Cost-effective fire performance
Louis-Guy Cajot
ArcelorMittal
Research & Development
Structural Long Products
Esch/Alzette GD Luxemburg

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Cost-effective fire performance

- High potential of steel in multi-storey buildings

One of the reasons explaining the differences: **Fire Safety Approach**.

- The present low market share in continental Europe is more particularly due to:
  - Weak knowledge from engineers and architects of the actual performances of the steel in case of fire, still mainly assessed through knowledge from fire test on single element.
  - **Fire Safety Engineering** not yet fully considered
Classical approach amongst “structural fire safety engineering” methods - Eurocodes 1, 3 and 4

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The ISO curve:
* has to be considered in the WHOLE compartment, even if the compartment is huge
* never goes DOWN
* does not consider the PRE-FLASHOVER phase
* does not depend on FIRE LOAD and VENTILATION CONDITIONS

Classical approach based on ISO-834 heating curve
Classical approach - Quick use of the Eurocodes

- Unprotected steel structures for fire resistance ≤ 30 minutes
- R30 unprotected steel structures (Overdesign [S355, S460]; benefit of the connections)
Classical approach based on ISO-834 heating curve

Steel protection for fire resistance > 30 minutes

The protection must be optimized and applied where it is really needed.
The performance based “structural fire safety engineering” approach according to Eurocodes 1, 3 et 4

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Fire Safety Engineering = Global Structural Behavior + Fire Development
Fire Engineering approach

Scientific analysis based on:
- Fire scenario
- Physical parameters influencing the fire development (fire load, ventilation, active fire fighting measures, …)

More controlled safety and more efficient solutions because better targeted
Fire Engineering approach

European research in the field of the fire engineering achieved between 1994 → 2006 allows to finalize the following technical developments:

- Fire safety concept evaluation based on natural fire.
- Required data for the fire development calculation methods (fire load [MJ/m²], fire spread, rate of heat release [kW/m²]).
- Definition of model scenario for usual buildings (offices, schools, shops,…).
- Take into account of the active fire fighting measures (sprinkler, smoke exhaust system,…).
- Air temperature field calculation method in case of fire.
- Steel temperature calculation method.
- Simulation of the behaviour of the structure submitted to the different fire scenarii and to the static loads.
- Building systems and technical solutions to guarantee that the structure survive the considered scenarii.
Fire Engineering approach

The implementation of the research results met the following difficulties:

- Existing regulations and standards based on standard fire.
- Habits and a priori in the minds of the professionals of construction.
- Different regulations depending on the countries and even on the regions.
- Low expertise of engineers, architects and authorities in that domain.
- Lack of training in that domain.
- No user-friendly calculation tools.

solved by:

- The natural fire was introduced in the Eurocodes, particularly Eurocode 1 - Fire Part.
- The fire engineering has been dealt with in decree and regulations in different European countries.
- User-friendly calculation tools were developed (Ozone), and put on the site www.arcelor.com/sections.
- Trainings were, and are organized (DIFISEK).
- A network of competent and qualified engineering offices in the field of fire engineering was developed (SECURE with STEEL).
Ozone
Natural Fire calculation according to EC1 Fire Part
Ozone
Natural Fire calculation according to EC1 Fire Part
**Dissemination of Fire Safety Engineering Knowledge**  

**Available tools for further dissemination**

http://www.arcelormittal.com/sections/DIFISEK/DIFISEK_welcome.html

- All Presentations and Syllabus in PDF - WP1 to WP5 (17 languages)
- Database for Fire Design Software (UK)

**Treated topics**

- **Part 1:** Thermal & Mechanical Actions  
- **Part 2:** Thermal Response  
- **Part 3:** Mechanical Response of Structures in Fire  
- **Part 4:** Software for Fire Design  
- **Part 5-1:** Worked Examples  
- **Part 5-2:** Illustration of Completed Projects

**SEMINARS**

DIFISEK  
DIFISEK+

- Austria  
- Belgium  
- Czech-Republic  
- Estonia  
- France  
- Germany  
- Greece  
- Hungary  
- Italy (Rome)  
- Lithuania  
- Poland  
- Portugal  
- Romania  
- Slovenia  
- Spain  
- Sweden  
- United-Kingdom
SECURE with STEEL in Europe
25 European engineering offices specialized in Fire Engineering assisted by 9 universities and/or research centers

ARUP, Fire University of Edinburgh (United Kingdom)
DGMR, Hamerlinck Advies bureau, Cauberg-Huygens (The Netherlands)
Swedish National Testing & Research Institute (Sweden)
Schmitt Schtumpf Fruhauf & Partner, Universität of Hannover (Germany)
Greisch, Technum, Steel Information Centre, University of Liège (Belgium)
Bernard Ingenieure (Austria)
Keonn (Poland)
Studio di Ingegneria delle Strutture (Italy)
CTU Prague (Czech Republic)
MP Ingénieurs ETH Zürich (Switzerland)
NB35, LABEIN (Spain)
Tal Projecto, Lda GIPAC, Lda University of Aveiro (Portugal)
Schroeder & Associés (Luxembourg)
Arches-Etudes, E2C Atlantique, Terrell International (France)
ACCESS STEEL

CHOICE OF FIRE ENGINEERING STRATEGY

Scheme development: Selection of appropriate fire engineering strategy for multi-storey commercial and apartment buildings

Table 2.1 Guidance on choice of design approach for a specific multi-storey building of conventional proportions, without an atrium

<table>
<thead>
<tr>
<th>Standard fire methods</th>
<th>Performance based methods</th>
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<tbody>
<tr>
<td>A. Manufacturer data</td>
<td>E. Simple calculations</td>
</tr>
<tr>
<td>B. EC data for composite construction</td>
<td>F. Advanced calculations</td>
</tr>
<tr>
<td>C. Simple calculations</td>
<td></td>
</tr>
<tr>
<td>D. Advanced calculations</td>
<td></td>
</tr>
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</table>

1. Building size – floor area per storey
   - Small, < 200 m²
   - Medium
   - Large, > 1000 m²

2. Building height
   - Up to 5 storeys
   - 6+ storeys

3. Taking benefit from active fire fighting measures
   - Detection, alarm and smoke exhaust
   - Sprinklers

4. Benefit from structural reserve
   - Economically sized for strength in cold design
   - Significantly oversized for strength in cold design

This is related to potential economies, which will be greater in relation to the additional design work for larger buildings.

Tailor buildings have greater potential for economy and longer fire resistance periods

Some national regulations and/or local authorities allow the presence of these measures to reduce fire loads

Implicit reserves of strength, for example from semi-rigid connections, and reduced exposure to fire increase the potential value of more advanced approaches

SSC02: Describes the main concepts of firesafety. Su regulatory requirements, introduces firesafety engineering and the use of the section factor to calculate fire protection.

SSC04: This document presents guidance on the firesafety for single-occupancy houses.

SSC08: Outlines the principal and practical requirements. Introduces fire engineering and covers passive fire or partially protected steelwork.

SSC04: This document presents guidance on the firesafety for specific conditions for multi-storey off...
The “structural fire safety engineering” approach
Eurocodes 1, 3 et 4

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Diagram showing the relationship between prescriptive and performance-based approaches in structural fire safety engineering.

Prescriptive
- Standard fire
- Classification
- Fire safety eng.

Performance based
- Natural fire
- Fire safety eng.

**Notes:**
- Eurocodes 1, 3 et 4
- Fire safety engineering approaches
- Standard vs. Natural fire classification
- Prescriptive vs. Performance-based methods
Test in Cardington (UK)
Test in Cardington (UK)

- Maximum steel temperature about 1150°C
- Fire calculation by element provides a failure at 680°C
- Why did the structure survive?
Test on single elements

Existing design methods assume isolated members will perform in a similar way in actual buildings.
Real behaviour in a building

**Membrane effect**

- In a building, catenary behaviour of the steel beam acting compositely with the concrete slab.
- Higher is the deflection, higher is the membrane effect.
Membrane effect highlighted by the ISO fire test of today

Fire resistance of secondary beams calculated as single elements

**EC4 Fire part**
- Critical temperature = 608 °C
- Fire resistance = 16’

**SAFIR Simulation**
- Fire resistance = 20’
Fire Safety Concept:
Protected main beams, unprotected secondary beams

T Mobile Headquarters
Hatfield Hertfordshire

School in Turkey

Buildings references
The “structural fire safety engineering” approach
Eurocodes 1, 3 et 4

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16-01-2008  FRACOF - Jan 2008  22
FRACOF Design

Unprotected Element
\[ R_{\text{(single element)}} < 30 \]

Protected Element

Test on the whole floor including connections
\[ R \geq 30 \]
\[ R = ? \]
# Example of Design Table

## Standard A-series mesh reinforcement

**Reinforcement strength 500 N/mm²**

### R 90 R 120

<table>
<thead>
<tr>
<th>Design Table 2</th>
<th>Mesh size, beam design factor and additional beam load (kN/m²) for fire resistance, concrete type and span 1</th>
<th>90 minutes fire resistance</th>
<th>120 minutes fire resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal weight concrete 80 mm concrete depth</td>
<td>Lightweight concrete 80 mm concrete depth</td>
<td>Normal weight Concrete 90 mm concrete depth</td>
</tr>
<tr>
<td>Span 2 (m)</td>
<td>Span 1 (m)</td>
<td>6.0</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>1</td>
</tr>
<tr>
<td>3.5</td>
<td>1.7 + 1.7</td>
<td>Mesh</td>
<td>A142</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beam</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load</td>
<td>7</td>
</tr>
</tbody>
</table>

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Span 1 = 9 m; Span 2 = 7 m; R120
FRACOF - Fire Resistance Assessment of partially Composite Floor

Economic fire design of steel beams in composite floor

**Objective**

That project will be a milestone in the strategy to develop the fire engineering. It will enable any engineers to use partially unprotected steel structure by using design tables/software approved by the Authorities.

**Deliverables**

There are three main deliverables for this project:
- Background Technical Report
- Design Guide
- Design Software

1. **Background Technical Report**
   To provide in-depth information on the development and verification of the design method.

2. **Design Guide**
   The design guide will consist of approximately 50 pages and will be based on the existing publication ‘Fire Safe Design: A new approach to multi-storey steel-framed buildings’. The design guide will present the principles of the design process using this method.

3. **Design Software**
   The design software will be made available free of charge and will be distributed via the Steel Alliance website.

**Dissemination**

Through Steel Alliance + IPO’s in Spain, Germany, Belgium, Italy, Luxembourg and the Netherlands, + DIFISEK, + ‘Secure with Steel’
TEST SET-UP

Within the framework of project FRACOF, a composite floor of about 60 m², supported by four protected boundary beams and two unprotected internal beams, subjected to standard fire exposure for 2 hours.
LOADING CONDITIONS

- Self weights of slab, steel beams, etc
- Dead load: 170 kg/m²
- Imposed load: 500 kg/m²
MESH REINFORCEMENT
TEST MONITORING
AFTER 120 MINUTES....
AFTER 120 MINUTES...

Cracks in concrete
AFTER 120 MINUTES…

Cracks in concrete
AFTER 120 MINUTES…

Deflected shape
Fire safety engineering is aimed at adopting a rational scientific approach which ensures that fire resistance/protection is provided where it is needed rather than accepting universal provisions which may over or under estimate the level of risk.

Institution of Structural Engineers