

- Column Repairs phased based on loading and accessibility. 3 different loading conditions:
  - Fully loaded drums and derricks
  - Empty drums
  - Removed drums and derricks
- Installing new shear reinforcement
- Augmenting damaged reinforcement



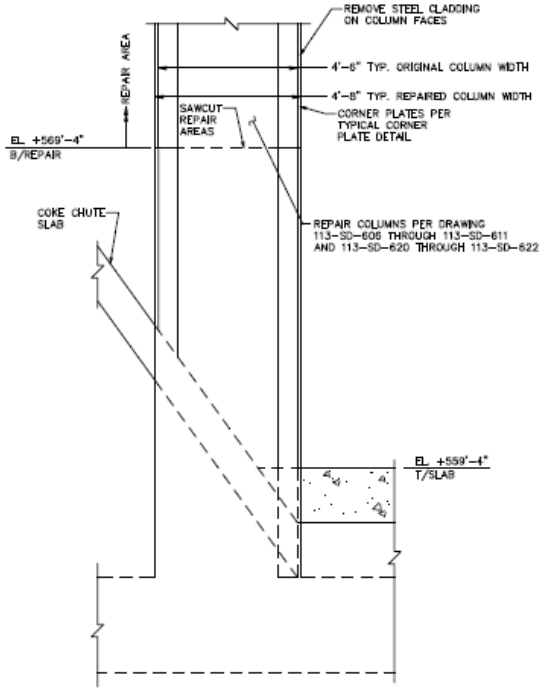
Phasing


P (kip)
9000
(Pmax)
(Pmax)
y
x
54 x 54 in
Code: ACI 318-11
Units: English
Run axis: Biaxial
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 08/11/17
Time: 13:24:36
-7000
7000
M (139°) (k-ft)
(Pmin)
-2000
(Pmin)
STRUCTUREPOINT - spColumn v5.50 (TM). Licensed to: Brindley Engineering Corporation. License ID: 00000-0000000-4-2293D-2293D

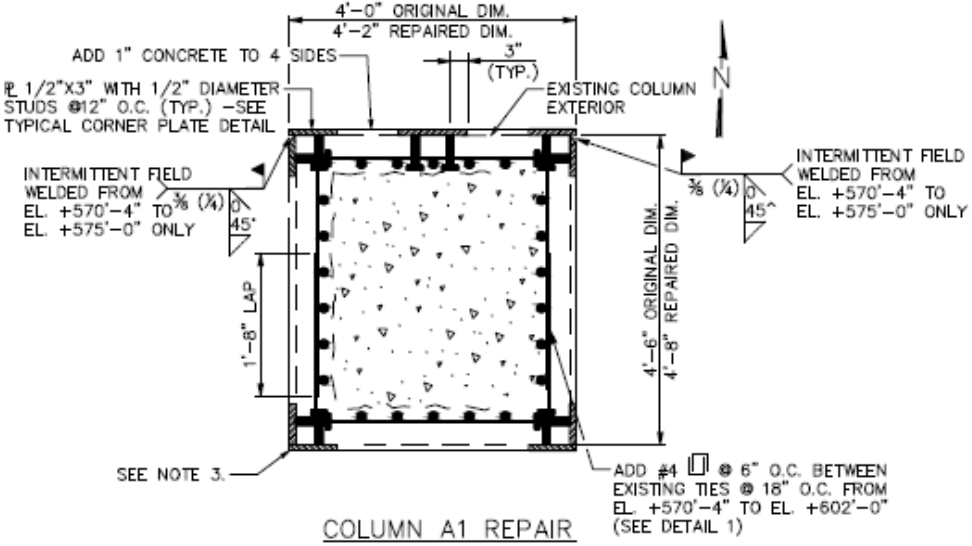

7000
My (k-ft)
y
x
54 x 54 in
Code: ACI 318-11
Units: English
Run axis: Biaxial
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 08/11/17
Time: 13:25:45
-7000
7000
Mx (k-ft)
-7000
P = 3008 kip
STRUCTUREPOINT - spColumn v5.50 (TM). Licensed to: Brindley Engineering Corporation. License ID: 00000-0000000-4-2293D-2293D

Repair strategy

- Stirrup spacing reduced from 18” to 6” to meet current seismic requirements and increase column ductility
- Vertical reinforcement augmented
- Cathodic protection installed
- Higher strength concrete

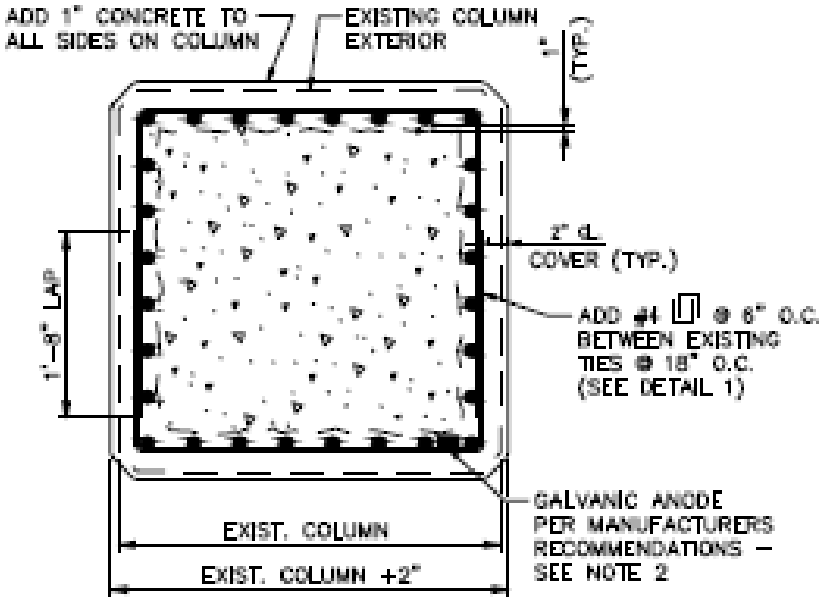


TYPICAL COLUMN LINE A REPAIR
ELEVATION LOOKING WEST



COLUMN A1 REPAIR

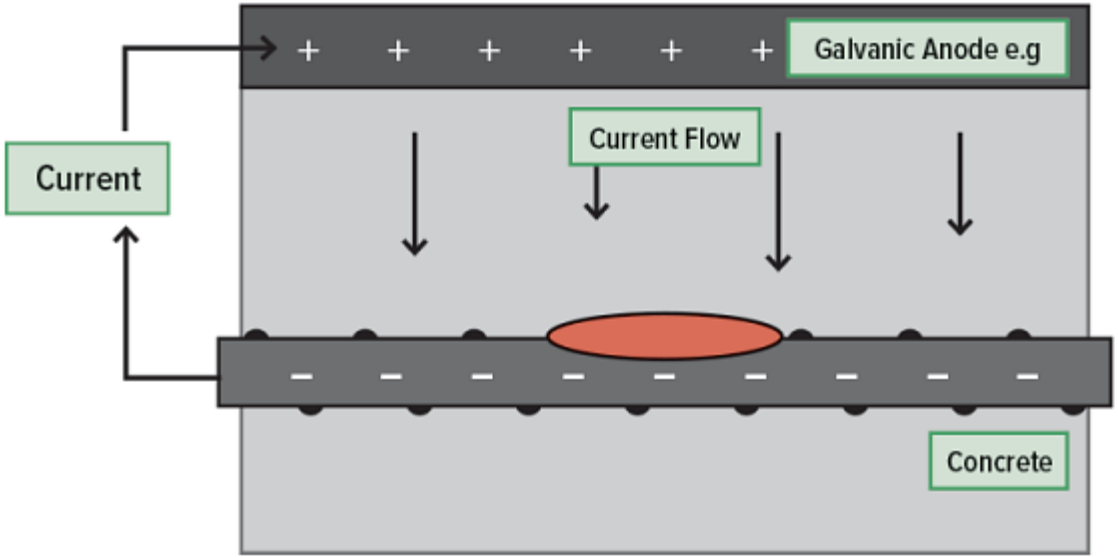
Repair strategy



Cathodic Protection

Anodic Ring (Halo Effect)

- Halo Effect phenomena is associated with a repair area that is surrounded by “new” corrosion sites.
- Halo Effect is one of the primary reasons for shot-lived repairs.

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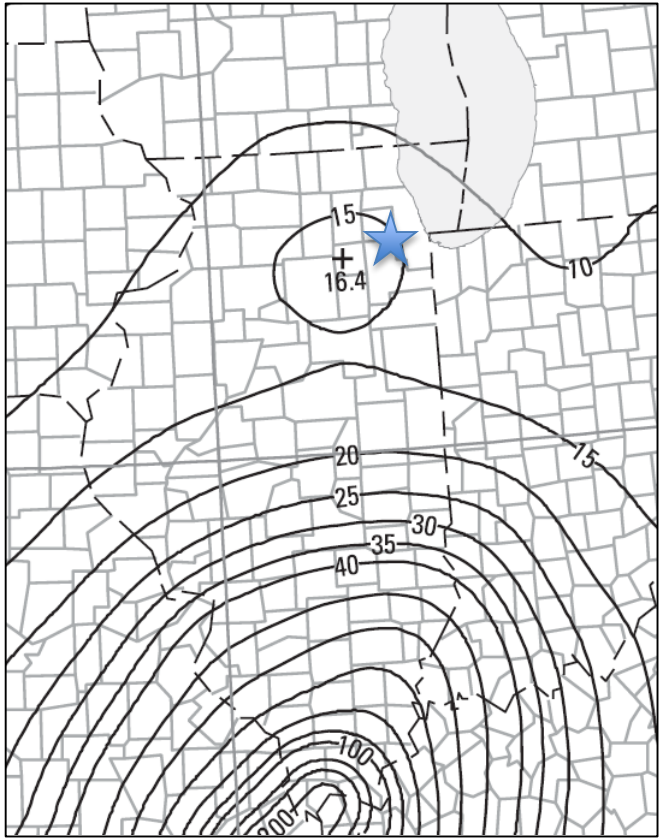

Explanation

Contour intervals, %g

300
200
150
125
100
90
80
70
60
50
40
35
30
25
20
15
10
5

Areas with a constant spectral response acceleration of 150% g

10 10 10 10 — Contours of spectral response acceleration expressed as a percent of gravity. Hachures point in direction of decreasing values

+ 16.9 — Point value of spectral response acceleration expressed as a percent of gravity

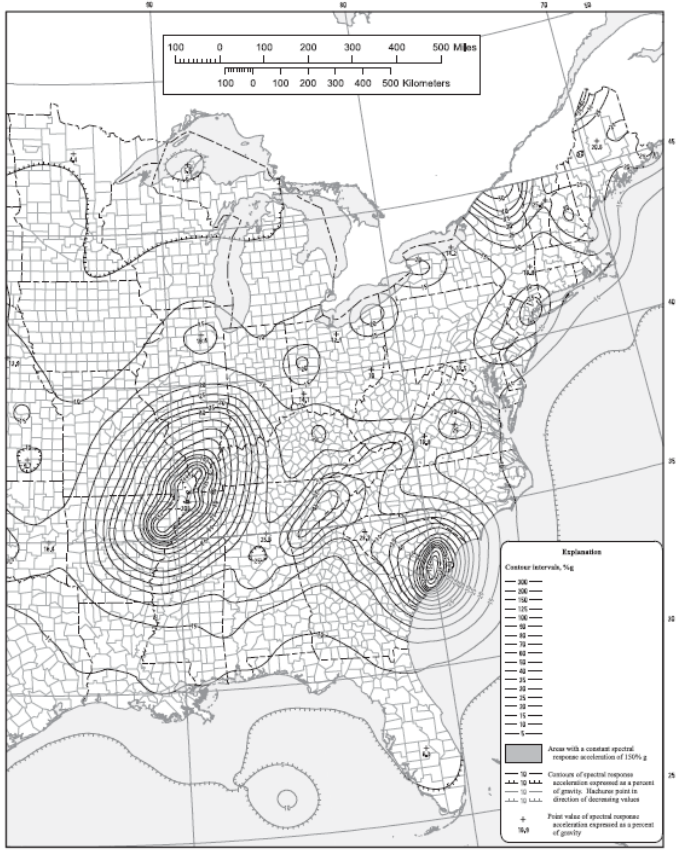

FIGURE 22-1 *(Continued)*

Per IBC 2012 Section 1901 General:

- 1901.1 Scope. The provisions of this chapter shall govern the materials, quality control, design and construction of concrete used in structures.
- 1901.2 Plain and reinforced concrete. Structural concrete shall be designed and constructed in accordance with the requirements of this chapter.

Zone 1 is an outdated term to define seismic risk which has been replaced by the term “seismic design category” (SDC). The current SDC corresponding to Zone 1 is “B” per ACI 318-14, Table R5.2.2.

Table R5.2.2—Correlation between seismic-related terminology in model codes

Code, standard, or resource document and edition	Level of seismic risk or assigned seismic performance or design categories as defined in the Code		
ACI 318-08, ACI 318-11, ACI 318-14; IBC of 2000, 2003, 2006, 2009, 2012; NFPA 5000 of 2003, 2006, 2009, 2012; ASCE 7-98, 7-02, 7-05, 7-10; NEHRP 1997, 2000, 2003, 2009	SDC[1] A, B	SDC C	SDC D, E, F
ACI 318-05 and previous editions	Low seismic risk	Moderate/ intermediate seismic risk	High seismic risk
BOCA National Building Code 1993, 1996, 1999; Standard Building Code 1994, 1997, 1999; ASCE 7-93, 7-95; NEHRP 1991, 1994	SPC[2] A, B	SPC C	SPC D, E
Uniform Building Code 1991, 1994, 1997	Seismic Zone 0, 1	Seismic Zone 2	Seismic Zone 3, 4

[1]SDC = seismic design category as defined in code, standard, or resource document.
[2]SPC = seismic performance category as defined in code, standard, or resource document.


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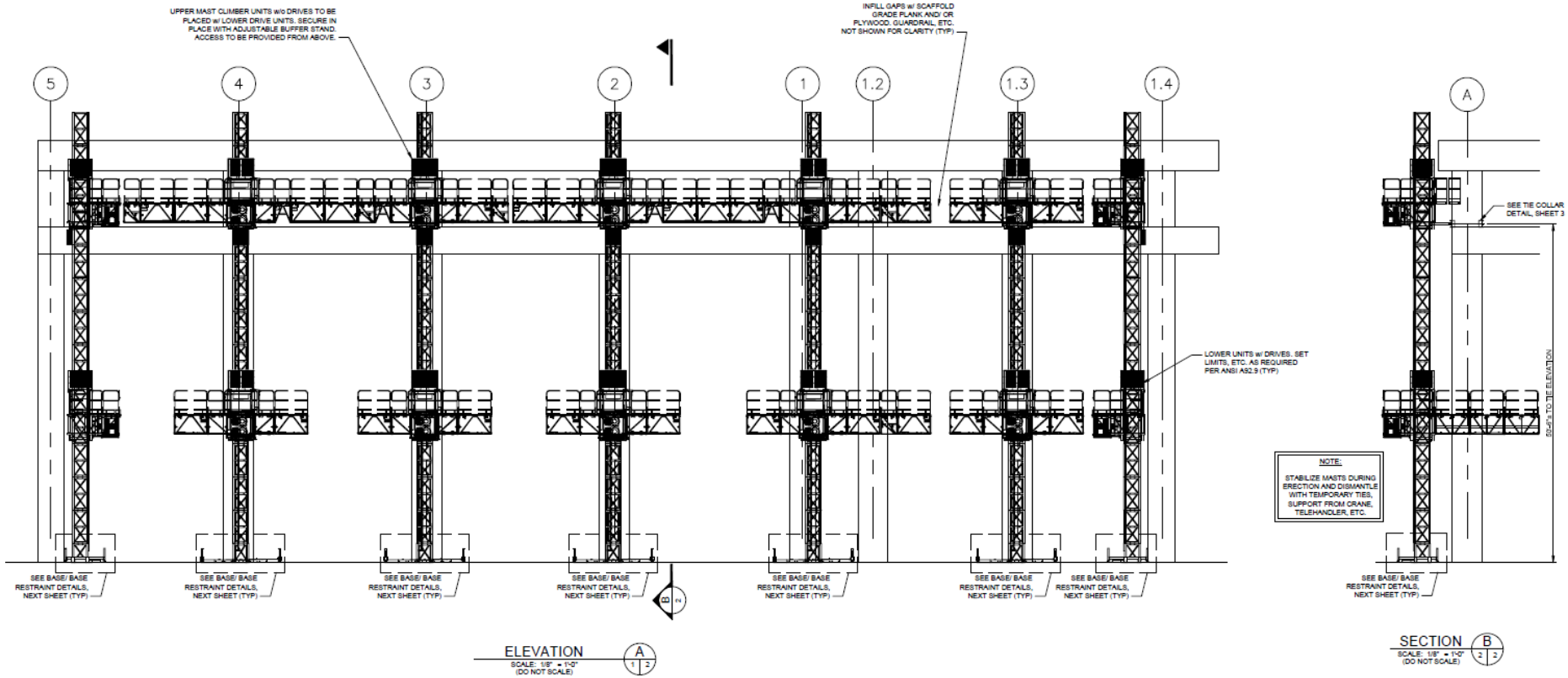
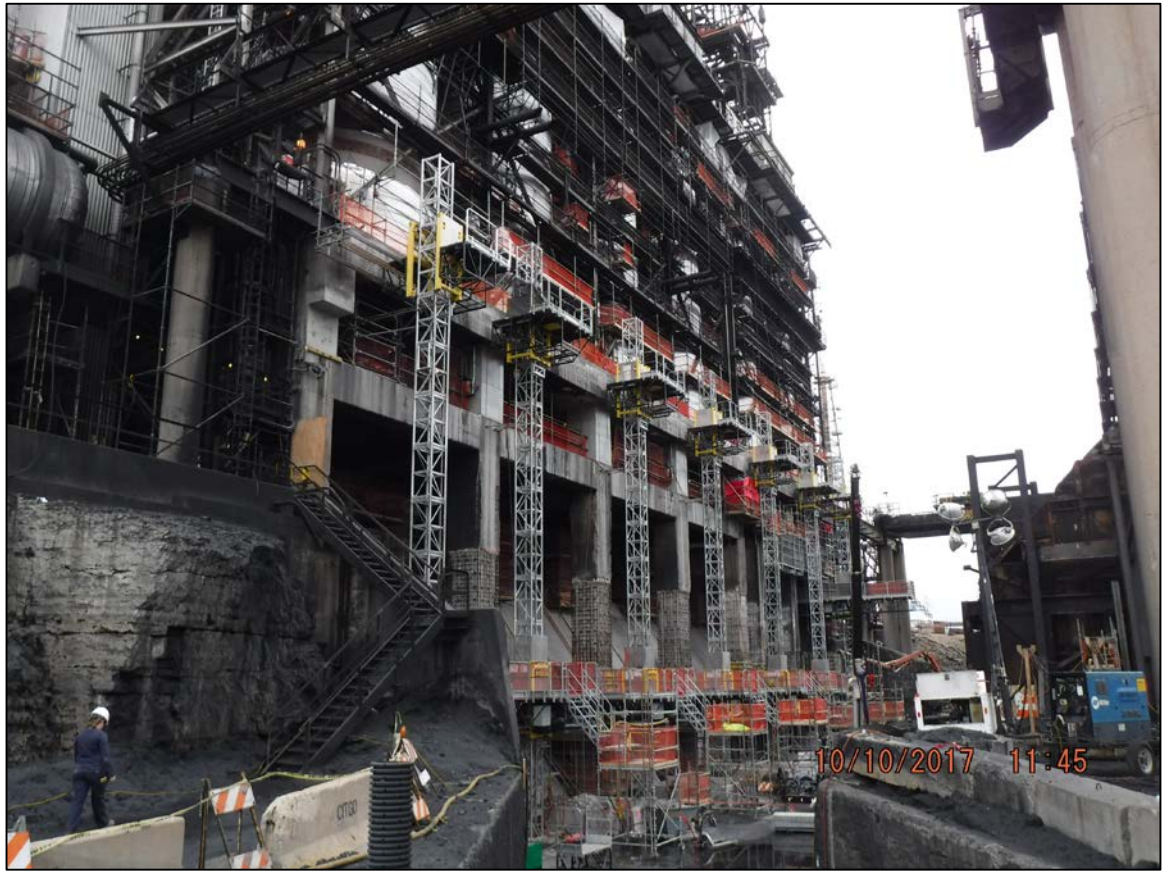
Mast Climbers

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Lessons Learned

- System for Identifying Reinforcement Augmentation
- Engineering Field Support Beneficial
- 30lb hammers for concrete surface and 15lb hammers around reinforcement
- Importance of considering constructability in repair design and in meeting current seismic code provisions

Project Team:

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QUESTIONS?