Bachelor Degree in Business Studies
Fire Safety, Engineering & Design: 2025-2026
Stage 2: BSEMS_B_Y2 : DAY 1 of 5

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Introduction

- Emails / Handouts
- Class President
- Phones etc.
- 5 DAYS
- Exam
  - Written Exam
  - Assignment

A	FSED-INTRODUCTION
1.1	Introduction
1.2	Understanding Structures
1.3	Fire Safety in Buildings
1.4	Fire Severity / Fire & Heat
1.5	Fire Resistance
1.6	Room fires
1.7	Compartment Fires
1.8	Aspects of Design - B1 & B3

B	MATERIALS
2.1	Structural materials & Fire Testing
2.2	SM at elevated temperatures
2.3	Design of structures exposed to fire
2.4	Steel structures
2.5	Concrete structures
2.6	Timber structures
2.7	Light frame construction
2.8	Construction Fire Technology

C	DESIGN METHODS
3.1	Prescriptive approach to fire design
3.2	Design Codes
3.3	TGD-B (IRL)
3.4	Eurocodes
3.5	IS3218 & IS3217
3.6	Design Methodology in Engineering a solution (Performance Based)
3.7	Class Assessment Test
3.8	BS7479 & Fire Safety Engineering I

D	Engineering Fire Safety
4.1	Fire Safety and Risk
4.2	Smoke Control
4.3	Fire Spread control
4.4	Advances in Fire Safety Design
4.5	Assessment and repair of fire-damaged structures
4.6	Upgrading existing construction to fire rated construction
4.7	Heritage Buildings
4.8	Fire Safety Engineering II

1.1-1.8 Fire Safety, Engineering & Design -INTRODUCTION

1. Introduction
2. Understanding Structures
3. Fire Safety in Buildings
4. Fire Severity / Fire & Heat
5. Fire Resistance
6. Room fires
7. Compartment Fires
8. Aspects of Design - B1 & B3

2.1-2.8 Fire Safety, Engineering & Design -MATERIALS

1. Structural materials
2. SM at elevated temperatures
3. Design of structures exposed to fire
4. Steel structures
5. Concrete structures
6. Timber structures
7. Light frame construction
8. Construction Fire Technology

3.1-3.8 Fire Safety, Engineering & Design - DESIGN METHODS

1. Prescriptive approach to fire design
2. Codes
3. TGD-B (IRL)
4. Eurocodes
5. Behaviour of Natural Fires
6. Design concepts
7. Class Assignment Test
8. BS7479 & Fire Safety Engineering

4.1-4.8 Fire Safety, Engineering & Design - Engineering Fire Safety

1. Fire Safety Engineering
2. Smoke Control
3. Fire Spread control
4. Advances in Fire Safety Design
5. Assessment and repair of fire-damaged structures
6. Upgrading existing construction to fire rated construction

Assignment

- A new six storey luxury hotel development is being prepared for design in a city centre location. The development comprises of a 3,000m2 leisure centre at ground floor level (Level 1), the First floor (Level 2) comprises of a reception, bar and breakfast room/restaurant and ancillary accommodation with 30 bedrooms per floor on Level 3 and Level 4. Level 5 and Level 6 comprise of two-storey private penthouse apartments. Each upper floor area is 1,500 m^2. A 3,000 m^2 of car parking space will be provided in the basement of the building. You are to prepare a briefing document for the client in relation to fire safety design considerations and challenges which will be pertinent to the brief.
- You are to prepare a briefing document for the client in relation to fire safety design considerations and challenges which will be pertinent to the brief.
- (a) Present and explain the main considerations for compliance with building regulation B1 in designing this building on the basis of complying with current fire safety design standards. 80 marks.
- (b) Evaluate the requirements for natural ventilation of the basement car park in accordance with regulation B3. 20 marks.

Assignment

The aim of the assignment is for you to apply the course material to a real-life situation by considering the issues relevant to the module.

Your written assignment should incorporate *all* of the following:

1. An executive summary explanation for the client, relevant to her/him as a lay person, of the challenges you have identified in your assignment.

   [*20 marks*]
2. A demonstration of your awareness of the factors involved in identification of the principal considerations. [*50 marks*]
3. Evidence of a good command of the subject. [20 marks]
4. Check for learning, summary and conclusions. [10 marks]

Stage 2: BBS DAY 1 of 5

1.1-1.8 Fire Safety, Engineering & Design

1. Introduction
2. Understanding Structures
3. Fire Safety in Buildings
4. Fire Severity / Fire & Heat
5. Fire Resistance
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8. Aspects of Design - B1 & B3

1.1 Introduction

1. Professional Engineers are responsible for engineering design and analysis. Engineers Ireland, IFE & IStructE.
2. Entry-level structural engineers may design the individual structural elements of a structure, for example the beams, column, and floor of a building.
3. Responsible for the structural design and integrity of an entire system, such as a building.
4. Structural engineers often specialize in particular fields, such as bridge engineering, building engineering, pipeline engineering, industrial structures or special structures such as vehicles or aircraft.
5. More defined and formalised profession in the late 19th Century.
6. Structural theories during the 19th and 20th century
7. ‘Civil Engineer’ covers all of the disciplines (before the term structural engineer come into existence).

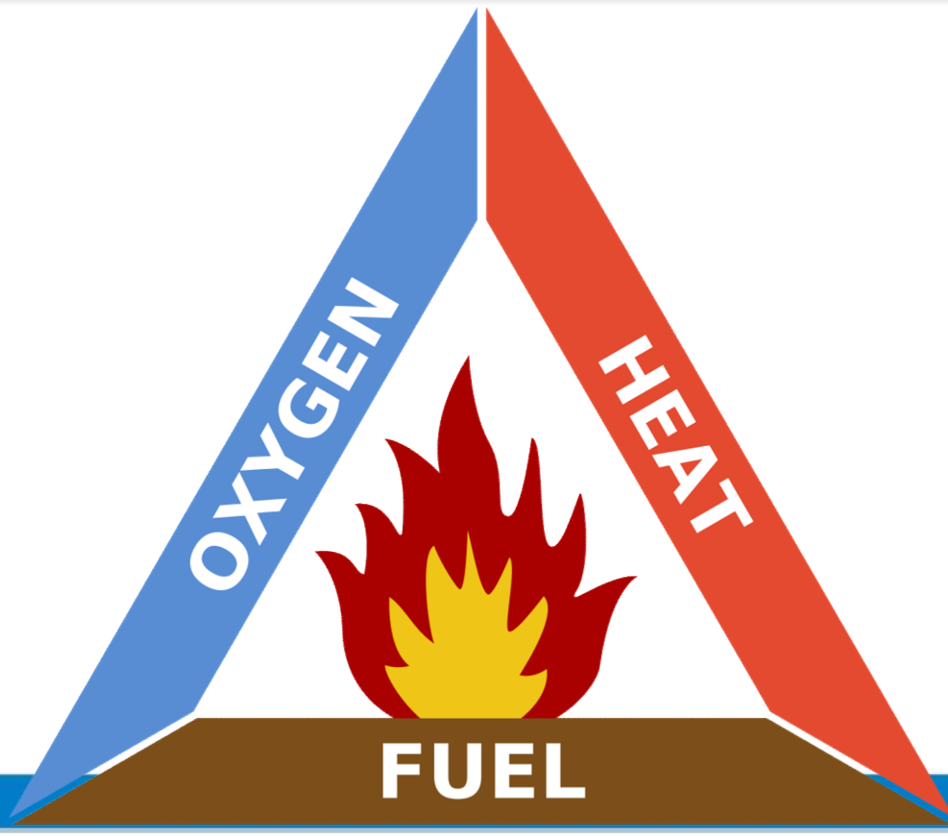
Fire Safety Engineering

- Involves the application of engineering principles, rules and expert judgment – based on scientific appreciation of the fire phenomena, of the effects of fire, and of the reaction and behaviour of people to:
- Save lives, protect property/jobs and preserve the environment and heritage.
- Quantify the hazards and risk of fire and its effects.
- Evaluate analytically the optimum protective and preventive measures necessary – to limit, within prescribed levels, the consequences of fire.
- Fire Safety Certificate application

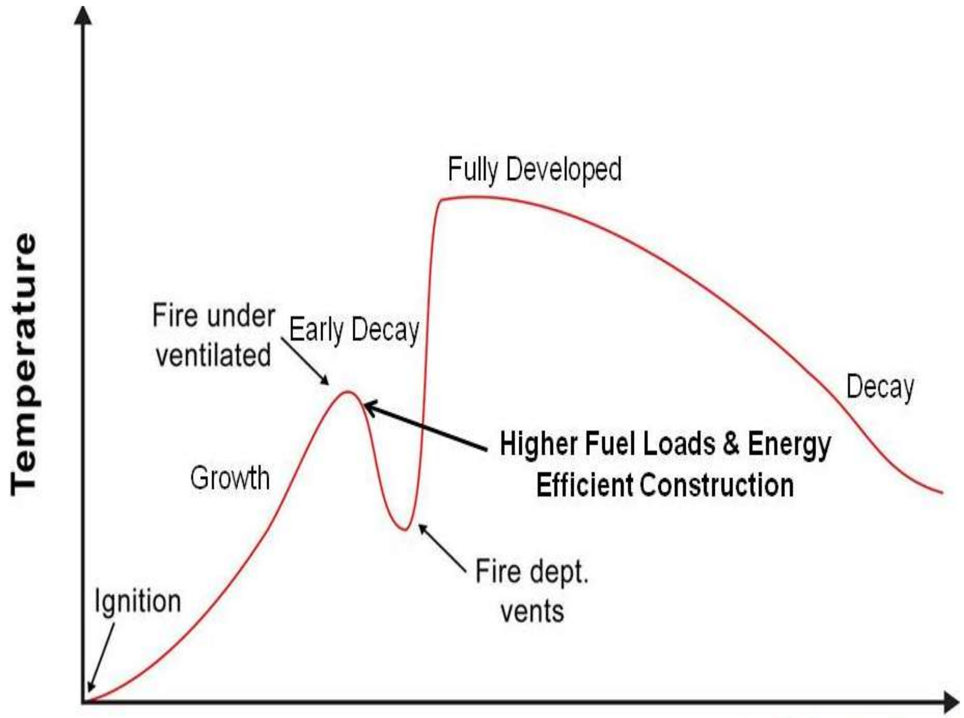
Fundamentals of fire science

- Combustion, the Triangle of fire,
- Fire development,
- Flashpoint,
- Limits of flammability,
- Heat of combustion, Heat transfer, Ignition,
- Pyrolysis,
- Thermal radiation & Flux, and,
- Flashover

Combustion, the Triangle of fire



Fire development



Flashpoint

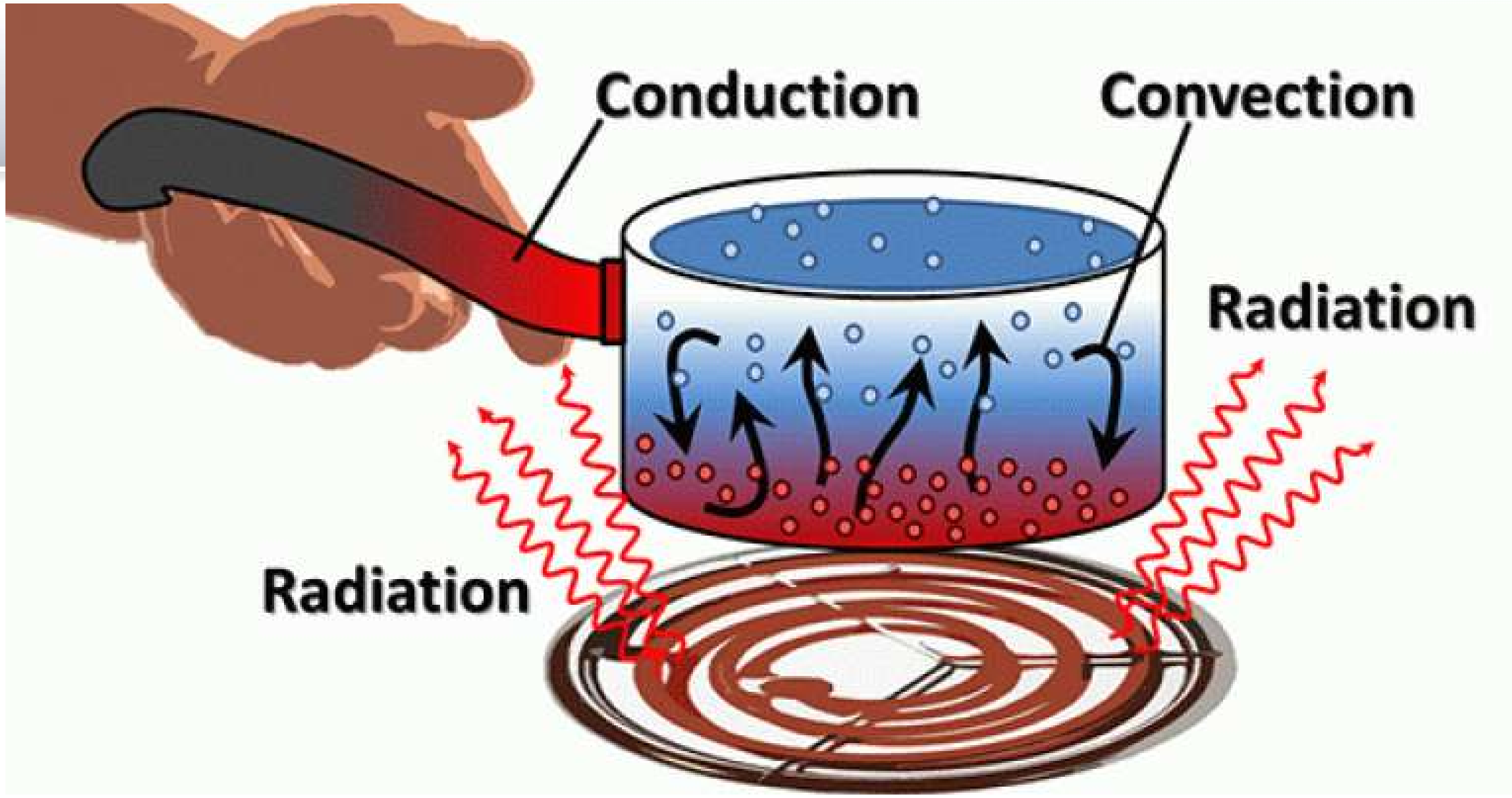
- **Flash point** for a flammable liquid is the minimum **temperature** at which there are enough vapours of the liquid to **ignite** when a **ignition** source (external) is brought near to it. ... Petrol has a **flash point** as low as -43°C and an auto **ignition temperature** of 246°C

Limits of flammability

- Above the upper **flammable limit** (UFL) the mixture of substance and air is too rich in fuel (deficient in oxygen) to burn. This is sometimes called the upper explosive **limit** (UEL). Below the lower **flammable limit** (LFL) the mixture of substance and air lacks sufficient fuel (substance) to burn.
- Lower **flammability limit** (LFL), usually expressed in volume per cent, is the lower end of the concentration range over which a **flammable** mixture of gas or vapour in air can be ignited at a given temperature and pressure.
- The **flammability** range is delineated by the upper and lower **flammability limits**

Heat of combustion, Heat transfer, Ignition

- What is Heat?
- What is temperature?
- How is it transferred?
  - Conduction
  - Convection
  - Radiation
- Ignition Sources?


Conduction
Convection
Radiation
Radiation

Thermal Radiation

- **Thermal radiation** is electromagnetic radiation generated by the thermal motion of charged particles in matter. When the temperature of a body is greater than absolute zero, inter-atomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature (Wikipedia)

Flashover

- Flashover is a heat-driven phenomenon
- A rapid increase in the heat level
- The sudden and rapid increase of fire through the compartment, caused by the ignition of fire gases from surrounding objects

Fully Developed Fires

- Fire growth and fully developed fires release large quantities of Heat – at various Rates of Heat Release (HRR).
- Fire Safety Engineering involves
  - The application of engineering principles, rules and expert judgment
  - Based on scientific appreciation of the fire phenomena, of the effects of fire, and of the reaction and behaviour of people
  - To save lives, protect property/jobs and preserve the environment and heritage; quantify the hazards and risk of fire and its effects;
  - To evaluate analytically the optimum protective and preventive measures necessary to limit, within prescribed levels, the consequences of fire.

Structural performance and safety from fire

- Current codes, standards, and design methods mostly prescribe requirements
  - to counter the potential effects of fire upon a structure.
- Increasing tendency to approach design in terms of performance – subject to statutory oversight.

Standard fire resistance Test

- Structural fire engineering has historically centred on the standard fire resistance test.
- BS476 – Fire tests
- ASTM E119 - Standard Test Methods for Fire Tests of Building Construction and Materials
- Internationally ISO 834 – Fire resistance Tests
  - do not relate to real fires
  - comparative in nature and provide little information about actual performance
  - this form of testing does not address connections between structural members in most cases.
- Cardington Tests - BRE
  - the structures were able to redistribute the loads and transfer the heat

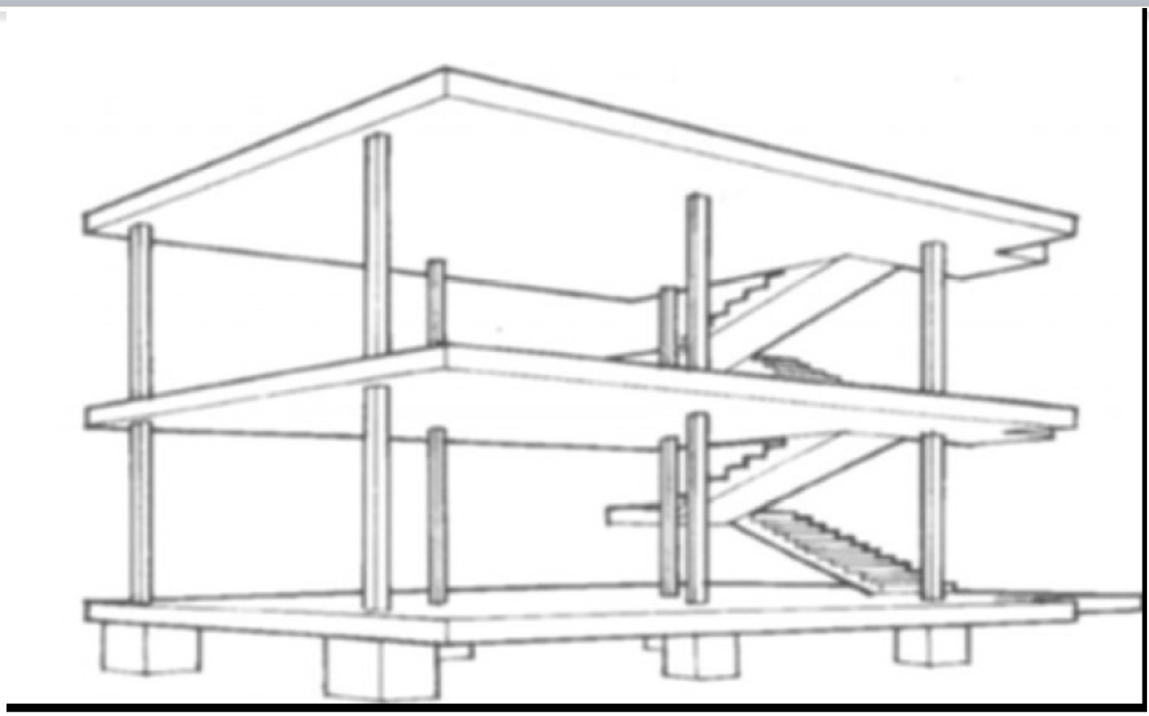
Design

- TGD-B’s main focus is life safety, fire brigade safety, and, to a certain extent, property protection.
  - Regulations are performance based while TGD-B is prescriptive
- The NFPA's 550 Guide to the Fire Safety Concepts Tree©
  - helpful in putting together fire protection strategies
  - managing the fire or managing the exposure
- Assist with the analysis of codes or standards
- Facilitate the development of performance-based designs
- Provide an overall structure with which to analyze the potential impact of fire safety strategies
- Identify gaps and areas of redundancy in fire protection strategies as an aid in making fire safety decisions
- For designer, engineer, architect, official, or consultant.

1.2 Understanding Structures

- Structures are built platforms for channelling loads from the building to the ground. Each structure consists of individual elements which are attached to one another, such as: beams, slabs, columns, stairs and foundations.

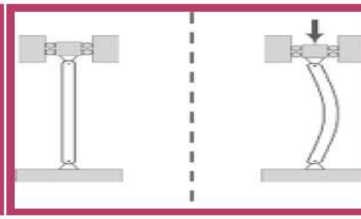
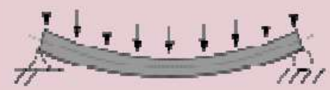
Understanding Structures



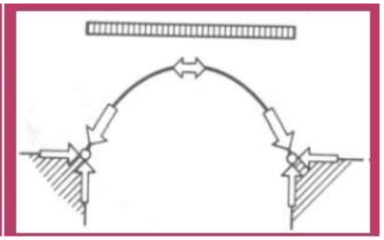
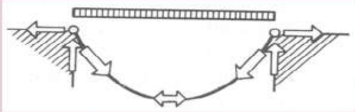
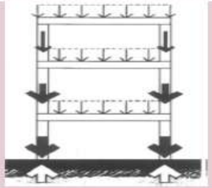
Understanding Structures

- Structural elements may be considered as follows:
- Line-forming elements: beams, columns, arches, trusses, frames
- Surface forming elements: walls, slabs, vaults, domes, hyperbolic paraboloids
- Flexible structures: cables, tents, nets, air supported membranes.

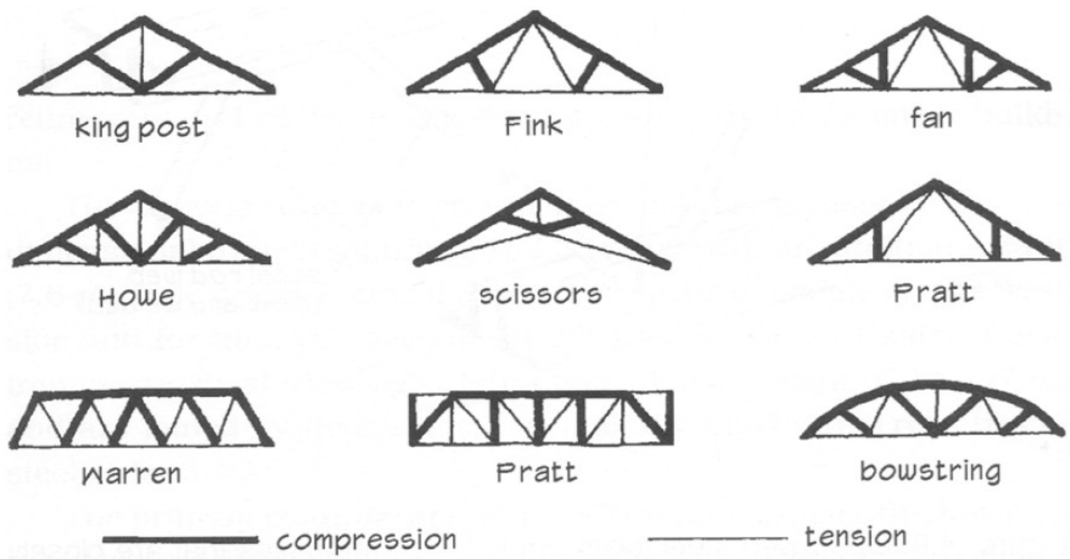
Understanding Structures

Column	**Element that carries only axial force - either tension or compression - or both axial force and bending. The axial capacity and the buckling capacity need to be designed. Buckling capacity is determined by the effective length, restraint conditions at ends, geometry and material. The capacity of a column to carry axial load depends on the degree of bending it is subjected to, and vice versa.**	
Beam	Element in which one dimension is much greater than the other two and the applied loads are usually normal to the main axis of the element. *Bending causes one part of the section of a beam (divided along its length) to go into compression and the other part into tension.* The compression part must be designed to resist buckling and crushing, while the tension part must be able to adequately resist being pulled apart. **Cantilevered**: (supported at one end only with a fixed connection **Simply supported**: supported vertically at each end; horizontally on only one to withstand friction, and able to rotate at the supports **Continuous**: supported by three or more supports Combination of the above	   *The upper half of the cantilevered beam is in tension and the lower half in compression.*

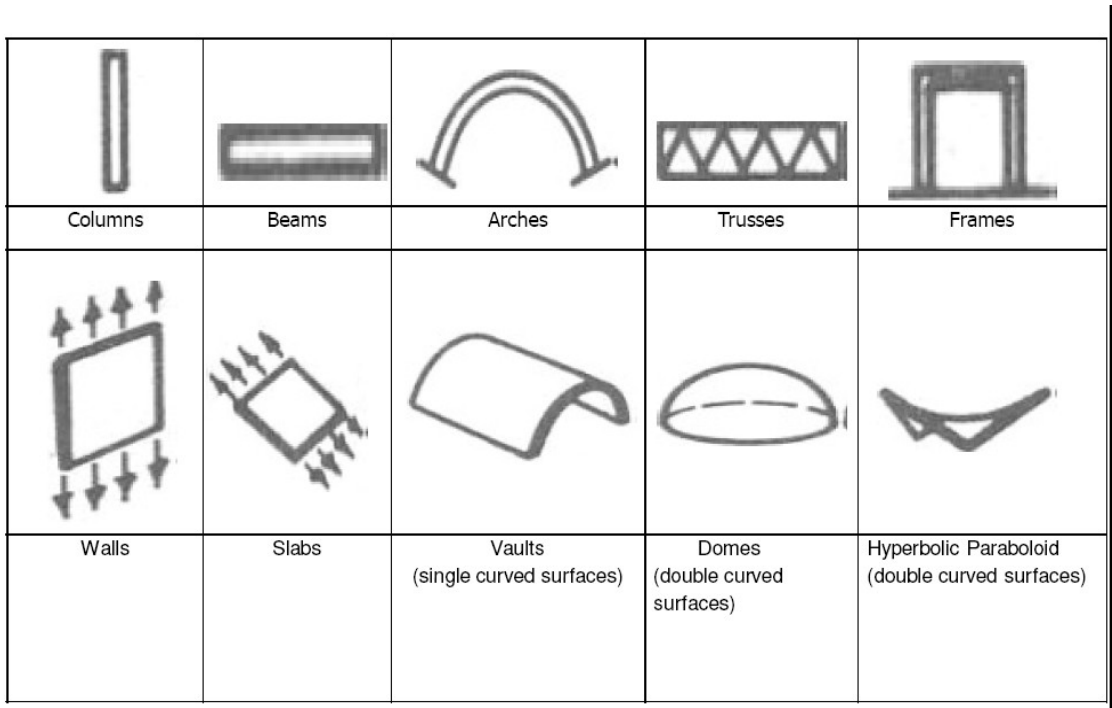
Understanding Structures

Arch	Only compression forces are developed in arched structures. Arches carry forces in compression in one direction only, which is why it is appropriate to build arches out of masonry. They are designed by ensuring that the line of thrust of the force remains within the depth of the arch. Maximum forces occur at reactions.	
Cable [catenary]	In cable only tension forces are developed. Maximum forces occur at reactions.	
Frame	A frame constitutes a post-and beam type structure having rigid joints between vertical and horizontal members. This joint rigidity imparts a stability against lateral forces.	
Bearing walls	Structures that support floors and roofs and then distribute vertical loads through the foundations to the support (usually soil).	

Understanding Structures



Forms of structural construction

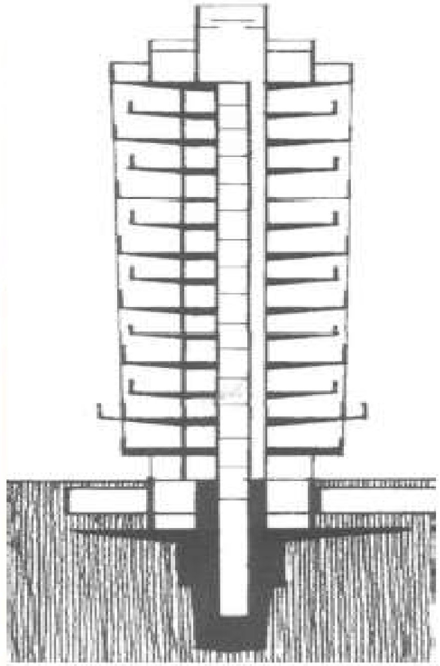


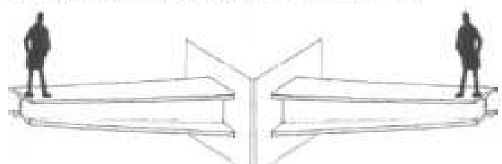
Structural Engineering theory

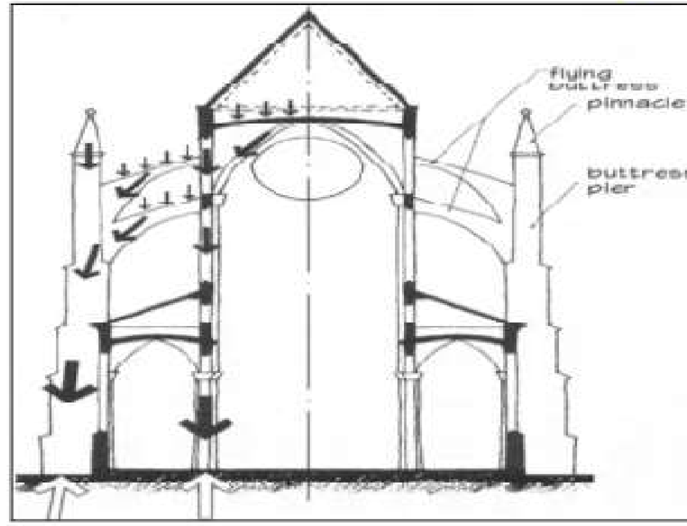
- Utilises a detailed knowledge of loads, physics and of materials to understand and predict how structures support and resist dead loads (self-weight) and live (imposed) loads.
- The professional engineer applies this knowledge with a detailed knowledge of mathematics and of relevant empirical and theoretical design codes.
- A knowledge of the properties of material used in structures exposed to the environment is also necessary (creep, strain, stress, corrosion resistance, hardness and durability).
- **Creep:** the tendency of a solid material to slowly move or deform permanently under the influence of stresses
- **Strain:** is the geometrical measure of deformation representing the relative displacement of a material $\Delta L/L$
- **Stress:** is the measure is the applied force over the applied area $\sigma = F/A$

Structural Stability

- The performance and period of stability of a structure or element is directly related to the material involved.
- Stability prevents structural collapse.
- The indicators for building collapse include:
  – loose masonry products and mortar joints;
  – Walls leaning in or out;
  – distorted, warped, or buckled members; prolonged fire exposure or excessive heat;
  – unusual creaks and cracking sounds;
  – deformations in excess of design parameters;
  – structural members pulling away from walls;
  – firefighting water adding additional weight and alterations to structural members.



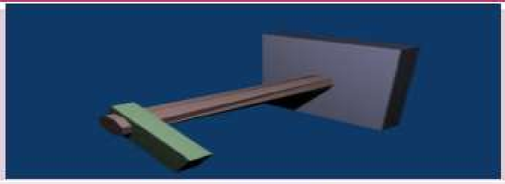
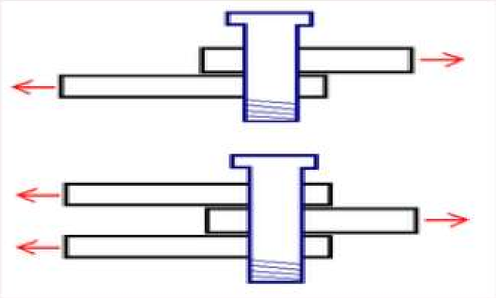
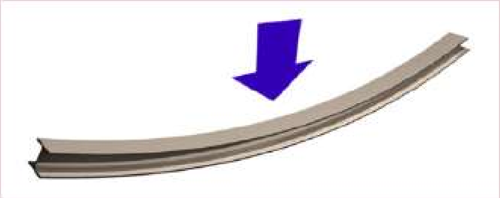


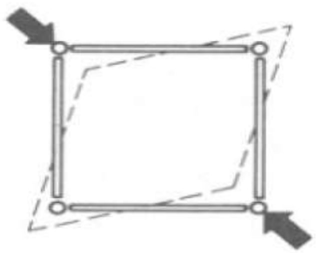


Flying butress (half arch)used to brace gothic church walls against horizontal forces

Research Tower & HQ, Johnson Wax Company, Racine, Wisconsin, 1951, Frank Lloyd Wright (National Historic Landmark)
Reinforced concrete central core cantilevered from the "taproot" foundation, to resist the overturning moment caused by lateral wind loading.

Describing Structural Concepts

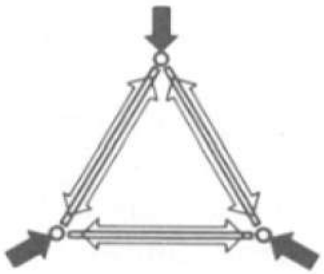
Concept	Graphic	Explanation
Torsion		**Twisting** induced by an applied **Torque**. Viewed in circular sections along the shaft that is twisted, the resultant shearing stress is perpendicular to the radius.
Shear		A **shear stress** is defined as a stress which is applied parallel or tangential to a face of a material, as opposed to a normal stress which is applied perpendicularly. Figure shows a bolt in **shear**. Top figure illustrates single shear, bottom figure illustrates double shear.
Bending		**Bending** (also known as **flexure**) characterizes the behaviour of a slender structural element subjected to an external load applied perpendicularly to an longitudinal axis of the element.



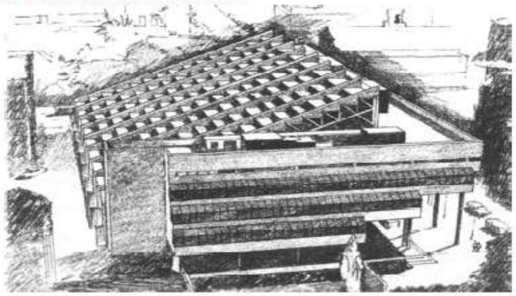
Unstable configuration

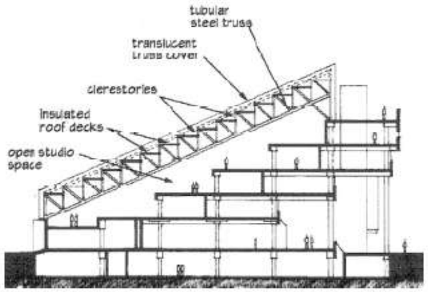
Pin Jointed elements

Stable configuration



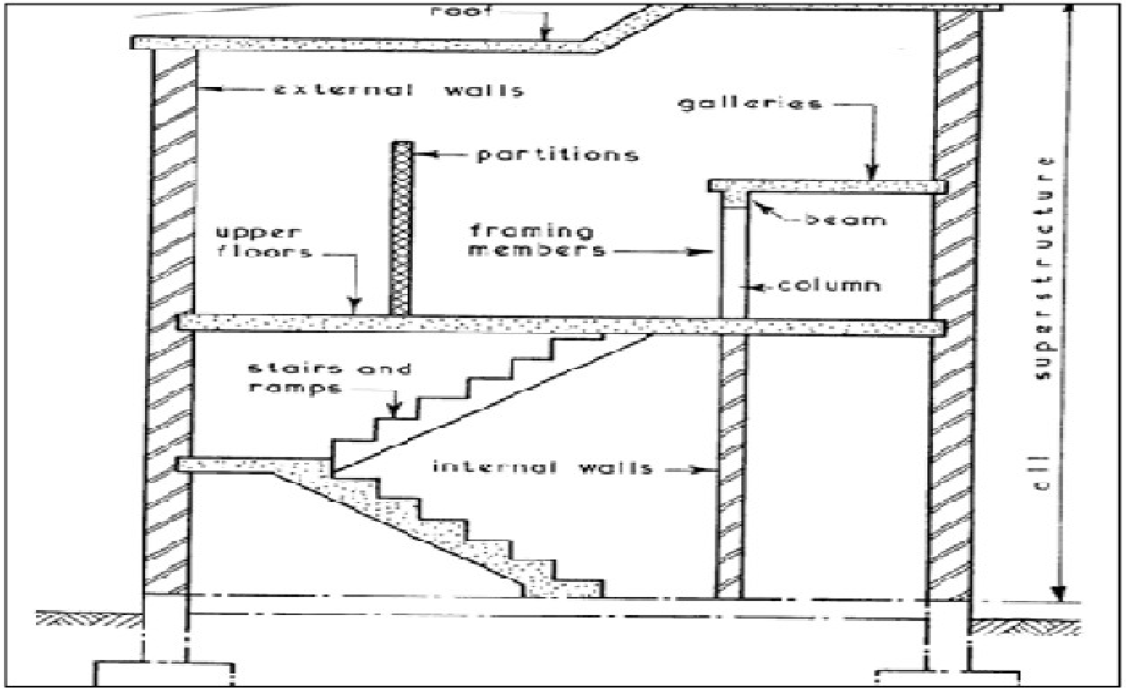
Member forces





Gund Hall, (Harvard School of Design), Cambridge, MA, 1972, John Anderson, (long span truss)

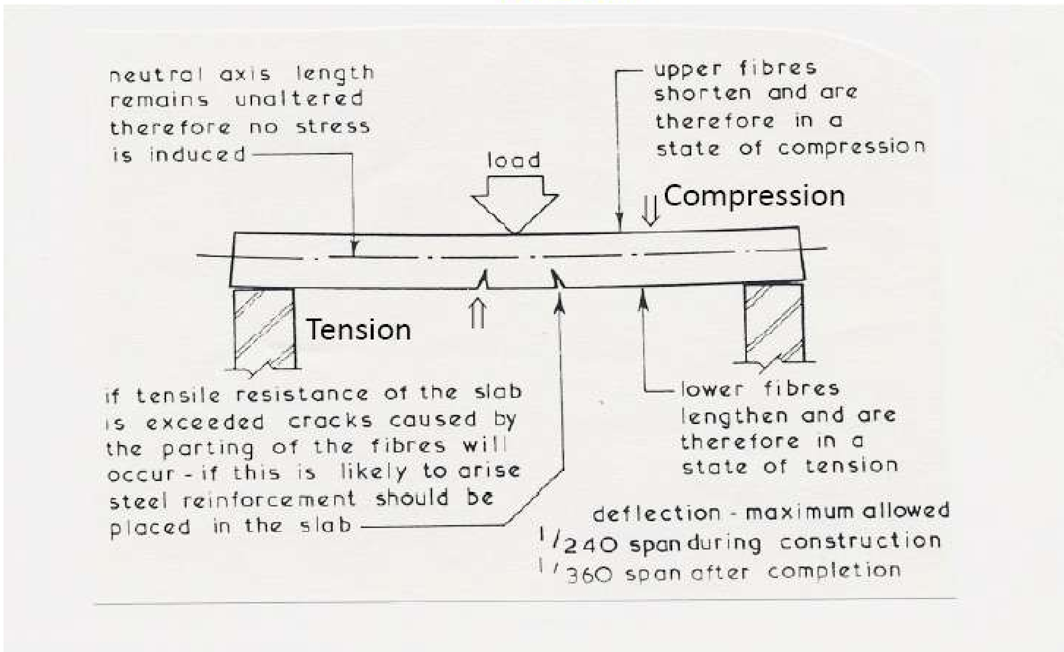
Section



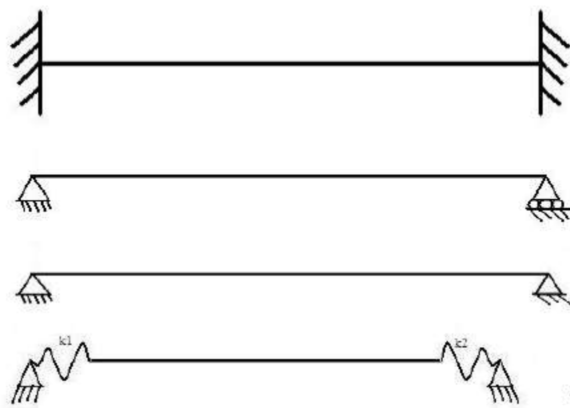
roof
external walls
galleries
partitions
beam
upper floors
framing members
column
stairs and ramps
internal walls
superstructure

Loading of a beam – reaction to loading

Fire = Load



Rotation and Translation

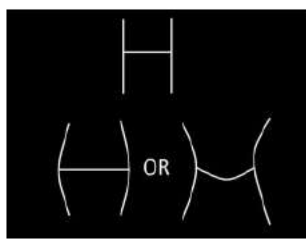


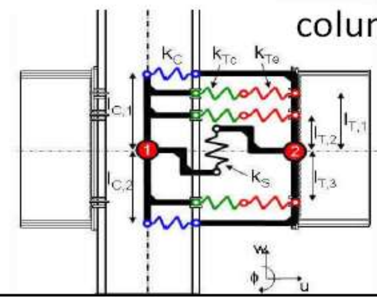
fixed-fixed [Joint type] beam

Pinned [Joint type] beam

Standard Fire Test Pinned Joint

Partial restraint against translation and movement at column/beam joint, like a spring

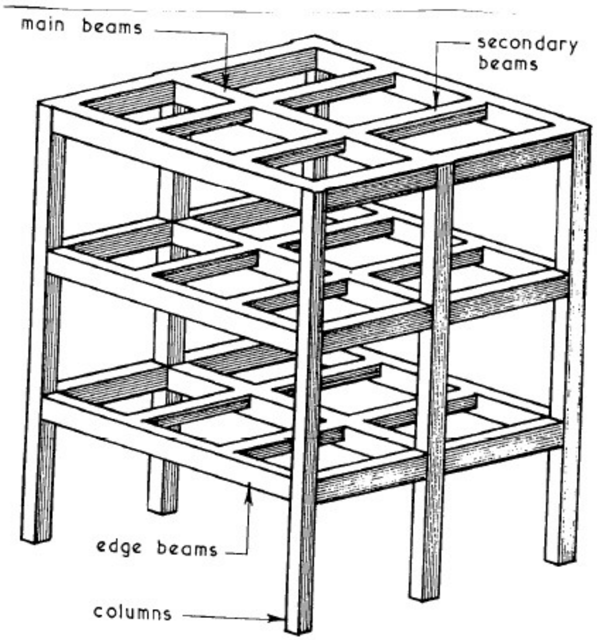




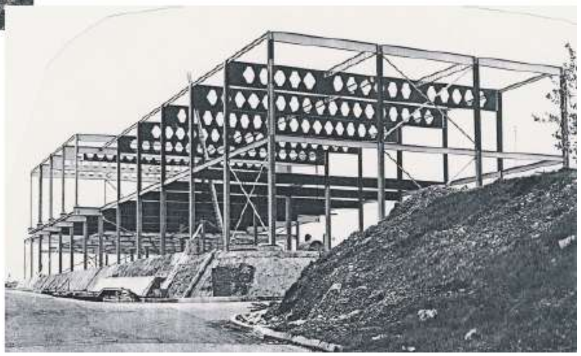
Structural Elements

Structural frames

- Reinforced Concrete
- Steel work
- Mixture of steel and concrete
  - Composite structure



Structural Elements



1.3 Fire Safety in Buildings

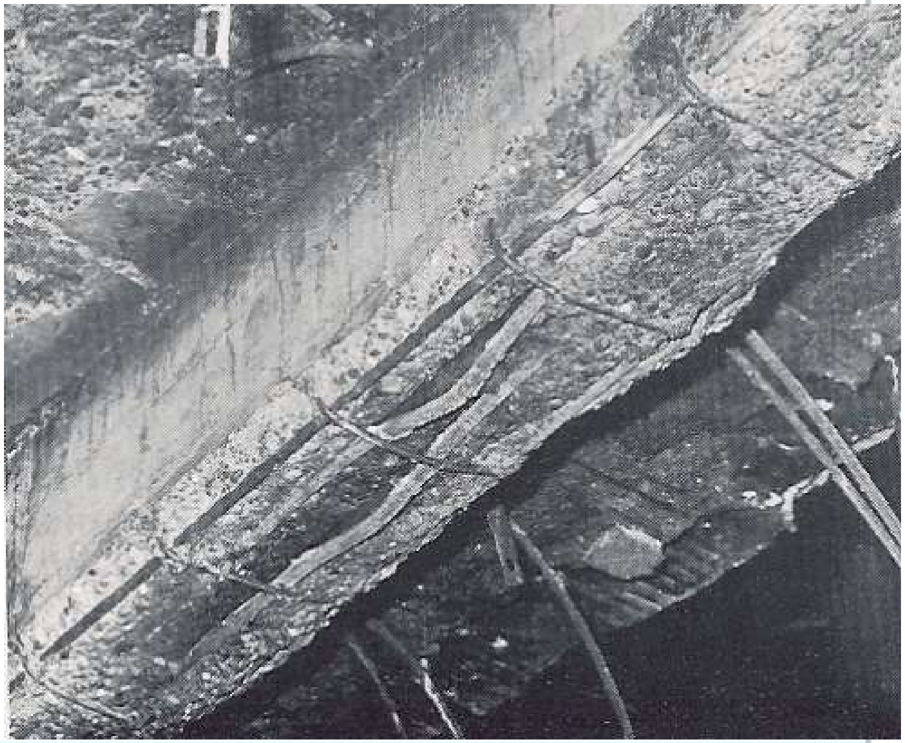
- Currently, our codes, standards, and design methods – prescribe fire resistance ratings and other related, prescriptive requirements
- To counter the potential effects of fire upon a structure.
- Increasing tendency to approach design in terms of performance – subject to statutory oversight.

Fire Safety Engineering addresses

- Life safety, property protection, public health and welfare, emergency services' responder safety, heritage protection and preservation, business continuity, design flexibility, and the client's cost effectiveness.
  - All of these goals are not necessarily regulatory, but may be expectations of building owners.
  - Technical Guidance Document B and associated codes do not encompass all of these goals.
  - TGD-B's main focus is life safety, fire brigade safety, and, to a certain extent, property protection.

Spalling of cover of a R.C. beam – reaction to fire

- Direct exposure to fire
- Indicates reinforcement buckled



Fire Brigade Issues

- TRUSS COLLAPSE
- CEILING COLLAPSE
- STAIRWAY COLLAPSE
- EXTERNAL STAIRS COLLAPSE
- MASONRY WALL COLLAPSE
- PARAPET WALL COLLAPSE
- WOODEN FLOOR COLLAPSE
- FIRE BRIGADE FIRE FIGHTING OPERATIONS
- SEARCH AND RESCUE AT A COLLAPSE

Elements requiring protection

- Columns
  - Vertical loads
- Beams
  - Horizontal loads
- Floors
  - Pipes
- Walls
  - Doorsets
  - Glazing
- Stairwells
- Shafts
- Voids
  - Cavity Barriers

Passive Fire Protection

- in-built features
- elements which tend to apparently remain inactive
- no activation by external source
  - available at all times
  - restrict fire from altering the building

Objectives of passive protection

- To prevent the start of fire
- To restrain the growth of a fire
- To delay the manifesting of untenable conditions
- To avoid structural failure

Performance maintained

- Structural elements continue to remain stable,
- Sub-division by compartments remains intact,
- Building layout construction is controlled,
- Combustibility of Surfaces is restricted,
- Openings are suitably protected, and
- Hidden voids are sealed and sub-divided.

Approaches to ensure safety from fire

1. A Prescriptive Approach (deemed-to-satisfy rules) [TGD-B: spelled out rules].
2. A Performance-based approach [engineering solutions] to address a particular part of the design with the rest of the design following a prescriptive based approach
3. A Full Performance-based approach [engineering solutions].

Life Safety

- The fundamental minimum legislative requirement for the structural fire design of buildings.
- Life safety requirements comprise reasonable:
  - Safe egress of the occupants from the building or reasonable safe movement of occupants to designed refuge areas within the building.
  - Safe operating conditions for fire fighters.
  - Safety to people in the proximity of the building (including fire-fighters) from the threat of possible collapse of the building.

Fire Performance

- Fire Resistance:
- What level of integrity/insulation in minutes will the product resist a fully developed fire?
- Fire resistance is the time (in minutes) for which an element of construction can withstand a specified heating regime whilst still meeting specified performance criteria - the ability of an item to fulfil for a stated period of time the required stability and/or integrity and/or thermal insulation, and/or other expected duty specified in a standard fire resistance test.
- The term Fire Resistant refers only to this ability
- [Fire Safety Vocabulary (ISO 13943)].
- Reaction to Fire:
  - Will the product contribute to fire growth?
  - Reaction to Fire is the response of a material in contributing to its own decomposition to a fire to which it is exposed, under specified test conditions.

1.4 Fire Severity / Fire & Heat

- Fire Severity – "Temperature, Temperature, Temperature"
- Factors influencing the severity of a compartment fire can be summarised as follows:
  - Combustion behaviour of the fuel/fire loading
  - Fire load type, density and distribution
  - Compartment size and geometry
  - Ventilation conditions of compartment
  - Thermal properties of compartment boundaries

Fire Severity

- Want to know
  - how hot the compartment becomes
  - what the temperature is at a particular time, and
  - what factors affect the rise/fall of the temperature
- Severity is predicted using fire curves
- Occurrence of flashover in a compartment fire imposes a transition to the fire development
- Fire Models are classified under pre- or post-flashover except for the computational fluid dynamic (CFD) models, which cover both phases.

Fire Severity

- Influencing factors
- – Combustion behaviour of the fuel/fire loading
- – Fire load type, density and distribution
- – Compartment size and geometry
- – Ventilation conditions of compartment
- – Thermal properties of compartment boundaries
- Heat is transferred
  - to structural elements through conduction and convection
  - in a steady state heat flow for simplicity
  - for transient heat flow a full analysis requires the solution of time dependent partial differential equations

Severity at Flashover

- Hot gas layer under ceiling reaches about 500 - 600^{o}C
- Radiation downwards to floor is 15 -20 kW/m2
  – Ignites all combustible materials in the enclosure
- Flames appear from compartment openings
- Average compartment temperature after flashover in range 700 - 1200^{o}C

Severity at Flashover

- Fire severity (measured through the HRR and fire growth rate) revealed during the flashover analysis should match with the expected or reported fuel present in the compartment.
- If the incident fire growth or heat release rate produced flashover conditions, or produced flashover faster than the analysis would indicate based on the expected fuel, an investigator would want to explain these inconsistencies.

Severity at Flashover

- In relation to the influence of the enclosure lining materials the Thermal Inertia of linings is a critical factor in the time to flashover. Thermal inertia is given as $k\rho c$
- where k = thermal conductivity, ρ = density and c = specific heat.
- The low thermal inertia of some enclosure boundaries contributes to heat retention, to reduced 'time to flashover' and is typical of modern highly insulated construction.
- For compartment boundaries with high thermal inertia the construction absorbs heat, delays the 'time to flashover', and is typical of traditionally poorly insulated construction.

Severity at Flashover

- Flashover is generally considered to be non-survivable, and therefore having a reliable estimate of when flashover occurred can allow a reasonable estimate of the last possible time that a fire fatality victim could have been alive in a flashed-over compartment.
- Escape and egress time estimates may also be made from this data.
- In such analyses it can generally be assumed that escape from or through a fully involved room is impossible.

Severity of a Fire

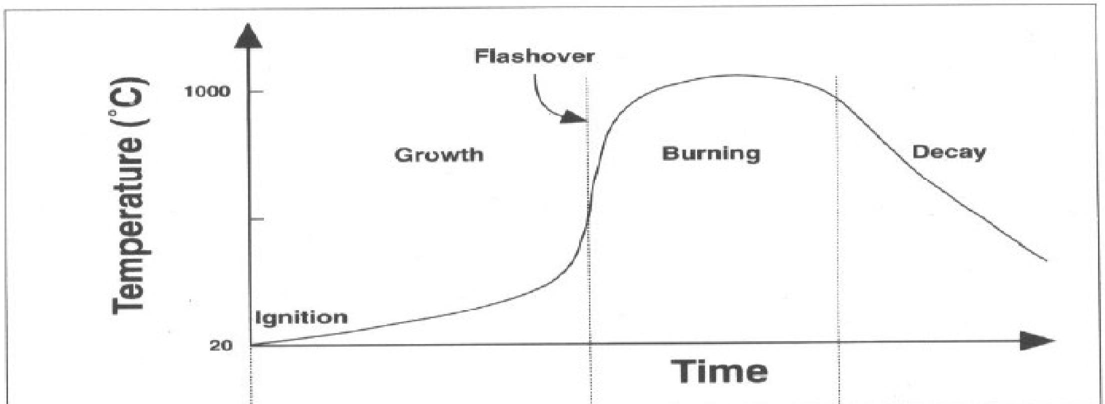
The severity of a fire can be calculated using one of the following options:

- Standard/nominal Fire Model – standard, external and hydrocarbon fires
- Time Equivalences Model - relate standard fires to real fires
- Parametric Fire Model - for post-flashover fires
- Localised Fires Model- for pre-flashover fires
- External Wall windows Model – for fires through openings of fire compartment
- Zone Models – one-zone models for pre-flashover fires
– two-zone models for post-flashover fires
- CFD or Field Models - for general fire and smoke modelling.

Severity of a Fire

- Complexity increases from simple fire models to field models with the first four models above being considered as simple models, whereas the zone and CFD models are advanced models.
  - – Input parameters vary
  - – Advanced models require very detailed input data
- Simple models require little input
  - – gas temperature of a compartment is taken as uniform and represented by a temperature-time relationship
  - – More suitable for modelling post-flashover fires
  - – Smoke movement and fire spread cannot be considered
- In the advanced fire models
  - – theoretical computer models simulate the heat and mass transfer process associated with a compartment fire.
  - – Compartment gas temperatures are predicted in much more detail and both smoke movement and fire spread may be taken into account.

Fire Development Curve

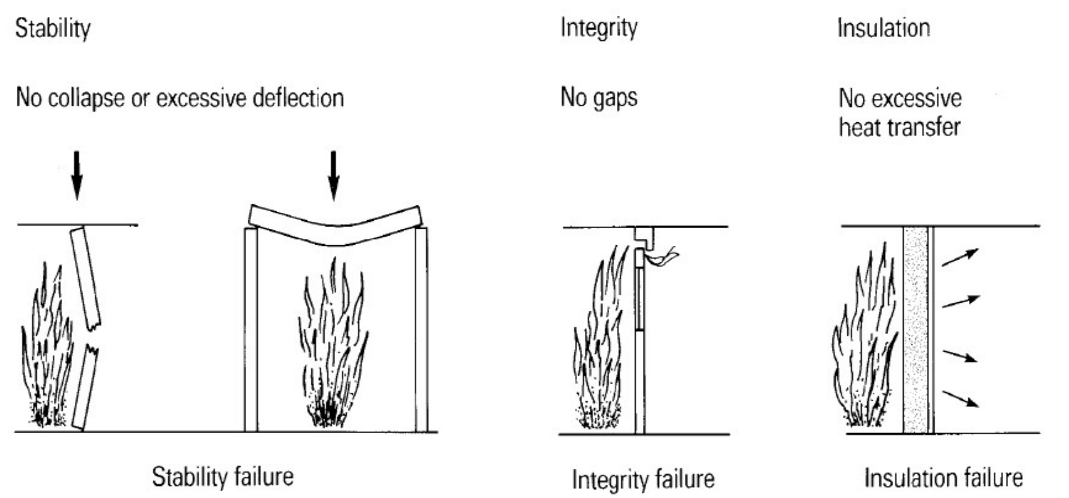


Stage	Growth	Burning	Decay
Fire behaviour	Fuel controlled	Ventilation-controlled	Fuel-controlled
Human behaviour	Escape	Death	
Detection	Smoke detectors Heat detectors	External smoke and flame	
Active control	Extinguish by hand, sprinklers or Fire Service. Smoke control	Control by Fire Service	
Passive control	Flammability, surface spread of flame	Fire resistance, containment, collapse	

1.5 Fire Resistance

- 'fire resistance' is immunity to the effects of fire up to a required degree
  - (Design of fire-resisting structures, HL Malhotra, Agniconsult 1982).
- structural fire resistance is categorized in accordance with the ability of components responsible for fire resistance such as limiting temperature, time period and load capacity, which should be achieved without causing failure under fire
  - given by the British Standards Institution

Three parts of fire resistance



- Loadbearing capacity is the resistance to collapse or excessive deflection
- Integrity is the resistance to penetration of sustained flame or hot gases.
- Insulation is the resistance to excessive temperature rise on the unexposed face.

Table 1.5.1 Minimum periods of fire resistance as per TGD-B

		Minimum periods of fire resistance (minutes)					
		Depth of lowest basement		Height of top floor above ground			
		not more than 10m	**not more than 10m**	**not more than 5m**	**not more than 18m**	**not more than 30m**	**more than 30m**
Residential flats and maisonettes	*Unsprinklered*	90	60	30	60	90	120
Office	*Unsprinklered*	90	60	30	60	90	Not permitted
	Sprinklered	60	60	30	30	60	120
Shops and Commercial	*Unsprinklered*	90	60	60	60	90	Not permitted
	Sprinklered	60	60	30	60	60	120
Assembly and Recreation	*Unsprinklered*	90	60	60	60	90	Not permitted
	Sprinklered	60	60	30	60	60	120
Industrial	*Unsprinklered*	120	90	60	90	90	Not permitted
	Sprinklered	90	60	30	60	60	120

Fire resistance by Calculation

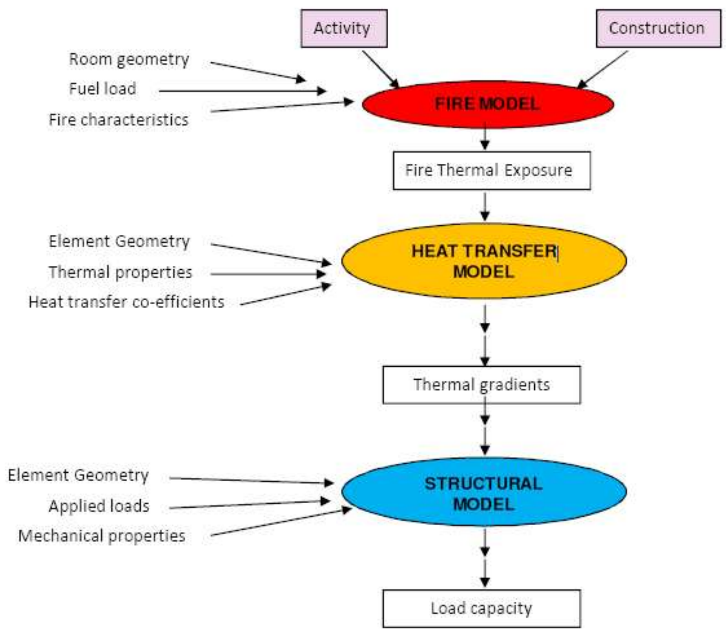


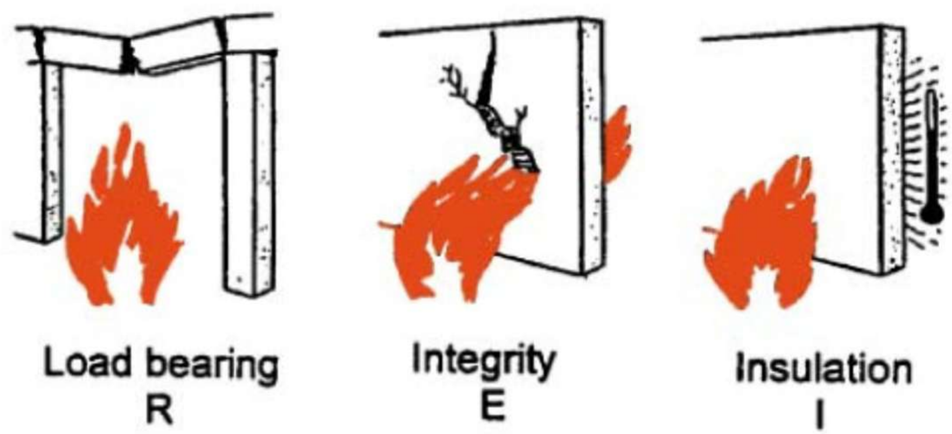
Figure 1.5.1 Flow chart for calculating the load capacity of a structure exposed to fire
[Taken from Fig. 6.5 *[A.H. Buchanan, Structural Design for fire safety, Wiley]*.]

Fire Resistance

- ‘The time (in minutes) for which an element of construction can withstand a specified heating regime whilst still meeting specified performance criteria’

EC Fire Resistance Parameters

- R - Load-bearing capacity (stability)
- E - Integrity
- I - Insulation
- S - Smoke leakage
- W - Radiation
- M - Mechanical Actions
- C - Self-closing



Reaction to Fire

- Response of a material in contributing to its own decomposition to a fire to which it is exposed, under specified test conditions

Euroclass / BSI System

- A1 non-combustible
- A2 limited-combustibility
- B similar to Class O
- C similar to Class 1
- D similar to Class 2
- E similar to Class 3
- F no performance

Reaction To Fire Tests

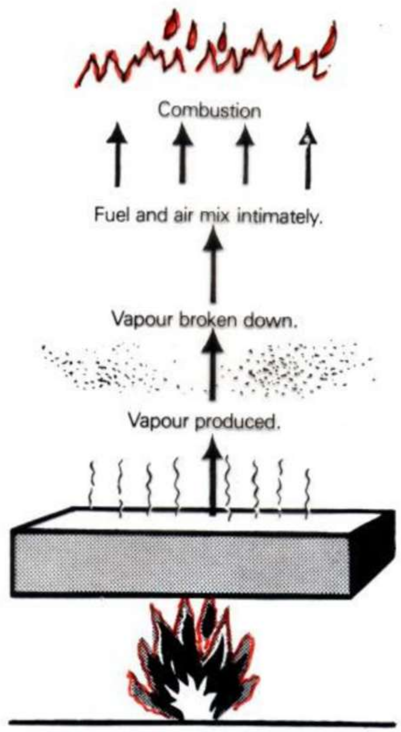
- Pre-flashover scenario
  - Less severe exposure
- Testing of materials
  - E.g. Wall & ceiling linings
  - Small/medium scale tests
  - Defined relationship with real and reference fire scenarios
- Fire Resistance Test
  - Post-flashover scenario
  - Severe exposure

Test of construction

  - Large scale test
  - element (e.g. wall, door)
  - Standard Fire
    - Less well defined relationship with real fire scenarios

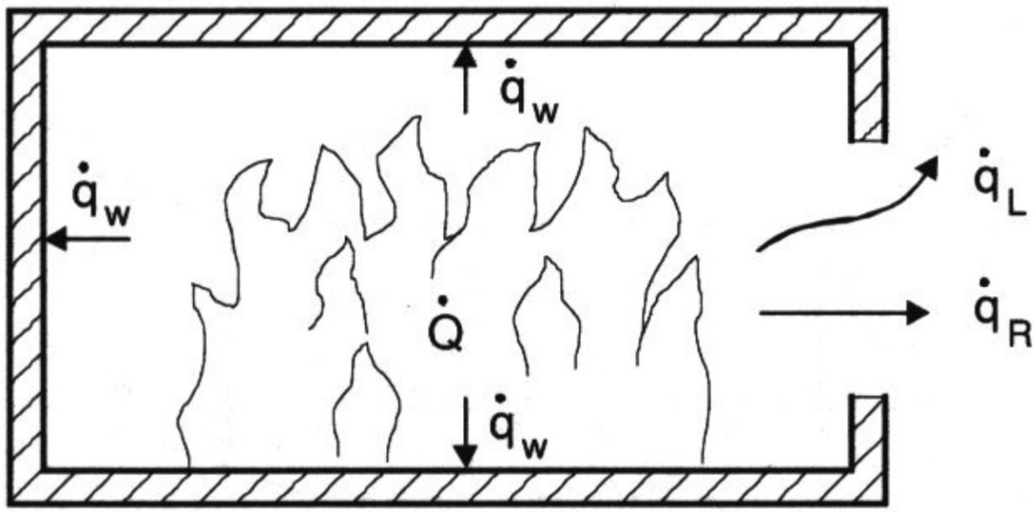
1.6 Room Fires

- Fire Development
- Fuel
- Combustible Solid



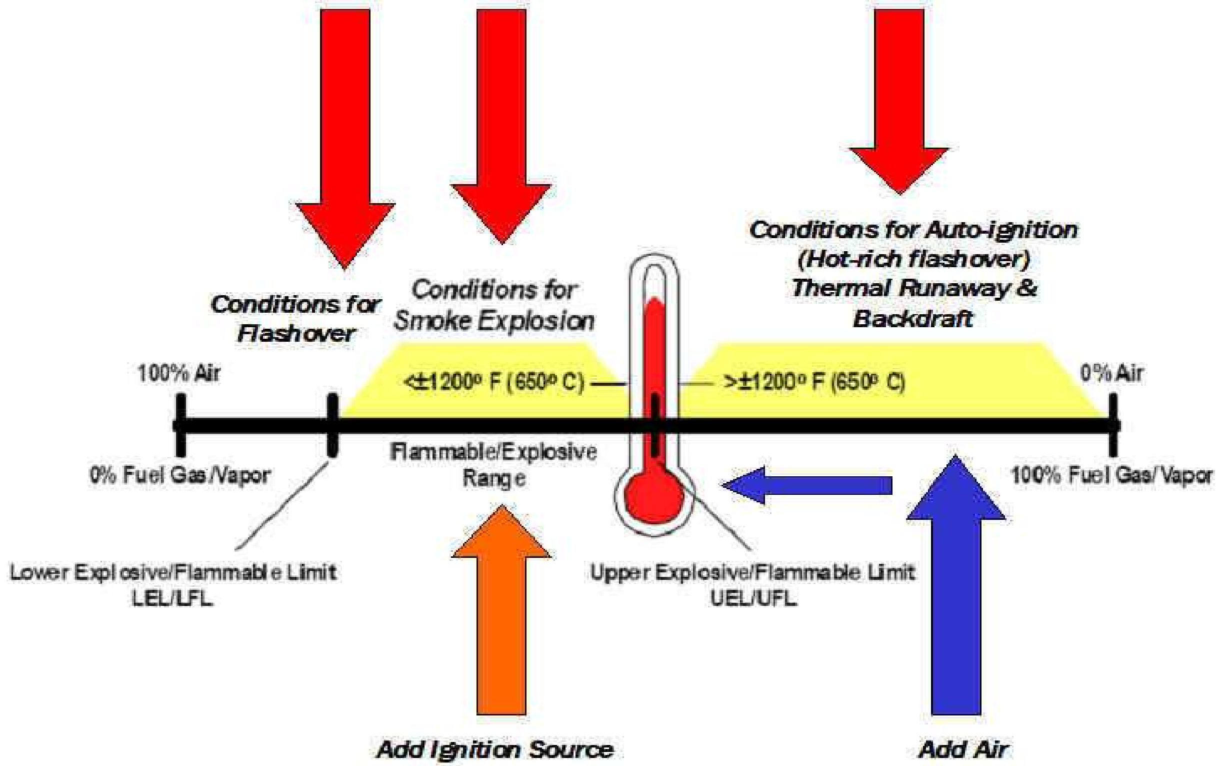
Energy Balance for a FDF

Q = qW + qR + qL

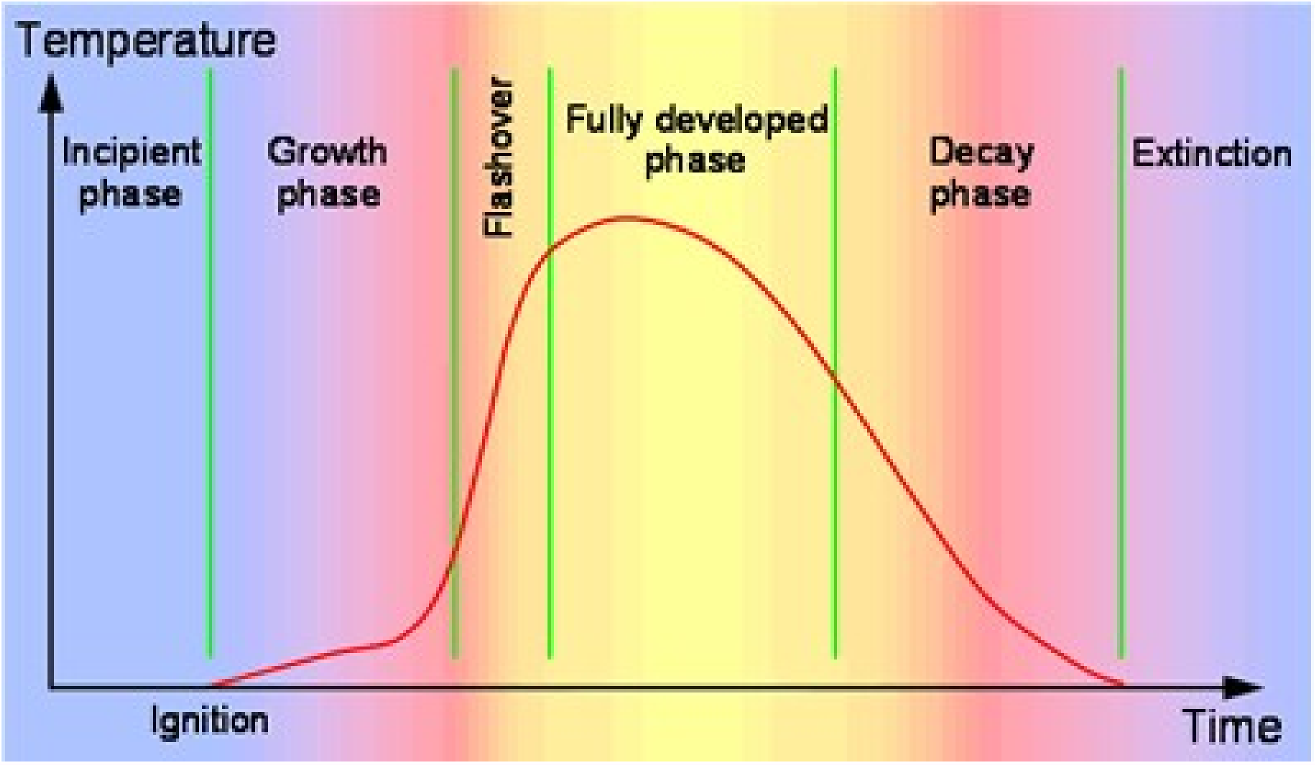


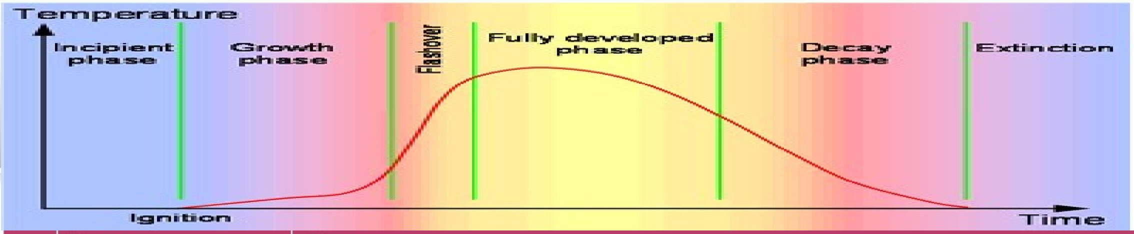
Energy balance for a fully developed compartment fire.

Localised Fires – Flashover



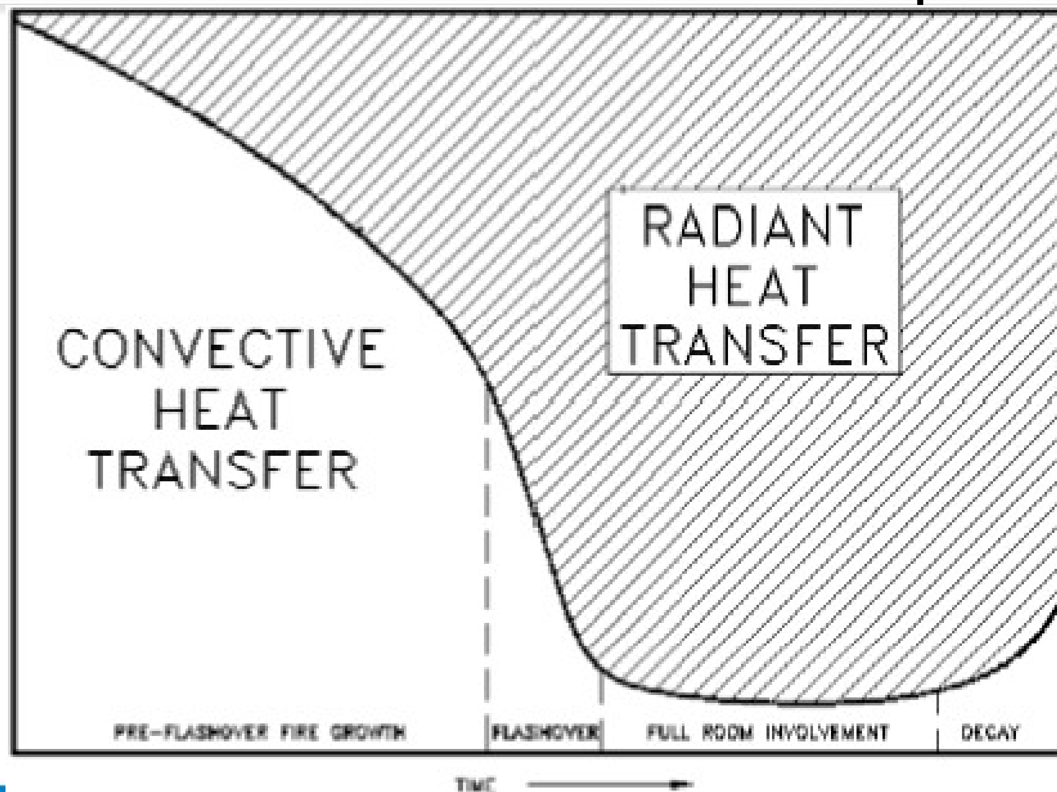
Fire Growth Curve





	Phases	Phases
1	Incipient	Heating & combustion – smouldering, flaming or radiant
2	Growth (pre-flashover)	Ignition, localized fire, smoke & combustion products (pyrolysis) layered beneath ceiling forming hotter upper layer. Smoke layer will descend if uninterrupted
3	Flashover	Radiation from burning flame and hot smoke layer may lead to instant ignition of unburned combustible within whole compartment.
4	Fully developed (post-flashover)	After flashover, the rate of heat release reaches maximum and the burning rate becomes steady. Fire controlled by ventilation or by fuel. Normally, this the most critical stage for structural damage and fire spread to occur.
5	Decay	After sustained burning, the rate of burning decreases as fuel is spent and the fire decays
6	Extinction	Fire will cease on full consumption and no more energy is released

Relationship (proportions) of heat transfer mechanisms within a compartment

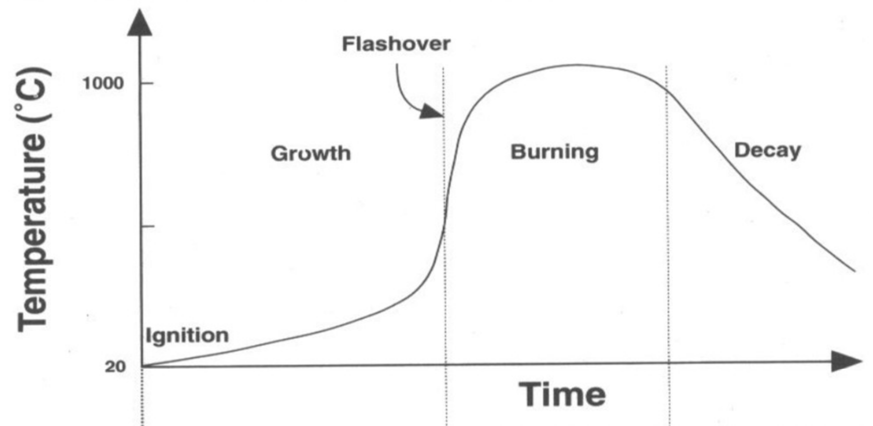


Heat Transfer

- At the time of flashover the hot gas layer under the ceiling reaches about 500 - 600^{o}C, with heat radiation downwards to floor at 15-20 kW/m2, ignition of all combustible materials in the enclosure, flames appearing from enclosure openings with the average enclosure temperature after flashover in the range 700 - 1200^{o}C.
- Flashover represents the transition to a state of total surface involvement in a fire of combustible materials within the enclosure.
- Obviously, evacuation must occur before flashover.

- For comparative sakes, the effects of Thermal Radiation:
- Direct summer sun (1.0 kW/m2), Pain after 8 secs exposure (6.4 kW/m2);
- Pilot ignition of wood (12.5 kW/m2) and typical post-flashover burning (100-150 kW/m2).

Typical Fire development Curve

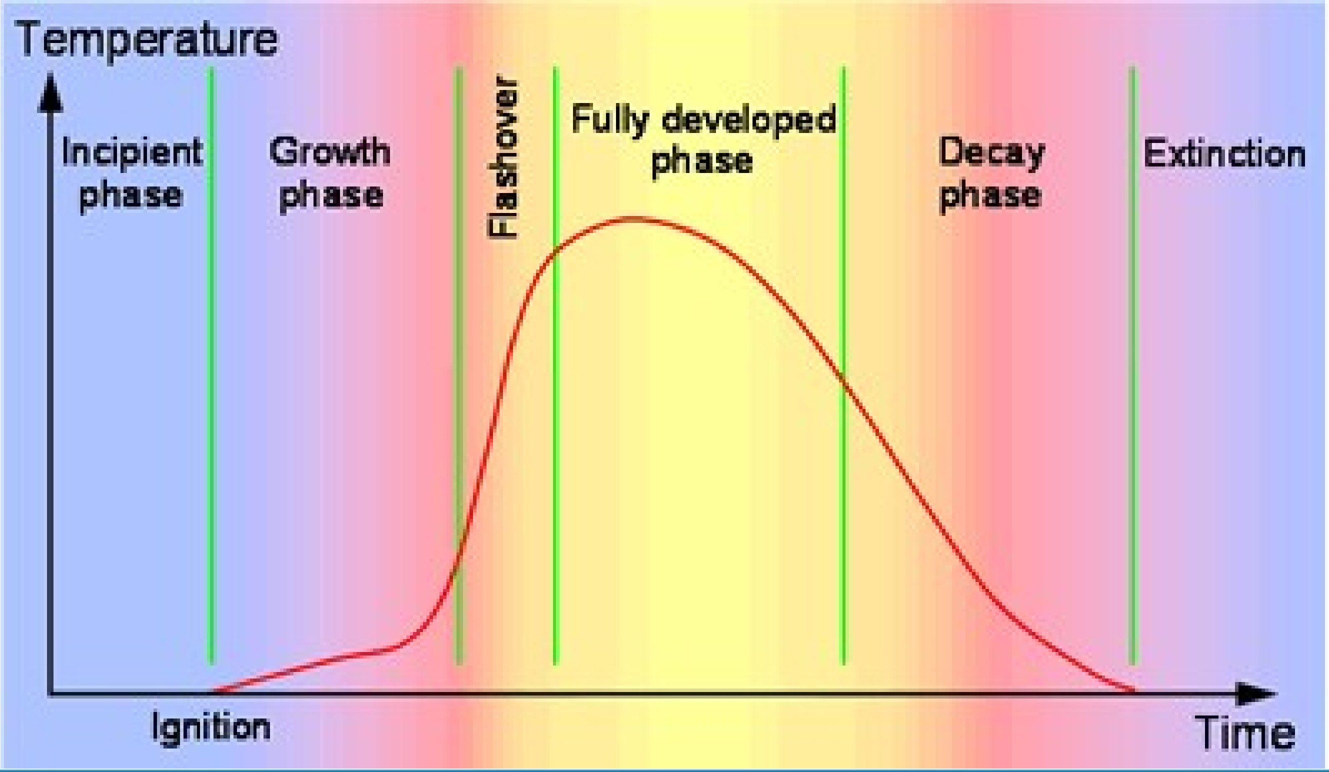


Stage	Growth	Burning	Decay
Fire behaviour	Fuel controlled	Ventilation-controlled	Fuel-controlled
Human behaviour	Escape	Death	
Detection	Smoke detectors Heat detectors	External smoke and flame	
Active control	Extinguish by hand, sprinklers or Fire Service. Smoke control	Control by Fire Service	
Passive control	Flammability, surface spread of flame	Fire resistance, containment, collapse	

Fully Developed Fire

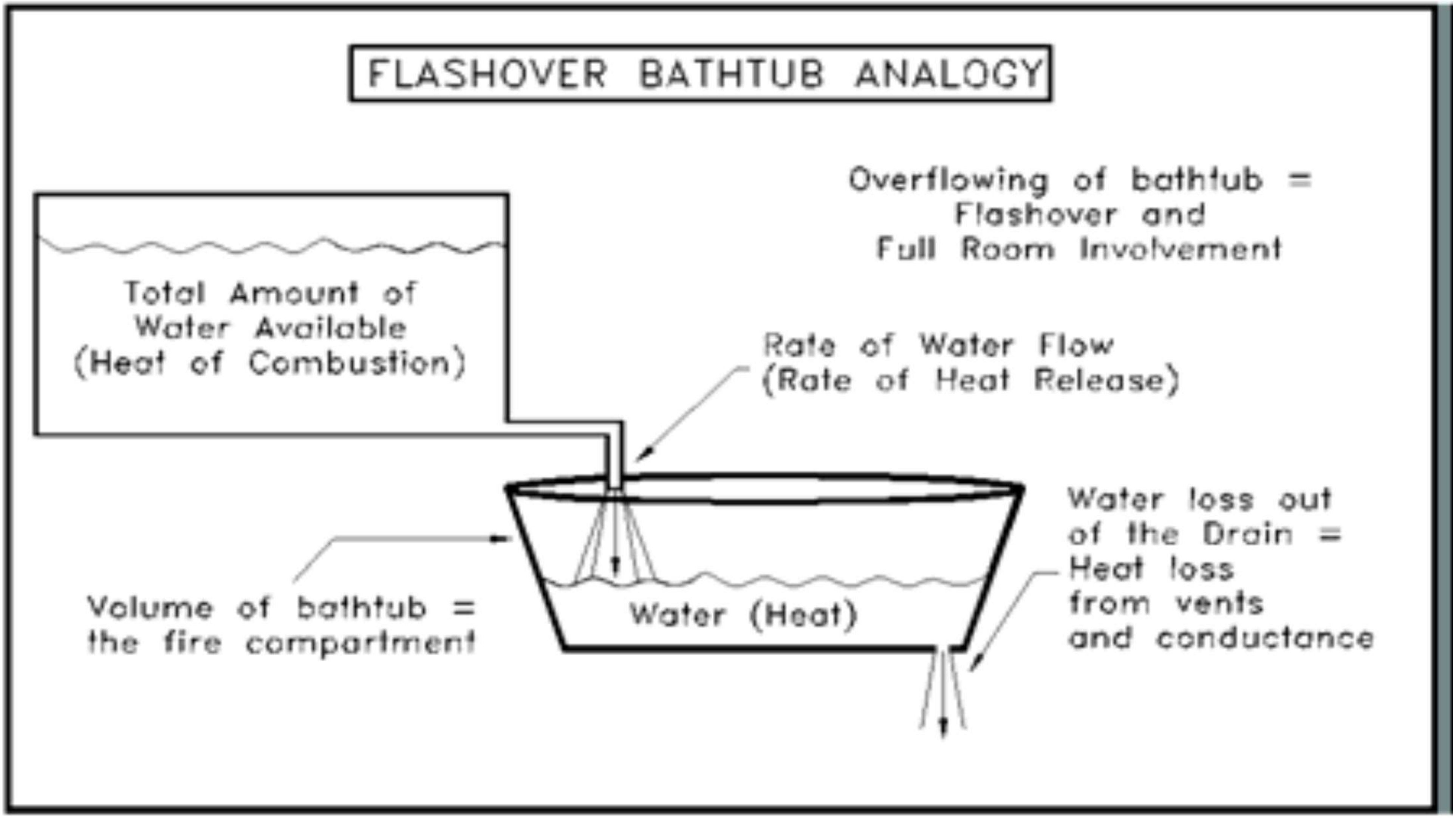
- Energy release from fire is at its greatest
- Limited by availability of
  - oxygen (ventilation), or
  - Fire load (fuel)
- Unburned gases in ventilation-controlled fires causes flaming from openings
- Very high average temperatures (700^{o}C - 1200^{o}C)
- Has potential to severely damage building
- Evacuation of enclosure must occur before flashover

1.7 Compartment Fires



Objectives of compartmentation

- Set out in TGD-B in section 3.2
  - Prevent rapid spread of fire which could trap occupants
  - Reduce the size of fires
  - Complimentary to MOE provisions (B1).


FLASHOVER BATHTUB ANALOGY
Overflowing of bathtub = Flashover and Full Room Involvement
Total Amount of Water Available (Heat of Combustion)
Rate of Water Flow (Rate of Heat Release)
Water loss out of the Drain = Heat loss from vents and conductance
Volume of bathtub = the fire compartment
Water (Heat)

Construction of Compartment Floors and Compartment Walls

- Standards are to
  a) form a complete barrier to fire between compartments
  b) have the appropriate fire resistance (Tables A1 and A2)
  c) be constructed in accordance with 3.2.5.1 to 3.2.5.11.
- Junctions are a particular source of weakness and require attention to detail and to workmanship
  – between walls/floors (3.2.5.9),
  – Courtyards, light-wells and opposing elevations(3.2.5.10), and
  – Compartment walls and roof (3.2.5.11).

Fire Resistance for compartmentation by calculation.

- Involves calculating the load capacity (containment ability) of a structure exposed to fire and is subject to verification in the time domain, the temperature domain, or in the strength domain.
- The calculation process has 3 essential component models:
- A fire model, a heat transfer model and a structural calculation model.

(a) A fire model: Input is by way of a selected time-temperature curve (standard fire cf. ISO834, measured real fire (cf. research data), or a parametric fire curve (cf EC3).

(b) A heat transfer model (HTM): Calculations require the geometry of element(s), the Material's Thermal properties, and the Heat Transfer co-efficients of boundaries. The load capacity (containment ability) of a fire-exposed element/structure depends on the internal temperatures as heat is conducted from the surface to the interior of material.

Fire Resistance Calculation

(c) A structural model:

Hand calculations possible for simple elements but computer models are required for analysis of frames or larger structures.

Models for a framework of interconnected members of different materials need to include design data for

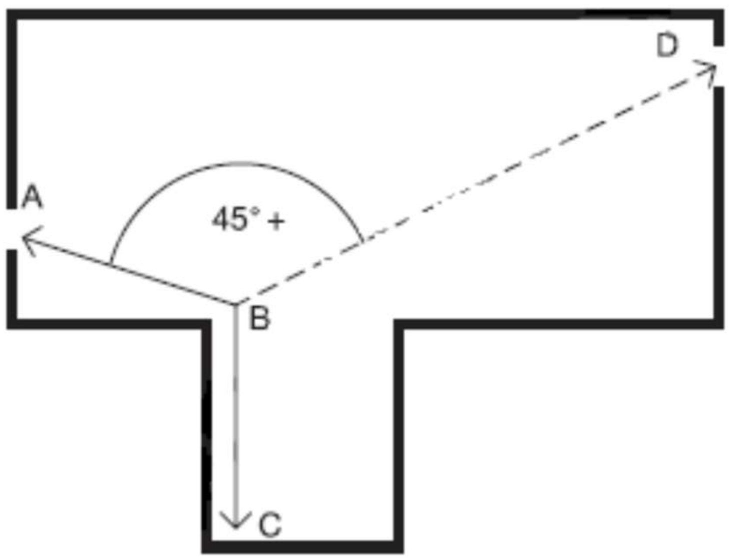
(i) the effects of thermal expansion, (ii) loading and unloading,

(iii) large deformations, and (iv) non-linear material properties (i.e. temp dependent).

Areas of interest or calculations include Walls, Floors, Beams, Columns, penetrations, Junctions/Gaps, Fire Doorsets, Ducts, Glass, Heritage construction

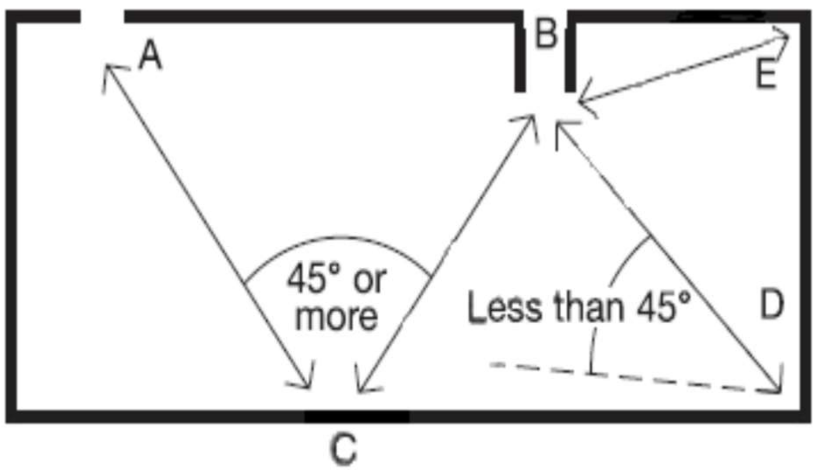
(NFPA-909 has tabulated fire rating data for masonry walls, hollow clay tile floors, heritage doors, and cast iron columns).

1.8 Aspects of Design - B1 & B3



Travel distances in dead end condition

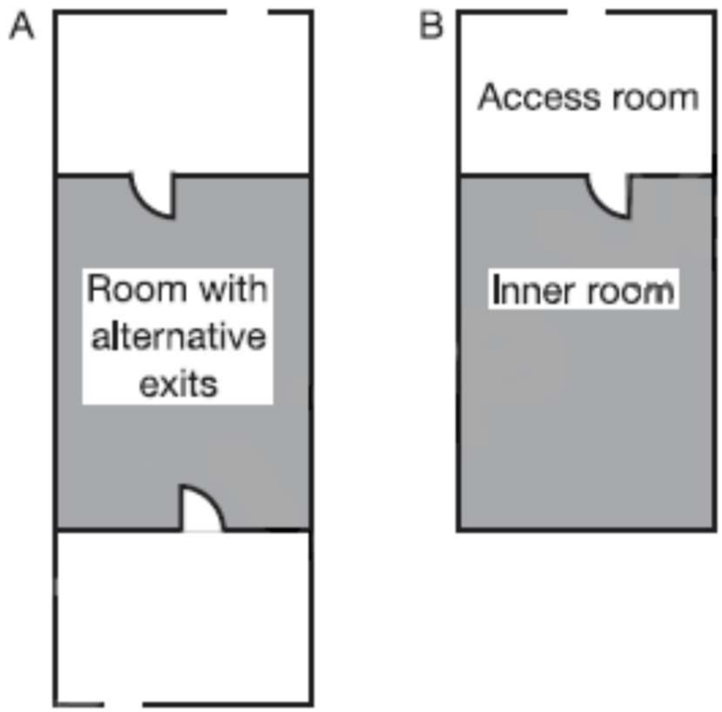
Alternative escape routes.



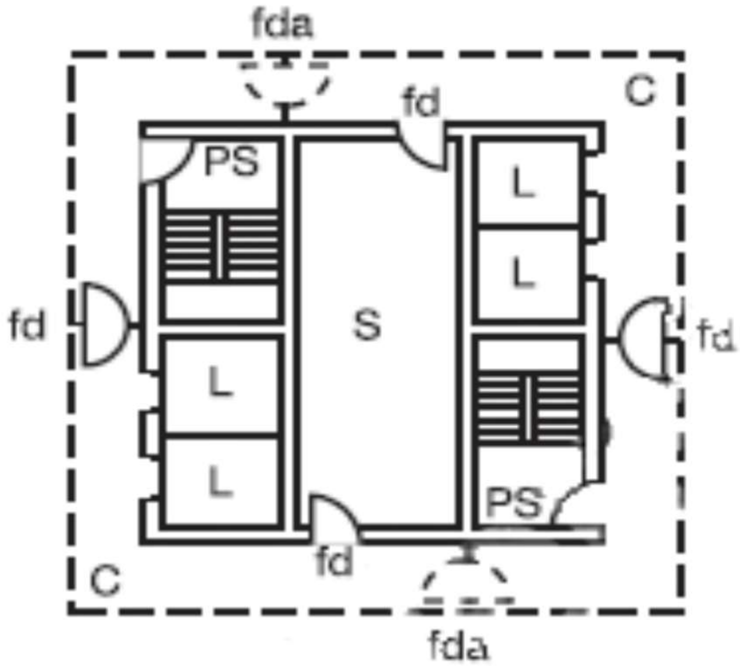
Angle A, B and D should be at least 45°. C, B & A or C, B & D (whichever is less) should be no more than the maximum distance given for alternative routes, and C, B should be no more than the maximum distance for travel where there are no alternative routes.

Alternative escape routes - Escape routes sufficiently separated by either direction and space, or by fire-resisting construction, to ensure that one is still available should the other be affected by fire.

Inner rooms and access rooms.



Exits in a central core



S Services, toilets, etc
C Corridor off which accommodation opens
fd Self-closing FD20S fire doors
PS Protected stairway
fda Possible alternative position for fire door
A Accommodation (eg, teaching space)

Table 1.1	**Occupancy load factor as per TGD-B**	
	Accommodation [1]	Occupancy load factor
	Standing area in assembly and recreation building	0.3
	Bar, lounge bar	0.5
	Restaurant, dining room, meeting room, committee room, staff room	1.0[2]
	Factory production area, open plan offices	5.0
	Bedroom or study bedroom	8.0[3]
	Offices, kitchen	7.0
	Storage building, car park	30.0[4]

TGD-B Notes:

(1) Includes categories appropriate to those purpose groups and building types other than those covered by codes of practice and other documents outlined in pars. 1.1.1 to 1.1.6. Where accommodation is not directly covered by the descriptions given, the nearest reasonable value may be selected.

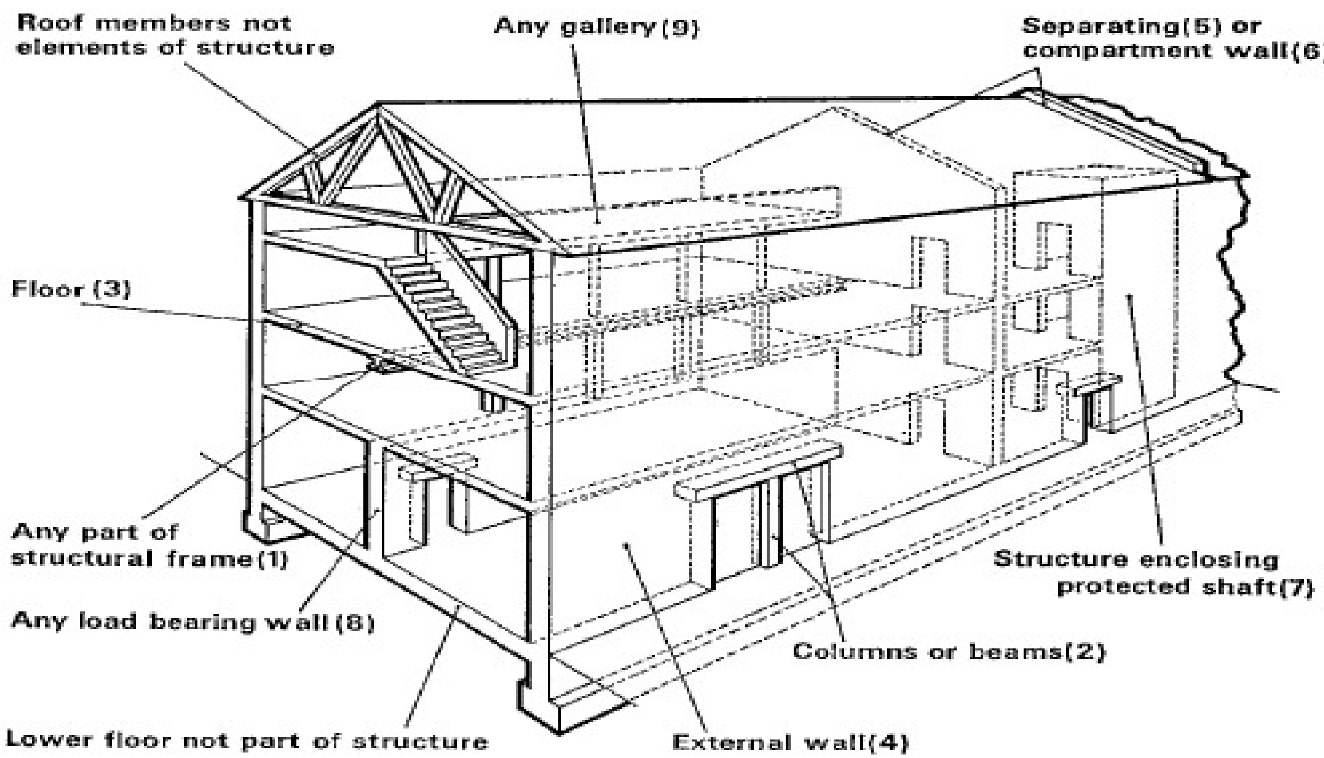
(2) Alternatively the occupant capacity may be taken as the number of seats provided, if the occupants will normally be seated. In the case of continuous seating, a width of 400 mm should be allowed per person.

(3) Alternatively the number of bed spaces provided.

(4) Alternatively 2 persons per parking space.

Table 3	**Suggested Floor factors / Occupancy load factor as per BS5588-6:1991**	
	Bench Seating	0.3[a]
	Ice Rinks	1.2
	Standing spectator areas	0.3
	Exhibition	1.5[b]
	Bowling alley/billiard or snooker hall	9.5
	Museum/art gallery	5.0
	Studio (radio, television, film, recording)	1.4

[a] If the number and length of benches is known, a factor of 450 mm per person should be used.
[b] Alternatively, a factor of 0.4 m^2 may be used over the gross area of gangways and other clear circulation space between stalls and stands



Junction of compartment wall or compartment floor with other walls (see 3.2.5.8)
Fig 1.8.1: TGD-B: Diagram 11: Compartment walls and compartment floors: Par. 3.2.4

Table 2.8.1

Limits on the construction sizes of compartments in a multi-storey building

Use of building	Limit on Area of floor		Limit on Volume
Nursing Homes	1500 m^2	*100x15*	No limit
Offices	4600 m^2		2800 m^3
Assembly Building (dancing)	1900 m^2		21000 m^3
High Hazard factory	2800 m^2	*100x28*	17000 m^3

Building Regulations (fire safety)

- B1 – Means of Escape
- B2 – Internal fire Spread (Linings)
- B3 – Internal Fire Spread (Structure)
- B4 – External Fire Spread
- B5 – Access and Facilities for the Fire Service

Building Regulations (fire safety)

- B1 - adequate means of escape …… capable of being safely and effectively used
- B2 - adequate resistance to the spread of flame and a rate of heat release which is reasonable
- B3 - stability will be maintained ……..adequate resistance……….. to inhibit the spread of fire within the building
- B4 – resistance to the spread of fire to and from neighbouring buildings.
- B5 - access for fire appliances and …. facilities … to assist the fire service in the protection of life and property

Assignment

The aim of the assignment is for you to apply the course material to a real-life situation by considering the issues relevant to the module.

Your written assignment should incorporate *all* of the following:

1. An executive summary explanation for the client, relevant to her/him as a lay person, of the challenges you have identified in your assignment.

   [*20 marks*]
2. A demonstration of your awareness of the factors involved in identification of the principal considerations. [*50 marks*]
3. Evidence of a good command of the subject. [20 marks]
4. Check for learning, summary and conclusions. [10 marks]

Assignment

- Each student is required submit a 1,500 to 2,000 word assignment document following attendance at the course module.
- Students will submit their module assignment to IT Carlow Blackboard.
- Assignments must be uploaded by [TBA].
- Assignments should be submitted typed in 1 ½ line spacing and should include a bibliography.
- Each assignment must be presented on A4 size paper (white), font size 12.
- Students must retain a hard copy and an electronic copy of their project.
- All assignments should be accompanied by an Assignment Cover sheet and a personal declaration that the work is entirely the student's for the purpose of academic assessment.
- Each student assignment should demonstrate an understanding of academic theory on the part of the student and should also relate to their work environment.

Plagiarism

3.11 Plagiarism is regarded as either intentionally or unintentionally the '*passing off*' of others' work as one's own. This includes the using of others' ideas, information presented or accessed in either visual or audio formats and asking or paying another to produce work.

- *In short, do not;* Pass off another's work as your own
- Ask another to do work which you claim as your own
- Buy or copy work from electronic sources which you claim as your own or Use another's ideas as your own

3.12 Plagiarism can be either an intentional act whereby work is deliberately utilised and claimed as one's own, or it can occur unintentionally either through bad academic practice by the student or failure to inform yourself about the Institute's regulations. Plagiarism is not confined to written assignments, projects or theses; it incorporates all academic work, including practical workshops, demonstrations, three dimensional work and artistic practice.

3.13 It is imperative that students reference their own work and provide a bibliography to support their referencing within the assignment. Students must be aware that lecturers may use specialist plagiarism detection software and other appropriate measures where plagiarism is suspected.

Bachelor Degree in Business Studies
Fire Safety, Engineering & Design: 2025-2026
Stage 2: BSEMS_B_Y2 : DAY 1 of 5

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