Performance Based Design for the Fire Situation, leading to Economic and Safe Fire Resistance

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Summary

This contribution describes the present state of the art in fire engineering developments according to EN1991-1-2 (DAV 20.11.2002). In the presently described buildings, instead of paying for protection materials in order to fulfill ISO fire requirements of 120 minutes and more, this money was used for the installation of active fire safety measures. Active fire safety produces real safety for people, f.i. by adequate partitioning, by safe escape routes, by proper smoke venting or by conveniently designed & maintained sprinkler systems. But at the same time active fire safety contributes in helping the structure resist realistic heating conditions, as the potential severity of a fire and its probability of occurrence are cut down .

Keywords: Fire design situation, Risk of fire activation, Active fire safety measures, Realistic fire resistance, Eurocode on Actions, Actions in the fire situation, EN1991-1-2.

1. Introduction

The European Commission issued on 21 December 1988 a directive concerning the products used in the construction of buildings and civil engineering works, "CPD", in order to fix essential requirements to be met like mechanical resistance and stability, safety in case of fire etc.
In the Interpretative Document "safety in case of fire", published on 28 February 1994, it is foreseen that the essential requirement may be satisfied as far as structural elements are concerned by tests or design methods or a combination of tests and calculations.

2. Essentials for performance based design

A first step consists in accepting the global structural analysis in the fire situation, in considering the accidental combination rule for actions during fire exposure and in designing according to natural fire conditions. A second step consists finally in considering Performance Based Requirements i.e. the fire safety of occupants and firemen, the protection of property and environment, a realistic required fire resistance period, and a realistic structural fire design including active fire safety.

The main objective is given by the acceptable safety level, which may be defined by comparison to the different existing risks in life including the structural collapse of a building in normal conditions of use. The target failure probability not to be exceeded in normal conditions as well as in fire, is given by $7{,}23 \cdot 10^{-5}$ for the building life of ~55 years.

Reliability calculations have shown that a connection may be established between the reliability index β_{fi} , related to the probability of structural failure in case of fire p_{ffi}, and the probability $p_{fi,55}$ of getting a fully fire engulfed compartment during the life time of the building as shown in Fig.1. That probability $p_{fi,55}$ is depending on the compartment size, the type of occupancy and the active fire safety measures implemented.

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Hence the design fire load $q_{f,d}$ may be calculated by multiplying the characteristic fire load $q_{f,k}$ by the partial factors δ_{q1} and δ_{q2}, and the differentiation factor δ_n as follows
$q_{f,d} = m \cdot \delta_{q1} \cdot \delta_{q2} \cdot \delta_n \cdot q_{f,k}$ [MJ/m²], where δ_{q1} and δ_{q2} refer to the fire activation risks and δ_n to the active fire safety measures.

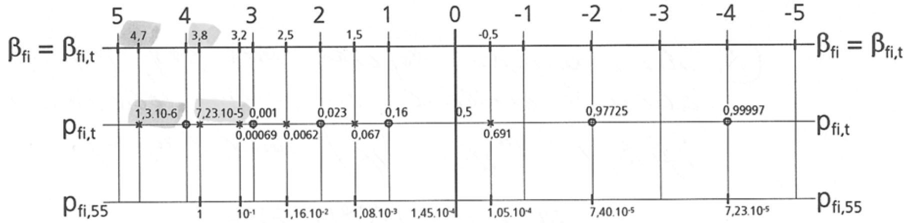

Fig.1: Reliability index β_{fi} as a function of the probability $p_{fi,55}$ of getting a fully fire engulfed compartment during the life time of the building.

3. Performance based design of some buildings

For all the buildings presented in the full paper, the natural design fire curve has been calculated using the Software OZONE developed under the leadership of the author by the University of Liège. The most critical fire scenario leads to air temperatures of approximately 500°C. This fire curve was f.i. applied to the continuous composite columns, of the DEXIA-BIL building shown on Fig.2, thus leading to maximum concrete temperatures of 255°C, respectively to a maximum horizontal deformation of ~ 5mm. Furthermore, in order to discover internal load redistributions during heating, the entity composed of a continuous beam connected to the corresponding continuous column was analysed on behalf of the software CEFICOSS. This leads to a maximum deflection of 4cm in the composite beam at 30minutes of natural heating, but also to horizontal displacements of ~ 4cm at the level of connection beam to column. The minimum proper value MPV of the entity beam - column clearly indicates, that failure was never to be envisaged and that the structure even recovers practically its full strength after that natural fire.

Fig.2: DEXIA-BIL building A,B and C as finished end 2006.

4. Conclusions

Under these conditions the following amazing result could be obtained, which consists in finally having conceived and realized a tower building, 75m high, with steel columns and steel beams kept visible and unprotected. It is for the first time that such an innovative step has been undertaken, not forgetting that the active fire safety implemented brings even people's safety to the highest possible level.