Fire Safety Engineering
New possibilities for wood products

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Fire Safety of Wooden Structures
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Fire safety of buildings

The basis is the essential requirement for fire safety concerning building products

Requirements according to CPD:

- Load-bearing capacity of construction can be assumed for a specific period of time
- Generation and spread of fire and smoke are limited
- Spread of fire to neighbouring works is limited
- Occupants can leave the works or can be rescued
- Safety of rescue teams is taken into consideration

How to apply regulations

In most countries two alternative ways to show required fire performance

1. Design according to the fire classes and numerical criteria given in building code
2. Case by case attestation with verified methods (performance based fire safety engineering)
   - Requires advanced engineering methods
   - Analysis methods and also generalized case studies for different applications are available (i.e. wooden facades)

⇒ Thus wood can be used in load bearing structures up to 4 - 6 stories or even more

⇒ In linings wood has a wide range of use both at interior and exterior applications

Tools for fire safety assessment

Fire simulation

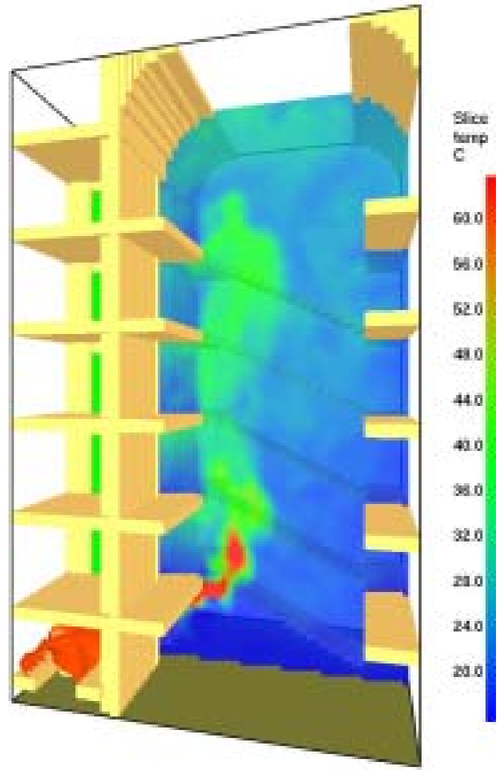
- Fire Dynamics Simulator, FDS
  - Development in co-operation NIST, USA and VTT

Evacuation simulation

- In combination with fire simulation

Fire risk analysis

- Utilizing fire statistics, active fire protection, etc.



Combining these tools:

VTT has developed a Probabilistic Fire Simulator, PFS, method by which results are given as probabilities for events (of concern / to be avoided)

Case study
USE OF WOOD IN FACADES

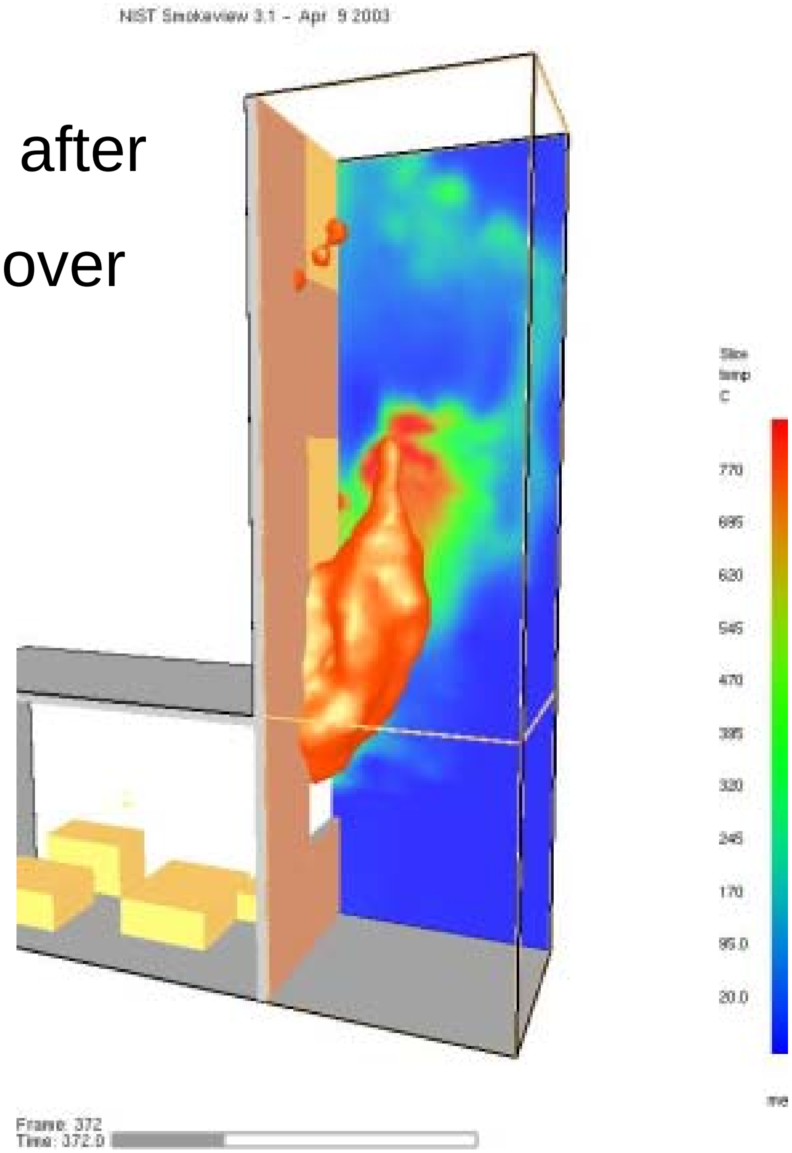
Timo Korhonen and Jukka Hietaniemi, VTT

Funded by:
Wood Focus
Tekes

Background

- Prescriptive part of Finnish regulations restricts use of wood in facades to 2 floors (if not sprinklers used)
- Performance based part of regulations can be used to show acceptable fire performance of wooden facades
- Thus a case study was made and extended to a more general level
- Objective was to show that relative changes in fire safety are within acceptable limits when a concrete facade was replaced with wood

6 min after flashover



Wooden facades - Summary of results

- Wooden facade (minimum D,s2,d2 class) does cause only a limited increase in the probability of fire spread to apartments above in case of a flashover in the room of origin of fire.
- This increase is well within the limits which variation in other parameters (distance to fire brigade, room shape, window dimensions, etc.) can cause.
- In the studied typical apartment buildings people are killed in fire only in the room/apartment of origin of fire or in the staircase. Wooden facade does not practically increase the number of incidents.
- Property losses can be restricted by proper construction of fire stops in ventilation cavities of facades as well as eaves and roof/attic structures.

Case study
BASIS FOR RISK-BASED FIRE RESISTANCE REQUIREMENTS

Jukka Hietaniemi
VTT Building and Transport

This work has been carried out with a financial grant from the European Coal and Steel Community

ECSC Steel RTD Programme Contract No. 7210-PR-251

BACKGROUND

- Fire resistance requirements vary significantly in different European countries
  - some of the differences correspond to obvious diversities in construction practices and culture, etc.
  - yet, many differences have no obvious technical basis

e.g., stability (R) requirement in offices

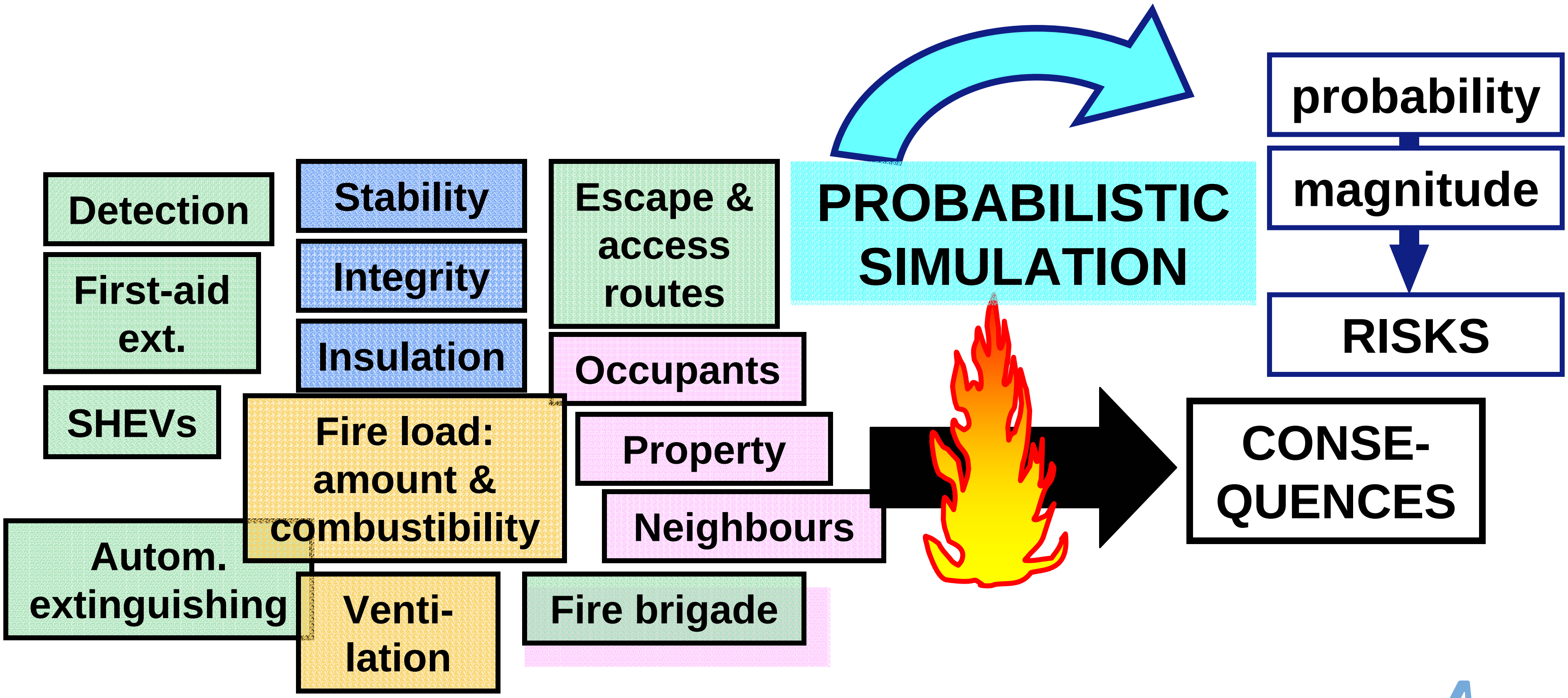
	FI	FR	GR	LU	GB NS/S		DK		NO	ES	SE
1-2	30 60	0	30		30	30	30	60	30	60	30
3	60	0	60	90	60	30	60		60	60	60
4	60	60	60	90	60	30	60		60	60	60
5	60	60	90	90	60	30	120	60	90	60	60
6	60	60	90	90	60	30	120	60	90	90	60
7	60	60	90	90	90	60	120	60	90	90	60
8	60	60	90	120	90	60	120	60	90	90	60
9	120	60	90	120	90	60	120	60	90	90	90
10	120	60	90	120	90	60	120	60	90	120	90
>10	120	120	90	120	-	120	120	60	90	120	90

BACKGROUND, cont'd

- The differences correspond to the fact that the fire resistance requirements -like most other technical regulations - have evolved through a historical development process under the influence of various social, economical and technical factors
  - thus, their basis and approaches used have some degree of non-coherence and there may be inconsistencies
- The present regulatory systems are not bad or wrong, but there is room for considerable improvements

THE RISK BASED METHODOLOGY

- A schematic overview:



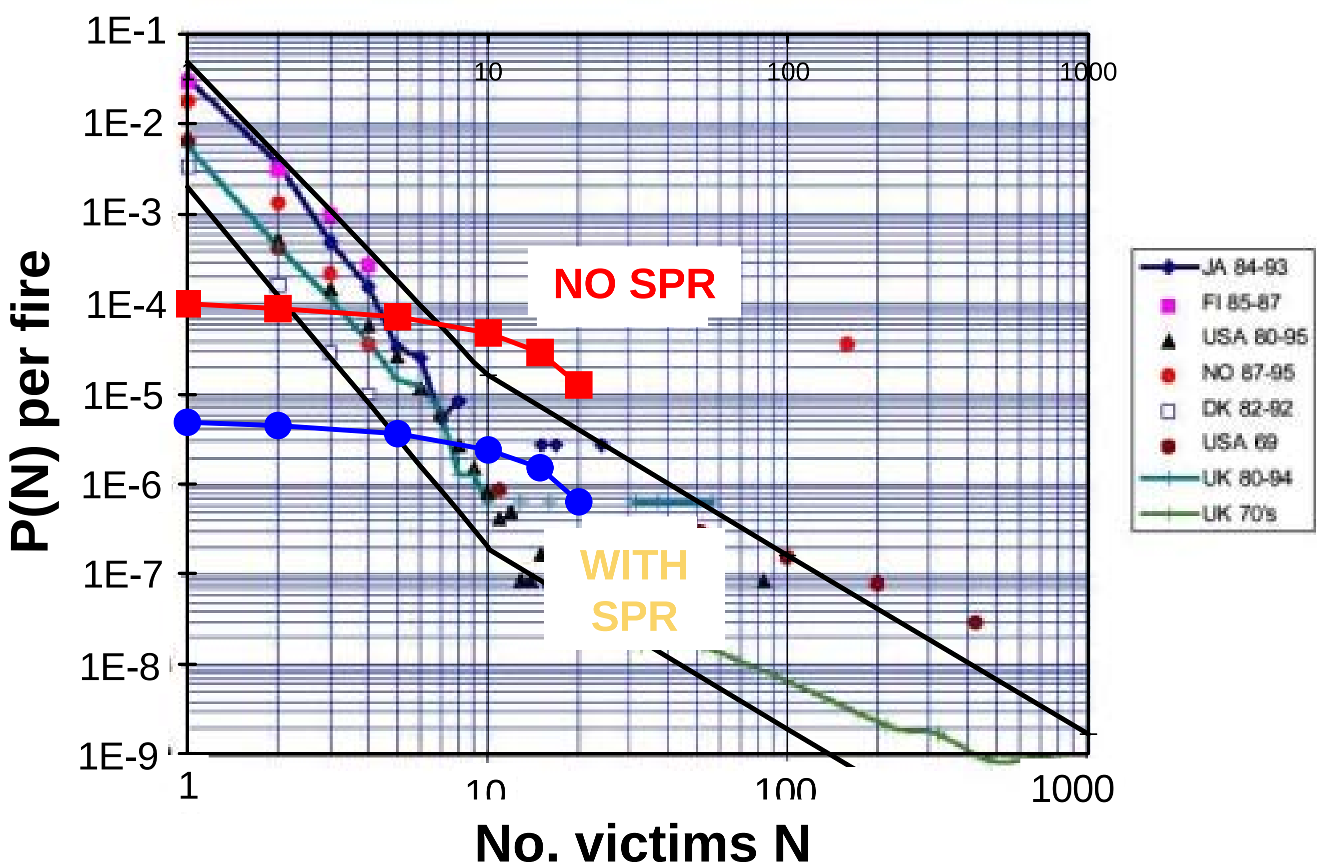
METHODOLOGY, summary

- 1. Monte Carlo simulations on the fire scenarios
- 2. Modelling of fire hazards with the associated consequences and their probabilities
  - for example:
    - probability of structural failure with respect to some failure criterion
    - probability that *N* persons are exposed critically to smoke
- 3. Taking into account the active fire protection measures
- 4. Putting results together to get estimates of the risks

NOTE: This is a short list, but when unfold, it incorporates a vast amount of data and fire satefy engineering, both with respect to the fire itself and its influence on structures & persons

ARE THE RISKS TO LIFE HIGH OR LOW?

- Compare with fire statistics (Keski-Rahkonen/VTT1999)
  - fire deaths, several building types, many countries
- without sprinklers the risk of multivictim fire is elevated



Case study
PERFORMANCE OF LOAD-BEARING GLULAM BEAMS IN NATURAL FIRE

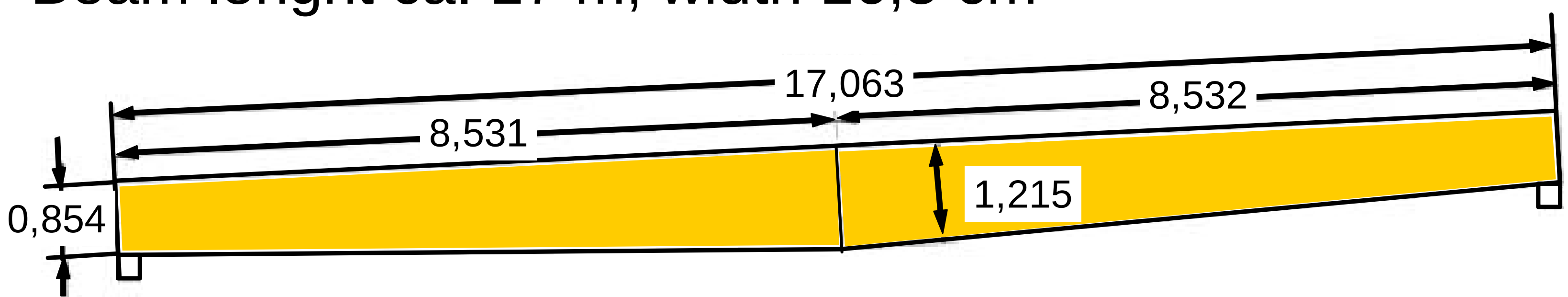
Jukka Hietaniemi and Timo Korhonen
VTT Building and Transport

THE TARGET BUILDIND

- A grocery shop in the South-West region of Finland
  - Lowest snow-load region in Finland
- Close to a fire brigade, about 0,5 kilometers
- Size: length 50 m, width 34 m, height 5,5 m
- Load-bearing structures: glulam beams

STRUCTURES

- Beam lenght ca. 17 m, width 16,5 cm



STRUCTURAL ANALYSIS

- Limit state function with random quantities
  - failure analysis using the Monte Carlo technique

Strength: log-normal

Permanent load: normal

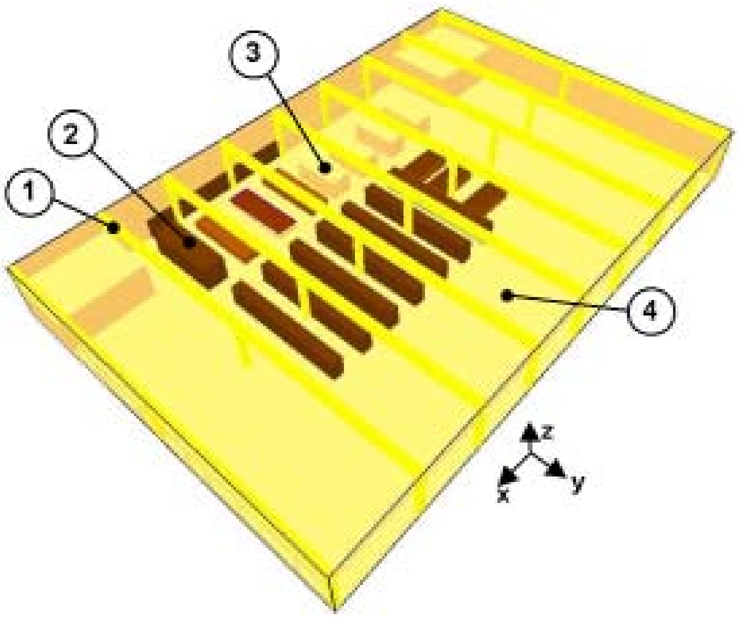
Snow load: different normal distr. for each winter month

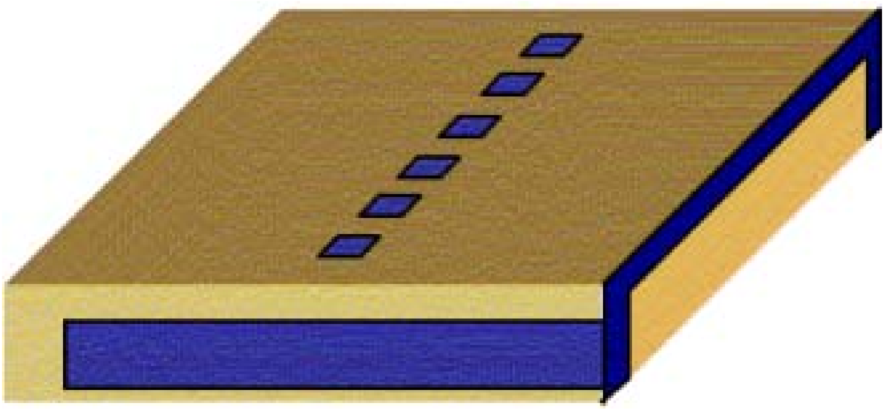
$$g = F \times k_{\mathrm{mod},fi} \times k_{m,\alpha} - \left(\frac{N_{xp} \times (G + Q)}{b_{red} \times h_{red}} + \frac{6 \times M_{yp} \times (G + Q)}{b_{red} \times h^{2}_{red}} \right) \times \mathrm{model}$$

Dimensions of the beam diminish due to charring under the fire exposure: they are calculated on basis of the fire simulations

FIRE SIMULATION: DETERMINISTIC STUDY

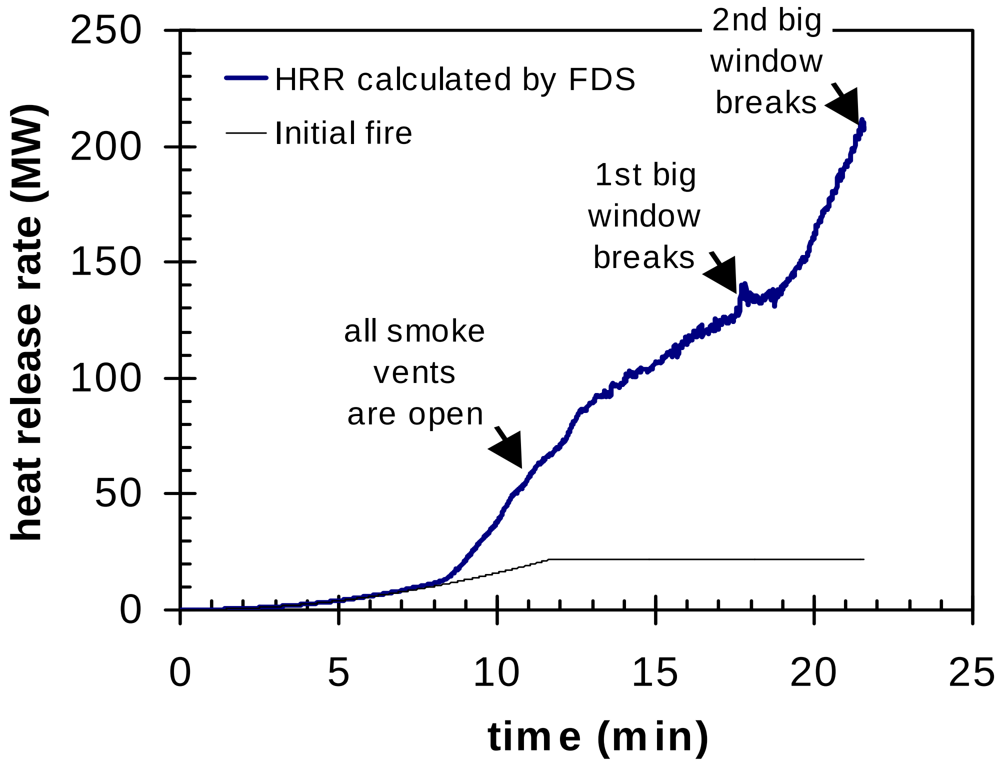
- The standard fire curve and results of simple fire models do not necessarily represent well the natural fire exposure in such a large volume building
- Thus, as a first step, the fire was analysed using the 3D field fire model FDS3





SOME RESULTS OF THE FIRE SIMULATION

- Example of a HRR curve



FIRE SIMULATION: PROBABILISTIC STUDY

- Fire is a strongly random incident and deterministic study can capture only some aspects of the wide variety of ways that the fire may develop
- A probabilistic approach in which the parameters characterising the fire are treated as random quantities accounts for better to the random character of the fire incident
- In this study we use PFS-Ozone model developed by VTT

INPUT:

Set of random variables characterised by distributions

→

FIRE SIMULATION:

Ozone zone model run in Monte Carlo mode (5000 runs/study)

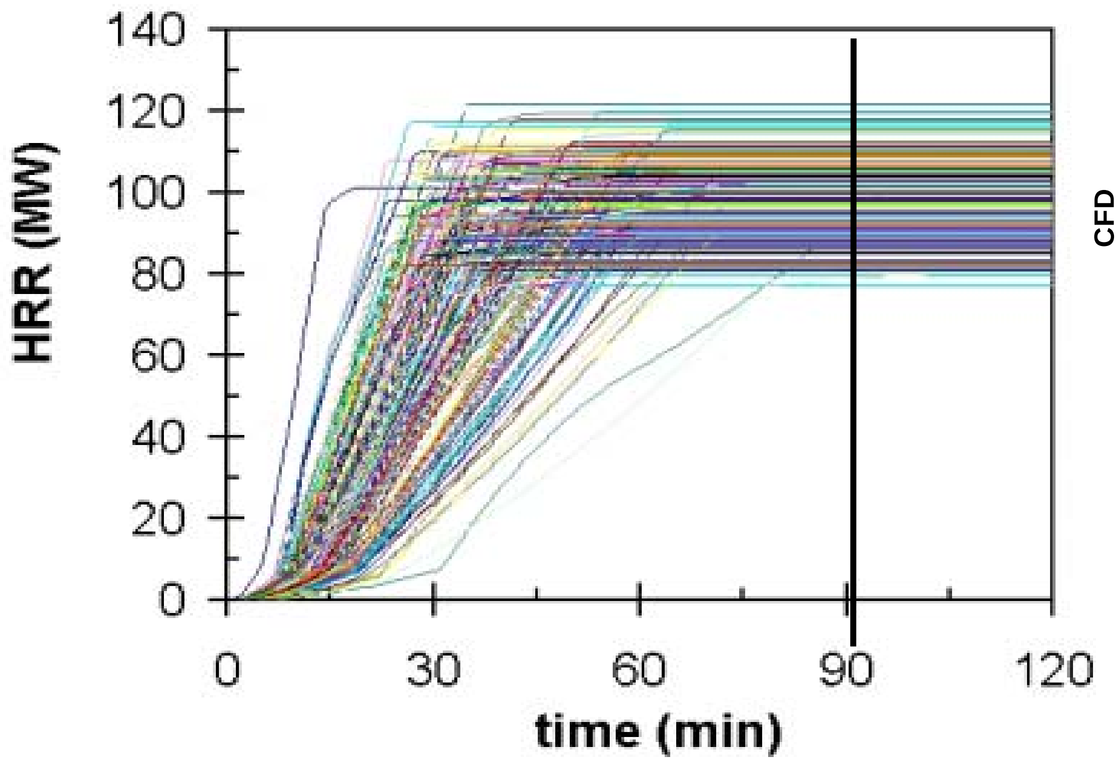
→

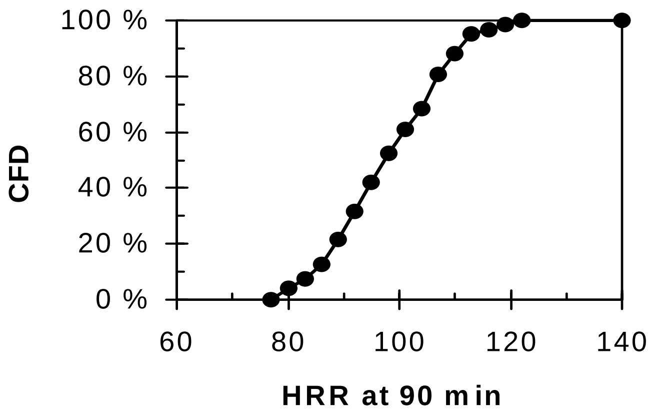
OUTPUT:

Random sets of curves of HRR, T_upper, Z_layer,…

RESULTS OF PROBABILISTIC FIRE SIMULATION

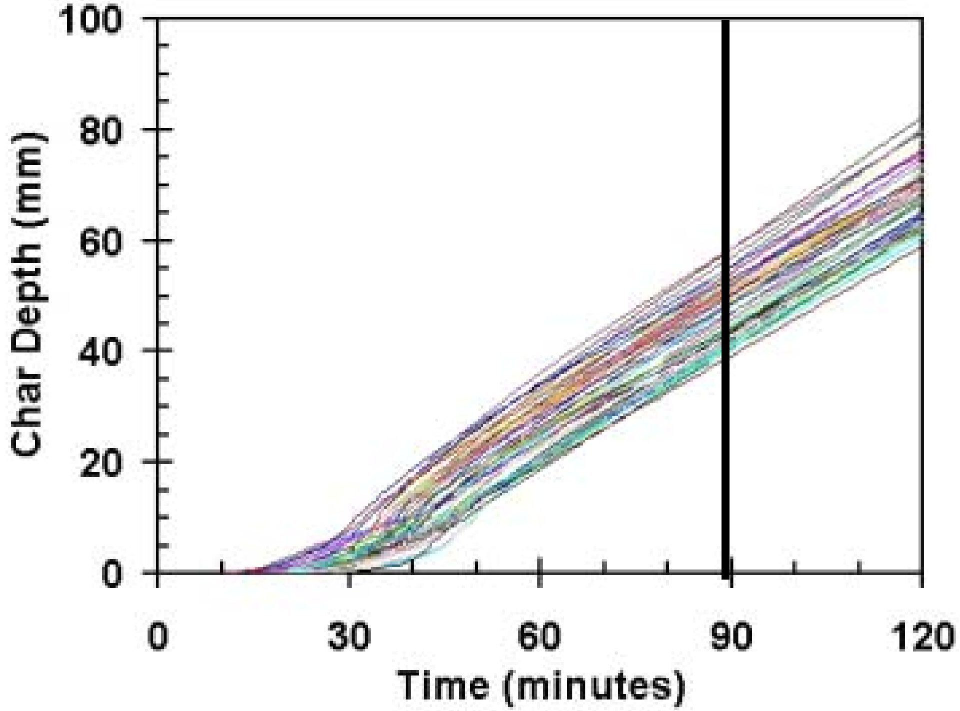
- Example of HRR curves (300s initial fire, SV's open)

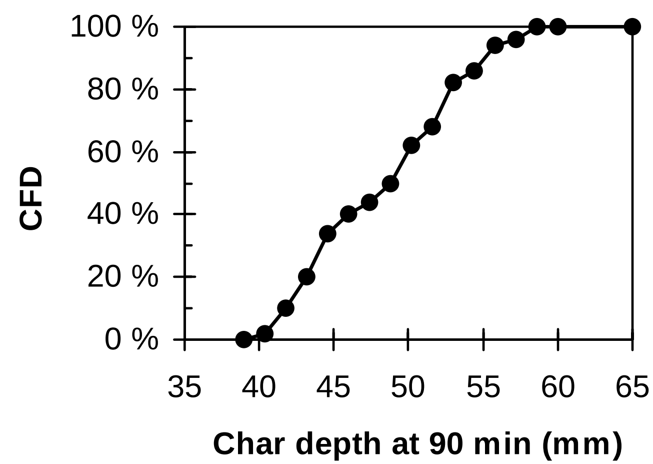




CHARRING CALCULATED ON THE BASIS OF THE PROBABILISTIC FIRE EXPOSURE

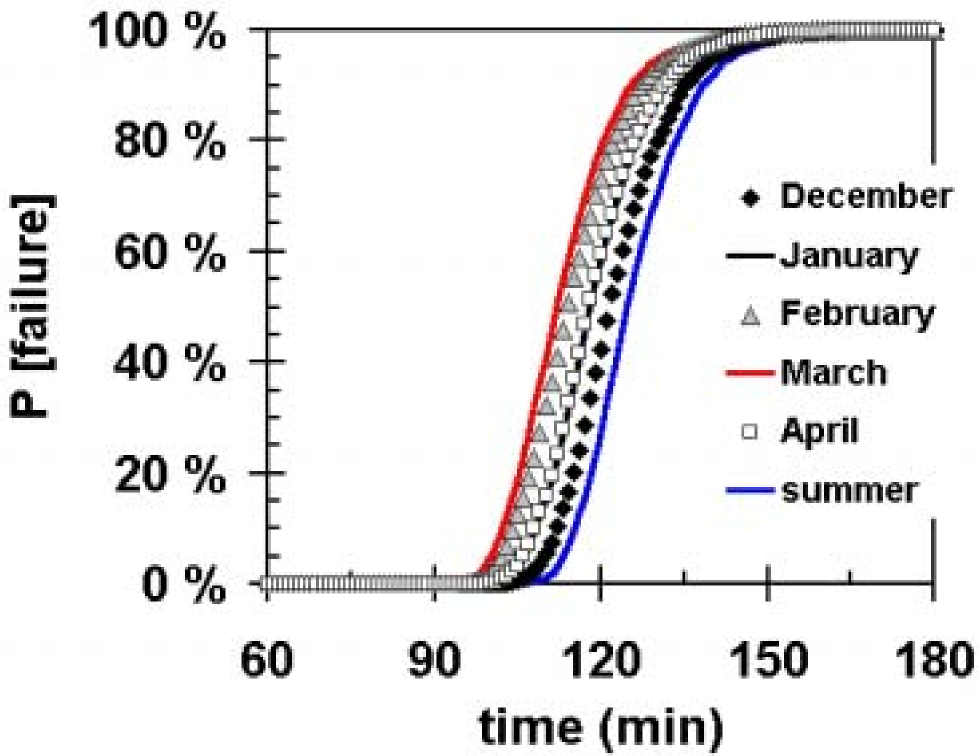
- Charring rate calculated by solving the equation for the pyrolysis front progression





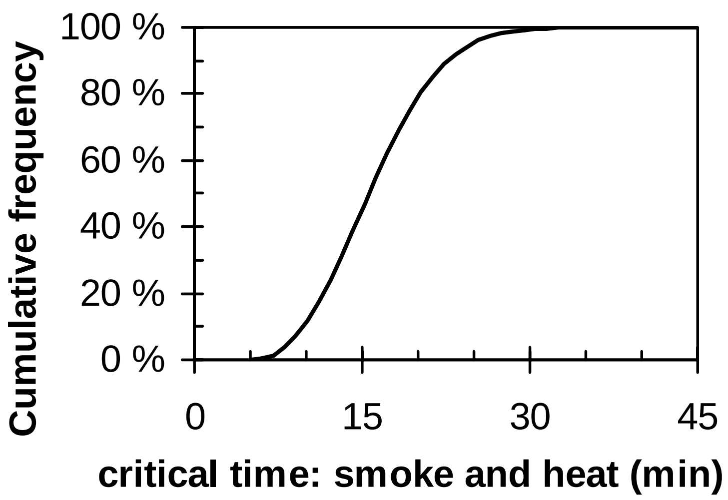
FAILURE PROBABILITY IN A NOT-EXTINGUISHED FIRE

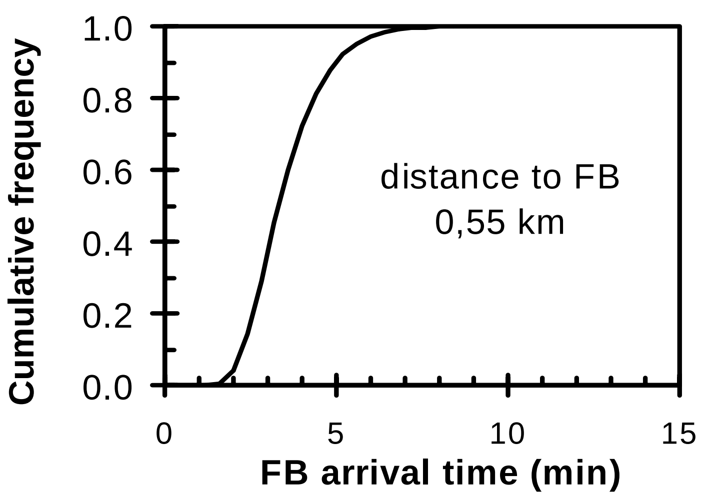
- In the unlikely case that the fire is not extinguished, then beams will fail between 75-120 min, depending on the fire scenario



FIRE SAFETY ASPECTS

- **Role of structural fire performance:**
  - structural performance gives adequate fire safety for civilians, firemen and neighbours (isolated building)





FIRE SAFETY ASPECTS

Improving the fire safety

- The reason why the fire brigade may occasionally arrive too late is that alarm may come too late
  - Faster detection & alarming would be a very efficient way to improve fire safety

Conclusions

- Wood structures are not the critical to the fire safety in the building studied; if one should want to improve fire safety, investment to e.g. faster detection would be much more efficient than investments to structural fire protection

Concluding remarks

Fire safety engineering

- New tool for wood area in most countries
- Quite many countries accept performance based fire safety design in principle
- FSE / fire risk analysis is made for the object of concern as a whole resulting to the required safety level without prescribing which materials can be used and which not
- Today the FSE experience concerning building with wood is still quite limited and not gathered together - this situation does not allow full utilisation of the possibilities
- Fire risk analysis can also be used to assess national prescriptive regulations/guidelines - provides a tool for possible changes and harmonisation of regulations