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Comparative Evaluation of Prescriptive, Performance-Based and Risk-Based Fire Safety in an Office Building

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Building description
- Three-storey office building with a central atrium
- Ground floor: 900 m², 1st-2nd floor: 600 m²
- 250 occupants during daytime (special use: 400 occupants)
- Prescriptive fire safety design according to the Danish Building Regulations
  - Full coverage sprinkler system
  - Four independent exits on the ground floor
  - Two stairwells

Performance-based analysis
- The requirement was that ASET must exceed RSET for all design scenarios
- Untenable conditions were determined by criteria for heat flux, temperature, visibility and smoke layer height
- Six plausible, severe scenarios including system failures were analyzed (see Figure 3)
- ASET was determined by FDS-simulations (see Figure 4)
- RSET was determined according to the method described in the SFPE-handbook. It was assumed that all occupants commenced egress simultaneously

The safety level of the prescriptive design could not be accepted when analyzed by a deterministic performance-based method due to the inclusion of the failure scenarios.

Risk-based analysis
- In the risk-based approach 50,000 scenarios were analyzed. Each scenario was sampled from probability distributions by use of Monte Carlo simulations. This created a broad spectrum of possible fires (both severe and non-severe). Some of the distribution used were:
  - failures of fire installations
  - fire growth rates, fire size and location of the fire
  - time, day and use of building
  - occupant load and distribution
  - reaction and decision time and walking distance for occupants
- ASET was determined by use of zone-models. The early stages of a fire were simulated using a 1-zone model while the later stages of the fire were modeled by 2-zone models (see Figure 6) where both the Heskestadt and the balcony spill plume model was used.
- RSET was calculated using the SFPE-handbook method as in the performance-based analysis, but determined for each individual by sampling input for both pre-movement and movement time.
- The risk-level was found by calculating the number of occupants exposed to critical conditions for each scenario (see Figure 7) and creating a cumulative curve displaying frequency vs. consequence (see Figure 8). The acceptable risk-level was found on the basis of fires statistics in British Standards in lack of a Danish acceptance curve.

The safety level of the prescriptive design could be accepted in the risk-analysis as the risk was included.

Conclusion
- The prescriptive design did not meet the requirements when evaluated by a performance-based analysis
  - This comes as a direct result of assuming an equal probability of occurrence for the scenarios with single system failures and the non-failure scenarios.
  - This contradicts the intention of performance-based design, which was to introduce more flexibly and cost-effectiveness without changing the safety level
- The prescriptive design did meet the requirements when evaluated by a risk-based analysis
  - As a result, the risk-based approach validates the prescriptive design
- In order for risk-based design to gain acceptance in Denmark there is a need for a risk-profile, which is accepted and approved by both society and legislative parties. The development of such a risk-profile merits further study.