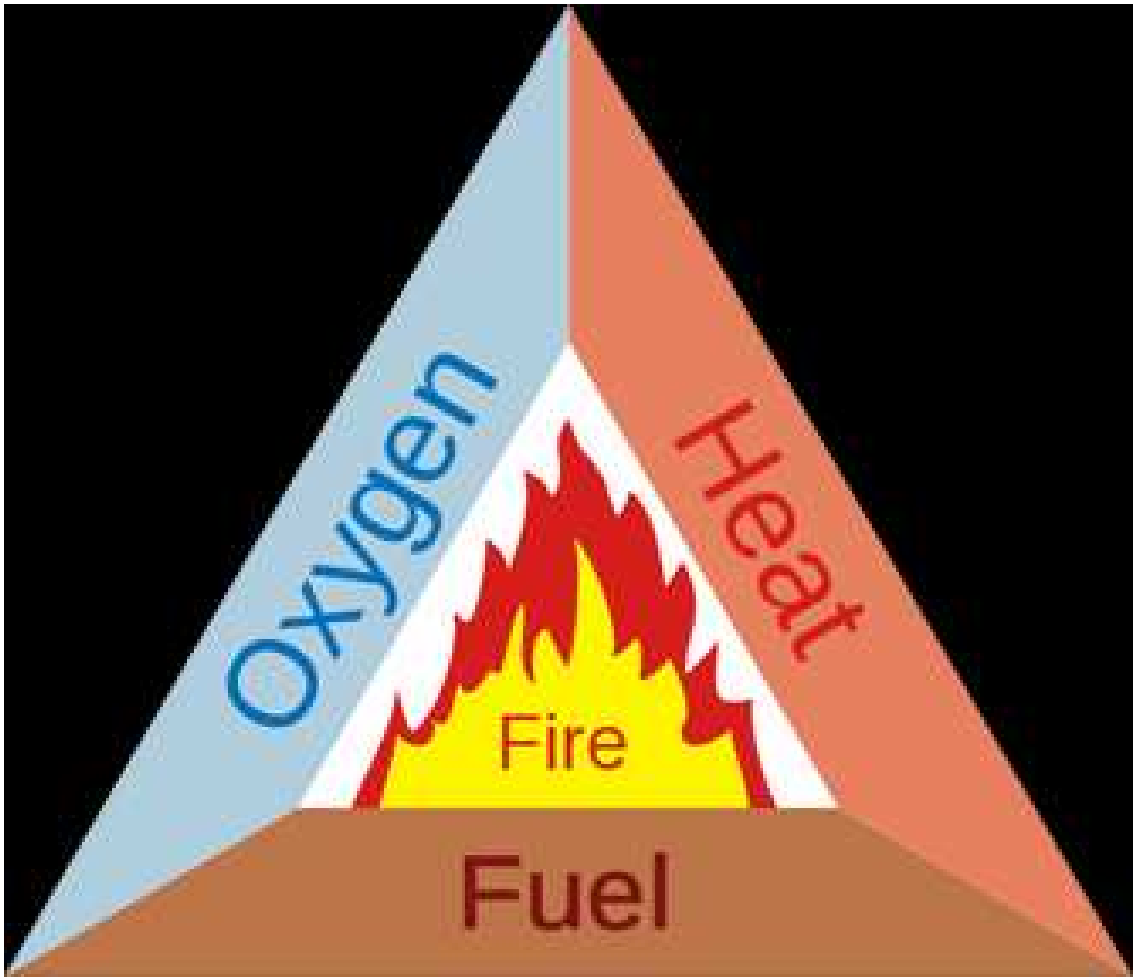
Fire Technology

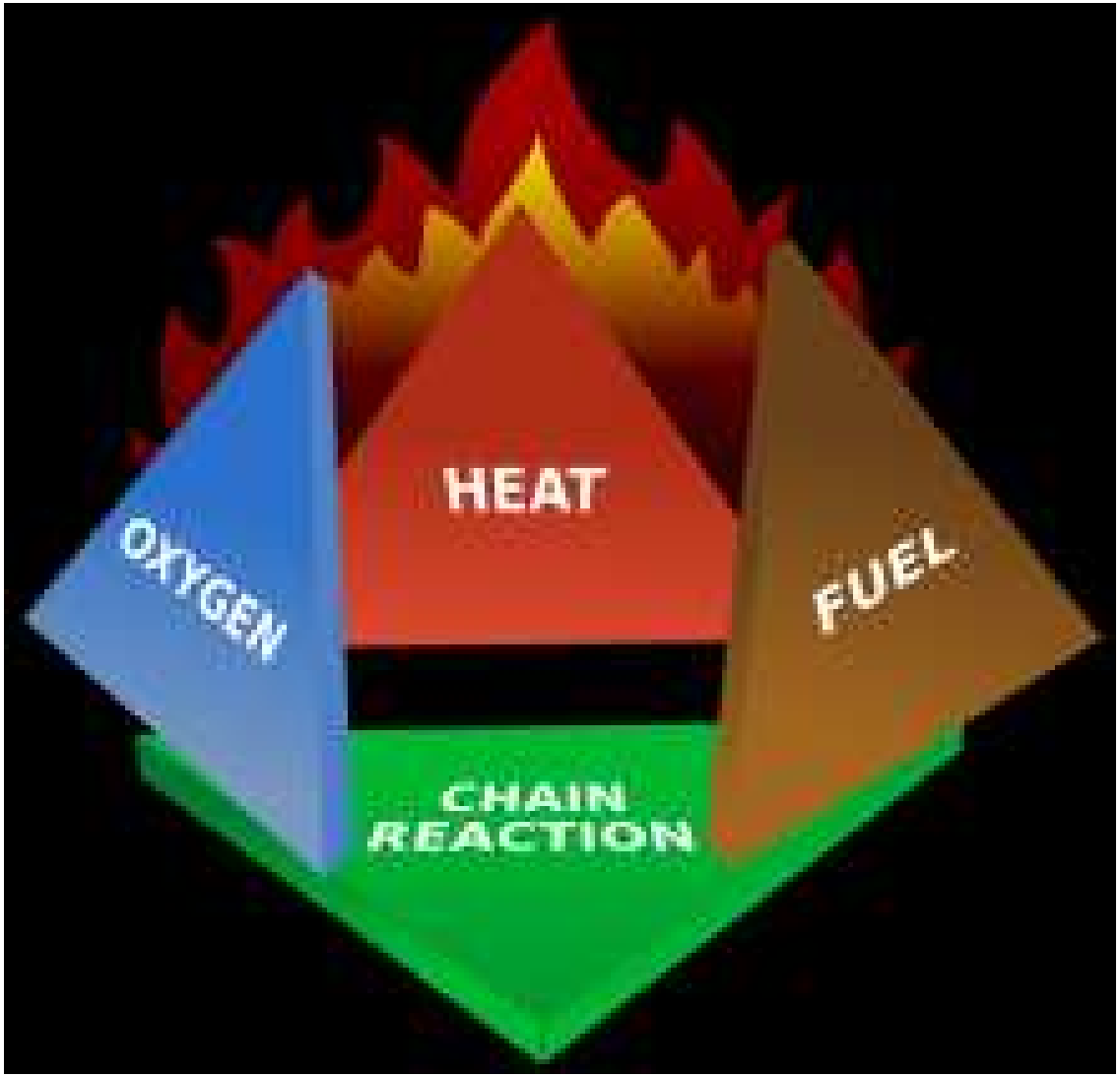
CONTENTS

1. INTRODUCTION



Fire Triangle

(火三角)



Fire Tetrahedron

(火四面體)

1.1. FIRE PROTECTION

From the fire tetrahedron, we learnt that we could stop fire by obstructing the chain reaction(s), hence, by means of:

- Reduce the fuel
- Reduce the oxygen
- Reduce the heat

Is it possible?

For the sake of fire safety in building, we have implemented measures to overcome this issue, for example:

Element of Fire Triangle	Method to Reduce the Element
Fuel	The authority had implemented rules & regulation on the use of non-combustible materials for the furniture.
Oxygen	CO_2 type portable fire extinguisher to dilute the oxygen content of the air around the fire
Heat	Wet type fire fighting equipment to lower the temperature

However, victims of a fire disaster are usually died of smoke inhalation.

Hence, Beside putting out the fire, it is crucial for us to evacuate people out of

the premises asap at time of fire and implement some measures to control the spread of smoke, esp. for those premises with high nos of people, e.g. theatre, cinema, shopping arcade, etc.

1.2. COMPARTMENT FIRE DEVELOPMENT

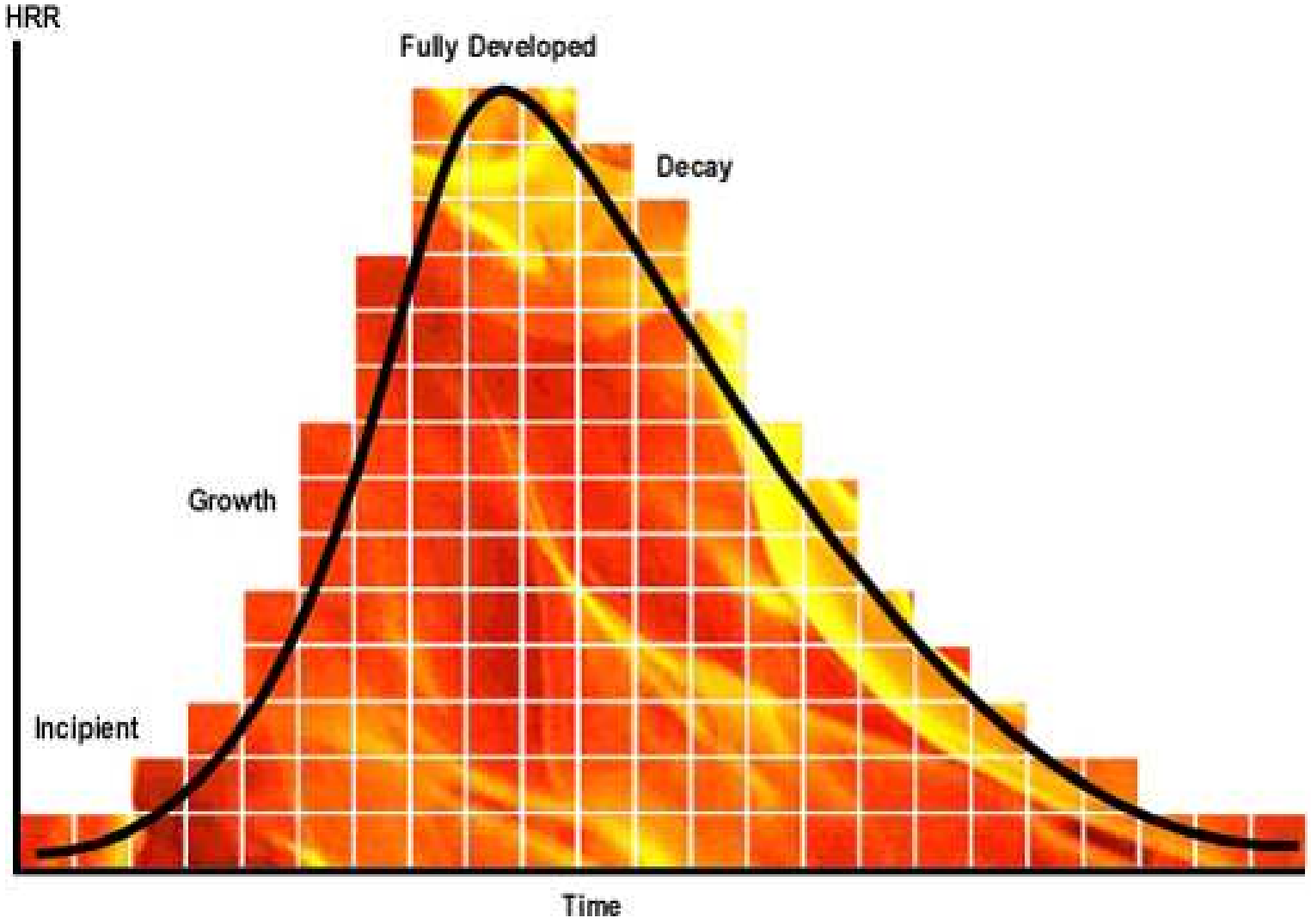
Part of the process of reading the fire involves recognizing the stages of fire development and burning regime (e.g., fuel or ventilation controlled). Fire conditions can vary considerably throughout the building with one compartment containing a fully developed fire, an adjacent compartment in the growth stage, and still other compartments yet uninvolved.

Similarly, burning regime may vary from compartment to compartment.

Recognizing the stages of fire development and burning regime allows firefighters to predict what is likely to happen next (if action is not taken), potential changes due to unplanned ventilation (such as failure of a window), and the likely effect of tactical action.

Compartment fire development can be described as being comprised of four stages: incipient, growth, fully developed and decay. Flashover is not a stage of development, but simply a rapid transition between the growth and fully developed stages.

Figure: Heat Release Rate (HRR) and Fire Development



Compartment fires do not always follow the simple, idealized fire development curve illustrated in the figure. The speed with which the fire develops, peak heat release rate, and duration of burning are dependent on both the characteristics of the fuel involved and ventilation profile (available oxygen).

Going back to the basics of fire behavior, ignition requires heat, fuel, and oxygen. Once combustion begins, development of an incipient fire is largely dependent on the characteristics and configuration of the fuel involved (fuel controlled fire). Air in the compartment provides adequate oxygen to continue fire development. During this initial phase of fire development, radiant heat warms adjacent fuel and continues the process of pyrolysis. A plume of hot gases and flame rises from the fire and mixes with the cooler air within the room. This transfer of energy begins to increase the overall temperature in the

room. As this plume reaches the ceiling, hot gases begin to spread horizontally across the ceiling. Transition beyond the incipient stage is difficult to define in precise terms. However, as flames near the ceiling, the layer of hot gases becomes more clearly defined and increase in volume, the fire has moved beyond its incipient phase and (given adequate oxygen) will continue to grow more quickly.

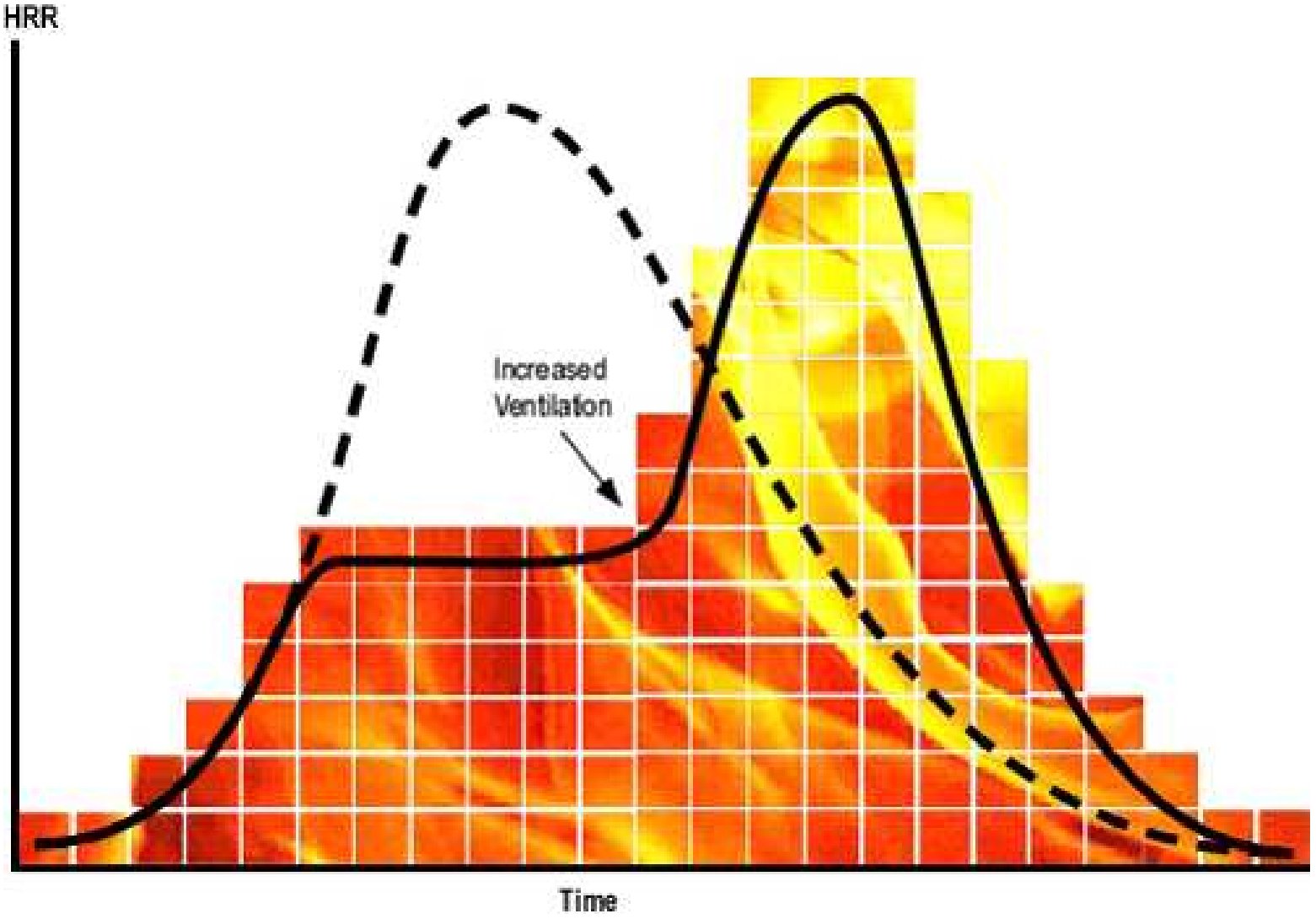
Depending on the size of the compartment and ventilation profile, there may only be a limited indication (or no indication at all) from the exterior of the building that an incipient stage fire is burning within.

1.3. HAZARD OF VENTILATION CONTROLLED FIRES

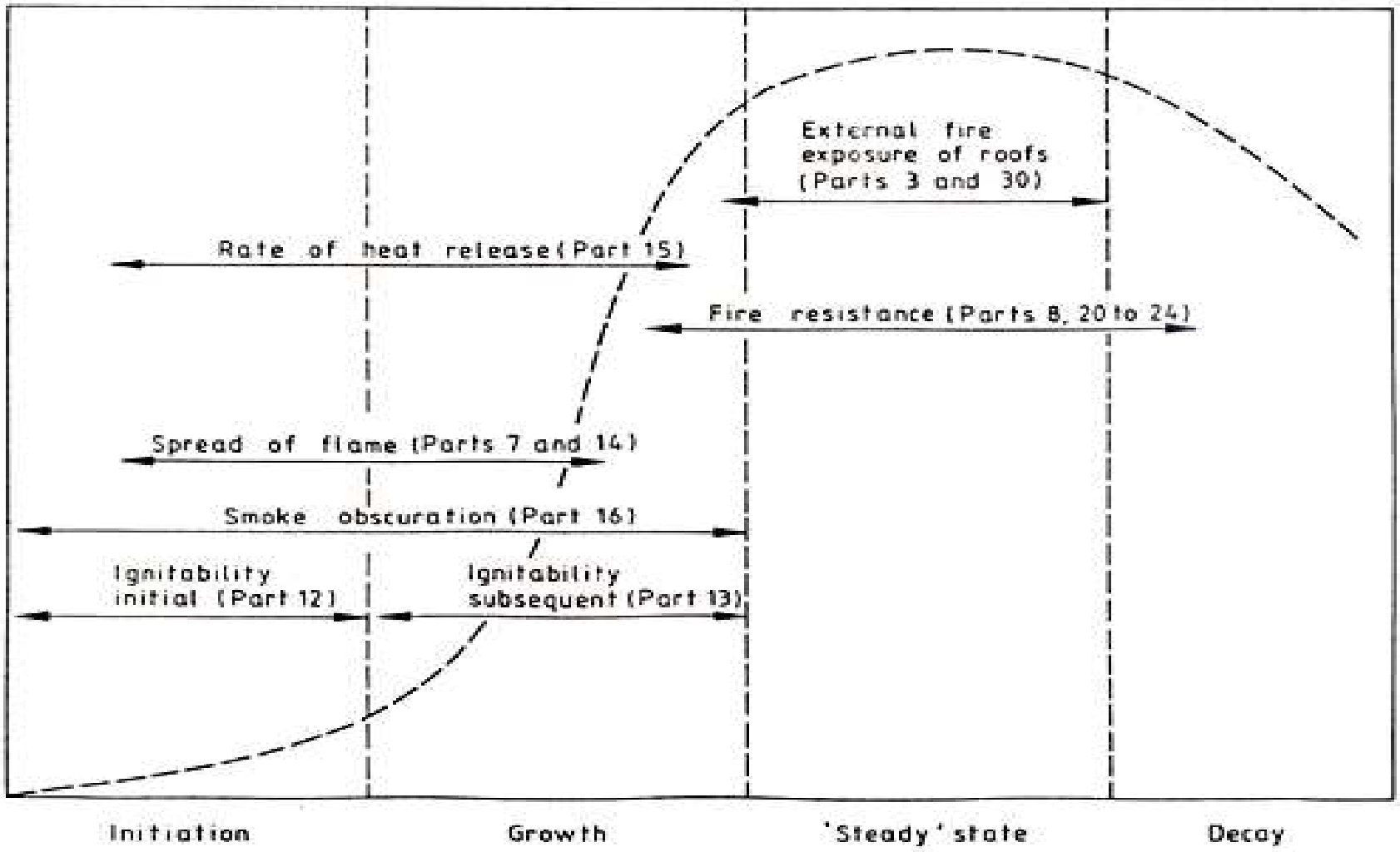
Many if not most fires that have progressed beyond the incipient stage when the fire department arrives are ventilation controlled. This means that the heat release rate (the fire's power) is limited by the ventilation profile, in particular, the existing openings.

If ventilation is increased, either through tactical action or unplanned ventilation resulting from effects of the fire (e.g., failure of a window) or human action (e.g., exiting civilians leaving a door open), heat release rate will increase, potentially resulting in a ventilation induced flashover as illustrated in the following figure.

Figure: Ventilation Induced Flashover

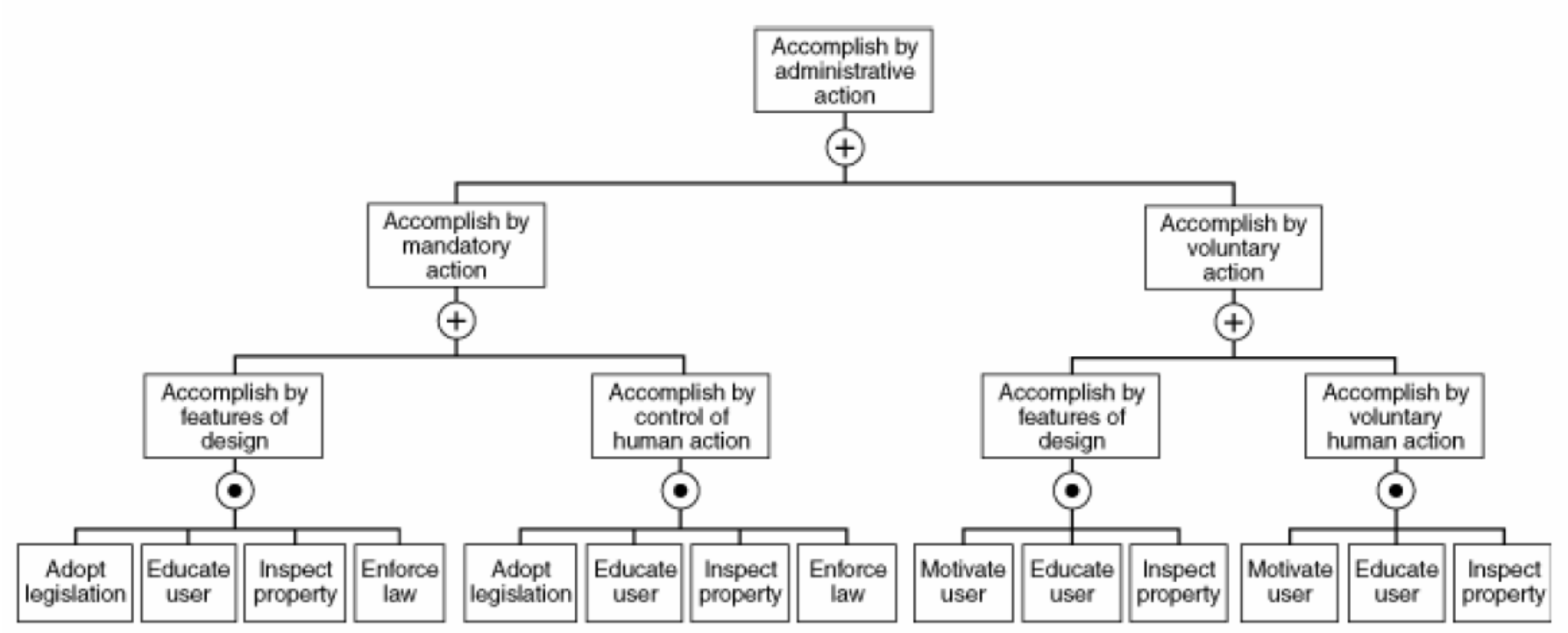


1.4. STAGES OF FIRE & CORRESPONDING BS 476 STANDARDS



BS No.	BS476 - Fire tests on building materials and structures	No. of pages of the basic BS
BS476: Part 3:	External fire exposure roof test	16
BS476: Part 4:	Non-combustibility test for materials	12
BS476: Part 6:	Method of test for fire propagation for products	20
BS476: Part 7:	Surface spread of flame tests for materials	20
BS476: Part 10:	Guide to the principles and application of fire testing	12
BS476: Part 11:	Method of assessing the heat emission from building materials	20
BS476: Part 12:	Method of measuring the ignitability of products using direct flame impingement	20
BS476: Part 13:	Method of measuring the ignitability of products subjected to thermal irradiance	36
BS476: Part 15:	Method of measuring the rate of heat release of products	40
BS476: Part 20:	Method for determination of the fire resistance of elements of construction (general principles)	40
BS476: Part 21:	Method for determination of the fire resistance of loadbearing elements of construction	20
BS476: Part 22:	Method for determination of the fire resistance of non-loadbearing elements of construction	24
BS476: Part 23:	Method for determination of the construction of components of the fire resistance of a structure	20
BS476: Part 24:	Method for the determination of the fire resistance of ventilation ducts	24
BS476: Part 31:	Method for measuring smoke penetration through door sets and shutter assemblies	
BS476:Section 31.1:1983	Method of measurement under ambient temperature conditions	12
BS476: Part 32: 1989	Guide to full scale fire tests within buildings	16
BS476: Part 33: 1993	Full-scale room test for surface products	40

1.5. NFPA STANDARD 550 - NFPA FIRE SAFETY CONCEPT TREE



This concept tree can be used as tools for effective communication amongst different parties.

2. FIRE TERMINOLOGY

2.1. FIRE RESISTANCE

During a fire test of a product's or a construction's fire resistance the properties are determined when exposed to a certain heat exposure, normally an equivalent room fire. The fire resistance is one or several properties of the assembled construction/product and consequently not a sole property of the incorporated materials. The construction can then be classified in different fire technical classifications.

2.2. COMPARTMENTATION

A compartment in premises is formed by the structural enclosures, e.g. reinforced wall, FRP door, fire dampers, etc. Compartmentalization in structures, such as land-based buildings, traffic tunnels, ships, aerospace vehicles, or submarines, is the fundamental basis and aim of passive fire protection. The idea is to subdivide a structure into "fire compartments", which may contain single or multiple rooms for the purpose of limiting the spread of fire, smoke and flue gases, in order to enable the three goals of fire protection:

- life safety
- property protection
- continuity of operations.

2.3. FIRE PRECAUTIONS

Fire safety refers to precautions that are taken to prevent or reduce the likelihood of a fire that may result in death, injury, or property damage, alert those in a structure to the presence of a fire in the event one occurs, better enable those threatened by a fire to survive, or to reduce the damage caused by a fire. Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building.

2.4. FIRE PREVENTION

The goal of fire prevention is to educate the public to take precautions to prevent fires, and be educated about surviving them. It is a proactive method of reducing emergencies and the damage caused by them.

2.5. FIRE PROTECTION

Fire protection is the study and practice of mitigating the unwanted effects of fires. It involves the study of the behaviour, compartmentalisation, suppression and investigation of fire and its related emergencies, as well as the research and development, production, testing and application of mitigating systems.

2.6. F.R.P. (FIRE RESISTANCE PERIOD)

FRP means the period for which the element of construction is capable of resisting the action of fire. E.g., a fire resisting door is a door which, together with its frame can stand for certain hours of fire.

2.7. FIRE LOAD

The total fuel contributed to a fire by a building's contents, combustible materials used in its construction, and/or its finishes.

3. THE EFFECTS OF FIRE ON MATERIALS AND STRUCTURE

Materials are classified as combustible or non-combustible by identifying those which made little or no thermal contribution to the heat of the furnace and do not produce a flame, and by calling the remainder 'combustible'.

3.1. COMBUSTIBILITY AND NON-COMBUSTIBILITY

BSI BS 476-4: 1970, Fire tests on building materials and structures — Part 4: Non-combustibility test for materials, this document includes definition of non-combustibility. Determines whether materials; with or without coatings; used in construction or finishing of buildings meet the definition.

3.2. NON-COMBUSTIBLE MATERIALS

The non-combustible materials have the following characteristics:

- do not contribute to the growth of fire
- most of the structural members are of this type
- can be danger if the critical temperatures for the materials is reached; the following may happen:
  - decomposition
  - fusion
  - deflection
  - loss of strength

For example:

- steel - loss of strength, expand, bend, buckle.
- Concrete -spalling, loss of cover

4. THE EFFECTS OF FIRE ON MATERIALS AND STRUCTURE

4.1. COMBUSTIBLE MATERIALS

- contribute to growth of fire as fuel
- spread of flume
- for example : wood, paints, wall paper, petroleum, plastic etc.

5. GENERAL BEHAVIOUR OF MATERIALS IN FIRE

5.1. TIMBER

- 220 to 300 ℃
- Charring – insulation
- No significant loss in strength

5.2. TIMBER PRODUCT

- Ease of ignition
- Rapid spread

5.3. CONCRETE

- Disintegrates at 400-500 ℃

- Cover to project steel bars
- Loss of strength above 600℃

5.4. STONE

- Loss in strength at 575 ℃

5.5. PLASTIC

- Combustible
- Toxic smoke
- Charring at 400 ℃ and burn at 700-900 ℃

5.6. CLAY PRODUCTS

- Fusion above 1000 ℃

- Can resist building fire

5.7. BRICK – GOOD RESISTANCE TO FIRE

5.8. STEEL

- increase in strength up to 250 ℃,
- return to normal strength at 400 ℃ followed
- rapid loss of strength at the critical temperature 550 ℃
- High strength steels behave similar to mild steel
- for pre-stressed concrete tendons the critical temperature is 400 ℃
- high thermal expansion can be a problem eg. 10m @ 550℃ be expanded by app. 60 mm
- spread the fire on the reverse side

- unprotected solid steel - 1/2 FRP
- unprotected structural steels in an open space

5.9. ALUMINIUM

- loss strength rapidly, critical temperature is about half of steel, melting point is about 650 ℃
- thermal expansion is about twice of steel
- a higher standard is required if aluminium is used
- aluminium cladding, common application of aluminium, does not survive for long in fires

6. FIRE PROTECTION OF STRUCTURE AND CONSTRUCTION

6.1. ACTIVE FIRE PROTECTION

the installation of fire fighting services starting, eg:

- a warning system
- fire extinguishing system such as sprinklers, high expansion foam etc.

6.2. PASSIVE FIRE PROTECTION

- Fire resisting construction
- Means of escape in case of fire
- Means of access for fire fighting and rescue

7. FIRE RESISTING CONSTRUCTION – COMPARTMENTATION

7.1. COMPARTMENTATION

- To prevent the spread of fire within a building. It must be divided into compartments of restricted cubic capacity

Class	Use	Compartment Volume	Fire Resistance Period
1	Domestic	Not exceeding 28 000 m^3	1 hour
2	Hotel bedroom		
3	Office		
4	Shop, restaurant and hotel foyer	Not exceeding 7 000 m^3	1 hour
5	Place of public entertainment		
6	Hospital		
7	Place of assembly	Exceeding 7 000 m^3 but not exceeding 28 000 m^3	2 hours
8	Carparking		
9	Bulk storage and warehouse	Not exceeding 7 000 m^3	2 hours
10	Industrial undertaking except bulk storage and warehouse	Not exceeding 28 000 m^3	2 hours

- Table 3 Maximum Compartment Volume

Use	**Maximum Compartment Volume**
Bulk storage and warehouse	7,000 m^3 where the compartment floor is above basement level but not exceeding 30 m above mean street level
	3,500 m^3 where the compartment floor is at basement level or greater than 30 m above mean street level
All other uses	28,000 m^3

TABLE A

WALLS CONSTRUCTED WHOLLY OF NON-COMBUSTIBLE MATERIALS

Construction and Materials	Minimum thickness in mm (excluding plaster) for period of		
	4 hrs.	2 hrs.	1 hr.
SOLID CONSTRUCTION			
Solid bricks of clay, concrete or sand lime without plaster	225	225*	100
Reinforced concrete -			
(a) containing not less than 1 per cent of vertical reinforcement	180	100	75
Concrete cover to main reinforcement	25	25	15
(b) containing less than 1 per cent of vertical reinforcement	240	160	120
Concrete cover to main reinforcement	25	25	25
HOLLOW BLOCK CONSTRUCTION			
Clay blocks (outer web not less than 13 mm thick) of 2 cells not less than 50 per cent solid finished with 13 mm gypsum plaster on each side		100	100
Concrete blocks of one cell in wall thickness not less than 50 per cent solid finished with 13 mm gypsum plaster on each side			190

* Where finished with 13 mm gypsum plaster on each side, the thickness may be reduced to 100 mm.

TABLE B

WALLS NOT CONSTRUCTED WHOLLY OF NON-COMBUSTIBLE MATERIALS

Construction and Materials	Minimum thickness of finish in mm on each face for period of	
	2 hrs.	1 hr.
SOLID CONSTRUCTION		
Wood wool slabs - complying with BS 1105 -		
(a) 50 mm minimum thickness with gypsum plaster finish		13
(b) 75 mm minimum thickness with gypsum plaster finish	13	6
Gypsum plaster board in cores not less than 19 mm thick in section not more than 1.2 m wide supported top, bottom and sides in steel channels or a timber framework, with gypsum plaster finish		10
HOLLOW CONSTRUCTION		
Steel or timber framing with facings on each side of -		
(a) Portland cement plaster, Portland cement-lime plaster or gypsum plaster on metal lathing		19
(b) 2 layers of 10 mm thick gypsum plaster board with gypsum plaster finish		Nil
(c) 13 mm thick gypsum plaster board with gypsum plaster finish		6
(d) 19 mm thick gypsum plaster board with gypsum plaster finish		Nil

TABLE C

FLOORS AND LANDINGS

Construction and Materials	Minimum thickness in mm for period of		
	4 hrs.	2 hrs.	1 hr.
SOLID REINFORCED CONCRETE CONSTRUCTION			
Thickness of concrete	170	125	100
Concrete cover to all reinforcement -			
simply supported	55*	35	20
continuous	45*	25	20
SOLID PRESTRESSED CONCRETE CONSTRUCTION			
Depth including screed	170	125	100
Concrete cover to all steel -			
simply supported	65*	40	25
continuous	55*	35	20

* Reinforcement consisting of expanded metal lath or a wire fabric not lighter than 0.5 kg/m^2 with 2 mm diameter wire at not more than 100 mm centres or a continuous arrangement of links at not more than 200 mm centres should be incorporated in the concrete cover at a distance not exceeding 20 mm from the face.

TABLE D

STEEL COLUMNS AND BEAMS

Construction and Materials	Minimum thickness of protection in mm for period of		
	4 hrs.	2 hrs.	1 hr.
SOLID PROTECTION			
Columns and hangers (mass per metre not less than 45 kg)			
(a) Concrete not inferior to Grade 20 and reinforced in accordance with the Code of Practice for the Structural Use of Steel	75	50	50
(b) Solid bricks of clay, concrete or sand lime	75	50	50
Beams (mass per metre not less than 30 kg)			
Concrete not inferior to Grade 20 and reinforced in accordance with the Code of Practice for the Structural Use of Steel	75	50	50
HOLLOW PROTECTION			
Columns and hangers (mass per metre not less than 45 kg)			
(a) Solid bricks of clay, concrete or sand lime reinforced in every horizontal joint with steel binding wire not less than 2.5 mm in thickness or steel mesh weighing not less than 0.5 kg/m^2.	115	50	50
(b) Portland cement plaster, Portland cement-lime plaster or gypsum plaster on metal lathing.			19
(c) Gypsum plaster on 10 mm gypsum plaster board with 1.6 mm diameter wire binding at 100 mm pitch			13
(d) Gypsum plaster on 19 mm gypsum plaster board with 1.6 mm diameter wire binding at 100 mm pitch		13	7
Beams (mass per metre not less than 30 kg)			
(a) Portland cement plaster or Portland cement-lime plaster on metal lathing			19
(b) Gypsum plaster on metal lathing		22	16
(c) Gypsum plaster on 10 mm gypsum plaster board with 1.6 mm diameter wire binding at 100 mm pitch			13
(d) Gypsum plaster on 19 mm gypsum plaster board with 1.6 mm diameter wire binding at 100 mm pitch		13	7

In this Table -

"hollow protection" means there is a void between the protective material and the web of the steel section, such hollow protection to columns should be effectively sealed at each floor level.

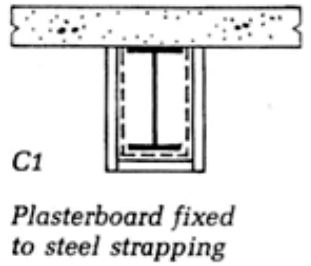
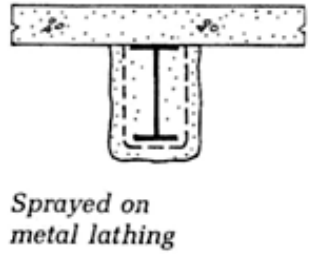
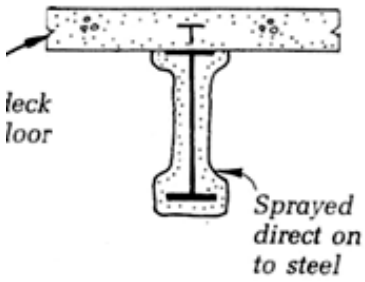
"solid protection" means casing which is bedded close to the steel without any intervening cavities and with all joints in that casing made full and solid.

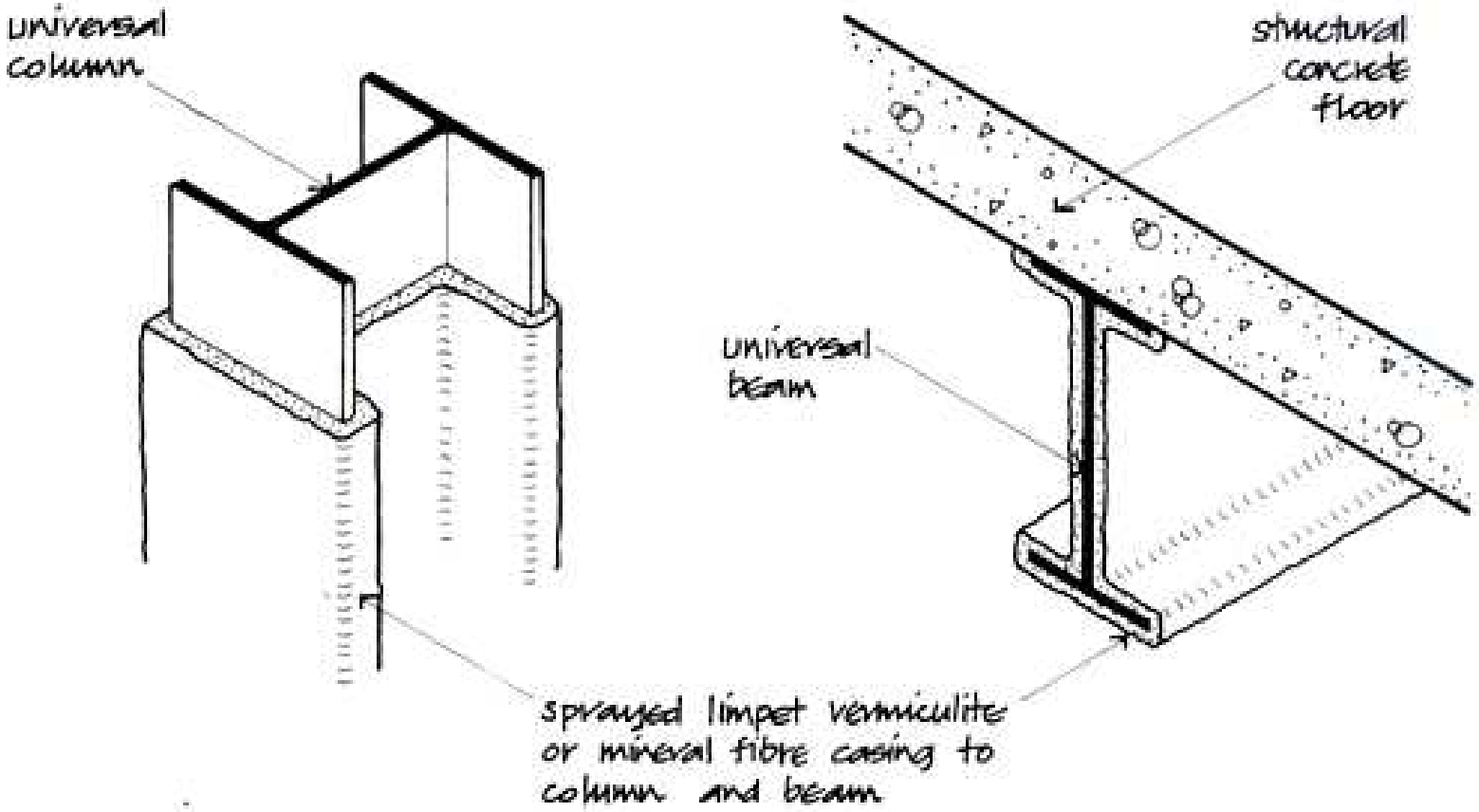
TABLE E

REINFORCED CONCRETE COLUMNS AND BEAMS

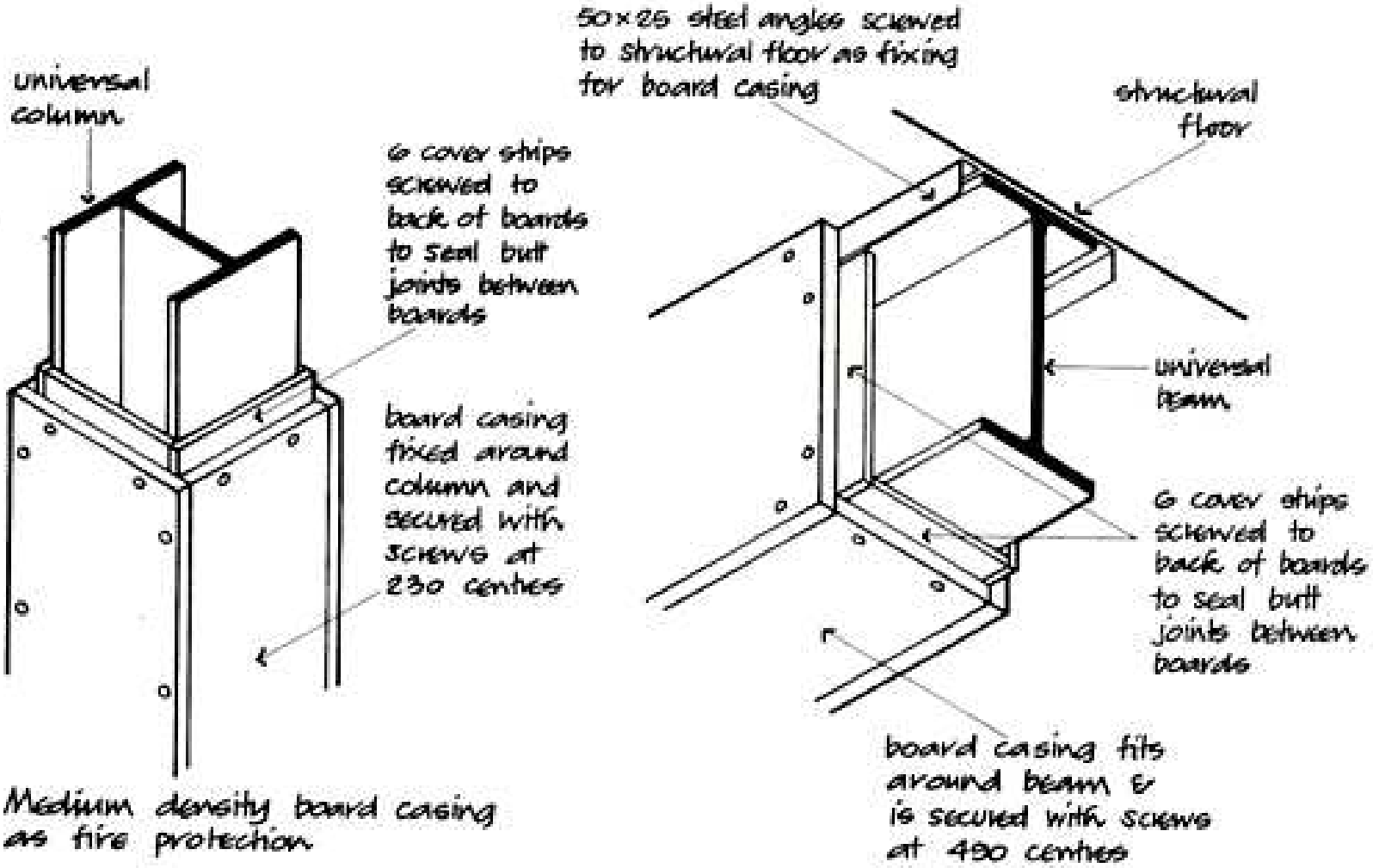
Construction and Materials	Minimum overall size of column in mm for period of		
	4 hrs.	2 hrs.	1 hr.
REINFORCED CONCRETE COLUMNS AND HANGERS			
(a) Fully exposed columns and hangers	450	300	200
Concrete cover to main reinforcement	35	35	25
(b) 50 per cent exposed of columns and hangers	350	200	160
Concrete cover to main reinforcement	35	25	25
(c) One face exposed of columns and hangers	240	160	120
Concrete cover to main reinforcement	25	25	25
REINFORCED CONCRETE BEAMS			
Width of beam	280	200	200
Concrete cover to main reinforcement -			
simply supported	80*	50*	30
continuous	60*	40	30
PRESTRESSED CONCRETE BEAMS			
Width of beam	280	200	200
Concrete cover to tendons -			
simply supported	90*	70*	30

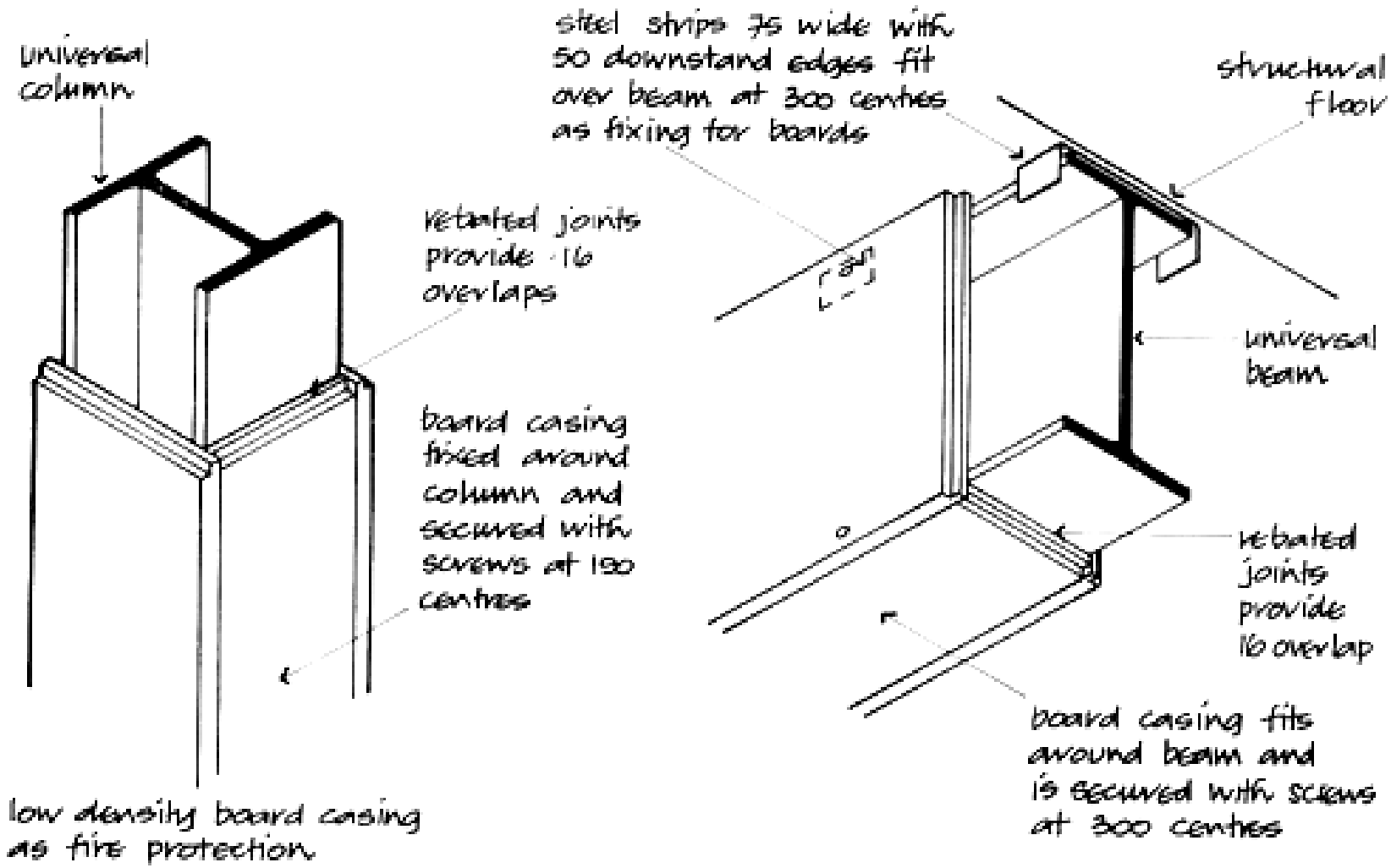
* Reinforcement consisting of expanded metal lath or a wire fabric not lighter than 0.5 kg/m^2 with 2 mm diameter wire at not more than 100 mm centres or a continuous arrangement of links at not more than 200 mm centres should be incorporated in the concrete cover at a distance not exceeding 20 mm from the face.

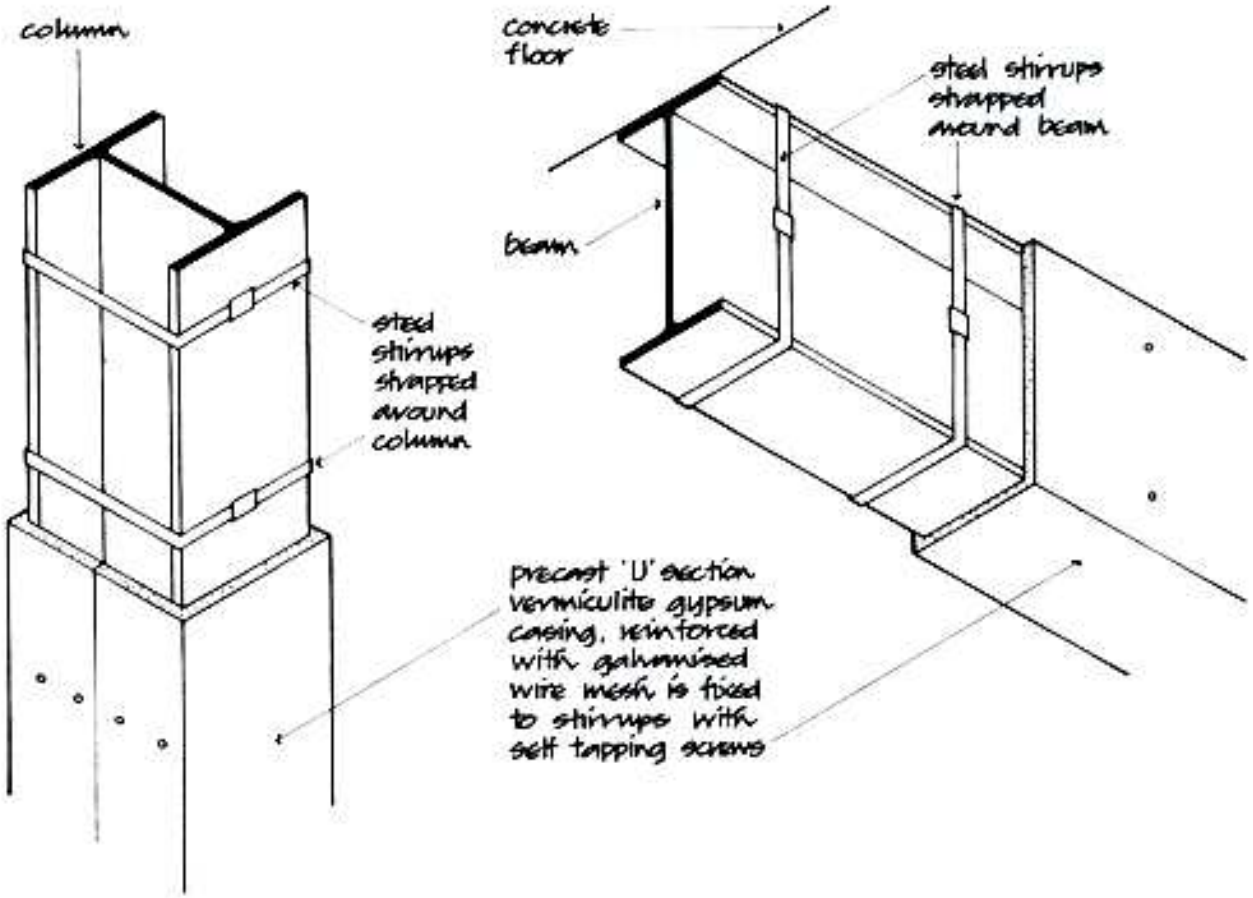
Hollow protection	*It means that there is a void between the protective material and the web of the steel section and such hollow protection to columns shall be effectively sealed at each floor level.*	
Solid protection	It means casing which is bedded close to the steel without any intervening cavities and with all joints in that casing made full and solid.	
Profile protection	It is not defined in the code of practice, which is usually referred to the types of coating sprayed, applied or painted to the required thickness according to the profile of the steel members.	



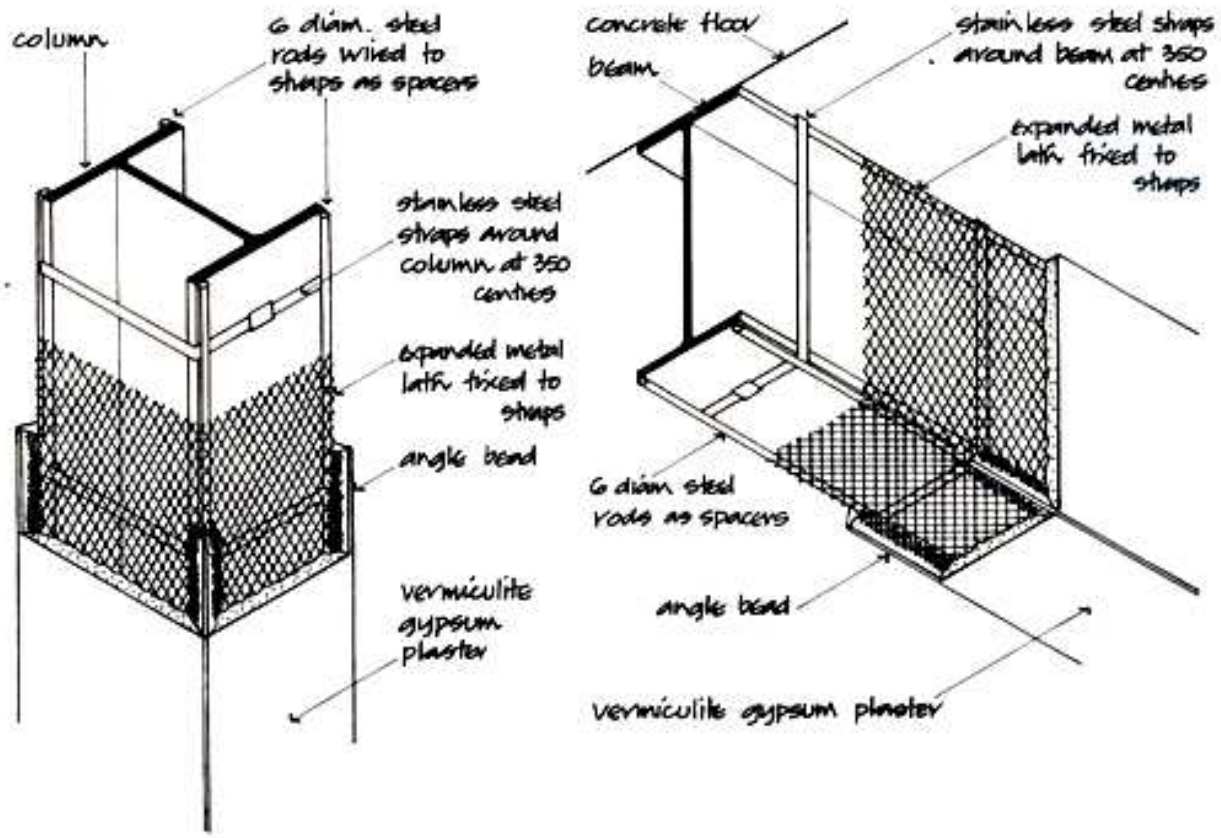
Fire protection of structural steelwork by sprayed limpet casing


universal column
6 cover strips screwed to back of boards to seal butt joints between boards
board casing fixed around column and secured with screws at 230 centres
Medium density board casing as fire protection
50×25 steel angles screwed to structural floor as fixing for board casing
structural floor
universal beam
6 cover strips screwed to back of boards to seal butt joints between boards
board casing fits around beam & is secured with screws at 450 centres


universal column
rebated joints provide 16 overlaps
board casing fixed around column and secured with screws at 190 centres
low density board casing as fire protection
steel strips 75 wide with 50 downstand edges fit over beam at 300 centres as fixing for boards
structural floor
universal beam
rebated joints provide 16 overlap
board casing fits around beam and is secured with screws at 300 centres



Fire protection of structural steelwork using precast vermiculite gypsum 'U' section casing



Fire protection of structural steelwork using metal lath and plaster casing

8. FIRE SAFETY REQUIREMENTS OF A CONTRACTOR'S SHED

8.1. FROM PNRC 54 - CRITERIA FOR CONTRACTOR'S SHEDS THAT COULD BE CERTIFIED BY RGBC/RSC

a) The contractor's shed is of single storey with storey height less than 3m and with floor area less than 230 m^2;

b) The base of the contractor's shed from the ground level, if stilted above ground, does not exceed 1.5m;

c) The proposed shed does not pose any geotechnical concern in that

(i) The maximum gradient across the site for erection of shed is not more than 15º.

(ii) The overall gradient of an area bounded by lines 10m outside the footprint of the shed in any direction is less than 15º.

(iii) There is no slope within the area 10m outside the footprint of the shed steeper than 30º or higher than 1.5m.

(iv) There is no retaining wall or terrace wall higher than 1.5 m either within the site for erection of shed or within the area 10m outside the footprint of the shed.

d) The contractor's shed is not sited

(i) on a cantilevered structure; or

(ii) above a hoarding or covered walkway; and

e) The contractor's shed is located within the boundaries of the building site and is not readily accessible to the general public.

Fire Safety Requirements for Contractor's Sheds

Shed Design	Fire Safety Requirements
Shed(s) to be certified by registered contractors	
Single-storey less than 230 m^2	One 4.5 kg CO2 or 9-litre water type fire extinguisher at each entrance.
Shed(s) to be certified by AP/RSE	
Structure exceeding one storey and less than 230 m^2	(i) One 4.5 kg CO2 or 9-litre water type fire extinguisher at each entrance. (ii) At least one open staircase to be provided.
Single-storey in excess of 230 m^2	(iii) One 4.5 kg CO2 or 9-litre water type fire extinguisher at each

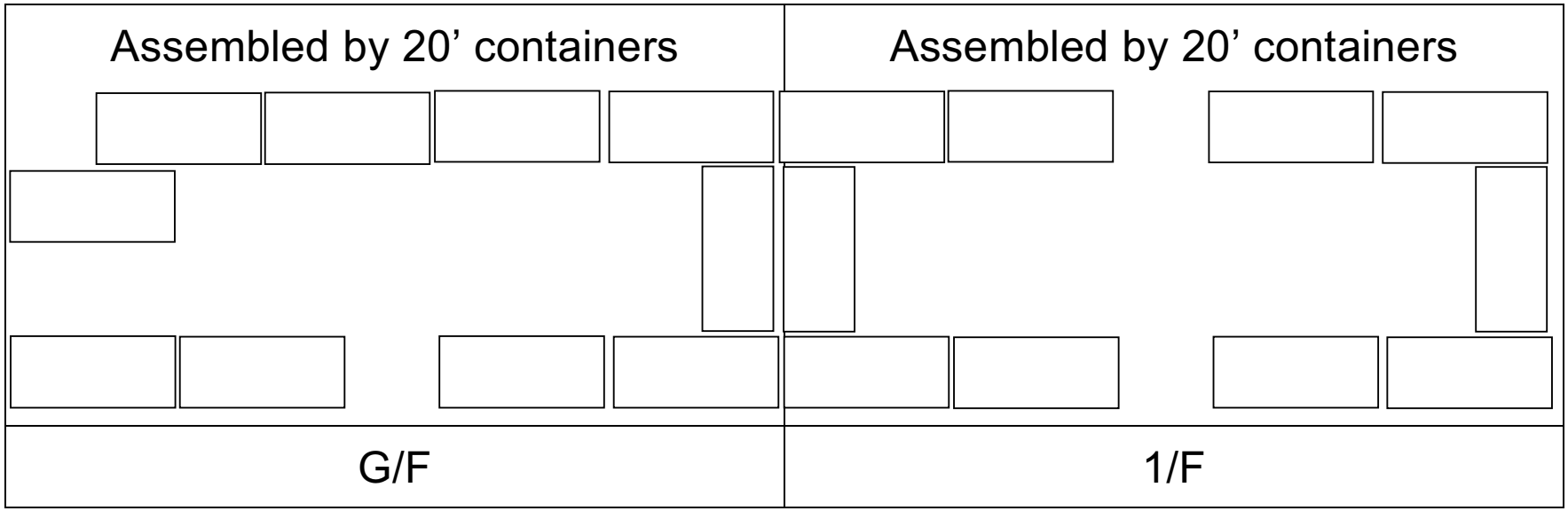
	entrance. (iv) Access for fire engine to be provided to reach 30m travel distance from the shed.
Other designs; or non-compliance with Fire Safety Requirements in this table for the above structures	Fire Services Department to formulate requirements on a case-by-case basis.

Note :

Travel distance within the shed should comply with the Code of Practice for the Provision of Means of Escape in Case of Fire 1996.

8.2. CLASS WORK

For a contractor's shed with the following items, please state the fire protection requirements:



- The site office is to be enclosed with corrugated GI sheets
- Openings at end & middle of the office