



Technical Conference on the Federal Building and Fire Safety Investigation of the World Trade Center Disaster

Comments on NIST'S recommendations by Roger Plank and Ian Burgess University of Sheffield, UK

NIST, Gaithersburg, MD, USA 13-15 September 2005





Increase structural integrity

- 1. Develop design tools and modify codes to prevent progressive collapse.
- Develop new standards for wind tunnel testing and performance standards for estimating wind loads on tall buildings.
- 3. Develop limits for lateral sway for tall buildings.

Important to distinguish between different degrees of local failure



Column failure – progressive collapse





Single column failure may be sustained by alternative load paths

Multiple column failure catastrophic





Consequence of element failure





Consequences differ

- •**Columns** are key elements failure may be disastrous.
- **Joint** failure may initiate fire spread and progressive collapse.
- Beam deflection does not in itself cause structural failure, unless it allows fire spread or causes effects to columns or joints.





Enhance fire resistance

- 4. Review basis for construction classification and fire rating requirements.
- 5. National programme of research into improved fire testing of structural components and systems.
- 6. Improve testing methods for spray-applied fire protection that reflect in-service conditions.
- Adopt "structural frame" approach ensure whole structural frame has same fire resistance rating.

Similar approaches being used in UK

May be inconsistent depending on aspect ratio and type of slab



Structural fire resistance methods



Protect members on column gridlines

Similar philosophy to "Structural Frame" approach.

Numerical modelling of representative areas of structure in design fire scenarios.



























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600°C















26

Example: Principal membrane tractions







Structural fire resistance methods



Non-square structural frames:

Much lower enhancement of capacity due to tensile membrane action.























New methods for fire-resistant design

- 8. Set the objective that uncontrolled building fires should burn out without local or global collapse.
- 9. Develop performance based codes and supporting test methods and design tools to allow the fire performance of the entire structure in real building fires to be evaluated.

10.

Realistic fire model + burnout more logical than standard fire + time

Global behaviour very different from individual elements in isolation

Also provides details of connection forces



Whole structure/member analysis







Design tools for structural fire engineering



🔊 Neal_Demo.vul - Vulcan

_ 8 ×

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Axial forces in heated floor truss









New methods for fire-resistant design

- 8. Set the objective that uncontrolled building fires should burn out without local or global collapse.
- 9. Develop performance based codes and supporting test methods and design tools to allow the fire performance Connection forces can be very large

Need to know connection robustness as well as stiffness

Benefit of component based approach for connections

performance material systems.



Failure at tab plates in WTC 5 column trees









Cardington Beam-Column Joint Fire Test 7





Beam shear buckling Beam flange buckling



Cardington Beam-Column Joint Fire Test 2





End plate split on one side of attachment to web



Cardington Beam-Beam Joint Fire Test 2





Shear failure of bolts in fin plate connection





- A flexible approach based on modelling the zones of fundamental behaviour ("components") within a joint.
- Reassembling a model of the joint with springs.









Experimental test program and analytical / semiempirical models by S. Spyrou (1998 – 2001) at the University of Sheffield:

- Tension zone of endplate joints as T-Stub
- Compression zone in the column web







Compression zone testing









Enhance fire resistance

- 4. Review basis for construction classification and fire rating requirements.
- 5. National programme of research into improved fire testing of structural components and systems.
- 6. Improve testing methods for spray-applied fire protection that reflect in-service conditions.
- Adopt "structural frame" approach ensure whole structural frame has same fire resistance rating.

More emphasis on scientific rather than proof testing – to improve understanding.









Gas Temperature (°C)



Fire resistance times based on standard furnace tests - NOT on survival in real fires.

 EC1 Parametric Fire temperature-time curves.
 Based on fire load and compartment properties.

1200 1000 **Standard Fire** 800 600 Typical EC1 **Parametric fire** 400 curve 200 1200 $\mathbf{0}$ 2400 3600 Time (sec)



BS demonstration fire test: the aftermath









Improved procedures and practice

- 25. Independent third party certification of as-designed and as-built safety.
- 26. Aggressively enforce current building regulations on sprinklers and egress <u>on existing buildings</u>.
- 27. Require building owners to retain records of design, test data, construction, maintenance and modifications for the whole life of a building and store them securely offsite.
- 28. Ensure structural and fire safety engineers work together with architects to ensure fire safety where innovative or unusual structural or fire safety systems are involved.





Education and training

- 29. Train architects and fire safety engineers in structural engineering; train structural engineers, architects and fire protection engineers in modern fire engineering principles.
- 30. Develop training material in the use of computational fire dynamics and thermo-structural analysis tools.

Better to give structural engineers training in effects of fire on structure (rather than train fire engineers/scientists in structural engineering)



Press coverage



. "Engineers fear their efforts to produce innovative tall building designs will be stifled following publication of a comprehensive report into the World Trade Center tower collapses in 2001."

- NCE







Thank you