Fire Endurance Testing * of WTC Tower Typical Floor Construction

John Gross, Bill Grosshandler, Monica Starnes

• Test results will provide fire endurance ratings to evaluate three primary factors
  – test scale
  – fireproofing thickness
  – thermal restraint

Fire Endurance Testing of
WTC Tower Typical Floor Construction

• Three tests will be performed…
  – 17 ft (5.2 m) span assembly, thermally restrained
  – 35 ft (10.7 m) span assembly, thermally restrained
  – 35 ft (10.7 m) span assembly, thermally unrestrained
Fire Endurance Tests

• Test 1: 17 ft (5.2 m) span assembly, thermally restrained
  – Represents current US practice for establishing a fire endurance rating of a building construction.
  – Typical of the floor assembly test furnaces used by the US testing laboratories that routinely conduct the ASTM E119 test.
Fire Endurance Tests

- Test 2: 35 ft (10.7 m) span assembly, thermally restrained
  - Twice the scale of the first test. Represents a full-scale assembly of a 35 ft floor panel.
  - Allows direct comparison to Test 1 of the effect of test scale on fire endurance rating.
  - Includes individual rod and double angle structural members. Steel temperatures will be recorded for comparison of fireproofing thickness and the limiting criteria.
Fire Endurance Tests

- Test 3: 35 ft (10.7 m) span assembly, thermally unrestrained
  - Allows direct comparison to Test 2 of the effect of thermal restraint on fire endurance rating.
  - Tests 2 and 3 will bound behavior of a floor system that is indeterminately restrained.
ASTM E119

• ASTM E119 prescribes a standard exposing fire of controlled extent and severity

• Performance is defined as the period of resistance to standard exposure before the first critical point in behavior (conditions of acceptance or end point conditions) is observed.

• Conditions of acceptance include (for floor systems)
  – Sustained applied load during classification period
  – Maximum temperature on unexposed side of the specimen
  – Maximum and average temperatures of the steel joists
Elevations of Test Configuration

END VIEW
(Note: Bridging trusses are not shown for clarity)

SIDE VIEW
(Note: Bridging trusses are not shown for clarity)

- Reinforced concrete slab with metal decking
- Main trusses
- Steel bars
- Steel double angles
Plan View of Test Configuration

- Bridging truss
- Steel double angles
- Main truss
- Steel bars
**Instrumentation**

- **Temperature Measurements** (exceed ASTM E119 requirements)
  - Measurement of the temperature of the steel along the length of the members
  - Measurement of the temperature of the unexposed surface (top) of the concrete slab
  - Measurement of the temperature of the bottom of the concrete slab (steel deck)

- **Deflection** (not required by ASTM E119)
  - Deflection measurements will be made at 9 locations on the unexposed side of the specimen as well as at mid-span on the bottom chord of both main trusses
• **Gas Temperatures** (not required by ASTM E119)
  - Gas temperatures will be continuously recorded at three locations using plate thermometer and aspiration thermocouples

• **Heat Flux** (not required by ASTM E119)
  - Radiative heat flux will be measured at lower surface of metal deck and to the bottom flange of the main trusses using wide-angle radiometers
Thermocouples on Main Trusses
Thermocouples on Unexposed Surface of Concrete Slab

Note: Dimensions for locations may vary slightly depending on deck valley and crest occurrence in actual construction.
ASTM E119 Conditions of Acceptance
(or end point criteria)*

- Transmission of heat through the specimen shall not have been such as to raise the average temperature on its unexposed surface more than 250 °F (139 °C) above its initial temperature.

- The temperature of the steel shall not have exceeded 1300 °F (704 °C) at any location

- The average temperature of the steel recorded by four thermocouples at any section shall not have exceeded 1100 °F (593 °C)

* Tests will be conducted until specimen fails to sustain the applied load (without damaging the furnace)
Schedule for Testing

• Start – “Kick-off” meeting with Contractor held August 18, 2003

• Testing – approximately 9 months

• Results – shortly thereafter
May 2003 Progress Report: Fire Protection
(Page 74)

• In October 1969, … , the Port Authority stated, in a letter to the fireproofing contractor, that
  
  – “All Tower beams, spandrels, and bar joists requiring spray-on fireproofing are to have a ½” \[1/2 \text{ in}\] covering of Cafco.
  
  – The above requirements must be adhered to in order to maintain the Class 1-A Fire Rating of the New York City Building Code.”[1]

• In 1999, the Port Authority established “guidelines regarding fireproofing repairs, replacement, and upgrades” for the towers. The guidelines for tenant spaces may be summarized as follows:

  – For full floors undergoing new construction or renovation, the bar joists should be fireproofed with 1-1/2 in of spray-on mineral fiber fireproofing. Refireproofing requires removal of existing material and controlled inspection.

  – For “tenant spaces less than a full floor undergoing new construction or renovation,” the floor trusses “need only meet the original construction standard. Fireproofing shall be inspected and patched as required to the greater of 3/4 in or to match existing” if it has already been upgraded to 1-1/2 in.
Truss Specified Mechanical Properties

About 50 truss variants (60’, 35’, bridging trusses, 20+ variants per length

Top Chord
A242
Typically 2.5” x 1.5” x 0.25”

Web
A36 (60’ truss) (1.09” round)
A242 (35’ truss) (0.98” round typ)

Bottom Chord
A36
Typically 3” x 2” x 0.37”

ASTM Specifications
A36: Yield Point = 36ksi
A242-70 type 2: Yield Point = 50 ksi
As-Built Properties

- Truss components typically meet contemporaneous specification. A36 components far exceed minimums.

- No obvious differences (chemistry/microstructure/mechanical) between steel specified as A36 and that specified as A242.

- Truss steel would meet (chemistry and yield strength) present-day A572 (Type 2 or Type 4) Grade 50 steel.
Selection of Key Test Parameters

- Fireproofing Thickness
- Steel Specification

Should the planned tests address the fire endurance rating of …

- what was originally specified for the design?
  - 0.5 in of fireproofing per letter to DiBono
  - minimum steel strength (36 ksi; 50 ksi)

- as-built conditions at time of collapse?
  - 0.75 in of fireproofing per measurements
  - Supplied steel strength (over 55 ksi)
If test is for ...

Specified Conditions

- Will provide design information not available in the early 1960s
- Will establish minimum performance expectation for specified system

As-built Conditions

- Will provide as-built information for investigative purposes
- Will establish data on performance of as-built system at time of collapse
Other Considerations...

- Steel primer paint

Should the planned tests have primed or unprimed steel?
  - WTC steel was primed
  - Testing Laboratories generally require that steel not be primed or require the use of specific primers