Building Construction

Contents

Introduction

What's In This Chapter?

This section will introduce you to common terminology used in construction and describe the effects of fire on materials. It will also assist you in understanding the parts of buildings.

It is essential to have a basic knowledge of building construction so that you are familiar with the way materials and structures react in a fire.

One of the main objectives when attacking a structure fire is to:

- isolate
- minimise
- contain

any possible spread of the fire through the building.

If a fire is intense or has been prolonged, you must also be able to recognise signs of building collapse -- a result of the structure weakened by fire.

Different building materials will react differently to the same fire, whilst the same materials can behave differently to different fires. Having a knowledge of the material's fire behaviour properties, their impact on how the structure as a whole may behave when on fire and how the various building components either contribute or resist a fire can assist you in determining what may happen during a fire or subsequent fire investigation.

Construction Materials

Introduction

NZFS personnel should know the following:

- behaviour of building construction materials in a fire, and
- the ability to assess the material's capability to resist fire and its effects for the time required to:
  - safely effect an emergency evacuation
  - facilitate the search and rescue requirements of the operational staff.

The Territorial Authority is responsible for monitoring and approving the physical components of a building. This includes construction materials and fire protection systems. NZFS has legal obligations that impact fire safety should matters of non-compliance become known during the course of duties.

This might necessitate NZFS advising the Council that a building is dangerous and immediate action is required under section 64 of the Building Act, or systems are required for a safe, expeditious and efficient evacuation. To do this, knowledge of the Building Act, the associated legislation flowing from it and the behaviour of construction materials is important.

Fire safety legislation which pertains to emergency evacuation and the systems within the building include:

- people management systems
- fire wardens
- training and education of occupants.

Key Issues

The key issues with how materials behave in fire that impact upon how much risk they pose are:

- Ease of ignitibility
- Heat release rate (HRR)
- Time to reach peak HRR
- Total calorific value (fuel load)
- Surface flame spread (SFI)
- Quantity and quality of smoke produced (SDI)
- Nature of use in the building (thermally thin, vertically positioned, in the rooms hot upper layer and well ventilated – hung like curtains or thermally thick,, horizontally positioned, on the floor and poorly ventilated – flooring boards)

The most common item first ignited in a building is either:

- a furnishing
- an object brought into the building for personal or daily use.

These items are increasingly becoming more synthetic, which can greatly increase the ease of ignitibility, HRR, fuel load and volume of smoke produced. The number of these items is increasing due to our consumer-orientated society. Escape routes, which can often become lined with these items or their packaging, is a fire risk management concern.

General rules of building design

In terms of building design the general rules are:

- Any lightweight constructed building, whether of steel, timber or polystyrene will not withstand the effects of fire as well as one that is of a more solid construction. Lightweight materials more rapidly absorb heat generated from a fire as they have a higher surface area to volume ratio, so they heat up to failure temperature faster and thus collapse sooner.
- Any building which uses panel type construction techniques will fail earlier than those where construction was insitu as the number of connections between construction members is fewer while the expansion effects are also multiplied by unbroken longer material component lengths.
- Modern construction materials, methods and components are becoming more synthetic and composite in nature and can have a much higher HRR and rate of spread of flame.

Further Reading

The contents of this chapter of this chapter of the manual contains but an overview of Building Construction.

Brannigan's Building and Construction for the Fire Service 4th ed. by Francis L. Brannigan and published by the National Fire Protection Association, Massachusetts, USA in 2008 is recommended as is the *Fire Service Manual, Volume 3 Fire Safety, Basic Principles of Building Construction* by HM Fire Service Inspectorate Publications Section and published by HMSO in 2001.

The *Fire Engineering Design Guide 3rd ed.* edited by Michael Spearpoint and published by the New Zealand Centre for Advanced Engineering, Christchurch, in 2008 is also recommended.

Building Terms and Descriptions

Introduction

It is important that Fire Service personnel can recognise and describe elements of structure in order to:

Understand (in more than general terms) how a building is constructed.

Recognise construction materials, elements, assemblies, and building life safety features.

Knowledgably inspect / survey buildings for compliance with the Building Act and Fire Safety and Evacuation of Buildings Regulations.

Match expected building performance to evacuation proposals.

Accurately describe buildings (or building remnants) in any Reports written by the Fire Service.

A list of building terms is listed below.

This list is not exhaustive. Many terms used in the construction field have specific meaning within the Building Act and subservient documents such as Acceptable Solutions and New Zealand Standards.

Common building terminology

Aggregate	The coarse or fine mixture of sand, stone, and rocks used to make concrete.
Architrave	The moulding surrounding a door or window opening.
Baluster	A post used to support a hand rail.
Balustrade	A row of balusters supporting a hand rail.
Barge board	A fixed board along the edges of a gable, covering the end of horizontal roof members.
Beam	A structural member that is positioned horizontally to carry loads between supporting columns.
Beam (laminated)	A beam with several pieces permanently attached – either side by side, or one above the other.
Bearer	A type of beam for carrying loads between piles.
Bonding	Can be: The overlapping of brickwork Adhesion between concrete and reinforcing Adhesion between any two materials.
Bottom plate	The bottom member of a wall, which sits on the floor joists.
Ceiling	The overhead internal lining of a room.

Cladding	Any material used to enclose the exterior sides of a building or structure.
Column	An upright shaft constructed of materials (e.g. concrete, metal, or brick).
Corbelling	Brackets of brick or stone, used to support the wall plate.
Dwang or nogging	Short members fixed between studs in a framed wall.
Eaves	The lower parts of a roof projecting beyond the face of a wall.
Fascia	A board fixed horizontally to the lower ends of rafters, to which spouting might be fixed.
Fire wall	A wall of concrete or masonry with a four-hour fire rating, used to separate two fire compartments and extending from the foundations to or above the roof.
Flight	A series of steps which join one floor or landing to the next floor or landing.
Gable	The triangular part of an outside wall, between the sides of the roof and the line of the eaves.
Going	The horizontal distance from face to face of consecutive risers in a stair.
Jamb	A vertical side member of a doorframe, door lining or window frame.
Joists	Structural timbers, rectangular in shape, and laid on edge at approximately regular spacing to support the flooring and ceilings of a building.
King post	Vertical members forming a tie from the apex of the roof to the middle of the tie beam, in a king post roof truss.
Landing	Platform at the end of one or more flights of stairs.
Lining	General term for the internal coverings of a building's framework.
Lintel	A horizontal beam placed over an opening in a wall such as a door or window, carrying the load above the opening.
Masonry	Stone or brickwork.
Matrix	Cement paste in which sand, particles of mortar, or the aggregates of concrete are imbedded.
Member	A part of a building (e.g. a rafter is a member of a roof).
Mezzanine	Flooring which is above ground floor level and is not supported by walls on all four sides.
Monolithic	Formed of a single stone, or cast to form a structurally continuous mass.
Newel post	Either: An upright post fixed at the foot or head of a stairway, or at a point of direction change, or The central column carrying the inner ends of steps in a spiral stairway.
Nogging	See 'Dwang'.
Nosing	A projecting, rounded, semi-circular edge to a flat surface such as a step.
Partition	Any wall dividing an area. It can be non-load bearing and moveable.
Party wall	Wall of thin construction to divide rooms.

Pile	A support driven or cast into the ground.
Portal frame	A frame of steel-reinforced concrete, or timber constructed with rigid joints.
Principal rafter	The inclined member of a truss carrying the purlins.
Purlin	A horizontal member laid to span across rafters or trusses, to which the roof cladding is attached.
Queen post	One or two vertical posts forming vertical ties in a queen post roof truss (or in any framed truss with two principal posts).
Rafter	A sloping beam forming part of the roof.
Reinforcing	Adding support to material such as steel-reinforced concrete.
Ridge	Highest part or apex of a roof.
Ridge board	Horizontal timber into which the rafters are framed.
Rise	The vertical distance through which anything rises (e.g. the rise of a stair).
Riser	Vertical surface of a step; step height.
Roof	The exterior top covering of a building.
Sarking	Boarding or sheet material secured to rafters, trusses or purlins, which may also serve as the ceiling lining.
Sash	A frame, moveable or fixed, normally used within the main frame of a window or fanlight.
Sill	The lowest horizontal member of a frame for a door or window.
Soffit	The lower face or under-surface of anything (e.g. the undersides of a roof's eaves).
Spandrel	Triangular space under the outer string of a stair.
Spouting	Rainwater pipes on the outside of a building.
String	Inclined support-carrying ends of the steps of a stair.
Stud	Vertical member forming part of a wall or partition onto which cladding may be fastened.
Tie (collar)	A timber member tying a pair of rafters usually placed about midway between the wall plate and the ridge.
Top plate	Top member of a wall, on which the ceiling joists sit.
Transom	Intermediate horizontal member of a window frame.
Tread	The horizontal surface of a step.
Truss	A framework used to support a roof.
Under-purlin	Horizontal timber laid under rafters to support them.
Wall plate	Collective term. (See 'Top plate' and 'Bottom plate'.)

Other Terms and Definitions

Intumescent

This term is used to describe a material that expands when heated, usually forming a chary mass, which provides insulation from heat to the material to which it is bonded.

Module of elasticity

Measures the ability of a material to distort from its original shape and restore to its original shape.

Spalling

This term is used to describe the crumbling or peeling of concrete / masonry when it is heated.

Kelvin Temperature Scale

The Kelvin temperature scale (K) has what is called absolute zero temperature (0°). This is the temperature at which molecular energy is a minimum and it is equal to –273.15° on the Celsius scale. To compare the two scales we will use water. Water will freeze at 0°C, which is 273.15°K, and will boil at 100°C or 373.15°K. It is easy to work out the Kelvin temperature from Celsius by simply adding 273.15 to the Celsius temperature. Scientists use the Kelvin scale when testing the properties of material when exposed to heat and fire.

Specific heat capacity

Specific heat capacity of a substance is the amount of thermal energy (heat) needed to raise the temperature of 1kg of the material by 1° Kelvin.

If the surfaces in a room heat up quickly they will radiate, or reflect, a large amount of the heat back into the room and possibly cause further fire development.

If the room is insulated with a material with low thermal conductivity, the fire may develop more quickly due to greater availability of thermal energy in the room.

However, if the room had a lining with high thermal conductivity it would allow heat to travel outside of the room. Combined with materials that heat up slowly, the fire will possibly take longer to develop. Of course, if heat is escaping from the room there is potential for fire to develop in a location outside of the involved room.

Thermal conductivity

This term describes how easily or not heat transfers along or through an object. Objects, which are dense, such as steel, will conduct heat easily as opposed to wood, which is less dense and is not a good conductor of heat.

Thermal diffusivity

This term is used to describe the overall heating up of a structure. Calculations are used to determine how heat is defused (spread) through a structure. The nature of the materials used in a structure will directly affect the ability of heat to move through the structure. Materials that conduct heat easily (conductors) have a high value of thermal diffusivity while materials that do not move heat easily (insulators) have a lower value of thermal diffusivity.

By understanding this, fire engineers can determine the likely effects of fire on a structure due to the materials used. Of course the actual design and quality of the workmanship will also impact on actual results in a fire.

Thermal expansion

This term is used to describe the ability of material to increase in size and/or length when heated.

Steel is a good example:

- A railway track, when heated during hot weather, expands lengthwise and the gap between the lengths is reduced making the "clickety-clack" of the train quieter in summer, as the gap is smaller. Of course, in recent years the gaps have been welded to reduce noise. As a result, the steel expands and is forced to buckle, as the expansion space (gap) no longer exists.
- An increase in length of the steel beam could lead to serious weakness of the building and increased chance of at least partial building collapse.

Coefficient of expansion

Different materials will expand at different rates. This rate is known as the coefficient of expansion. It is not necessary to know the coefficient of all materials but it is useful to understand how it works.

The coefficient for steel is 0.000012 per K (Kelvin degrees) or C (Celsius)

To work out how much a steel beam will expand, multiply the length of the beam by the coefficient and the increase in temperature.

Therefore, for a 10m beam with an increase in temperature of 500°C the calculation will be:

10 x 0.000012 x 500 = 0.06 of a meter or 60mm.

Ultimate strength

The actual strength of the material

Yield strength

The point at which material will break.

Tensile strength

A measure of the ability of a material to withstand lengthwise stress. It is expressed as the greatest stress that the material can stand without breaking.

Compressive strength

A measure of the ability of a material to withstand downward pressure from a weight being placed on it.

Concepts of Structure

Introduction

Gravity is defined as: the natural force of attraction exerted by a celestial body, such as Earth, upon objects at or near its surface, tending to draw them toward the centre of the body

(<< http://www.thefreedictionary.com/gravity>> read 8/8/2010).

However, Brannigan (2008) describes the force of gravity as ' . . . **the eternal enemy of every building'**.

Buildings defy gravity. As structures, they are designed to counteract the forces of gravity by distributing the forces through elements of structure to a neutral plane.

Forces

Buildings also defy other forces imposed on them such as wind, earthquake, and the dead and live loads imposed by our use of the building. These forces are also distributed through elements of structure to a neutral plane. An external force is more commonly referred to as a load; an internal force is a stress.

Generally, there are three types of forces can be applied to a structural member, a compression force is trying to crush the element of structure, a tension force is trying to make the element longer, a shear force is trying to make two elements slide past one another.

The purpose and principals of Building Act 1991 simply explained in section 6, that the Act was for ensuring that buildings were " . . . safe, sanitary and have means of escape form fire . . .". Section 3 of the Building Act 2004 expands on the simpler definition detailed in the 1991 Act but essentially says the same as the 1991 Act.

"Safe" meaning simply that buildings shouldn't fall down. Buildings should be designed and built to withstand the forces expected to be applied to the structure.

It stands to reason therefore that damage to any of the elements of structure distributing forces to the neutral plane will affect the structure's ability to stand safely and at worst, cause the structure, in total or in part, to collapse.

Furthermore, any damage to the systems used to connect elements of structure together, so that forces can be distributed effectively to the neutral plane, will also affect the structure's ability to stand.

Loads

Introduction

"Load" describes a particular weight or pressure being applied

Load Types

In relation to buildings, several terms are used to describe different load types

Dead Loads

This is the weight of the building itself and all the permanent built-in equipment.

Modern buildings are increasingly being built with lighter materials to save weight. However, lighter materials generally have less fire resistance (e.g. a larger steel beam retains its strength in a fire longer than a smaller steel beam).

Some buildings may have had dead weight added over the years, in the form of additional equipment (e.g. air conditioning units) – possibly without the building being strengthened to accommodate this. In a fire, a building may collapse earlier than expected due to these increased loads.

Live Loads

Live loads are any loads that are not a dead load.

Live loads include items such as furniture, people, and other non-fixed equipment (e.g. a built-in steel vault would be a dead load, but a portable safe would be a live load).

Live loads are constantly changing – what is observed one day will not be the same the next.

Static Loads

These are loads applied gradually to a structure, such as material being added to a storeroom. The load increases when an item is added, but may remain static for some time.

Impact Loads

This is a load suddenly applied to a building. This type of load is more likely to cause a collapse than a slow increase in the load on the building.

Lateral Load

These are loads applied to the walls of a structure horizontally to the ground (e.g. leaning a ladder against a wall is applying a lateral load). Wind is a lateral load.

Concentrated Load

These are heavy loads confined to a small area of the building. Items such as safes, filing cabinets or pianos are concentrated loads. Such items can cause collapse if the area they are in is weakened.

Fire Load

The sum of the net calorific values (in MJ) of the combustible contents that can reasonable be expected to burn within a fire cell.

References

Brannigan, FL. 2008. *Brannigan's Building and Construction for the Fire Service, 4th ed.,* NFPA, Massachusetts.

Fire Service Manual, Vol. 3, 2001. *Fire Safety, Basic Principles of Building Construction,* HMSO London.

Elements of Structure

The elements of structure used to assemble a structural frame are as follows:

- Beams
- Columns
- Arches
- Load bearing walls
- Connecting systems

Beams

A beam transmits forces in a direction perpendicular to such forces to the points of support. The definition of a beam does not consider its attitude. The beam can be vertical, horizontal or somewhere in between? If an element of structure is transmitting forces in a direction perpendicular to the force to the points of support, the element is a beam. A rafter is a beam, so is a lintel.

Different terms are used to describe various types of beams:

There are simple, continuous and fixed beams. Cantilever, suspended and transfer beams. Joists, girders, and as mentioned above, rafters and lintels. Beams can be made of wood, steel and reinforced concrete

Columns

A column transmits compression forces along a straight path in the direction of the member. The definition of a column also does not consider its attitude. The column can be vertical, horizontal or somewhere in between? If an element of structure is transmitting compression forces along a straight path in the direction of the member, the element is a column. Studs are columns, so are braces.

Columns can be made of wood, steel and reinforced concrete.

Arches

An arch combines the function of a beam and a column. The arch is under compression along its entire length. Arches tend to push outwards at the base and therefore must be braced or tied. And while the graceful and classical Roman arch is not a common sight in modern building, the portal frame or rigid frame (an arch derivative) is often encountered in large buildings such as halls and warehouses.

Arches (as portal frames) can be made of wood, steel and reinforced concrete.

Load Bearing Walls

A wall is a wide slender column. Being a column, it transmits compressive forces from above to the ground (as the neutral plane), via other elements of structure.

The load bearing wall carries these forces as well as supporting its own weight. A non-load bearing wall only supports its own weight.

Connecting Systems

Relevance to Fire Service Activities

Familiarisation and Inspection Visits

An opportunity to identify damage or alterations to key elements of construction.

An opportunity to identify the application of dead loads to structures. A roof is not initially designed to take additional loads such as air-conditioning units.

Fire Fighting

An ability to appreciate that the application of water to a structure on fire adds to the live-load total for the structure.

An ability to assess a structure on fire for indicators of impending collapse as key elements of structure and/or their connecting systems are affected by the fire.

Fire Investigation

An ability to forensically reconstruct a building by 'imagineering' to possibly establish fire spread based on the collapse sequence of the structure as key elements of structure and/or their connecting systems were affected by the fire.

An ability to assess a building post fire for stability issues prior to and during investigative activities. Excavating fire debris alters live-load totals and the direction of force applied to the structure remnants.

Behaviour of Materials in Fire

Description

In this section, you will be introduced to the common materials used in construction and how they are affected by fire.

Most fire fighting is conducted in and around structures. Therefore, knowledge of the materials used is needed to provide knowledge of what to expect and how to remain safe at a structure fire incident.

If necessary, refer back to the definitions and information in the previous sections.

Properties of building materials

Materials have three distinct properties, which are assessed before the material is considered suitable for construction purposes:

- Combustibility
- Flammability
- Surface spread of flame

Combustibility

A material is combustible if it is capable of burning or if you want the technical wording "if they are capable of undergoing combustion, that is, being consumed by oxidation, with the production of heat, usually incandescence (glowing), or flame, or both."

Flammability

This refers to how easily ignited the material may be. Material may be combustible but not easily ignited.

Surface spread of flame

This refers to how quickly or slowly flame will spread along the surface of a given material.

Material is classified into four categories as determined by laboratory tests:

- Very low rate of surface spread of flame
- Low rate of surface spread of flame
- Medium rate of surface spread by flame
- Rapid rate of surface spread by flame.

Treatment of material

In many cases material can be treated with fire retardant products to reduce the rate of flame spread or to make them harder to become combustible.

While two materials may look the same they may react differently in a fire due to whether they have had fire retardant treatment.

Steel

Steel is a common material in modern construction and can be found in domestic houses as well as high-rise buildings. Steel is a good conductor of heat.

Effects of fire

The ability of steel structures to remain functional during a fire is dependent on a number of things.

You must understand that steel losses half of its strength at approximately 550°C, a temperature easily attainable in a fire.

The load on the steel will also play a part. The greater the load the more likely an early failure could occur.

Also playing a part will be the design and construction of the steel components. Depending on the space made available to accommodate expansion, a steel component could cause a collapse situation sooner rather than later. A 10m steel beam will expand 60mm for each 500°C rise in temperature.

To slow down the impact of heat on steel, insulation is used. The type and qualities of the insulation will have a direct impact on the behaviour of the steel. Good insulation will slow the heating process providing more time to attack the fire from within.

The bottom line for you is to be aware that fire generates enough heat to impact the strength of steel in a building. The result can lead to structural failure.

Increasing resistance to fire

Steel can be made to retain its strength for longer periods under fire conditions through the following:

- insulation
- over-sizing the steel components (using a larger, thicker piece of steel than is required for the normal load being placed on it).

Insulation

Insulation materials must be non-combustible and immune from giving off smoke and toxic gases when heated. The materials being used need to be reliable, consistent, efficient and applied correctly throughout the structure.

These products must also be durable enough to withstand surface damage during construction and be resistant to weathering or erosion.

Insulating products

A number of options for insulating steel are available on the market.

Board products

Four types of board product are:

- Gypsum boards
- Fibre reinforced calcium silicate board
- Vermiculate / sodium silicate board
- Mineral fibreboard.

For each of these products, their installation around the steel is critical to their actual performance. The use of incorrect attachment methods or general poor workmanship will reduce the insulating properties of the board.

How they work

When installed, the boards create an air pocket around the steel member. (See figure 2.2). Heat transfer to the steel is reduced due to the air space and the insulating properties of the board. As these products are designed not to combust, they prevent flames from having direct contact with the steel effectively reducing the heat flow.

Concrete encasement

Concrete encasement of steel members involves surrounding a component such as a beam with concrete. This forms a barrier between a heat source and the steel. The concrete also has a load bearing capacity increasing overall strength of the structure.

Sprayed coatings

Another alternative is to use a spray on coating. There are several spray-applied products available including:

- Cementations plasters
- Mineral fibres
- Magnesium oxychloride cements
- Intumescent material.

Intumescent paints for example react with heat to form a thick chary mass that protects the steel from heat. Several layers may be needed to obtain the adequate insulation. The paint allows the clear site of the member, but it is expensive and not suitable for outside use.

Over sizing

It is possible to increase the fire resistance of a structure by increasing the size of the member. By increasing the cross section of a steel beam the strength increases, which in turn increases the time it will take for the beam to heat up to a temperature where it is in danger of failing.

This method can be both expensive and consume additional space in the structure.

Aluminium

Modern building techniques are introducing widespread use of aluminium for both structural and cladding purposes.

Advantages

Aluminium provides the following advantages:

- Reduced weight of the structure
- Resistance to corrosion
- Ease of handling and working
- High strength to weight ratio

Disadvantages

The disadvantages are:

- Very rapid loss of strength in a fire (strength affected at 100 – 225°C)
- High expansion rates (approximately twice the rate of steel)
- High thermal conductivity (three times that of steel)
- Low melting point (660°C)

As with steel, insulation can reduce the effects of fire on aluminium.

Common Uses

Aluminium is replacing timber for the construction of partition walls, especially in commercial buildings, but can be found increasingly in domestic construction. Due to the disadvantages mentioned above, aluminium framed partitions can be expected to fail sooner than timber framing.

Aluminium window frames are also common.

Concrete

Concrete is usually made from a combination of:

- Cement
- Sand
- Blue metal aggregate (building mix)
- Water

It may be poured as a slab for a floor, used for columns and beams and as protective covering (insulation) of other materials.

Effects of fire

Concrete can crumble and peel when heated and this is known as spalling.

The removal of layers through spalling will reduce the thickness of the concrete, exposing steel reinforcement to greater temperatures, which in many cases may lead to failure of the component.

Causes of spalling

Spalling is not totally understood, however, scientists and engineers have developed theories related to its causes. The main causes of spalling appear to be:

- excessive compression or restraint of the material
- the formation of high pressure steam in the material
- the splitting of aggregate used in the concrete mix.

Expansion

In a fire the outer and inner layers of concrete heat up at differing rates. This results in differing expansion rates in layers of the concrete.

The unequal expansion in the adjacent layers cannot relax due to the steel reinforcement causing internal stresses, which may cause the layers to separate.

Water vapour

Spalling occurs when water vapour is driven out of the cement during heating. The result is a pressure build up in the pores within the cement. Eventually the pressure will build to a point where it is greater than the tensile strength of the concrete and explosive spalling will occur.

Splitting of aggregate

The splitting of the aggregate is due to the thermal instability of the small solids, in other words the stones / gravel / builders mix. The chance of splitting of aggregate increases with the size of the aggregate.

If you have ever built a fire on a riverbank with river stones around it, you may have noticed that some of the stones will have split due to the heat from your fire

Effect of spalling

Spalling may result in only light damage to the exterior surface of the concrete or can be severe enough to expose the steel reinforcement rods, which can put the fire resistance property of the structure at risk of collapse.

With steel, it is possible to enhance the fire performance of concrete by applying layers of insulation such as the boards mentioned in the previous section.

Secondary reinforcement is the preferred method for enhancing fire resistance of concrete. This is usually accomplished with a wire mesh to hold the concrete up to the steel, preventing the insulating layer of concrete from falling off.

Masonry/ Stone

There are many types of stone products used in construction for both structural and aesthetic purposes. Though used less often in today's modern buildings, you may still come across it.

Masonry units such as blocks, bricks, slabs and stone can produce walls that have considerable fire resistance but can also be a potential danger on the fire ground. The masonry units are held together using cement based mortar and often incorporate steel reinforcing and, depending on the type of block, concrete filling

Fire resistance

The resistance of a masonry wall to fire depends on the relationship between height, length, thickness and loading of the wall. This is known as the slenderness ratio. How this type of masonry unit is produced and its moisture content determines its resistance.

Spalling

Spalling can occur on larger surfaces, and cracking of walls is not uncommon. The extent to which this occurs depends on how the units were made. The mortar used in such walls may affect the performance of the wall as a whole.

Heat penetration

Heat penetration is a slow process in masonry walls. The transfer of heat through a wall can take from approximately one hour, for a single brick wall, to more than four hours, for plastered double brick walls.

Types of stone

The three main types of stone found in building construction today are:

- granite
- limestone
- sandstone

Granite

Granite has a pleasant appearance and has been used extensively in construction over the years. In modern times it is used far less for load bearing and more for decorative facings.

When granite is subjected to heat, it expands rapidly. At approximately 575°C the rock will shatter or spall. When water is applied to hot granite, failure will be accelerated, which could cause load-bearing structures to collapse. This is similar to thermal shock with glass.

Limestone

Limestone will start to decompose in fire at around 800°C. When water is applied, the surface skin of the stone will fall away with a loss of 50% of its strength. If limestone has been used for load bearing, collapse of the building may result.

Sandstone

Sandstone will shrink in a fire and crack losing approximately 30% of its strength. Applying water will cause spalling and further weaken the load carrying capacity of sandstone.

Note: When confronted with load bearing stonework at a fire, you must take care to observe for cracks that may appear. If cracks are observed, take precautions to ensure that the danger of collapse is notified to all attending the fire.

Bricks

Bricks are made of a number of different materials. The most common are:

- fire clay bricks (fired in a kiln)
- concrete bricks (made form cement and fine aggregate)

Apart from some spalling, clay bricks are seldom affected by fire. However, they pose a significant hazard to fire fighters.

Bricks have low thermal conductivity meaning that the side of the brick exposed to flame will heat up and expand more rapidly than the protected side. This will cause the wall to bow and move off vertical leading to collapse.

When working close to brick walls, watch for signs of cracking and bowing, which are signs of collapse.

Glass

Glass is used in two main ways in building construction.

1. Glazing for windows and doors: generally little fire resistance but may be modified or treated. For example, wire reinforced glass is more effective in resisting fire than plain glass.

2. Fibreglass insulation (Batts®). This does not burn and is an excellent thermal insulator with many applications within the building industry.

Fibreglass reinforced plastic building products such as translucent window panels, etc. These windows may be designed to melt at a certain temperature to provide ventilation to a fire in a compartment. Note that the plastic component of this material may be combustible.

Glass windows, doors and walls

Glass does not burn so it will not contribute to the fire load of a structure or directly aid the spread of the fire.

Modern glass and glazing systems provide an effective barrier to the spread of smoke and flames. It may also provide some protection from radiant heat.

On the other hand, older standard glass found in most New Zealand homes can be a weakness in the structure. The glass will most likely break and fall out of its frame during a fire and will allow the fire to spread along with smoke.

This can be a benefit if the glass is in an external wall or door as it may provide useful ventilation. Of course, this is totally dependent on the circumstances of the fire.

There is a risk posed by the potential for glass to break and of course injury from broken glass.

Unless glass is treated in some way, it will radiate heat from a fire. When a fire is well involved, the heat radiated through glass is a hazard with the possible combustion of material on the other side of the glass. It also poses a risk to anyone in the area.

Thermal shock

Thermal shock refers to the consequences of a sudden change in temperature. In relation to glass, thermal shock will occur when cold water is applied to heated glass. This will cause the glass to shatter.

It is important that you are aware of this potential when operating a branch, because your actions could lead to windows breaking suddenly. Of course the force of water from the branch could be enough to break a window on its own.

Advantages of glass

On the positive side, glass has the advantage of allowing you to see through doors, windows, etc. It enables the location of people and the fire more quickly due to the visibility provided by glass.

The advances that have been made in glass design have enabled glass to be used in places where fire protection is required.

Glass provides an easy option for compartment ventilation because, in most cases, it is relatively easy to break.

Note: Windows may break without warning during a fire -- keep clear of unbroken windows in compartments with potential for backdraught.

Wired glass

A common form of fire resistant glass is wired glass. Wired glass solves the problem of stability and integrity by holding the glass in place. Unless treated further, this glass does not provide insulation from radiant heat. Its advantages are that it will delay the spread of smoke, flames and hot gases.

Laminated glass

Modern glass products have been developed which will retain their structural integrity as well as reduce heat radiation and transmission. This type of glass will commonly be a form of laminated glass (two or more bonded sheets) with a transparent intumescent layer between the sheets of glass. When heat is applied to this type of glass the intumescent layer expands and becomes opaque. This process will usually occur when temperatures reach 120° C and above.

Intumescence and glass

The effects of the intumescent material reduce heat radiation through the glass providing some protection to people and materials on the other side of the glass.

Many office buildings will have glass partitions of this nature.

Laminated glass may be difficult to break through and can be used in large sizes. Therefore, it can be used for internal walls where other opaque fire resistant materials such as brick or concrete would have been used in the past.

Glass installation

A key factor affecting the ability of any glass to function appropriately in a fire is the installation and framing. Incorrect installation or poor workmanship may reduce the ability of the glass to perform as specified.

The overall effectiveness of glass in a fire is a combination of the type of glass, the frame and the installation.

Double glazing

Double-glazing is now quite common especially in domestic buildings. Two panes of glass are used with a gap of at least 5mm between the panes. This does not increase the fire resistance of the window and in fact can cause the glass to shatter with explosive force.

Fibreglass insulation

The most common insulation material in New Zealand is Pink® Batts®. This is a glass wool product constructed of fine glass fibres bonded with a resin. The glass fibres do not burn when subjected to fire but will melt. On the other hand, the resins used are combustible and can be difficult to extinguish. This product has varying fire resistant ratings and will assist in slowing the spread of fire, as it will insulate building members from heat. This protection will be lost once the product begins to melt causing it to move away from the structural members.

Wood/Timber

Wood is, without doubt, the most common material used in construction and will be found in almost every structure. It can be found in floors, roofs, beams, columns, partitioning, stairs, doors and window framing.

Heat conduction

Wood is not a good conductor of heat but is combustible.

Wood also has a low expansion rate when heated and does have reasonable resistance to fire.

The level of fire resistance can be enhanced by various treatments applied to the timber.

The fire resistance of timber is dependent on three things:

- The performance of its protective covering (i.e. Gibraltar board)
- The extent of charring of the timber member
- The load carrying capacity of the uncharred portions of the timber member

Advantages in construction

Wood has a good strength to weight ratio, is affordable and easy to work with.

Effects of fire

When combustion takes place, a layer of charcoal is formed on the burning surface, which helps to insulate and protect the unburnt wood below the charred zone. (see Fig 2.4)

The low thermal expansion of wood allows the char layer to stay in place even with continued heating.

The low thermal conductivity helps the undamaged wood below the char to retain its strength.

The following factors will affect how much strength is retained in wooden members exposed to fire:

- The thickness, or cross sectional area
- The quality of workmanship during construction

- Whether it is hard or soft wood
- Whether the wood has been treated with fire retardant products.

Charring

Charring is the thermal degradation (pyrolysis) of wood when it is exposed to fire.

In general, it has been found that wood chars at an almost consistent rate of between 30mm – 50mm depth per hour. This is dependent on the type of wood, moisture content, etc.

It should be noted that the char rate could be as high as 4mm per minute, which is equal to 264mm per hour.

Char diagram

Fig 2.4 Char diagram.

Importance to Fire Investigators

Wood charring depths can provide valuable clues to fire severity and burning duration – allowing the fire safety officer to allocate approximate times to events during the fire's development.

Extreme care must be used when determining origin and cause by this method alone because localised burning behaviour is heavily dependent upon the optimal factors in the fire triangle and fire ground activities.

A good example of how deeper charring can be misleading is often seen in the damage around wooden window frames, where the fire has vented. These wooden structures are most often completely consumed, yet seldom was the fire burning there for long.

This is a case where the available ventilation and venting heat are maximised, including direct flame impingement upon the wood frames. The vaporised fuel gases from within the compartment ignite as they meet oxygen leaving it at the window boundary.

Also fire ground techniques and tactics can leave pockets of fire burning for long periods, before final extinguishments, due to the difficulties presented by the containment, priority, resources or access.

Light timber frames

Light timber frames can be found everywhere being extensively used in residential houses, offices and factories.

These walls are most commonly covered with plasterboard for interiors and a number of differing claddings for exterior walls.

Interior partition walls constructed of a timber frame with a plasterboard covering are commonly referred to as Dry Wall construction.

Effects of fire

The covering over the frame will provide insulation of the timber members; the type and thickness of the covering will impact the level of protection and, therefore, the fire resistance of the wall.

If insulation such as Pink® Batts® is included in the wall, further resistance may result.

The strength of a wall is affected by the connections of the various members.

A variety of methods such as nails, nail plates, bolts, etc., can be used to join the various members. All of these are metal and are therefore good conductors of heat. When exposed to flame, these connectors will rapidly heat up and can cause charring to the timber. As a result, the connection may be weakened and could fail if under sufficient load

Connections (Nails, bolts, metal fasteners)

The material used to connect timber members and the method and type of connection used determines the fire resistance of timber structures.

The connections themselves may have greater fire resistance than the timber, however, the way they react to fire can directly affect the timber.

Metal fasteners

Metal fasteners tend to heat more rapidly than the wood. This can cause the wood in contact with the fastener to char and/or cause loss of strength of the timber. The good thermal conductivity of metals will lead to the heating of the wood interior causing charring which weakens the wood. The effect will be to reduce the load-carrying capacity of the timber member.

Generally, nailed spliced plates give the best fire resistance with bolted joints having about half the resistance.

Toothed plate connectors have the lowest fire resistance rating. The nailed spliced plate and bolt connections perform better due to the smaller area of steel exposed to fire and the low surface area in contact with the timber.

Glued Connections

Glued wood members generally behave in the same way as solid wood when thermosetting adhesives are used. Some adhesives, including epoxies are sensitive to high temperatures and must be used with caution.

Building Boards

This material is used extensively for partitioning in buildings. It is relatively inexpensive and easy to work with.

Boards vary in size and thickness. The use of boards will vary depending on the areas they are used in, be it flooring, walls or ceilings. Boards are produced with varying

Types of boards are described below:

Fibreboards

Usually made from wood fibres and derives their strength and cohesion by “felting” of the particles under pressure. Adhesives may also be added during manufacture. Common brands you may be familiar with are “Pinex”, hardboards, particleboards and chipboards. Normally these boards are combustible but not easily ignitable.

Plaster boards

Constructed of gypsum plaster held between sheets of heavy paper. The paper will combust the plaster will not (see below for more detail). It is commonly referred to as Gibraltar board or simply Gib.

Asbestos

This is no longer used in modern construction as it poses a serious health hazard. Many older commercial buildings may still have asbestos roofs and walls. If you suspect asbestos to be present at a structure notify the OIC immediately.

Cement boards

These have replaced asbestos but it can be difficult to tell the difference between the two. If in doubt, treat it as asbestos. Cement boards are most often used for exterior cladding usually with a sprayed plaster finish.

Plywood

Made up of wood sheets laid in alternate directions to increase strength. Susceptibility to fire depends on the type of wood and bonding material used.

Soft boards

Made by milling wood chips producing wood fibres that are compressed and dried to form wood fibre boards using a binding substance or the woods own natural resins for the purpose. Soft board is divided into natural and impregnated soft board depending on whether any binding substance has been added.

Gib board fire resistance

The fire resistance of these boards depends on interrelated properties:

- The quality and formulation of the gypsum plaster board
- The ability of the board to remain in place and not disintegrate or fall after dehydration

- Resistance to pull through of nails and screw heads after dehydration, especially in ceilings
- The ability of the material to resist ablation (melting) from the fire side during extreme fire exposure
- Resistance to excessive shrinkage, which can cause cracking within the board or separation of joints between sheets.

Reaction to fire

When board is heated from one side, the temperature increases continuously until about 100°C is reached. At this point there will be a delay in the heating while water in the gypsum is driven off. As the heating continues, the 100°C temperature plateau will slowly move through the board until the whole board is dehydrated.

Once the board is dehydrated, its ongoing resistance properties are diminished.

Regular plaster board

Regular plasterboard will crack after relatively short exposure to fire allowing flames and hot gases into the wall cavity behind the board.

Reinforced boards

To combat the cracking problem mentioned above, reinforced boards tend to develop many small, fine cracks that enhance the fire resistance. The reinforcement usually consists of glass fibres mixed in the gypsum plaster. The glass fibres help to bond the plaster together.

Lightweight Sandwich Panels

These panels are commonly found in buildings used for food processing where hygiene and thermal insulation are important. They are often used in walls and ceilings

These panels present serious risk to fire fighting activities.

Construction

These panels consist of a polystyrene core sandwiched between sheets of metal. The metal sheets are usually only attached to the polystyrene.

Consequences

With a traditional building, we would say that the fire is in the building. With these types of panels the building itself is on fire.

As these panels add greatly to the fire load, they are a serious concern. The heated polystyrene may either melt and flow out of the panels or will be converted to a flammable gas within the heated panel. The reaction will depend on the temperature, the type of polystyrene and how well the panels are held together.

No matter which occurs, there will be severe heat and damage.

There is an increased chance of collapse with this type of material. It is also difficult to extinguish fires inside these panels as the steel covering prevents access to the interior until collapse occurs. In turn, this will slow down attempts to stop the fire spreading.

Panels some distance from the firebase may collapse due to the rapid spread of fire within or heat transfer from the fire to the panels. Note that you don't have to be close to the fire to be in a collapse zone.

Effects of Fire

These panels present 3 major problems in relation to fire, which are:

- Their potential large contribution to the fire load of the structure.
- Hidden fire spread within the panels.
- Rapid loss of strength when exposed to fire.

The behaviour of these panels will depend to a great extent on type of filler and its behaviour when exposed to heat. In most cases, the polystyrene filler will melt and shrink away from the containing metal sheets. As a result, the metal sheets will collapse.

Identification

The identification of these panels once installed can be difficult due to the finishing which may be applied to them.

The best time to identify the panels is during construction. Be aware of the construction going on in your area. In the case of these panels, it is recommended that the information be

Structural Components

Introduction

The combination of materials, construction method, age and loads on a building will directly impact how that structure will perform in a fire. This chapter cannot cover every aspect or type of construction. However, having an understanding of common structures will assist you in operating safely at structure fire incidents.

Behaviour of buildings in a fire

The behaviour of buildings in a fire depends on many factors including:

- Location of the fire
- Intensity of the fire
- Duration of the fire
- Fire resistance of the structure
- Loading on the structure

For the fire fighter, this means it can be difficult to determine or predict exactly what is happening, what course the fire is going to take and the ultimate impact on the structure.

Situations change rapidly. There are known effects of fire on certain materials and there are known paths of fire development in certain types of construction or construction features.

Your knowledge of these will assist you in remaining safe and aware of what is, or could be, happening around you in a fire.

Dangerous Conditions

You must be aware of the dangers created during a fire. There are two primary types of dangerous conditions to be expected at a structure fire:

1. Conditions that are contributing to the intensity and the spread of a fire.
2. Conditions that may be contributing to potential collapse of the structure.

These two conditions are related. The intensity of a fire increases the likelihood of the structure collapsing.

It is also important to note that fire fighting activities may be adding to these conditions. For example, the build up of water applied to a fire may cause excessive loading on structural members and lead to collapse.

Fire Spread and Intensity in Structures

A number of conditions may exist in a structure, which assist in spreading a fire and increasing the intensity of a fire. It is in your interests to be aware of these conditions.

Furnishings and Finishes

Furnishing and finishes is recognised as a major contributing factor in fire spread and smoke production and have resulted in numerous deaths. They are part of the fire load and must not be overlooked during pre- incident planning (CFRM).

Roof Coverings

In New Zealand the predominant roof covering is iron or steel, which is not combustible.

Many flat roof buildings may have a timber-based roof overlaid with a tarpaper or simply tar. These roofs will combust and must be treated carefully.

Iron roofs may prove dangerous as they can trap heat and hot gas. This increases fire intensity in the roof frame structure leading to collapse of the roof.

Wooden Floors and Ceilings

As well as adding to the overall fire load of the structure, wooden floors and ceilings can become weak during a fire and collapse. Fire can spread without detection in cavities under the floor, seriously affecting the integrity of the floor.

Large Open Spaces

Large open spaces such as theatres, warehouses or even the attic space in a house will contribute to the spread of the fire, as there are no barriers to slow the fire. If you had two identical houses, removed the interior walls of one of them and set them both alight, the one with no walls will develop more quickly.

Floors

Floors come in various types: timber, stone, concrete, etc. The combination of the floor material and its method of support provide its strength. When one or more structural components are affected by fire, a partial or total floor collapse can occur.

The wooden floors found in many domestic structures have a void space within that fire, hot smoke and gases may travel.

Walls

Walls perform three functions:

- They carry the weight of the building structure, for example roof and floors in multi-story buildings.
- Provide a screen to keep out the weather
- Divide the building into rooms.

Load Bearing Walls

Load bearing walls help carry the weight of the building. They can be made from brick, stone or concrete, etc., providing the strength to carry the load and weather protection. In the case of a framed wall, the framing carries the loads and the cladding provides the weather protection.

Non-load bearing walls

Non-load bearing walls are usually the partition walls and are normally of thin construction

Party walls

Party walls are a load-bearing wall between two structures such as in a town house. These walls are usually thicker than standard walls, as they must support beams on either side for each separate structure.

Sleeper wall

A sleeper wall is a load-bearing wall built in a honeycomb fashion to give support to ground floor joists, particularly used on sloping ground.

Fire walls

A firewall is a wall that has been built to withstand the effects of fire and prevent it from spreading. It may be used within a structure to isolate a compartment or between adjoining structures.

Glass curtain walls

Glass curtain walls and storefronts are exterior building walls, which do not carry any floor or roof loads. They consist of a combination of glass, aluminium and other surface material supported by the frame, which is most often aluminium.

These walls are used today in:

- office buildings
- hotels
- retail outlets

- hospitals, and many more.

They may also be used as part of the interior design of a building.

Walls contain fire

Well-constructed walls can also be effective in containing a fire. How the wall performs will be related directly to the materials used and the quality of workmanship.

Windows

Windows are made of two main parts:

- The sash – this is the frame in which the glass is fixed
- The frame – this is the outer heavier constructed part of the window, which is fixed to the building.

Types of windows

There are many types of windows. The key difference is in the opening method. Windows may be hinged on any of the four sides and open out or in. Some windows may open by rotating around centrally located pins either top and bottom or on the sides. In older homes sliding sash windows are common. These open by one window sliding over the top of the other.

Fire resistance

The fire resistance of windows is determined by the following:

- The construction of the wall around the window frame
- The construction of the window frame itself
- The type of glass used

Doors

There are numerous types of doors used in commercial and domestic construction.

Hinged doors

These are the most common types of doors. They close flush against the door jamb and their construction can be of the following:

- Flush door – the surface of this type of door is plain without any projections. Usually made of a wooden core or honeycomb paper core, sandwiched between two layers of plywood or hardboard
- Panelled door – these usually have a wooden frame with either wooden or glass panels set into the frame
- Ledged doors – these are usually lightweight with braced frame on one side and panelling on the other
- Metal doors – these are usually found in high fire or security risk areas.

Swing doors

This type of door is mounted on pins in the top and bottom of the door allowing it to swing in either direction. The door may consist of one or two leaves and they are often used as smoke stop doors.

Revolving doors

These doors will consist of a number of leaves, commonly three or four, which rotate around a central pivot.

Sliding doors

These doors open by sliding in tracks at the top and bottom of the door.

Folding doors

These are usually of lightweight construction and are often used as room dividers where space is at a premium. Can be constructed of timber, aluminium with fabric cover among others.

Cantilever doors

Usually found as a garage door and often referred to as a tilter door. These doors are counter balanced and open upward and when open lie horizontal with the ceiling.

Roller shutter doors

A common type of garage door usually made of steel, which rolls up on large cylinder when opening.

Fire resistance of doors

The fire resistance of doors is determined by the following:

- construction of the frame
- construction of the wall around the frame
- thickness and surface finish of the door
- type of door
- fit of the door into the frame
- workmanship

Fire doors

Doors can be considered fire or smoke stop doors if they open in the direction building occupant will be moving in to safety. Roller and sliding doors can only be considered if they are fitted with automatic door closers.

Revolving doors, folding doors and cantilever doors cannot be used as fire or smoke stop doors.

Cantilever and roller doors can be extremely difficult to open in a fire due to buckling of the door or its tracks

Stairs

It is important you understand how stairs can be affected by fire and also how they can be of assistance in a fire.

Stair Designs

There are various stair designs and materials used in the construction of stairs. The combination of materials used, stair design and quality of workmanship will determine the stability of stairs in a fire.

Domestic houses

The internal stairs in domestic properties will generally be constructed of timber or reinforced concrete.

The resistance of the timber components will determine the resistance of timber stairs. Observing char rates in the structural members will give you some indication of the remaining strength of the stair.

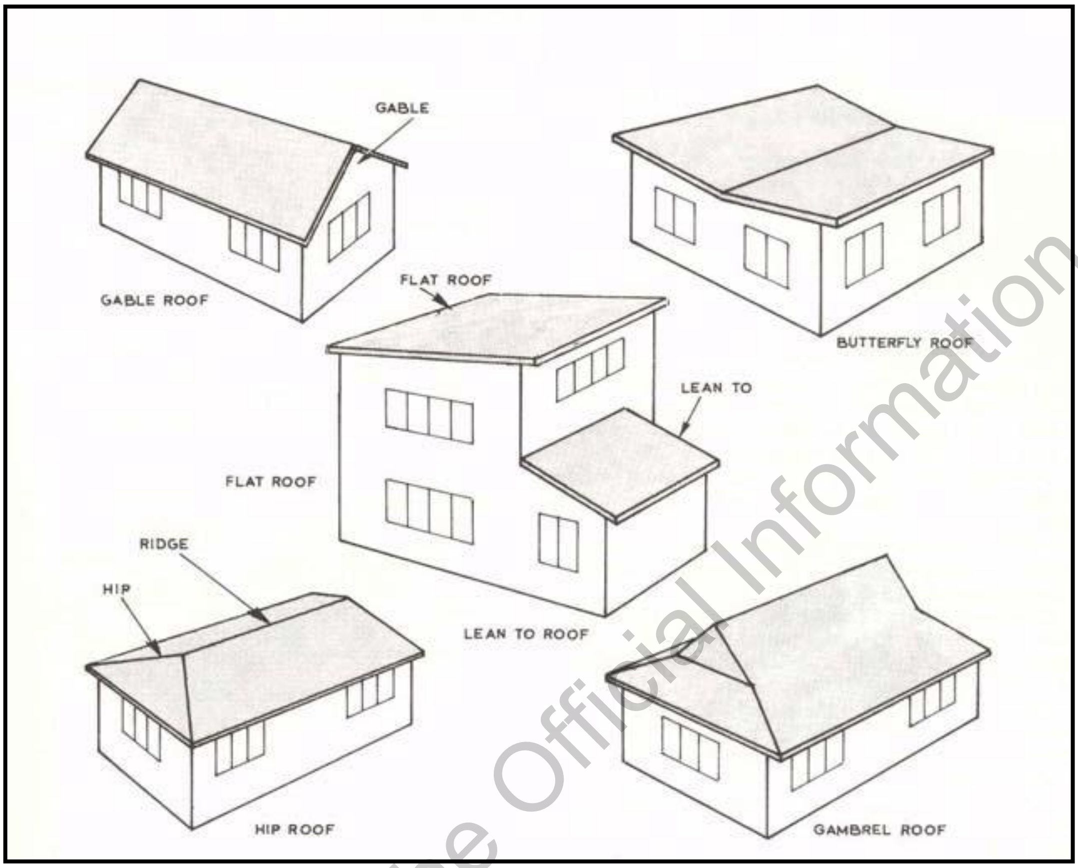
High Rise

In high-rise buildings, the construction of stairways or stairwells is crucial to the evacuation process of the building. Stairs will provide the main means of escape for building occupants and access to the fire.

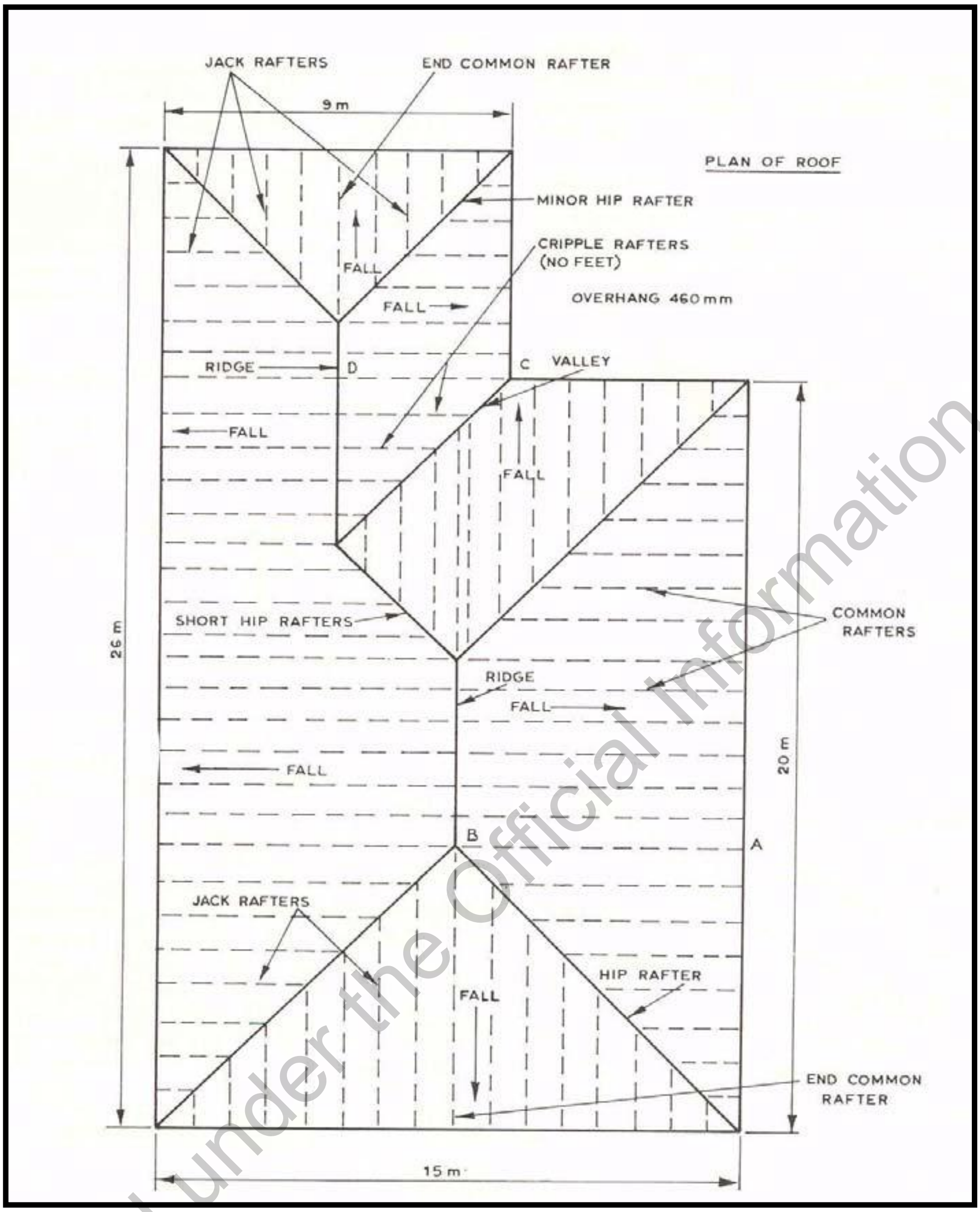
The building code and regulations stipulate certain requirements for stairs in high-rise buildings. Assuming all requirements of material use and construction methods and standards have been met, the stairs may be the safest part of the structure

Roofs

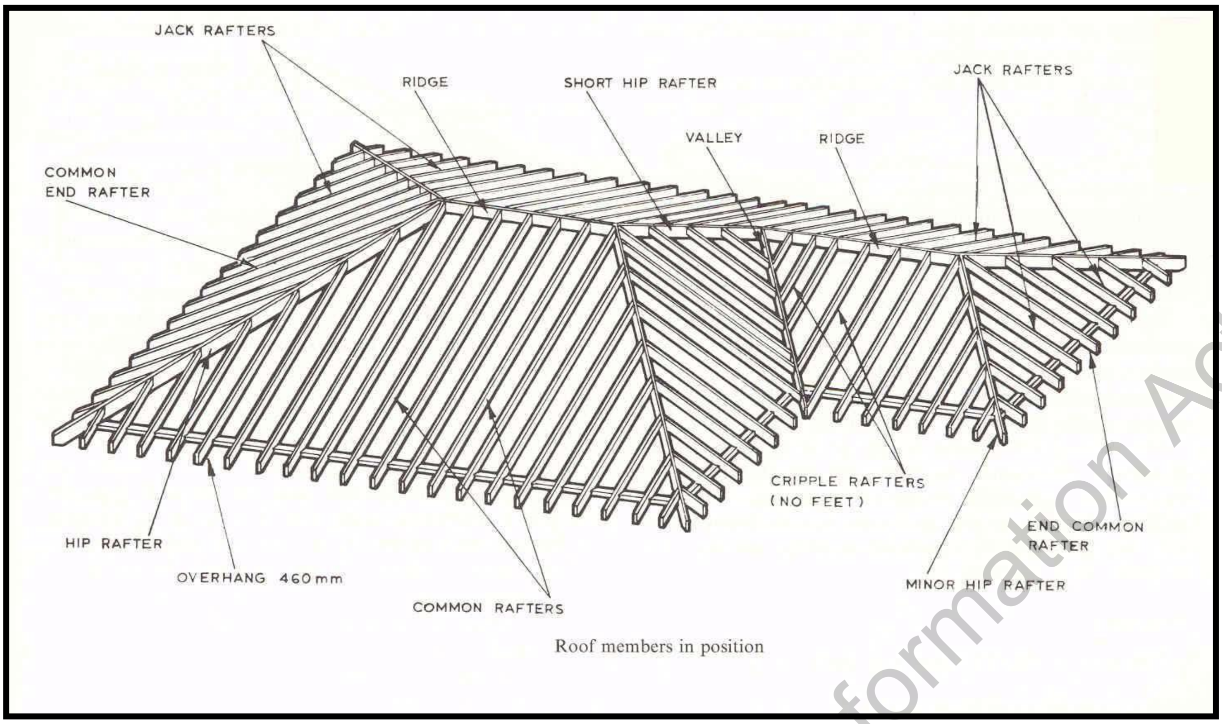
A roof is the structure, which sits on top of the building to keep out the weather. Roofs can be described as either flat, curved or pitched.



Roof Designs (Open Polytech of New Zealand



Roof Layout (Open Polytech of New Zealand



Roof Components (Open Polytech of New Zealand

Types of pitched roof

This is the most common type of roof and comes in several forms:

- Close coupled roof
- Trussed roof
- Mansard roof
- Saw Tooth Roof

Close coupled roof

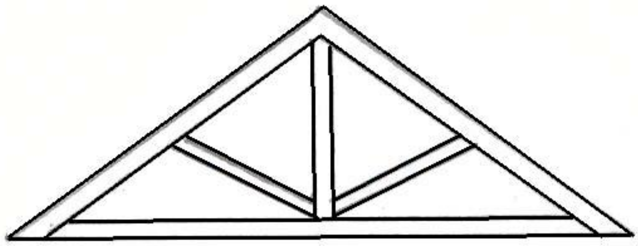
This is the simplest and most common form of pitched roof. Timber rafters about 300mm apart run from the ridge board to the wall plate on an external wall. These rafters carry the roofing material. When rafters are over 2m in length, purlins are used to support the centre of the rafter. Over wide expanses, two purlins may be required.

The rafters are attached to the ceiling joist, which is attached to the top wall plate.

Trussed roof

Where large expanses are required on a roof, use is made of the trussed roof. Two roof truss designs are shown in Figure 3.6.

King Post Trust



Queen Post Trust

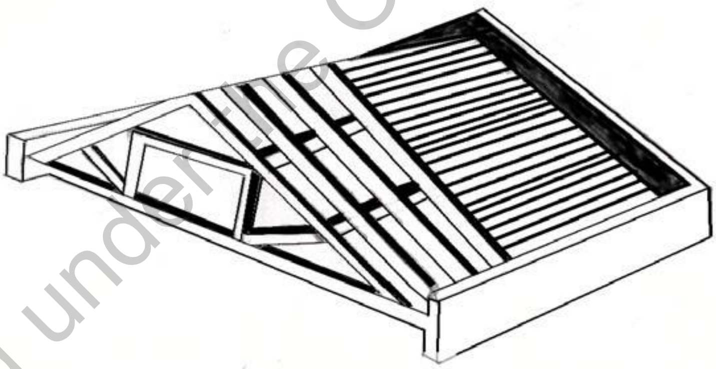


Fig 3.6 Diagram depicting King and Queen post roofs.

Mansard Roof

Named after a French architect this roof is designed to enable the roof space to be used as an extra room, which in effect becomes another story in the building. As you can see in the diagram below this type of roof creates voids.

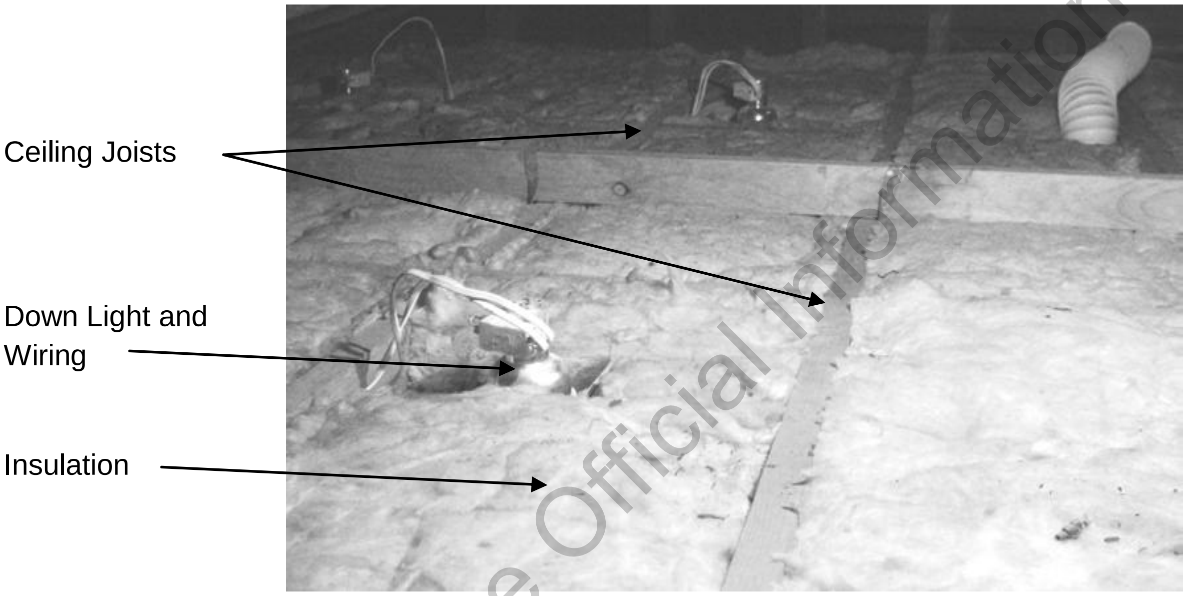
1. On the sides of the room and
2. Above the room.

Ceilings

The type of roof on the building determines the size of a ceiling space. A flat roof will usually have a small space with a pitched roof having a large space.

These spaces are cause for concern because of the concealed air space. As we have discussed, fire can spread rapidly into this space and as the space is open fire is likely to develop rapidly.

Ceiling from the roof space



Construction

The ceiling may be attached directly to the joists and battens, or it may be suspended below these creating a false ceiling. False ceilings are common in modern high-rise buildings where plaster-ceiling panels in an aluminium frame are hung on wires from the underside of the floor above.

It is not unusual to find that older homes, which have undergone renovations, have one or even two false ceilings. Once again these void spaces provide the fire with an undetected path to spread in.

Buildings and Fire

Introduction

This module will introduce you to development and behaviour of fire in structures, looking at factors affecting development and spread of fire and the dangers of smoke.

Fire Development

The growth and development of a fire will be determined to a greater extent on the shape of the building / enclosure and the ventilation in the immediate area of the fire.

Factors in fire development

A fire will usually start as the result of heat igniting some material. How the fire develops will be affected by the following factors:

- The flammability of the initial material ignited.
- The amount of radiant heat produced. Is it high enough to ignite other material in the compartment?
- The amount of fuel available in the compartment.
- The oxygen supply to the compartment. A well-sealed compartment may result in the fire smothering itself as the available oxygen supply is exhausted. This could however also develop to a backdraught situation.
- The space between the available fuels. Close spacing = rapid spread, wide spacing = slower spread.
- The size and surface area of the fuel available
- The size and position of the source of ignition
- The size of openings in the compartment.
- The shape of the compartment

Smoke

Most casualties from fire incidents are from smoke. There are reported cases where casualties have been found several floors away from the fire floor as the result of smoke movement within a building. Remember, smoke can contain many hazardous and flammable gases, many of them life threatening.

Smoke Management

The first step in managing smoke is at the construction and decorating stage of a building.

It is possible to reduce the amount of smoke by using products that produce low amounts of smoke and toxic gases.

Of course. it can be assumed that most people will not be considering the effects of fire when they purchase office furniture or furniture for their apartment.

The other option is to ensure the construction is of a high standard. As we know smoke will rise and will find ways to escape the fire area if they exist. Buildings may have many services such as piping and cabling running through them between floors. If the holes through which these run are not correctly sealed they provide a path for the smoke to move through.

Building Shafts

Elevator shafts, stairways and service shafts are a prime weakness in buildings in relation to the distribution of smoke. Fig 4.1 provides a summary of how smoke can spread in a high-rise building.

Also note that smoke can move between floors via the outside of a building.

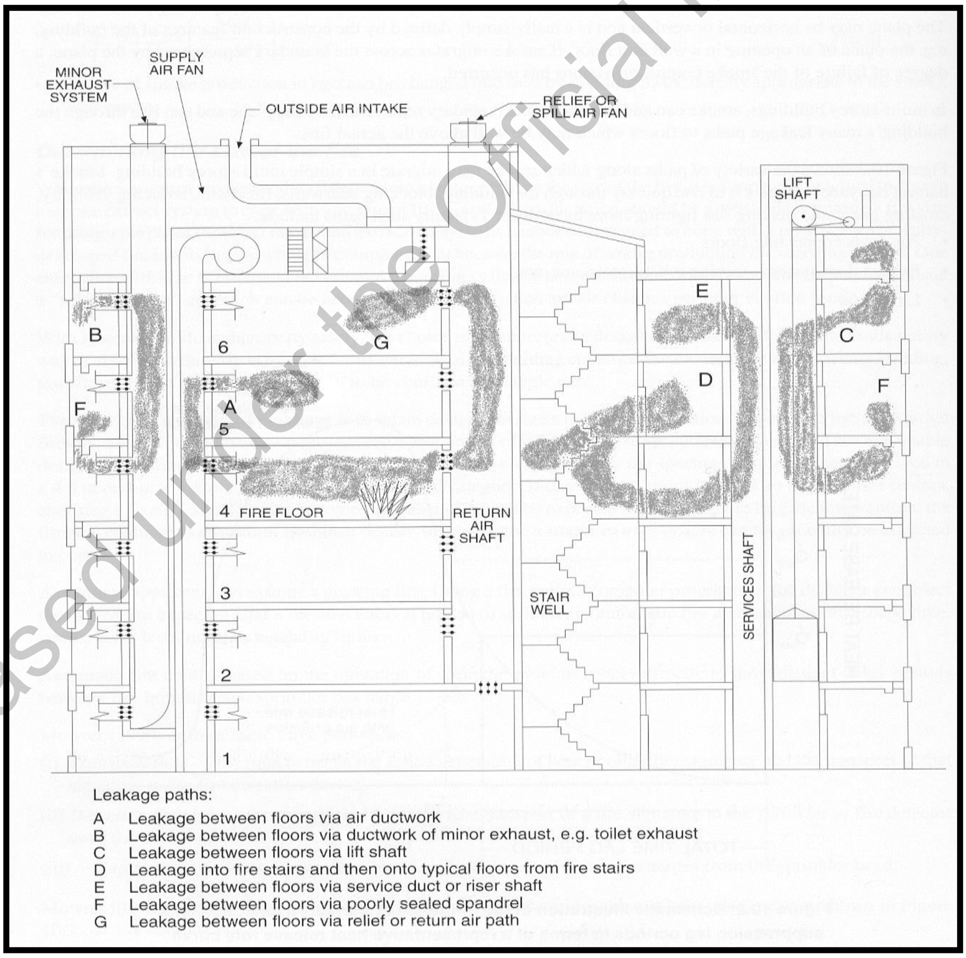


Fig 4.1 Smoke movement in buildings

(courtesy of Fire Engineering Design Guide Canterbury University.)

Passive Systems

Introduction

This module will introduce you to the passive fire systems used in construction.

Buildings are specifically designed for a purpose. The purpose can fall into three main areas though there are many more:

- People (office blocks, apartments, hotels etc)
- Processes (manufacturing)
- Storage (warehouses)

The construction of the building and the materials used must be applied in such a way that certain levels of protection are achieved.

The success of a complete and safe evacuation will be a result of the combination of building features --some structural and some additional systems.

The design of a building may include all or some of the following:

- safe pathways
- fire cells
- automatic fire doors
- smoke doors
- smoke lobbies
- fire detection systems
- sprinkler systems
- fire suppression equipment

Fire Cells

A fire cell is a building or part of a building that by its nature of location and construction provides for separation from other parts of the building. In some circumstances a fire cell may be considered to be a building in its own right. For example in a block of flats each flat may be a fire cell and considered as an individual building.

Fire cells serve two main purposes:

- Containment of fire
- Safe refuge from fire

Fire Containment

The construction of a fire cell requires that the cell will contain a fire and the products of combustion, preventing them from escaping to adjoining parts of the building.

Types of Buildings

Introduction

This module looks at particular types of structures and some of the features specific to them that you should be aware of in terms of construction and fire development

Early New Zealand Homes

Most houses constructed in the period 1900 – 1940 will have similar construction characteristics. Most will be timber frame with timber cladding. The roofs will vary from tile to corrugated iron. The interior of these houses can vary considerably as many will have undergone extensive renovations with more modern materials and construction methods introduced into the structure. Of course, there is no way of knowing this when you approach an incident.

FFig 6.1 Photo courtesy of Thorndon Fire Station. Web site

Timber framing

The older the building, the drier the timber is likely to be. Dry timber will combust faster and ignite more easily than damp timber. It is also unlikely that there will be any fire resistant properties added to the timber.

It is common to find older houses with no dwangs in the walls and often the insulation will be in the form of old newspaper or none at all. Combine this with no top plate on the walls and you have a cavity that will act like a chimney and carry flame, smoke and hot gases quickly into the ceiling space allowing rapid spread of the fire.

Wall cladding

As stated before the interior cladding may be of modern plasterboard products. Alternatively, the original sarking walls may be in place.

Sarking is flat planking placed across the walls providing the wall cladding and also the bracing; hence the lack of dwangs.

In original homes the sarking is covered with scrim (a type of sacking cloth) and then wallpaper is applied.

It is common to find Gib attached directly to the sarking of walls in renovated older homes

Figure 6.2 provides an indication of possible wall structure you may find in an older domestic property

Other Features

Flooring is often of tongue and groove floorboards

Ceilings in these homes can pose risks. Older plasterboard ceilings may fail and collapse relatively early.

Another material often found in ceilings is a soft board. Pinex is the most common brand name. It is also used for heat and sound insulation in walls and floors. It is often used for notice boards and backing for dartboards etc.

In a fire the dry, loose fibrous structure of soft boards, combined with resins they may contain will ignite easily and burn quickly.

These boards will collapse early in a fire allowing rapid transfer of the fire to other parts of the structure

Insulation

Older properties are less likely to have insulation in walls unless they have been renovated.

Ceiling insulation on the other hand is likely to have been installed. Either in the form of Pink® Batts® or Insulfluff.

Insulfluff will combust and is difficult to extinguish. It is also very light and will be easily blown around by the force of fire fighting activities.

Modern Homes

Modern homes have the advantage of being more fire resistant due to the advances in building materials and changes to construction techniques. Materials being used have improved fire resistant properties allowing the structures to retain their strength for longer and also slowing the spread of fire within the structure. It is important to note that the construction methods and workmanship will affect the overall resistance of the structure to fire.

Polystyrene cladding

Polystyrene cladding can pose serious risks to fire fighters. This is a recent arrival on the domestic scene. It is supplied in large sheets and provides a quick way of closing in the structure. It is not uncommon to see a house under construction with what appears to be solid walls and no windows or doors. The building has been in-closed with the sheets and the sheets will simply be cut away in the appropriate places for doors and windows. See figures 6.4 and 6.5

The exterior of the polystyrene is covered in plaster and painted to provide protection. The final finish gives a look similar to masonry or cement board construction with a sprayed plaster finish.

Identification

It may not be possible to identify the construction as polystyrene panels simply from a visual inspection. The exterior will however be slightly flexible when pressure is applied to it. The interior will be covered by plasterboard's and other common interior lining products.

Reaction to Fire

So long as the interior and exterior covering materials remain intact, the polystyrene will be protected from direct fire. Of course, the heat generated by a fire could cause the polystyrene to melt.

In other words, the effect of fire will be similar to the effect of fire on lightweight sandwich panels with one exception. The interior covering of the polystyrene will not necessarily collapse due to the polystyrene failing, as the plasterboard will be fixed to the framing material not the polystyrene. The exterior plaster will however fall away as the polystyrene is affected.

The presence of polystyrene means there is potential for substantial fire load in the structure and if the material becomes involved the increased intensity of the fire and probable rapid spread could affect the integrity of other structural members.

Fig 6.5 Polystyrene features pre and post finishing

Commercial Buildings

Commercial building can range from a row of shops on the street to multi story office or apartment blocks.

There are also industrial sites housing manufacturing and warehousing.

The one thing common to the majority of these structures is the basic material used in construction. In most cases this will be steel, concrete and glass.

Signs of Collapse & Know Your Patch

Know Your Patch

It pays to know your patch and be aware of the construction and renovations projects in the area. Observing the construction as it develops can assist in determining the likely risks such as hidden cavities a building may poses. Also the materials being used and the construction method will allow you to plan appropriate responses to the structure.

The more you know about a buildings construction the better.

Is it steel framed or timber framed, is it a tilt slab construction or does it use sandwich panels. By knowing this beforehand you can identify the collapse risks among others.

Building Surveys / Know your Building

When buildings are being inspected as part of CFRM and the development of risk plans, it is important to watch for indications that a building may have undergone remedial strengthening work.

In Wellington, for example, there has been a great deal of work done to strengthen older buildings against earthquakes. These same buildings are likely to have posed serious collapse potential in fire situations prior to the strengthening work.

Even now, the structural integrity of these buildings is not as it was when they were originally built. The method of strengthening may be sound for an earthquake, but may not perform particularly well in a fire situation. For example, unprotected steel beams have been used to form internal bracing in some buildings. In a fire we know that steel will heat up rapidly and lose its strength resulting in collapse. Steel will also expand and may push walls over.

Remember, strengthening for earthquakes does not mean strength for fires.

During inspections, it is important to note the factors that may affect the intensity and spread of fire, as well as factors that may accelerate the chance of collapse. Observing loading on floors is of particular importance.

From office to apartment

The recent boom in renovations of office building to residential apartments poses a number of risks. The nature of the building occupancy has changed significantly and with it the fire loading and ignition possibilities. In the 2001 and 2002 there were 1,567 reported kitchen fires. With one kitchen per apartment --you can understand the risk.