Pentagon – Case Study

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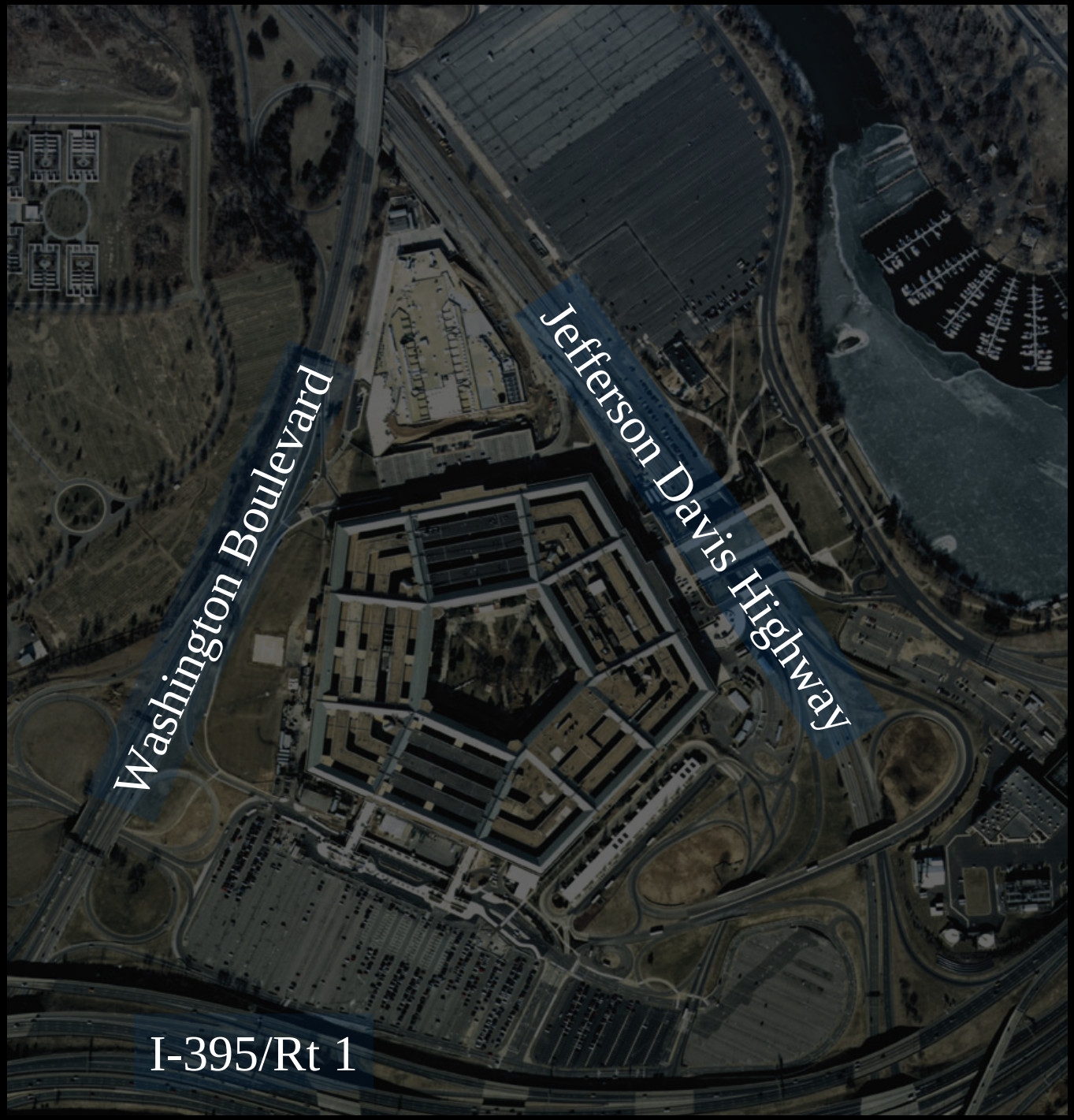
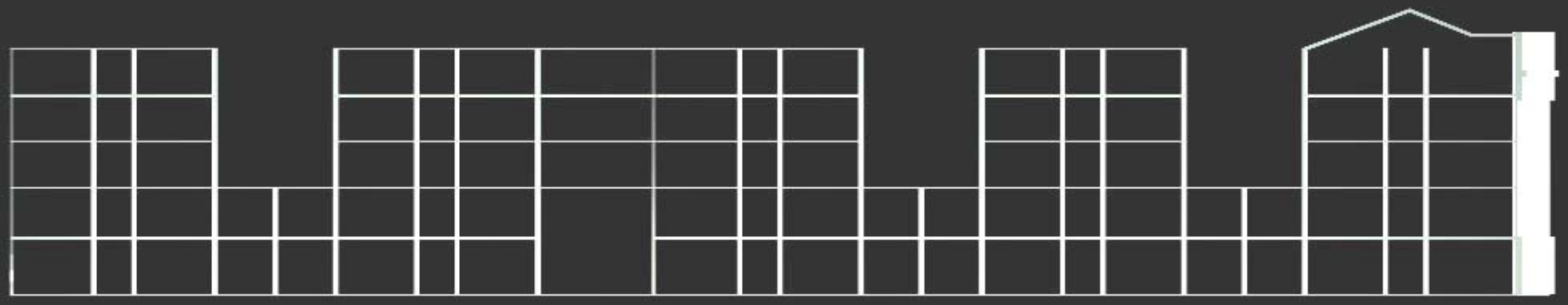

Washington Boulevard
Jefferson Davis Highway
I-395/Rt 1

Original Construction
5 rings, wedges, and floors

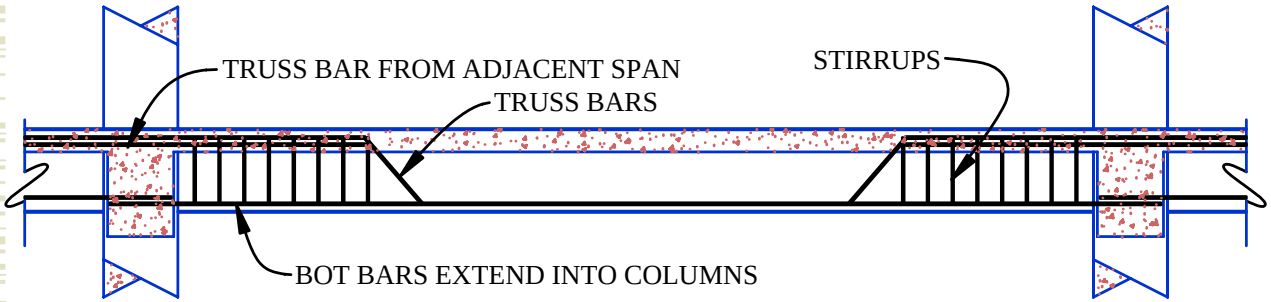
Cross Section through Pentagon

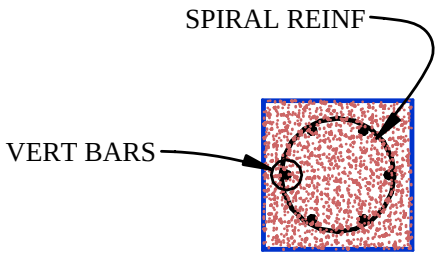


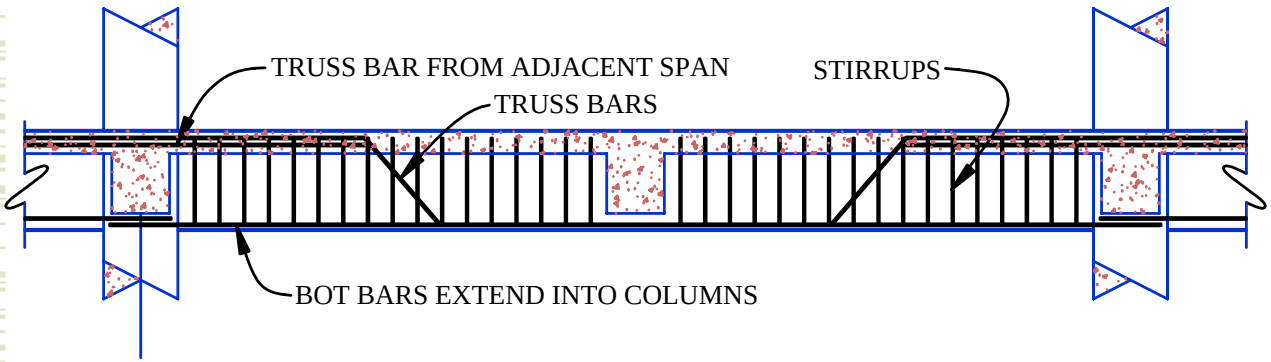
Structural System

- Reinforced concrete
- Square columns: 14 / 16 / 20 in
- Girders on column lines
- Spans: 20 and 10 ft
- Intermediate beams at 10 ft on center
- Concrete strength: 2,500 psi (specified)
- Steel yield strength: 40,000 psi
- Designed for 150 psf live load

Typical Column, Girder, Beam







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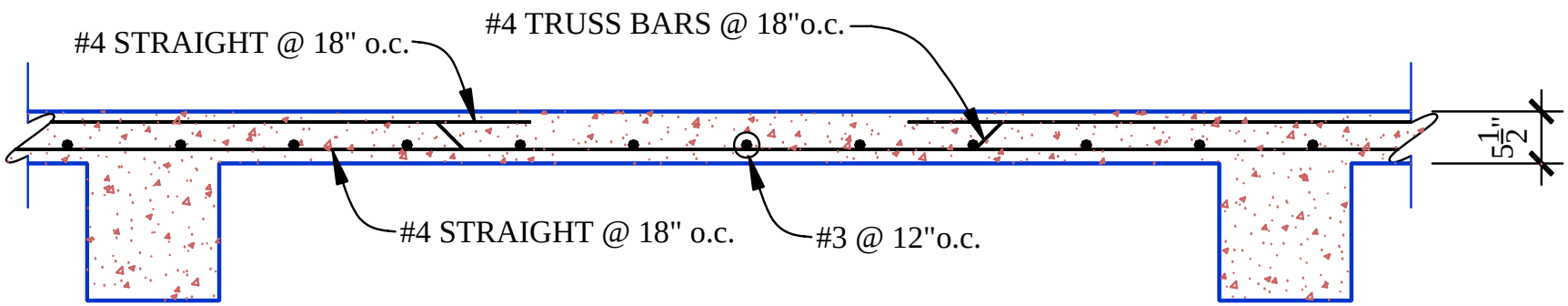
Typical Slab



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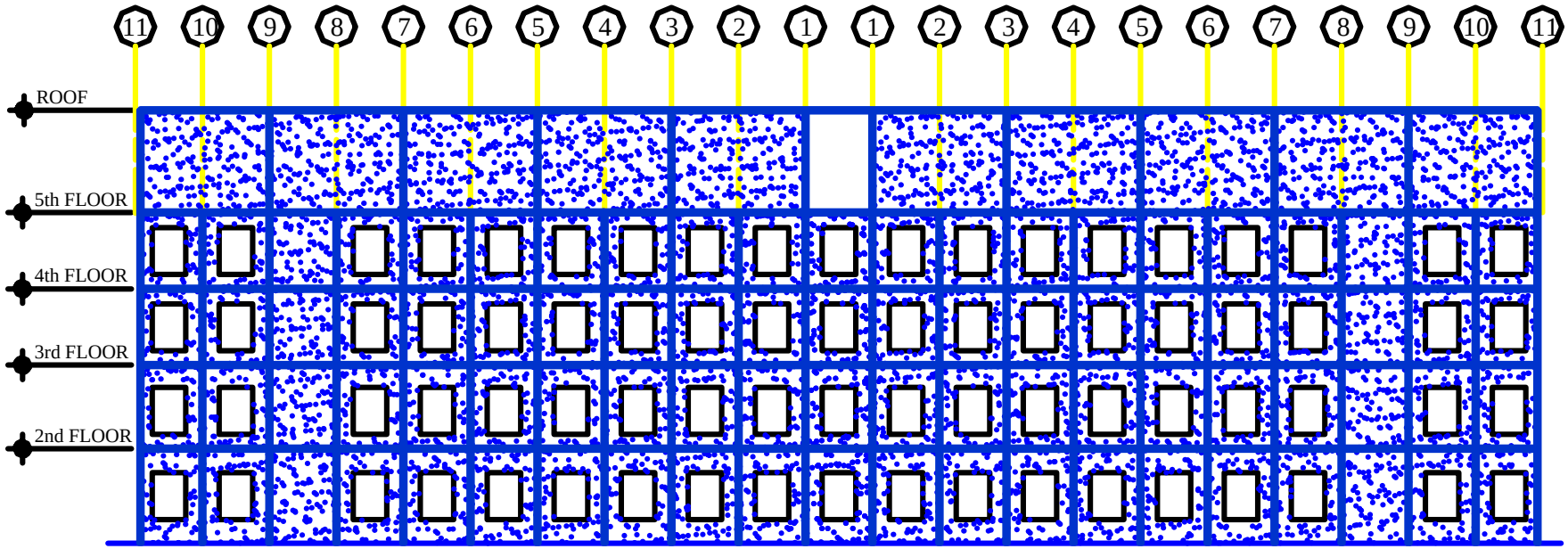
Exterior Wall



NOTE: EXTERIOR INFILL WALLS CONSIST OF 5" LIMESTONE PANELS OVER (2) WYTHE BRICK MASONRY INFILL INSIDE CONCRETE FRAME.

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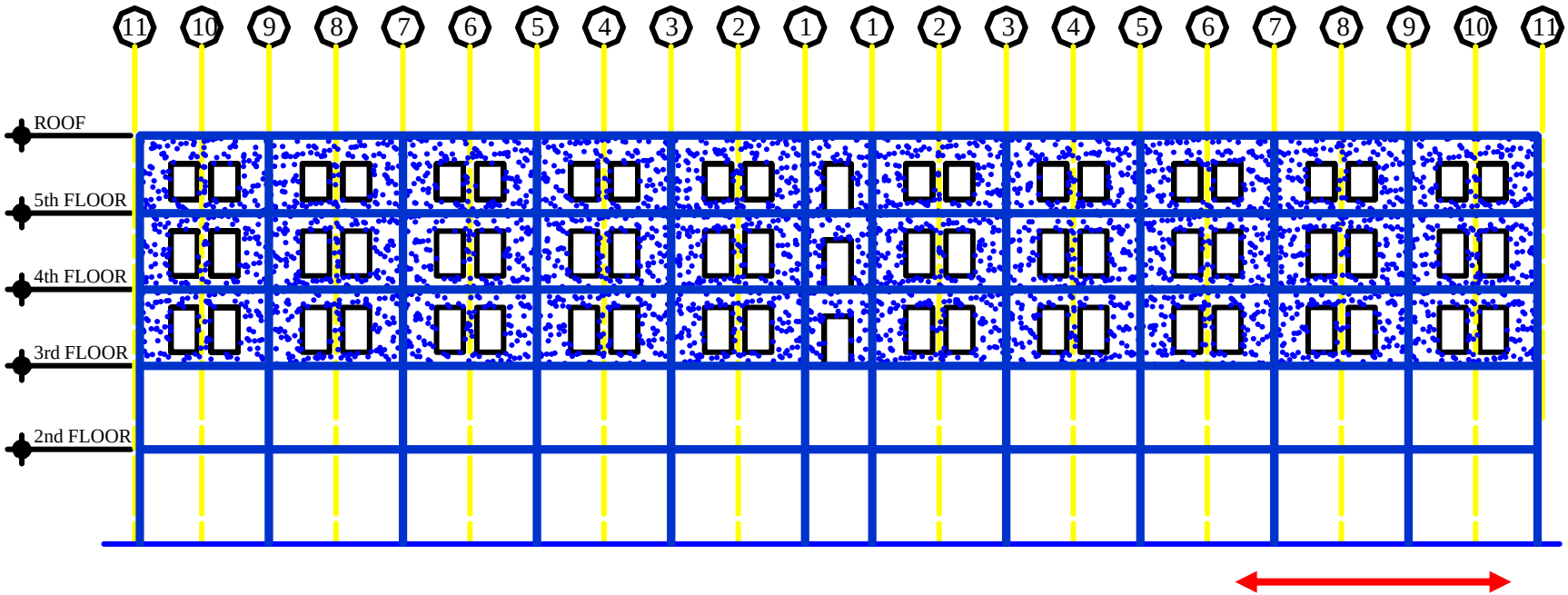
Lightwell Wall



LS Lost columns

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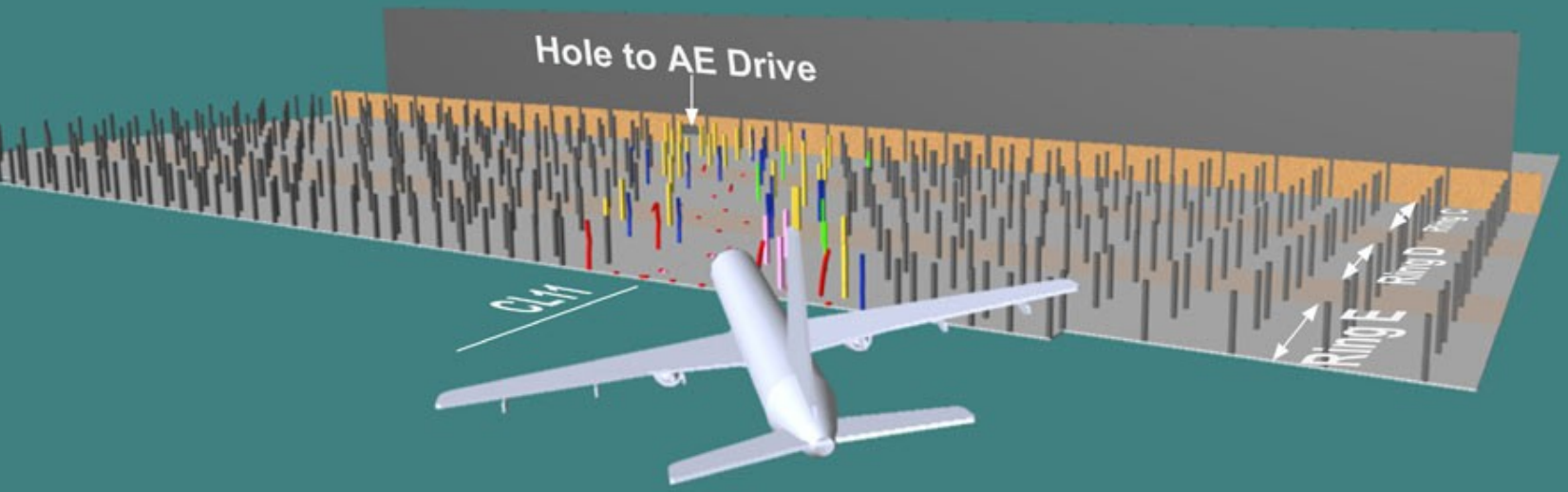

- Light cracking and spalling, no significant impairment
- Heavy cracking and spalling, with significant impairment
- Large deformation, with significant impairment
- Missing, broken, disconnected
- Presumed to have significant impairment

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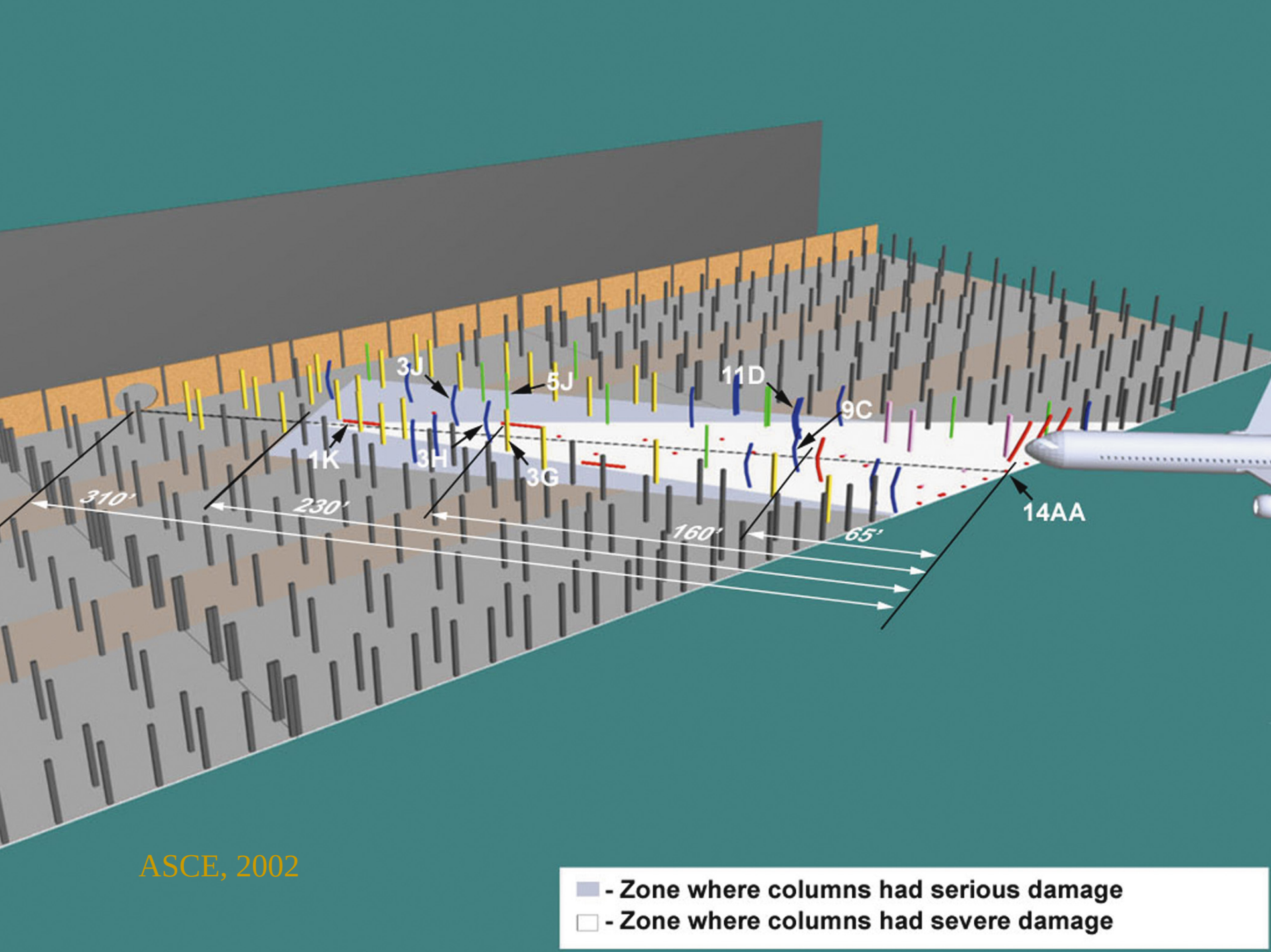
3J
5J
11D
9C
1K
3H
3G
14AA
310'
230'
160'
65'
- Zone where columns had serious damage
- Zone where columns had severe damage

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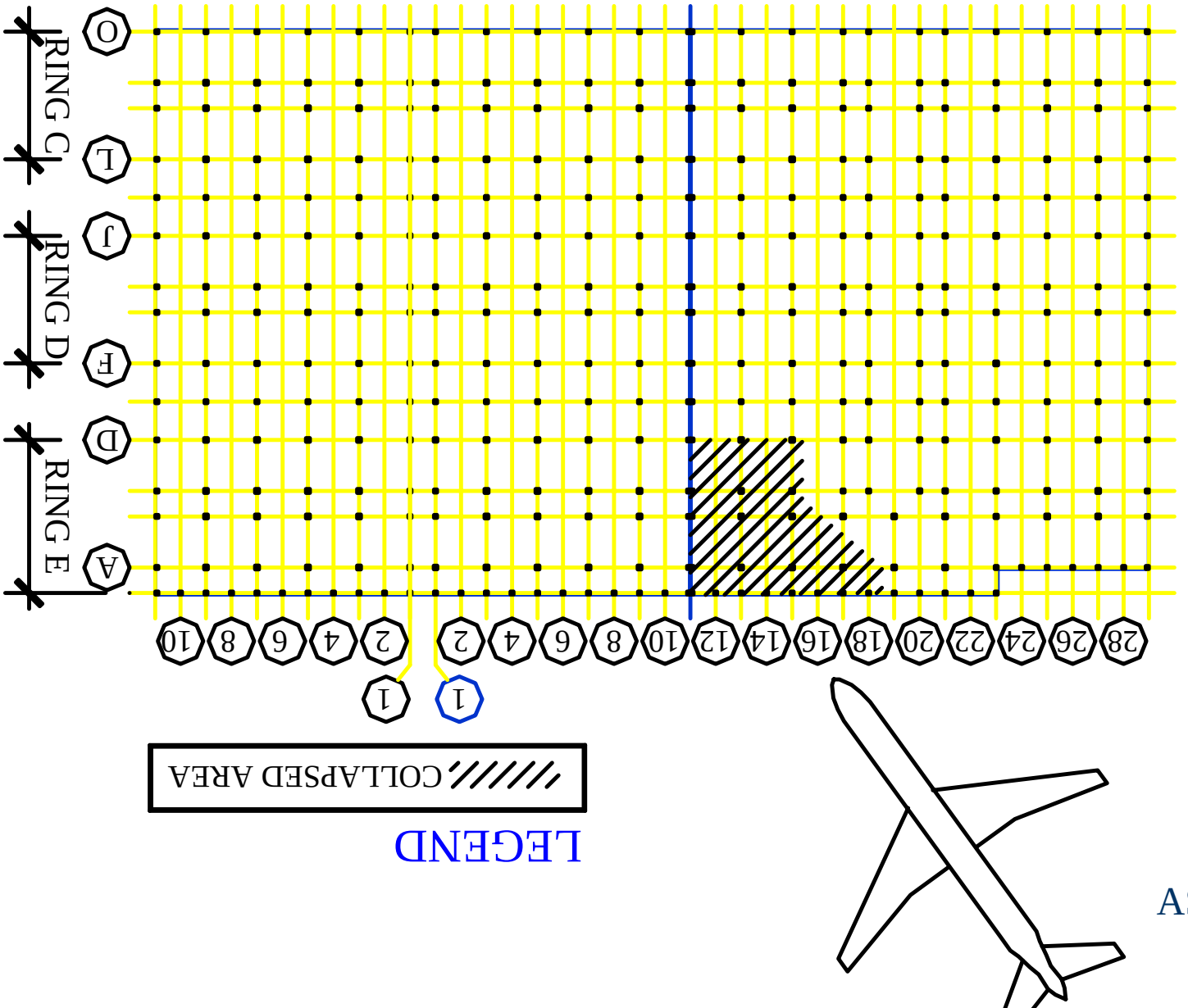
Collapse Area



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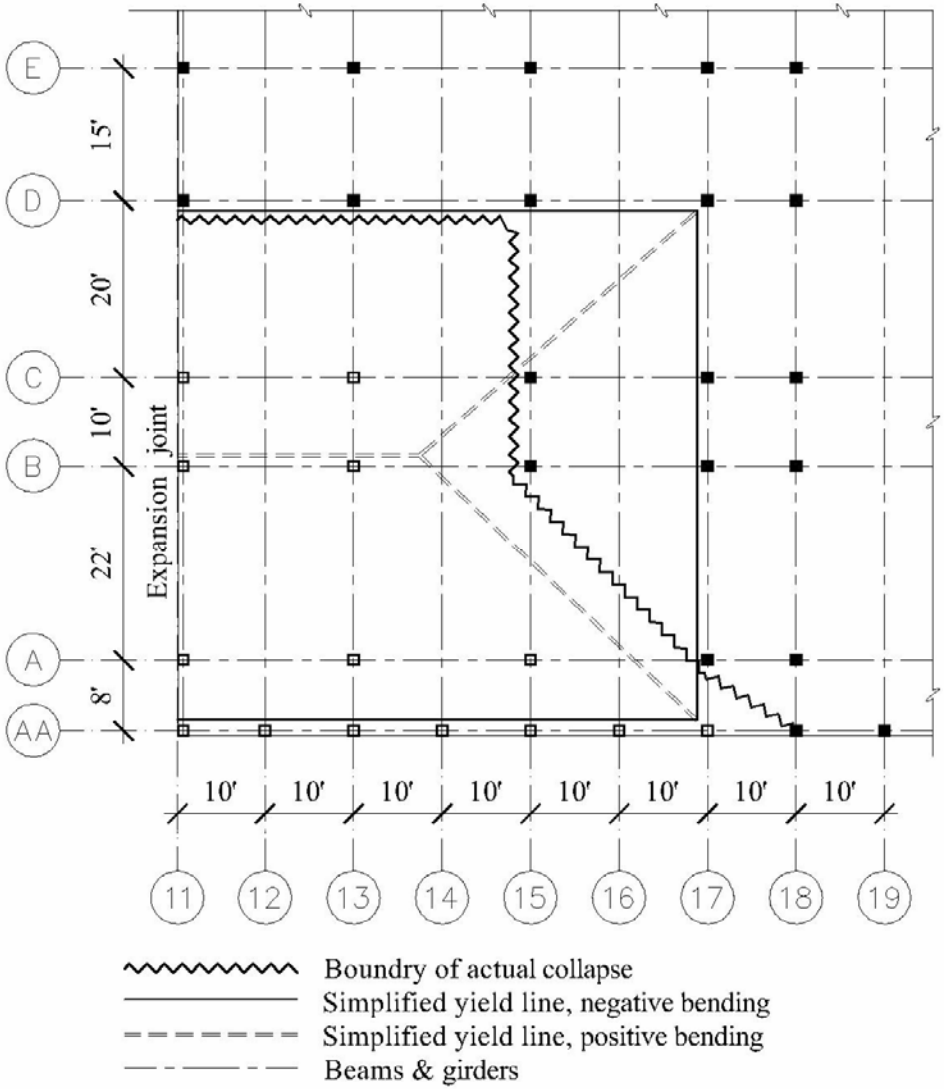

Simplified Yield Line Analysis in Collapsed Area

Capacity: 160 psf

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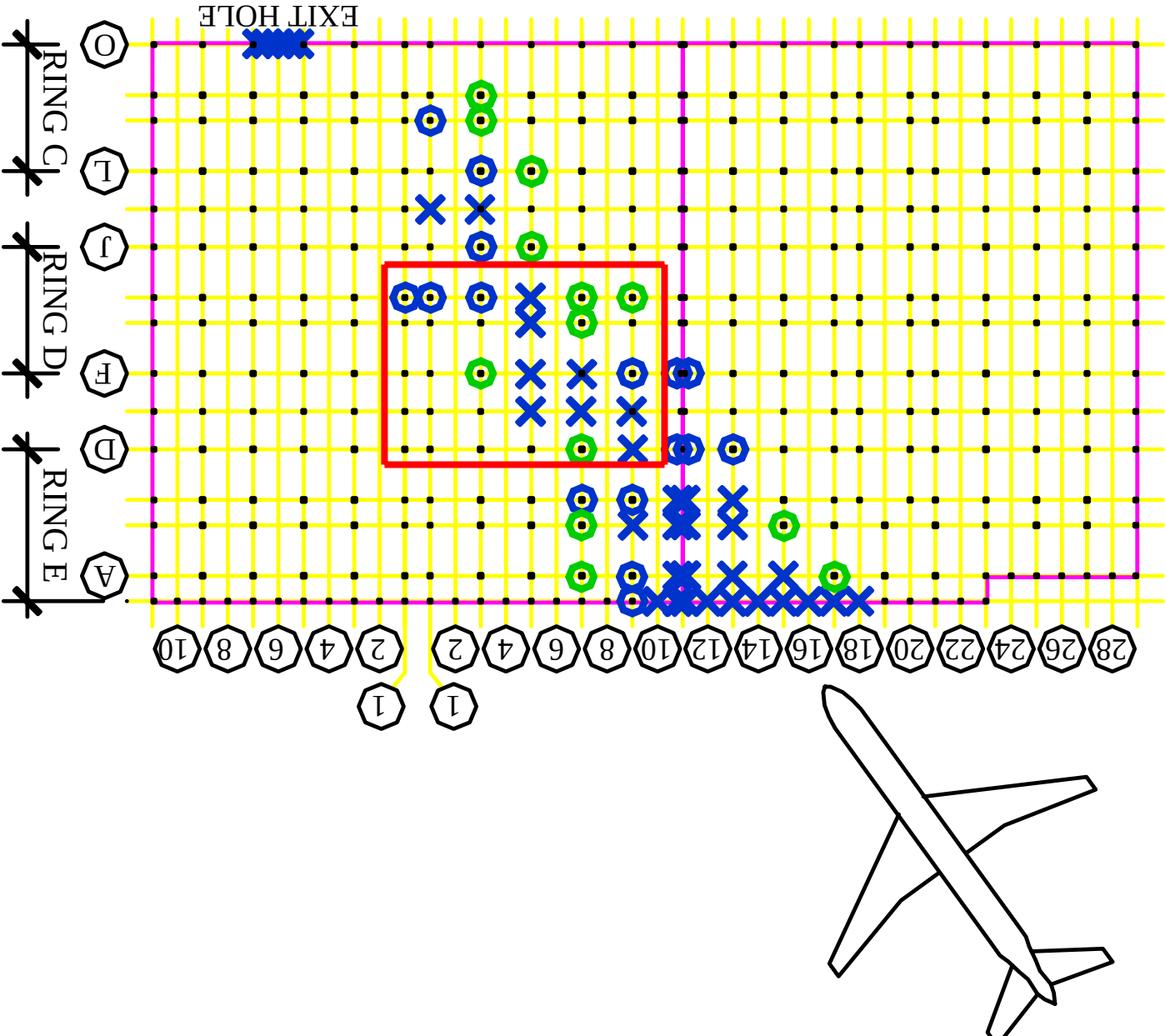
Heavily Damaged Area that Survived



Essentially all damage in the first story

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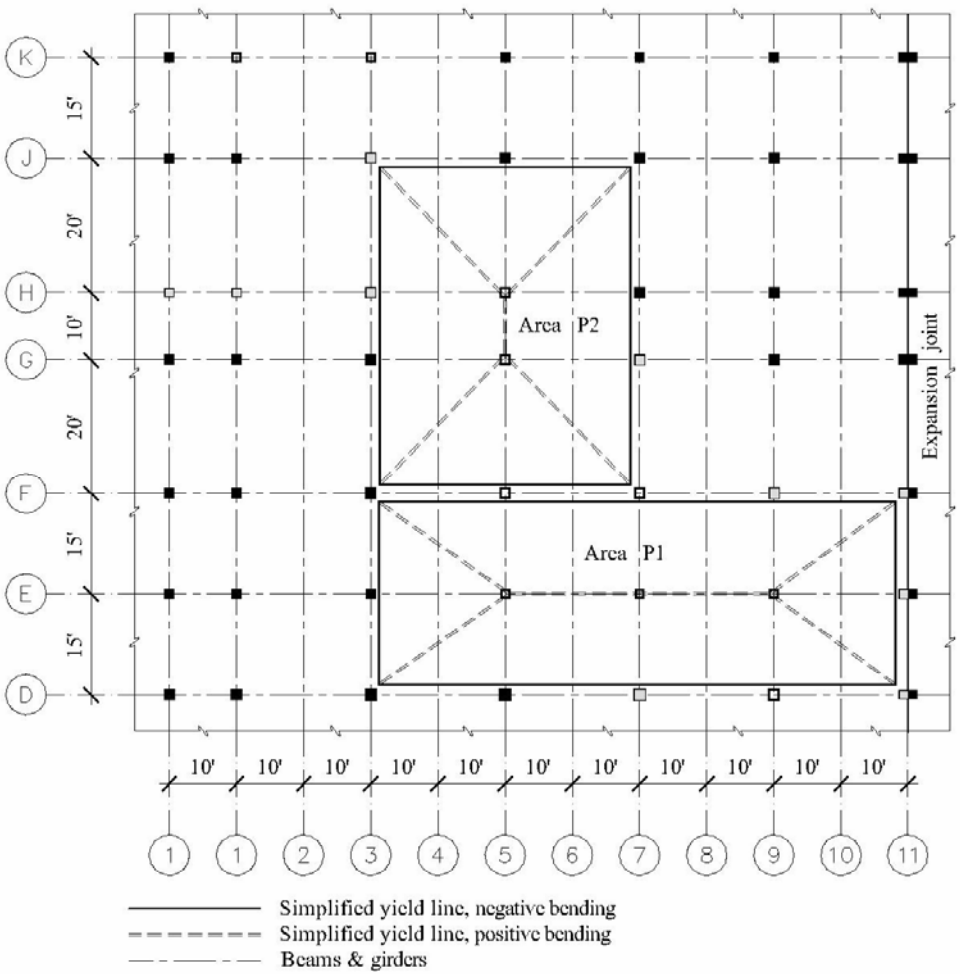

Yield Lines over Missing Columns

Capacity: 300+ psf

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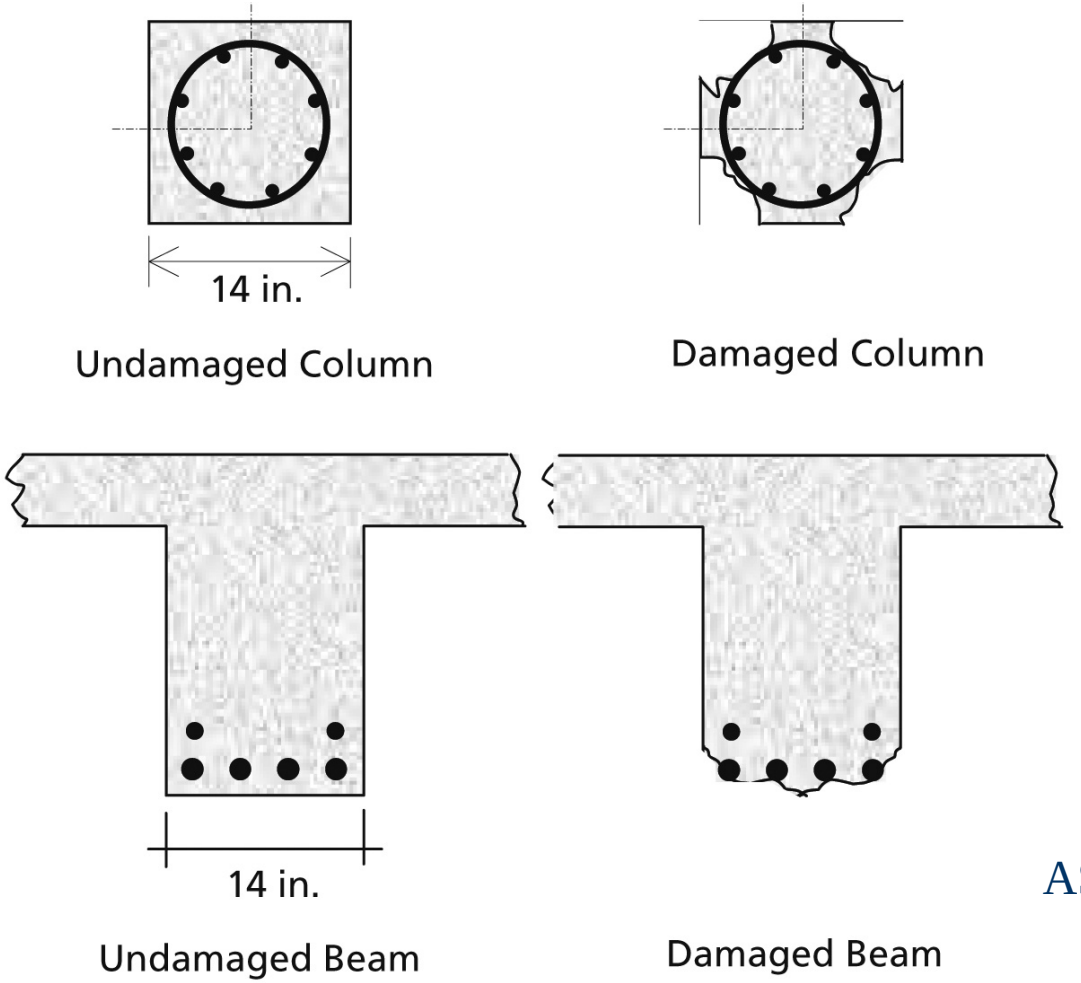
Floor Capacities

- Undamaged: 1,300 psf
- In area that survived: 300 psf
- In area that collapsed: 160 psf

Fuel Load

- Aircraft fuel: 15,700 Btu/sq ft
- Contents: 17,600 Btu/sq ft
- Fire achieved 1,560 ^{o}F in 30 minutes
- Between E-119 and E-1529

Thermal analyses



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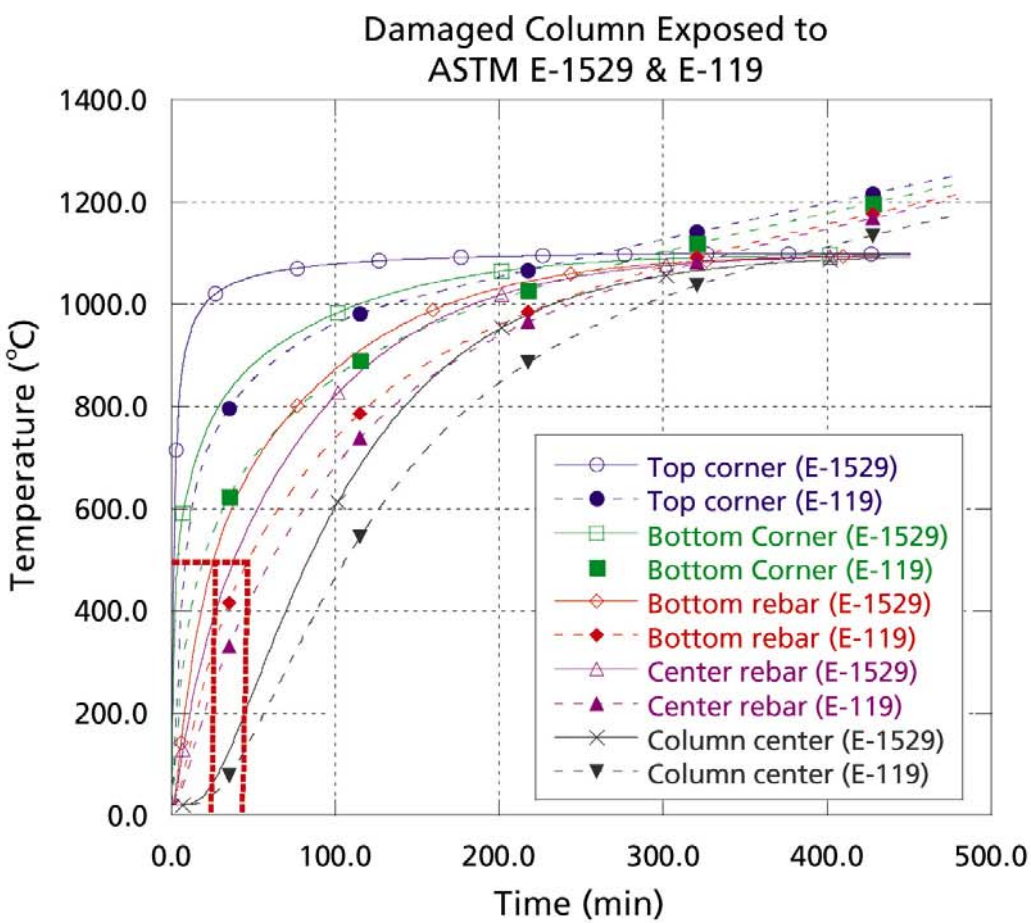
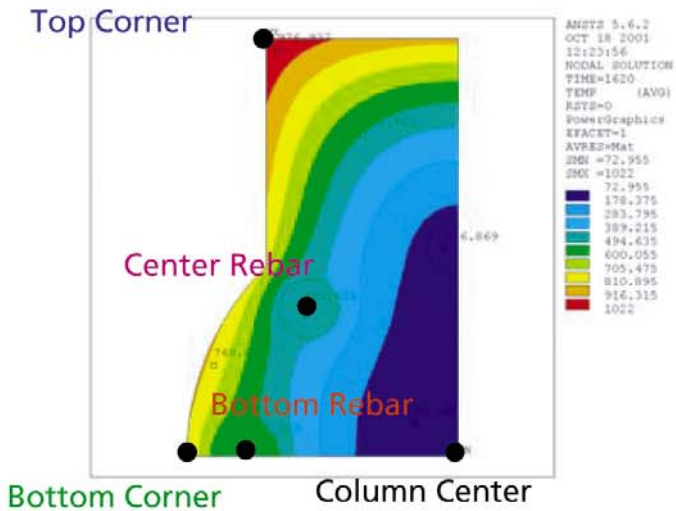
Temperature in Damaged Column





Reinforcement at 500 °C in:
- 25 min (E-1529)
- 50 min (E-119)

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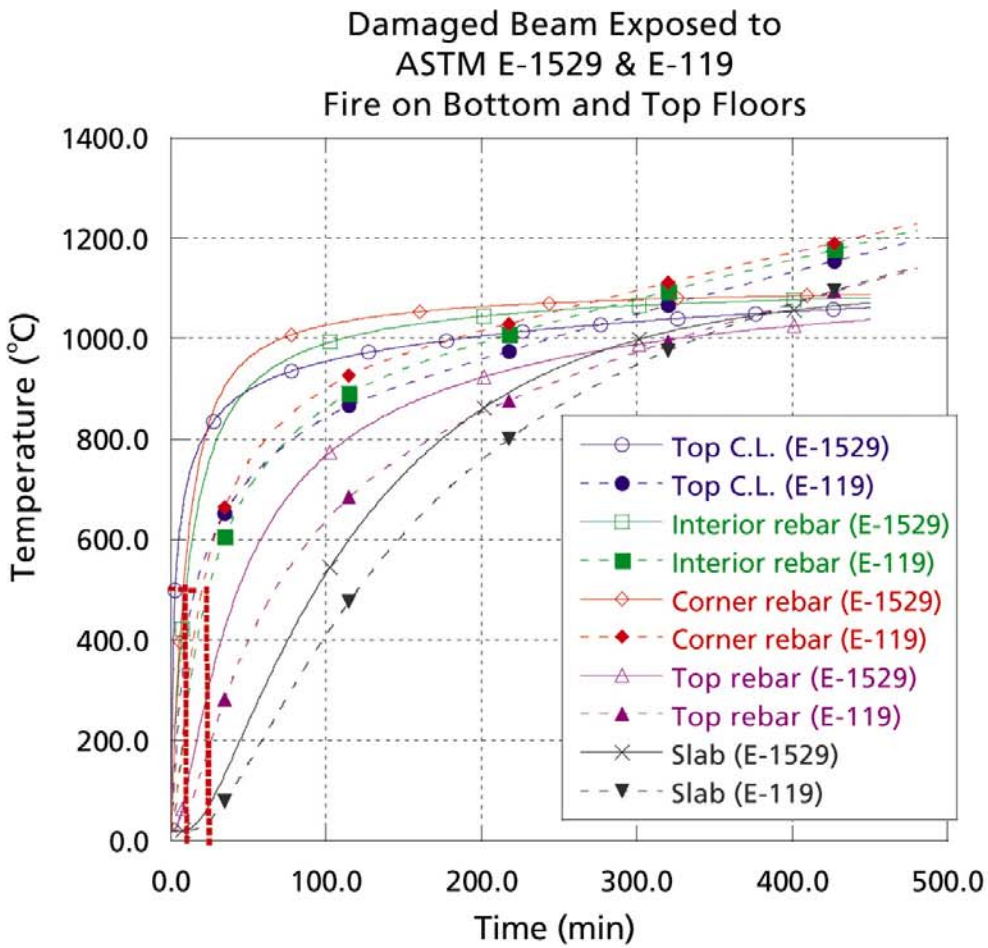
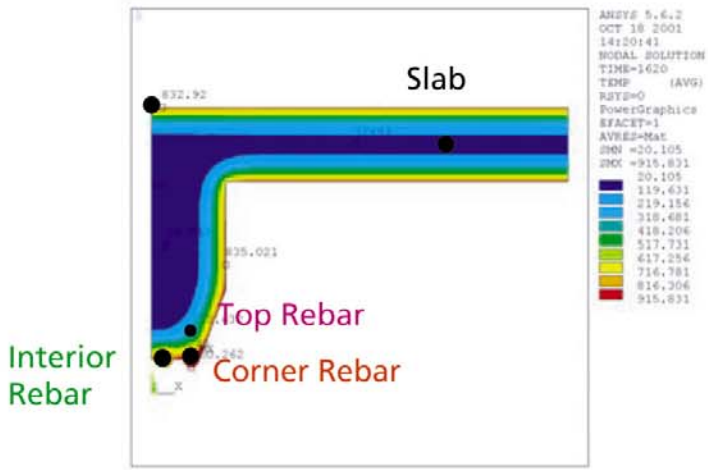
Temperature in Damaged Beam





Reinforcement at 500 °C in:
- 12 min (E-1529)
- 20 min (E-119)

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Fire Response

- Undamaged columns: 90 to 120 minutes
- Damaged columns: 25 to 50 minutes
- Damaged beams: 12 to 20 minutes

- Compares favorably to 19 minute time to collapse

Reasons for Performance

- Redundant load paths
- Short spans
- Continuity
- High design load
- Ductility of spiral columns
- Deep beam behavior of exterior walls