PART 4: Software for fire design

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ABSTRACT: One of the main objectives of the ECSC project DIFISEK+ is the collection and evaluation of publicly available software for fire design. In order to evaluate them in a correct manner it is necessary to classify them and to establish an evaluation criterion. In 1992, Friedman performed a survey of computer fire models for the Forum for International Co-operation on Fire Research. In 2003, Olenick & Carpenter updated it incorporating more softwares and a discussion of the categories of them. In this document we present a new classification taking into account the classification defined by them and updating the list of softwares, highlighting the publicly available fire software. In this document we establish the more important aspects to broach for evaluate fire software. In this manner we provide a guide to select the fire software that fits better to users needs. A total of 177 softwares have been detected, 30 of them are publicly available.

1 INTRODUCTION

The objective of the structural fire safety engineering is to obtain reliable calculation methodologies for the design of safe structures in case of fire. In order to reach this objective it is necessary to demonstrate through these methodologies that the structure maintains its load bearing function during a period of time longer than the time required to be safe (See figure 1).
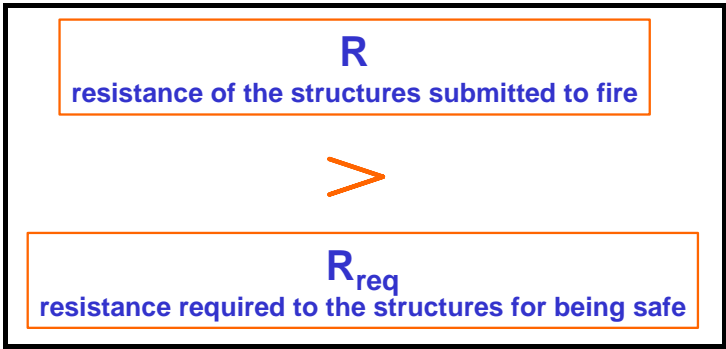

Fig.1 Requirement to fulfil for obtain a safe structure

During the last 15 years a lot of projects have been made to develop calculation methodologies to determinate the resistance of the structure submitted to fire. All these methods have been reflected in the Eurocodes and are related to the different events that occur during a fire (See figure 2- Chain of events).
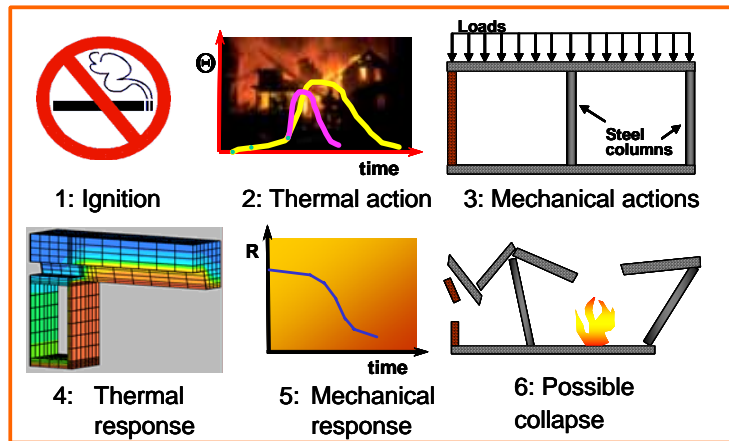
Fig. 2 Chain of events during a fire

To determinate the safety of a structure is also necessary to have clearly the requirements that the structure has to fulfil. Normally these requirements are defined in function of the time. In each country there are codes and regulations specifying these requirements (prescriptive requirements). Through the fire safety engineering, different methodologies has been developed to determinate these requirements in a more realistic way (performance based requirements; see figure 3 - requirements).
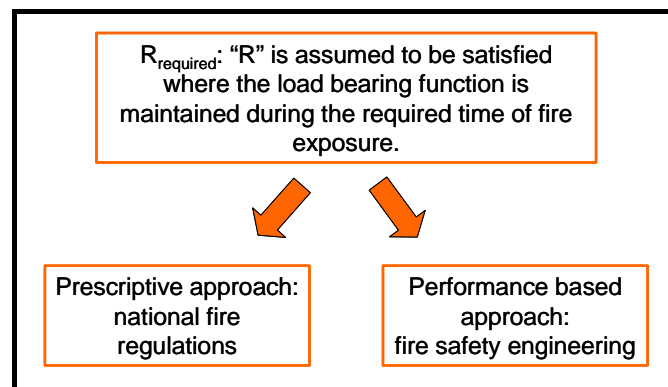

Fig. 3 Requirements

In order to obtain these two parameters (R $_{\text{resistance of the structure submitted to fire}}$ and R $_{\text{required for being safe}}$), a lot of fire software have been developed. A total of 177 fire software have been detected, being 30 of them publicly available.

In this document we not only want to give a collection of fire software, we want to provide a guide to select the fire software that fits better to users needs. It is very important to know what is a fire model, what is a fire software and what is the field of application of these fire models to evaluate them.

A fire model is a tool that describes an event in relation to fire, from the combustion to evacuation and to structural collapse (not only the fire growth process and smoke transport process). All models can be broken down in experimental models and mathematical models. The experimental ones are models that operate in physical or human space, these models are out of the scope of this document; where as mathematical models are a series of equations that describe something, in our cases an event in relation to fire. These last models studied are in the scope of this document.

Mathematical models are divided in deterministic and statistic models. The first are governed by physical, thermal and chemical laws; whilst the statistic ones are not directly governed by these laws, only make statistical predictions about an event. Due to the complexity of these equations and the great number of iterations needed to obtain accurate results is necessary to use computers. Software

for fire design is only a tool developed to solve these mathematical equations, both deterministic and statistic.

There are a lot of events associated to a fire. In order to facilitate the evaluation of the software we have adopted the classification in function of the most common events that they solve (application field of software).

2 CLASSIFICATION OF FIRE SOFTWARES:

The most common fire softwares describe the transport of smoke and heat in enclosures. These softwares are named zone models and field models. But there are more types of models according to their application fields, like Structural fire resistance models or detector response models. The classification adopted by Olenick & Carpenter is broken down in six types of application fields: Structural fire resistance, zone, field, egress, detector response and miscellaneous. We reduce the number of application fields to five, merging the zone and field models in a more general group named "Fire thermal models". In this way we obtain a classification only in function of the application field of the software and not in function of the mathematical method used to solve the different events.

Into this classification we can distinguish two different groups (see figure 4):

- The first one closely related to the thermal and mechanical response of the structure during a fire (see figure 2 chain of events)
- The second one focused to determinate the requirements that a structure has to fulfil for being safe in case of fire.
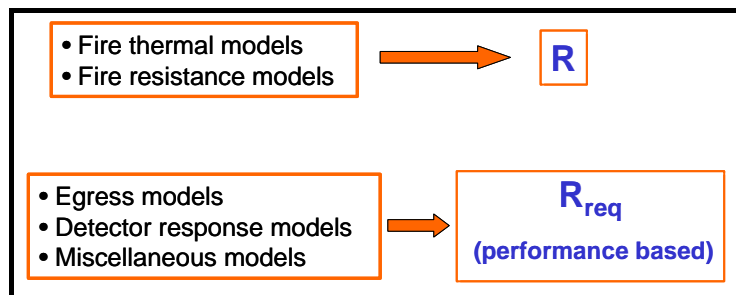

Fig. 4 Groups of application fields

2.1 *Fire Thermal models:*

Into this application field we can found different types of software in function of the method to solve the thermal response associated to a fire. To classify them we follow the classification of the EN 1991-1-2:2002 for the "Thermal actions for temperature analysis" (See figure 5).

Fire thermal models		
Nominal temperature – time curves (Prescriptive rules)	Standard temperature – time curve	
	External fire curve	
	Hydrocarbon curve	
Natural fires (Performance based rules)	Simplified fire models	Compartment fires
		Localised fires
	Advanced fire models	Zone models
		Field models

Fig. 5 Thermal actions for temperature analysis – Fire Thermal models

In this way the classification of the Fire Thermal models is the following one:

- Simplified Fire Thermal models: divided in Compartment fires and localised fires.
- Advanced Fire Thermal models: divided in Zone models and Field models

2.1.1 *Simplified Fire Thermal models*

These models are based on specific physical parameters with a limited field of application. For compartment fires a uniform temperature distribution is assumed and for localised fires a non-uniform temperature distribution is assumed.

Application field: Simplified fire Thermal models			
Model	Country	Id. Number	Short description
DIFISEK-CaPaFi	Luxembourg	1	Calculation of the temperature in a steel member heaten up by 1 to 5 local fire sources. Based on EN 1991-1-2, prEN 1993-1-2 and the ECSC projects "Large Compartment" & "Closed Car Parks".
DIFISEK-EN 1991-1-2 Annex A	Luxembourg	2	Calculation of the parametric temperature-time curves in a compartment and the temperature of a protected and unprotected steel member submitted to that parametric temperature-time curve. Based on EN 1991-1-2 Annex A and prEN 1993-1-2.
DIFISEK-TEFINAF	Luxembourg	3	Calculation of the temperature field in the steel section under the ceiling in function of the time and on the radial distance from the fire. Based on the report EUR 18868 "Development of design rules for steel structures submitted to natural fires in large compartments".
Parametrická teplotní křivka	Czech Republic	174	Derives parametric temperature curve of compartment fire. The required input is: dimensions of the compartment and openings, the fire load, material properties of the walls. Can be used for any geometrical shape of the compartment, any number and size of windows. The parameters are calculated and the curve is plotted on the screen.
Přestup tepla	Czech Republic	175	Calculates temperature of steel elements at fire. It uses increment method described in EN 1993-1-2. The sections can be unprotected or protected by sprayed materials or boards. The program contains databank of hot rolled steel sections to be used but allows also a user input of the section factor A/V. Standard curve, hydrocarbon curve or parametric curve (input of the parameters is required) can be used. The gas and steel temperatures are plotted on the screen and output to a text file.

The first three softwares have been developed by Profil-Arbed and have been updated by Profile Arbed Researchers (PARE) for this project.

The other ones have been developed by FINE, CTU Prague, and are available in www.access-steel.cz/page-nastroj

2.1.2 Advanced Fire Thermal models

2.1.2.1 Zone models:

A zone model is a computer model that divides the room(s) under study into different control volumes, or zones. The most common zone models will split a room into two zones, an upper hot zone and a lower cold zone. A particular case of zone models is the one-zone models. These ones are based on the assumption that there is no stratification and the fire compartment can be treated as a furnace with homogeneous properties. Some zone models include the possibility to switch from a two-zone model to a one-zone model when the required conditions are reached (i.e. flashover).

To be able to use the governing equations that are the base of these models, fire protection engineers must make several assumptions. Many of these assumptions are based on observations from experimental tests and models. The main assumptions are:

- Smoke stratifies into two distinct layers (as can be seen in real fires). Layers are also assumed to be uniform throughout, which is not true, but the differences within each layer are so small compared to the differences between layers, in consequence this assumption is acceptable.
- The fire plume acts as a pump of mass (smoke particles) and heat to the upper zone. However, the plume volume is assumed to be small compared to the upper and lower zones and this is in fact negligible.
- The majority of room contents are ignored; heat is lost to the room envelope, not to the furniture. (Some zone models can determine flame spread to a small number of furnishings)

The input data are usually the room geometry, room construction (including all walls, floors and ceilings), number of vents (or holes) and their sizes, room furnishing characteristics, and the heat release rate (what is burning)

The output data are usually the prediction of sprinkler and fire detector activation time, time to flashover, upper and lower layer temperature, smoke layer height, and species yield.

Zone models cannot accurately take into account re-radiation from the surroundings. The heat release rate is not an output, tests must be done to quantify the size fire and the engineer expertise will be adequate for modelling in a correct way each case under study.

Application field: zone models			
Model	Country	Id. Number	Short description
ARGOS	Danish	4	Multiroom zone model
ASET/ASET-B	USA	5	One room zone model without ventilation
ASMET	USA	6	Atria Smoke Management Engineering Tool
Branzfire	New Zealand	7	A multi-room zone model fully integrated with a flame spread and fire growth model applicable to room fire scenarios.
BRI-2	Japan/US	8	Two-layer zone model for multi-storey, multiroom smokes transport
CCFM/Vents	USA	9	Multiroom zone model with ventilation
Cfire-X	German/Norway	10	Zone model for compartment fires, particularly liquid hydrocarbon pool fires
CiFi	France	11	Multiroom zone model
COMPBRN	USA	12	Compartment zone model
COMPF2	USA	13	Single room postflashover compartment model
DACFIR-3	*USA*	*14*	*Zone model for aircraft cabin*
DSLAYV	Sweden	15	Single compartment zone model
FAST/CFAST	USA	16	Zone model to predict the environment in a compartment structure
FASTLite	USA	17	Feature limited version of CFAST

FFM	USA	18	Preflashover zone model
FIGARO II	*German*	*19*	*Zone model for determining untenability*
FIRAC	USA	20	Uses FIRIN, including complex vent systems
FireMD	USA	21	One room, two zone model
FireWalk	USA	22	Uses CFAST model with improved visualisation
FireWind	Australian	23	Multiroom zone model with several submodels
FIRIN	USA	24	Multiroom zone model with ducts, fans and filters
FIRM	USA	25	One room, two zone model
FIRST	USA	26	One room zone model with ventilation
FLAMME-S	France	27	Two-zone model
FMD	USA	28	Zone model for atria
HarvardMarkVI	USA	29	Earlier version of FIRST
HEMFAST	USA	30	Furniture fire in a room
HYSLAB	Sweden	31	Preflashover zone model
IMFE	Poland	32	Single compartment zone model with vents
MAGIC	*France*	*33*	*Two-zone model for nuclear power stations*
MRFC	**German**	**34**	**Multiroom zone model, smoke movement and thermal load on structures**
NAT	**France**	**35**	**Single compartment zone model focused to the response of the structures**
NBS	USA	36	Preflashover zone model
NRCC1	Canada	37	Single compartment zone model
NRCC2	Canada	38	Large office space zone model
OSU	USA	39	Single compartment zone model
Ozone	**Belgium**	**40**	**Zone model focused to the response of the structures**
POGAR	Russia	41	Single compartment zone model
RADISM	UK	42	Zone model incorporating an immersing ceiling jet within the buoyant layer, sprinklers and vents
RFIRES	USA	43	Preflashover zone model
R-VENT	Norway	44	Single room smoke ventilation model
SFIRE-4	Sweden	45	Postflashover zone model
SICOM	France	46	Single compartment zone model
SMKFLW	Japan	47	One layer zone model for transport of smoke in buildings
Smokepro	Australian	48	Single compartment smoke zone model
SP	UK	49	Postflashover zone model
WPI-2	USA	50	Single compartment zone model
WPIFIRE	USA	51	Multiroom zone model
ZMFE	Poland	52	Single compartment zone model

Most of these softwares are focused on the smoke and heat transport. Their application to the structural fire engineering is fixed only to the determination of the gas temperature (in order to determinate, in a following step, the temperature in the structural members). The softwares in bold are directly focused on structural design in case of fire. The softwares in cursive are focused on particular cases and their application to the structural fire engineering design is very low. Other three models have been detected, but no information about them has been obtained: CISNV (Russia), FirePro (UK) and FireWalk (USA).

2.1.2.2 Field models:

A field model represents the cutting edge of fire protection engineering. The CFD model will apply a 3-dimensional grid of elementary control volumes to the enclosure under study. These control volumes are like those used in zone modelling, however where zone modelling might have two or three zones; a CFD model will have hundreds of thousands of control volumes.

CFD modelling solves time dependent differential equations (known as the Navier-Stokes equations), for each control volume. This detailed approach is much more difficult and time consuming, but the Navier-Stokes equations are only constrained by the boundary surface of the problem. This allows for fewer assumptions and more complex room geometry.

The input data are the detailed room geometry, room construction (including all walls, floors and ceilings), number of vents (or holes) and their sizes, room furnishing characteristics, fuel/combustion characteristics, turbulence parameters, and radiation parameters.

The output data are the smoke and heat movement/velocity, prediction of sprinkler and fire detector activation time, time to flashover, temperatures in the domain, velocities, smoke layer height, and species yield.

CFD requires a large amount of computing time, as the number of control volumes increases the computational time increases. Certain parameters are assumed; CFD models must be validated before being totally trusted.

CFD models can be used for complex geometry (like curved walls). CFD modelling is used extensively in other engineering fields (such as mechanical and aerospace), this means that many engineers, much more than with zone modelling, can test, develop and verify the CFD codes.

Application field: Field models (CFD)			
Model	Country	Id. Number	Short description
ALOFT-FT	*USA*	*53*	*Smoke movement from large outdoor fires*
CFX	**UK**	**54**	**General purpose CFD software**
FDS	USA	55	CFD code specific for fire related flows
FIRE	Australian	56	CFD model with water sprays and coupled to solid/liquid phase fuel to predict the burning rate and extinguish process
FISCO-3L	German/Norway	57	One room field model for describing the interaction of sprinkler sprays with fire gases with forced or natural ventilation
FLUENT	**USA**	**58**	**General purpose CFD software**
JASMINE	UK	59	CFD model for fire and smoke spread
KAMALEON	Norway	60	CFD model for fire linked to a finite element code for thermal responses of the structures
KOBRA-3D	German	61	CFD model for heat transfer and smoke spread
MEFE	Portugal	62	CFD model for one or two compartments, includes time response of thermocouples
PHOENICS	**UK**	**63**	**General purpose CFD software**
RMFIRE	Canada	64	Two dimensional field model for the transient calculation of smoke movement
SMARTFIRE	UK	65	Fire field model
SmokeView	USA	66	Tool for visualising FDS data
SOFIE	UK/Sweden	67	CFD model for fire and smoke spread
SOLVENT	*USA*	*68*	*CFD model for heat transfer and smoke spread in a tunnel*
SPLASH	UK	69	Field model for describing the interaction of sprinkler sprays with fire gases
STAR-CD	**UK**	**70**	**General purpose CFD software**
TUNFIRE	*UK*	*71*	*CFD model for heat transfer and smoke spread in a tunnel*
UNDSAFE	USA/Japan	72	Field model for outdoors and indoor fires

Most of these softwares are focused on the smoke and heat transport in case of fire. Their application to the structural fire engineering is fixed only to the determination of the temperature in the structural members. The softwares in bold are CFD codes of general purpose. The softwares in cursive are

focused on particular cases and their application to the structural fire engineering design is very low. Other three models have been detected, but no information about them has been obtained: STREAM (Japan), VESTA (Netherlands) and FLOTRAN (USA).

2.2 *Structural fire resistance models:*

These models simulate the response of building structural elements exposed to fire. The principal purpose of them is to determine the failure time of the elements submitted to fire. Thermal and mechanical laws govern them.

Like for Fire Thermal models, we can found different types of software in function of the method used to solve the mechanical response associated to a fire. To classify them we follow the classification of the Eurocodes (EN 1991-1-2:2002 and EN 1993-1-2:2005) for the design procedures (See figure 6).

In this way the classification of the Structural fire resistance models is broken down in simplified and advanced structural fire resistance softwares.

The input data are usually the material properties and boundary conditions of the structural elements (including fire loads).

The output data are the failure time, the stress and displacements of the elements.

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

Fig. 6 Structural design procedures classification

2.2.1 *Simplified Structural fire resistance models:*

These models calculate the structural behaviour of the elements in an individual manner, each structural element isolated from the rest of the structure; and are based in simplified methods. Some of these are incorporated into zone or field models.

Application field: Simplified Structural fire resistance models			
Model	Country	Id. Number	Short description
AFCB	Luxembourg	73	Composite beam fire design according to Eurocode 4
AFCC	Luxembourg	74	Composite column fire design according to Eurocode 4
CIRCON	*Canada*	*75*	*Fire resistant model for reinforced concrete columns with circular cross section*
COFIL	Canada	76	Fire resistance of circular hollow steel sections filled with plain concrete
Elefir-EN	Portugal/Belgium	173	Fire resistance of steel structural elements according EN version of Eurocode 3

Elefir	Belgium	77	Fire resistance of steel structural elements according Eurocode 3
H-Fire	Germany	78	Calculation of design resistances for composite members exposed to fire by using the simple calculation models of the EN 1994-1-2
INSTAI	Canada	79	Fire resistance of insulated circular hollow steel columns
INSTCO	Canada	80	Fire resistance of circular concrete-filled tubular steel sections
POTFIRE	France	81	Fire resistance of concrete filled hollow section - based in annex G of Eurocode 4
RCCON	*Canada*	*82*	*Fire resistance model for reinforced concrete columns with rectangular cross section*
RECTST	Canada	83	Fire resistance of insulated rectangular hollow steel columns
SQCON	*Canada*	*84*	*Fire resistant model for square reinforced concrete columns*
WSHAPS	Canada	85	Fire resistance of protected W-shape steel columns
Požární odolnost	Czech Republic	176	Calculates resistance of steel elements exposed to fire. The calculation is based on EN 1993-1-2. The program contains databank of hot rolled steel sections, fire protection can be considered. Standard curve, hydrocarbon curve or parametric curve (input of the parameters is required) can be used to describe the fire behaviour. The element can be loaded by tension, compression, bending or combination of axial force and bending moment.

The softwares in cursive are only valid for concrete structural members.

2.2.2 *Advanced Structural Fire Resistance models:*

These models can simulate a partial or a whole structure in static or dynamic modes, providing us with the collapse time of whole building if it occurs. These softwares are finite element codes and frequently are of general purpose.

Application field: Advanced Structural fire resistance models			
Model	Country	Id. Number	Short description
ABAQUS	**USA**	**86**	**General purpose finite element code**
ALGOR	**USA**	**87**	**General purpose finite element code**
ANSYS	**USA**	**88**	**General purpose finite element code**
BoFire	Germany	89	BoFire is a transient, non-linear, incremental computer code based on the finite element method. For the material properties the thermal and mechanical definitions of ENV 1994-1-2 are implemented. Steel, concrete and composite steel and concrete structures can be analysed.
BRANZ-TR8	*New Zealand*	*90*	*This program is for analysing the fire resistance of reinforced or prestressed concrete floor systems*
CEFICOSS	Belgium	91	Fire resistant model
CMPST	France	92	Mechanical resistance of sections at elevated temperatures
COMPSL	*Canada*	*93*	*Temperatures of multilayer slabs during exposure to fire*
COSMOS	**USA**	**94**	**General purpose finite element code**
FASBUS	USA	95	Mechanical resistance model for structural element exposed to fire
FIRES-T3	USA	96	Finite element heat transfer for 1 , 2 or 3D conduction
HSLAB	Sweden	97	Transient temperature development in a heated slab composed of one or several materials.
LENAS	France	98	Mechanical behaviour of steel structures exposed to fire
LUSAS	**UK**	**99**	**General engineering analysis software**
NASTRAN	**USA**	**100**	**General purpose finite element code**
SAFIR	Belgium	101	Transient and mechanical analysis of structures exposed to fire
SAWTEF	USA	102	Structural analysis of metal-plate connected wood trusses exposed to fire
SISMEF	France	103	Mechanical behaviour of steel and concrete composite structures submitted to fire
STA	UK	104	Transient conduction in heated solid elements
STELA	UK	105	Three-dimensional finite-volume model, integrated into JASMINE and SOFIE, for calculating the thermal response of structural elements to fire gases
TASEF	Sweden	106	Finite element code for temperature analysis of structures exposed to fire
TCSLBM	*Canada*	*107*	*Two dimensional temperature distributions for fire exposed concrete slab/beam assemblies*
THELMA	UK	108	Finite element code for temperature analysis of structures exposed to fire
TR8	*New Zealand*	*109*	*Fire resistance of concrete slabs and floor systems*
VULCAN	UK	110	Three-dimensional frame analysis program, which has been developed mainly to model the behaviour of skeletal steel and composite frames, including the floor slabs, under fire conditions
WALL2D	*Canada*	*111*	*Model for predicting heat transfer through wood-stud walls exposed to fire*
Ocel požár	*Czech Republic*	*177*	*Forms a part of static system FINE 10. Calculates resistance of steel elements exposed to fire. The*

calculation is based on EN 1993-1-2. The program contains databank of hot rolled steel sections, user defined sections can be entered, fire protection can be considered. Standard curve, hydrocarbon curve or parametric curve (input of the parameters is required) can be used to describe the fire behaviour. The element can be loaded by tension, compression, bending or combination of axial force and bending moment. The internal forces are taken from structural analysis done by FINE 2D or FINE3D. Can be used as stand-alone program, the loads must be input in that case.

The softwares in cursive are not valid for steel structures. The softwares in bold are finite element codes of general purpose. Other two models have been detected, but no information about them has been obtained: HEATING and TAS (USA).

2.3 *Egress models:*

Egress models predict the required time to evacuate a building. These models are usually used in performance-based design analyses for alternative design and to determinate the location of congestion areas during evacuation.

Some of these models are linked to zone or field models in order to determine the time to the onset of untenable conditions in a building.

The most sophisticated also includes interesting features like the psychological effect of fire on occupants, air toxicity effect or the effect of the decreasing visibility. Some of these also have useful graphical features showing the movement of the people during evacuation process.

The input data are usually the occupation of the building, the geometry of the building (exits, stairs, elevators, corridors, etc.).

The output data are usually the time necessary for evacuating the building and the location of congestion areas.

These are usually statistic models.

Application field: Egress			
Model	Country	Id. Number	Short description
AEA EGRESS	USA	112	Analysis of occupant egress
ALLSAFE	Norway	113	Egress model including human factors
ASERI	German	114	Movement of the people in complex geometry, including smoke and fire spread factors
BGRAF	USA	115	Emergency egress model that incorporates a stochastic model of the human decision
EESCAPE	Australian	116	Evacuation of multi-storey buildings via staircases
EGRESS	UK	117	Egress model for complex geometry including visualisation
EGRESSPRO	Australian	118	Egress model including sprinkler and detectors activation
ELVAC	USA	119	Evacuation of multi-storey buildings via elevators
EVACNET	USA	120	Determines the optimal evacuation plan
EVACS	Japan	121	Evacuation model for determining the optimal design
EXIT89	USA	122	Evacuation of high-rise buildings
EXITT	USA	123	Node and arc type egress model with people behaviour included

Model	Country	Id. Number	Short description
EXODUS	UK	124	Evacuation tool for the safety industry
GRIDFLOW	UK	125	Egress simulation of the time required for occupants to clear each floor of multi-storey buildings and total building clearance time
PATHFINDER	USA	126	Egress model
PEDROUTE	UK	127	Pedestrian simulation model
SEVE_P	France	128	Egress model with graphical outputs including obstructions
SIMULEX	UK	129	Co-ordinate based egress model
STEPS	UK	130	Simulation Software of Pedestrian Movements- 3D visualisation
WAYOUT	Australian	131	Egress part of FireWind package

Other five models have been detected, but no information about them has been obtained: BFIRE, ERM, Magnetic Simulation, Takashi´s Fluid Model and VEGAS (UK).

2.4 *Detector response models:*

Detector response models determine the time to activation of an active fire safety device, like thermal detectors, sprinklers or smoke detectors.

These models assume a zone approach to calculate the smoke and heat transport and use submodels to determine the response of the thermal detectors to the heat and smoke flow. In short these models use a simplified modelling and calculate the heat transfer to the detector element to determine the time to activation.

The input data are usually the characteristics of the detector element to analyse, its location and the heat release rate of the fire. For the most sophisticated models, the geometry of the compartments and their materials are required.

The output data are the time of activation of the device and in the most sophisticated models the effect of the device activation.

It is necessary to take care to select correctly the model because some of these are only valid for flat ceiling or unconfined ceilings.

Application field: Detector response models			
Model	Country	Id. Number	Short description
ASCOS	USA	132	Analysis of Smoke Control Systems
DETACT-QS	USA	133	Calculates thermal detector activation time under unconfined ceilings, arbitrary fire
DETACT-T2	USA	134	Calculates thermal detector activation time under unconfined ceilings, t2 fire
FPETOOL	USA	135	Set of engineering equations useful in estimating potential fire hazard and the response of the space and fire protection systems to the developing hazard.
G-JET	Norway	136	Smoke detection model
JET	USA	137	A Model for the Prediction of Detector Activation and Gas Temperature in the Presence of a Smoke Layer
LAVENT	USA	138	Response of sprinkler links in compartment fires with curtains and ceiling vents
PALDET	Finland	139	Response of sprinklers and fire detectors under unconfined ceilings
SPARTA	UK	140	Sprinkler particle-tracking model, integrated into JASMINE, for evaluating the effect of sprinklers on fire gases

SPRINK	USA	141	Sprinkler response for high-rack storage fires
TDISX	USA	142	Warehouse sprinkler response

One more model has been detected, but no information about it has been obtained: HAD.

2.5 *Miscellaneous:*

There are some models associated with fire engineering which are not included in the previous categories. Some of these have features that fulfil more than one of the previous categories and others treat specific aspects of fires not included in the other categories. These models have been termed miscellaneous.

Many of these models are computer programs, which contain many submodels and therefore can be used for several of the application fields listed before. These are computer packages formed by separate models which each one treat an individual aspect of fire.

Application field: miscellaneous models			
Model	Country	Id. Number	Short description
ALARM	UK	143	Economic optimisation of code compliance measures
ASKFRS	UK	144	Package of models including a zone model
BREAK1	USA	145	Window response to fire
BREATH	UK	146	Dispersion of contaminants in a network of compartments with forced ventilation
Brilliant	Norway	147	CFD model combined with analytical models
COFRA	USA	148	Fire risk assessment model
CONTAMW	USA	149	Airflow model
CRISP	UK	150	Fire zone model with egress and risk assessment
FIERAsystem	Canada	151	Risk assessment model that include a suite of correlations
FireCad	USA	152	Front end for CFAST
FIRECAM	Canada	153	Risk damage assessment
FIREDEMND	USA	154	Determinates the water demand necessary to extinguish a fire
FIRESYS	New Zealand	155	Package of program for working under performance based codes
FIREX	German	156	Simple zone models combined with empirical correlation
FIVE	USA	157	Fire induced vulnerability evaluation
FRAME	Belgium	158	Fire risk assessment model
FREM	Australian	159	Fire risk evaluation model
FriskMD	USA	160	Risk based version of zone model FireMD
HAZARD I	USA	161	Zone model with extensive egress capabilities
JOSEFINE	UK	162	Integrated fire interface to zone and CFD models, and egress and risk simulation models
MFIRE	USA	163	Mine ventilation systems
RadPro	Australian	164	Fire radiation model
Risiko	Switzerland	165	Risk assessment model
RISK-COST	Canada	166	Expected risk to life and costs associated to fire
RiskPro	Australian	167	Risk ranking model
SMACS	USA	168	Smoke movement trough air-conditioning systems
SPREAD	USA	169	Predicts the burning rate and spread rate of a fire ignited on a wall
ToxFED	UK	170	Calculation of Fractional Effective Dose (FED) from smoke layer species concentrations
UFSG	USA	171	Predicts upward flame spread and growth on non-charring and charring materials
WALLEX	Canada	172	Calculation of heat transfer from window fire plume to

One more model has been detected, but no information about it has been obtained: Dow indices (USA).

2.6 *Publicly available fire software:*

Between all the detected software during this study, 30 are publicly available. These softwares are listed in the following table:

Publicly available fire software			
Model	Application field	Id. Number	Available in
DIFISEK-CaPaFi	Fire Thermal models – Simplified	1	www.sections.arcelor.com
DIFISEK-EN 1991-1-2 Annex A	Fire Thermal models – Simplified	2	www.sections.arcelor.com
DIFISEK-TEFINAF	Fire Thermal models – Simplified	3	www.sections.arcelor.com
ASET/ASET-B	Fire Thermal models – Zone	5	www.fire.nist.gov
ASMET	Fire Thermal models – Zone	6	www.fire.nist.gov
CCFM/Vents	Fire Thermal models – Zone	9	www.fire.nist.gov
FAST/CFAST	Fire Thermal models – Zone	16	www.fire.nist.gov
FIRST	Fire Thermal models – Zone	26	www.fire.nist.gov
OZONE	Fire Thermal models – Zone	40	www.ulg.ac.be www.sections.arcelor.com
ALOFT-FT	Fire Thermal models – Field	53	www.fire.nist.gov
FDS	Fire Thermal models – Field	55	www.fire.nist.gov
SmokeView	Fire Thermal models – Field	66	www.fire.nist.gov
AFCB	Structural fire resistance – Simplified	73	www.sections.arcelor.com
AFCC	Structural fire resistance – Simplified	74	www.sections.arcelor.com
ELEFIR	Structural fire resistance – Simplified	77	www.ulg.ac.be
Elefir-EN	Structural fire resistance – Simplified	173	www.eccspublications.eu
H-Fire	Structural fire resistance – Simplified	78	www.stahlbau.uni-hannover.de
POTFIRE	Structural fire resistance – Simplified	81	www.cidect.org
ELVAC	Egress	119	www.fire.nist.gov
EVACNET	Egress	120	http://www.ise.ufl.edu/kisko/files/evacnet
ASCOS	Detector response	132	www.fire.nist.gov
DETACT-QS	Detector response	133	www.fire.nist.gov
DETACT-T2	Detector response	134	www.fire.nist.gov
FPETOOL	Detector response	135	www.fire.nist.gov
JET	Detector response	137	www.fire.nist.gov
LAVENT	Detector response	138	www.fire.nist.gov
BREAK1	Miscellaneous	145	www.fire.nist.gov
FIREDEMND	Miscellaneous	154	www.fire.nist.gov
Parametrická teplotní křivka	Fire thermal model - Simplified	174	www.access-steel.cz/page-nastroje-pro-navrhovani/
Přestup tepla	Fire thermal model	175	www.access-steel.cz/page-nastroje-pro-navrhovani/
Požární odolnost	Structural fire resistance model - Simplified	176	www.access-steel.cz/page-nastroje-pro-navrhovani/

3 ASPECTS TO EVALUATE:

The main aspects of fire design software to evaluate are:

- Calculation methodology – Physical and mathematical models used
- Documentation of the software
- User aspects

3.1 *Calculation methodology – Physical and mathematical models used:*

The most important concept of the calculation methodology is the *formulation used* by the software to perform the calculations. These formulations are normally based in physical or thermal laws or in

experimental data and theories. The reliability of the software depends strongly on the accuracy and truthfulness of the formulation used.

It is impossible to take into account all the variables in relation with an event to calculate it, in order to perform the calculations we have to make assumptions. *The assumptions adopted* by the software to perform the calculations are clearly an important concept to evaluate its accuracy.

Both the formulation used and the assumptions adopted limit the versatility of the software. The *limitations of the software* are not only imposed by these concepts. There are other concepts, like the model size and the geometry complexity that also limit the software. These limitations will tell us if the software fits well to our study case or not.

3.2 *Documentation of the software:*

When we start to use software is very important to have a clear information about it. The most important documents are *User's Guide, Technical guides, papers and validation examples*. The quality and clearness of these documents will be very important for making a correct use of the software and therefore for the reliability and accuracy of the results obtained.

3.3 *User aspects:*

These aspects have no relation with the reliability and the accuracy of the software but have a great importance when we use it. A good *software interface* allows us to define the input data in an easy way, avoiding errors during this process; the *inputs and outputs reporting* is very important to facilitate the analysis of the results and a good *graphics* provide us with a better vision of the event simulated. These three concepts will make the software user friendly and could reduce the errors and the reporting time of the results.

4 EVALUATED SOFTWARES

During this project has been captured a lot of data about different fire design softwares. Due to the great quantity of softwares detected, we have fitted our study to fourteen softwares. For these softwares we have collected the information to evaluate them in depth (see point 3) and we have put it in a text format (Annex I). In addition we have created a database with all this information adding the non-evaluated softwares (for these last we only have collected the general information). This database will be available in the DIFISEK+ partners web sites.

4.1 *The information of each software collected in text format:*

- Software identification (general information): Name, Version, Year, Application Field, Country, Author/s, Organisation/s, System Requirements, Computer Language, Size, Available in, Contact Information and Description.

- Evaluation aspects:

    - Calculation Methodology: Formulation Used, Assumptions Adopted and Limitations
    - Documentation: User´s Guide, Technical Guides, Papers and Validation Examples.
    - User´s Aspects: Interface, Input/Output Reporting and Graphics.

- Conclusions: Evaluation of the evaluations aspects listed above and User Level Requirement.

4.2 *Fifteen softwares evaluated in depth:*

- Thermal Fire models (4):

    - Simplified Thermal Fire models (1): DIFISEK-EN 1991-1-2 Annex A
    - Advanced Thermal Fire models (3): FAST/CFAST and OZONE (Zone) and FDS (Field)

- Structural fire resistance models (8):

    - Simplified Structural Fire Resistance models (6): AFCB, AFCC, Elefir, Elefir-EN, H-Fire and Potfire
    - Advanced Structural Fire Resistance models (2): Abaqus and BoFire

- Egress models (1): Evacnet4

- Detector response models (2): Detact-Qs and Jet

See annex I and database.

5 ANNEX I: SOFTWARES

5.1 *DIFISEK-EN 1991-1-2 Annex A*

5.1.1 *General information (ID Number: 2)*

- Name: Difisek-EN 1991-1-2 Annex A
- Version: 1
- Year: 2004
- Application Field: Fire Thermal Models - Simplified
- Country: Luxembourg
- Author/s: L.G. Cajot; M. Haller
- Organisation/s: Arcelor LCS Research Centre
- Language: English
- System requirements: Windows
- Size: 2.26 MB
- Cost: Free
- Available in: www.sections.arcelor.com

Description:

Calculation of the parametric temperature-time curves in a compartment and the temperature of a protected and unprotected steel member submitted to that parametric temperature-time curve. Based on EN 1991-1-2 Annex A and prEN 1993-1-2.

5.1.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: See EN 1991-1-2 Annex A and prEN 1993-1-2
- Assumptions adopted: It is assumed that the fire load of the compartment is completely burnt out. If fire load densities are specified without specific consideration to the combustion behaviour, then this approach should be limited to fire compartments with mainly cellulosic type fire loads.
- Limitations: The temperature-time curves used are valid for fire compartments up to 500 m^2 of floor area, without openings in the roof and for a maximum height of 4 m.

Documentation:

See EN 1991-1-2 Annex A and prEN 1993-1-2

User's aspects:

- Interface: Windows, Excel
- Input/Output reporting is given by simply Excel-files.
- Graphics: Excel graphics

5.1.3 *Conclusions:*

- Reliable calculation methodology
- Documentation: EN 1991-1-2 Annex A and prEN 1993-1-2

- User-friendly
- User knowledge level required: Low

5.2 *FAST/CFAST:*

5.2.1 *Software identification (ID Number 16):*

- Name: FAST/CFAST
- Version: FAST 3.1.7/CFAST 5.1.1
- Year: 2004
- Application Field: Zone model
- Country: US
- Author/s: Walter W. Jones
- Organisation/s: NIST – National Institute of Standards and Technology
- System requirements: A 386 or later compatible PC; 4 MB of free extended memory; VGA compatible graphics display.
- Computer Language: FORTRAN/C
- Size: FAST 11.1 MB / CFAST 6.73 MB
- Available in: www.fast.nist.gov or www.nfpa.org
- Contact information: www.fast.nist.gov or contact with Walter W. Jones by e-mail wwj@nist.gov

Description:

FAST is a collection of procedures, which builds on the computer model CFAST to provide a engineering estimation of fire hazard in compartment structures. The major functions provided include calculation of:

- The production of enthalpy and mass (smoke and gases) by one or more burning objects in one room, based on small or large scale measurements.
- The buoyancy-driven as well as forced transport of this energy and mass through a series of specified rooms and connections (doors, windows, ducts,…).
- The resulting temperatures, smoke optical densities, and gas concentration after accounting for heat transfer to surfaces and dilution by mixing with clean air.

CFAST is a two-zone model used to calculate the evolving distribution of smoke and fire gases and the temperature throughout a building during a fire. Version 3.1.6 models up to 30 compartments, a fan and duct system for each compartment, 31 individual fires, up to one flame-spread object, multiple plumes and fires, multiple sprinklers and detectors, and the ten species considered most important in toxicity of fires including the effective fatal dose. The geometry includes variable area-height relations, ignition of multiple objects such as furniture, thermophysical and pyrolysis databases, multi-layered walls, ignition through barriers and vents, wind, the stack effect, building leakage, and flow through holes in floor-ceilings connections.

5.2.2 *Evaluation Aspects:*

Calculation Methodology:

- Formulation used: CFAST is based on solving a set of equations that predict the state variables (pressure, temperature and so on) based on enthalpy and mass flux over small increments of time. These equations are derived from the conservation equations for energy mass, and momentum, and the ideal gas law. The errors, which might be made, cannot come from these equations, but rather come from numerical representation of the equations or from simplifying assumptions.

- Assumptions adopted: The basic assumption of all zone fire models is that each room can be divided into a small number of control volumes, each of which is internally uniform in temperature and composition. Within CFAST, all rooms have two zones except the fire room, which has additional zones for the fire plume and ceiling jet, which are calculated separately to account for mass and heat transfer between the zones and between the zones and compartment surfaces. To simulate the fire growth, the system utilises a user specified fire, expressed in terms of time specified rates of energy and mass released by the burning item(s). Individual determinations are made for both incapacitation and lethality from temperature and toxicity, along with potential incapacitation from burns due to flux exposure.
- Limitations: The CFAST model does not include a fire growth model. No interactions between temperature and toxicity are currently included.

Documentation:

- User's guide:
  User's guide for FAST: Engineering tools for stimating fire growth and smoke transport NIST-SP-921; 200 p. March 2000.
  Peacock, R. D.; Reneke, P. A.; Jones, W. W.; Bukowski, R. W.; Forney, G. P.
  Available in: www.fire.nist.gov
  User´s guide for CFAST Version 1.6.
  NISTIR-4985; 106 p. December 1992.
  Portier, R. W.; Reneke, P. A.; Jones, W. W.; Peacock, R. D.
  Available in: www.fire.nist.gov
- Technical guides:
  Technical reference for CFAST: an engineering tool for estimating fire and smoke transport. NIST TN 1431; 190 p. March 200.
  Jones, W. W.; Forney, G. P.; Peacock, R. D.; Reneke, P. A.
  Available in: www.fire.nist.gov
- Papers and Validation examples:
  "A review of four compartment fires with four compartment fire models", Deal, S. Fire safety Developments and Testing, Proceedings of the annual meeting of the Fire Retardant Chemicals Association. October 21-24, 1990, Ponte Verde Beach, Florida, 33-51.
  "Verification of a model of fire and smoke transport", Peacock, R. D.; Jones, W. W.; Bukowsky, R. W. Fire Safety Journal., 21 89-129 (1993).
  "The accuracy of computer fire models: some comparisons with experimental data from Australia", Duong, D. Q. Fire Safety Journal 1990, 16(6), 415-431.
  "Comparison of fire model predictions with experiments conducted in a hangar with a 15 m ceiling", Davis, W. D.; Notarianni, K. A.; McGrattan, K. B. NIST, NISTIR 5927 (1996).

User's Aspects:

- Interface: MS-DOS
- Input/Output Reporting: Includes a text report generator.
- Graphics: Includes a graphic report generator.

5.2.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Medium

5.3 *OZONE*

5.3.1 *Software identification (ID Number 40):*

- Name: OZONE
- Version: V2.2.2
- Year: 2002
- Application Field: Zone model
- Country: Belgium
- Author/s: J. F. Cadorin and J. M. Franssen from ULG and L. G. Cajot; M. Haller and J. B. Schleich from Arcelor
- Organisation/s: University of Liege, Inst. de Mécanique el Génie Civil, 1, Chemin des Chevreuils, 4000 Liege 1, Belgium. And Arcelor LCS research centre
- System requirements: Windows based PC.
- Computer Language: FORTRAN – Visual Basic
- Size: 5 MB
- Available in: www.ulg.ac.be ; www.sections.arcelor.com
- Contact information: www.ulg.ac.be or contact with Jean Marc Franssen (jm.franssen@ulg.ac.be) or J. F. Cadorin (jf.cadorin@ulg.ac.be)

Description:

The computer code Ozone V2 has been developed to help engineers in designing structural elements submitted to compartment fires. The code is based on several recent developments, in compartment fire modelling on one hand and on the effect of localised fires on structures on the other hand. It includes a simple compartment fire model that combines a two-zone model and a one-zone model. It also takes into account the localised effect of a fire with the help of Hasemi´s model. Thus it is a pre- and post- flashover model. It calculates the temperature of a steel section submitted to that compartment fire and, finally, evaluates the fire resistance of simple steel elements, according to EC3 ENV 1993-1-2. It has been developed in the scope of two European researches "Competitive Steel Buildings through Natural fire safety Concept" and "Natural Fire Safety Concepts – Full Scale Test, Implementation in the Eurocodes and Development of an User Friendly design tool". In Ozone several improvements have been made: the wall model is made by finite element (is implicit) and two different combustion models have been developed to cover different situations of use of the code.

5.3.2 *Evaluation Aspects:*

Calculation Methodology:

- Formulation used: Numerical two-zone models are based on eleven physical variables. These variables are linked by six constraints and four differential equations describing the mass and energy balances in each zone. The mass balance equation express the variation of the mass of the gas of each zone, that is equal to the mass of combustion gases created by the fire, plus the mass coming into the compartment through the vents minus the mass going out of the compartment through the vents. The energy balance equation expresses the balance between the energy generated in the compartment by the combustion and the way in which this energy is consumed: by the heating of the gases in the compartment, by the mass loss of hot air through the openings (Including a negative term accounting for the energy of incoming air), by the radiation loss through the openings and by the heating of the partitions. In the case of one zone model, the number of variables is reduced to six, the number of constraints to four and the differential equations to two. Ozone includes a partition model and two combustion models.
- Assumptions adopted: The main hypothesis in zone models is that the compartment is divided in zones in which the temperature distribution is uniform at any time. In one-zone models, the temperature is considered uniform within the whole compartment. This type of model is thus valid in case of fully developed fires, contrary to two-zone models, which are valid in case of localised

fires. In this last model there are a hot layer which is close to the ceiling and a cold layer closed to the floor.

- Limitations: Ozone does not include a pyrolisys model but includes two combustion models (external and extended flame models) that will modify the evolution of the Heat Release Rate curve (RHR – defined by the user) in function of the oxygen mass balance. The room geometry is restrained to four walls and three vents.

Documentation:

- User's guide:
  "The design Fire Tool Ozone V2.0 – Theoretical Description and Validation On Experimental Fire Tests"
  Rapport interne SPEC/2001_01 University of Liege, Belgium, June 2001.
  J. F. Cadorin; J. M. Franssen; D. Pintea.
  Available in: www.ulg.ac.be
- Technical guides:
  Is included in the User's Guide.
- Papers and Validation examples:
  "Competitive steel buildings through natural fire safety concepts"
  Part 2: Natural fire models - The one zone model OZone, Final report
  CEC Agreement 7210-SA/125/126/213/214/323/423/522/623/839/937.
  Profil ARBED, March 1999.
  Available by contact: ecsc-steel@cec.eu.int
  "Natural Fire Safety Concepts- Full Scale Test, Implementation in the Eurocodes and Development of an User Friendly design tool"
  Part 2: Natural fire models - The one zone model OZone, Final report
  CEC Agreement 7210-PA/PB/PC/PE/PF/PR-060.
  Draft final report, December 2000.
  Available by contact: ecsc-steel@cec.eu.int
  "On the application field of Ozone V2"
  Rapport interne NºM&S/2002-003 University of Liege, Belgium, 2002.
  J. F. Cadorin
  "Compartment fire models for structural engineering"
  Doctoral thesis of J. F. Cadorin University of Liege.
  J. F. Cadorin
  Available in: www.ulg.ac.be

For more information send e-mail to contacts.

User's Aspects:

- Interface: Visual Basic
- Input/Output Reporting: Includes a text report generator.
- Graphics: Includes a graphic report generator.

5.3.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Medium

5.4 *FDS - Fire Dynamics Simulator & Smokeview:*

5.4.1 *Software identification (FDS - ID Number: 55 – ID Number: 66):*

- Name: FDS – Fire Dynamics Simulator / Smokeview
- Version: FDS Version 3 / Smokeview Version 3.1
- Year: 2002
- Application Field: Field model (CFD)
- Country: U.S.A
- Author/s: FDS - Kevin McGrattan, Glenn Forney. / Smokeview – Glenn Forney
- Organisation/s: NIST – National Institute of Standards and Technology
- System requirements: UNIX or PC of PII 450 or better.
- Computer Language: FORTRAN 90
- Size: 5.48 MB + 24 MB for examples and documentation
- Available in: www.fire.nist.gov
- Contact information: www.fire.nist.gov or contact with Kevin McGrattan kevin.mcgrattan@nist.com

Description:

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriated for low-speed, thermally driven-flow with an emphasis on smoke and heat transport from fires. FDS has been aimed at solving practical fire problems in fire protection engineering and at the same time providing a tool to study fundamental fire dynamics and combustion.

Smokeview is a visualisation program that is used for display the results of FDS simulation. Smokeview visualises FDS modelling results by displaying: particle flow, 2D or 3D shaded contours of gas flow data such as temperature and flow vectors showing flow direction and magnitude. Smokeview also visualises static data at particular times again using 2D or 3D contours.

5.4.2 *Evaluation Aspects:*

Calculation Methodology:

- Formulation used: An approximate form of the Navier-Stokes equations appropriate for low Mach number applications is used in the model. The approximation involves the filtering out of acoustic waves while allowing for large variations in temperature and density. This gives the equations an elliptic character, consistent with low speed, thermal convective processes. The computation can either be treated as a Direct Numerical Simulation (DNS), in which dissipative terms are computed directly, or as Large Eddy Simulation (LES), in which the large-scale eddies are computed directly and the sub-grid scale dissipative processes are modelled. The choice of DNS or LES depends on the objective of the calculation and the resolution of the computational grid. There are two combustion models used in FDS. For a DNS calculation where the diffusion of the fuel and oxygen can be modelled directly, a global one step, finite rate chemical reaction is most appropriate. In a LES calculation where the grid is not fine enough to solve the diffusion of the fuel and oxygen, a mixture fraction-based combustion model is used.
- Assumptions adopted: The low Mach number equations are solved numerically by dividing the physical space where the fire is to be simulated into a large number of rectangular cells. Within each cell the gas velocity, temperature, etc, are assumed to be uniform, changing only with time. The accuracy with which the fire dynamics can be simulated depends on the number of cells incorporated into simulation.
- Limitations: The calculations must be performed within a domain that is made up of rectangular blocks, each with his rectilinear grid. Non rectangular domains cannot be modelled. FDS do not have a pre-processor, a text input data file generation is required (non user friendly).

Documentation:

- User's guide:
  "Fire Dynamics Simulator (Version 3) – User´s Guide"
  NISTIR 6784 2002.
  McGrattan K. B., Forney G. P., Floyd J. E., Hostikka S. And Prasad K.
  Available in: www.fire.nist.gov
  "User´s Guide for Smokeview Version 3.1 – A Tool for Visualising Fire Dynamics Simulation Data"
  NISTIR 6980 2003.
  Forney G. P. and McGrattan K. B.
  Available in: www.fire.nist.gov
- Technical guides:
  "Fire Dynamics Simulator (Version 3) – Technical reference Guide"
  NISTIR 6783 2002.
  McGrattan K. B., Baum H. R., Rehm R. G., Hamins A., Forney G. P., Floyd J. E., Hostikka S. and Prasad K.
  Available in: www.fire.nist.gov
- Papers and Validation examples:
  Papers and examples are availables in www.fire.nist.gov

User's Aspects:

- Interface: FDS MS-DOS / Smokeview – Windows Open GL view
- Input/Output Reporting: Smokeview program.
- Graphics: Smokeview program.

5.4.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- FDS non user-friendly
  Smokeview user-friendly
- User knowledge level required: High

5.5 *AFCB (Composite Beam Fire Design)*

5.5.1 *Software identification (ID Number 73)*

- Name: AFCB (Composite Beam Fire Design)
- Version: 3.07
- Year: 2003
- Application Field: Structural fire resistance Models
- Country: Luxembourg
- Author/s: Henri Colbach
- Organisation/s: Arcelor LCS research centre
- System requirements: Windows 95/98/2000/NT, 100 Mhz, 32 MB RAM, 6x CD-ROM drive.
- Size: 3 MB
- Available in: The software is available for free download at www.sections.arcelor.com.
- Contact information:
    Arcelor LCS research centre
    66, rue de Luxembourg
    L-4221 Esch-sur-Alzette

Phone (+352) 5313-3007
Fax (+352) 5313-3095
E-mail: europrofil.dsm@profilarbed.lu
Internet: www.sections.arcelor.com

Description:

The program AFCB calculates the ultimate bending moments for composite beams at room temperature according to EUROCODE 4 Part 1.1 (ENV 1994-1-1) and for the ISO fire classes R30, R60, R90, R120 and R180 with accordance to the EUROCODE 4 Part 1.2 (ENV 1994-1-2).

The software has the following structure:
- INPUT DATA:
  - <u>Project:</u> general information concerning the project.
  - <u>Section:</u> there are three different ways to define the profile:
  a) Type the complete name of the profile in upper case letters (e.g. HE 300 A)
  b) Select the series of the profile by giving the name of the series (IPE, HE, HL, HD, HP, W, UB or UC), then select the profile in the list.
  c) Select the profile directly in the list.
  - <u>Slab:</u> although the program does not make any calculations for the slab, it needs some information about it to determine its participation in the beam resistance and the reductions to be made in fire case.
  - <u>Rebars:</u> the user has to define the rebars in the concrete between the flanges and the rebars in the slab.
  - <u>Materials:</u> define the mechanical properties for each material: yield point of the steel profile, characteristic cylinder strength for concrete in the profile and in the slab and the yield point of the rebars in the profile and of meshes in the slab.
  - <u>Material safety factors:</u> the user can choose the factors applied to the resistance of each material for both cases: service conditions and fire conditions.
  - <u>System:</u> the user can choose among three possible calculation types:
  a) Calculation of section resistance: determine the plastic resistance values of the given section.
  b) Dimensioning under given load: the user can define loads. The beam will be first examined in cold situation and if its resistance is insufficient for this case, the user will have to modify the section. If it is sufficient in cold case, the calculation for the fire case will follow the first calculation. If in the fire case the section is insufficient the program will try other rebar-combinations in order to find one who gives the section a sufficient resistance. The rebar combinations are written in the file "rebars.reb". The user can modify this file.
  c) Dimensioning under given minimum section resistance: similar to b). The main difference is that in this case the needed resistance values of the section are not calculated using loads but are to be introduced directly. Use this calculation type if you use resistance moments calculated by hand or with another program.
- RESULTS: the program calculates for the cold case and the fire case the following results:
  - Ultimate positive moments, M+
  - Ultimate negative moments, M-
  - Ultimate shear forces
  - For the calculation types b) and c), the program calculates the capacity ratio and the reinforcements (if any were made).
  - Details: The complete calculation details in service conditions and for the chosen fire class are written in this sheet. The user can find all the introduced data to the upper border of the concrete slab. Moreover, it contains also all the reduced values of the positive moments and all the reduced values of the negative moments.

- Graphic: According to the calculation-type the following graphics can be displayed: section graphic, moment curve, graphics for the calculation of the section resistance.

5.5.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: the calculation methodology is the included in the Eurocode 4 Parts 1.1 and 1.2.
- Assumptions adopted:
  - This program deals with simply supported or continuous beams.
  - Annex H of ENV 1994-1-1 is not considered.
  - The shown reinforcements for the rebars in the profile reproduce only the rebar definition text for the calculation. This can be different from the rebars used for the calculation. Check in "Details" or in the graphic which rebars were actually placed and used for calculation.
- Limitations:
  - The verification of the shear forces is not included in the program. This has to be done separately.
  - Only open sections are available for the calculations.

Documentation:

- User's guide: it is included in the help modulus of the software.
- Technical guides: Eurocode 4 Parts 1.1 and 1.2.
- Available at: The software is available for free download at www.sections.arcelor.com
- Papers and validation examples: the software is validated enough because it follows the same calculation methodology that the Eurocode 4.

User's aspects:

- Interface: Windows
- Input/Output reporting: the user can print the output in condensed form or in complete form. In the complete form, all the input data and the output (results for ultimate positive and negative moments and for the ultimate shear, and the resistance of the section to positive and negative moments in cold and fire situations) are printed.
- Graphics: The program plots a drawing of the section and the distribution of resisted moments for positive and negative moments in cold and fire situations.

5.5.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Medium

5.6 *AFCC (Composite Column Fire Design)*

5.6.1 *Software identification (ID Number 74)*

  - Name: AFCC (Composite Column Fire Design)
  - Version: 3.05
  - Year: 2003

- Application Field: Structural fire resistance Models
- Country: Luxembourg
- Author/s: Henri Colbach
- Organisation/s: Arcelor LCS research centre
- System requirements: Windows 95/98/2000/NT, 100 Mhz, 32 MB RAM, 6x CD-ROM drive.
- Size: 2,5 MB
- Available in: The software is available for free download at www.sections.arcelor.com.
- Contact information:
    Arcelor LCS research centre
    66, rue de Luxembourg
    L-4221 Esch-sur-Alzette
    Phone (+352) 5313-3007
    Fax (+352) 5313-3095
    E-mail: europrofil.dsm@profilarbed.lu
    Internet: www.sections.arcelor.com

Description:

The program AFCC calculates the ultimate loads for composite columns AF 30/120 at room temperature according to Eurocode 4 Part 1.1 (ENV 1994-1-1) and for the ISO fire classes R30, R60, R90 and R120, with accordance to the Eurocode 4 Part 1.2 (ENV 1994-1-2).

The software has the following structure:
- INPUT DATA:
    - Project: general information concerning the project.
    - Section: there are three different ways to define the profile:
    a) Type the complete name of the profile in upper case letters (e.g. HE 300 A)
    b) Select the series of the profile by giving the name of the series (IPE, HE, HL, HD, HP, W, UB or UC), then select the profile in the list.
    c) Select the profile directly in the list.
    - Rebars: the user has to define the diameter of the rebars and their position.
    - Materials: define the mechanical properties for each material: yield point of the steel profile, characteristic cylinder strength for concrete in the profile and the yield point of the rebars in the profile.
    - Material safety factors: the user can choose the factors applied to the resistance of each material for both cases: service conditions and fire conditions.
    - Buckling lengths: the user has to define the buckling lengths for the weak and strong axes of the AF-column both in service and fire conditions.
    - Eccentricities: eccentricity of the load in the weak axis and in the strong axis of the profile (both in mm).
- RESULTS: the program calculates for 5 conditions – room temperature for service conditions, fire resistance time 30 minutes (R30), fire resistance time 60 minutes (R60), fire resistance time 90 minutes (R90) and fire resistance time 120 minutes (R120) – the following loadings:
    - Ultimate axial load, buckling around the weak axis of the profile (first column)
    - Ultimate axial load, buckling around the strong axis of the profile (second column)
    - Ultimate eccentric load about the weak axis (third column)
    - Ultimate eccentric load about the strong axis (fourth column)
    - Ultimate eccentric load about both axis of the profile (fifth column)
    - Details: the complete calculation details (buckling length, plastic load, critical load, relative slenderness ratio, buckling coefficient) in service conditions and for the fire classes R30, R60, R90 and R120 are written. The weight per meter of the column is also given, including separate informations on the profile, the concrete and the rebars.
    - Graphic: this part of the program shows a general view of the cross-section defined by the user (geometric data of the steel profile, position of the rebars…)

5.6.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: the calculation methodology is the included in the Eurocode 4 Parts 1.1 and 1.2.
- Assumptions adopted:
  - This program calculates columns under loads with small constant eccentricities.
  - The program only calculates double-symmetric, partly-encased columns with uniform section over the whole length of the column.
  - Annex H of ENV 1994-1-1 is not considered.
  - The percentage of the rebars should fulfil the following rules: ENV 1994-1-1, 4.8.3.1(3e) and 4.8.2.5(3) and ENV 1994-1-2, 4.3.6.2(2).
- Limitations:
  - Only open sections are available for the calculations.

Documentation:

- User's guide: the user's guide is included in the help modulus of the software.
- Technical guides: Eurocode 4 Parts 1.1 and 1.2.
- Available at: The software is available for free download at www.sections.arcelor.com
- Papers and validation examples: the software is validated enough because it follows the same calculation methodology that the Eurocode 4.

User's aspects:

- Interface: Windows
- Input/Output reporting: the user can print the output in condensed form or in complete form. In the complete form, all the input data and the output (service conditions weak and strong axis, Fire classes R30, R60, R90, R120 weak and strong axis and the weights per unit length of the steel profile, concrete, main rebars and total weight) are printed.
- Graphics: The program plots a drawing of the section.

5.6.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Medium

5.7 *Elefir:*

5.7.1 *Software identification (ID Number 77):*

- Name: Elefir
- Version: 2.1
- Year: 1998
- Application Field: Structural fire resistance models
- Country: Belgium
- Author/s: Dan Pintea, Laurent Miévis, Gilles Gustin, Jean-Marc Franssen

- Organisation/s: University of Liege
- System requirements: Windows 95 or higher.
- Size: 8 MB
- Available in: University of Liege website (http://www.ulg.ac.be/matstruc/Download.html)
- Contact information: Jean-Marc Franssen (jm.franssen@ulg.ac.be)

Description:

ELEFIR is a computer software that calculates the fire resistance of simple steel elements made of I sections loaded around the strong axis.

- Typical shapes of sections are available: HD, HE, HL, HP, IPE, UB, UC, W, L.
- Two options for fire exposure: three or four sides of the element.
- Options for section protection: no protection, contour encasement and hollow encasement.
- Properties of several protection materials are available: rock/glass wool, gypsum and also allows for the introduction of a new material defined by the user.
- Several heating curves are available: ISO curve, external fire curve, hydrocarbon curve, ASTM curve and there is also the possibility of introducing an user-defined curve.

The following calculations can be performed:

- Calculation of the time in which the critical temperature of the element is reached.
- Reached temperature after the introduced critical time.
- Calculation of the critical temperature of the element and the critical time for members subjected to tension, compression and bending and compression.

5.7.2 *Evaluation aspects:*

Calculation methodology:

- Formulation used:
  - The calculations are based in the ENV 1993-1-2 (Eurocode 3).
  - The Belgian national application document (NBN ENV 1993-1-2) can also be used.
- Assumptions adopted:
  - The temperature in the section is considered as an equivalent uniform distribution.
- Limitations:
  - Only open sections are available.
  - Fire exposure only on 3 or 4 four sides of the element.
  - Only for sections with double symmetry.
  - If during heating the section changes to Class 4, the software stops. It does not apply the last modification of EN 1993-1-2 that allows to consider that the class of the section remains in fire condition as at room temperature.

Documentation:

- User's guide: no available, but not necessary (easy to use)
- Technical guides: ENV 1993 1-2 (Eurocode 3)
- Papers and validation examples: no available

User's aspects:

- Interface: Windows
- Input/output reporting: Text file and graphs included.

- Graphic: The program plots the temperature curves.

5.7.3 *Conclusions:*

- Reliable calculation methodology
- Documentation: ENV 1993-1-2 (EC3)
- User-friendly
- User-knowledge level required: low.

5.8 *Elefir-EN:*

5.8.1 *Software identification (ID Number 173):*

- Name: Elefir-EN
- Version: 1.0
- Year: 2008
- Application Field: Structural fire resistance models
- Country: Portugal/Belgium
- Author/s: Bárbara Pires, Nuno Lopes, Paulo Vila Real, Dan Pintea, Jean-Marc Franssen
- Organisation/s: University of Aveiro/University of Liege
- System requirements: Windows 95 or higher.
- Size: 8 MB
- Available in: with the ECCS Eurocode Design Manual "Fire Design of Steel structures" (www.eccspublications.eu)
- Contact information: Paulo Vila Real (pvreal@ua.pt), (Jean-Marc Franssen (jm.franssen@ulg.ac.be)

Description:

Elefir-EN is a computer software that calculates the fire resistance of simple steel elements made of I, H, L, RHS and CHS sections loaded around the strong axis or around weak axis.

- Typical shapes of sections are available: HD, HE, HL, HP, IPE, UB, UC, W, L, RHS, CHS.
- Two options for fire exposure: three or four sides of the element.
- Options for section protection: no protection, contour encasement and hollow encasement.
- Properties of several protection materials are available: rock/glass wool, gypsum and also allows for the introduction of a new material defined by the user.
- Temperature dependent thermal properties of protection material can be defined by the user.
- Several heating curves are available: ISO curve, external fire curve, hydrocarbon curve, localized fires, parametric fire curves and there is also the possibility of introducing an user-defined curve.

The following calculations can be performed:

- Calculation of the time in which the critical temperature of the element is reached.
- Reached temperature after the introduced critical time.
- Calculation of the critical temperature of the element and the critical time for members subjected to tension, compression, bending and compression, bending and shear, global plastic analysis of continuous beams.
- Evaluate the needed thickness of the fire protection material to ensure a certain fire resistance.

5.8.2 *Evaluation aspects:*

Calculation methodology:

- Formulation used:
  - The calculations are based in the EN 1991-1-2 and EN 1993-1-2 (Eurocode 3).
- Assumptions adopted:
  - The temperature in the section is considered as an equivalent uniform distribution.
- Limitations:
  - Fire exposure only on 3 or 4 four sides of the element.
  - Only for sections with double symmetry in bending and compression.
  - Only for Class 1, 2 and 3.

Documentation:

- A chapter on the ECCS Eurocode Design Manual "Fire Design of Steel structures", was written to explain the use of Elefir-EN

User's aspects:

- Interface: Windows
- Input/output reporting: Text file and graphs included.
- Graphic: The program plots the temperature curves.

5.8.3 *Conclusions:*

- Reliable calculation methodology
- Design manual available at ECCS
- User-friendly
- User-knowledge level required: low.

5.9 *H-Fire*

5.9.1 *General information (ID Number: 78)*

- Name: H-Fire
- Version: 04.1
- Year: 2004
- Application Field: Structural fire resistance Models - Simplified
- Country: Germany
- Author/s: P.Schaumann, S.Hothan
- Organisation/s: University of Hannover, Institute for Steel Construction
- Language: German, English
- System requirements: Pentium PC, Microsoft Windows, Microsoft Office
- Size: 12.6 MB
- Cost: Free
- Available in: University of Hannover, Institute for Steel Construction
- Contact information: www.stahlbau.uni-hannover.de

Description:

Calculation of design resistances for composite members exposed to fire by using the simple calculation models of the EN 1994-1-2

5.9.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: The calculations are based on the simple calculation models of the ENV 1994-1-2 (Eurocode 4), except composite slab based on the simple calculation model of prEN 1994-1-2
- Assumptions adopted: like simple calculation models
- Limitations: like simple calculation models

Documentation:

- User's guide: Short description available at www.stahlbau.uni-hannover.de
- Technical guides: The calculations are based on the simple calculation models of the ENV 1994-1-2 (Eurocode 4), except composite slab based on the simple calculation model of prEN 1994-1-2
- Available at: To get a version, please go to www.stahlbau.uni-hannover.de
- Papers and validation examples: none

User's aspects:

- Interface: Windows; Microsoft Excel and Microsoft Access
- Input/Output reporting: The Program reports most of the input data and all output data
- Graphics: Where necessary, the program plots curves

5.9.3 *Conclusions:*

- Reliable calculation methodology
- Documentation: High detailed
- User-friendly
- User knowledge level required: Medium

5.10 *Potfire (ID Number 81):*

5.10.1 *Software identification:*

- Name: Potfire
- Version: 1.11
- Year: 2001
- Application Field: Structural fire resistance
- Country: France
- Author/s: Geneviève Fouquet, George Tabet, Bin Zhao, Julien Kruppa
- Organisation/s: CTICM, TNO, CIDECT
- System requirements: Pentium 200 Mhz, W95, CD-Rom, and 24 MB RAM
- Computer Language:
- Size: 15 MB
- Available in: www.cidect.org
- Contact information: www.cidect.org

Description:

The POTFIRE computer program is a design tool based on the modelling practices described in annex G of EC4 ENV 1994-1-2 "General rules - Calculation of behaviour to fire".

POTFIRE allows either the evaluation of the fire resistance duration of an unprotected concrete filled hollow section column under known design load(s) or the evaluation of the ultimate load bearing resistance after a given exposure time to the standard ISO fire.

5.10.2 *Evaluation Aspects:*

Calculation Methodology:

- Formulation used: The full set of generalised equations used within the model to describe thermal, mechanical and structural behaviour is given in Annex 2 of the "POTFIRE User's Manual", included in the software.
- Assumptions adopted: The POTFIRE user should take note that careful detail design of the top and bottom of a single column or at the joints of a continuous column is necessary to ensure that the loads are introduced into the column in a proper way and load transfer maintained during the fire condition.
- Limitations: The Eurocode 4 Part 1.2 Annex G is limited to a range column size (diameter and length).

Documentation:

- User's guide: Yes (Included in the software)
- Technical guides: Advice on good fire design detailing is given both in Eurocode 4, Part 1-2 and in the CIDECT Design Guide 4 "Design Guide for Structural Hollow Section Columns Exposed to Fire".
- Papers and Validation examples: No

User's Aspects:

- Interface: Windows, all the input and output data is showed in a calculator like screen.
- Input/Output Reporting: The software provides full report of input and output data.
- Graphics: The software does not provide graphic information.

5.10.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Low

5.11 *ABAQUS*

5.11.1 *General information (ID Number: 86)*

- Name: Abaqus
- Version: 6.4
- Year: 2003
- Application Field: Structural fire resistance Models - Advanced
- Country: United States
- Author/s: David Hibbit, Bengt Karlsson, Paul Sorensen
- Organisation/s: Abaqus Inc.
- Language: English
- System requirements: For Windows environment:
    Windows 2000 Professional (SP3 is strongly recommended)
    Pentium© III (or later) proccessor with speeds of 2 GHz or greater are recommended
    Compaq Visual Fortran 6.0 (Update A)
    Microsoft Visual C/C++ 6.0 (12.00.8804)
    Internet Explorer 5.5 or Netscape 6 (required for online documentation)
- Size: -
- Cost: Consult Abaqus distributors
- Available in: www.abaqus .com
    Abaqus Inc
    1080 Main Street
    Pawtucket, RI 02860-4847
    Tel: +1 401 727 4200
    Fax: +1 401 727 4208
- Contact information: www.abaqus.com

Description:

Abaqus software is a suite of interoperable applications for finite element analysis. It provides a unified system for engineering analysis and digital prototyping in support of design and manufacturing.

5.11.2 *Evaluation aspects:*

Calculation methodology:

- ABAQUS/Standard: provides a rich variety of analysis procedures allowing problems ranging from routine linear analyses to complex multi-stage nonlinear analyses to be solved efficiently and robustly. It can simulate a variety of physical phenomena such as heat transfer, mass diffusion, and acoustics, in addition to stress/displacement analyses.
- ABAQUS/Explicit: provides finite element solution techniques to simulate a wide variety of dynamic and quasi-static events (especially those involving impact and other highly discontinuous events) in accurate, robust, and efficient manner. It supports not only stress/displacement analyses but also fully coupled transient dynamic temperature-displacement, acoustic, and coupled acoustic-structural analyses.
- ABAQUS/CAE: finite element modeling environment with functionality organized in modules and toolsets.

Documentation:

- Available documentation:
    - Training:
        - Getting started with Abaqus
        - Getting started with Abaqus/Standard: Keywords version
        - Getting started with Abaqus/Explicit: Keywords version
        - Lecture notes

    - Analysis:
        - Abaqus analysis user's manual

    - Modeling and visualization:
        - Abaqus/CAE user's manual

    - Examples:
        - Abaqus example problems manual
        - Abaqus benchmarks manual

    - Reference:
        - Abaqus theory manual

User's aspects:

- Interface: Windows
- Input/Output reporting: Input data reporting through the input (*.inp) file and output data reporting throught the output database (*.odb) file.
- Graphics: 2D/3D representing of the model and of the output database.

5.11.3 *Conclusions:*

- Reliable calculation methodology

- Documentation: High detailed
- No user-friendly
- User knowledge level required: High

5.12 *BoFire*

5.12.1 *General information (ID Number: 89)*

- Name: BoFire
- Version: 7
- Year: 2004
- Application Field: Structural fire resistance Models
- Country: Germany
- Author/s: Peter Schaumann, Jens Upmeyer, Florian Kettner
- Organisation/s: Institute for Steel Construction
- Language: German
- System requirements: Windows 95/98/2000/NT, 100 Mhz, 32 MB RAM
- Size: 200 kB
- The software is not available at the moment

Description:

BoFire is a transient, non-linear, incremental computer code based on the finite element method. For the material properties the thermal and mechanical definitions of ENV 1994-1-2 are implemented. Steel, concrete and composite steel and concrete structures can be analysed.

5.12.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: A transient, non-linear, incremental computer code based on the finite element method
- Assumptions adopted:
  - This program deals with beams, columns or plane frame of any cross section.
  - The material properties of ENV 1994-1-2 (1994) are implemented.
- Limitations:
  - No three-dimensional structures
  - No plates of panels with two-axial load bearing capacity
  - No shear deformation of the cross section (Bernoulli-hypothesis)

Documentation:

There is no documentation available at the moment

User's aspects:

- Interface: Windows
- Input/Output reporting is given by simply text-files. The windows based surface HaFront can be used to create the Input-File.
- Graphics: The code included data plotting library DISLIN provides the opportunity to produce colored countourplots of the temperature distribution or 3-dimensional graphics of stresses or strains

5.12.3 *Conclusions:*

- Reliable calculation methodology
- Documentation is not available yet
- User-friendly
- User knowledge level required: Medium

5.13 *Evacnet4:*

5.13.1 *Software identification (ID Number 120)*

- Name: Evacnet4
- Version: 1.4
- Year: 1998
- Application Field: Egress
- Country: United States
- Author/s: T.M. Kisko, R.L. Francis, C.R. Nobel
- Organisation/s: University of Florida
- System requirements: Windows 95 or higher
- Size: Less than 1 MB
- Available in: http://www.ise.ufl.edu/kisko/files/evacnet
- Contact information: Thomas Kisko, 352-392-1293, kisko@ise.ufl.edu

Description:

EVACNET4 is an interactive computer program that models building evacuations. The program accepts a network description of a building and information on its initial contents at the beginning of the evacuation. From this information, EVACNET4 produces results that describe an optimal evacuation of the building. Each evacuation is optimal in the sense that it minimises the time to evacuate the building. People are evacuated as quickly as possible.

5.13.2 *Evaluation aspects:*

Calculation methodology:

- Formulation used: EVACNET takes the network model that the user provides and determines an optimal plan to evacuate the building in a "minimum" amount of time. This is done using an advanced capacitated network flow transhipment algorithm, a specialised algorithm used in solving linear programming problems with network structure.
- Assumptions adopted: The formulation of an EVACNET model forces certain assumptions to be made. These assumptions can cause the results of the model to be less than realistic. The better understanding that the users have of these assumptions, the better their chances are in producing valid results. The principle assumptions that the user should be aware that are included:
  - EVACNET is a linear modelling system. Dynamic arc capacities and arc traversal times do not change over time.
  - EVACNET does not model behavioural aspects. The only actions that are modelled are those that lead to achieving the minimum evacuation time.
  - EVACNET is based on a global viewpoint; not an individual viewpoint. This means that in achieving the optimal evacuation plan, EVACNET has the capability to "see" everything. In an actual evacuation individuals independently attempt to achieve an optimum. One chief use of EVACNET can be to train potential evacuees and/or the floor wardens on optimal building evacuation plans.
- Limitations:

Documentation:

- User's guide: Yes (Available at: http://www.ise.ufl.edu/kisko/files/evacnet)
- Technical guides: Yes (Available at: http://www.ise.ufl.edu/kisko/files/evacnet)
- Papers and validation examples: See validation references at: http://www.ise.ufl.edu/kisko/files/evacnet

User's aspects:

- Interface: MS-DOS
- Input/output reporting: the program gives information on the bottlenecks and the people that is inside the building when the critical time is reached.
- Graphic: the program does not plot any graphic.

5.13.3 *Conclusions:*

- Less Reliable calculation methodology
- High detailed documentation
- No user-friendly
- User knowledge level required: Low

5.14 *Detact-QS:*

5.14.1 *Software identification (ID Number 133)*

- Name: Detact-QS
- Version: 1.3
- Year: -
- Application Field: Detector response
- Country: United States
- Author/s: D.D. Evans
- Organisation/s: NIST (National Institute of Standards and Technology)
- System requirements: PC 286
- Size: 64K free memory
- Available in: Computer program available on NIST at no cost www.fire.nist.gov
- Contact information: www.fire.nist.gov

Description:

DETACT-QS is a program for calculating the actuation time of thermal devices placed below unconfined ceilings. It can be used to predict the actuation time of fixed temperature heat detectors and sprinkler heads subjected to a user specified fire. The required program inputs are the height of the ceiling above the fire, the distance of the thermal device from the axis of the fire, the actuation temperature of the thermal device, the response time index (RTI) for the device, and the rate of heat release of the fire. The program outputs are the ceiling gas temperature and the device temperature both as a function of time and the time required for device actuation.

5.14.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: DETACT-QS is an empirical model, which is based on data correlations from a series of large-scale fire experiments. The model solves a definite integral using a quasi steady state assumption. It solves several algebraic equations to produce predictions. DETACT-QS is

composed of an algorithm which predicts the maximum temperature and velocity of an unconfined ceiling jet, under a smooth, flat, horizontal ceiling at a given radius from the centerline of the fire. It also uses a lumped mass, convection heat transfer algorithm for predicting the activation time of a thermal detector. The correlations used in DETACT-QS were developed by Alpert and use a response time index developed bay Heskestad.

- Assumptions adopted: DETACT-QS assumes that the thermal device is located in a relatively large area, therefore is only the fire ceiling flow heats the device and there is no heating from the accumulated hot gases in the room.
  The model assumes that the detector being analysed is mounted on an unconfined, unobstructed, smooth, flat, horizontal ceiling and that the detector is located at the points of maximum temperature and velocity within the ceiling jet. Only convective heat transfer is considered between the ceiling jet and the thermal detector; no conductive loss or radiative heat transfer is considered. The detector is treated as a lumped mass. Temperatures and velocities of the plume and ceiling jet are uniform and assumed to be the maximum values in the plume. The fuel package and the plume are assumed to be in an unobstructed vertical axis. No ventilation or stratification effects are considered. No transport time (or lag time) is considered for the hot gases to travel from fuel to the detector. For each heat release rate input interval, the heat release rate is averaged over the interval and assumed constant.

- Limitations:
  - DETACT-QS underpredicts temperatures in scenarios involving low ceilings when the detector is close to the fire centreline, but temperature predictions improve as the radial distance from the fire to the detector increases. As the ceiling height increases, the agreement between the predictions and measured data improves.
  - There is better agreement between predictions and experimental results for devices with higher RTIs than with devices with lower RTIs.
  - The use of DETACT-QS would not be appropriate in small areas where a gas layer would develop prior to activation.

Documentation:

- User's guide: No
- Technical guides: "Evaluation of the computer fire model DETACT-QS" Morgan J. Hurley, Daniel Madrzykowski
- Available at: NIST Publications at NIST Web Page www.fire.nist.gov.
- Papers and validation examples: Comparison with experimental results available in the Technical Guide document.

User's aspects:

- Interface: MS-DOS
- Input/output reporting: The program outputs are the ceiling gas temperature and the device temperature both as a function of time and the time required for device actuation.
- Graphic: the program does not plot any graphic

5.14.3 *Conclusions:*

- Reliable calculation methodology
- Low detailed documentation
- No user-friendly
- User knowledge level required: Low

5.15 *Jet:*

5.15.1 *Software identification (ID Number 137)*

-   Name: Jet
-   Version: 1.0
-   Year: 1999
-   Application Field: Detector response
-   Country: United States
-   Author/s: William D. Davis
-   Organisation/s: NIST (National Institute of Standards and Technology)
-   System requirements: W95/98/2000. Pentium 166 MHz or higher is recommended. 32 MB of RAM.
-   Size: 4 MB
-   Available in: Computer program available on NIST at no cost (http://fire.nist.gov). The software and documentation is found under the selection Fire Modelling Software Online.
-   Contact information:
    William D. Davis
    National Institute of Standards and Technology
    100 Bureau Dr. Stop 8642
    Gaithersburg, Md., 20899-8642
    301-975-6884
    william.davis@nist.gov

Description:

JET is a two-zone compartment fire model that solves the conservation equations for mass and energy to obtain upper layer temperature and layer height. Convective losses to the ceiling from the ceiling jet and radiation losses from the fire are used to calculate the ceiling temperature as a function of distance from the plume centreline. Correlations that are sensitive to upper layer temperature and depth provide plume centreline ceiling temperature and maximum ceiling jet temperature and velocity as a function of radius.

The compartment geometry can be represented using a series of draft curtains and walls. A one-room compartment with a door may be modelled using a simple draft curtain equal in length to the width of the door. Gas flows from the upper layer can exit either under the draft curtains, through ceiling jets, or with forced ventilation. The forced ventilation option allows gas flows to enter or exit the compartment.

Fusible links are used to control the opening of the ceiling vents. The heating of fusible links includes a balance between the convective heating of the link in the ceiling jet and the conductive cooling of the link as heat flows from the link to the supporting structure.

Applications that are appropriate for JET include:

a) Determination of activation times for fusible links controlling vents and sprinklers in compartments bounded by walls, draft curtains, or combinations of walls and draft curtains for user defined fire sizes and growth rates. Compartments with one or more sides unbounded may be modelled.

b) Determination of the impact of draft curtains, ceiling vents and forced ventilation on the depth of the smoke layer and the activation of fusible links.

c) Determination of the ceiling temperature as a function of upper layer depth and temperature and radial distance from the plume centreline with or without ceiling vents and forced ventilation.

d) Determination of maximum ceiling jet temperature and ceiling jet velocity as a function of upper layer depth and radial distance from the plume centreline with or without ceiling vents and forced ventilation.

5.15.2 *Evaluation aspects:*

Calculation methodology:

- Formulation Used: The used formulation is explained in the user's guide.
- Assumptions adopted:
  - The compartment is rectangular in plan
  - JET is a two-zone model where each zone or layer is assumed to be uniform in density and temperature. The temperature and density of the upper layer responds to a growing fire while the lower layer is assumed to remain at ambient temperature and pressure. A fire driven ceiling jet is assumed to flow along the flat ceiling.
  - The fire is characterised by a time dependent heat release rate, HRR, a time dependent radiative fraction, and either a constant fire diameter or a variable fire diameter which is determined using a HRR per unit area for the burning material.
  - The flames from the fire do not touch the ceiling and the fire is always located near the centre of the compartment or curtained area.
- Limitations:
  - The impact of a ceiling vent on the local temperature and velocity of the ceiling jet is neglected.
  - Based on comparisons to experimental data found in the user's guide, the predictions of JET generally agreed with experimental results for compartments with ceiling heights up to 22 m. JET may continue to perform well at ceiling heights greater than 22 m but there has been no experimental comparisons at these greater heights.

Documentation:

- User's guide: "The Zone Fire Model JET: A Model for the Prediction of Detector Activation and Gas Temperature in the Presence of a Smoke Layer" National Institute of Standards and Technology, NISTIR 6324 (1999).
- Technical guides: "The Zone Fire Model JET: A Model for the Prediction of Detector Activation and Gas Temperature in the Presence of a Smoke Layer" National Institute of Standards and Technology, NISTIR 6324 (1999).
- Available at: Computer program available on NIST at no cost (http://fire.nist.gov). The software and documentation is found under the selection Fire Modelling Software Online
- Papers and validation examples: Comparison with experimental results available in the Technical Guide document.

User's aspects:

- Interface: Windows
- Input/output reporting: all the output generated by the program is written to a text file.
- Graphic: the program does not plot any graphic in the output file where the output is written.

5.15.3 *Conclusions:*

- Reliable calculation methodology
- High detailed documentation
- User-friendly
- User knowledge level required: Medium

REFERENCES:

[1] Olenick S. M. And Carpenter D. J., May 2003, "An Updated International Survey of Computer Models for Fire and Smoke", Journal of Fire Protection Engineering, Vol. 13

[2] Friedman R., 1992, "An International Survey of Computer Models for Fire and Smoke", Journal of Fire Engineering Vol. 4

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