Control of Fires by Building Design

From ‘active’ to ‘passive’ systems, the control of fires in buildings is still a vital challenge

There is a saying that goes “there are three causes of fire: men, women and children.” It is often unwise to make sweeping generalizations, but it is safe to say that most fires originate from deliberate or careless actions of human beings, so, as long as we have people in buildings, we will have fires.

Death by fire is terrible, and a major fire disaster always creates a considerable upsurge of interest in fire safety matters. To date our record of multiple death fires in New Zealand has been mercifully good in comparison with some major countries and we must be sure it remains that way.

In the interest of life safety, and to limit destruction of property we need to minimize the effects of fire, so this bulletin aims to provide a background to how a fire develops and spreads, and to show how the design of a building can influence this fire behavior.

By an understanding of these processes it is hoped that designers and manufacturers of building materials can contribute to the continuing effort needed to control fire losses.

Fire Development

A carelessly thrown match or cigarette butt in a waste paper tin is a typical way in which people start fires. The initial event in the development of this fire is the Ignition of the original combustible material in the tin. Once this has happened, and there is a continuing supply of combustible material, and of oxygen, the fire will grow.

Whatever the cause, a fire is usually small when it starts, and grows in size until it reaches a stage where it gradually spreads. If this small fire is to become a serious fire it will have to grow and spread to involve the whole room. Unless the supply of oxygen is depleted (say by the doors and windows remaining tightly closed) or the amount of combustible materials is inadequate, or the fire is extinguished at this early stage, the fire will continue to grow and spread at an increasing rate as more combustible material becomes involved.

Fig. 1 shows the various ways in which heat from a fire can influence (Continued on page 46)

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the surroundings. Varying degrees of convection, conduction and radiation are always present, but initially radiation is the most important influence.

**Fig. 2** represents a room before ignition of the rubbish in a tin located in a corner. **Fig. 3** shows the situation after ignition in the tin. A plume of flame is rising up the wall. At this stage the flame has not reached the ceiling, although there is a quantity of hot air and combustion products rising above the fire. The radiation from the flames has ignited the adjacent furniture.

In **Fig. 4** the combustion of this extra material has increased the flow of heat energy so that the flames have now reached the ceiling. The heating of the surrounding materials is causing them to evolve combustible vapors which, being hot, rise and accumulate as a layer under the ceiling.

Once the flames reach the ceiling level these vapors can ignite and increase the rate at which fire will spread throughout the room. The radiant heat from the flaming gases under the ceiling will cause ignition of the remaining combustible materials.

**Fig. 5** shows the rapid involvement of the whole room, which is termed flashover. When flashover occurs, the oxygen level in the room drops quickly, and it is usually found there are substantial quantities of carbon dioxide, carbon monoxide and other toxic gases generated rapidly.

If occupants are still alive the combination of these gases and the very rapid rise in temperature means they have no further chance of survival. Furthermore when firemen arrive at this stage it is impossible for them to enter such a space and they have to tackle the extinguishment from the exterior of the compartment. Then their principal concern is to limit the fire spread beyond the immediate space involved.

**Passive Protection**

It is up to this point of flashover that the present fire bylaw controls building design with a view to ensuring sufficient time after ignition to permit the escape of occupants. In certain types of buildings and occupancies e.g. theatres, halls, places of assembly the flame spread behaviour of lining materials is controlled.

Measures are to be introduced shortly to control the smoke generation characteristics of lining materials, as it is now well recognized that the principal killer in most fires is smoke, rather than the fire itself. Smoke usually contains sufficient quantity of carbon monoxide to render people unconscious, if it does not kill them.

Moreover many building materials produce large volumes of smoke when burning, and this can obscure visibility and limit the safe use of
and in doing so activates a water spray nozzle which is designed to limit the fire development by damping down the immediate fire area. At the same time sprinkler systems sound an alarm at a prominent point in the building, or at the fire station. Such active systems have not been put to as much use in New Zealand as they could be.

In New Zealand sprinklers have a very good record of achieving their purpose, but are considered by many to be an expensive addition to the capital cost of a building and for this reason designers and building owners are often loath to have them installed. However the performance advantages of sprinkler systems should be given full consideration when considering the type of fire protection to be installed.

**Fire Resistance**

It has been the practice in New Zealand to rely on “passive” systems for protecting structures from the effect of fire and for limiting the spread of a fire once developed. This introduces the concept of fire resistance which is applied to elements of a building structure rather than to the individual material.

The object of fire resistance is to ensure that the element of structure will not collapse, or will contain the fire for a time assessed on the basis that various types of building occupancies generate varying degrees of risk. This time defines the period during which it is expected a fully (Continued on page 48)
developed fire might continue to bum if no extinguishment methods are applied.

Modern fire technology is proving this traditional approach to be very conservative and less rational than first thought. However the method provides the currently used, world-wide basis for building design.

Fig. 6 illustrates a developed fire in a space within a building. It is subjecting its surroundings to an abnormal loading from the effects of high temperature. To limit the damage caused by this fire the columns on the fire floor, and the beams and floor above must not collapse. To protect property on the floor above or in the adjacent space the floor and walls must resist penetration by heat and flames.

Fire Resistance Test

The fire resistance rating of an element of structure is the time a load bearing member takes to collapse, or if a separating element until it ceases to prevent the spread of fire beyond it.

Fire resistance is a specific term related to the performance in a standard fire test which attempts to simulate a real fire. This test is little more than a formal method of comparing constructions and its principal use is a standard means of defining performance for bylaw use. It is now widely recognized that the standard fire test seldom represents a real fire situation (it may be better or worse than a real fire) and its use is limited to this means of comparison and control.

If a wall has been assigned by test a one hour fire resistance rating, a specimen of this wall has successfully survived for one hour attack from one side in a standard fire test.

In a real building a similar wall would not necessarily stop a fire from spreading for exactly one hour. It may fail before this, or it may endure considerably longer.

Material Behaviour In Fires

The major load carrying elements of a building—columns, beams and floors—are required by the bylaw to have fire endurance to ensure that the structure supported by them will not collapse during the specified time.

It is useful here to understand a little of how the main types of materials used in structural members behave in fire. Timber burns at a reasonably predictable rate, and therefore substantial timber members can be used with confidence as structural members which provide fire resistance.

On the other hand, exposed structural steel members, while they will not burn, are very susceptible to temperature gradients, and the resulting distortions in fire will usually cause premature, and often
spectacular, collapse of unprotected steel structures. There have been developed various means of protecting steel by providing insulation to keep the steel temperature below a critical level above which distortion, becomes disastrous. The commonest means of protection is by concrete encasement, but there are other more sophisticated but also more expensive insulating materials used.

In recent years techniques have been developed of using hollow columns containing water which in the event of fire is circulated to keep the steel cool and several buildings have been built overseas using this approach.

Reinforced and prestressed concrete generally behave satisfactorily in fire although precautions have to be taken to ensure that reinforcing is protected by adequate concrete cover, again to prevent excessive temperature rise, and there is a need to avoid thin sections which are susceptible to fire attack.

Fire Resisting Elements

There is a range of wall systems consisting of timber or metal studs with lining boards containing gypsum plaster, which are shown by test to be capable of producing fire resistance ratings of up to 4 hours.

There are floor systems which consist of timber flooring and joists protected on the underside by non-combustible ceilings which can similarly provide extensive fire resistance.

It is often thought that separating elements such as floors and walls need to be of non-combustible material such as concrete and brick. This is not necessarily so and many successful constructions using a combination of non-combustible and combustible materials offer a variety of fire resistance ratings.

A wall constructed of entirely combustible materials such as timber studs and particle board linings takes time to be consumed by fire, and although this time involved is rather short in terms of the present concepts of fire safety this construction can provide a degree of fire resistance.

Penetrations Through Floors

If a fire resisting element is a floor, it may have penetrations for lifts, stairs and services. All these need careful treatment to prevent spread of fire and smoke through them. Lift shafts and stair wells require enclosing to prevent spread from the fire floor to spaces above. Lifts should not be used in a fire emergency, and stairwells must be made safe so people may escape from the floors above a fire-involved floor.

It is preferable that services be contained within vertical ducts which can be given fire resisting walls to isolate them from the floor areas. It is not always possible to avoid holes through floors for services, in which case care is needed to render the penetration resistant to flame and smoke.

Penetrations Through Walls

Where doors are required in fire walls, or in routes of escape, the bylaw requires these to have a fire resistance rating. The fire door assembly (door leaf, frame, lock, hinges and closer) must be able to withstand the standard fire test for the rating specified.

In routes of escape, the fire door must not only limit the spread of smoke and flames, but also it must retard any heat transmitted through the door, to avoid danger to fire safety on the unexposed side. On the other hand, steel doors can be successfully used to prevent fire spread through a doorway in a factory fire wall and can transmit much heat and radiate it from the unexposed face.

This is acceptable if combustible materials are not stored on the far side and if the door does not open onto a route of escape. A successful fire door requires careful design and proof by testing for fire resistance.