Fire Resistance - Implications for regulations and standards of the September 11th terrorist attacks on the World Trade Centre

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Malaysia May 2003
Questions

- What is fire resistance?
- What does it mean?
- How do we measure it?
- How do we provide it?
UK Building Regulations

“The building shall be designed and constructed such that, in the event of a fire, its stability will be maintained for a reasonable period”
UK Building Regulations

- Building Regulations are only concerned with the safety of those in and around buildings.
- Issues of property protection are left to the insurance industry.
- However, in real fire situations there is a critical link between damage and compartmentation.
- The general assumption is that current requirements are sufficient to allow for evacuation.
- No specific provision to avoid overall collapse of the building.
Traditional means of ensuring compliance

- Reliance on results from standard tests on individual elements or components
- Test scenario incapable of simulating the complex thermal and structural environment in real buildings during a real fire
- Association of survival time in a standard test with a corresponding period in a real fire situation in a real building
Standard Fire Test

- BS476 Part 20
- ISO 834

\[ \theta_g = 20 + 345 \log_{10}(8t+1) \]

where \( \theta_g \) = gas temperature (°C)

\( t = \) time (minutes)
Standard testing

BS 476 pt 21 - ISO 834

Evaluating single simply supported members in laboratory furnaces
Comparison between natural and standard fires

- Time (mins)
- Temperature (deg C)

Lines and markers for different categories:
- BS476
- tmr
- ECSC 6
- TF2000
- steel house
- hollowcore
- DEMO
- CORNER
Infinite number of design fire scenarios

- Dependent upon:
  - nature of the ignition source
  - quantity of oxygen available for combustion
  - nature and distribution of combustible items
  - geometry of the fire compartment
  - nature of the construction materials
Fire engineering design and the Building Regulations

In the UK the Building Regulations provide a performance based regulatory framework for the fire safety of buildings that allow for alternative fire engineering methods as a means of satisfying the mandatory requirements.
Fire engineering design

“There is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way”
Time equivalence

- The problem is to define a relationship between fire resistance (a known quantity) and fire severity (an unknown quantity).
- Initial work considered severity purely in terms of the available fire load - still forms the basis of the UK regulations.
- Subsequent work investigated the role of ventilation in determining the burning rate of combustible material.
- More recent work has considered the influence of compartment linings on fire development and compartment size and geometry.
Time equivalence

- Fire resistance generally based on results from standard tests
- Fire severity can now be calculated (see previous slide)
- One method of relating severity in a natural fire to resistance obtained from standard test results is to use the concept of time equivalence
- This allows prescribed resistance to be assigned to a structural member based on the individual characteristics of the building and is a welcome step in the right direction
- Time equivalence may either be calculated using a simple equation or taken from experimental data from natural and standard fire tests
However, there are a number of drawbacks........
Time equivalence

- Relies on the availability of adequate data for a wide range of materials - to date this concept has only been validated for protected and, to a lesser extent, unprotected steel elements.

- Still related to a nominal fire exposure that bears little relationship with real fire behaviour.

- A lack of understanding of the behaviour of modern glazing systems subject to fire may result in an over-specification of fire resistance OR an under-specification of fire resistance. Any design solution should incorporate sensitivity studies on the extent of the openings able to contribute to the combustion process.
Natural Fires

- Natural Fire Safety Concept
  - Fire design based on the physical characteristics of a fire compartment
  - Takes into account the influence of active measures and firefighting
  - Probabilistic approach
Fire Growth and Development

- Fire Growth and development is determined by a number of factors:
  - fire load (quantity of fuel available for combustion)
  - fire load type (calorific value of the fire load - heat release rate)
  - distribution of the fire load (temperature uniformity and speed of fire spread)
Fire Growth and Development

- Compartment Size and Geometry
- Ventilation
  - quantity, location and geometry of openings will determine the burning rate
- Thermal properties of the compartment linings - the form of construction will have an appreciable influence on the severity and duration of the fire.
Fire Growth and Development

- Automatic Detection
- Active Measures - Sprinklers
- Fire Brigade Response
- Building Management
- Effective separation and compartmentation
- Quality of workmanship
Calculation Methods

- Zone Methods - Ozone
  Transition between localised fire and fully engulfed compartment
  Development of heat release curve

- CFD modelling
  Complex and time consuming
Calculation Methods

- Eurocode Parametric Equation
  - Based on theoretical work by Wickstrom supported by Scandinavian experimental programme.
  - Number of limitations based on the extent of the validation
  - Not valid for large compartments
  - Restrictions on range of thermal properties
  - Restrictions on opening factor
Calculation Methods

- EC 1 Part 2.2 - Parametric Equation

\[ \theta_g = 1325(1 - 0.324e^{-0.2t^*} - 0.204e^{-1.7t^*} - 0.472e^{-19t^*}) \]

where \( t^* = t \Gamma \)

and \( \Gamma = (O/b)^2/(0.04/1160)^2 \)

\( O \) is the opening factor

and \( b \) relates to the thermal inertia
Changes to the latest version of EN1991-1-2

- **Scope of Equation**
  - \( 0.02 \leq O \leq 0.2 \ (m^{1/2}) \)
  - \( 100 \leq b \leq 2000 \ (J/m^2 \ s^{1/2} \ ^\circ K) \)
  - \( A_f \leq 500m^2 \)
  - mainly cellulosic fire loads
  - maximum compartment height = 4m
  - concept of limiting duration (20 minutes for office fires)
Comparisons with revised EC equation

comparison between EC1 parametric calculation and measured values

temperature (deg C)
time (mins)

- test 1
- prediction
- test 2
Comparisons with revised EC equation

Cardington fire test - 16.1.03

- Temperature (deg C) vs. time (mins)

- Graph showing temperature over time for average and EC1 conditions.

- Key:
  - average
  - EC1
Conclusions/Recommendations

- The revised version of the parametric equation produced in the EN version of the fire part of the Eurocode for Actions provides an accurate prediction of post-flashover fire behaviour within a wide range of compartment sizes and constructions.

- Comparisons with test data are being carried out as part of the calibration exercise associated with the development of the new code and drafting of the National Annex.
The Challenge

- To provide a simplified calculation procedure to take into account all the factors which influence fire growth and development.
- To validate the procedure against all available test data and, where possible, to utilise numerical simulations
- To provide a calculation method which is independent of the form of construction
- To integrate the above into calculation methods for heat transfer and structural performance