PART 4

SOFTWARE FOR FIRE DESIGN

Fire design objective

R

resistance of the structures submitted to fire

>

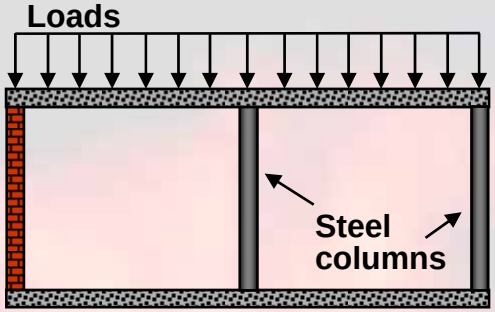
R_{req}

resistance required to the structures for being safe

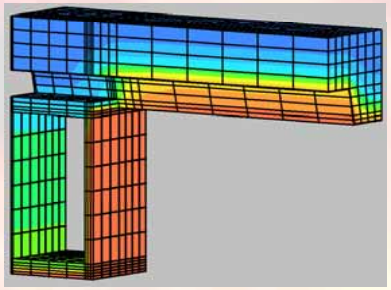
R → Chain of events during a fire

1: Ignition

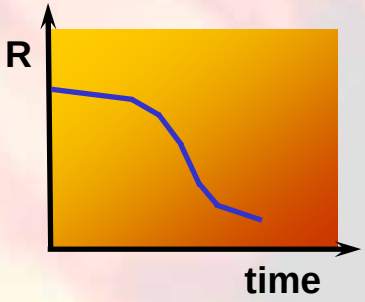
2: Thermal action



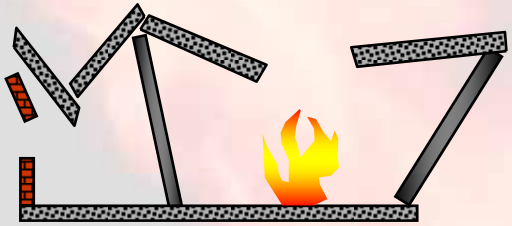
3: Mechanical actions



4: Thermal response



5: Mechanical response



6: Possible collapse

→ **Calculation methodologies - Eurocodes**

R_{req} → **Safety criterion**

$R_{required}$: “R” is assumed to be satisfied where the load bearing function is maintained during the required time of fire exposure.

Prescriptive approach: national fire regulations

Performance based approach: fire safety engineering

Fire design software - Classification

The most common classification of them is broken down in five categories:

- Fire thermal models
- Fire resistance models

→ **R**

- Egress models
- Detector response models
- Miscellaneous models

→ **R_{req} (performance based)**

Fire thermal models

Fire thermal models

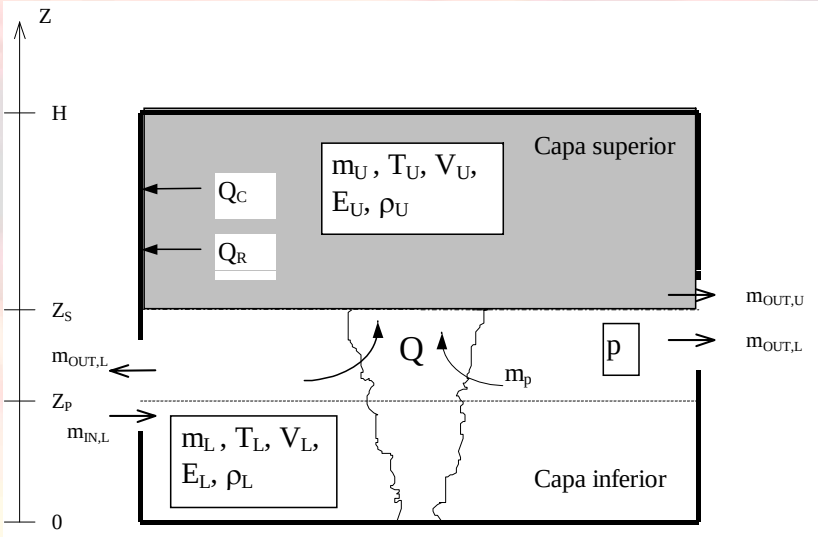
<table>
<tr><th colspan="3">Fire thermal models</th></tr>
<tr><td rowspan="3">Nominal temperature – time curves (Prescriptive rules)</td><td colspan="2">Standard temperature – time curve</td></tr>
<tr><td colspan="2">External fire curve</td></tr>
<tr><td colspan="2">Hydrocarbon curve</td></tr>
<tr><td rowspan="4">Natural fires (Performance based rules)</td><td rowspan="2">Simplified fire models</td><td>Compartment fires</td></tr>
<tr><td>Localised fires</td></tr>
<tr><td rowspan="2">Advanced fire models</td><td>Zone models</td></tr>
<tr><td>Field models</td></tr>
</table>

Zone models

Zone models

There are two principal types of zone models:

• Two Zone models: fire compartment considered as divided in two zones (hot - cold) with homogeneous properties
• One Zone models: fire compartment considered as a furnace



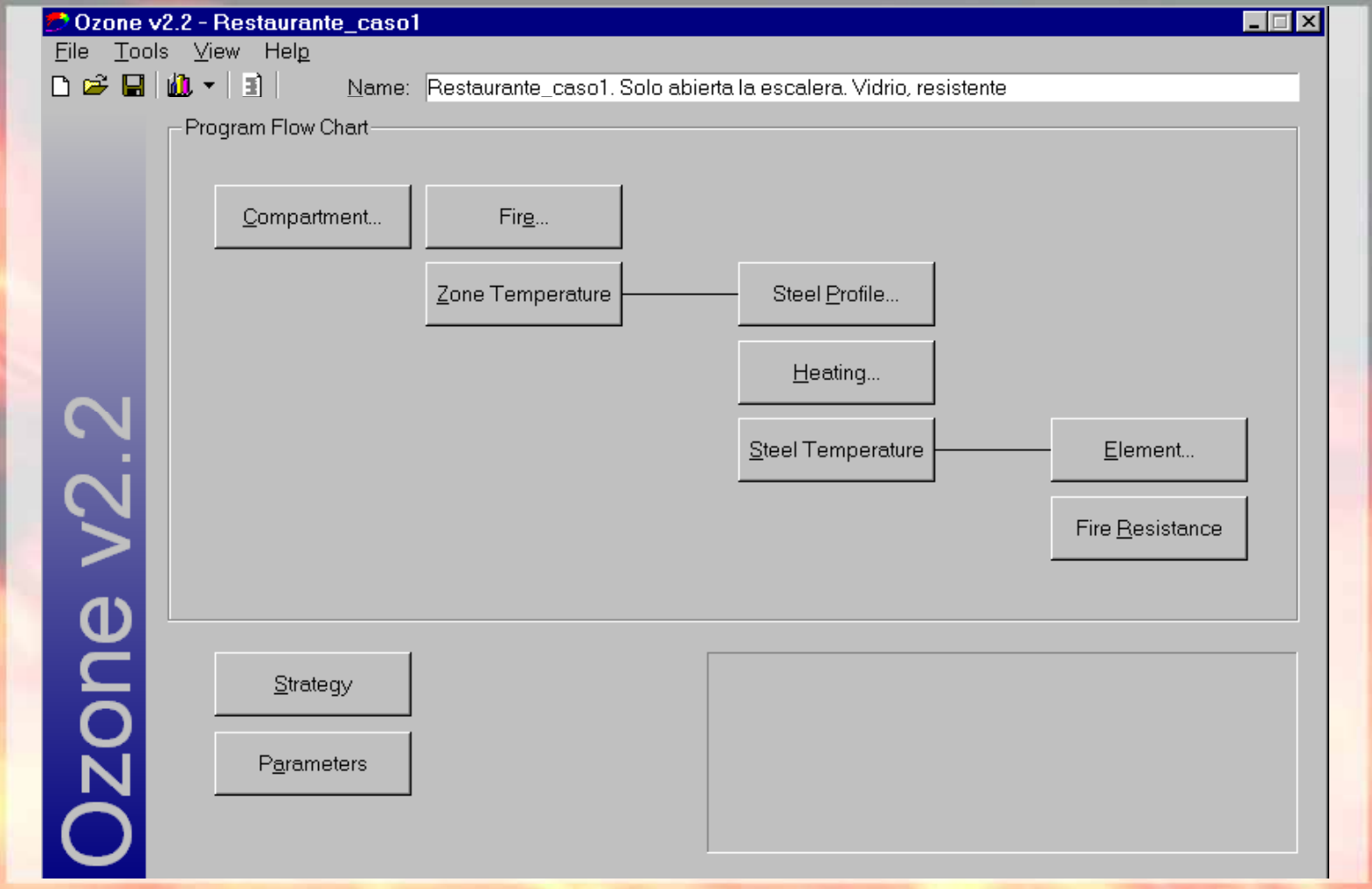
There are one compartment models (only one compartment) and multi-compartment models (considered several adjoining compartments)

Resolution of equations
- Mass balance
- Energy balance

Zone models - Ozone

Software sheet – general description			
Name	OZone		
Version	2.2.2	Year	2002
Country	Luxembourg	Language	English
System	Windows	Size	5 MB
Authors	J. F. Cadorin, J. M. Franssen (Uni. Liège) L.G. Cajot, M. Haller, J.B. Schleich		
Organisation	Arcelor LCS Research Centre		
Application field	Fire Thermal model - Zone		
Availability	Free – www.ulg.ac.be Free – www.sections.arcelor.com		
Contact	Arcelor ASC: asc.tecom@arcelor.com		
Formulation	Based on mass and energy balance equations		
Short description	Model to predict the thermal action of a defined fire. Heat transfer to simple steel elements and time to collapse (EN 1993-1-2) incorporated		

Ozone - Main menu

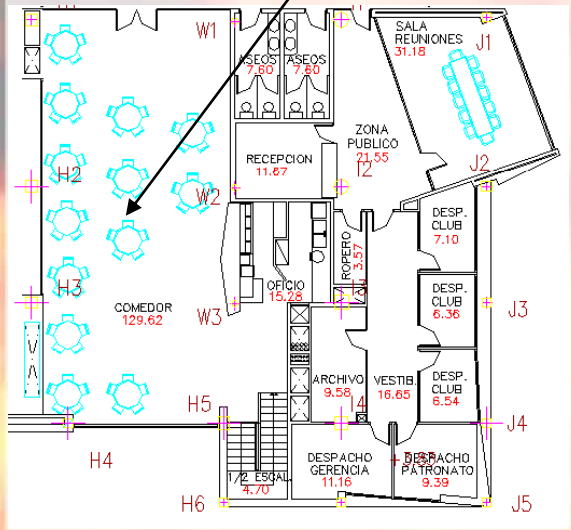


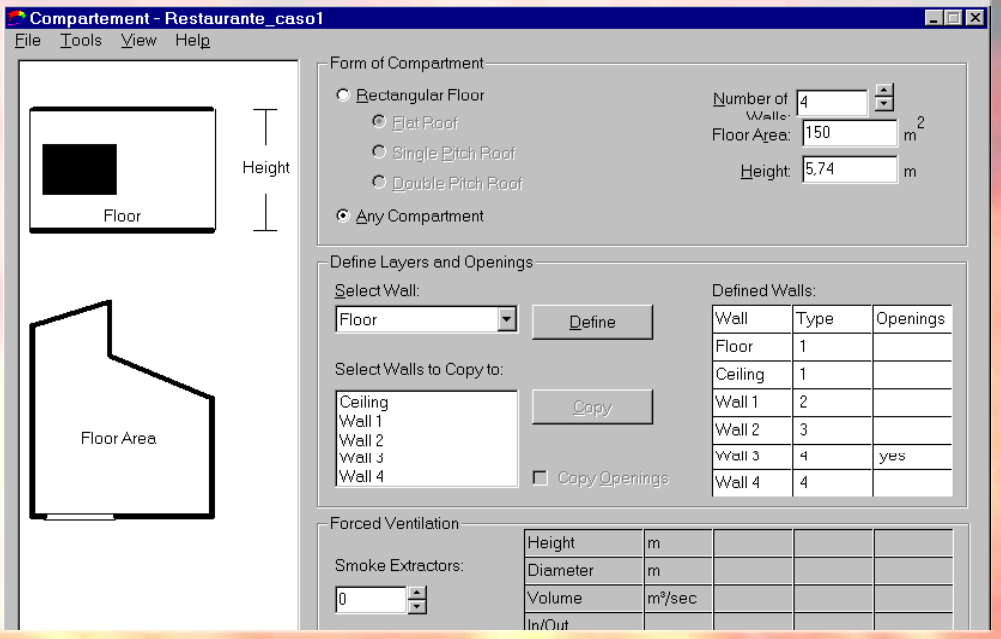
Ozone - Case study

Fire scenario: fire in a restaurant at third storey
Design fire: fully developed fire - tα growth phase
Objective: fire resistance of steel beams
(Requirement of R90)

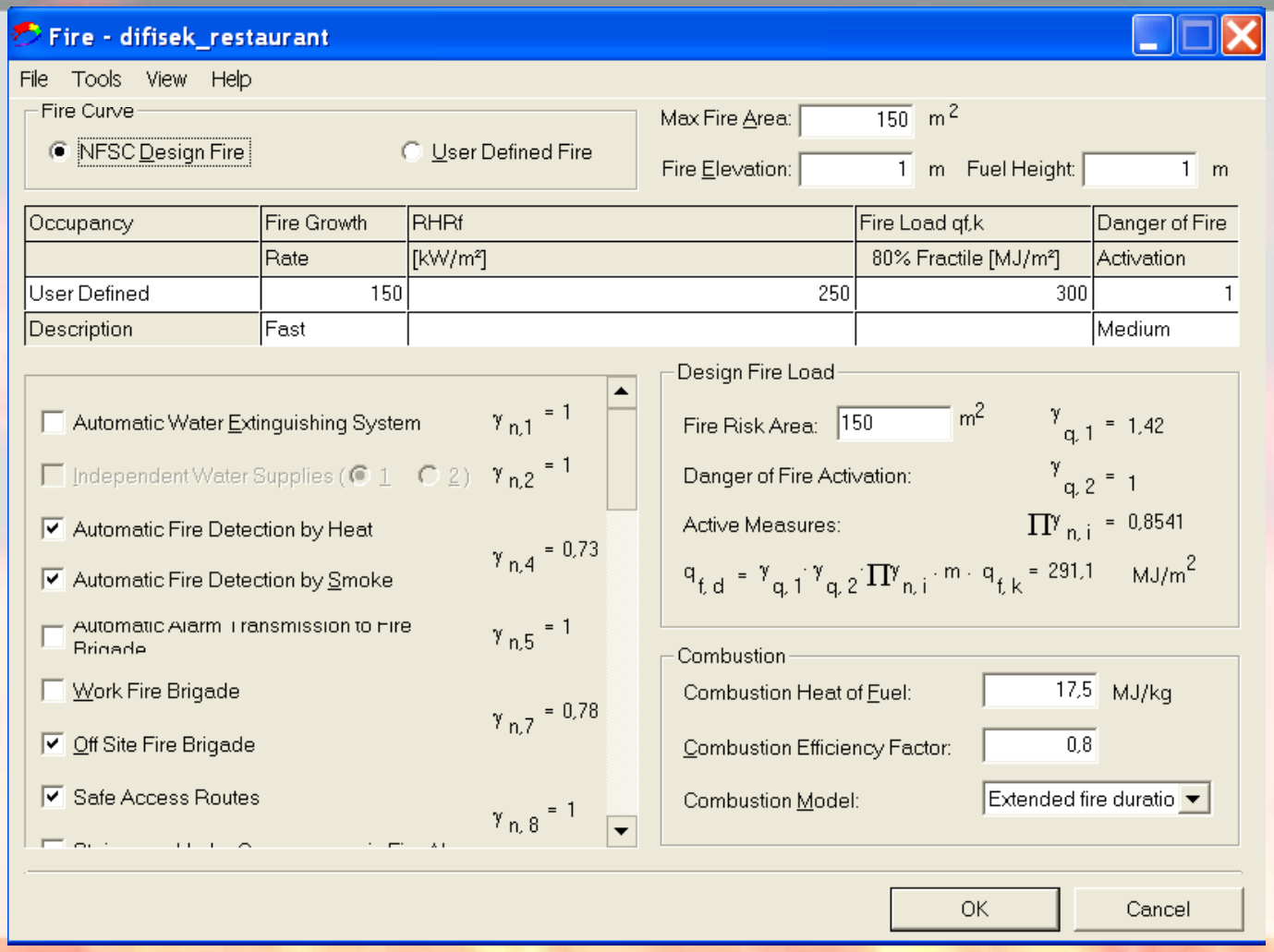
Fire compartment definition:

Fire area

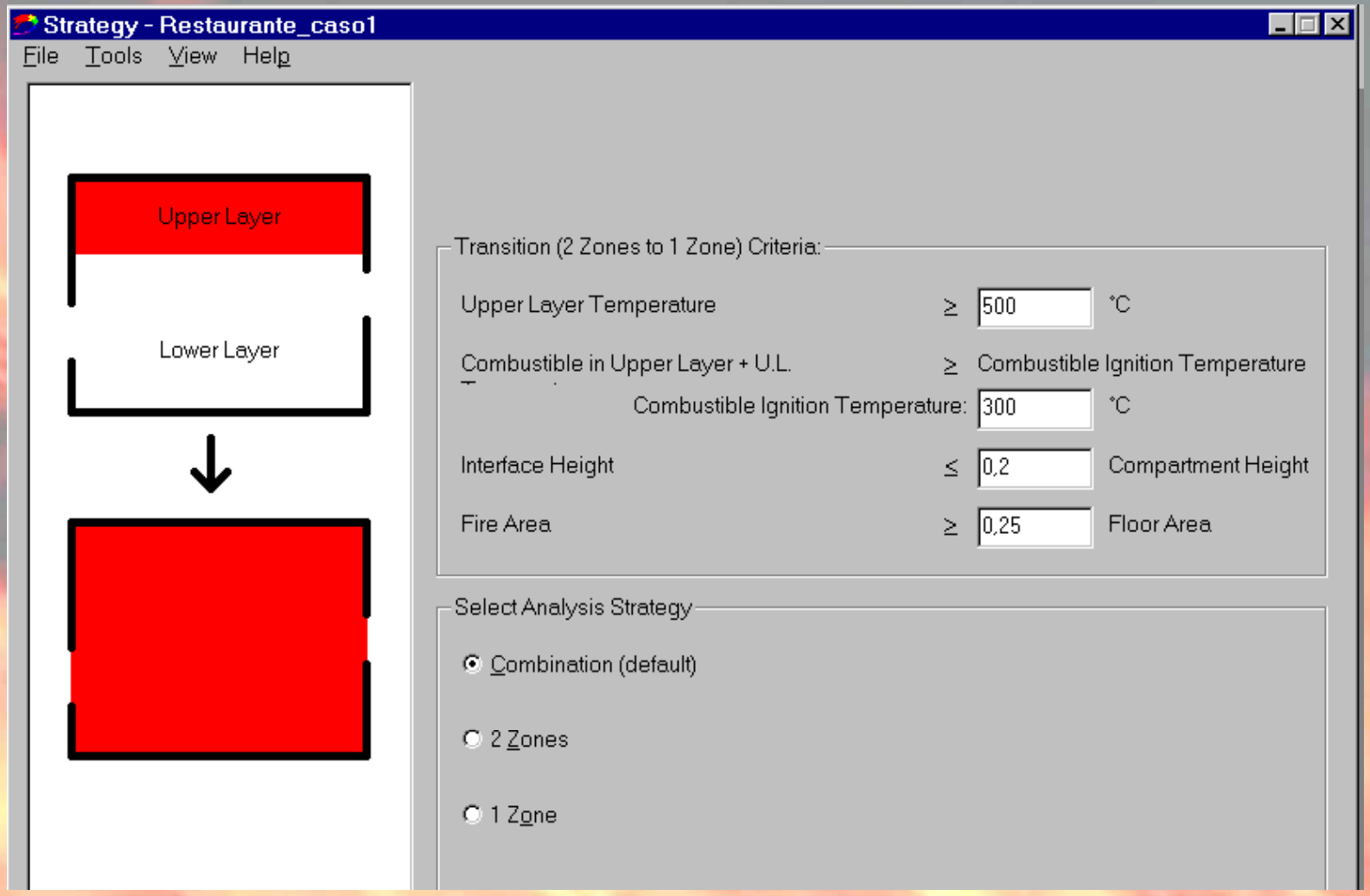




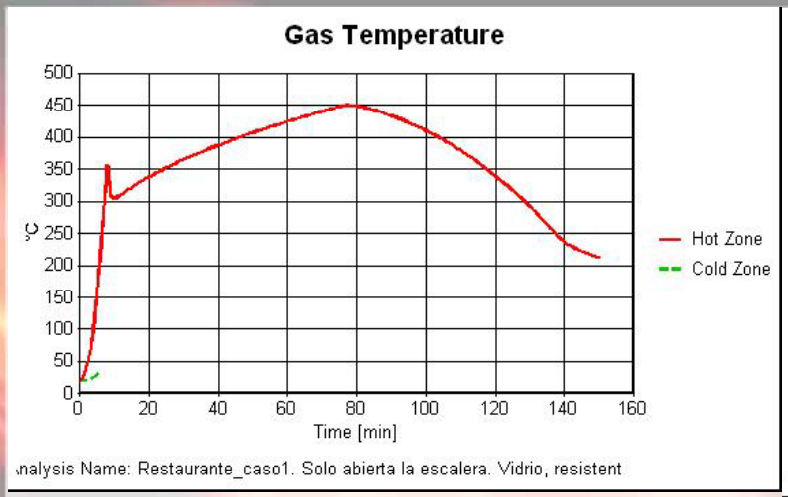
Ozone - Input data: Definition of Fire

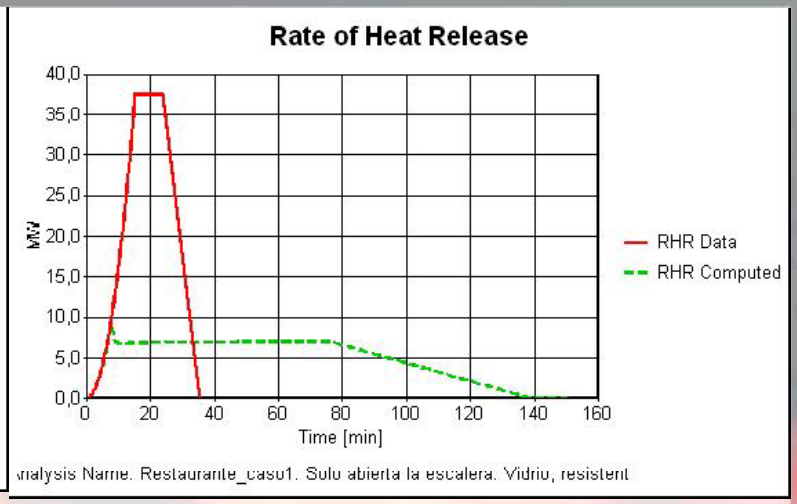


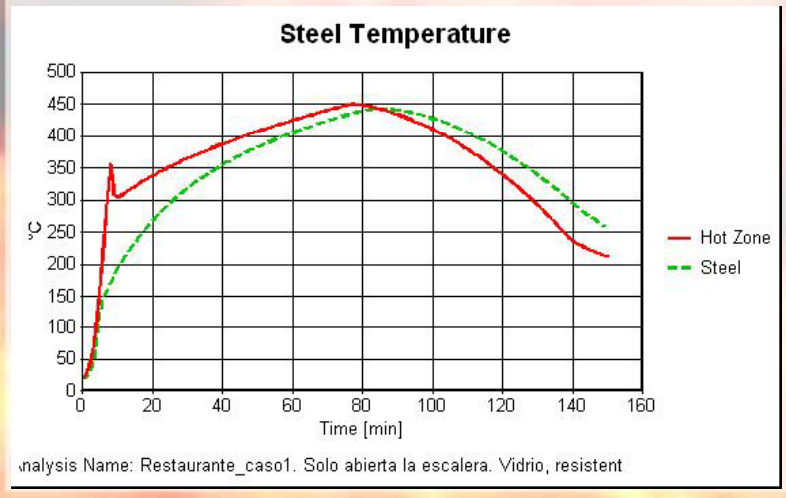
Ozone - Input data:
Criteria for switching from 2 zones to 1 zone



Ozone - Output







Switch from 2 zones to 1 zone: 120”
(fire governed by ventilation)

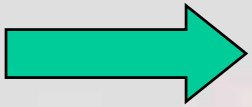
Field models

Field models

Fire Model

+

CFD Code



Fire Field Model

General description of fire phenomenon.

Physical variables description.

CFD Code Types

Specific CFD

Physical models adjusted to fire problems:

SOFIE, FDS...

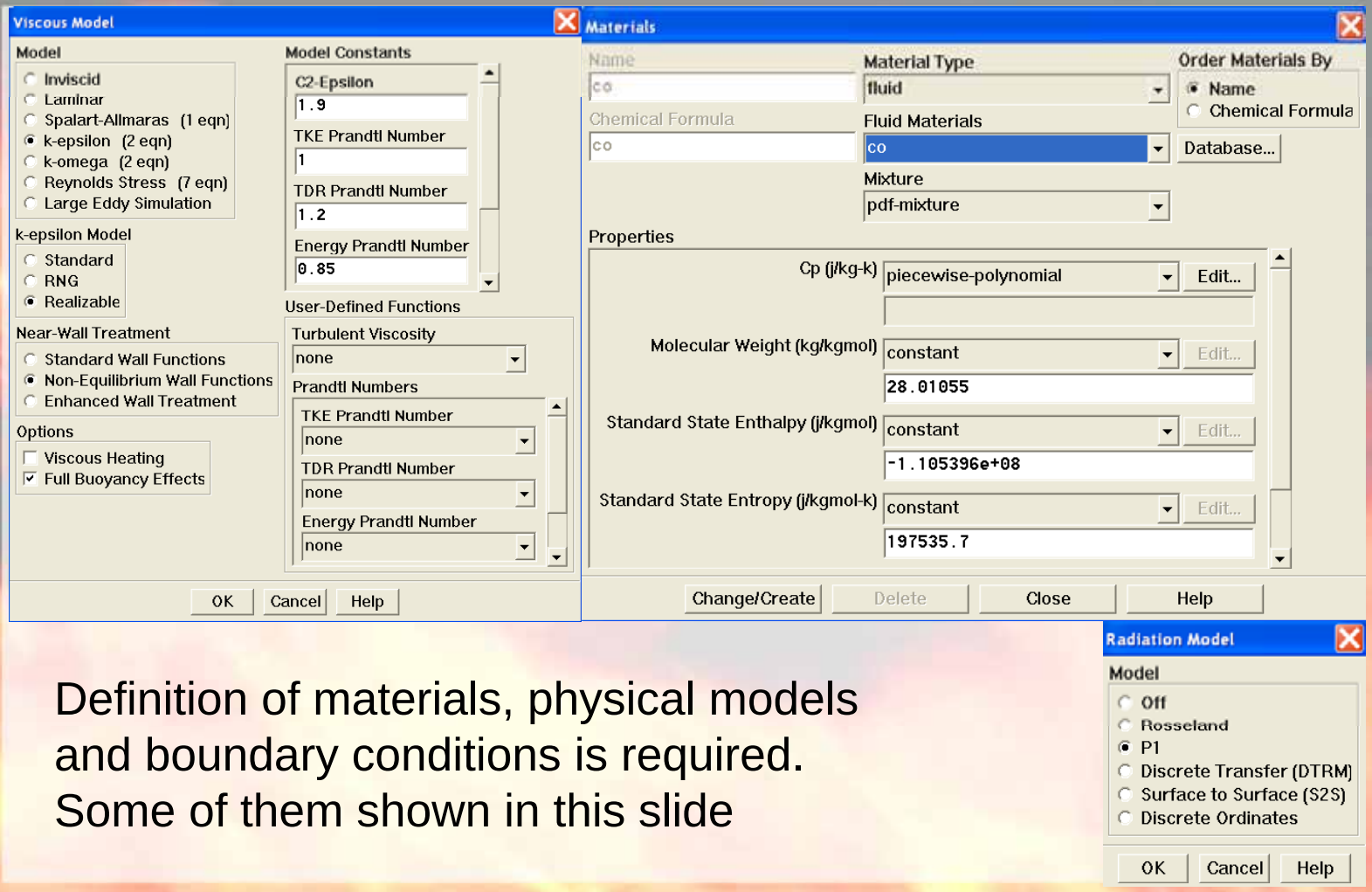
General CFD

More physical models and material properties, selected and adjusted by user to fire modelling: Fluent, CFX,PHOENIX..

Field models - Fluent

Software sheet – general description			
Name	Fluent		
Version	6.1.22	Year	2004
Country	USA	Language	English
System	Windows/UNIX		
Organisation	Fluent Inc.		
Application field	Fire Thermal model - Field.		
Availability	Commercial software		
Contact	www.fluent.com		
Formulation	Based on mass and energy balance equations.		
Short description	General purpose CFD		

Fluent - Input data



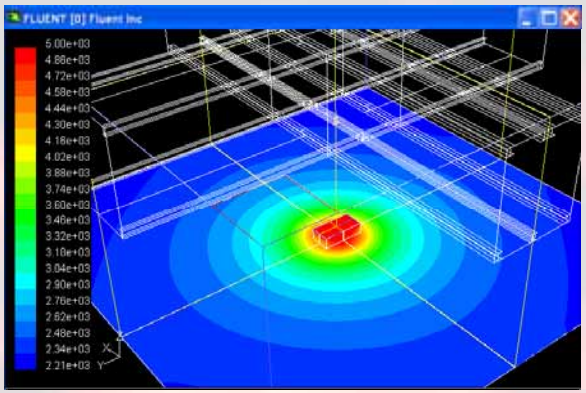
Definition of materials, physical models and boundary conditions is required. Some of them shown in this slide

Fluent- Output data

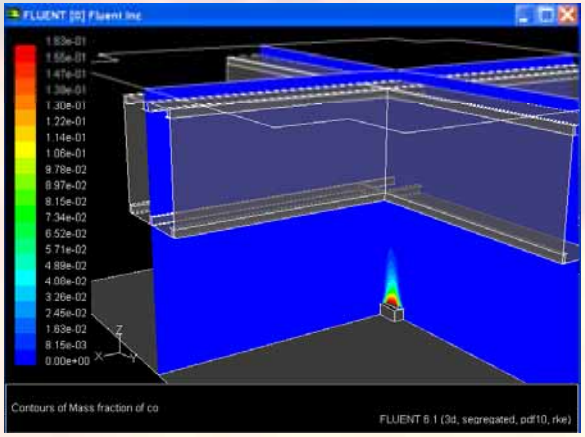
User friendly pre and post processing, but a deep knowledge on fire engineering and CFD is required.

Examples of post processing

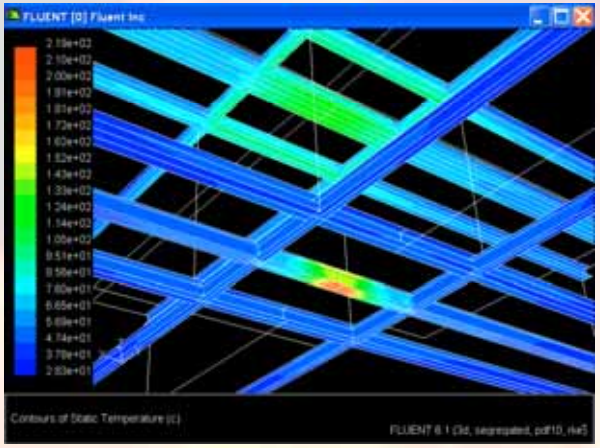
Radiation values



Smoke control: CO concentration



Predicted steel temperatures



Fire resistance models

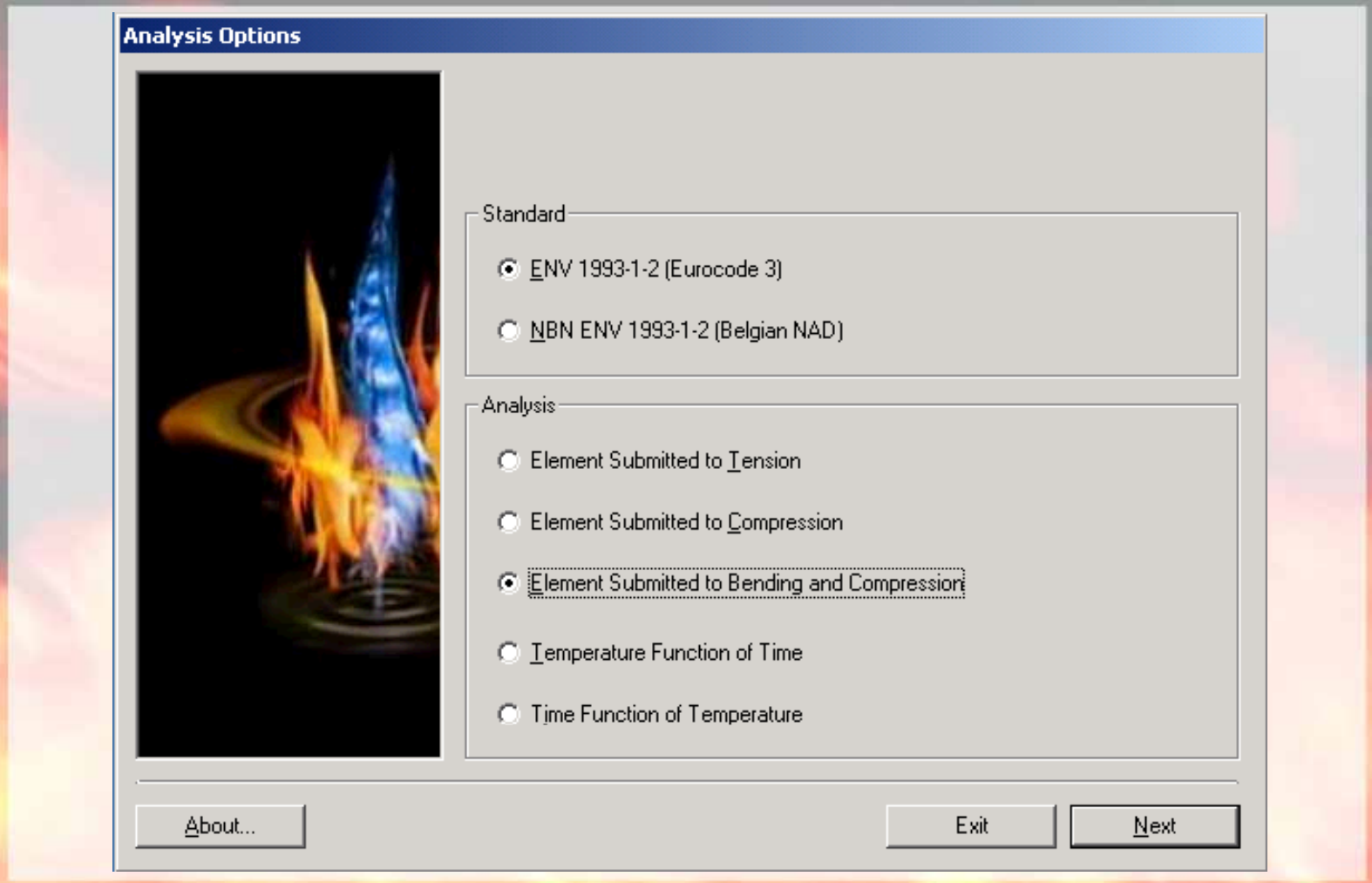
Fire resistance models (FRM)

Structural design procedure			Tabulated data	Simple calculation methods	Advanced methods
Prescriptive based rules	Member analysis	Calculation of mechanical actions and boundaries	YES	YES	YES
	Analysis of part of the structure		NO	YES (if available)	YES
	Analysis of entire structure	Selection of mechanical actions	NO	NO	YES
Performance based rules	Member analysis	Calculation of mechanical actions and boundaries	NO	YES (if available)	YES
	Analysis of part of the structure		NO	NO	YES
	Analysis of entire structure	Selection of mechanical actions	NO	NO	YES

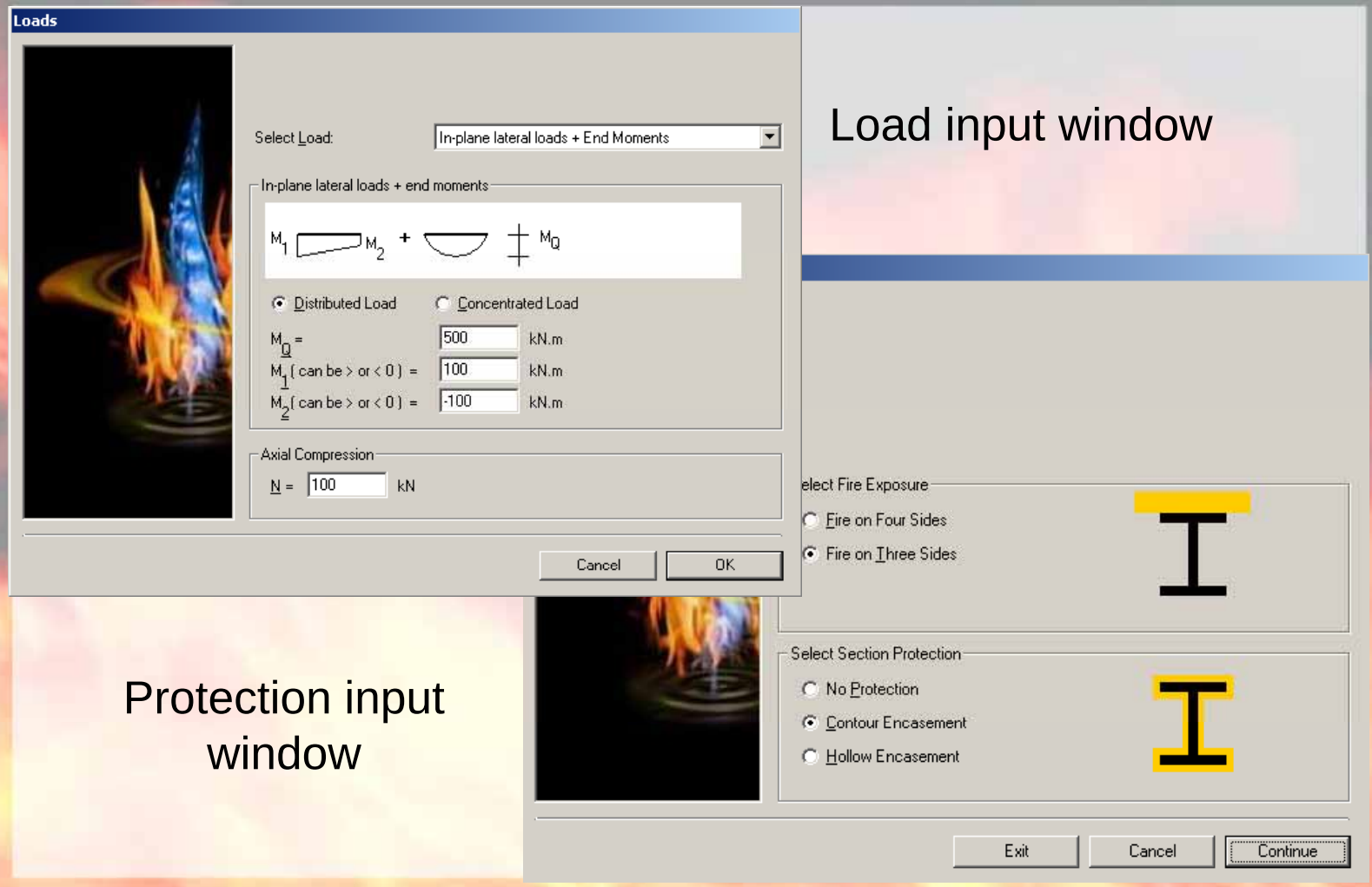
Simplified FRM - Elefir

Software sheet – general description			
Name	Elefir		
Version	2.1	Year	1998
Country	Belgium	Language	English
System	Windows	Size	8 MB
Authors	D. Pintea, L. Mievis, G. Gustin, J. M. Franssen		
Organisation	University of Liege		
Application field	Fire resistance model (simplified)		
Availability	Free – www.ulg.ac.be		
Contact	University of Liege - www.ulg.ac.be		
Formulation	Based on EN 1993-1-2 (eurocode 3)		
Short description	Software for the calculation of the fire resistance of simple steel elements made of open sections.		

Elefir - Main menu



Elefir - Input data



Elefir - Output data

```
                Results Elefir

Data
----

Date : 05/08/2004
Time : 13:30:06

Calculation following ENV 1993-1-2
Time function of temperature

Type of Cross-Section : IPE
Profile : IPE 300
Area of the cross-section :  53,81  cm²
Critical Temperature : 486 °C

Exposed to Fire on 3 faces
Temperature-Time Curve : ISO Curve

Type of Protection      : Contour Encasement
==> Section factor A/V =  187.7063 m-1
Type of material        : rock/glass wool
Thickness               : 10 mm
Specific Heat           : 850 J/kg.°K
Thermal Conductivity    : 0,04 W/m.°K
Unit Mass               : 150 kg/m³
```

```
Results
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Time/Temperature evolution in the steel section calculated
by ELEFIR using relation 4.22 of ENV 1993-1-2
Time [min.] ; Temperature [°C]

0 ; 20
5 ; 43
10 ; 77
15 ; 112
20 ; 147
25 ; 181
30 ; 215
35 ; 247
40 ; 278
45 ; 308
50 ; 337
55 ; 365
60 ; 391
65 ; 416
70 ; 441
75 ; 464
79,9 ; 486
```
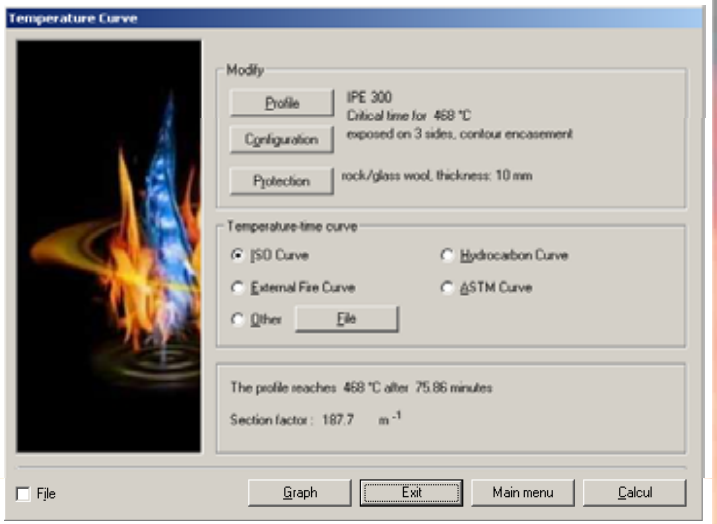
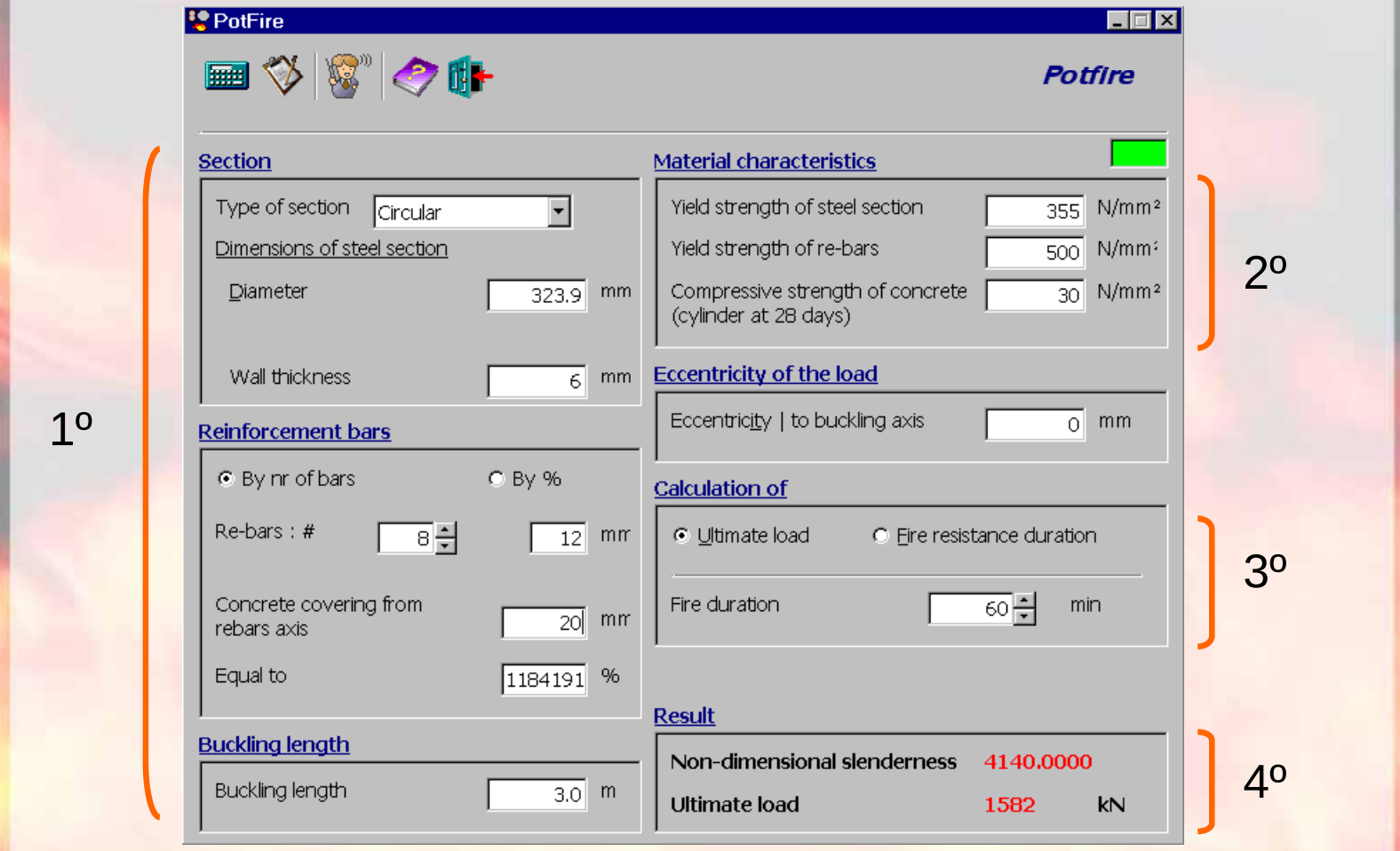




```
The temperature of  486 °C is obtained after  75.86 min.
```

Simplified FRM - Potfire

Software sheet – general description			
Name	Potfire		
Version	1.11	Year	2001
Country	France	Language	English
System	Windows	Size	15 MB
Authors	G. Fouquet, G. Tabet, B. Zhao, J. Kruppa		
Organisation	CTICM, CIDECT, TNO		
Application field	Fire resistance model (simplified)		
Availability	Free – www.cidect.org		
Contact	CIDECT - www.cidect.org		
Formulation	Based on EN 1994-1-2 Annex G		
Short description	Fire resistance duration of unprotected filled hollow section columns		

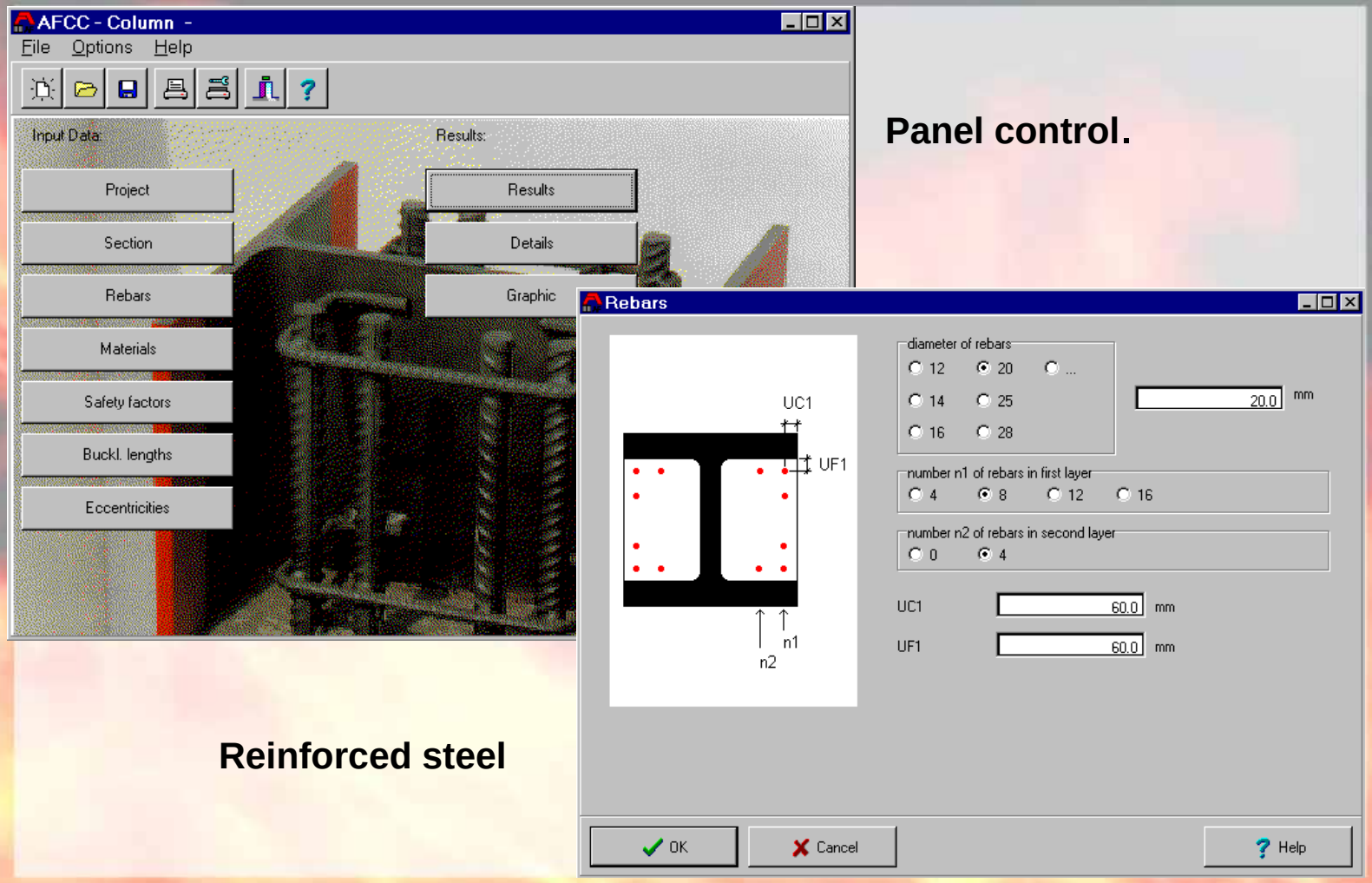
Potfire - Main menu/Input-output data



Simplified FRM - AFCC

Software sheet – general description			
Name	AFCC		
Version	3.06	Year	2004
Country	Luxembourg	Language	English
System	Windows	Size	2.5 MB
Authors	H. Colbach		
Organisation	Arcelor LCS Research Centre		
Application field	Fire resistance model (simplified)		
Availability	Free – www.sections.arcelor.com		
Contact	Arcelor ASC: asc.tecom@arcelor.com		
Formulation	Based on EN 1994-1-2		
Short description	Composite columns fire design		

AFCC - Main menu/input data



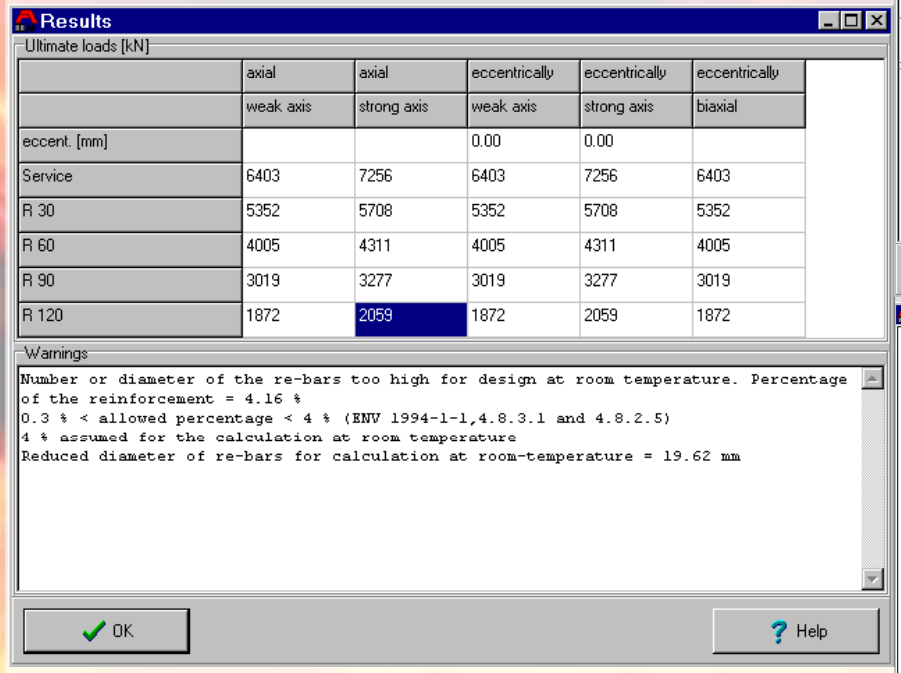
Panel control.

Reinforced steel

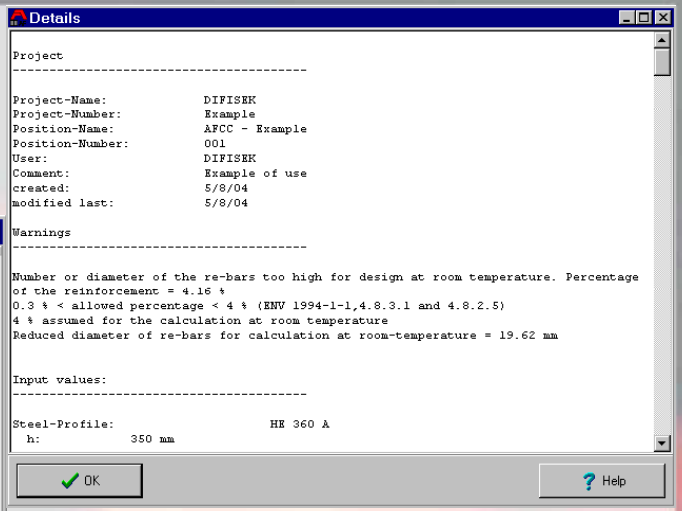
AFCC - Output data

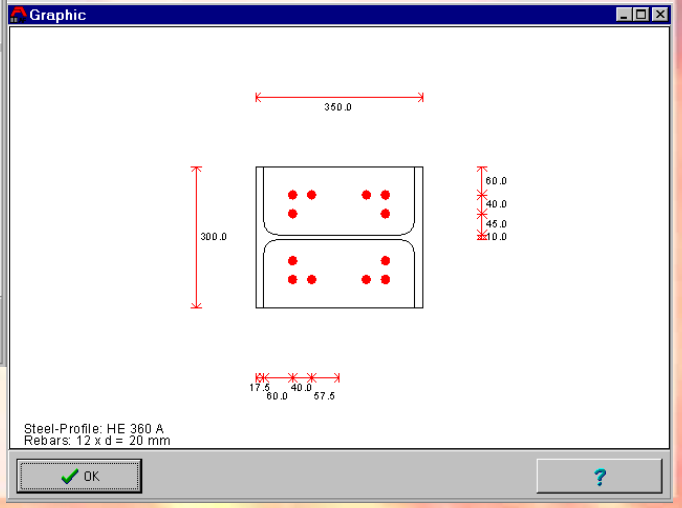
Results

Write report



	axial	axial	eccentrically	eccentrically	eccentrically
	weak axis	strong axis	weak axis	strong axis	biaxial
eccent. [mm]			0.00	0.00	
Service	6403	7256	6403	7256	6403
R 30	5352	5708	5352	5708	5352
R 60	4005	4311	4005	4311	4005
R 90	3019	3277	3019	3277	3019
R 120	1872	2059	1872	2059	1872



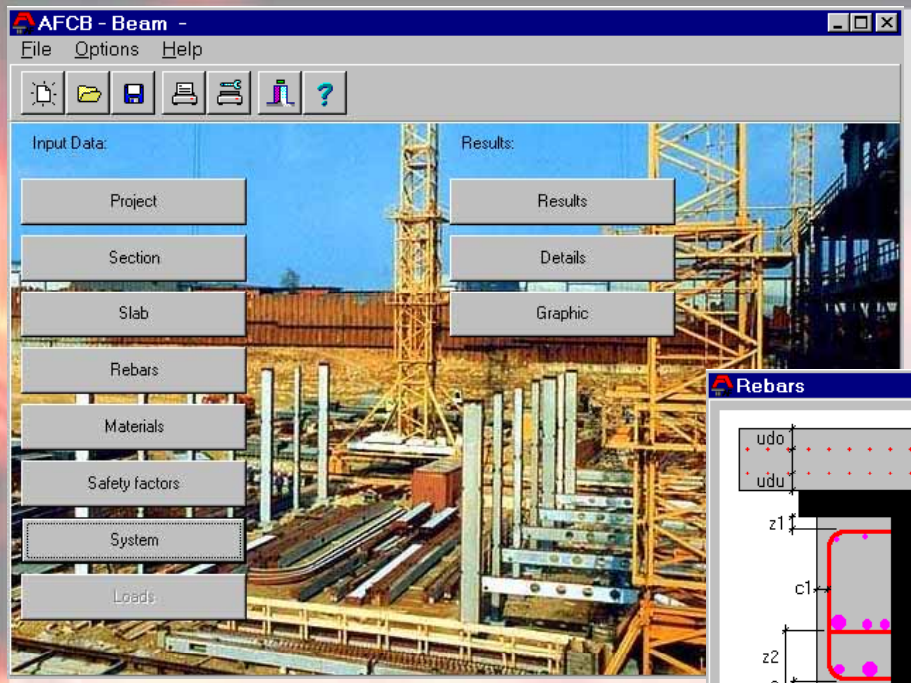


Drawing detail

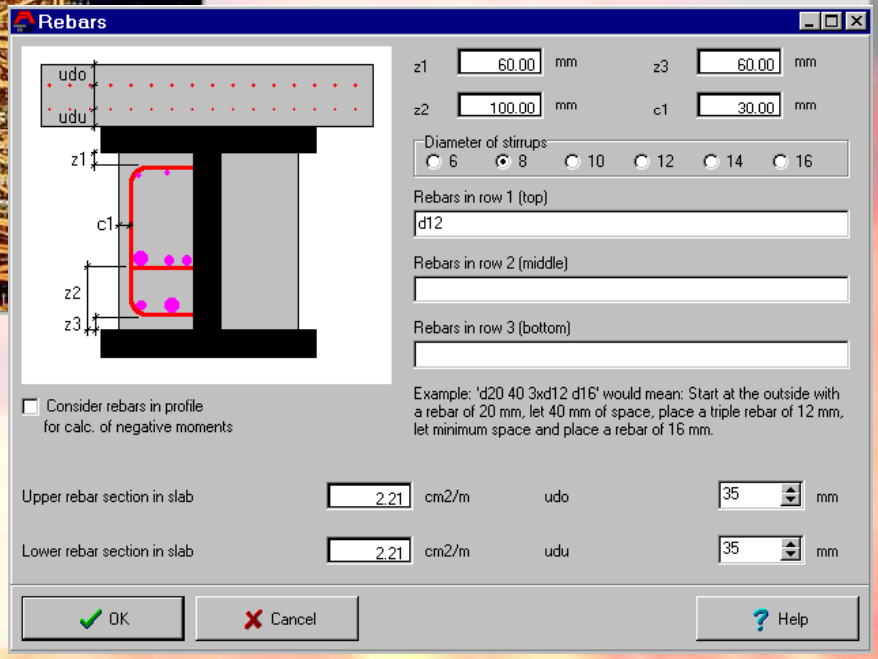
Simplified FRM - AFCB

Software sheet – general description			
Name	AFCB		
Version	3.07	Year	2004
Country	Luxembourg	Language	English
System	Windows	Size	3 MB
Authors	H. Colbach		
Organisation	Arcelor LCS Research Centre		
Application field	Fire resistance model (simplified)		
Availability	Free – www.sections.arcelor.com		
Contact	Arcelor ASC: asc.tecom@arcelor.com		
Formulation	Based on EN 1994-1-2		
Short description	Composite beams fire design		

AFCB - Main menu / input data



Panel control.

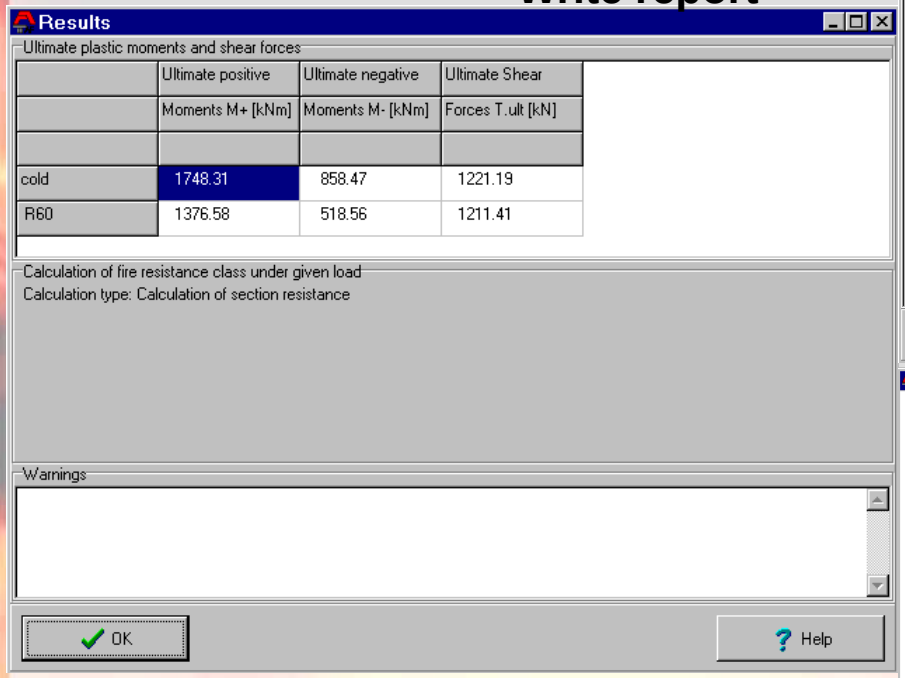


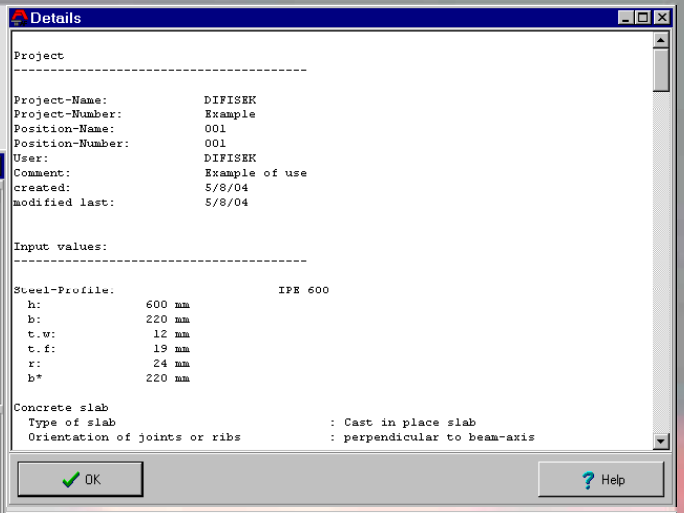
Reinforced steel

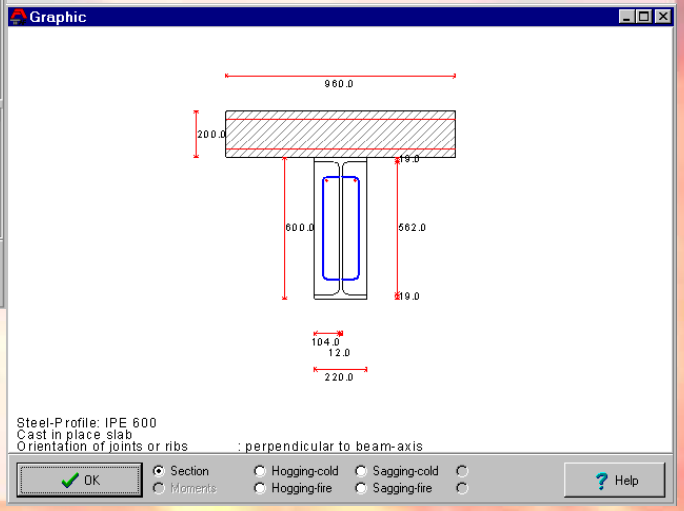
AFCB - Output data

Results

Write report







Drawing detail

Advanced calculation methods

The advanced calculation methods have three principal phases

Pre-processing

- Definition of the structure (finite elements)
- Material definition (linear/non-linear)
- Selection of mechanical and thermal actions and boundaries..

↓

Processing - calculation phase

↓

Post-processing - output reporting

Advanced FRM - Safir

Software sheet – general description			
Name	Safir		
Version	9.8	Year	2002
Country	Belgium	Language	English
System	Fortran/Visual Basic	Size	----
Authors	J. M. Franssen		
Organisation	University of Liege		
Application field	Fire resistance model (advanced)		
Availability	Commercial software		
Contact	JM.Franssen@.ulg.ac.be		
Formulation	Finite element code		
Short description	Finite element model for the behaviour of the structures in fire.		

Advanced FRM - Ansys

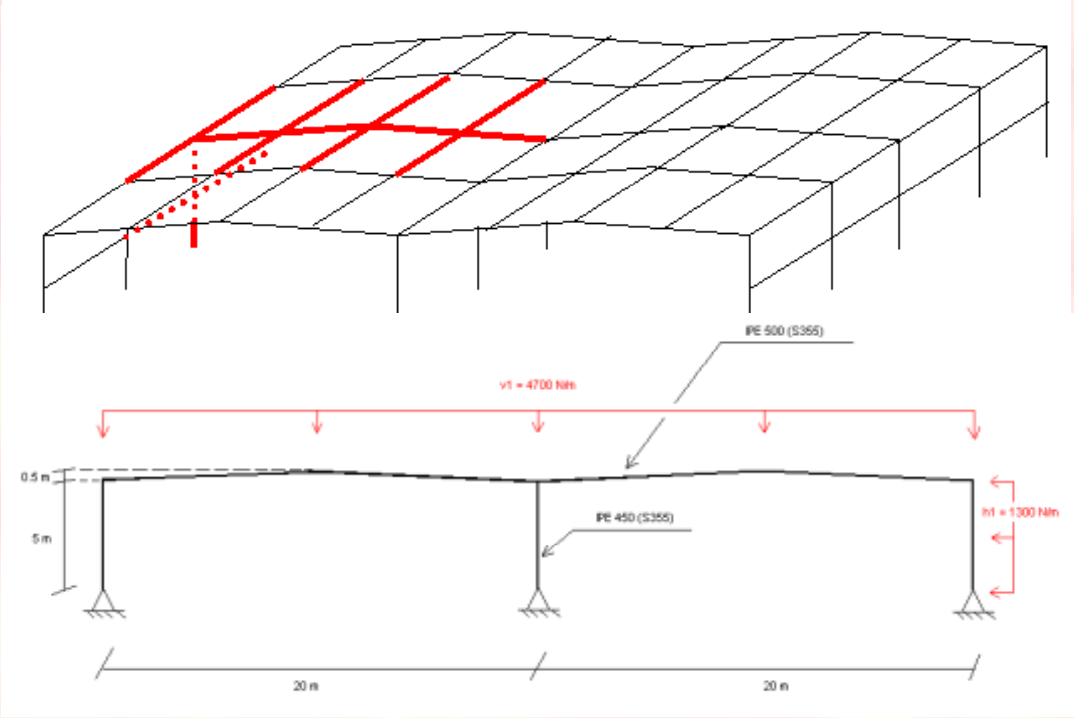
nSoftware sheet – general description			
Name	Ansys		
Version	8.1	Year	2003
Country	U.S.A	Language	English
System	-----	Size	----
Authors	-----		
Organisation	ANSYS Inc.		
Application field	Fire resistance model (advanced)		
Availability	Commercial software		
Contact	Ansys – www.ansys.com		
Formulation	Finite element code		
Short description	General purpose software		

Advanced FRM - Example: Abaqus

Software sheet – general description			
Name	Abaqus		
Version	6.3	Year	2003
Country	U.S.A	Language	English
System	MS-DOS	Size	----
Authors	Hibbitt, Krlsson and Sorensen		
Organisation	ABAQUS Inc.		
Application field	Fire resistance model (advanced)		
Availability	Commercial software		
Contact	Abaqus – www.abaqus.com		
Formulation	Finite element code		
Short description	General purpose software		

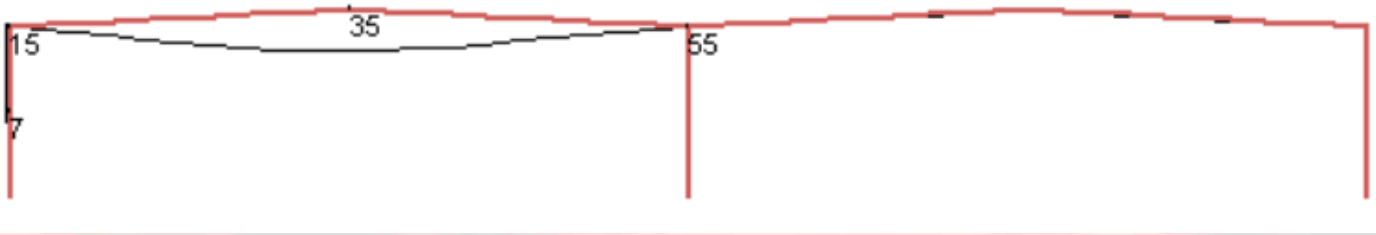
SAFIR/ANSYS/ABAQUS - Case study

Fire scenario: fire in an industrial building
Design fire: ISO curve
Objective: definition of fire resistance of the whole structure and the influence of the affected zone on the rest of the structure.

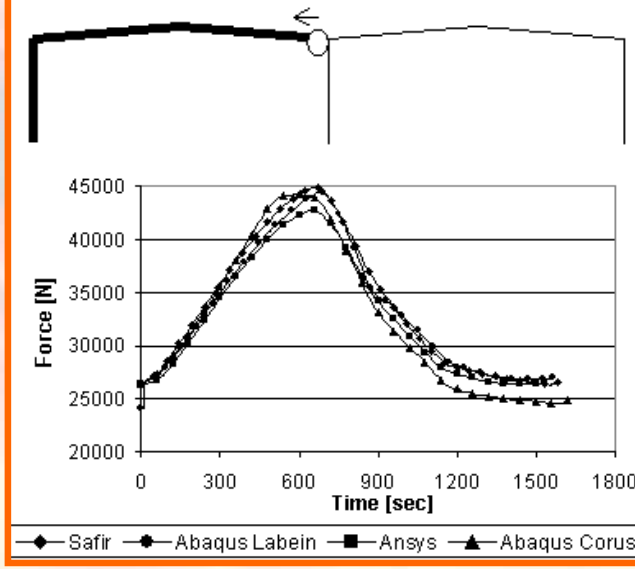


SAFIR/ANSYS/ABAQUS - Case study

2D



Deformed shape without amplification (static mode)

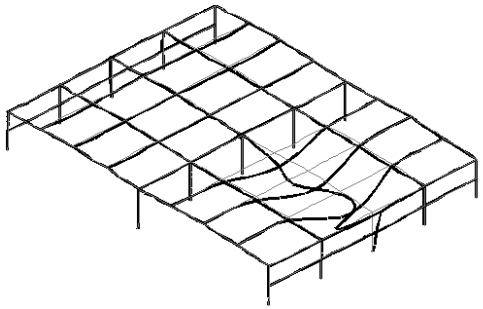


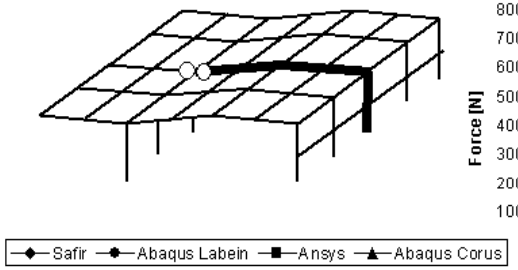
Deformed shape without amplification (dynamic mode)
Left frame collapse towards inside of the building.

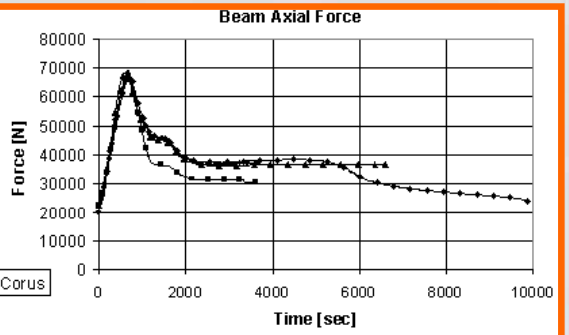
Axial force - No bigger than the effect of the wind in service condition.

SAFIR/ANSYS/ABAQUS - Case study

3D - With more than one frame without hot purlins

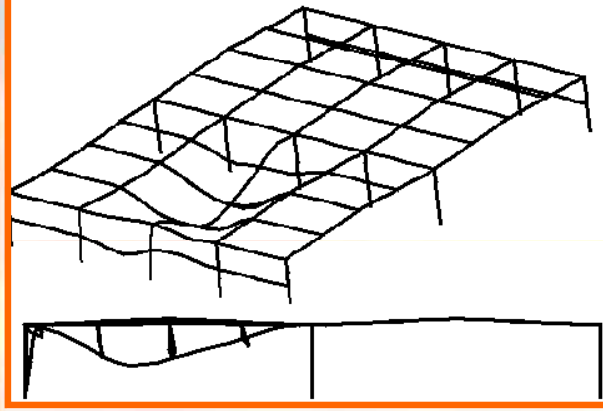


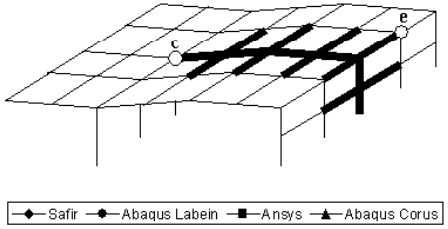


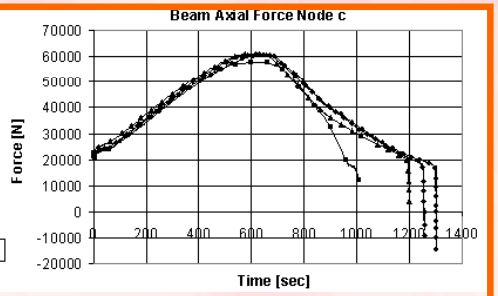


Deformed shape(x10) - The purlins support the frame submitted to fire

3D - With more than one frame with hot purlins



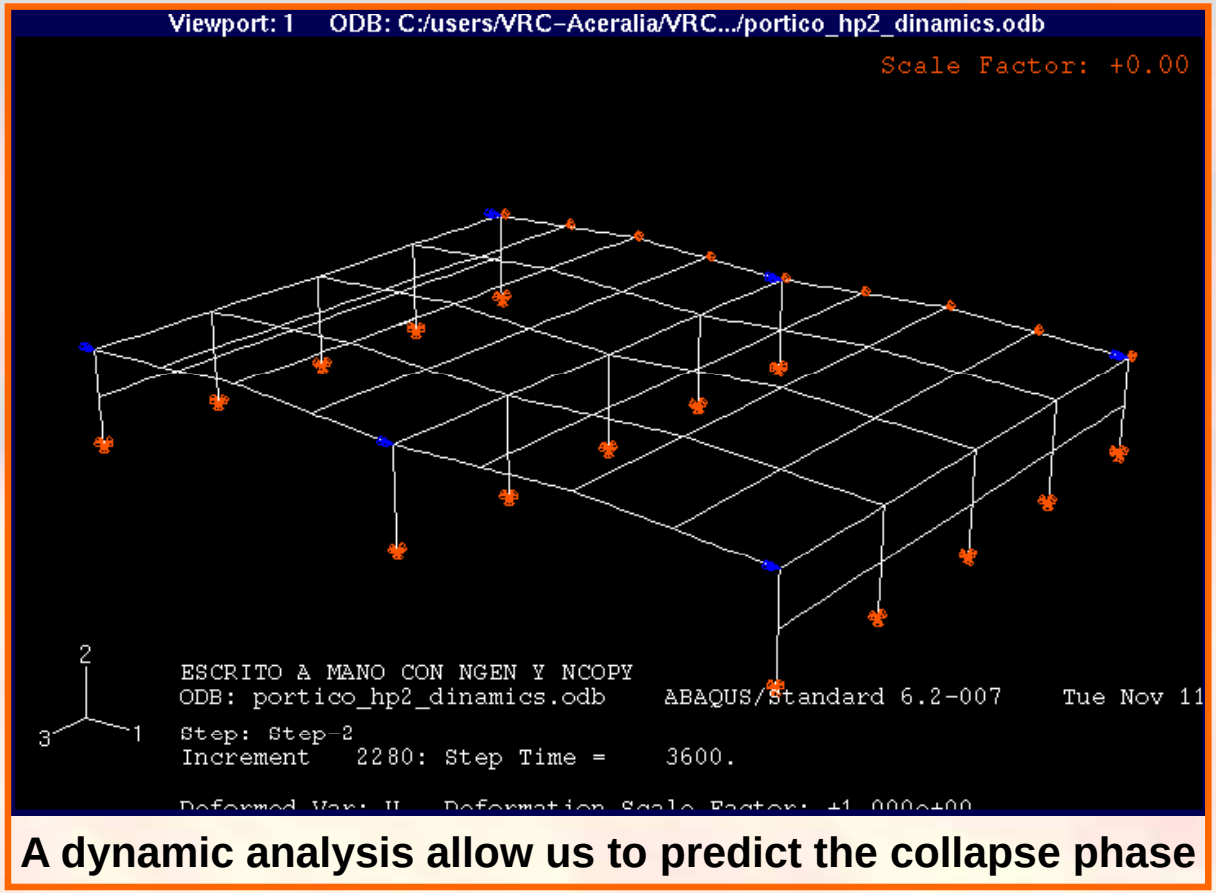




Deformed shape without amplification
Axial load

SAFIR/ANSYS/ABAQUS - Case study

3D - With more than one frame with hot purlins (Dynamic)



A dynamic analysis allow us to predict the collapse phase

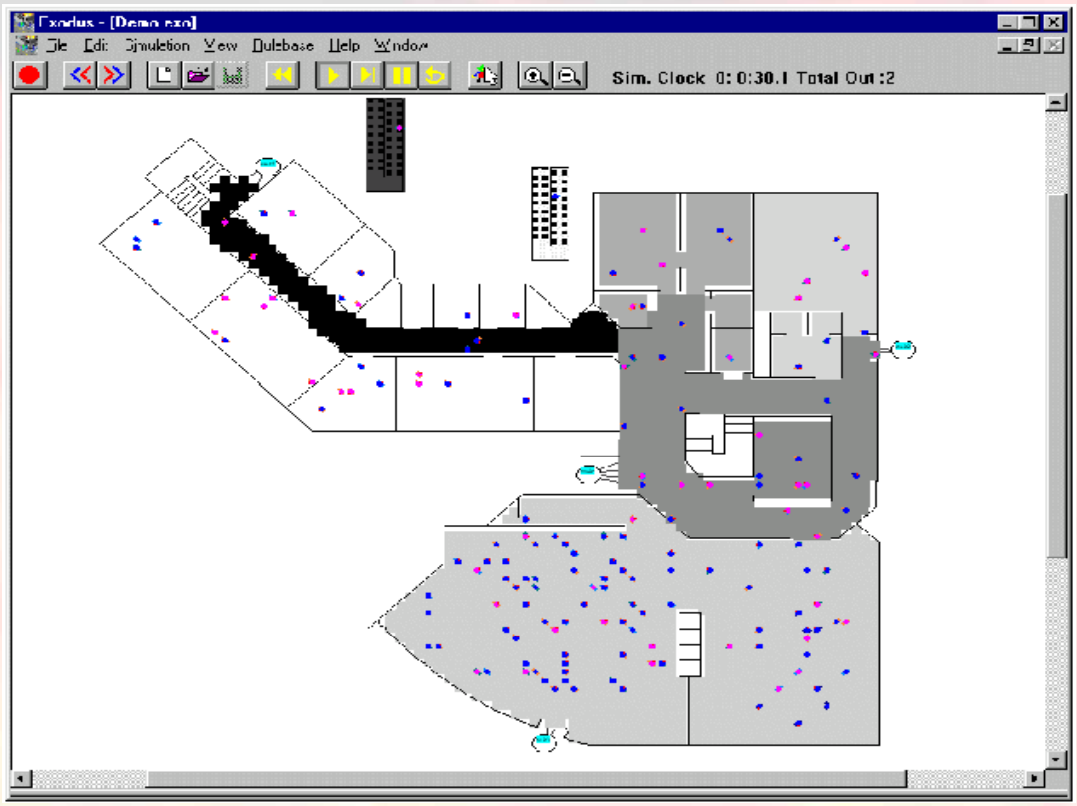
Egress and detector response models

Egress models - Exodus

Software sheet – general description			
Name	Exodus		
Version	4.0	Year	2004
Country	England	Language	English
System	Windows	Size	-----
Authors	E. Galea, St. Gwyne, S. Blake, L. Filippidis		
Organisation	University of Greenwich		
Application field	Egress model		
Availability	Commercial – www.fseg.gre.ac.uk		
Contact	E.R.Galea@greenwich.ac.uk		
Formulation	-----		
Short description	Egress model based on human behaivour		

Egress models - EXODUS

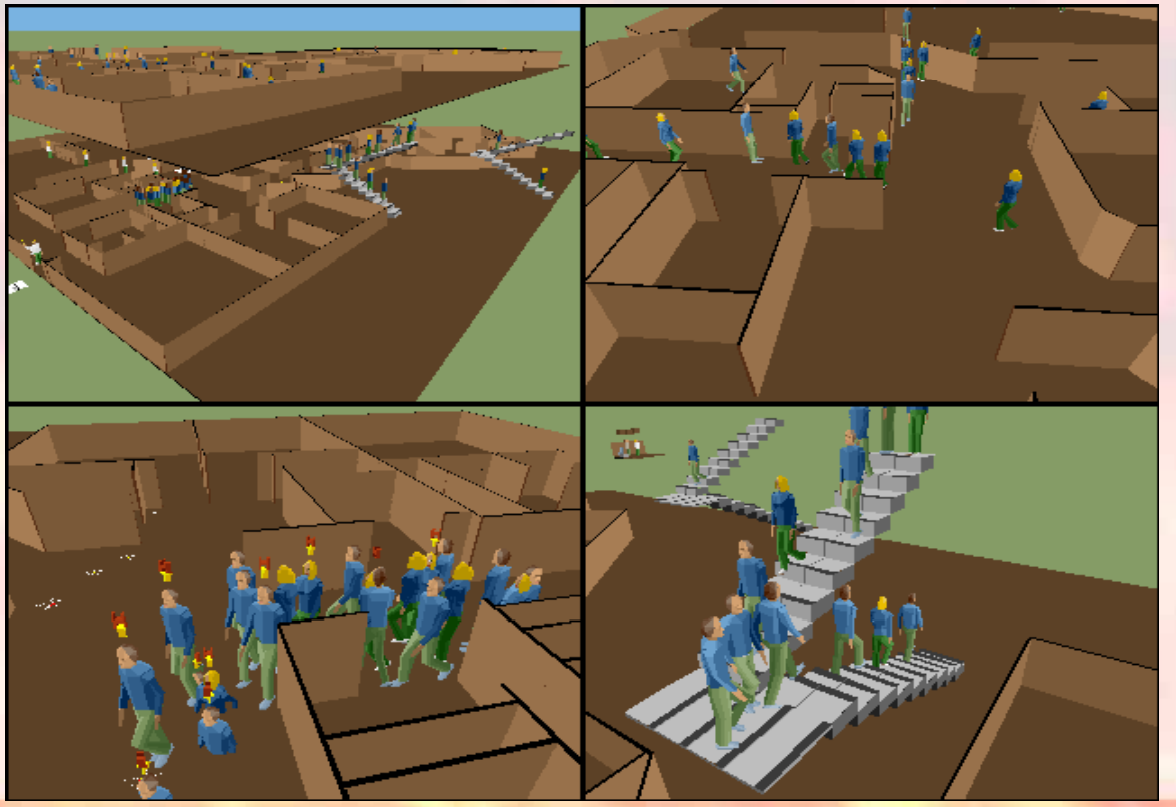
•Simulation allow user to asses the level of safety along the evacuation.



Egress models - EXODUS

Results:

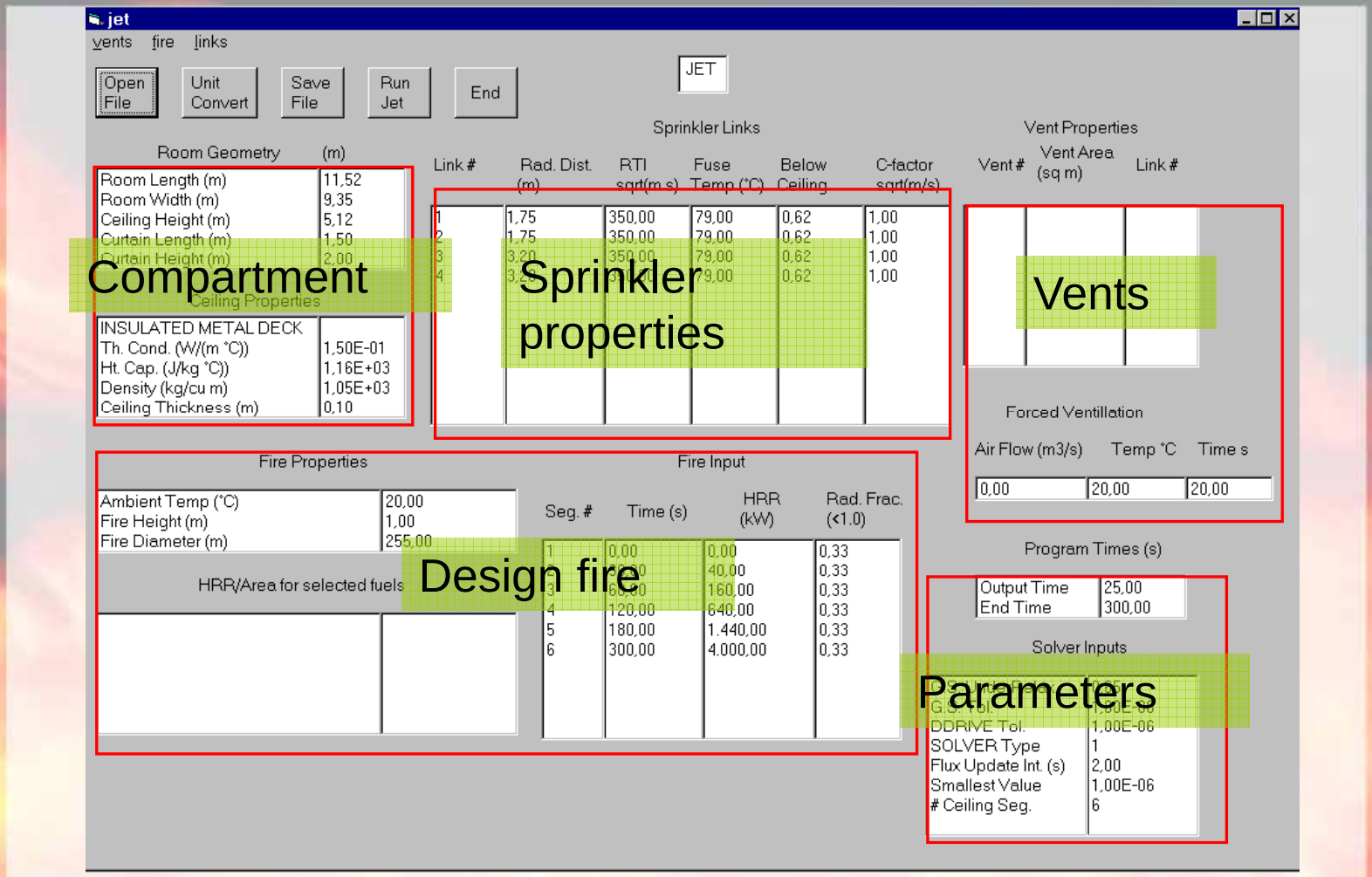
Simulations can be viewed with the post-processing tool VR-EXODUS



Detector response models - Jet

Software sheet – general description			
Name	Jet		
Version	1.0	Year	1999
Country	U.S.A	Language	English
System	Windows	Size	4 MB
Authors	W. D. Davids		
Organisation	NIST (National Institute of Standards and Technology)		
Application field	Detector response models		
Availability	Free – www.fire.nist.gov		
Contact	NIST - www.fire.nist.gov		
Formulation	Zone model based on code LAVENT Algorithm for plume centerline temperature Algorithm for ceiling jet depending on smoke layer depth		
Short description	Sprinkler response – Time to activation		

Jet - Main menu / input data



SOFTWARE

IN CZECH/ENGLISH LANGUAGE

Software available in Czech/English language

Freeware www.access-steel.cz

- **Calculation of parametrical temperature curve**

- **Heat transfer**
  to protected and unprotected steel elements

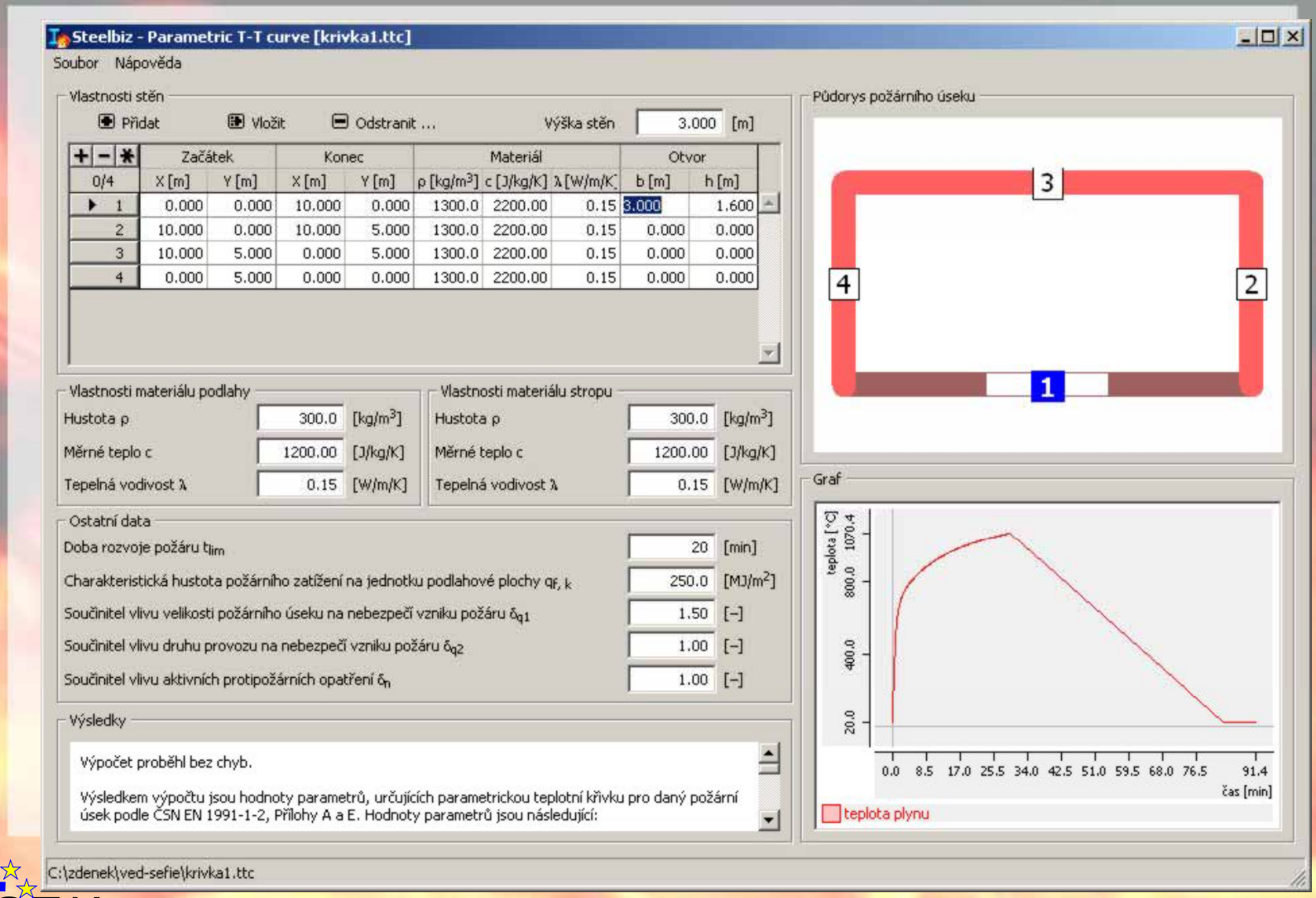
- **Fire resistance**
  of steel elements

Commercial software www.fine.cz

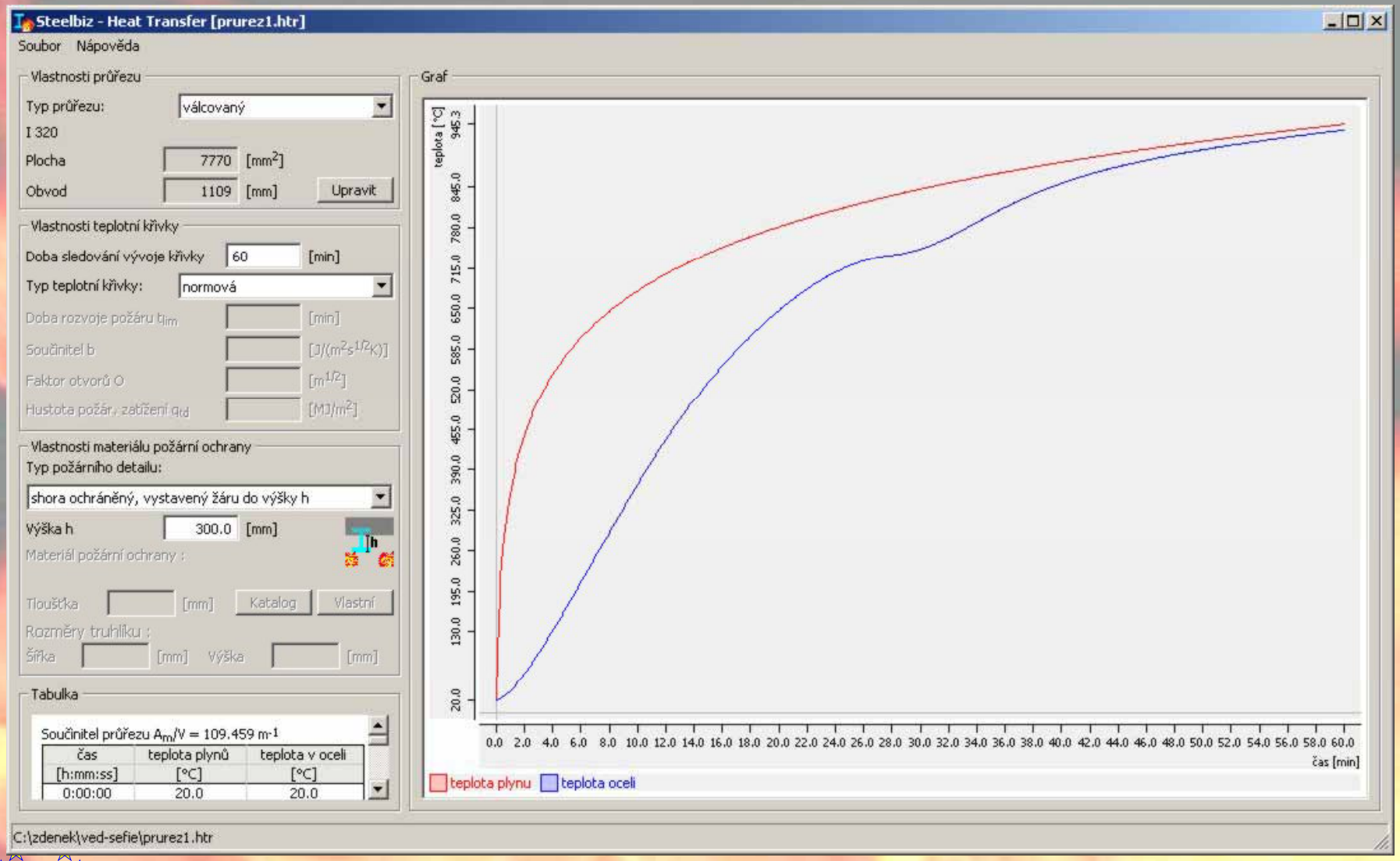
- **Fin 10 - Steel Fire**

Czech and English languages

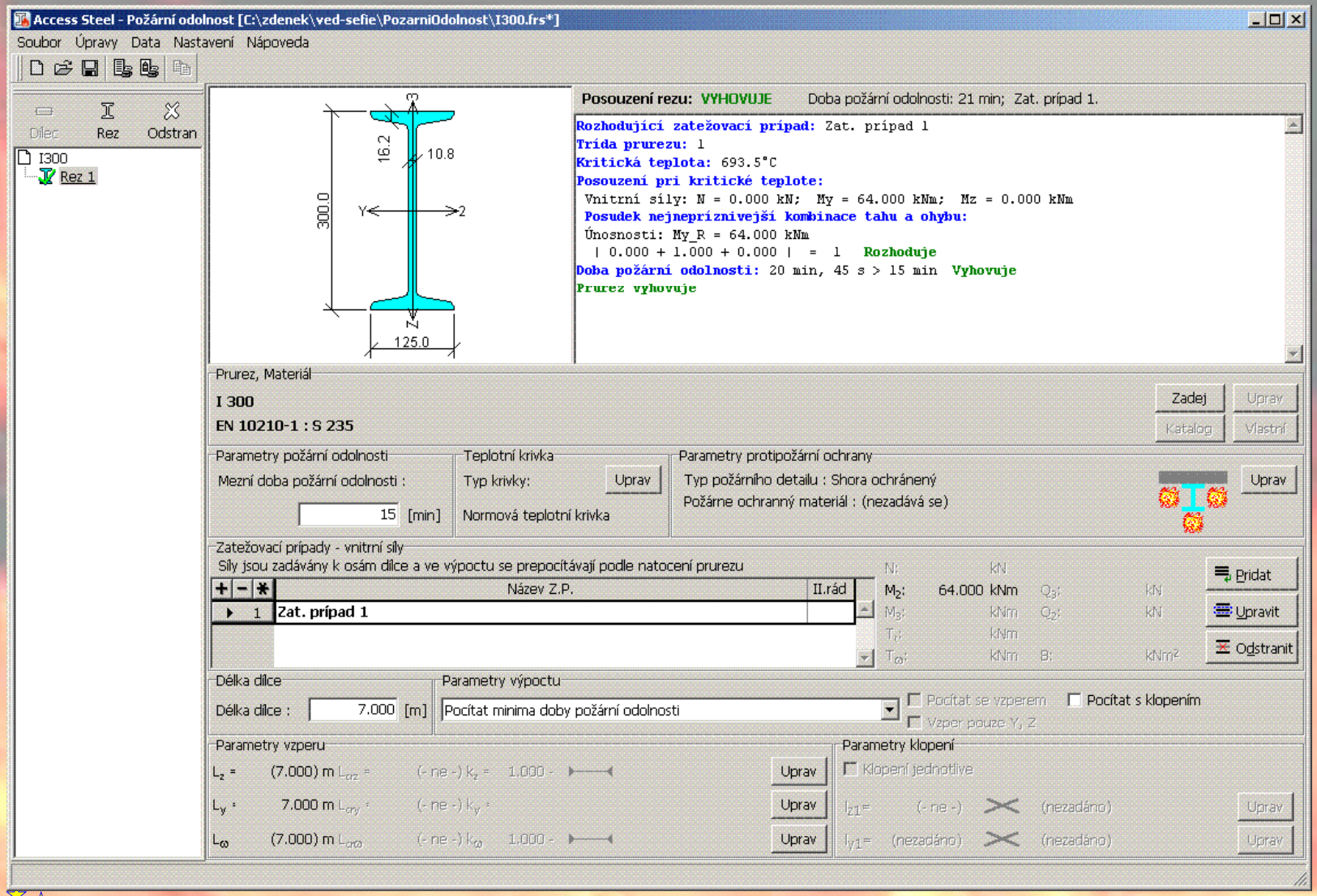
Parametrical temperature curve



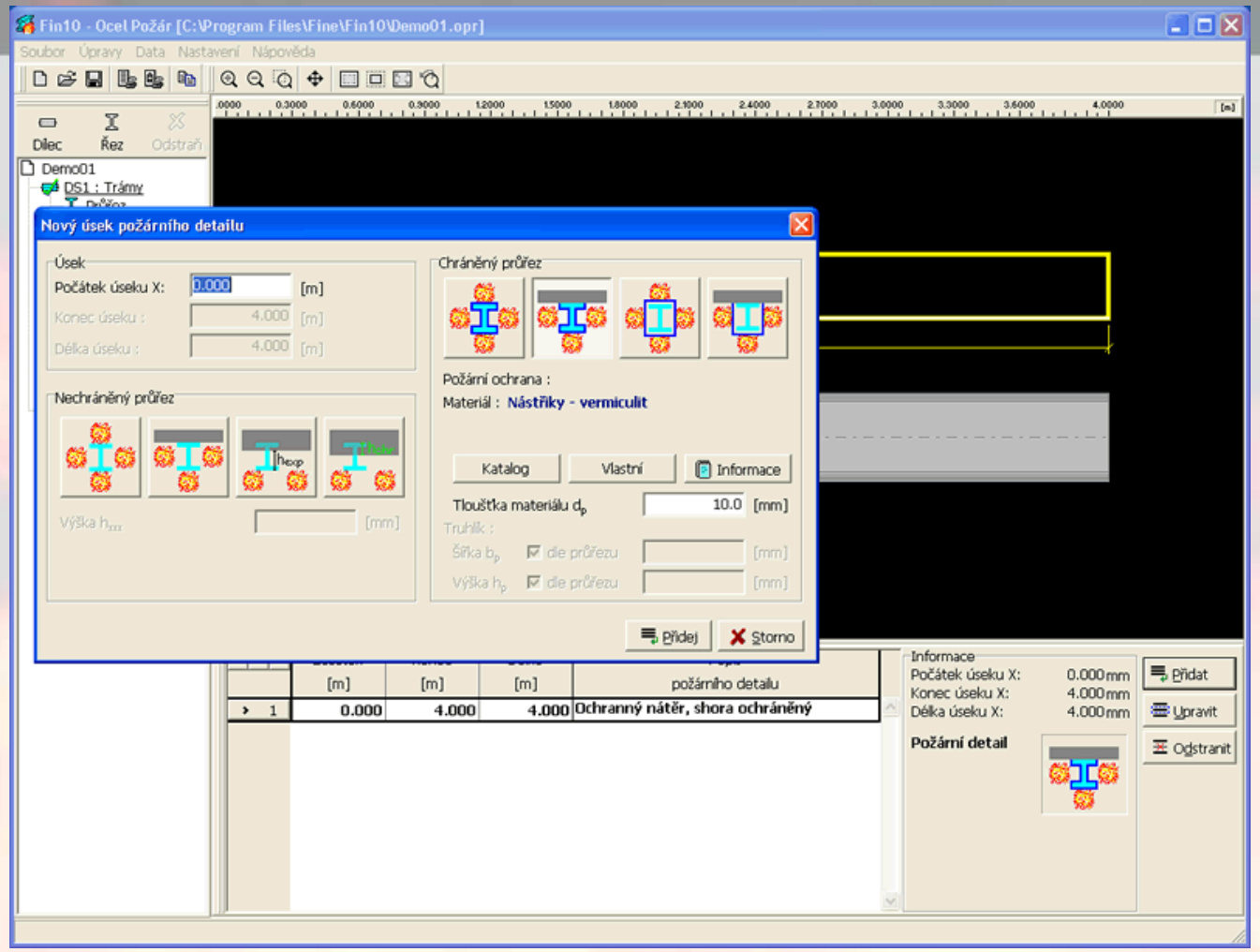
Heat transfer



Fire resistance

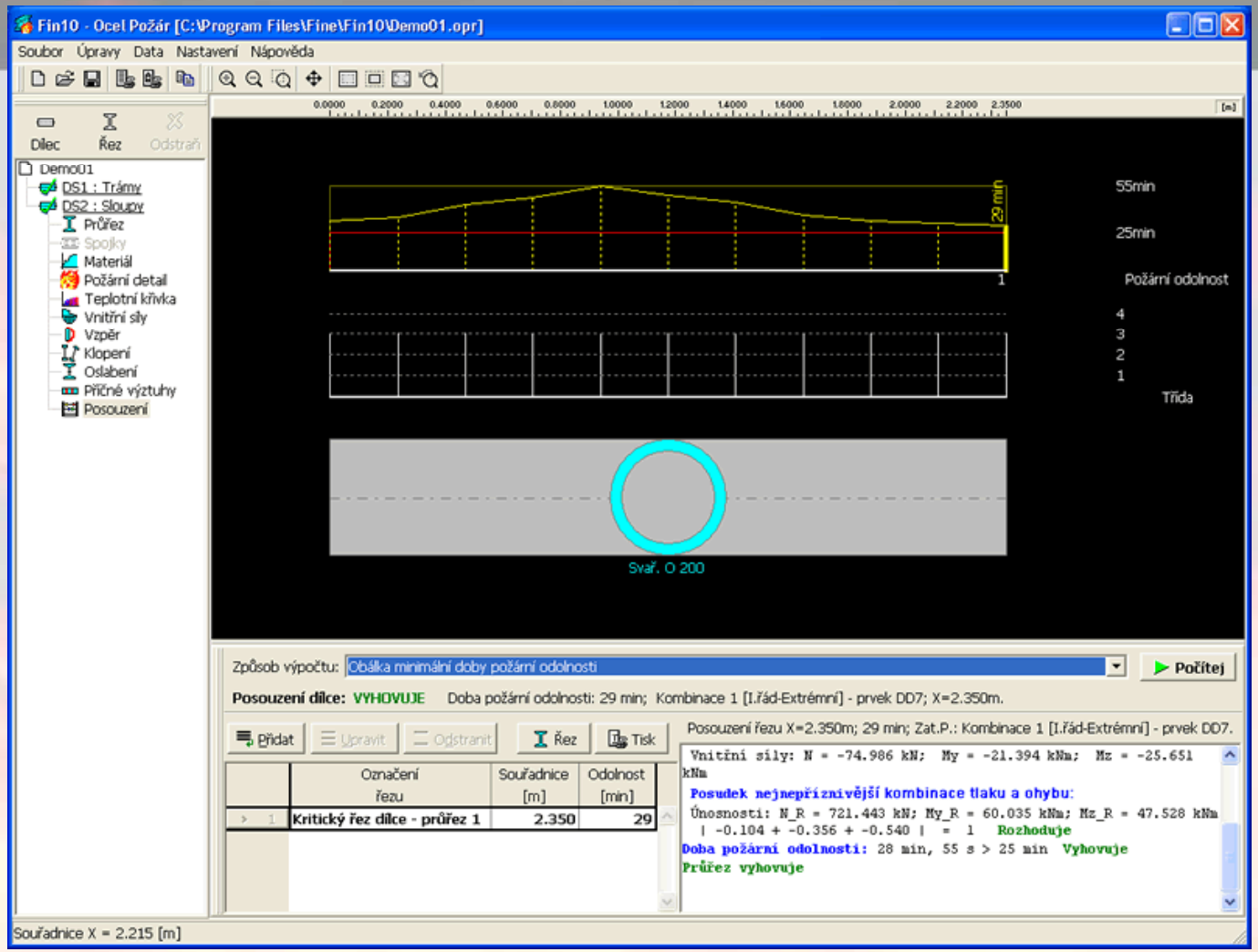


Fin10 - Steel Fire - Input data



Input of fire protection data

Fin10 - Steel Fire - Output data



Output - fire resistance

Thank you for your attention