IBCI Conference 2010
Thursday 25th March 2010
FIRE DESIGN AND EURO CODES

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Contents of Presentation

- Brief History of the Structural Eurocodes
- Key Aspects of the Eurocode System
- Current Status of Eurocodes in Ireland
- Overview of key fire sections of the Eurocodes
- Case Studies

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Brief History of Eurocodes

- Treaty of Rome 1976 – Removal of artificial barriers to trade
- European Commission 1980 – requirement for harmonized design standards – started the Eurocode drafting process
- 1989 EC transferred responsibility to CEN *[Comite Europeen de Normalisation]*
- CEN Committee TC250 and subcommittees wrote the standards
- ENV+NAD → IS EN + National Annexes
- Period of co-existence with national standards
- 58 Eurocodes in total published between 2002 and 2007
- CEN remain responsible for revisions
- 30 YEAR PROCESS

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Key Aspects of Eurocode System (Objectives)

- Common design criteria
- Provide a common understanding
- Facilitate the marketing and use of structural components and kits in EU Member States;
- Facilitate the marketing and use of materials and constituent products, the properties of which enter into design calculations;
- Be a common basis for research and development, in the construction industry;
- Allow the preparation of common design aids and software;
- Increase the competitiveness of the European civil engineering firms, contractors, designers and product manufacturers in their global activities

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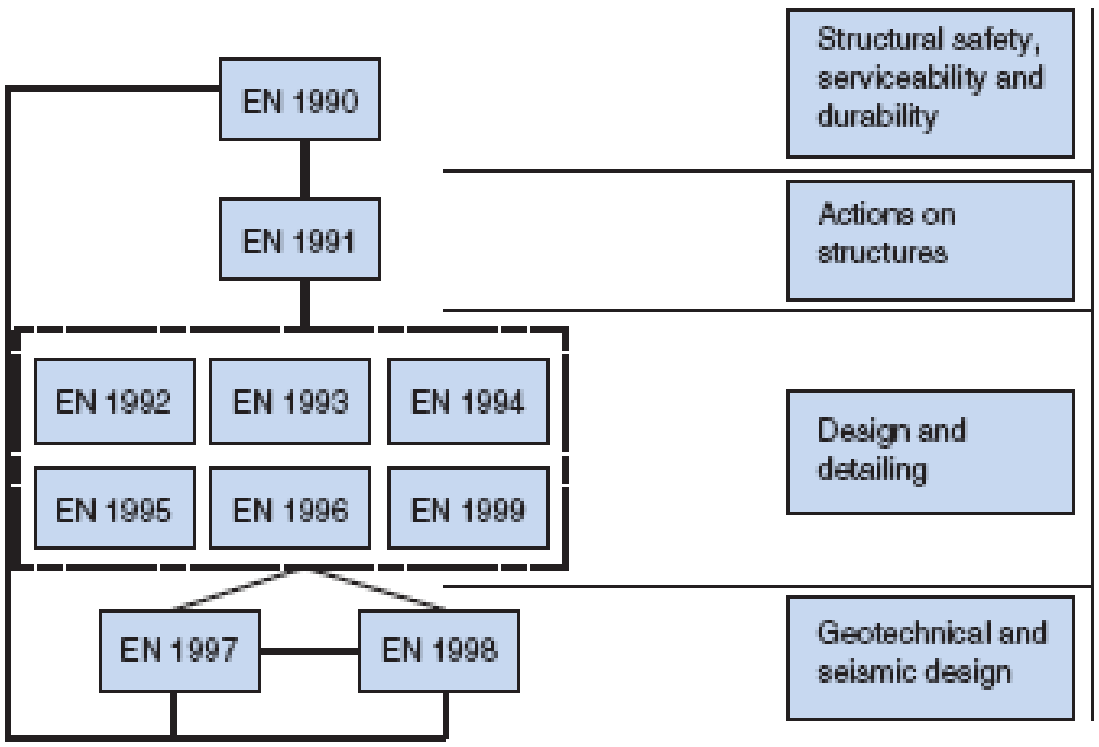
Key Aspects of Eurocode System

Partial Factors

Loading

Material Codes

Not relevant to fire design



The links between the Eurocodes

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Key Aspects of Eurocode System

- Support National Regulations (are subservient to)
- National Regulations set Nationally Determined Parameters (NDP)
- Principals (P) and Application Rules
- Normative Annexes
- Informative Annexes
- National Annex specifies NDPs and indicates which Informative Annexes may be used
- Non-contradictory complementary information (NCCIs)
- Contradictory National Codes to be withdrawn by March 2010

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Current Status of Eurocodes in Ireland

Eurocode Part	Title	National Annex Publication Status
IS EN 1990:2002	Basis of structural design	**Published March 2005**
IS EN 1991-1-1:2002	Actions on structures. General actions. Densities, self-weight, imposed loads for buildings	**Published March 2005**
IS EN 1991-1-2:2002	Actions on structures. General actions. Actions on structures exposed to fire	**Published Feb 2007**
IS EN 1992-1-2:2004	Design of concrete structures. Structural Fire design	**Published 13 January, 2010**
IS EN 1993-1-2:2005	Design of steel structures. General rules. Structural fire design	**NA out for public consultation 19Feb 2010**
IS EN 1994-1-2:2005	Design of composite steel and concrete structures. General rules. Structural fire design	**NA out for public consultation 19Feb 2010**
IS EN 1995-1-2:2004	Design of timber structures. General. Structural fire	**NA out for public consultation 19Feb 2010**
IS EN 1996-1-2:2005	Design of masonry structures. General rules. Structural fire design	**NA out for public consultation 06Nov 2009**
IS EN 1999-1-2:2007	Design of aluminium structures s. General rules. Structural fire design	**NA out for public consultation 19Feb 2010**

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CURRENT STATUS OF EUROCODES IN IRELAND

EXTRACT FROM EU COMISSION WEBSITE

"Under the Public Procurement Directive, it is mandatory that Member States accept designs to the EN Eurocodes. The EN Eurocodes will become the standard technical specification for all public works contracts. If proposing an alternative design one must demonstrate that is technically equivalent to an EN Eurocode solution.

As the National Standardisation Bodies are not expected to maintain the withdrawn National standards in practice, there will be little option but to use the EN Eurocodes. It is extremely likely that pressures from international clients and contractors, as well as other stakeholders like the insurance industry, will lead to their more rapid application for private construction"

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

nsai

National Standards Authority of Ireland

IRISH STANDARD

I.S. EN 1990:2002

ICS 91.010.30

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http://www.standards.ie

EUROCODE - BASIS OF STRUCTURAL DESIGN (INCLUDING IRISH NATIONAL ANNEX 2005)

This Irish Standard was published under the authority of the National Standards Authority of Ireland and comes into effect on:
March 24, 2005

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Price Code X

Údarás um Chaighdeáin Náisiúnta na hÉireann

National choice is allowed in EN 1990 through :

- A1.1(1)
- A1.2.1(1)
- A1.2.2 (Table A1.1)
- A1.3.1(1) (Tables A1.2(A) to (C))
- A1.3.1(5)
- A1.3.2 (Table A1.3)
- A1.4.2(2)

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

- IS EN 1990 used (together with IS EN 1991) with all other IS EN codes
- Sets out the principles for safety, serviceability and durability
- Provides the safety factors for actions and combination action effects (γ partial factors, ψ combination factors)
- Sets durability criteria
- Limit state code: FIRE is an Ultimate Limit state
- Material independent code (differs from BS codes)

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

- $E_d \leq R_d$
- Fire = "Accidental Design Situation" , so
- $\mathbf{E_{fi,d} = G_d + \psi_1 Q_{k,1} + \psi_2 Q_{k,2}}$

Therefore γ_G and γ_F taken as unity (for cold design γ_G = 1.35 and γ_F = 1.5) reflecting the low probability of fire and full load and also reflecting the acceptance of greater levels of damage in fire conditions

ψ_1, and ψ_2 are combination factors

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

Table NA. 2 - Values of ψ factors for buildings

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN1991-1-1)			
Category A: domestic, residential areas	0,7	0,5	0,3
Category B: office areas	0,7	0,5	0,3
Category C: congregation areas	0,7	0,7	0,6
Category D: shopping areas	0,7	0,7	0,6
Category E: storage areas	1,0	0,9	0,8
Category F: traffic area, Vehicle weight < or = 30Kn	0,7	0,7	0,6
Category G: traffic area, 30Kn < vehicle weight < or = 160Kn	0,7	0,5	0,3
Category H: roofs	0,6	0,0	0,0
Snow loads on buildings (see EN 1991-1-3)	0,5	0,2	0,0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0,0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0,0

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

- EXAMPLES (Fire Limit State Loading)

- OFFICE BUILDING
- $E_{fi,d} = G_d + 0.5\ Q_L$ where Q_L = live load and wind is not the dominant load
- SHOP
- $E_{fi,d} = G_d + 0.7\ Q_L$ where Q_L = live load and wind is not the dominant load

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

- Fire Limit State – Simplified Analysis
- Reduction Factor $\eta_{fi} = (G_k + \psi_1 Q_k)/(\gamma_G G_k + \gamma_Q Q_k)$
- $E_{d,fi} = \eta_{fi} \,.\, E_d$
- $Q_k/G_k = 2$, $\gamma_G = 1.35$, $\gamma_Q = 1.5$, $\psi_1 = 0.5$

  → $\eta_{fi} = 0.46$

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IS EN 1990:2002 AND NATIONAL ANNEX (2005)

Table NA.1 – Indicative Design Working Life

Design Working Life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 – 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 – 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100 (2)	Monumental building structures, bridges and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		
(2) Working life for bridges of 120 years may be used subject to the requirement of the clients		

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EUROCODE 1 (LOADINGS)
IS EN 1991-1-2:2002 AND NATIONAL ANNEX (2002)

nsai
National Standards Authority of Ireland

IRISH STANDARD

I.S. EN 1991-1-2:2002

ICS 13.220.50
91.010.30

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EUROCODE 1: ACTIONS ON STRUCTURES - PART 1-2: GENERAL ACTIONS - ACTIONS ON STRUCTURES EXPOSED TO FIRE

This Irish Standard was published under the authority of the National Standards Authority of Ireland and comes into effect on:
January 17, 2003

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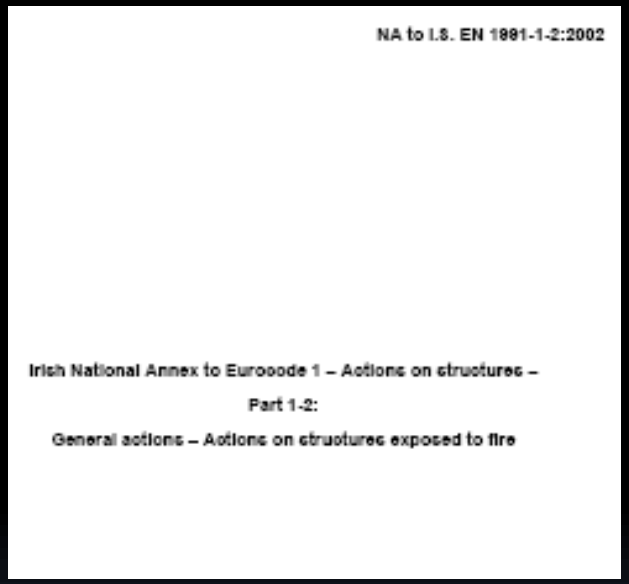

NA to I.S. EN 1991-1-2:2002

Irish National Annex to Eurocode 1 – Actions on structures –

Part 1-2:

General actions – Actions on structures exposed to fire

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IS EN 1991-1-2:2002 AND NATIONAL ANNEX (2002)

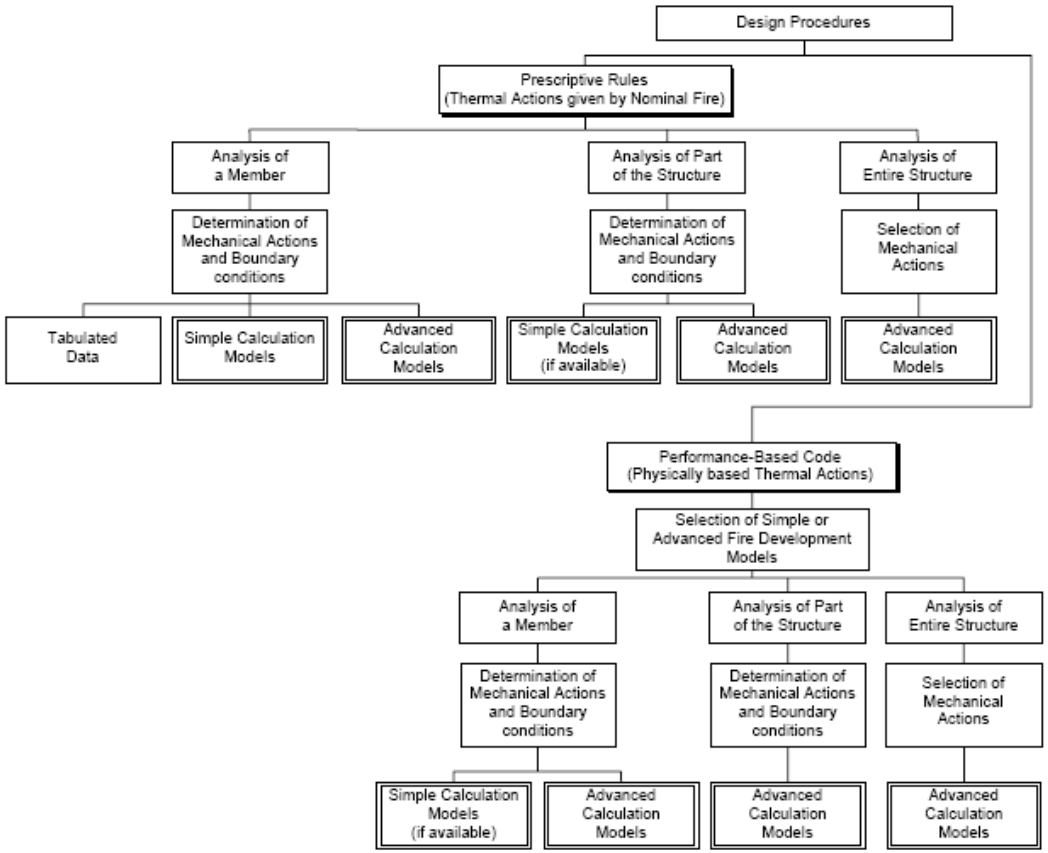

Figure 1 — Alternative design procedures

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Structural Fire Design Procedure

Step 1	**Design Fire Scenario (EC1)** • Compartment Fire • Localised fire
Step 2	**Design Fire (EC1)** • Nominal Fire Curves • Natural Fire Models
Step 3	**Temperature Analysis (EC 2 to 6, 9)** • Radiative and Convective transfer • Location/orientation of member
Step 4	**Mechanical Analysis (EC 0, 2 to 6, 9)** • Time Domain $t_{fi,d} \geq t_{fi,requ}$ • Strength Domain $R_{fi,d,t} \geq E_{fi,d,t}$ • Temperature Domain $\Theta_d \leq \Theta_{cr,d}$

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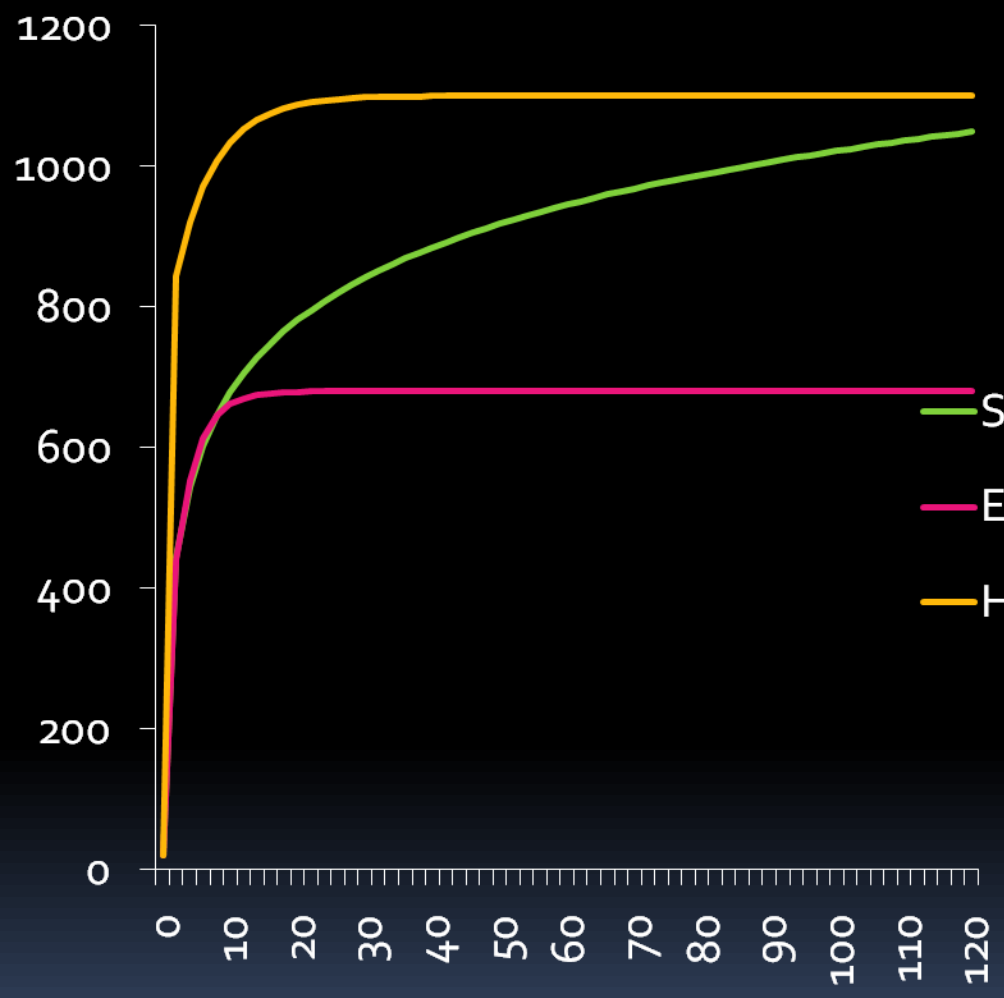
NOMINAL TIME-TEMP CURVES



$$\Theta_g = 20 + 345 \log_{10} (8\,t + 1)$$

$$\Theta_g = 660\,(1 - 0{,}687\,e^{-0{,}32\,t} - 0{,}313\,e^{-3{,}8\,t}) + 20$$

$$\Theta_g = 1\,080\,(1 - 0{,}325\,e^{-0{,}167\,t} - 0{,}675\,e^{-2{,}5\,t}) + 20$$

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Nominal Fire Curves – Standard Fire

- Option 1 = TGDB Table A2
- Option 2 = Equivalent time of fire exposure per NA.5.3 Annex F (NA.2.1.clause)
- Option 3 = Table 26/27 of BS9999 (also a time-equivalent based approach)

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Nominal Fire Curves – Equivalent Time of Fire Exposure NA.5.3

- Only applicable where design of members is based on tabulated data or simplified rules (i.e. not applicable in combination with complex structural response modelling)
- Not applicable to timber or composite steel/concrete
- $t_{e,d} = \beta \cdot q_{f,d} \cdot K_b \cdot w_f$

Where $q_{f,d}$ = design fire load density per NA.5.2

K_b = conversion factor for thermal properties of boundaries

w_f = ventilation factor

$= (6.0/H)0.3[0.62 + 90(0.4-\alpha_v)4/1+b_v.\alpha_h)] \geq 0.5$ or

$= O^{0.5} \cdot A_f/A_t$ for small compartments of less than 100sqm

B = Multipication factor per Table NA.8 taking account of height of building and usage

- NA recommends sensitivity analysis vs amount of ventilation

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EQUIVALENT TIME OF FIRE EXPOSURE NA.5.3 EXAMPLE

Equivalent Time of Fire Exposure according to Annex F of Irish National Annex to IS EN 1991-1-2:2002
EXAMPLE - HOTEL BEDROOM in BUILDING 25m High (40sqm, 3m high with 7.2 sqm of glazing)

Location	Scenario	Compartment height H (m)	Compartment floor area Af (sqm)	Area of vertical openings in the façade A_v (sqm)	Area of horizontal openings in the compartment roof A_h (sqm)	α_v (to be in range 0.025 to 0.25)	α_h	b_v (to be not less than 10.0)	Ventilation factor w_f (to be not less than 0.5)	Thermal inertia b (based on Annex A and Table A.2 of PD7974:Part3	Conversion factor for thermal properties of compartment boundaries k_b (min.sqm/MJ)	Multiplication risk factor β associated with height and use per Table NA.8	Fire load density $q_{f,k}$ according to occupany in Table NA.2 (80% fractile)	Additional Fire loads from the construction elements, linings and finishes	Combustion factor m	Factor to take account of sprinklers γ_i	Equivalent time of fire exposure for frame $T_{e,d}$ = $q_{f,d}.k_b.w_f.\beta$	TGDB Table A2
Unsprinklered hotel bedroom	100 % glazing failed	3	40	7.2	0	0.18	0	34.595	1.02287221	2510	0.055	1	570	57	1	1	35	90
Unsprinklered hotel bedroom	50 % glazing failed	3	40	3.6	0	0.09	0	23.6488	1.78659848	2510	0.055	1	570	57	1	1	62	90
Unsprinklered hotel bedroom	25 % glazing failed	3	40	1.8	0	0.045	0	18.0997	2.52311605	2510	0.055	1	570	57	1	1	87	90
Sprinklered hotel bedroom	100 % glazing failed	3	40	7.2	0	0.18	0	34.595	1.02287221	2510	0.055	1	570	57	1	0.61	22	90
Sprinklered hotel bedroom	50 % glazing failed	3	40	3.6	0	0.09	0	23.6488	1.78659848	2510	0.055	1	570	57	1	0.61	38	90
Sprinklered hotel bedroom	25 % glazing failed	3	40	1.8	0	0.045	0	18.0997	2.52311605	2510	0.055	1	570	57	1	0.61	53	90

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EQUIVALENT TIME OF FIRE EXPOSURE - BS9999

Table 26 Fire resistance periods for elements of structure (based on the ventilation conditions given in Table 27 A))

Risk profile	Minimum periods of fire resistance, in minutes B)					
	Height C) of top occupied storey above access level					
	Not more than 5 m	Not more than 11 m	Not more than 18 m	Not more than 30 m	Not more than 60 m	More than 60 m
A1 (Offices)	15 30	30 30	30 30	60 60	75 120/90	90 120/90
A2	30 D)	30	60	90	120	150
A3	60	60	90	120	300	300
A4 E)	—	—	—	—	—	—
B1 (Assembly)	30 30	30 60	30 60	60 60	60 120/90	75 120/90
B2 (Shops)	30 30	30 60	60 60	75 60	90 120/90	120 120/90
B3	30	45	75	105	135	180
B4 E)	—	—	—	—	—	—
Ci1 F)	45 G)	60	75	75	90	105
Ci2 F)	60 G)	90	105	120	—	—
Cii1 or Ciii1	30	30	30	45	60	60
Cii2 or Ciii2	30	45	60	75	90	105
C3 E)	—	—	—	—	—	—
C4 E)	—	—	—	—	—	—

NOTE 1 For occupancy characteristic A covering storage and car parks, and all basements, the fire resistance periods are as given in Table 25.

NOTE 2 Variation of the risk profile by the addition of sprinklers conforming to BS EN 12845 (new systems) or BS 5306-2 (existing systems) can be used to reduce the fire resistance as described in 6.5.

Table 26/27 - Well ventilated compartment

- Greater flexibility ,
- Reduced ratings in some circumstances, increased in other circumstances
- Based on a combination of Deterministic Analysis (time equivalent based on BSEN parametric fires) and Probabilistic Risk/Consequence Analysis (Risk = Φfrequency x Likelihood x Consequence)
- Height bands are related to fire-fighting height thresholds: i.e. ladder, high reach, dry riser, wet riser
- Applicable only to above ground storeys

SPRINKLERED

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Natural Fire Models

1. Parametric time – temperature curves per Annex A
2. External members – per Annex B
3. Localised fire sources – per National Annex
4. Advanced fire modelling

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NATURAL FIRE MODELS

1. Parametric T-t Curves (Annex A + NA.4)

heating phase

$$\Theta_g = 20 + 1\,325\,(\,1 - 0{,}324\,e^{-0{,}2\,t^*} - 0{,}204\,e^{-1{,}7\,t^*} - 0{,}472\,e^{-19\,t^*}\,)$$

cooling phase

$$\Theta_g = \Theta_{max} - 625\,(\,t^* - t^*_{max} \cdot x)$$

$$\Theta_g = \Theta_{max} - 250\,(\,3 - t^*_{max}\,)\,(\,t^* - t^*_{max} \cdot x\,)$$

$$\Theta_g = \Theta_{max} - 250\,(\,t^* - t^*_{max} \cdot x\,)$$

- Boundary properties, ventilation conditions, fire load density and fire growth rate all taken into account
- Easily set up on spreadsheet
- No allowance for height/risk!!! i.e. no β - factor

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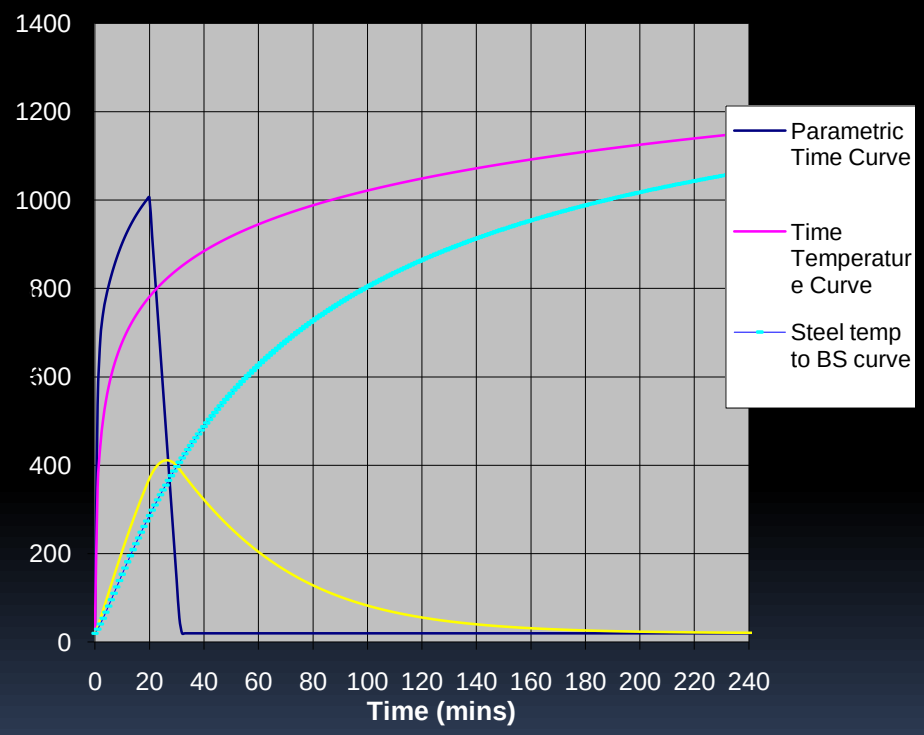
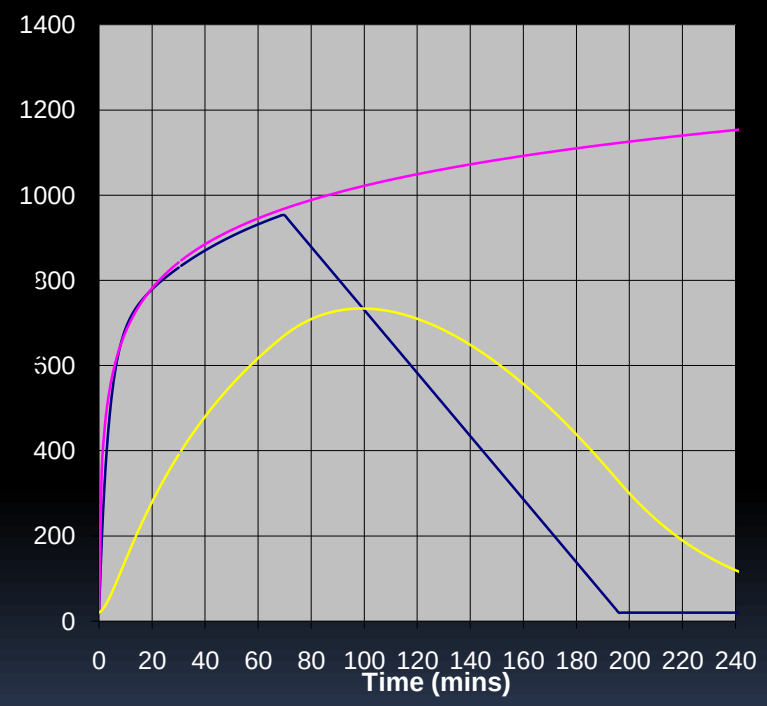
NATURAL FIRE MODELS

- Parametric T-t Curves (Annex A + NA.4)





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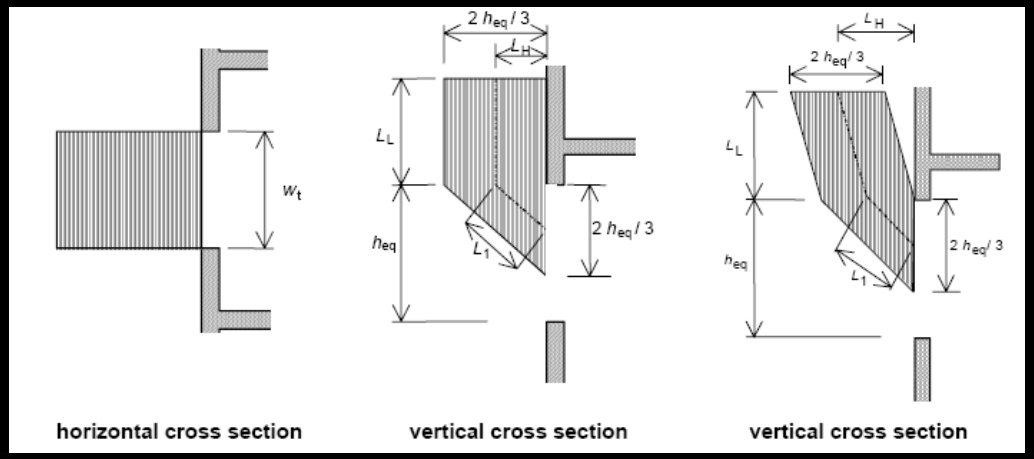
NATURAL FIRE MODELS

2. External Members (e.g. balcony walkway supports, Central Bank Macalloy bars)



Calculates flame shapes and temperatures, maximum compartment temperature, radiation and convection parameters

Use configuration factors to calculate radiative heat transfer

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Eurocodes 2, 3, 4, 5, 6, 9

- Material specific codes
- Tabulated data
- Heat transfer analysis
- Mechanical analysis at elevated temperature

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CONCRETE : Eurocode 2 Part 1-2

Until the National Annex is available, publication of this European Standard is solely for educational/training purposes and this standard should not be used in project design until the relevant National Annex is available.

Figure 1 : Alternative design procedures

Table 0.1 Summary table showing alternative methods of verification for fire resistance

	Tabulated data	**Simplified calculation methods**	**Advanced calculation models**
Member analysis The member is considered as isolated. Indirect fire actions are not considered, except those resulting from thermal gradients	**YES** - Data given for standard fire only, 5..1(1) - In principle data could be developed for other fire curves	**YES** - standard fire and parametric fire, 4.2.1(1) - temperature profiles given for standard fire only, 4.2.2(1) - material models apply only to heating rates similar to standard fire, 4.2.4.1(2)	**YES**, 4.3.1(1)P Only the principles are given
Analysis of parts of the structure Analysis of parts of the structure Indirect fire actions within the sub-assembly are considered, but no time-dependent interaction with other parts of the structure.	**NO**	**YES** - standard fire and parametric fire, 4.2.1(1) - temperature profiles given for standard fire only, 4.2.2(1) - material models apply only to heating rates similar to standard fire, 4.2.4.1(2)	**YES** 4.3.1(1)P Only the principles are given
Global structural analysis Analysis of the entire structure. Indirect fire actions are considered throughout the structure	**NO**	**NO**	**YES** 4.3.1(1)P Only the principles are given

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CONCRETE : Eurocode 2 Part 1-2

- Separating elements which are not load-bearing: Integrity (Criterion E) and Insulation (Criterion I) EI
- Load-bearing and not separating : Mechanical Resistance (Criterion R) R
  - Nominal – for specified duration
  - Parametric – for entire duration including cooling phase
- Load-bearing and separating : Criteria R, E and I - REI
- Example : Wall REI60, Column R60
- Letters “ef” and “HC” added if the performance is in respect of the external fire curve or the hydrocarbon curve e.g. REI-ef, REI-HC

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CONCRETE : Eurocode 2 Part 1-2

- Method 1 – tabulated data –(most likely to be used except where there are specific issues)
  - Applies to standard fire curves only
  - Subject to National Annex
  - Based on Normal Wt Concrete and silicious aggregates
- Method 2 – Simple calculation methods per Annexes B to E (informative) – Section 4.2 of code
- Method 3 – Advanced calculation methods- Section 4.3 of code (limited real design information in the code)
- Method 4 – Fire tests

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CONCRETE : Eurocode 2 Part 1-2

Method 1 – tabulated data

Columns to Eurocode

μ_{fi} = ratio of design axial load at fire limit state with design resistance at normal temperature

Table 5.2a: Minimum column dimensions and axis distances for columns with rectangular or circular section

Standard fire resistance	Minimum dimensions (mm) Column width b_{min}/axis distance a of the main bars			
	Column exposed on more than one side			Exposed on one side
	μ_{fi} = 0.2	μ_{fi} = 0.5	μ_{fi} = 0.7	μ_{fi} = 0.7
1	2	3	4	5
R 30	200/25	200/25	200/32 300/27	155/25
R 60	200/25	200/36 300/31	250/46 350/40	155/25
R 90	200/31 300/25	300/45 400/38	350/53 450/40**	155/25
R 120	250/40 350/35	350/45** 450/40**	350/57** 450/51**	175/35
R 180	350/45**	350/63**	450/70**	230/55
R 240	350/61**	450/75**	-	295/70

**
Minimum 8 bars
For prestressed columns the increase of axis distance according to 4.2.2. (4) should be noted.

Columns to BS8110

Table 4.2 — Reinforced concrete columns

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		0.5 h	1 h	1.5 h	2 h	3 h	4 h
		mm	mm	mm	mm	mm	mm
Fully exposed:							
dense concrete	Width	150	200	250	300	400	450
	Cover*	20	25	30	35	35	35
lightweight concrete	Width	150	160	200	240	320	360
	Cover*	20	20	25	35	35	35
50 % exposed:							
dense concrete	Width	125	160	200	240	300	350
	Cover*	20	25	25	25	30	35
lightweight concrete	Width	125	130	160	185	250	275
	Cover*	20	20	25	25	30	30
One face exposed:							
dense concrete	Thickness	100	120	140	160	200	240
	Cover*	20	25	25	25	25	25
lightweight concrete	Thickness	100	100	115	130	160	190
	Cover*	10	20	20	25	25	25

* Cover is expressed here as cover to main reinforcement (see 4.2.3). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

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CONCRETE : Eurocode 2 Part 1-2

Method 1 – tabulated data (continued)

Beams to Eurocode

Table 5.5: Minimum dimensions and axis distances for simply supported beams made with reinforced and prestressed concrete

Standard fire resistance	Minimum dimensions (mm)						
	Possible combinations of a and b_{min} where a is the average axis distance and b_{min} is the width of beam				Web thickness b_w		
					Class WA	Class WB	Class WC
1	2	3	4	5	6	7	8
R 30	b_{min}= 80 a = 25	120 20	160 15*	200 15*	80	80	80
R 60	b_{min}= 120 a = 40	160 35	200 30	300 25	100	80	100
R 90	b_{min}= 150 a = 55	200 45	300 40	400 35	110	100	100
R 120	b_{min}= 200 a = 65	240 60	300 55	500 50	130	120	120
R 180	b_{min}= 240 a = 80	300 70	400 65	600 60	150	150	140
R 240	b_{min}= 280 a = 90	350 80	500 75	700 70	170	170	160
a_{sd} = a + 10mm (see note below)							

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

a_{sd} is the axis distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of b_{min} greater than that given in Column 4 no increase of a_{sd} is required.

* Normally the cover required by EN 1992-1-1 will control.

Beams to BS8110

Table 4.3 — Concrete beams

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		0.5 h	1 h	1.5 h	2 h	3 h	4 h
		mm	mm	mm	mm	mm	mm
Reinforced concrete (simply supported): dense concrete	Width	80	120	150	200	240	280
	Cover*	20	30	40	50	70	80
lightweight concrete	Width	80	100	130	160	200	250
	Cover*	15	20	35	45	55	65
Reinforced concrete (continuous): dense concrete	Width	80	80	120	150	200	240
	Cover*	20	20	35	50	60	70
lightweight concrete	Width	60	80	90	110	150	200
	Cover*	15	20	25	35	45	55
Prestressed concrete (simply supported): dense concrete	Width	100	120	150	200	240	280
	Cover*	25	40	55	70	80	90
lightweight concrete	Width	80	110	130	160	200	250
	Cover*	25	30	45	55	65	75
Prestressed concrete (continuous): dense concrete	Width	80	100	120	150	200	240
	Cover*	20	30	40	55	70	80
lightweight concrete	Width	80	90	100	125	150	200
	Cover*	20	25	35	45	55	65

* Cover is expressed here as cover to main reinforcement (see 4.2.3). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

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CONCRETE : Eurocode 2 Part 1-2

Method 1 – tabulated data (continued)

Slabs to Eurocode

Table 5.8: Minimum dimensions and axis distances for reinforced and prestressed concrete simply supported one-way and two-way solid slabs

Standard fire resistance	Minimum dimensions (mm)			
	slab thickness h_s (mm)	axis-distance a		
		one way	two way: $l_y/l_x \leq 1,5$	two way: $1,5 < l_y/l_x \leq 2$
1	2	3	4	5
REI 30	60	10*	10*	10*
REI 60	80	20	10*	15*
REI 90	100	30	15*	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

l_x and l_y are the spans of a two-way slab (two directions at right angles) where l_y is the longer span.

For prestressed slabs the increase of axis distance according to 5.2(5) should be noted.

The axis distance a in Column 4 and 5 for two way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.

* Normally the cover required by EN 1992-1-1 will control.

Slabs to BS8110

Table 4.4 — Plain soffit concrete floors

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		0.5 h	1 h	1.5 h	2 h	3 h	4 h
		mm	mm	mm	mm	mm	mm
Reinforced concrete (simply supported): dense concrete	Thickness	75	95	110	125	150	170
	Cover*	15	20	25	35	45	55
lightweight concrete	Thickness	70	90	105	115	135	150
	Cover*	15	15	20	25	35	45
Reinforced concrete (continuous): dense concrete	Thickness	75	95	110	125	150	170
	Cover*	15	20	20	25	35	45
lightweight concrete	Thickness	70	90	105	115	135	150
	Cover*	15	15	20	20	25	35
Prestressed concrete (simply supported): dense concrete	Thickness	75	95	110	125	150	170
	Cover*	20	25	30	40	55	65
lightweight concrete	Thickness	70	90	105	115	135	150
	Cover*	20	20	30	35	45	60
Prestressed concrete (continuous): dense concrete	Thickness	75	95	110	125	150	170
	Cover*	20	20	25	35	45	55
lightweight concrete	Thickness	70	90	105	115	135	150
	Cover*	20	20	25	30	35	45

* Cover is expressed here as cover to main reinforcement (see 4.2.5). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

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CONCRETE : Eurocode 2 Part 1-2

Method 1 – tabulated data (continued)

Load-bearing walls to Eurocode

Table 5.4: Minimum dimensions and axis distances for load-bearing reinforced concrete walls

Standard fire resistance	Minimum dimensions (mm) Wall thickness/axis distance for			
	μ_{fi} = 0,35		μ_{fi} = 0,7	
	wall exposed on one side	wall exposed on two sides	wall exposed on one side	wall exposed on two sides
1	2	3	4	5
REI 30	100/10*	120/10*	120/10*	120/10*
REI 60	110/10*	120/10*	130/10*	140/10*
REI 90	120/20*	140/10*	140/25	170/25
REI 120	150/25	160/25	160/35	220/35
REI 180	180/40	200/45	210/50	270/55
REI 240	230/55	250/55	270/60	350/60

* Normally the cover required by EN 1992-1-1 will control.

Note: For the definition of μ_{fi} see 5.3.2 (3).

Load-bearing walls to BS8110

Table 4.6 — Concrete walls with vertical reinforcement

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		0.5 h	1 h	1.5 h	2 h	3 h	4 h
		mm	mm	mm	mm	mm	mm
Walls with less than 0.4 % reinforcement made from dense aggregate	Thickness	150	150	175	—	—	—
Walls with 0.4 % to 1.0 % reinforcement made from dense aggregate (concrete density up to 2.4 t/m³)	Thickness	100	120	140	160	200	240
	Cover*	25	25	25	25	25	25
Walls made from lightweight aggregate (concrete density 1.2 t/m³)†	Thickness	100	100	115	130	160	190
	Cover*	10	20	20	25	25	25
Walls with over 1.0 % reinforcement made from dense aggregate	Thickness	(See note)	(See note)	100	100	150	180
	Cover*	15	15	25	25	25	25

* Cover is expressed here as cover to main reinforcement (see 4.2.3). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

† For concrete of densities between 1.2 t/m³ and 2.4 t/m³ the value of wall thickness may be interpolated.

NOTE Use the minimum practical dimension but not less than 75 mm.

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CONCRETE : Eurocode 2 Part 1-2

Method 2 – simplified calculation methods

- Temperature profiles in Annex A
- 500° isotherm method as per Annex B1
- Zone Method as per Annex B2
- Annex E sets out a simplified method for slabs and beams which allows in the case of continuous slabs significant redistibution of moments towards the supports where the rebars are in the top of the beam/slab and obviously significantly cooler
- Gamma factor for concrete γ_M = 1.0 in EC2 and 1.3 in BS8110
- For rebar gamma factor = 1.0 in both codes

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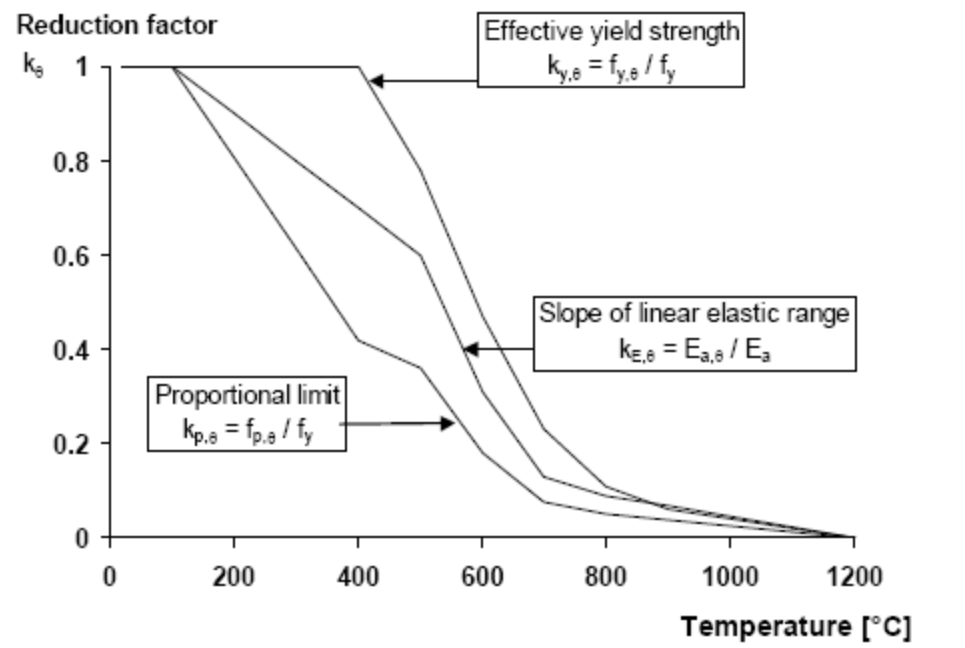
STEEL : Eurocode 3 Part 1-2

Capacity at fire limit state



Reduction factors for the stress-strain relationship of carbon steel at elevated temperatures

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STEEL : Eurocode 3 Part 1-2

- $\gamma_{M,fi}$ = 1.0 in EC3 (same as BS5950) – same as $\gamma_{M,0}$
- Simplified Calculation Methods
  - Calculate "Critical Temperature" based on Utilisation Factor
    $\mu_0 = E_{fi,d}/R_{fi,d,0}$ or conservatively $= \eta_{fi}[\gamma_{M,fi}/\gamma_{M0}]$
    (applicable to restrained beams or tension members only)
    NA may quote default μ_0 e.g. $\mu_0 = 0.65$ > θa.cr = OR
  - Calculate load bearing resistance at elevated temperature Vs design load at fire limit state
- Advanced Calculation Methods (very little detail)
- External Steelwork (as per Law and O Brien)

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STEEL : Eurocode 3 Part 1-2

Critical temperature method

Table 4.1: Critical temperature $\theta_{a,cr}$ for values of the utilization factor μ_0

μ_0	$\theta_{a,cr}$	μ_0	$\theta_{a,cr}$	μ_0	$\theta_{a,cr}$
0,22	711	0,42	612	0,62	549
0,24	698	0,44	605	0,64	543
0,26	685	0,46	598	0,66	537
0,28	674	0,48	591	0,68	531
0,30	664	0,50	585	0,70	526
0,32	654	0,52	578	0,72	520
0,34	645	0,54	572	0,74	514
0,36	636	0,56	566	0,76	508
0,38	628	0,58	560	0,78	502
0,40	620	0,60	554	0,80	496

NOTE: The national annex may give default values for critical temperatures.

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STEEL : Eurocode 3 Part 1-2

Critical temperature vs EN13381-4 Test Standard

7.11 Presentation of the Results

An example of a method of presenting the results is given in Table 30:

Table 30: Fire Resistance Classification R30 (30 minutes)									
Design Temp °C	350	400	450	500	550	600	650	700	limit
A/V	Thickness of material required in mm								
40									
60									
etc to limit									

- The limits on section factor, material thickness and temperature are those determined by Table 26.
- The section factor interval may be varied as required.
- The results may also be presented graphically.

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STEEL : Eurocode 3 Part 1-2

Simple

(1) For an equivalent uniform temperature distribution in the cross-section, the increase of temperature $\Delta\theta_{a,t}$ in an unprotected steel member during a time interval Δt should be determined from:

$$\Delta\theta_{a,t} = k_{sh} \frac{A_m/V}{c_a \rho_a} \dot{h}_{net} \Delta t \qquad (4.25)$$

where:

k_{sh}	is	correction factor for the shadow effect, see (2)
A_m/V	is	the section factor for unprotected steel members [1/m];
A_m	is	the surface area of the member per unit length [m²/m];
V	is	the volume of the member per unit length [m³/m];
c_a	is	the specific heat of steel, from section 3 [J/kgK];
$\dot{h}_{net}$	is	the design value of the net heat flux per unit area [W/m²];
Δt	is	the time interval [seconds];
ρ_a	is	the unit mass of steel, from section 3 [kg/m³].

$$\dot{h}_{net,r} = \Phi \cdot \varepsilon_m \cdot \varepsilon_f \cdot \sigma \cdot [(\Theta_r + 273)^4 - (\Theta_m + 273)^4]$$

$$\dot{h}_{net,c} = \alpha_c \cdot (\Theta_g - \Theta_m)$$

(1) For a uniform temperature distribution in a cross-section, the temperature increase $\Delta\theta_{a,t}$ of an insulated steel member during a time interval Δt should be obtained from:

$$\Delta\theta_{a,t} = \frac{\lambda_p A_p / V}{d_p c_a \rho_a} \frac{(\theta_{g,t} - \theta_{a,t})}{(1 + \phi/3)} \Delta t - (e^{\phi/10} - 1)\Delta\theta_{g,t} \qquad (\text{but } \Delta\theta_{a,t} \geq 0 \text{ if } \Delta\theta_{g,t} > 0) \qquad (4.27)$$

with:

$$\phi = \frac{c_p \rho_p}{c_a \rho_a} d_p A_p / V$$

Advanced e.g. TASEF

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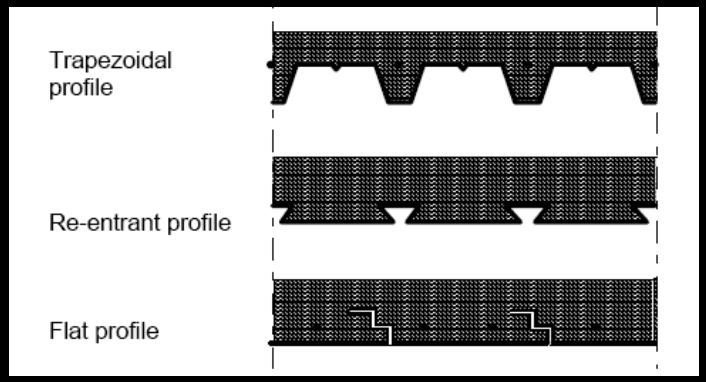
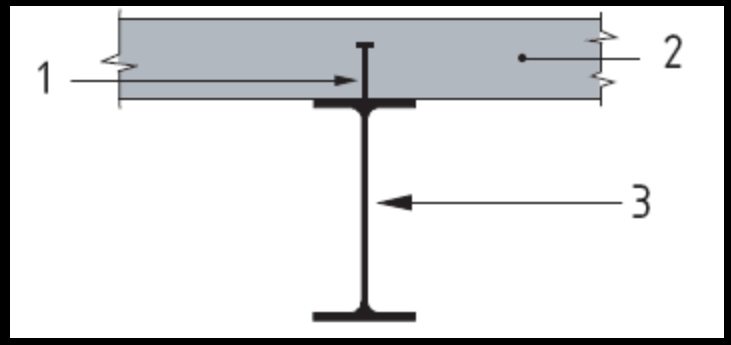
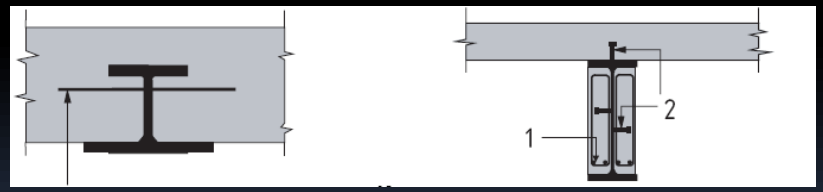
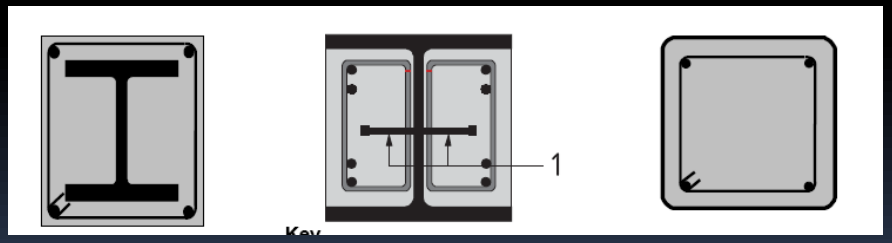
COMPOSITE : Eurocode 4 Part 1-2

Scope









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COMPOSITE : Eurocode 4 Part 1-2

Eurocode

NOTE: A method is given in D.4 of Annex D for the calculation of the effective thickness h_{eff}.

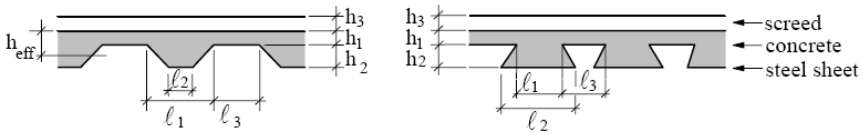


Figure 4.1: Symbols for trapezoidal sheeting **Figure 4.2: Symbols for re-entrant sheeting**

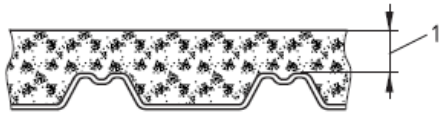
Table D.6: Minimum effective thickness as a function of the standard fire resistance.

Standard Fire Resistance	Minimum effective thickness h_{eff} [mm]
R 30	60 - h_3
R 60	80 - h_3
R 90	100 - h_3
R 120	120 - h_3
R 180	150 - h_3
R 240	175 - h_3

$$h_{eff} = h_1 + 0{,}5\, h_2 \left(\frac{\ell_1 + \ell_2}{\ell_1 + \ell_3} \right) \quad \text{for } h_2/h_1 \le 1{,}5 \text{ and } h_1 > 40 \text{ mm}$$

$$h_{eff} = h_1 \left[1 + 0{,}75 \left(\frac{\ell_1 + \ell_2}{\ell_1 + \ell_3} \right) \right] \quad \text{for } h_2/h_1 > 1{,}5 \text{ and } h_1 > 40 \text{ mm}$$

BS5950



Key
1 Insulation thickness (includes screed)

Figure 8 — Insulation thickness for trapezoidal profiled steel sheets

Table 13 — Minimum thickness of concrete for trapezoidal profiled steel sheets (see Figure 8)

Concrete type	Minimum thickness of concrete for a fire resistance period of:					
	30 min	60 min	90 min	120 min	180 min	240 min
	mm	mm	mm	mm	mm	mm
Ordinary dense structural concrete	60	70	80	90	115	130
Lightweight concrete	50	60	70	80	100	115

Key
1 Insulation thickness (includes screed)

Figure 9 — Insulation thickness for re-entrant profiled steel sheets

Table 14 — Minimum thickness of concrete for re-entrant profiled steel sheets (see Figure 9)

Concrete type	Minimum thickness of concrete for a fire resistance period of:					
	30 min	60 min	90 min	120 min	180 min	240 min
	mm	mm	mm	mm	mm	mm
Ordinary dense structural concrete	90	90	110	125	150	170
Lightweight concrete	90	90	105	115	135	150

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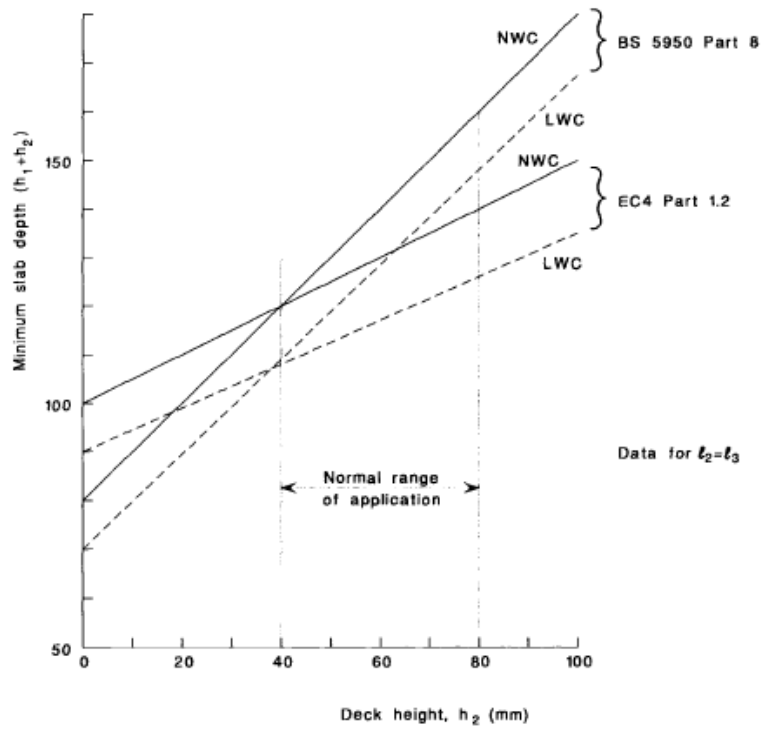

Figure 22 *Comparison of BS 5950: Part 8 and EC4: Part 1.2 in terms of insulation depth of composite slabs (R90 case)*

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COMPOSITE : Eurocode 4 Part 1-2

DESIGN OPTIONS

- Simple calculation models
- Advanced calculation Models
- Tabular Data for specific cases/structural forms

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SIMPLE CALCULATION MODELS

- Annex D gives methodology for calculating the moment of resistance (sagging and hogging) of the composite slab when subject to the standard time-temp curve and insulation thickness – similar to SCI P186
- Composite beams without concrete encasement
  - Method 1 – Critical Temperature Method (simply supported beams, depth less than 500mm slab, at least 120 thick)
  - Method 2 – Bending Moment of Resistance Method
- Partly encased beams and columns

Tabular Data for specific cases

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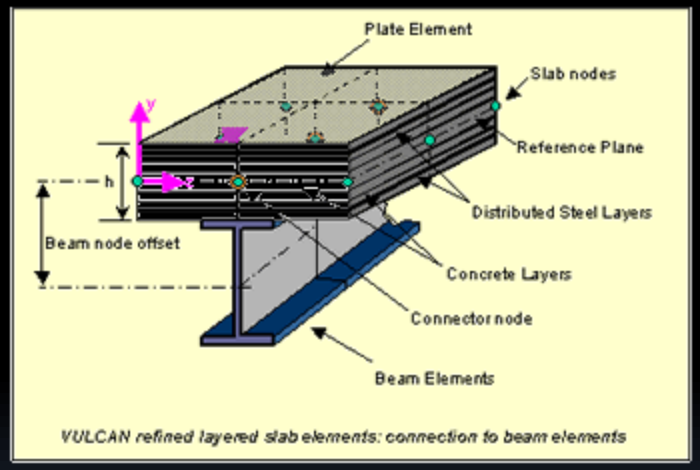
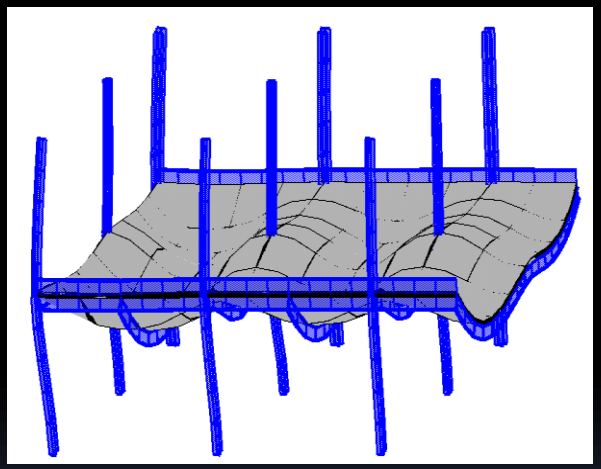
COMPOSITE : Eurocode 4 Part 1-2

ADVANCED CALCULATION MODELS e.g. Vulcan





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TIMBER : Eurocode 5 Part 1-2

- Replaces BS5268 Parts 2, 3, 4,5
- Method 1 - Residual Section, or
- Method 2 – Reduced Properties
- Method 1 is recommended in code
- More complex than BS5268
- Annex E of Code also covers separating elements – attributes minutes insulation to various elements of the barrier (somewhat similar to BS5268 Part 4.2)
- Code deals in detail with joints
- Code has charring rates for partly protected timber elements

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TIMBER : Eurocode 5 Part 1-2

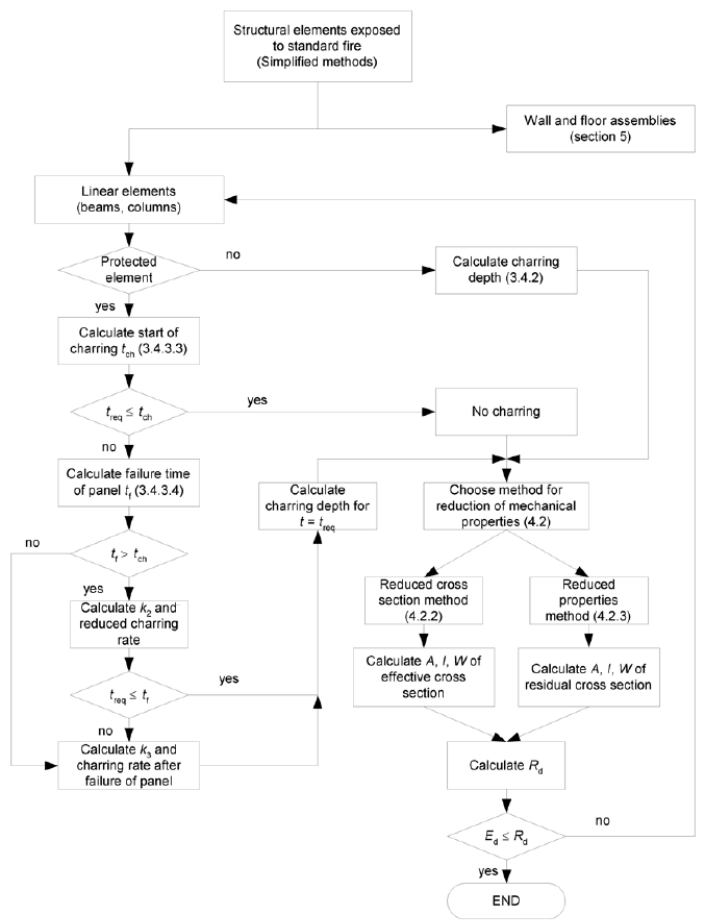

Figure F1 — Flow chart outlining the design procedure to check the load-bearing function of structural members

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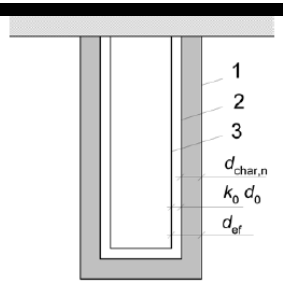
TIMBER : Eurocode 5 Part 1-2

Eurocode

Table 3.1 – Design charring rates β_0 and β_n of timber, LVL, wood panelling and wood-based panels

	β_0 mm/min	β_n mm/min
a) Softwood and beech		
Glued laminated timber with a characteristic density of ≥ 290 kg/m^3	0,65	0,7
Solid timber with a characteristic density of ≥ 290 kg/m^3	0,65	0,8
b) Hardwood		
Solid or glued laminated hardwood with a characteristic density of 290 kg/m^3	0,65	0,7
Solid or glued laminated hardwood with a characteristic density of ≥ 450 kg/m^3	0,50	0,55
c) LVL		
with a characteristic density of ≥ 480 kg/m^3	0,65	0,7
d) Panels		
Wood panelling	0,9[a]	–
Plywood	1,0[a]	–
Wood-based panels other than plywood	0,9[a]	–

[a] The values apply to a characteristic density of 450 kg/m^3 and a panel thickness of 20 mm; see 3.4.2(9) for other thicknesses and densities.



Key
1 Initial surface of member
2 Border of residual cross-section
3 Border of effective cross-section

Figure 4.1 — Definition of residual cross-section and effective cross-section

BS5268.4.1

Table 1 — Notional rate of charring for the calculation of residual section

Species	Charring in 30 min	Charring in 60 min
	mm	mm
a) All structural species listed in Appendix A of BS 5268-2:1989 except those noted in items b) and c)	20	40
b) Western red cedar	25	50
c) Hardwoods having a nominal density not less than 650 kg/m^3 at 18 % moisture content	15	30

NOTE Linear interpolation or extrapolation for periods between 15 min and 90 min is permissible.

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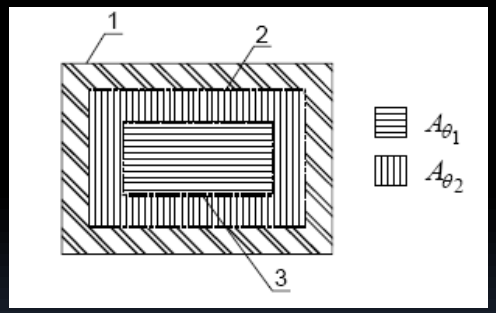
MASONRY : Eurocode 6 Part 1-2

- Method 1 – Tabulated Data
- Method 2 - Test Data
- Method 3 - Analysis
  - Simplified analysis based on residual section (similar to timber analysis)



  - Advanced calculation based on material properties at elevated temperatures

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MASONRY : Eurocode 6 Part 1-2

- Draft NA for Public Comment issued on 06 October 2009 until 01 December 2009
- Disallows design by calculation
- Includes tabulated data for various wall types e.g.

Eurocode NA

Table N.A.3.2 Dense and Lightweight Aggregate Concrete Masonry Minimum Thickness of Separating Loadbearing Single Leaf Walls (Criterion REI) for Fire Resistance Classifications

Row No.	Material Properties: Gross Dry Density, ρ [kg/m³]	Minimum Wall Thickness (mm) t_f For Fire Resistance Classification EI for Time (minutes) $t_{fi,d}$					
		30	60	90	120	180	240
1	*Group 1 units* Mortar: General Purpose, thin layer, lightweight						
1.1	Lightweight Aggregate $400 \le \rho \le 1700$						
1.1.1	$\alpha \le 1{,}0$	90	90	100	100	140	150
1.1.2		(90)	(90)	(90)	(90)	(100)	(100)
1.1.3	$\alpha \le 0{,}6$	70	75	90	90	100	100
1.1.4		(60)	(60)	(75)	(75)	(90)	(90)
1.2	Dense Aggregate $1200 \le \rho \le 2400$						
1.2.1	$\alpha \le 1{,}0$	90	90	90	100	140	150
1.2.2		(90)	(90)	(90)	(90)	(100)	(100)
1.2.3	$\alpha \le 0{,}6$	75	75	90	90	100	140
1.2.4		(60)	(75)	(75)	(75)	(90)	(100)
2	*Group 2 units* Mortar: General Purpose, thin layer, lightweight						
2.1	Lightweight Aggregate $240 \le \rho \le 1300$						
2.1.1	$\alpha \le 1{,}0$	90	100	100	100	140	150
2.1.2		(90)	(90)	(90)	(100)	(140)	(140)
2.1.3	$\alpha \le 0{,}6$	75	100	100	100	125	140
2.1.4		(75)	(75)	(75)	(90)	(100)	(125)

IS EN 1996-1-2 Nationally Determined Parameters

Draft For Public Consultation

End Date: 2009-12-01

IS325

Table 16a Solid masonry walls* exposed to fire from one side at a time

*Solid masonry walls include walls constructed from solid concrete blocks, or solid concrete bricks, or clay bricks

Masonry unit type	*Finishes*	*Minimum thickness (mm), excluding any finish, for a fire resistance of (hours)*											
		Loadbearing						Non-loadbearing					
		½	1	1½	2	3	4	½	1	1½	2	3	4
Blocks, dense concrete[1]	None	90	90	100	100	-	-	50	75	90	100	140	150
	Masonry finished with 13 mm thickness cement/sand render.	-	-	-	-	-	-	50	75	90	90	100	140
	Masonry finished with 13 mm thickness lightweight aggregate gypsum plaster	90	90	90	90	100	-	50	75	75	75	90	-
Blocks, lightweight concrete	None	90	90	100	100	140	150	50	75	75	75	125	140
	Masonry finished with 13 mm thickness cement/sand render.	-	-	-	-	-	-	50	75	75	75	90	100
	Masonry finished with 13 mm thickness lightweight aggregate gypsum plaster	90	90	90	90	100	-	50	50	63	75	75	-
Bricks, concrete[2] & calcium silicate[3]	None	90	90	100	100	190	190	75	75	90	100	170	170
	Masonry finished with 13 mm thickness lightweight aggregate gypsum plaster	90	90	90	90	100	-	75	75	90	90	90	-
Bricks, fired clay[4]	None	90	90	100	100	170	170	75	75	90	100	170	170
	Masonry finished with 13 mm thickness lightweight aggregate gypsum plaster	90	90	90	90	100	-	75	75	90	90	90	-

[1]Complying with I.S. 20 Part 1 : 1987
[2]Complying with I.S. 189: 1987
[3]Complying with I.S. 190: 1987
[4]Complying with I.S. 91:1983

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ALUMINIUM : Eurocode 9 Part 1-2

Very similar in content and presentation to the steel code

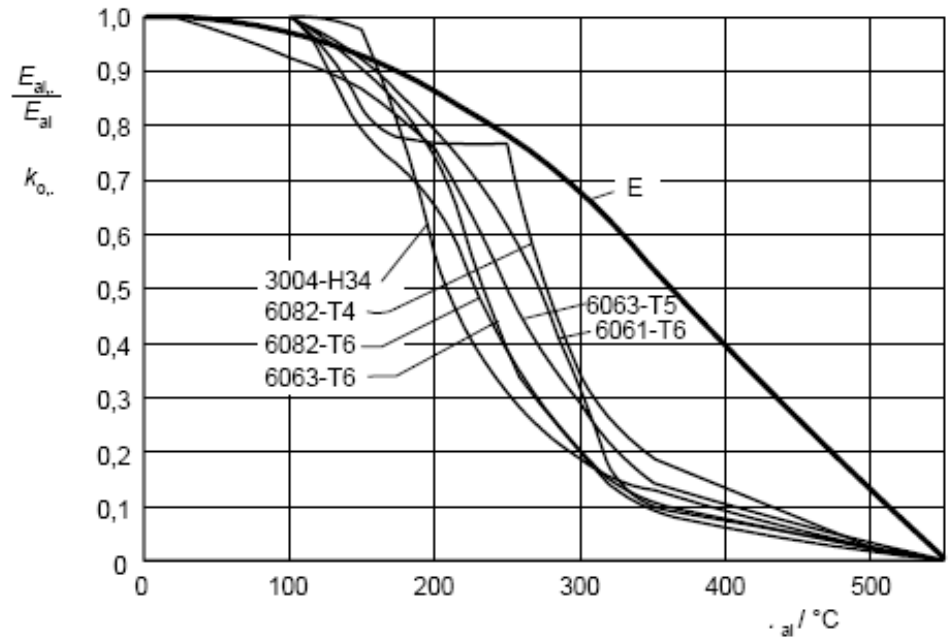

Figure 2a – 0,2% proof strength ratios $k_{o,\theta}$ and ratio E = $E_{al,\theta}/E_{al}$ for aluminium alloys at elevated temperature θ_{al} /°C for up to 2 hours thermal exposure period, EN-AW 3004 and 6xxx-alloys of Table 1a

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Childrens Hospital of Ireland (Mater Site)

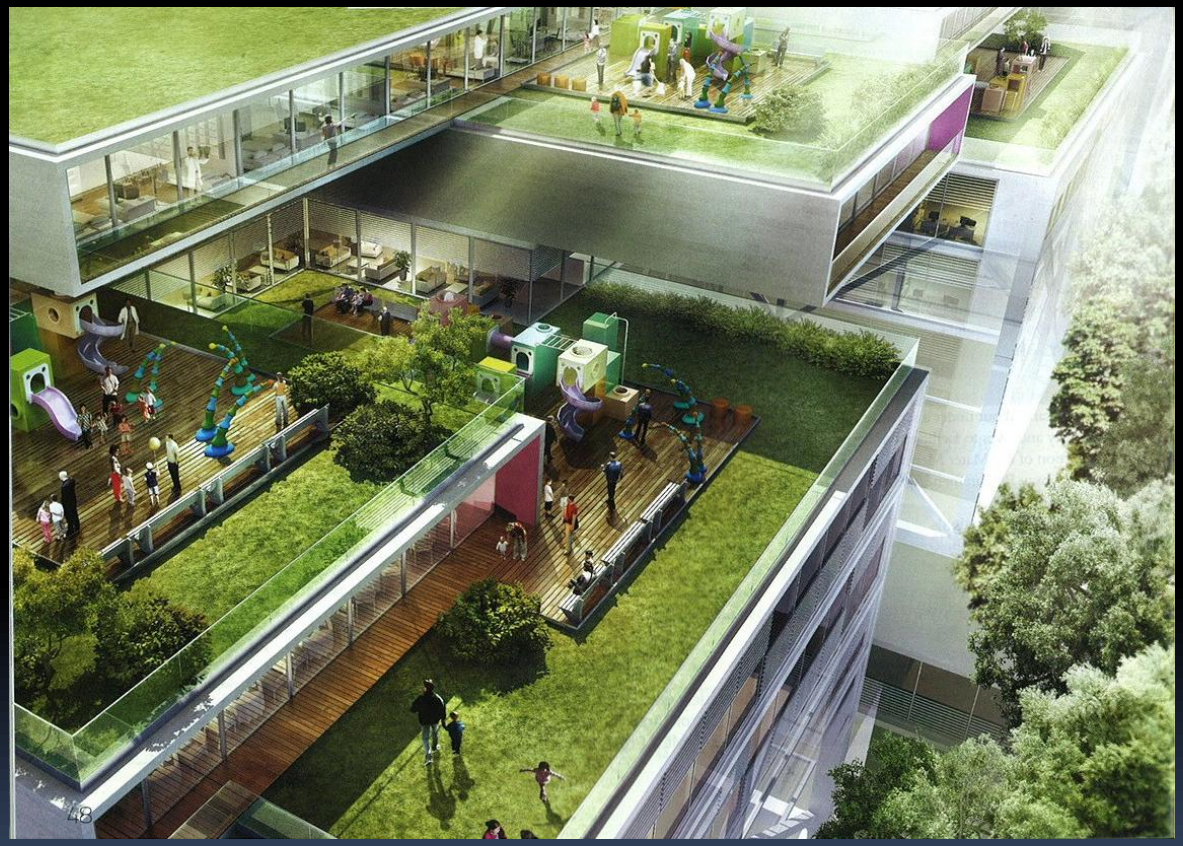
700m euro

110,000sqm

To start 2011
Design Build

Time Equivalent

FEL structural
response modelling



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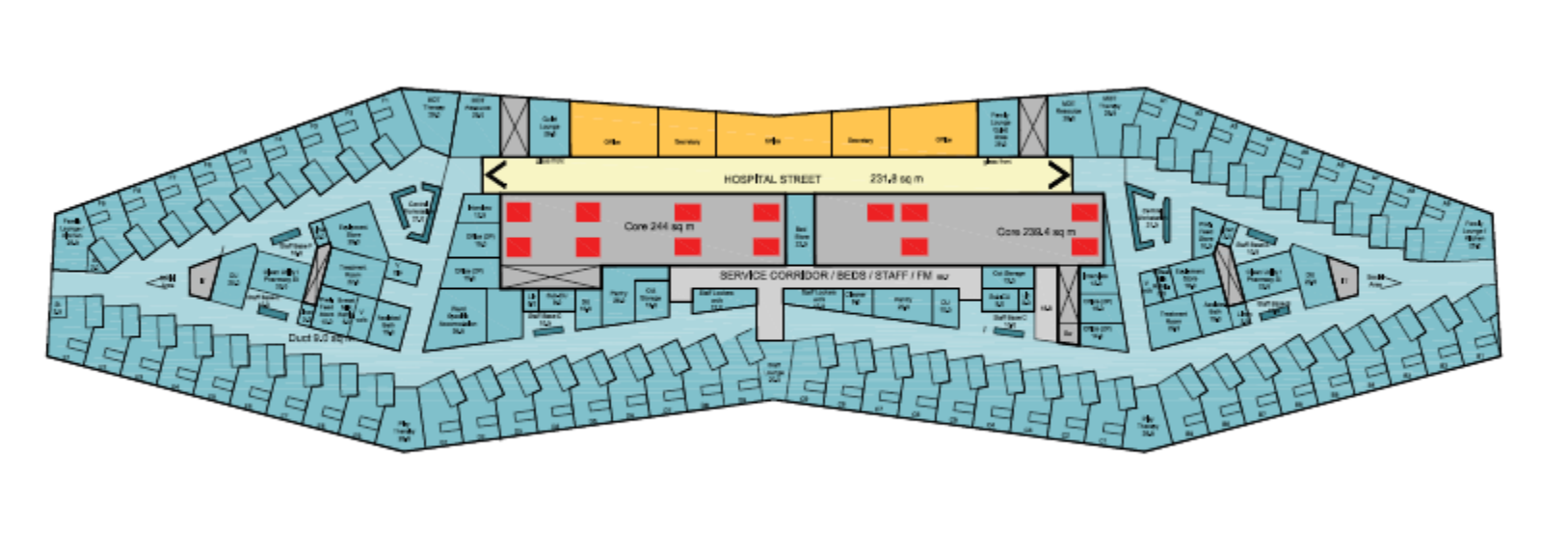
CHILDRENS HOSPITAL OF IRELAND (MATER SITE)



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Parkway District Centre Limerick

100,000 m^2 Shopping centre

-Structural steel frame with composite metal deck floor and composite beams

-Floor removed – oversized columns

-BS9999 reduced ratings

-FEL analysis of composite slabs/beams

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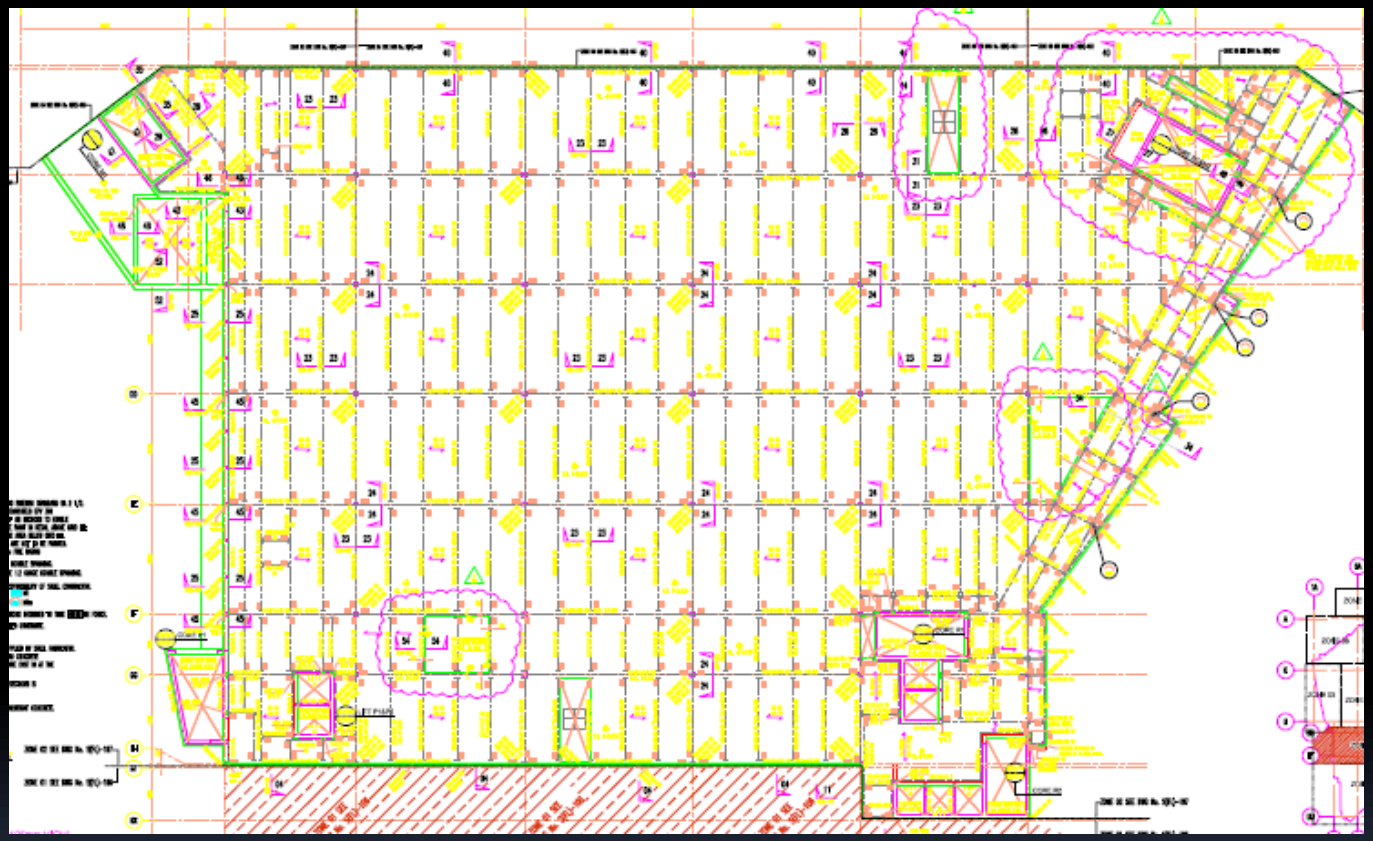
PARKWAY DISTRICT CENTRE LIMERICK



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AIBCM Project

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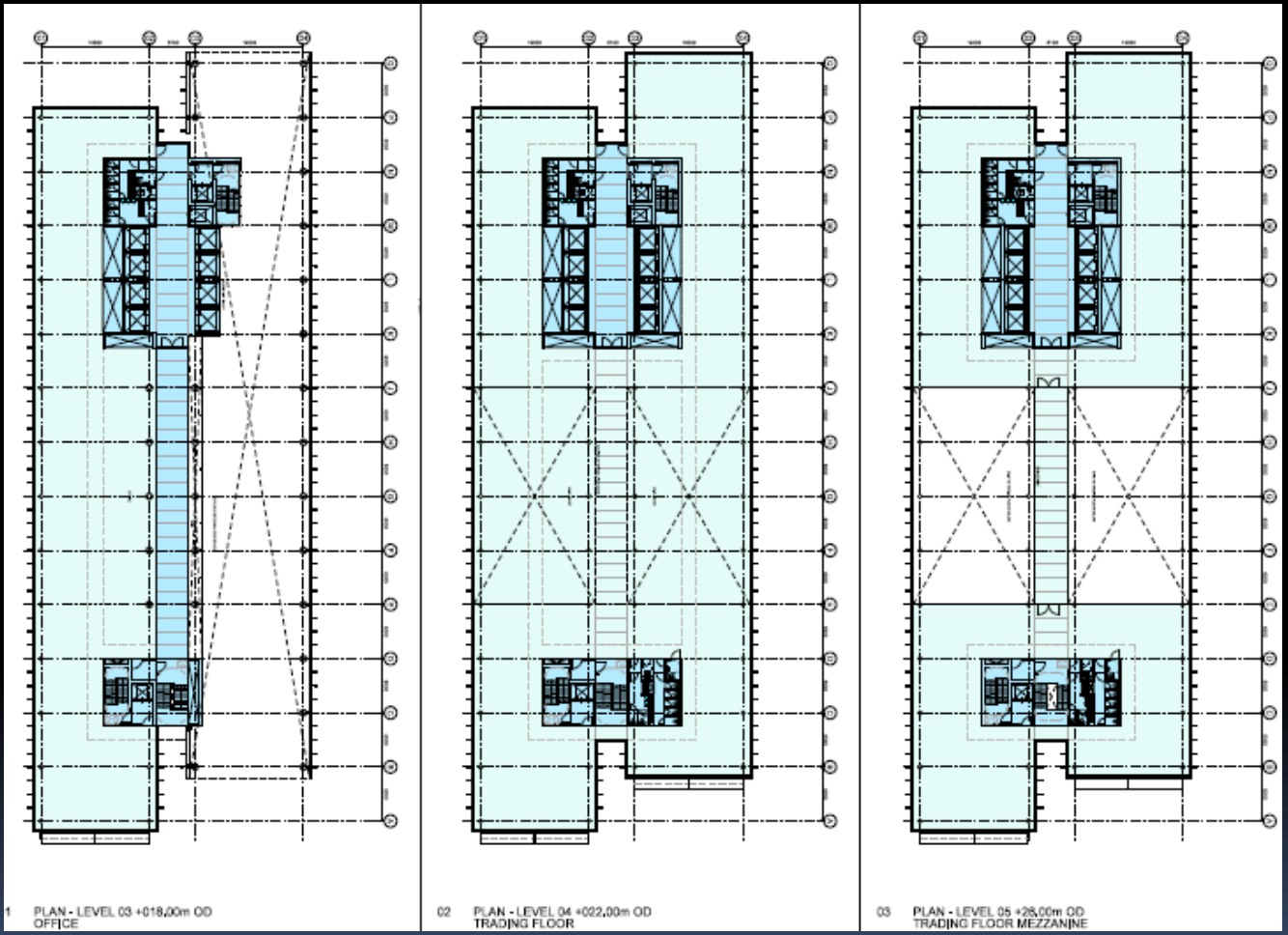
AIBCM Project



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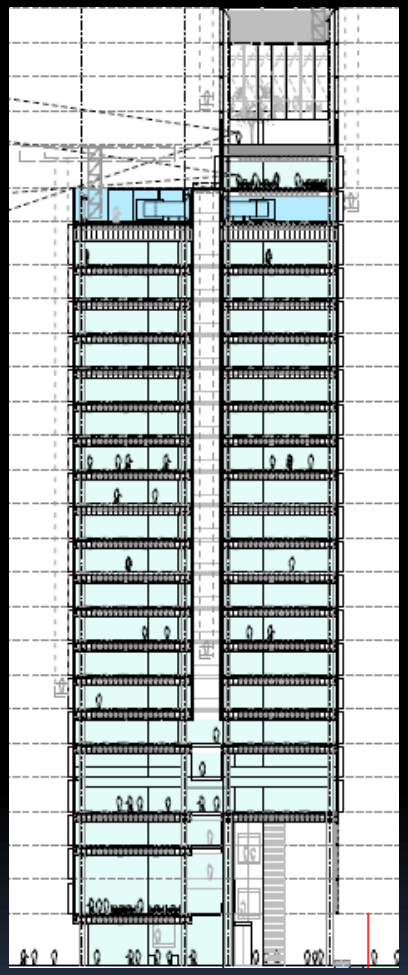
AIBCM Project



-AIBCM

- Design Fire load deduced from BS9999
- Small, Medium and large room fires
- Parametric Fire Curves to EC1

- Vulcan analysis of composite floors/frames

- Collonade columns external elements

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CENTRAL BANK - DUBLIN

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CONCLUDING COMMENTS

Thank you kindly for your attention and I hope you have gained some insight into the Eurocodes for Fire from my talk .

I also thank IBCI for inviting me to make this presentation today

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