Fire testing and BCA

- AS 1530.4
  - Fire Testing
- Fire Compartments
- Fire protection & safety
- BCA Reqirements
  - Type A, B & C Construction
- Exposed surface area
- Linear expansion
- Methods of Direct Fire Spread

Development by Standards Australia's Committee FP-018 Fire Safety.

AS 1530.4

The revision of test method is substantially based on ISO 834.

Standards Australia works closely with the international community in the development of the next generation ISO 834 Standard

The ISO 834 standard, if, universally adopted would also satisfy the needs of Australian Industry.

AS 1530.4

- SECTION 1. SCOPE AND GENERAL
- SECTION 2. GENERAL REQUIREMENTS
- SECTION 3. WALLS AND PARTITIONS
- SECTION 4. FLOORS, ROOFS, FLOOR/CEILING SYSTEMS ANDROOF/CEILING SYSTEMS
- SECTION 5. COLUMNS
- SECTION 6 BEAMS, GIRDERS AND TRUSSES
- SECTION 7. DOORSETS, SHUTTER ASSEMBLIES AND DAMPER ASSEMBLIES
- SECTION 8. GLAZING
- SECTION 9. AIR DUCTS
- SECTION 10. ELEMENTS PENETRATED BY SERVICES

- APPENDIX A. RADIANT HEAT FLUX MEASUREMENTS

Reference to other Australian Standards:

- AS/NZS1668.1—*The use of ventilation and airconditioning in buildings (Part 1: Fire and smoke control in multi-compartment buildings)*
- AS 1670.1—*Fire Detection, Warning, Control and Intercom Systems—System Design Installation and Commissioning—Fire*.
- AS 2118—A*utomatic Fire Sprinkler Systems*.
- AS 2441—I*nstallation of Fire Hose Reels*.
- AS 2665—*Smoke/Heat Venting Systems—Design, Installation and Commissioning*.
- AS 4391—*The use of ventilation and airconditioning in buildings - Smoke management systems - Hot smoke test*

2.9 Test Procedure

2.9.1.1 Furnace ignition. (all burners have been lit)

2.9.1.2 Standard heating conditions (Controlled with $T_1 - T_o = 345 \log_{10}(8t+1)$

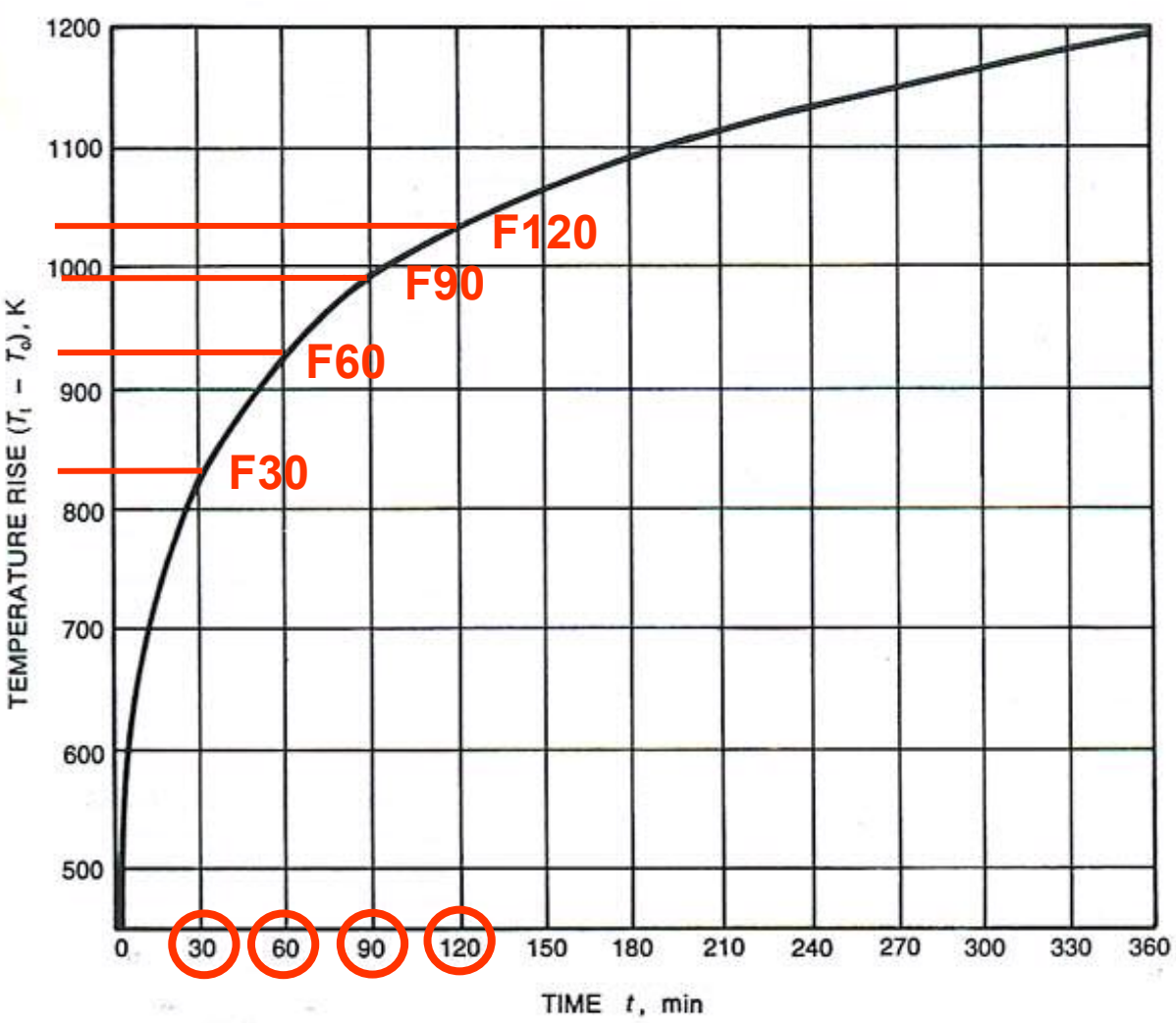
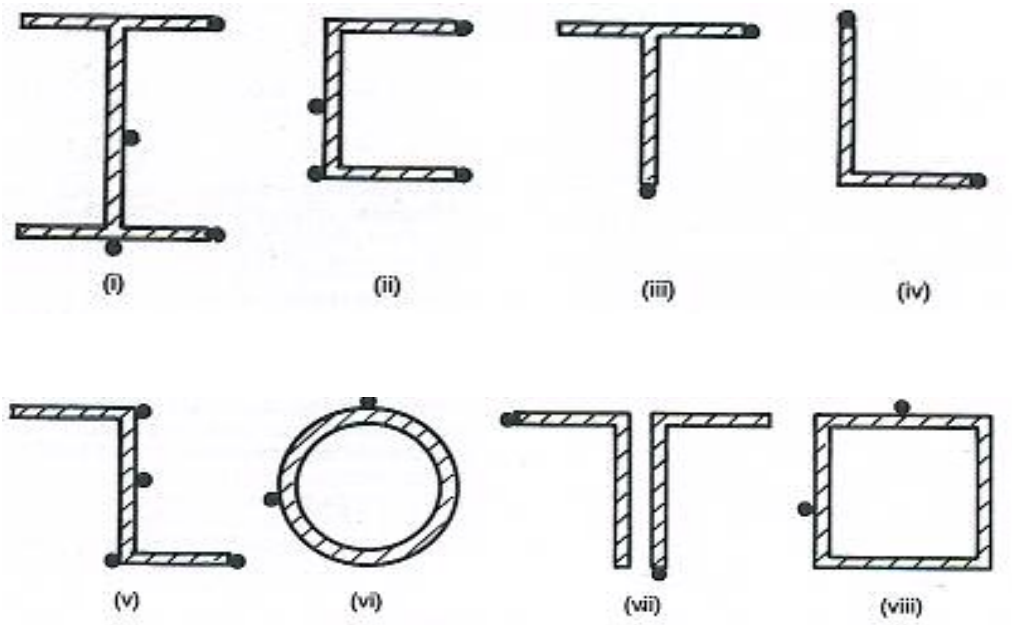


Figure 2.2
Standard time vs temperature rise curve

Recommended Location of Thermocouples on typical structural Sections



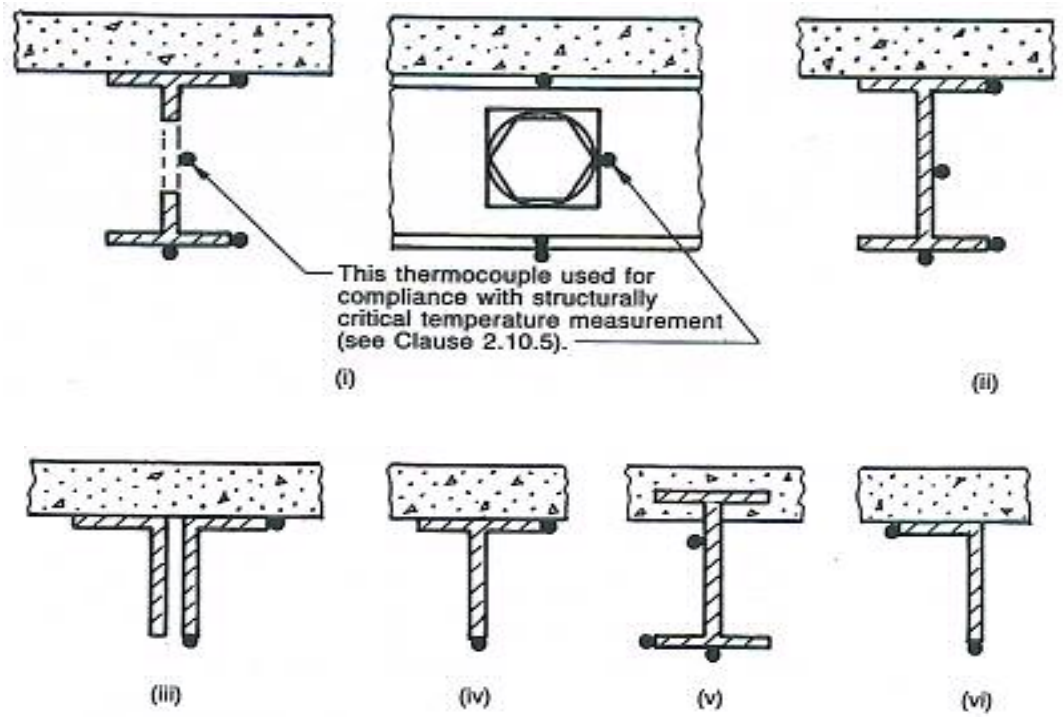
(a) Isolated sections

Figure 6.1

6.3.1 Thermocouples for structurally critical temperatures

6.3.1.2 Steel elements

Recommended Location of Thermocouples on typical Structural Sections



(b) Sections incorporating floor slabs

Figure 6.1

6.3.1 Thermocouples for structurally critical temperatures

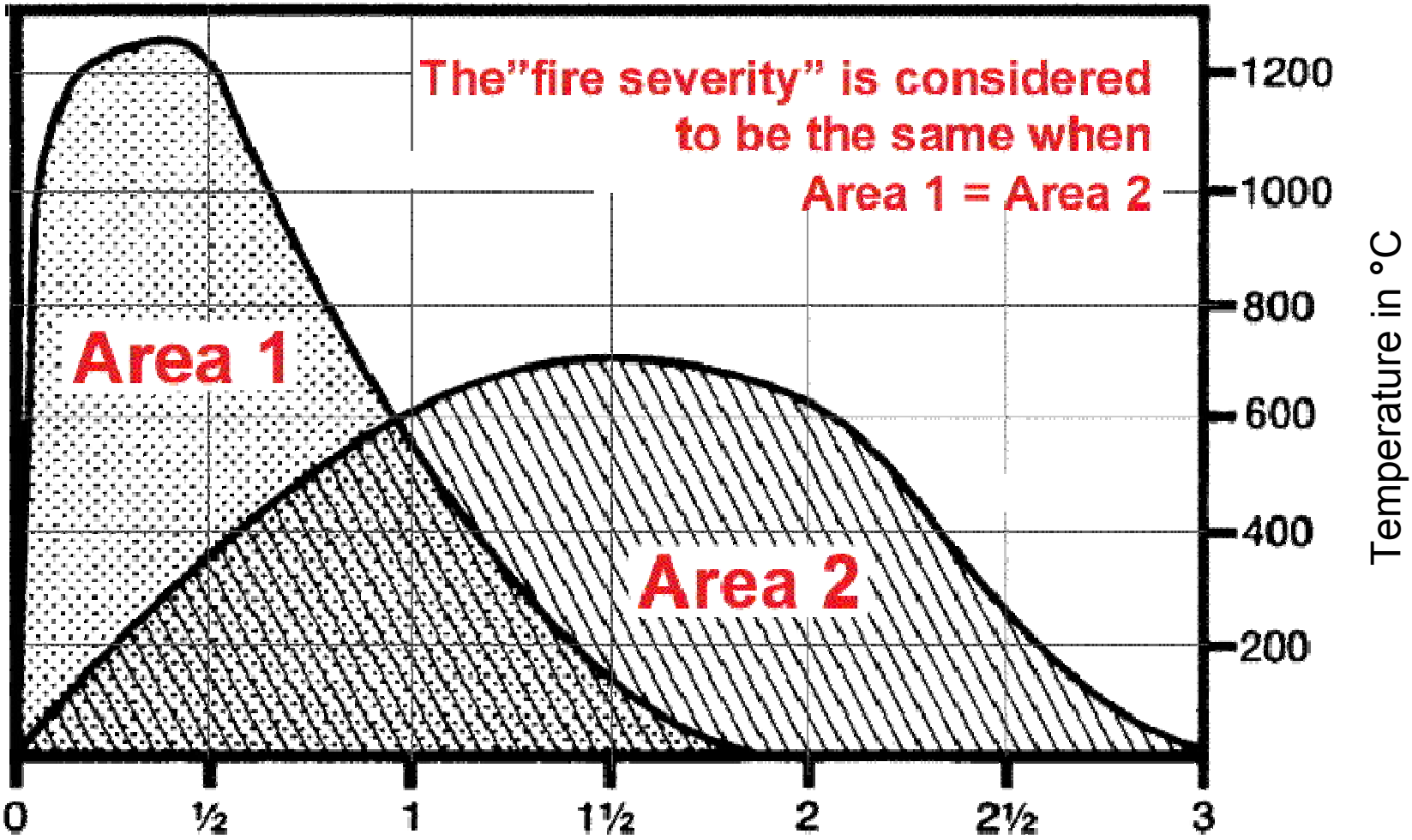
6.3.1.2 Steel elements

Relationship Between Fire Load and Fire Endurance

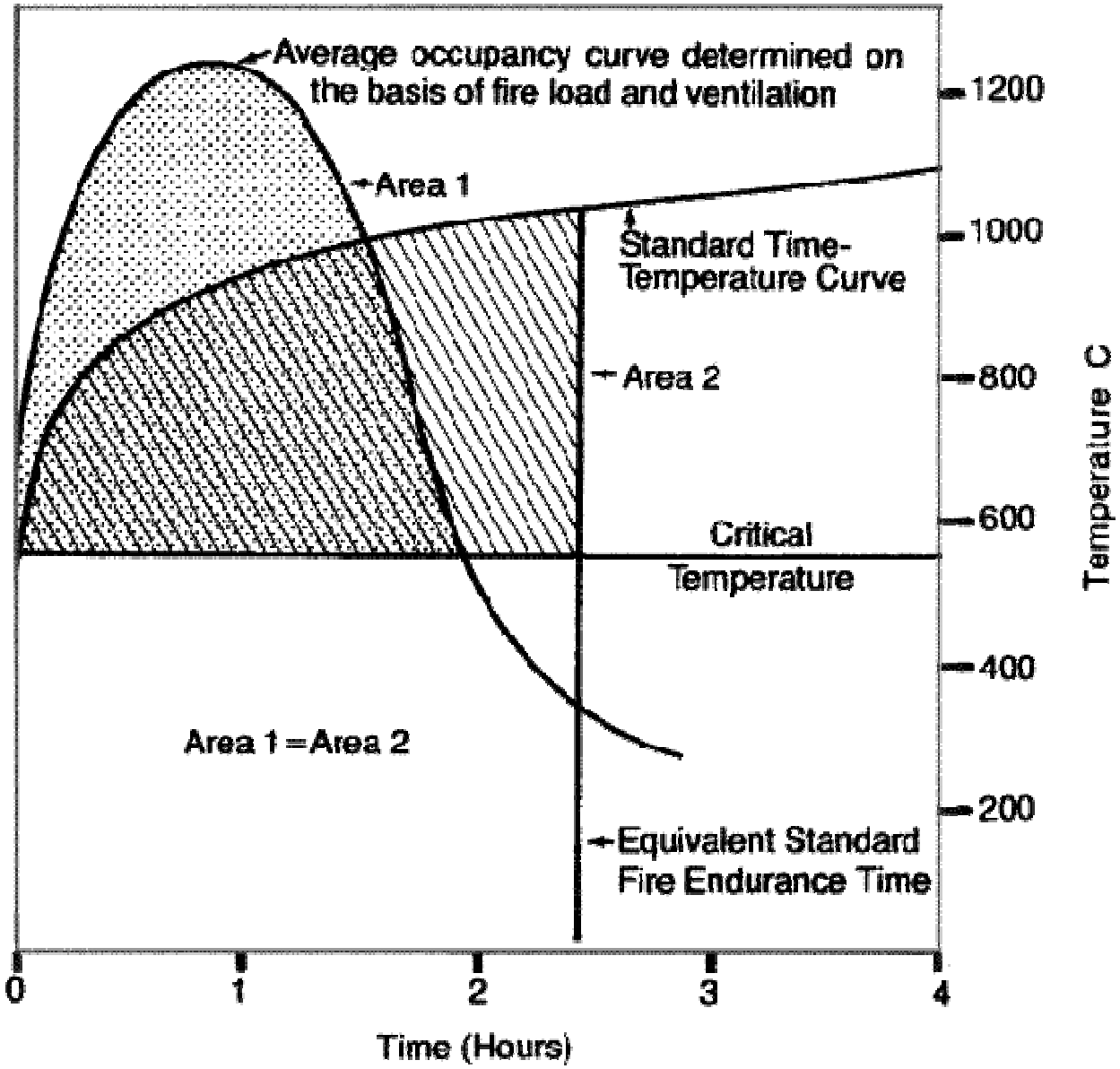
Average Fire Load kg/m^2	Equivalent Fire Endurance (hours)
25	½
37	¾
50	1
75	1½
100	2
150	3
200	4½
250	6
300	7½

* Determined on the basis of a potential heat of approximately 8.5 MJ

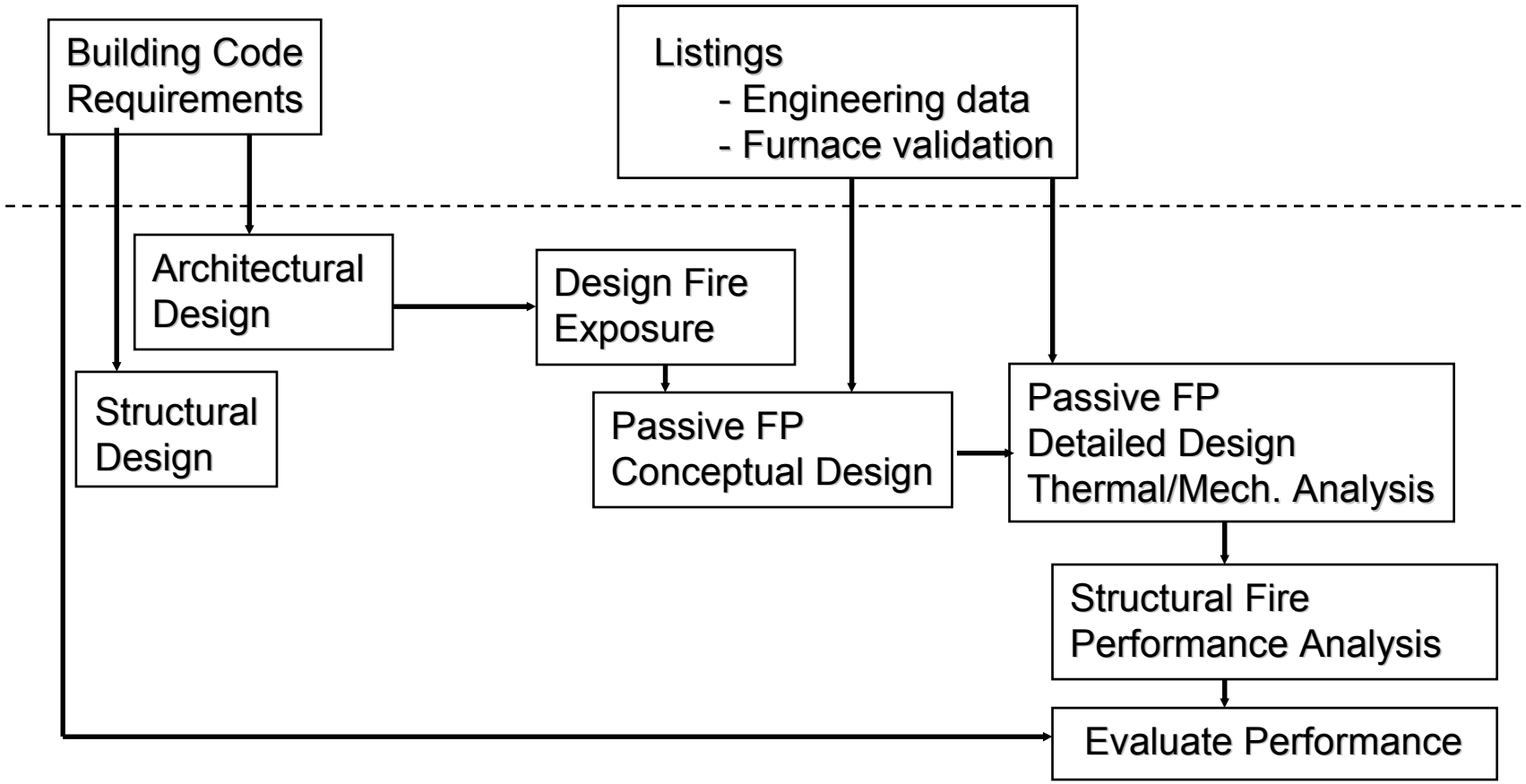
The “Fire Severity” Concept



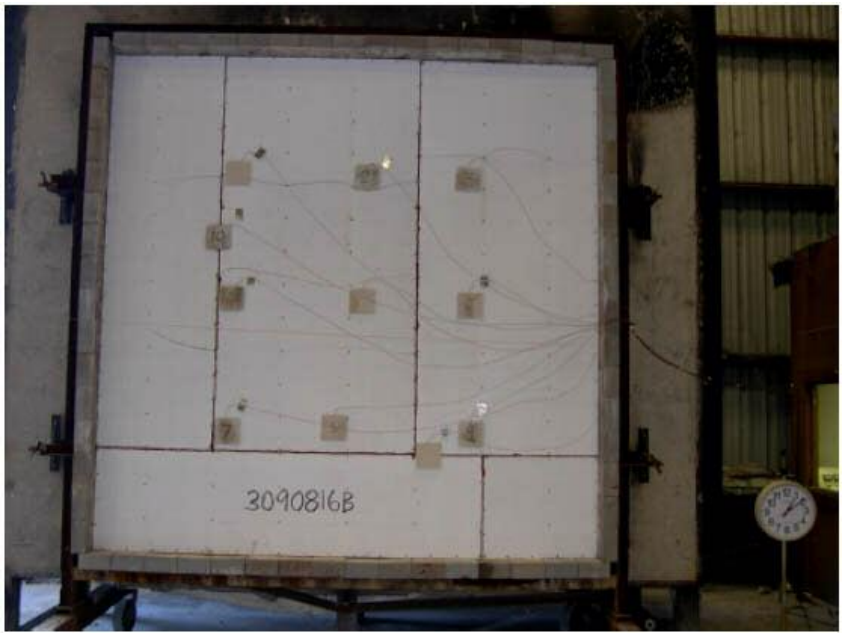
Determination of Equivalent Fire Endurance Time



Science-Based Structural Fire Protection Design



An example of a standard fire resistance test on two (2) fire door assemblies



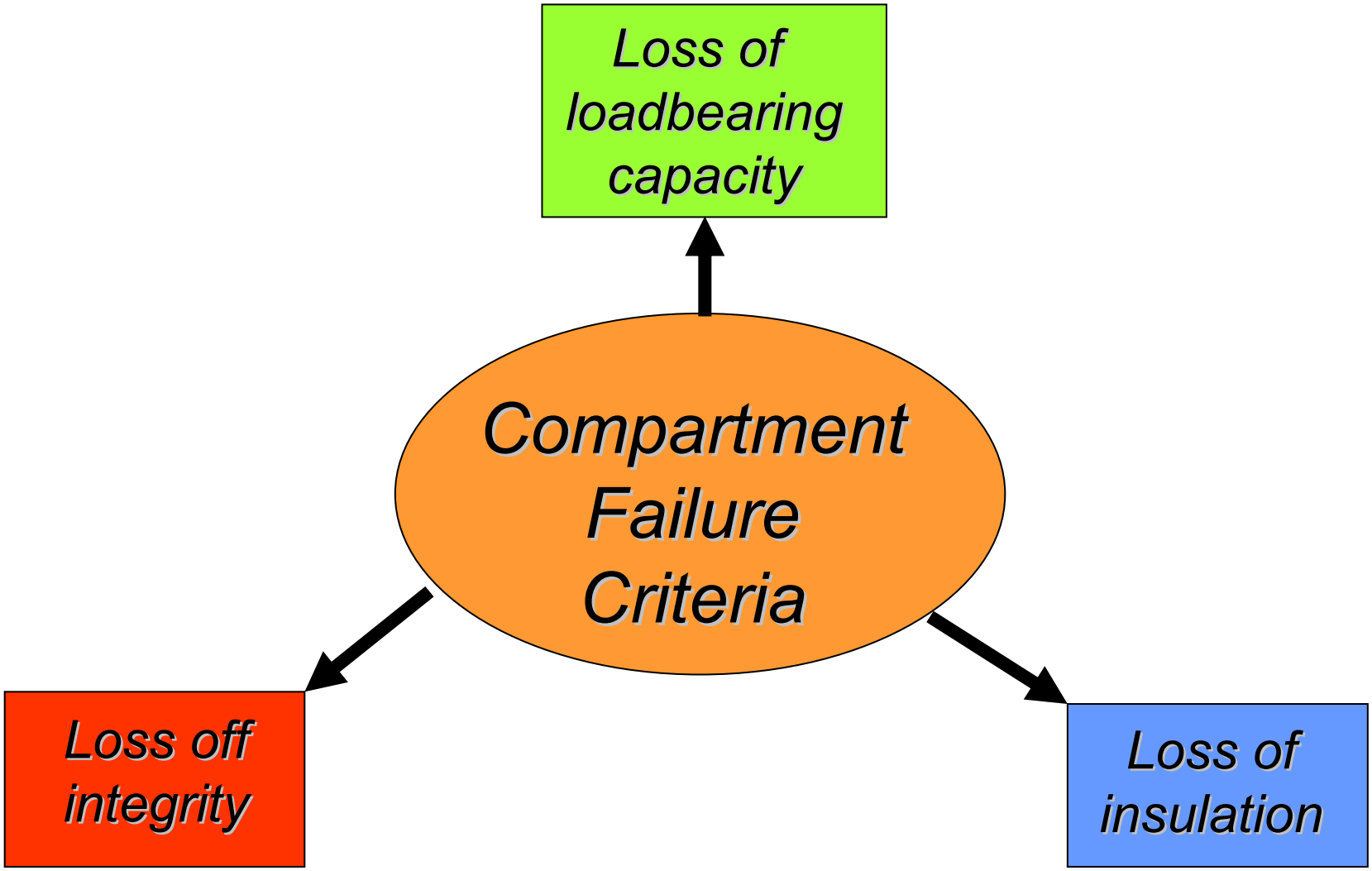
Attaching the thermocouples to the element

Preparation of the stud wall for mounting against the furnace

Element removed from the furnace

Fire resistant test of a non-loadbearing steel stud wall

Failure Criteria for Compartmentation



AS 1530.4 – 2.11 Criteria of Failure

- **Loss of loadbearing capacity:**

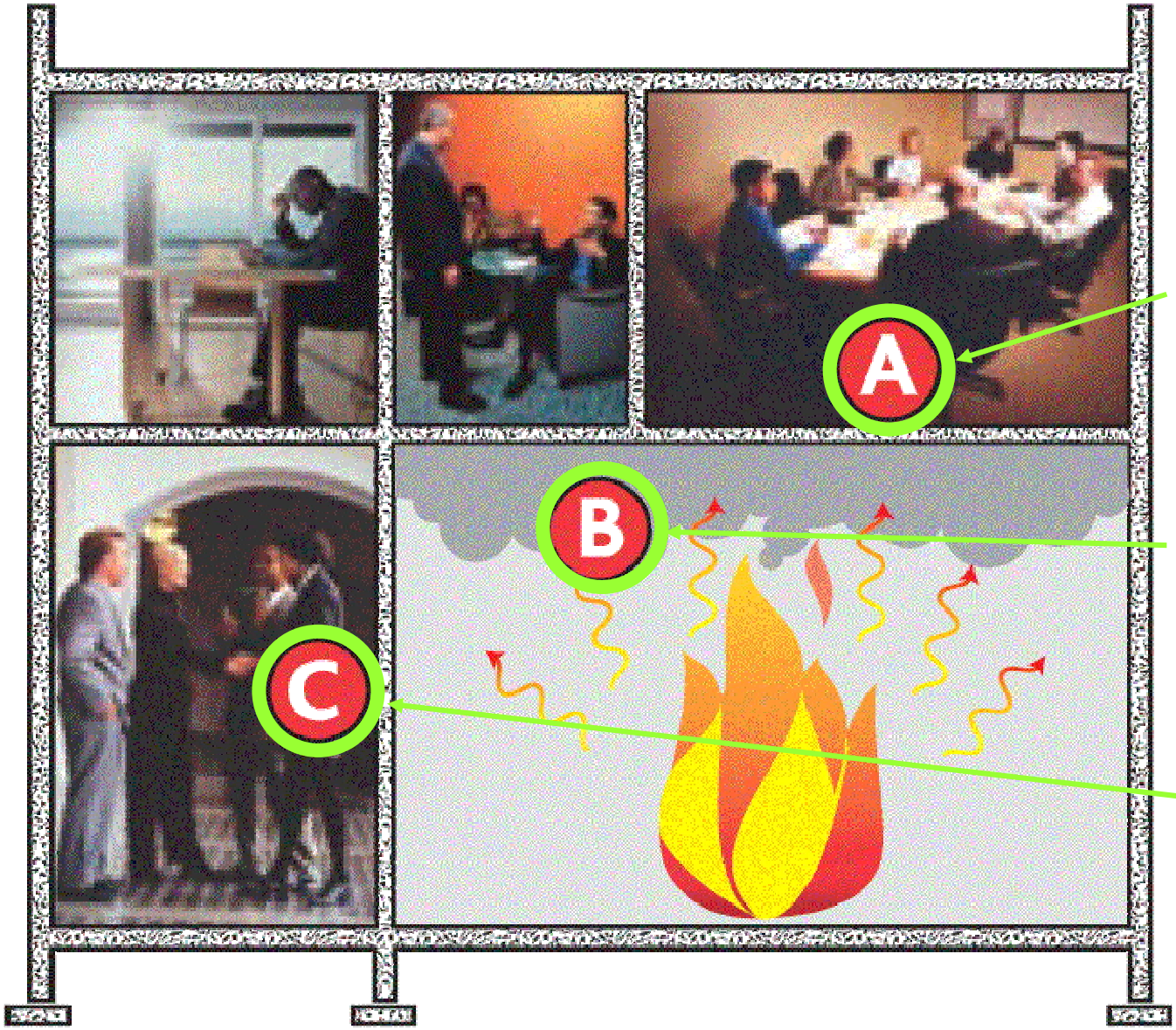
  Limit or rate of deflection:
  For flexural elements: **D = L/20**
  *** D = L^2/9000d,**
  * not before L30 is exceeded
  For vertical elements: **no specific requirements**
  d = distance from top structural section to bottom design tension zone

- **Loss of integrity:**

  Failure upon collapse when cracks, fissure or other openings through which flames or hot gases can pass occur

- **Loss of insulation:**

  Temperature rise: **+140°C average or, +180°C max.**



Fire Limit States

A: The structure should retain its loadbearing capacity.

B: The structure should protect people from harmful smoke and gases.

C: The structure should shield people from heat.

Compartment Failure or Failure of the Enclosure??

- Criteria for compartment failure or structural failure as given in Standardised test requirements provide a means of ranking the performance of materials and products under a specific set of conditions.

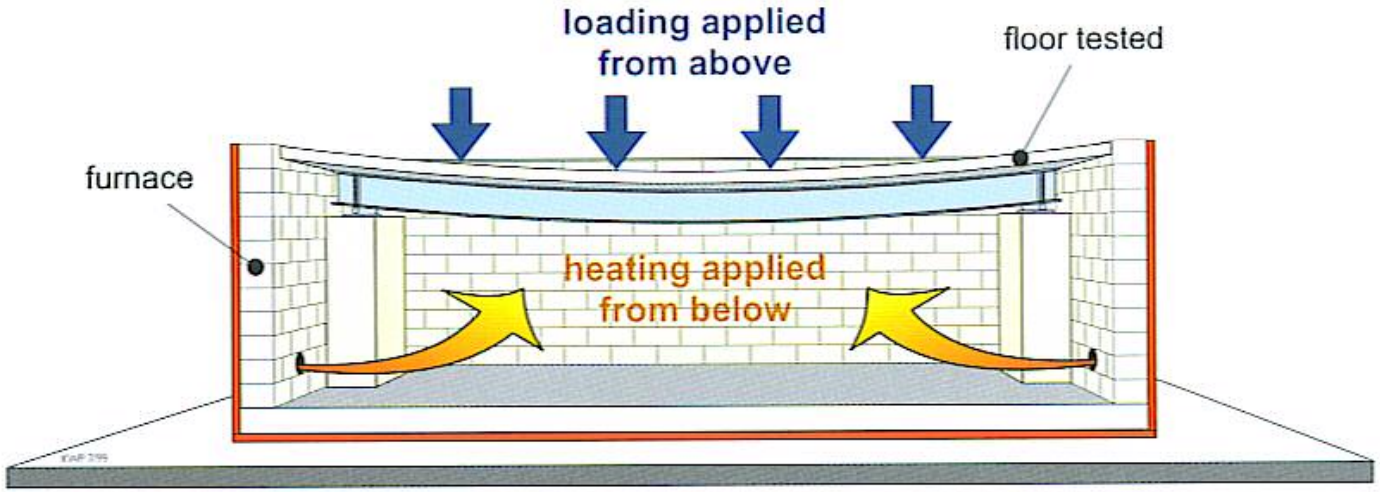
- The objective of defining a compartment is to **prevent fire spread.** In dealing with real fires in real buildings we should therefore dispense with the traditional approach of defining a compartment but quantify the ability of fire to spread from an **enclosure**.

Fire Compartments and Floors

The BCA definition of a *fire compartment* relevant to deemed-to-satisfy provisions refers to "any part of a building separated from the remainder by walls and/or floors each having an FRL not less than that *required* for a *fire wall for* that type of construction...." . This raises two questions:

Does the above definition imply that the floor *above* and the floor *below* are within the same fire compartment?

The term *floor* in the BCA should always be taken as referring to the floor *above.* That this is the case, is demonstrated by the fact that when a floor is tested under standard fire test conditions in accordance with AS1530.4, it is always tested from below, never from above. This testing standard is referenced by the BCA in Part A1 and called up in Specification A2.3.



SPECIFICATION A2.3
FIRE-RESISTANCE OF BUILDING ELEMENTS

1. **Scope**

   This Specification sets out the procedures for determining the FRL of building elements.

2. **Rating**

   A building element meets the requirements of this Specification if—

- Complies with Table 1 of this Specification; or
- Is identical with a prototype that has been submitted to the *Standard Fire Test*,
- Differs in only a minor degree from a prototype tested
- Is designed to Achieve the FRL in accordance with—

  AS 2327.1

  AS 4100 if it is a steel structure;

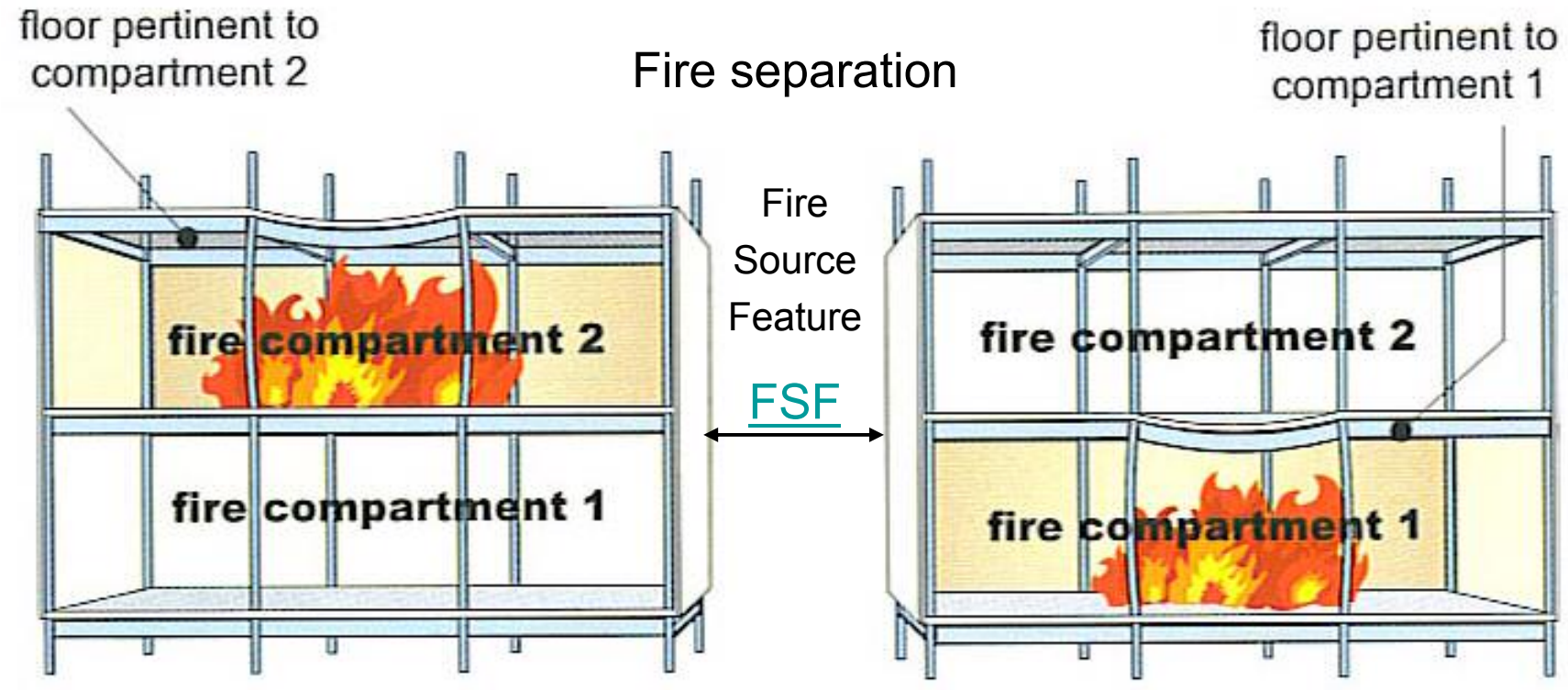
  AS 3600 if it is a concrete structure; or

  AS 1720.4 if it is a solid or glued-laminated timber structure; or

  AS 3700 if it is a masonry structure; or
- FRL is determined by calculation based on the performance of a prototype in the *Standard Fire Test*

SPECIFICATION A2.3 FIRE-RESISTANCE OF BUILDING ELEMENTS

Thus in the diagram below, the floor should be considered as the floor *above* the compartment and should have the appropriate FRL for that compartment (see also BCA Clause C2.9).



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PART C2 COMPARTMENTATION AND SEPARATION

C2.9 Separation of classifications in different storeys

If parts of different classification are situated one above the other in adjoining *storey's* they must be separated as follows:

(a) Type A construction — The floor between the adjoining parts must have an FRL of not less than that prescribed in Specification C1.1 for the classification of the lower *storey*.

(b) Type B or C construction — If one of the adjoining parts is of Class 2, 3 or 4, the floor separating the part from the *storey* below must—
  (i) be a floor/ceiling system incorporating a ceiling which has a *resistance to the incipient spread of fire* to the space above itself of not less than 60 minutes; or
  (ii) have an FRL of at least 30/30/30; or
  (iii) have a *fire-protective covering* on the underside of the floor, including beams incorporated in it, if the floor is *combustible* or of metal.

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Fire Protection Engineering

Fire Protection Engineering comprises active and passive ways of providing satisfactory protection level to buildings and/or its contents from fires.

Active fire protection for buildings includes fire detection and alarm systems, sprinkler, and other automatic fire fighting systems.

Passive fire protection deals with the design of a building for adequate load bearing resistance and for limiting fire spread under fire conditions. Structural Fire Engineering is generally categorized in this discipline.

Structural Fire Engineering

Structural Fire Engineering deals with specific aspects of passive fire protection in terms of analysing the thermal effects of fires on buildings and designing structural members for adequate load bearing resistance, i.e. the structural fire resistance.

Role of Fire Resistance in Fire Safety

- Prevent Building Collapse
- Prevent External Spread
- Vertical/Horizontal Fire Spread
- Means of Egress
- Smoke Control
- Firefighter Safety

Sound design for guaranteeing fire safety of buildings

Design Specifications

- Construction materials
- Layout of the facility
- Potential ventilation openings
- Interconnections among compartments
- Location of concealed spaces
- Proposed egress routes
- Anticipated fuel load (type & quantity)
- Functions in the building
- Passive fire protection systems
- Active fire protection systems
- Occupant load and characteristics

http://isotc.iso.org/livelink/livelink/fetch/2000/2122/138210/756475/842934/6576524/J.Mehaffey_Selection_of_Representative_Fire_Scenarios.pdf?nodeid=6587252&vernum=0

Building Code of Australia

PART C1 FIRE RESISTANCE AND STABILITY

Fire resistant Construction

Type A

Type B

Type C

PART C1 FIRE RESISTANCE AND STABILITY
Deemed-to-Satisfy Provisions

- **C1.1**
- **Type of construction required**
- The minimum Type of *fire-resisting construction* of a building must be that specified in Table C1.1 and Specification C1.1, except as allowed for—
  (i) certain Class 2, 3 or 9c buildings in C1.5; and
  (ii) * * * * *
  (iii) *open spectator stands* and indoor sports stadiums in C1.7.
  (iv) * * * * *
- Type A construction is the most fire-resistant and Type C the least fire-resistant of the Types of construction.

Table C1.1
TYPE OF CONSTRUCTION REQUIRED

Rise in storeys	**Class of building**	
	2, 3, 9	**5, 6, 7, 8**
4 OR MORE	**A**	**A**
3	**A**	**B**
2	**B**	**C**
1	**C**	**C**

Back to Separation 21

Vorward to Type A

BCA - Principles of classification

Class 1

Class 1A A single dwelling being a detached house or one or more attached dwellings.

Class 1B Boarding/guest house or hostel not exceeding 300m2 and not more than 12 people reside.

Which is not located above or below another dwelling or another Class of building other than a private garage.

Class 2 A building containing 2 or more sole occupancy units each being a seperate dwelling.

Class 3 A resident building, other than a Class 1 or 2, which is common place of long term or transient living for a number of unrelated persons.

Class 4 A dwelling in a building that is Class 5, 6, 7, 8 or 9 if it is the only dwelling in the building.

Class 5 An office building used for professional or commercial purposes, excluding buildings of Class 6, 7, 8 or 9.

Class 6 A shop or other building for the sale of goods by retail or the supply of services direct to the public.

Class 7 A building which is a carpark or for storage, or display of goods or produce for sale by wholesale.

Class 8 A laboratory, or a building in which a handicraft or process for the production, assembling, altering, repairing, packing, finishing, or cleaning of goods or produce is carried on for trade, sale or gain.

Class 9 A building of a public nature.

Class 9A A health care building.

Class 9B An assembly building in a primary or secondary school, but excluding any other parts of the building that are of another class.

Class 10 A non habitable building or structure.

Class 10A A private garage, carport, shed or the like.

Class 10B A structure being a fence, mast, antenna, retaining or free standing wall, swimming pool or the like.

3. TYPE A FIRE-RESISTING CONSTRUCTION

Fire-resistance of building elements.

Requirements for Type A construction—

Building elements must have an FRL (see Table 3)
External walls, common walls must be non-combustible;

Internal wall require an FRL with respect to integrity and insulation

load bearing internal wall or fire wall must be in concrete or masonry; and

non- load bearing walls

(i) internal wall required to be fire-resisting; and
(ii) lift, ventilating, pipe, garbage, etc must be non-combustible

back to fire type

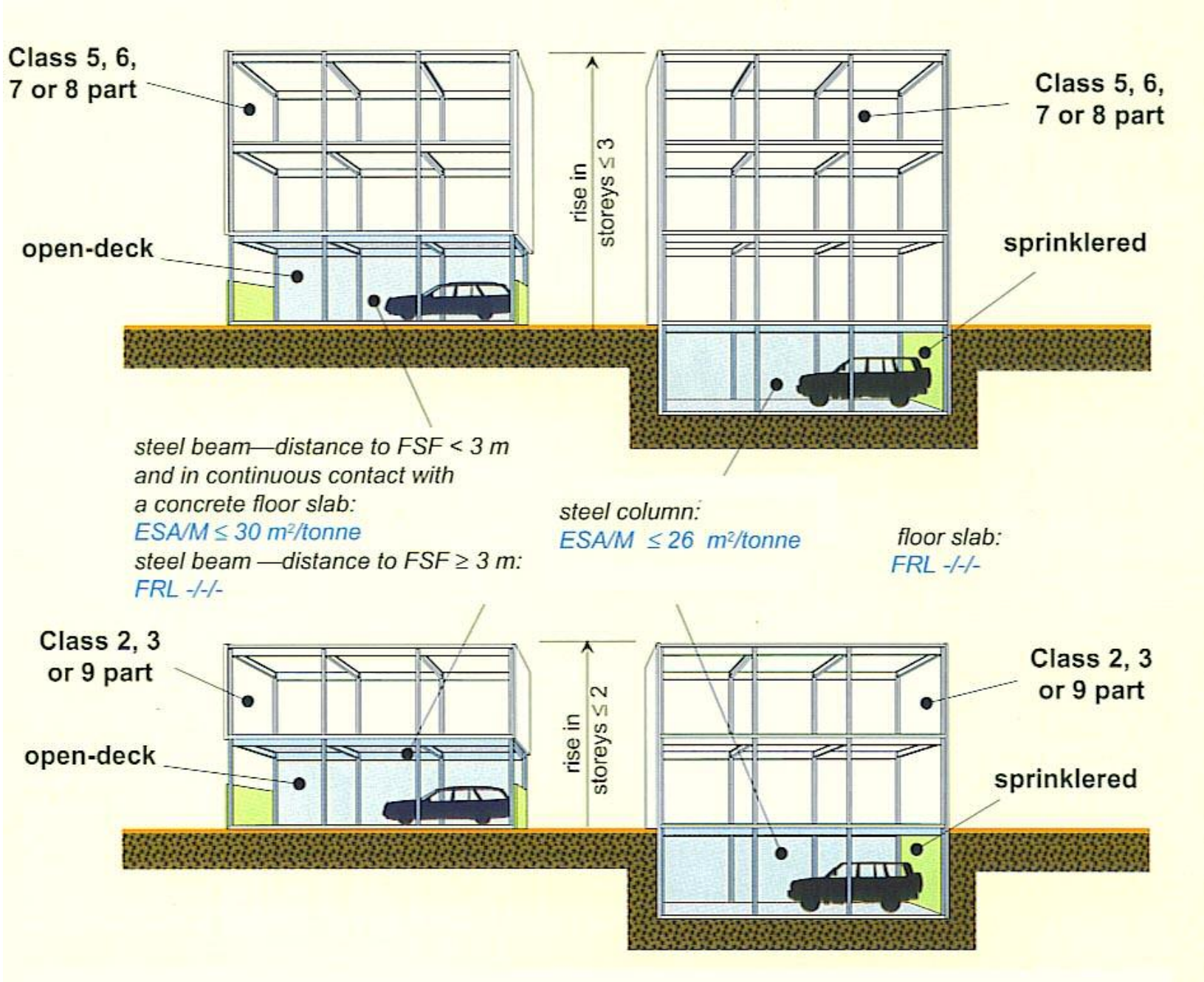
3. TYPE A FIRE-RESISTING CONSTRUCTION

Carparks

car park may comply with Table 3.9 if it is an *open-deck carpark* or

is protected with a sprinkler system

Slide 25


Class 5, 6,
7 or 8 part
open-deck
rise in
storeys ≤ 3
Class 5, 6,
7 or 8 part
sprinklered
steel beam—distance to FSF < 3 m
and in continuous contact with
a concrete floor slab:
ESA/M ≤ 30 m²/tonne
steel beam —distance to FSF ≥ 3 m:
FRL -/-/-
steel column:
ESA/M ≤ 26 m²/tonne
floor slab:
FRL -/-/-
Class 2, 3
or 9 part
open-deck
rise in
storeys ≤ 2
Class 2, 3
or 9 part
sprinklered

BCA extract
Table 3.9 Requirements for carparks

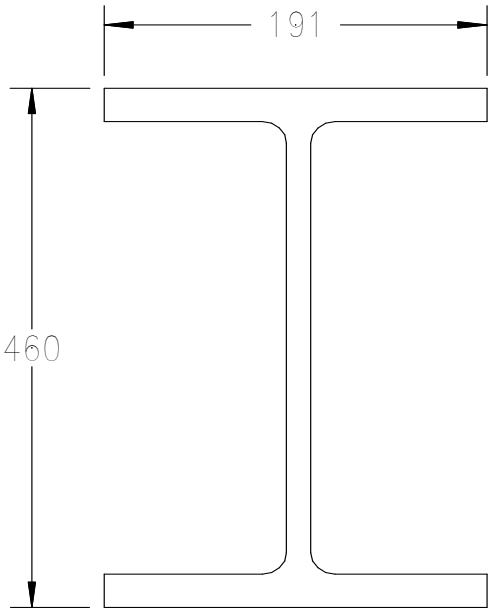
Column		
(a)	supporting only the roof (not used for carparking) and 3 m or more from a *fire-source feature* to which it is exposed	- / - / -
(b)	steel column, other than one covered by (a) and one that does not support a part of a building that is not used as a *carpark*	60/ - / - or 26 m^2/tonne
(c)	any other column not covered by (a) or (b)	60/ - / -

What this means?

ESA/M means the ratio of exposed surface area to mass per unit length

Exposed Surface Area to Mass (ESA/M)

Example – Unprotected Steel-Column 460 UB 82.1



Calculation example per unit length

ESA (m^2) = 0.191 x 4 + 0.460 x 2

= 0.764 + 0.920

= 1.684 m

ESA/M

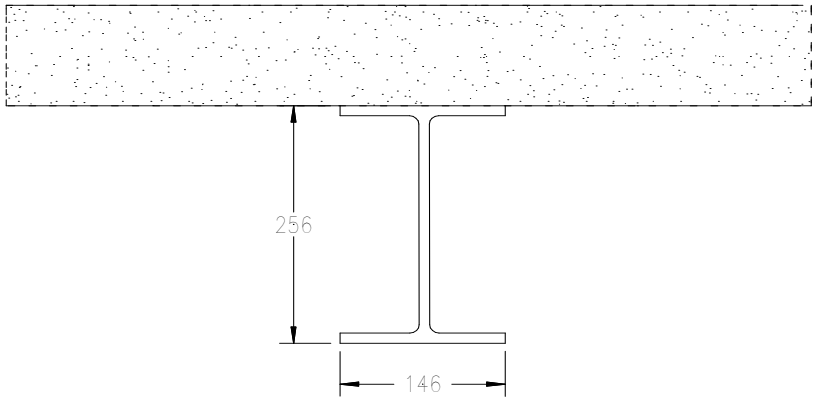
1.684 / 0.0821 = 20.5 m^2/tonne

It complies with the requirement of Table 3.9 (BCA) because 20.5 < 26

To Table 3.9

Exposed Surface Area to Mass (ESA/M) - (cont.)

Example – Concrete slab supported by steel-Beam 250 UB 37.3



Calculation example per unit length

ESA (m²) = 0.146 x 3 + 0.256 x 2

= 0.438 + 0.512

= 0.950 m

ESA/M

0.950 / 0.0373 = 25.5 m²/tonne

It complies with the requirement of Table 3.9 (BCA) because 25.5 < 30

To Table 3.9

4. **TYPE B** FIRE-RESISTING CONSTRUCTION

Requirements for **Type B** construction

All building element listed in Table 4, and any beam or column must have an FRL not less than that listed in the Table for the particular Class of building concerned

External walls, common walls, and the flooring must be non-combustible
Internal walls which have an FRL with respect to integrity and insulation

Load bearing internal wall and a load bearing fire wall must be of concrete or masonry

Non- load bearing internal wall require to be fire-resisting must be of non-combustible construction

Class 5, 6, 7, 8 or 9 buildings below the roof, internal columns and walls other than fire walls, need not comply with Table 4

Slide 25

5. TYPE C FIRE-RESISTING CONSTRUCTION

Requirements for **Type C** construction

in a Class 2 or 3 bu

Building elements listed in **Table 5** and any beam or column incorporated in it, must have an FRL not less than that listed in the Table for the particular Class of building concerned

External walls required by Table 5 have an FRL which is tested from the outside

Fire walls or internal walls of lightweight construction must comply with Specification C1.8 if an FRL is required

For Class 2 or 3 building, an internal wall to have an FRL must extend to the underside of the floor, ceiling, roof covering

Slide 25

SPECIFICATION C1.1 FIRE-RESISTING CONSTRUCTION

GENERAL REQUIREMENTS

2.1 Exposure to fire-source features

A building element is exposed to a *fire-source feature* if horizontal or vertical projection of the feature, is not obstructed by another part of the building that—

(i) has an FRL of not less than 30/–/–; and

(ii) is neither transparent nor translucent.

A part of a building element is not exposed to a *fire-source feature* if the *fire-source feature* is—

(i) an *external wall* of another building that stands on the allotment and is more than 15 m above the highest part of that *external wall*; or

(ii) a side or rear boundary of the allotment is below the level of the finished ground.

If various distances apply for different parts of a building element—

Clause 2.2 - SPECIFICATION C1.1 FIRE-RESISTING CONSTRUCTION (cont.)

Fire protection for a support of another part

Where a part of a building has an FRL which depends upon **direct** vertical or lateral support from another part to maintain its FRL, must

have an FRL not less than that *required*

if located within the same *fire compartment* the greater of that

(a) for the supporting part itself, and

(b) for the part it supports; and

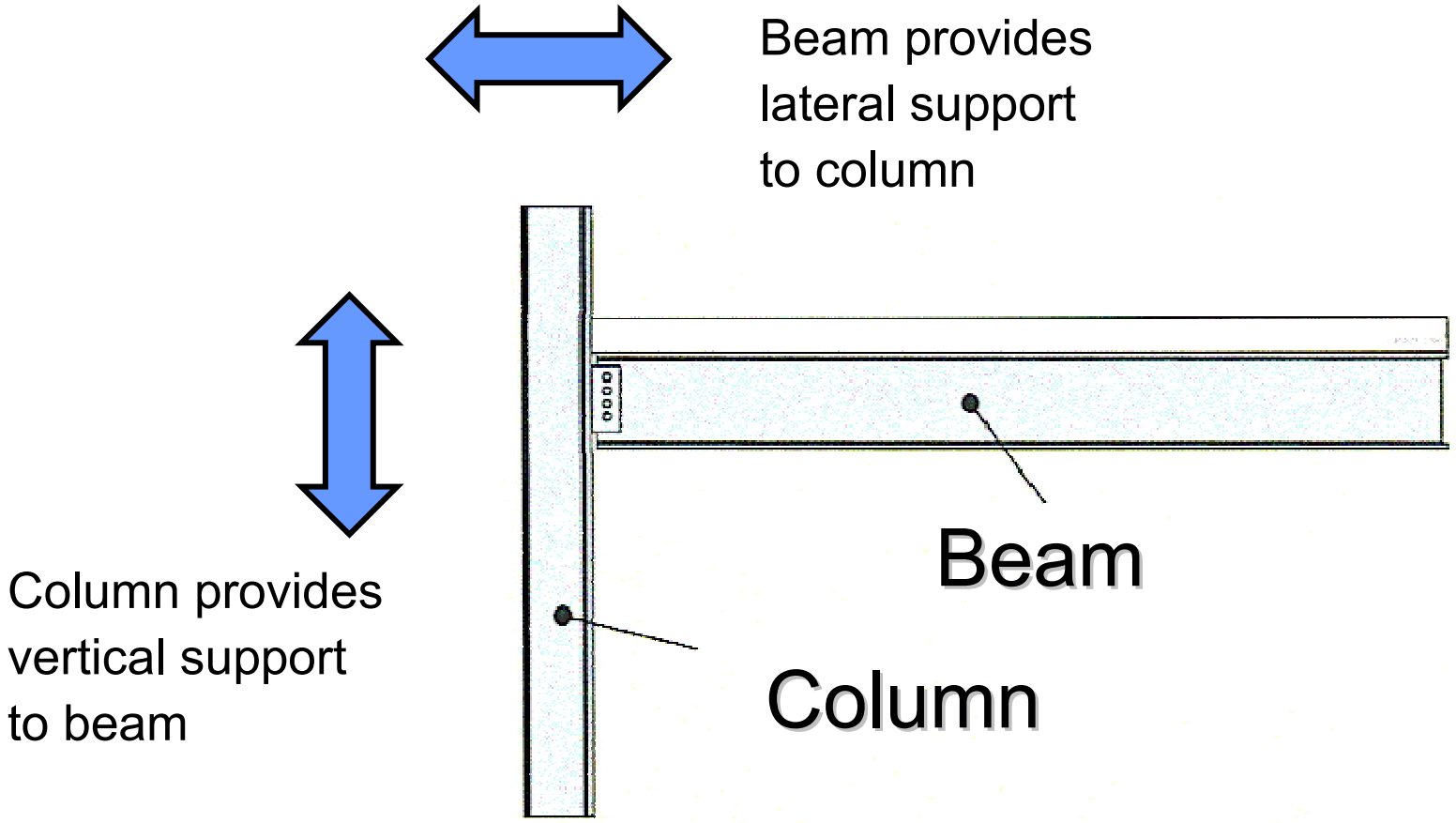
be *non-combustible*—

(a) if *required* by other provisions of this Specification, or

(b) if the part it supports is *required* to be *non-combustible*.

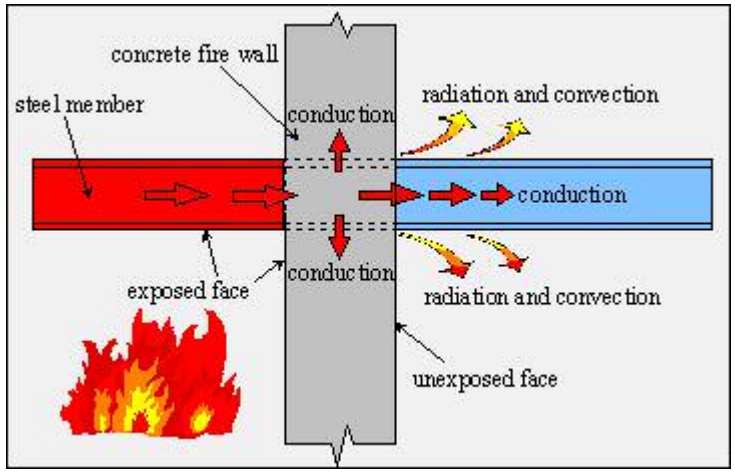
Vertical and lateral support

The diagram shows vertical and lateral support provided between a beam and a column

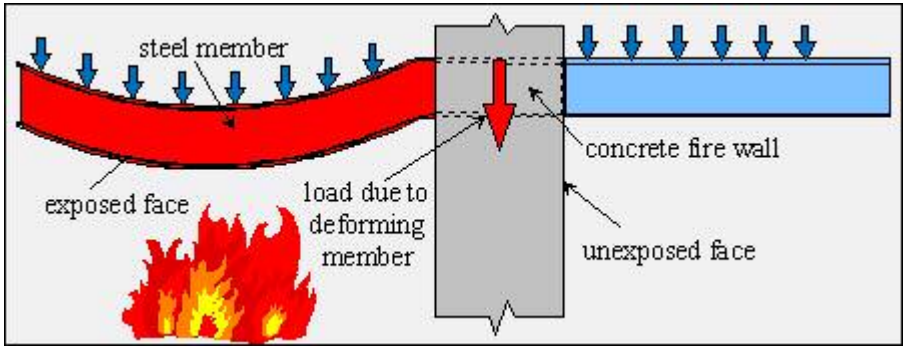


- **CAUTION**
- The fire safety systems in this building have been certified on the basis of complying alternative solutions, current building use, and design fuel loads and limitations.
- Any changes in building use, elements of building structure, or building services can affect building compliance and may require recertification by an accredited Building Surveyor.

Fire behaviour of steel members penetrating concrete walls



A penetrating member need to be fire protected for a certain length on each side of the wall to minimise the possibility of fire spread through heat conduction and excessive temperature rise to the unexposed member. This is necessary to ensure that ***lateral restraint*** will continue to be provided to the top of the wall by the member on the unexposed side of the wall,



In tests, the maximum steel temperatures recorded on the unexposed side of the test specimens decreased when the wall were thicker.

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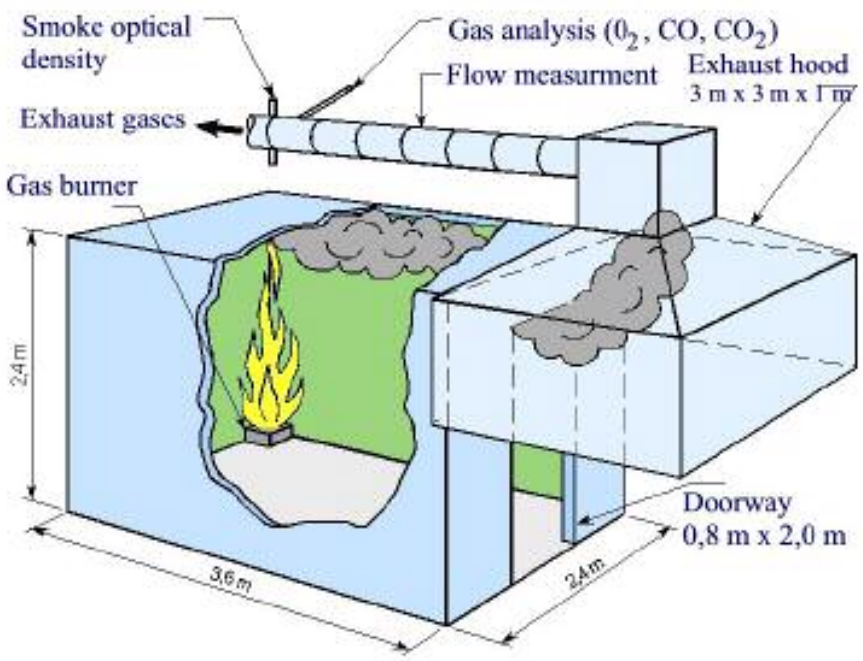
FIRE PROPERTIES OF WALL AND CEILING LININGS:

The measurement of heat release rate (HRR) and smoke production rate (SPR) are direct indicators of the fire hazard. The growth of the HRR enables a lining material to be classified with respect to time based on if or when flashover occurs.

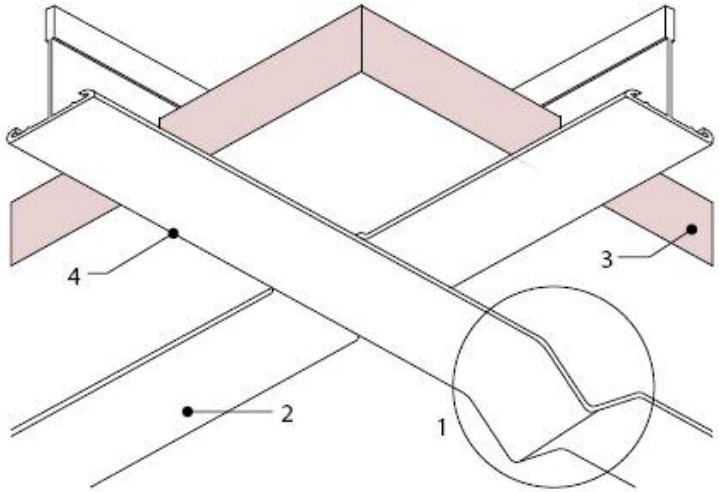


The burner in the corner subjects the test specimen to an exposure of 100 kW/10 min followed by 300 kW/10 minutes. Exhaust gases are removed and analysed to determine oxygen, carbon dioxide (CO_2), carbon monoxide (CO) and optical density.

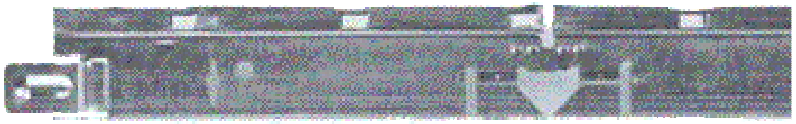
The HRR is calculated by oxygen consumption calorimetry and the SPR is determined from the optical density and flow rate in the duct.

http://www.branz.co.nz/branzltd/publications/pdfs/SR160.pdf

The Fire Resistance Rating of a acoustical ceilings system



A tee notch design of cross tees, allow a controlled collapse due to thermal expansion
(prevents unpredictable twisting, bending and bowing).
The ceiling remains flat to prevent ceiling panels dropping, or gaps occurring.



As Installed

After fire

http://international.usg.com/au/usgen/pdfs/suspension/DONN%20DXL%20Fire%20Rated%208-06%20.pdf

3.5 **Roof: Concession**

A roof need not comply with Table 3 if its covering is *non-combustible* and the building—

(a) has a sprinkler system complying with Specification E1.5 installed throughout; or

(b) has a *rise in storeys* of 3 or less; or

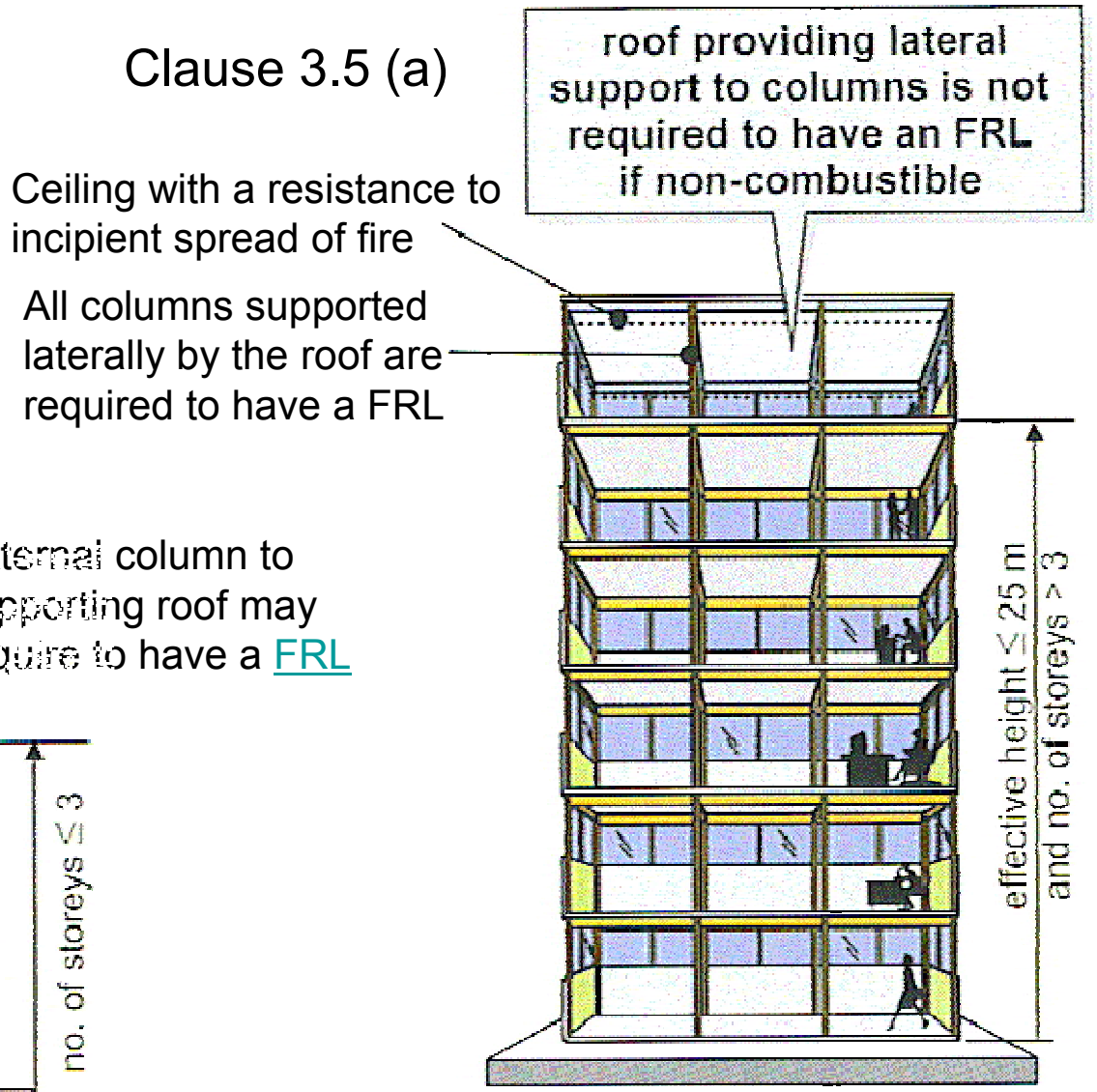
(c) is of Class 2 or 3; or

(d) has an *effective height* of not more than 25 m and the ceiling immediately below the roof has a *resistance to the incipient spread of fire* to the roof space of not less than 60 minutes.

Back to Table 3 (Roofs)

Type A construction

Clause 3.5 (a)



Clause 3.5 (b)

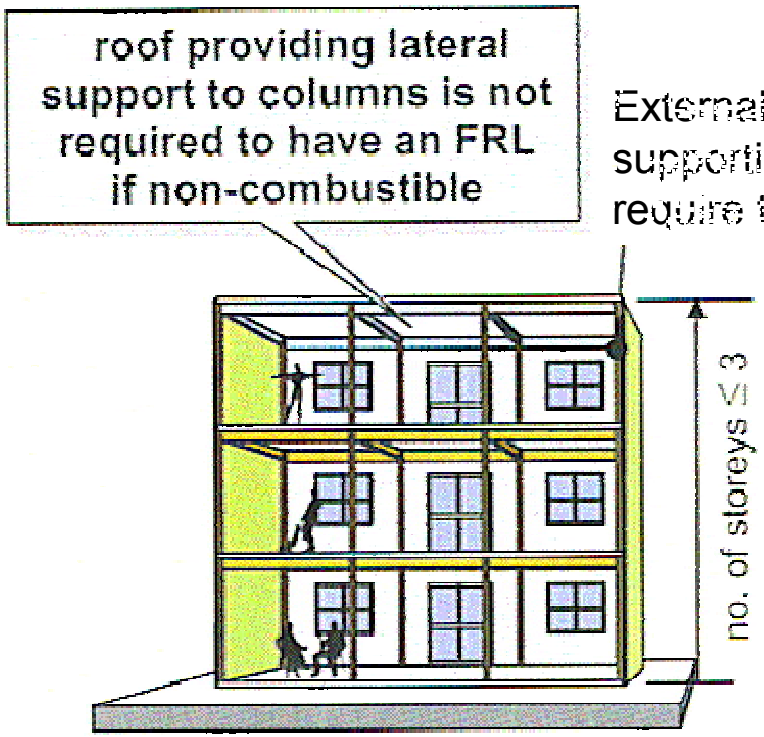


Table 3 TYPE A CONSTRUCTION: FRL OF BUILDING ELEMENTS

Building element	**Class of building — FRL: (in minutes)**			
	Structural adequacy/ Integrity/ Insulation			
	2, 3 or 4 part	**5, 7a or 9**	**6**	**7b or 8**
EXTERNAL WALL (including any column and other building element incorporated therein) or other external building element, where the distance from any *fire-source feature to which it is exposed is*—				
For *loadbearing parts*—				
less than 1.5 m	90/ 90/ 90	120/120/120	180/180/180	240/240/240
1.5 to less than 3 m	90/ 60/ 60	120/ 90/ 90	180/180/120	240/240/180
3 m or more	90/ 60/ 30	120/ 60/ 30	180/120/ 90	240/180/ 90
For non- *loadbearing parts*—				
less than 1.5 m	- / 90/ 90	- /120/120	- /180/180	- /240/240
1.5 to less than 3 m	- / 60/ 60	- / 90/ 90	- /180/120	- /240/180
3 m or more	- / - / -	- / - / -	- / - / -	- / - / -

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Table 3 TYPE A CONSTRUCTION: FRL OF BUILDING ELEMENTS (cont1)

Building element	**Class of building — FRL: (in minutes)**			
	Structural adequacy/ Integrity/ Insulation			
	2, 3 or 4 part	**5, 7a or 9**	**6**	**7b or 8**
EXTERNAL COLUMN not incorporated in an *external wall, where the distance from any fire-source feature to which it is exposed is*—				
less than 3 m	90/ - / -	120/ - / -	180/ - / -	240/ - / -
3 m or more	- / - / -	- / - / -	- / - / -	- / - / -
COMMON WALLS and FIRE WALLS—	90/ 90/ 90	120/120/120	180/180/180	240/240/240
INTERNAL WALLS—				
Fire-resisting lift and stair shafts—				
Loadbearing	90/ 90/ 90	120/120/120	180/120/120	240/120/120
Non- *loadbearing*	- / 90/ 90	- /120/120	- /120/120	- /120/120
Bounding *public corridors, public lobbies and the like*—				
Loadbearing	90/ 90/ 90	120/ - / -	180/ - / -	240/ - / -
Non- *loadbearing*	- / 60/ 60	- / - / -	- / - / -	- / - / -

Table 3 TYPE A CONSTRUCTION: FRL OF BUILDING ELEMENTS (cont2)

Building element	**Class of building — FRL: (in minutes)**			
	Structural adequacy/ Integrity/ Insulation			
	2, 3 or 4 part	**5, 7a or 9**	**6**	**7b or 8**
Between or bounding *sole-occupancy units*—				
Loadbearing	90/ 90/ 90	120/ - / -	180/ - / -	240/ - / -
Non- *loadbearing*	- / 60/ 60	- / - / -	- / - / -	- / - / -
Ventilating, pipe, garbage, and like *shafts* *not used for the discharge of hot products of combustion*—				
Loadbearing	90/ 90/ 90	120/ 90/ 90	180/120/120	240/120/120
Non- *loadbearing*	- / 90/ 90	- / 90/ 90	- /120/120	- /120/120
OTHER LOADBEARING INTERNAL WALLS, INTERNAL BEAMS, TRUSSES				
and COLUMNS—	90/ - / -	120/ - / -	180/ - / -	240/ - / -
FLOORS	90/ 90/ 90	120/120/120	180/180/180	240/240/240
ROOFS	90/ 60/ 30	120/ 60/ 30	180/ 60/ 30	240/ 90/ 60

Table 3.9 REQUIREMENTS FOR CARPARKS

Building element				**FRL (not less than) *Structural adequacy/Integrity/Insulation***
				ESA/M (not greater than)
Wall				
(a)	*external wall*			
	(i)	less than 3 m from a *fire-source feature* to which it is exposed:		
			Loadbearing	60/60/60
			Non- *loadbearing*	- /60/60
	(ii)	3 m or more from a *fire-source feature* to which it is exposed		- / - / -
(b)	*internal wall*			
	(i)	*Loadbearing*, other than one supporting only the roof (not used for carparking)		60/ - / -
	(ii)	supporting only the roof (not used for carparking)		- / - / -
	(iii)	non- *loadbearing*		- / - / -
(c)	*fire wall*			
	(i)	from the direction used as a *carpark*		60/60/60
	(ii)	from the direction not used as a *carpark*		as *required* by Table 3

Back to carpark

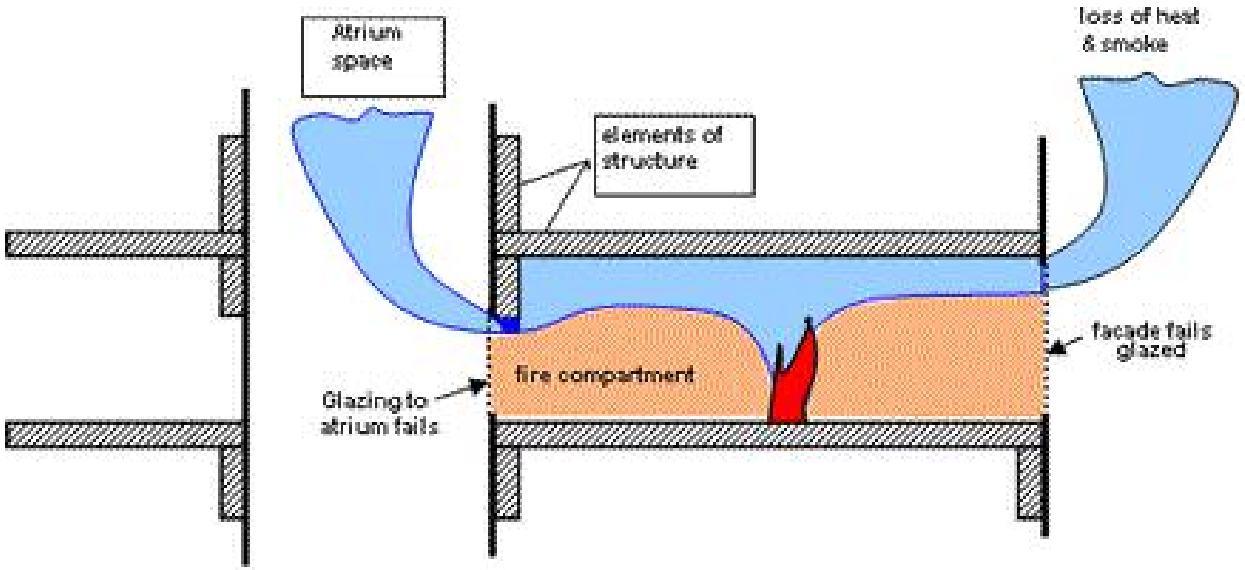
Table 3.9 REQUIREMENTS FOR CARPARKS (cont.)

Building element			FRL (not less than) *Structural adequacy/Integrity/Insulation*
			ESA/M (not greater than)
Column			
(a)	supporting only the roof (not used for carparking) and 3 m or more from a *fire-source feature* to which it is exposed		- / - / -
(b)	steel column, other than one covered by (a) and one that does not support a part of a building that is not used as a *carpark*		60/ - / - or 26 m^2/tonne
(c)	any other column not covered by (a) or (b)		60/ - / -
Beam			
(a)	steel floor beam in continuous contact with a concrete floor slab		60/ - / - or 30 m^2/tonne
(b)	any other beam		60/ - / -
Fire-resisting lift and stair shaft (within the *carpark* only)			60/60/60
Floor slab and vehicle ramp			60/60/60
Roof (not used for carparking)			- / - / -
Notes:	1.	ESA/M means the ratio of exposed surface area to mass per unit length.	
	2.	Refer to Specification E1.5 for special requirements for a sprinkler system in a *carpark* complying with Table 3.9 and located within a multi-classified building.	

Back to ESA/M

Key Factors for Time-Equivalent Analysis

- When a fire reaches a stage where there is full involvement of the combustibles within a compartment (known as flashover), the intensity of the heat in the hot smoke layer will cause glazing and non-fire resisting facades to fail, allowing hot gases to escape (see Figure below).
- Similarly, openings to atria will also allow hot gases to escape. The temperatures reached in a compartment and the duration of a fire depend on natural ventilation through openings to atria and glazing or non-fire
- resisting facades that fail in a fire.



http://www.mace.manchester.ac.uk/project/research/structures/strucfire/CaseStudy/steelComposite/default.htm

Thermal expansion

The linear expansion of a heated solid or liquid can be measured by a quantity α, the coefficient of linear expansion. This coefficient is defined in such a way that it measures the percentage change in the length per degree temperature change.

$$\Delta L = \alpha \times L_0 \times \Delta T$$

$$L = L_0 \times (1 + \alpha \times \Delta T)$$

$$L_0 = \frac{\Delta L}{\alpha \times \Delta T}$$

$$\alpha = \frac{\Delta L}{L_0 \times \Delta T}$$

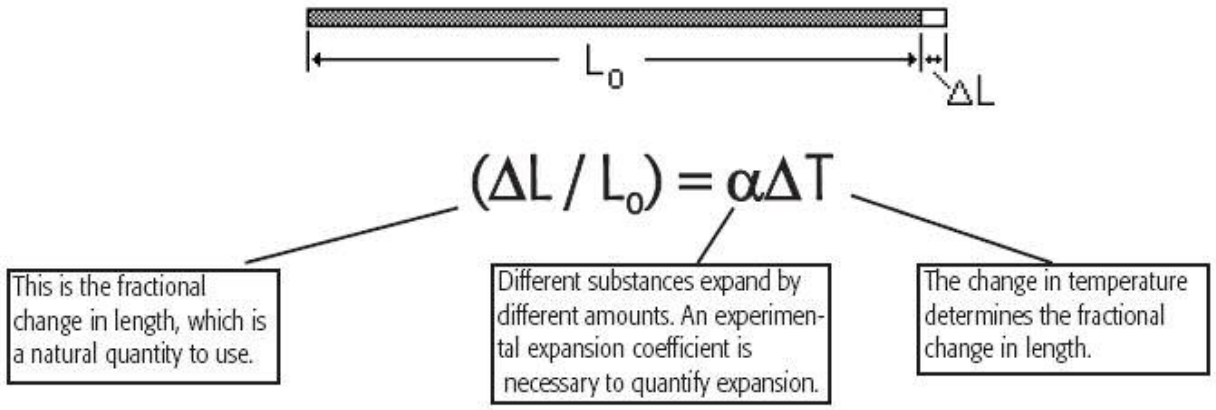
α = Coefficient of linear expansion
ΔL =Change in length
ΔT = Change in Temperature

Coefficient of Linear Expansion of Material

Coefficients of Thermal Expansion at 20° for different materials

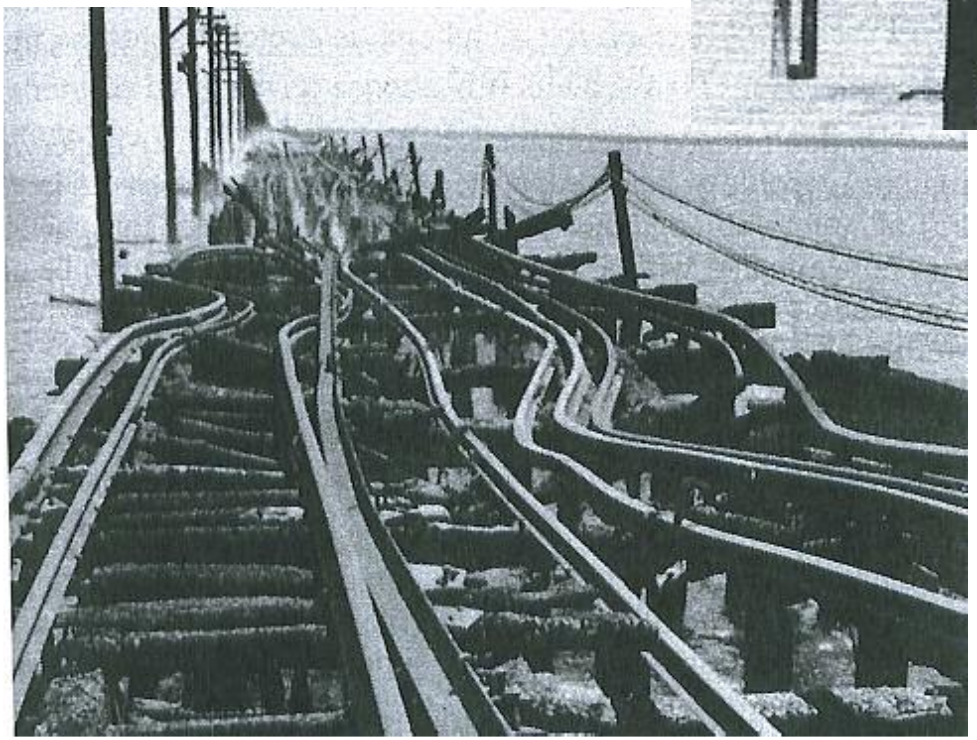
Material	Linear Coefficient α (1/ °C)
Aluminum	24 x 10^{-6}
Brass	19 x 10^{-6}
Copper	17 x 10^{-6}
Glass (ordinary)	9 x 10^{-6}
Glass (Pyrex)	3 x 10^{-6}
Iron/Steel	12 x 10^{-6}
Concrete	12 x 10^{-6}
Timber	4 x 10^{-6}

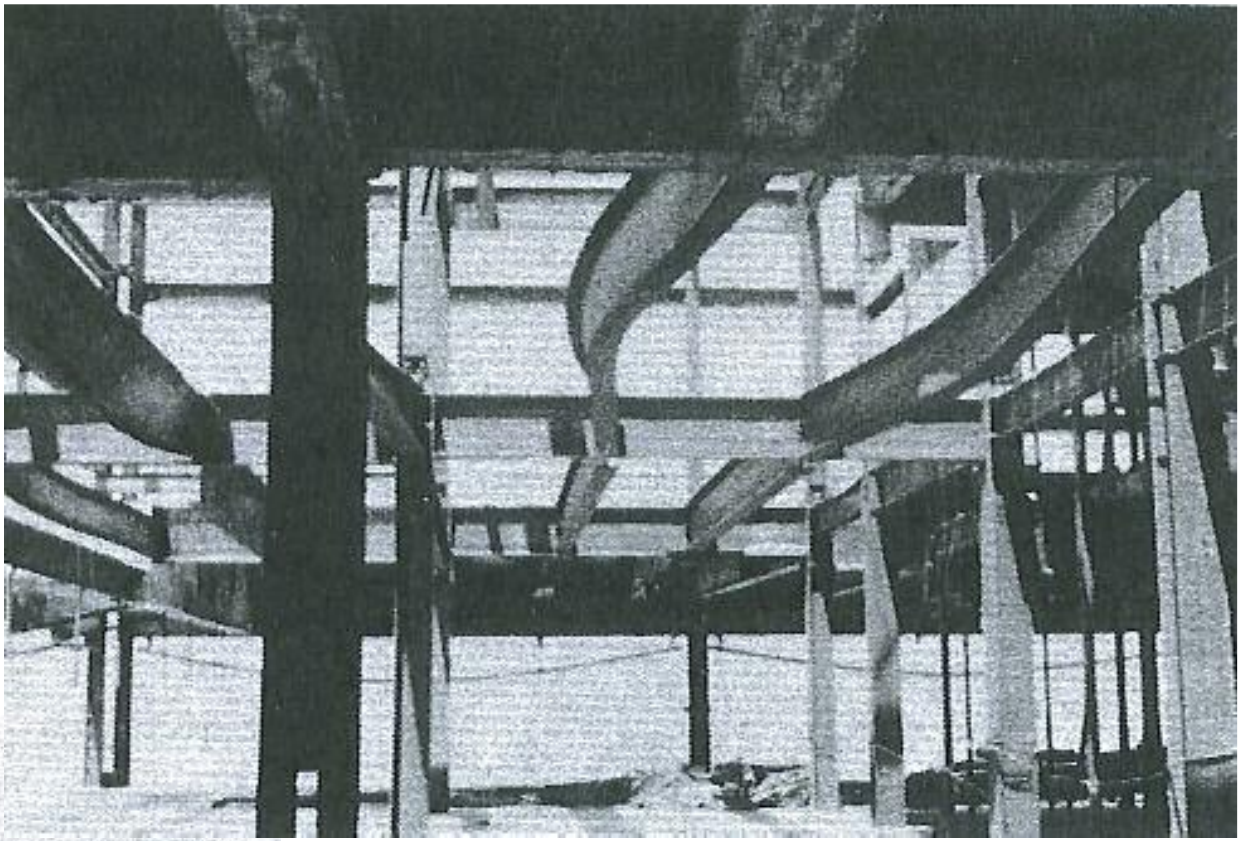
$$\Delta L = \alpha \times L_0 \times \Delta T$$



Thermal Expansion Damage

Thermal expansion of the rail line through fire





Unprotected steel damage in a high-rise building.

Fire load was minimal, the loss extensive

Mechanism of Fire Spread

- **Conduction**

  (Heat transfer to another body or within a body by direct contact.)

- **Radiation**

  (Heat transfer by way of electromagnetic energy.)

- **Convection**

  (Heat transfer by circulation within a medium, such as a gas or a liquid.)

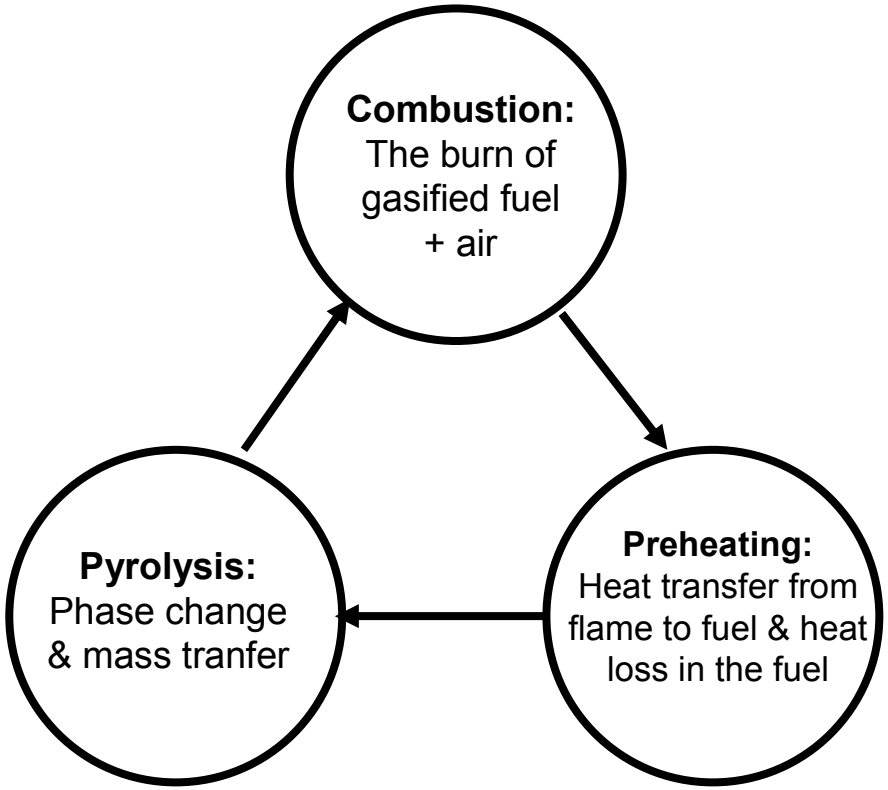
- **Pyrolysis**

  (The transformation of a compound into one or more other substances by heat alone. Pyrolysis often precedes combustion. Irreversible chemical decomposition caused by heat, usually without combustion.)

- **Mass transfer**

  (Physical processes that involve molecular transport of atoms and molecules)

Depiction of the flame spread mechanism on solid fuel



Flame spread phenomenon includes three major componens:

- Preheating unburned fuel
- Pyrolyzing combustible material,
- Burning gaseous fuel.

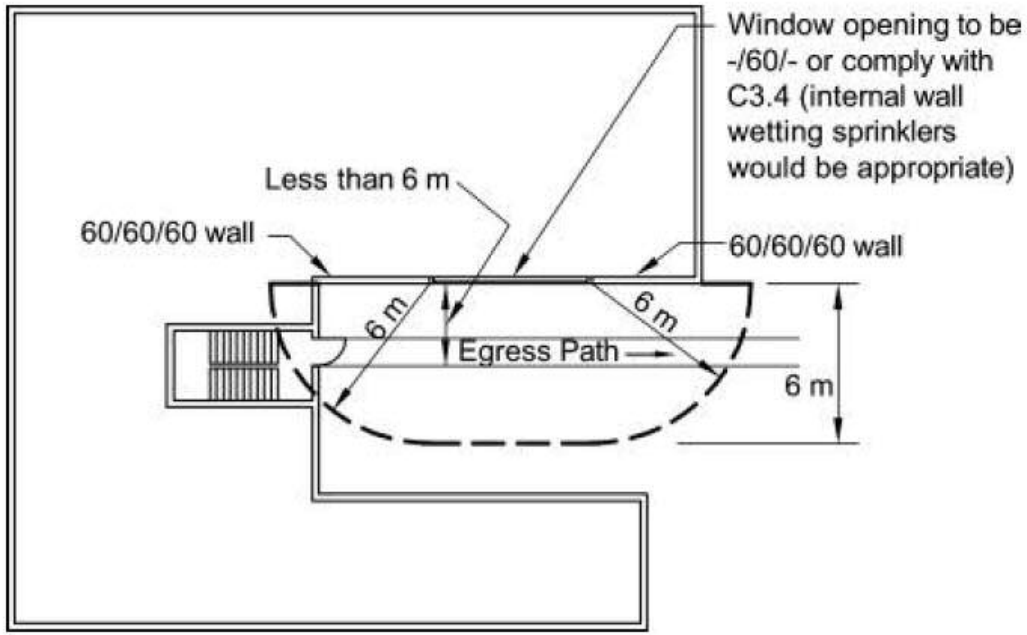
These three parts are connected by heat transfer, flow dynamics and other transport phenomena.

Accsess & Egress to fire

- In a fire engineering approach the conditions for failure and its consequences should be set in a **qualitative design review** for the particular building or structure concerned.
- Some of these may be more or less onerous than the traditional specifications given in Standardised test methods but should be prescribed to suit the particular circumstances and their potential impact on the overall safety of the building and its occupants.
- All enclosures can initially be considered as a compartment until one of the conditions for fire spread has been achieved.

Egress & Assess to Fire Isolated Stairs

- In assessing fire compartementtation / separation the fire rating of external walls which are adjacent to the discharge form fire isolated stairs, must be considered.
- The diagram indicates a scenario where the discharge from the fire isolated stirs is within 6 meters of the building and windows.
- The wall is to have a FRL of 60/60/60 from both directions and the window opening must be appropriately protected, for a full source for Q 1b)ii) appropriate treatment. (BCA D1.7)



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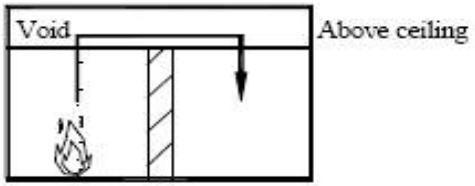
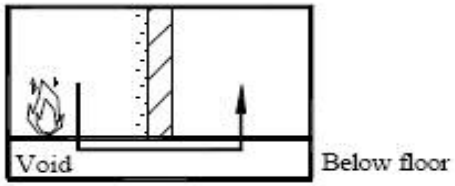
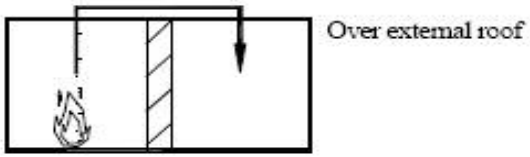
Methods of Direct Fire Spread



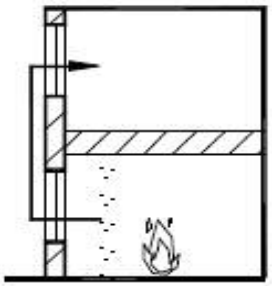
Spread Route:
1. Enclosure to ceiling void
2. Void to adjacent enclosure



Spread Route:
1. Enclosure to floor void
2. Void to adjacent enclosure



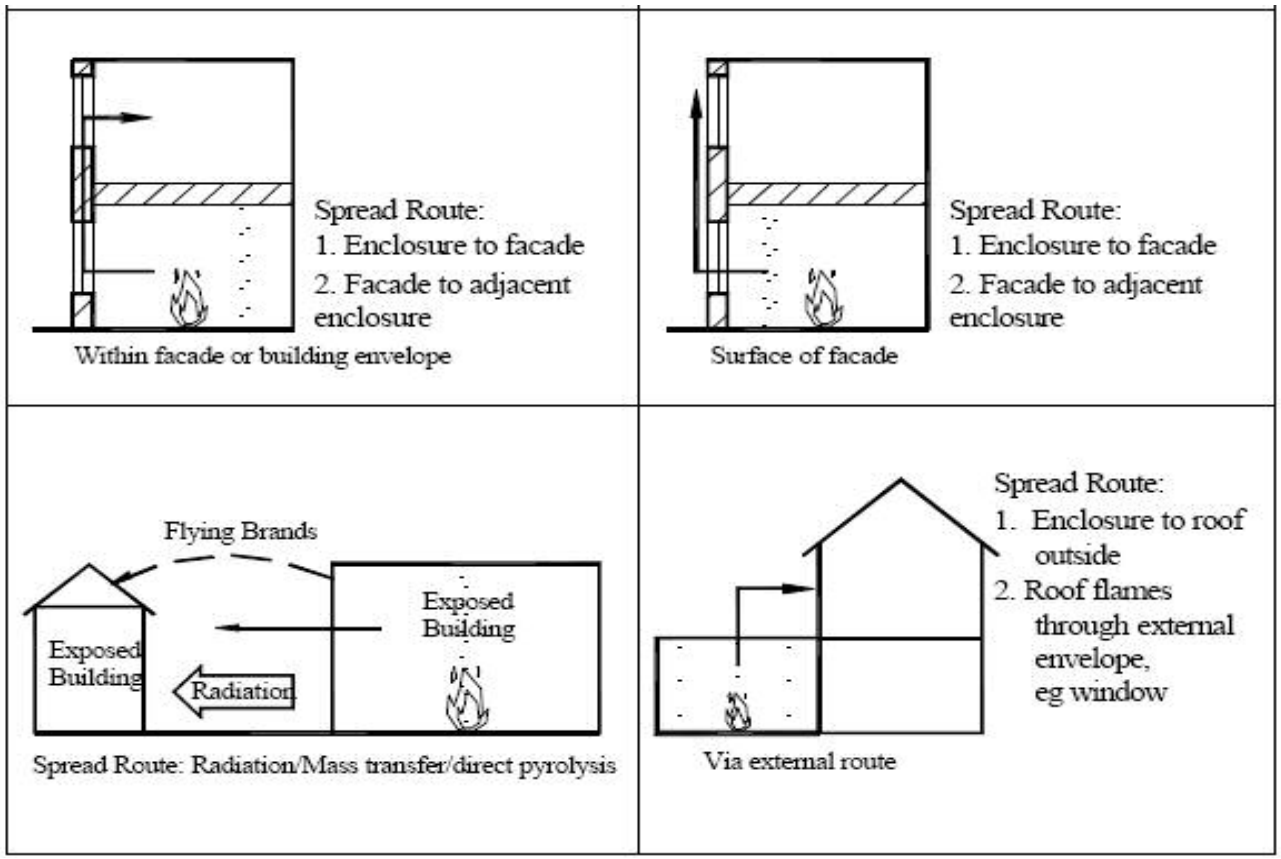
Spread Route:
1. Enclosure to roof
2. Roof to adjacent enclosure



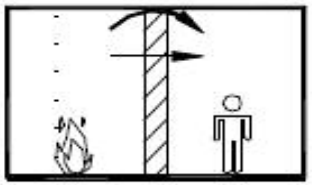
Spread Route:
1. Enclosure to outside
2. Outside to adjacent enclosure

Via windows

Methods of Direct Fire Spread

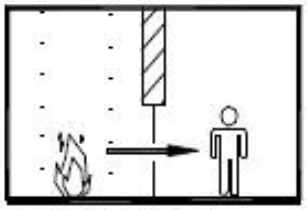


Methods of Direct Fire Spread



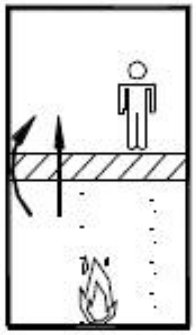
Through wall or openings created in wall

Spread Mechanism: Conduction, convection
Direct Pyrolysis (collapse)



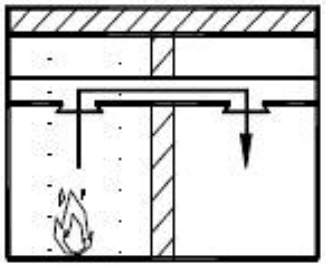
Through fixed opening

Spread Mechanism: Convection, Radiation
Direct Pyrolysis
Mass Transfer



Through floor

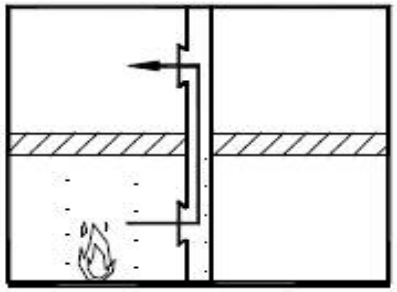
Spread Mechanism: Conduction, Convection
Direct Pyrolysis (collapse)



Along or through Horizontal Duct

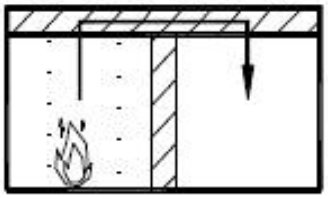
Spread Mechanism: Conduction, convection

Methods of Direct Fire Spread



Along or through Vertical Duct

Spread Mechanism: Conduction, convection

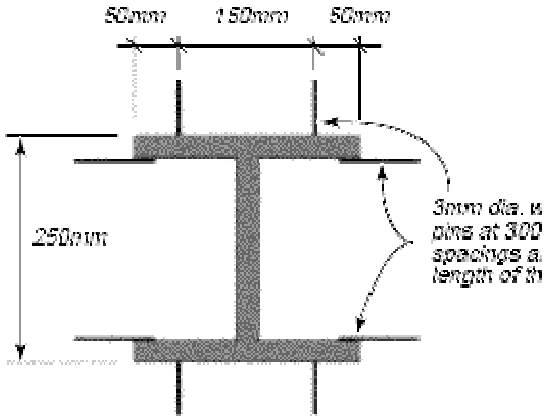


Spread Mechanism: Direct pyrolysis

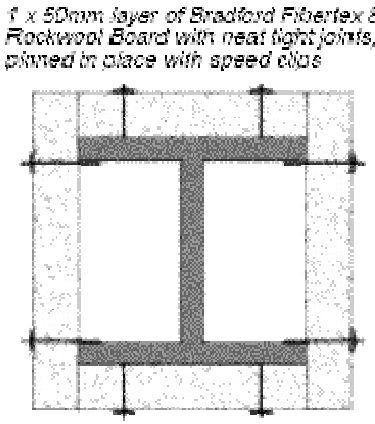
http://fire-research.group.shef.ac.uk/steelinfire/downloads/BRK_mech_stiff_2001.pdf

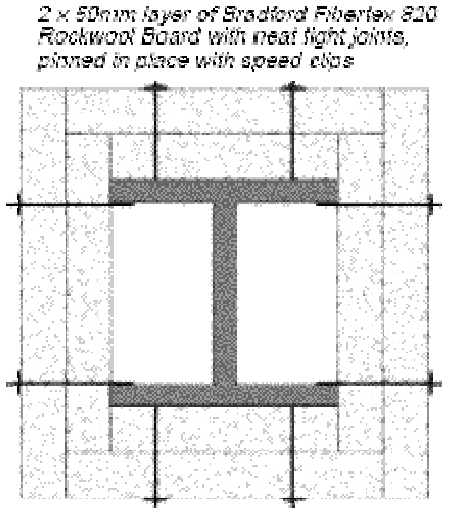
- BRADFORD FIRE PROTECTION FOR A TYPICAL STEEL COLUMN

CSR Bradford Insulation manufactures a range of very high density and fire rated Bradford Fibertex™ 820 Rockwool boards for installation around steel columns and beams.
Figure below shows a typical installation design for these applications.



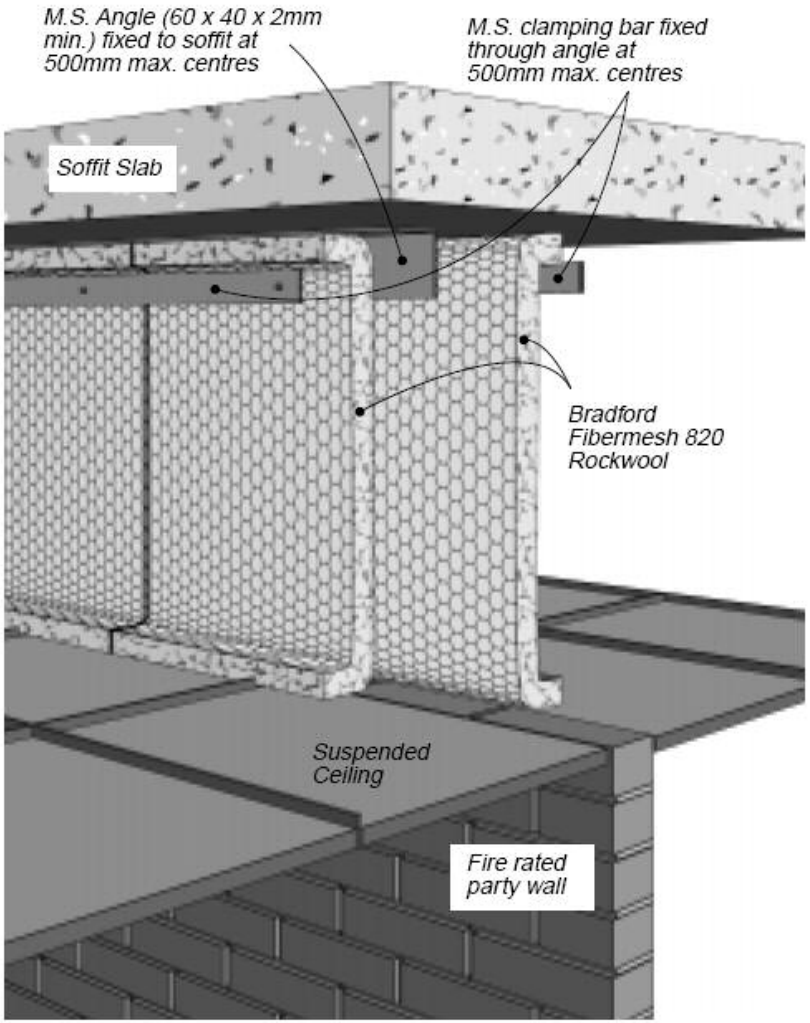
Fire Testing of Building Materials



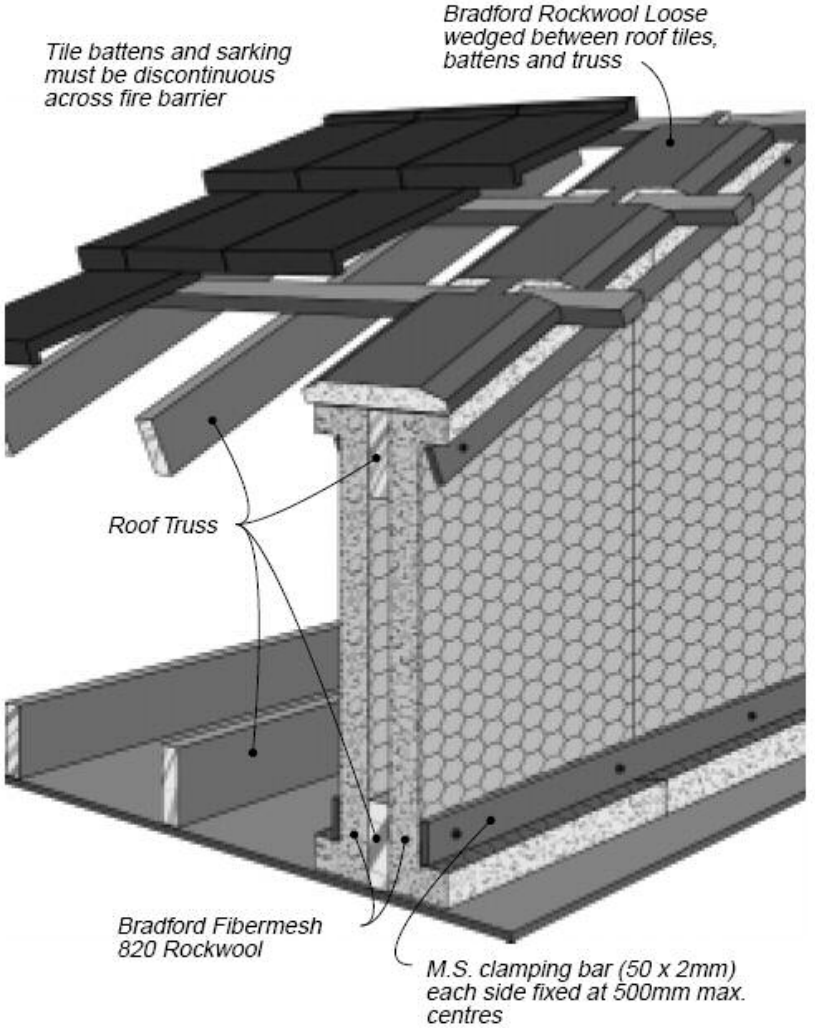


http://www.bradfordinsulation.com.au/technical/designguide/bradford/wBI105pg01_36.pdf

BRADFORD FIRE BARRIER STOP BETWEEN A MASONRY SOFFIT AND MASONRY WALL.

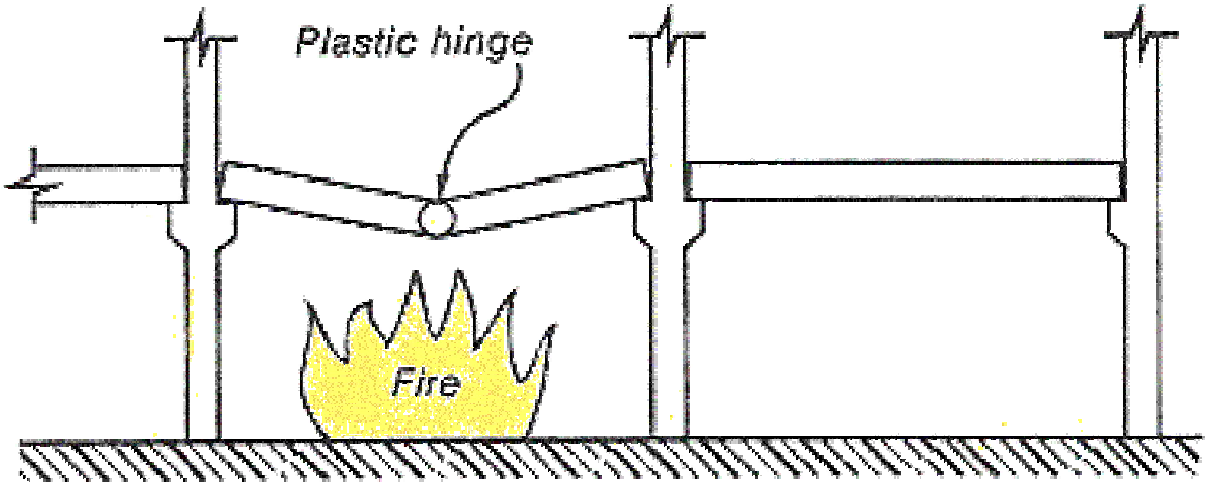


BRADFORD FIRE BARRIER STOP FOR A TRUSSED ROOF SPACE.

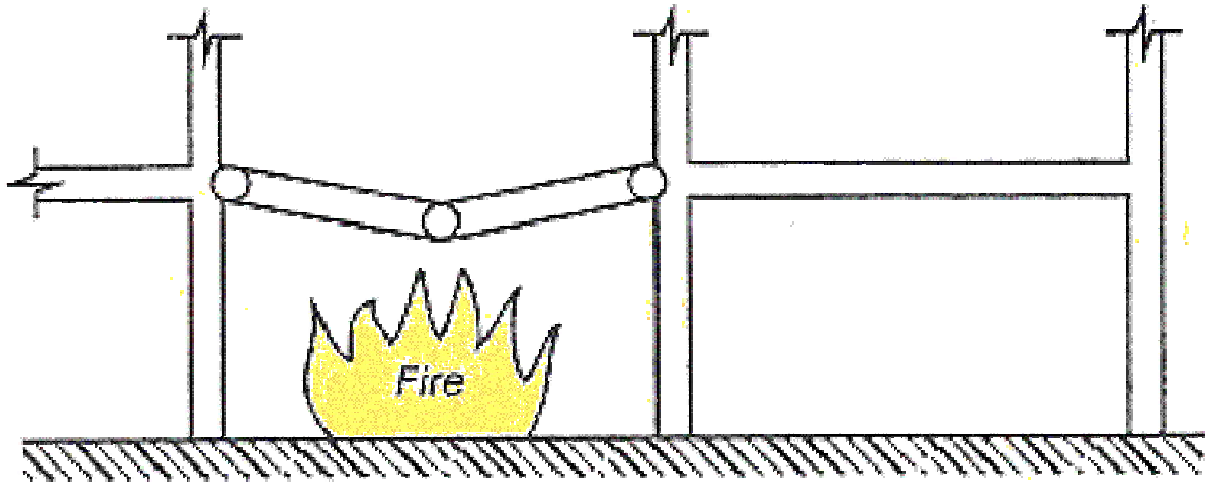


http://www.bradfordinsulation.com.au/technical/designguide/bradford/wBI105pg01_36.pdf

A simply supported beam will fail as soon as one plastic hinge forms in the beam. At this point the flexural capacity of the beam is same as the applied moments.



For a continuous beam the failure will not occur until three hinges are formed, thus increasing the fire resistance level of the structure.

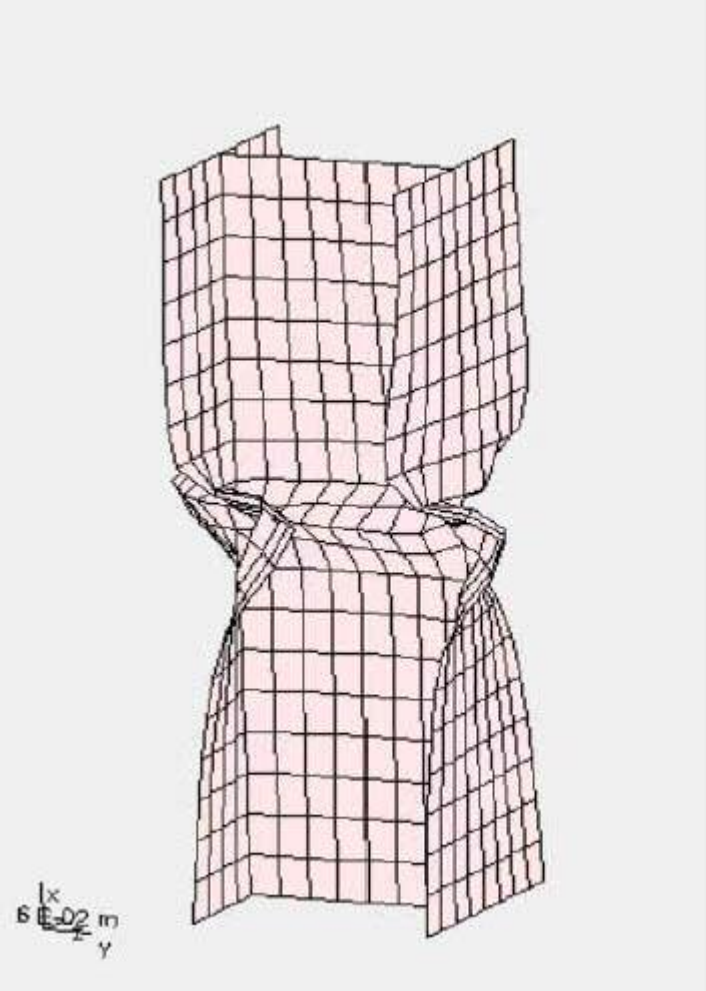


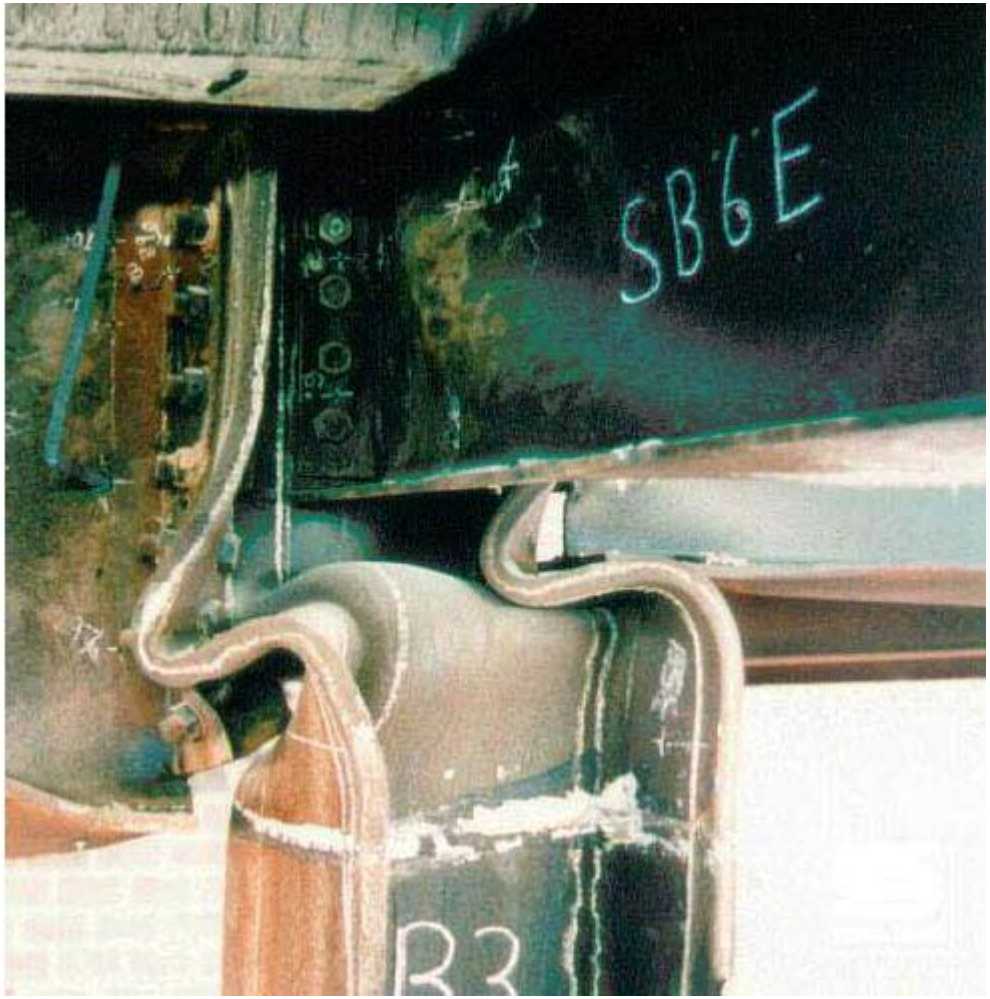
http://eprints.usq.edu.au/archive/00002230/01/GOUNDER_Sanjeevam-2005.pdf.pdf

Other Standards requirements

- AS 4100 Section 12
- AS 3600 Section 5
- AS 1720.4 Glum-lam Members

Modeling of the behavior of steel and composite structures exposed to sustained fires.





http://www.fire.nist.gov/bfrlpubs/fire02/PDF/f02043.pdf

Timber and Fire

The **fire ratings** can be achieved with timber by using a combination of all or some of the following:

- Fire grade lining – fire grade plasterboard or a combination of fire grade plasterboard and fibre cement. The timber takes longer to get to ignition temperature, and can remain functional for a longer period while the fire is burning.
- Fire stop – fire grade material used to close a gap or imperfection of fit that occurs where a service passes through a fire rated element or system to prevent spread of fire.
- Intumescent sealant – a fire resistant material used in fire grade linings (at joints, penetrations etc) which expands when exposed to fire to fill and/or seal gaps.
- Fire resistant Mineral wool – compressible, non-combustible, fire resistant material used to fill cavities or restrict the passage of smoke or gas.
- Over-sizing. – The timber can be oversized so that allowing for loss of material charring throughout the burn period, there will still be enough timber