Fire safety: a major asset of concrete, permanently challenged

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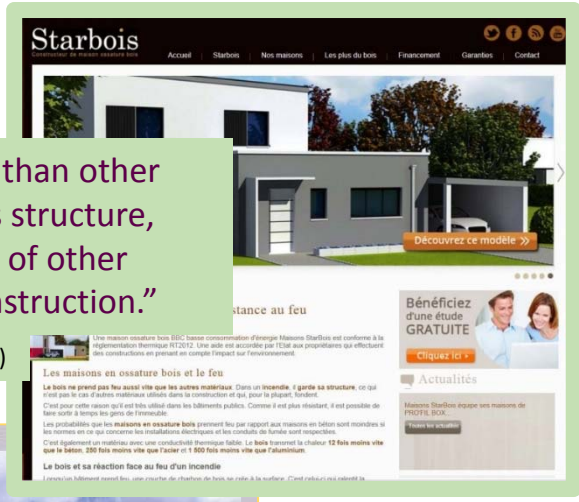
Great Fire London, 1666
The Museum of London
Anonymous artist

"Wood as such burns, but it does so in a controlled manner"

Building with wood – CEI-BOIS



"Wood burns slower than other materials. It keeps its structure, which is not the case of other materials used in construction."

Starbois (wood houses builder)

"Steel doesn't burn and resists to fire. This parameter is fundamental for multi storey buildings"

Steel and sustainable Development in Residential buildings - European Project FRCA 7215-PP-058

"When wood is subject to fire, it burns slower than all other materials. It transfers heat 10 times slower than concrete and 250 times than steel. Moreover, it is not emitting toxic gases"

Faire construire sa maison

« La France vise le record mondial des plus hautes tours d'habitation en bois »

« Le maire de bordeaux, Alain Juppé, a annoncé la construction dans sa ville de deux plus hautes tours de logements en bois au monde. Avec 50 mètres et 18 niveaux, elles seront construites par Eiffage et Kaufman & Broad »

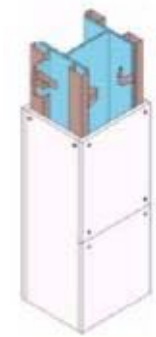
Les échos, mars 2016

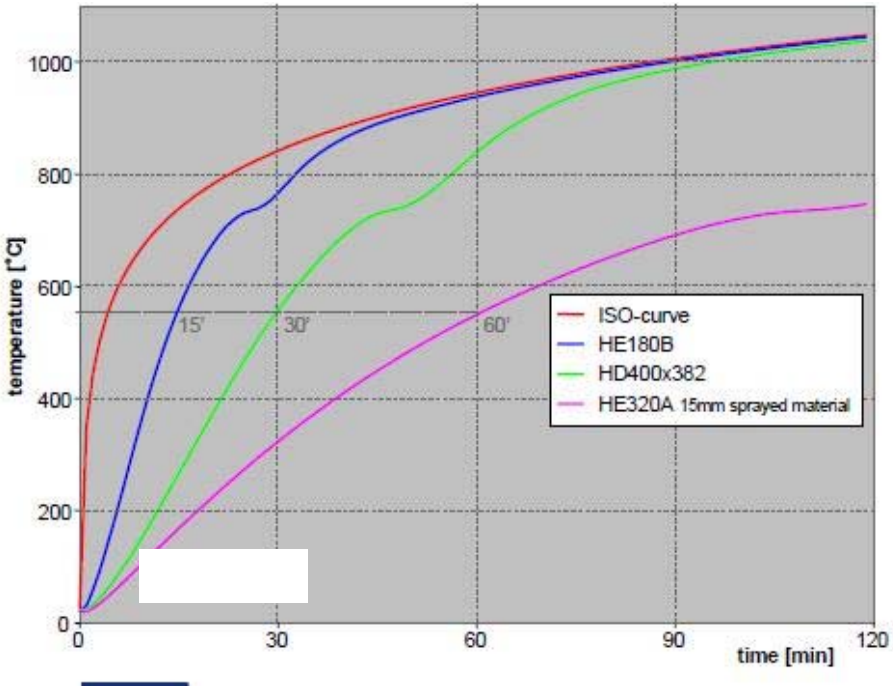
Steel protection according to ISO testing requirements

[Assessment Report of the Research Programme for the Research Fund for Coal & Steel (2012/2013)]

Critical examination of the ISO requirements

→ In the ISO approach, steel protection is required for fire resistance > 30'
Additional cost of fire protection > 40% of fabricated steel





France: warehouses / benefice for steel

MAJOR CHANGES IN BUILDING REGULATION IN 2009/2010 DUE TO STEEL LOBBYING:

Warehouse type	Before	After
1510 > 12,5 m storage of materials, products, or combustible substances in quantities greater than 500 tons in covered warehouses	R60 Or Sprinklers + Fire Safety Engineering study	R60 Or Sprinklers + R15
2662 & 2663 < 8m storage of the polymers such as plastics, rubber, elastomers, resins and synthetic adhesives. storage of tires	R30	R15
2662 & 2663 > 8 m → 12,5 m storage of the polymers such as plastics, rubber, elastomers, resins and synthetic adhesives. storage of tires	R60	R15
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Incorporation of smoke toxicity into the Construction Product Regulations

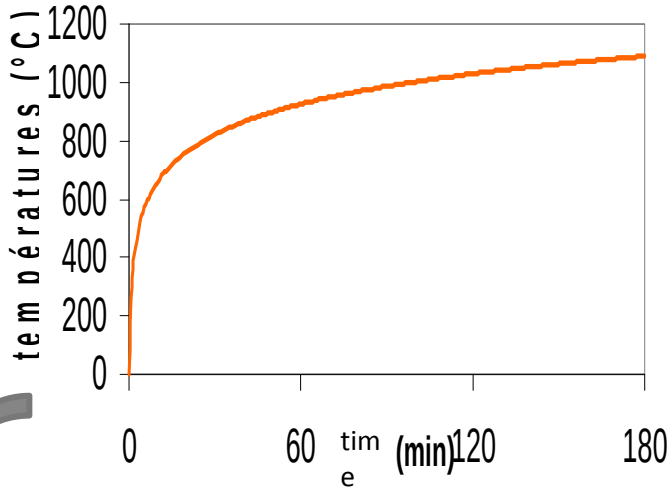
Dr Gwenole Cozigou speech, 23 March 2016

It seems that the ignition of construction products takes place under temperatures higher than those a person can survive. The person would therefore die before the construction products start contributing to the fire. For this reason regulating on smoke toxicity of construction products could prove not to be an effective way to save the lives of inhabitants in the room where fire is originating and a more effective approach could perhaps be the installation of reliable detection and alarm devices.

Fire Safety Engineering principles

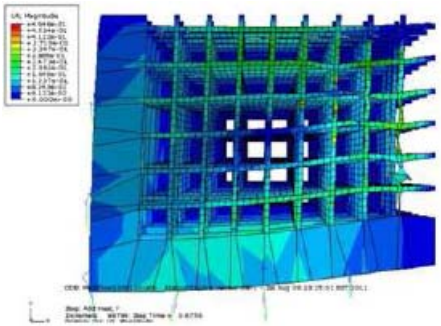
PRESCRIPTIVE-BASED DESIGN (*PAST* & PRESENT):

> A set of rules for how a building must be constructed
  - Orientated around standard testing
  - Don't necessarily provide optimum solution



PERFORMANCE-BASED DESIGN (PRESENT & FUTURE):

> Express defined objectives and allows designers to use any fire safety strategy to achieve adequate safety
  - Allow engineering and innovative solution
  - Relies on fire science
  - More flexible



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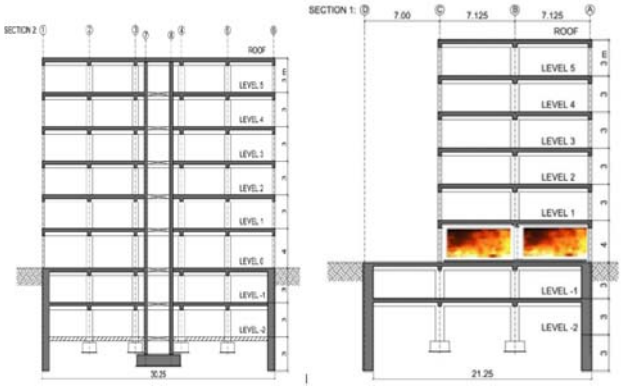
General Methodology

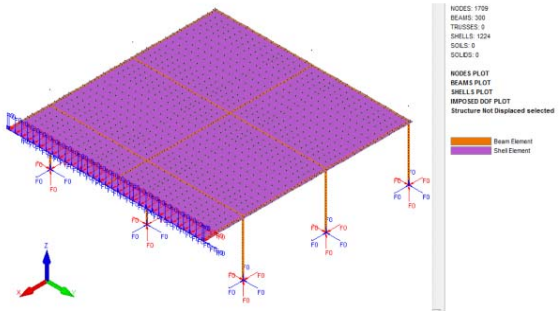
Fire Scenario and Design Fire



Fully developed fire

- to quantify the probability of failure

Structural detailed analysis (SAFIR)



General Methodology

A first standardized application to concrete:
example of a public building in ISO TC 92/SC4

Objective

No risk to life safety of occupants, fire fighters and others in the vicinity of the building, due to the structural behavior of the building once subjected to fire

Functional Requirement

Structural stability to prevent failure of any structural element during the entire duration of fire including the cooling phase

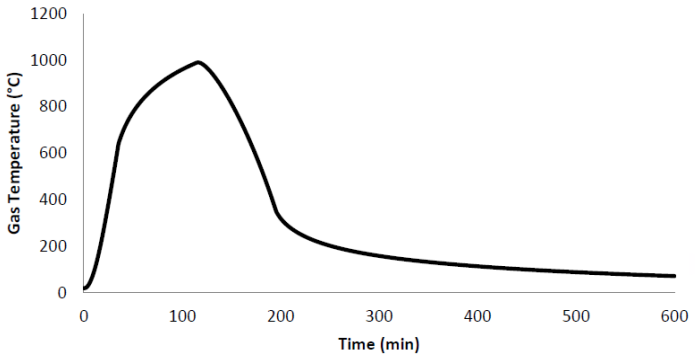
Performance Criteria

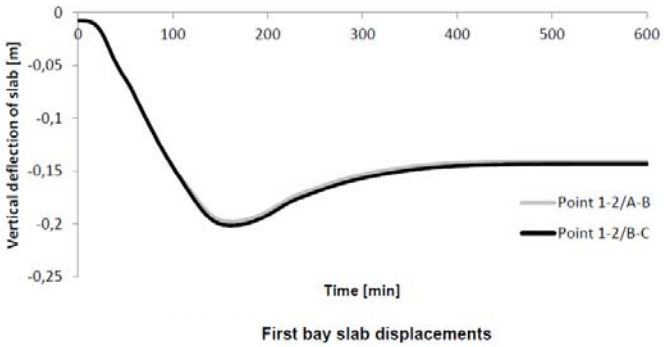
Simplified approach; Sensitivity analysis: critical temperature of 560°C in concrete reinforcement

Full detailed analysis :
No overall failure of the building, e.g. due to the loss of stability of columns, loss of shear capacity, rotational capacity (<250 mrad), maximum deflection of all slabs does not exceed 1/20 of their spans

Selection of design fire scenarios for detailed structural

All performance criteria are met during a ten hours fire duration





First bay slab displacements

Improve the safety of people and assets: The Fire Testing Centre in Épernon

FIRE TESTING

For standard tests and tests specifically designed to meet customer requirements, performed on materials, products, building components or assemblies, and therefore cover a range of scales:

Fire resistance testing: an exceptional furnace Promethee for fire tests under standard and real conditions

Intermediate-scale orientation tests: Assessment the fire performance of elements of shapes that are representative of structural components

Capacity (actual dimensions of structure):
6 m L x 4 m W x 2.6 m to 6 m H.
Multi-directional loading
(29 jacks, from 5 up to 300 kN)
Total power: 16 MW

Improve the safety of people and assets:
The Fire Testing Centre in Épernon

Testing **fire propagation on façades**: LEPIR 2 test (according to French IT 249)

Air-conveyance test rig: fire resistance tests of **very large** air-conveyance systems (throughput of up to 100,000 m³/h, internal sectional area of up to 4 m x 3 m, vertical load : 300 kN)

Material thermomechanical characterization tests :

- **Compressive-strength testing furnace and Tensile-strength testing furnace up to 800°C,**
- SEM, X-ray diffractometer from -20 °C to over 1 000 °C

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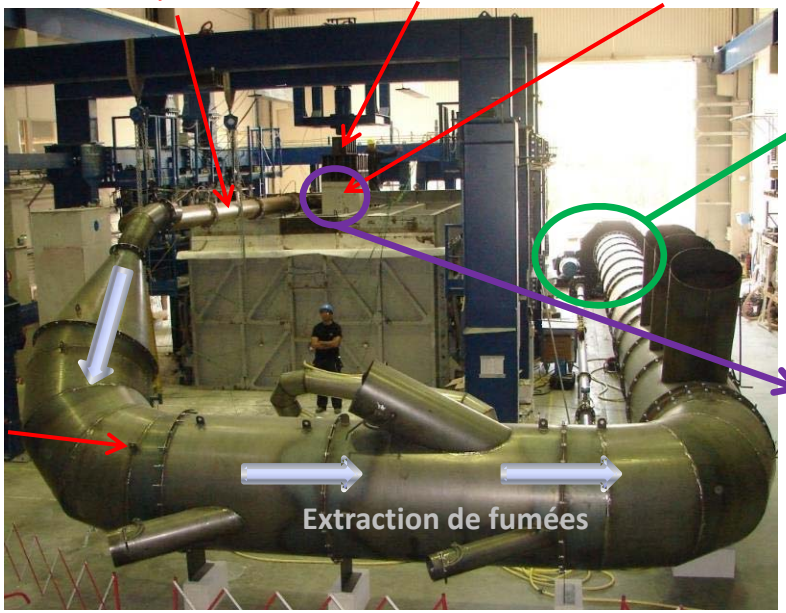
Testing facility: PEAHT

(Plateforme d'Essais Aérauliques à Haute Température)



Ventilateur 105 000 m³/h

Plaque perforée insérée dans le conduit C

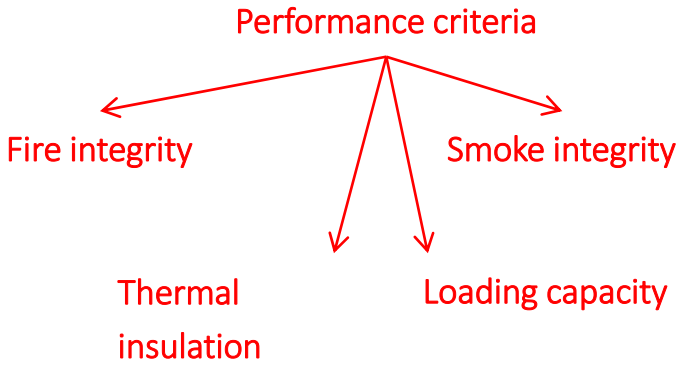
Vue d'ensemble de la PEAHT

Fire resistance test of concrete smoke exhaust ducts-columns

370 cm high
60×40 cm internal section and 100 × 80 cm external section 20 cm thick

View from inside of the furnace

Véolia headquarters, Aubervillliers (93)



<u>Références normatives :</u>
NF EN 1363-1 de mars 2013 « Essais de résistance au feu, Partie 1 : Exigences générales »
NF EN 1366-1 de novembre 2014 « Essais de résistance au feu des installations techniques, Partie 1 : Conduits de ventilation »
NF EN 1366-8 de février 2005 « Essais de résistance au feu des installations techniques, Partie 8 : Conduits d'extraction de fumées »

Design methods/Eurocodes…

…UPDATE OF THE CHALLENGING POINTS

> Eurocode 1-1-2 (fire actions):

- Harmonization of annex E: reduction of fire load in case of availability of fire fighting measurements → these reduction coefficient have been rejected in many countries however there is a will to push it again in the revision
- Annex C: a method to calculate the heat flux to the columns is being introduced : necessity to take into account all the existing experimental results
- What about the last improvement in the fire models for large open space buildings, their introduction should be considered for the revision…

Design methods/Eurocodes…

…UPDATE OF THE CHALLENGING POINTS

- Eurocode 2-1-2 (concrete) / Eurocode 4-1-2 (composite structures): which thermal conductibility curve to be used for concrete?
- Eurocode 2-1-2: amendment on Annex C is under preparation (new tabulated data for columns)
- Eurocode 2-1-2: how to consider spalling in a pragmatic way
- Eurocode 2-1-2: material properties for lightweight aggregates
- Eurocode 4-1-2: membrane effect is being introduced through a simplified method whose field of application should be carefully verified

Fire testing: fundamental questions for standardized tests

1. Fire reaction testing

   The considered fire action represents a starting fire – it does not give a real picture of the contribution of the materials in a fully developed fire

2. Fire scenarios in a FSE approach: how to take into account combustible structural materials ?

3. Fire resistance testing

   How to take into account the contribution of combustible tested products to fire intensity development (heat flux instead of temperature measurement in the furnace)?

4. Facade testing: no harmonized test at European level

   New building products and building designs are changing significantly the way fire is propagating from one floor to the other

Fire safety – a major working field for the concrete sector

3 PRIORITIES HAVE BEEN DISCUSSED AT THE LEVEL OF THE EUROPEAN CONCRETE SECTOR

- Studying the fire performance of new building products and new building designs, so as to take properly into account the contribution of these new systems to fire intensity development
- Using fire safety engineering as a tool for approaching the true reality of fire development and improving the safety of people and not only for reducing fire building resilience
- Carry on research projects in order to develop technical argumentation to design concrete structure in an optimized manner (risk assessment and no unnecessary safety margin)