September 11, 2001
The World Trade Center
New York City

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www.fema.gov/rebuild/mat/wtcstudy.shtm
Presentation

• *The site before the attack*
• *The attack and tower collapses*
• *Tower construction*
Fireballs

90m fireball ≈ 11,400 liters

Fuel Quantity (gal)
WTC 2 Collapse

- Initial collapse to south and west (towards zone of impact)
- Progressive collapse downward and to north west
WTC 1 & 2
• 110 stories
• WTC1 – 527 m (1,368 ft+ 360 ft Radio Tower)
• WTC2 – 415 m (1,362 ft)
• Floor plate of 63m x 63 m (207’ x 207’)
• Core 26m x 42m (87’ x 137’)
• 3,716 m² (40,000 square ft) per floor
• Constructed 1968-73
• 99 Elevators (each tower)
• 3 Egress Stairwells (each tower)

Tower Construction
• Lightweight concrete slabs on metal deck
• Composite trusses (bar joists)
• Exterior frame
• Interior columns in core
WTC 1 & 2

Innovations:
- use of dampers to reduce wind deflection
- use of shaft wall system to protect openings
- use of automated shop fabrication

Tubular Design

- Exterior columns carry wind plus DL and LL
- Interior columns primarily for DL and LL
- Truss system at the top

- Exterior columns stressed about 15% under DL and LL only. Without wind, a lot of redundancy.
Exterior Framing

- **Built up columns of plates at 1m (3'-4'') oc**
- **Spandrels of plates**
- **Trusses doubled up at 2m (6'-8'') apart**
- **Two – way action due to bridging trusses**

- **Myth: No water in the columns**
Myth: bearing seat weakness

0.8m
Effects of Aircraft Impact

- Impact shattered and fractured 2/3 of columns on one face
- Partial collapse of floors occurred at impacted columns
- Debris penetrated building core
  - damaged core columns
  - damaged stair shafts and elevators
- Impact caused failure of fireproofing in affected area
- Initiated fire
GENERAL NOTES:
(1) Column damage captured from photographs and enhanced videos.
(2) Damage to column lines 111-115 at level 06 is estimated.
Above Floor 89, All Type 120 Column Plates 1/4 inch
End Plates 1-3/8 inches

Moment Capacity of Bolt Group = \( 2(a)(C_p(F_u)(1.18)/A_p) + 2(a+b)(C_p(F_u)(1.18)^*(A_p) - 1,468 \text{ in-k} \)

*Note: The factor 1.18 reflects the fact that production bolts exceed the minimum specified tensile.
Egress

- First use of shaft wall enclosures
- Overpressures from fire ball blew out the walls and ceilings
- Skyways at 44th and 78th floors

- Myth: Extra stairwell..a function of width
Myth
1993 Bombing

- Smoke was a problem in the towers
- Structural damage in basement
- Led to improved evacuation practices
- Fluorescent paint in stairwells
Fireproofing

- Asbestos Tower 1 up to 39th floor was abated previously
- Doubled up thickness in Tower 1 at levels of impact
- Tower 2 only 78th floor

- Sprinklers added; not in original
- Sprinklers disabled by plane damage

Fire Characteristics

- Fuel burns at the rate of approximately 1,000 gallons per minute for each 10,000 sq. ft. of fire area.
- With fire involved in extensive portions of at least 4 floors, jet fuel was consumed within the first 3 or 4 minutes.