Fire Engineering

Introduction

Buildings must be designed in accordance with the requirements of the Building Code (BC) to ensure:

- people will be safe as they escape following a fire in a building
- firefighters can undertake rescue and firefighting operations without being exposed to undue risk
- damage to neighbouring property is avoided

Contents

Building law in New Zealand

New Zealand's main systems for governing building work, collectively known as building controls, are the Building Act 2004 (BA), the Building Regulations 1992, and the Building Code (BC), which is the first schedule to the Building Regulations. All building work must comply with the BC.

The BA mainly applies to the physical aspects of building work. Other legislation may also apply to building proposals, the ongoing use of a building, consumer protection, and the health and safety of workplaces in buildings.

Compliance Documents are published by the Department of Building and Housing to help people comply with the BC. Many Compliance Documents reference New Zealand Standards.

An alternative solution is a building design solution that differs from those contained in the Compliance Documents, but is accepted by a Building Consent Authority (BCA) as meeting the requirements of the BC.

The consents and inspections process ensures that building work complies with the BC. In other words it is safe, durable and does not endanger health, both for the current users of the building and to protect those who may buy and use the property in the future.

Components of a Fire Engineering Design

To show that the performance requirements of the BC are met, the building designer would normally appoint a fire engineer to undertake the design work in respect of fire safety.

The engineer uses calculations, engineering design methods, and in some cases computer fire models to demonstrate that the proposed performance-based solution for the building meets the requirements of the BC.

Role of Fire Engineers

The NZFS employs several Fire Engineers throughout the country. Please see the chapter on Fire Engineers for further information.

The Design Fire

Purpose of Design Fire Selection

To carry out an assessment of the fire safety aspects of a building design, a fire engineer will generally have to perform some calculations based on the likely fire scenarios that could arise in the building and assess their potential impacts. These fire scenarios are known as design fires. A design fire may be required as an input to a computer model, or may be used to assess the risk of structural collapse, or may be required to determine fire resistance ratings of building features.

Design Fire Location

The fire engineer should test his/her design against a range of different fire locations, unless the design is sufficiently simple for there to be a single obvious 'worst case'. The locations selected for design purposes will, in general, be dictated by the likelihood of a fire arising in a particular location. This will depend in turn on what there is to burn and the potential for ignition.

Design Fire Severity

Depending on the type of calculation being carried out, the design fire may be a slow, growing or a fast or ultra fast fire. It may also be a fully developed or flashover fire. Ideally the fire engineer would test his/her design against a range of different fire locations and severities. Severity is usually expressed in terms of the heat release rate (kW or MW) of the fire.

There are well established techniques for determining the fire severity of fully developed or flashover fires. The heat release rate in a room that is required to bring about flashover, and the expected steady heat release rate following flashover, can be estimated relatively simply.

For many purposes the fire is assumed to be growing. There is a range of experimental evidence to draw upon when estimating how fast fires will grow, but the rate of growth is highly dependent on what is assumed to be burning. In some designs this may be reasonably well known; in others, much less so, particularly when it is recognised that the fire engineering design has to be valid for the life of the building.

Design of Means of Escape

Protection of people from illness or injury

The objective of the BC in respect of means of escape, Clause C2.1 (a), is that people are to be safeguarded from illness or injury as they escape from a fire. There are a number of ways in which people could be injured by a fire:

- effects of heat
- effects of toxic gases contained in smoke
- effects of irritant components of smoke

These effects increase the longer a person is exposed to the fire. Therefore anything that delays escape can increase the potential for injury for those escaping. Delay can be caused by people:

- having difficulty in locating escape routes
- encountering congestion in escape routes
- suffering loss of visibility in a smoky environment
- undertaking actions not directed towards escape

Therefore, any assessment of the potential for injury must take into account the time for which people are likely to be exposed, as well as what they are likely to be exposed to.

Smoke Generation and Movement

Once the design fires have been established, there are a number of possible calculations that might need to be carried out. Given that most people in fire die from the toxic effects of smoke, the fire engineer will often carry out smoke movement or smoke filling calculations. The calculation methods available range from relatively simple hand calculations and equations, to computer models that can take days to run.

Engineers have to exercise great care when selecting and using computer models as even the most sophisticated are prone to errors if wrongly applied. Many fire models have only been validated against experiments in domestic room-sized compartments and may not give valid results for large or complex spaces.

The toxic products likely to be in smoke and the effects of these products on people are reasonably well understood. This has led to the concept of tenability limits – values of exposure to toxic products, heat or lack of oxygen that are thought to be the maximum that can be tolerated by people before being overcome by the effects of the fire.

Fire engineers may use estimates of toxic product production and tenability limits to demonstrate that exposure to smoke in particular circumstances is not likely to cause illness or injury to building occupants.

Movement of People

In assessing any design, it will be essential to know that people can escape before being overcome by the effects of fire. The time it takes people to escape depends on two separate sets of factors – design of escape routes and people behaviour.

Design of Escape Routes

The distance that people will have to travel before they are in a safe place will determine how long it takes them to get there. This is important in buildings such as airports and railway stations where travel distances can be long.

More importantly, in situations where there are many people trying to escape at once, the width of doors, corridors and stairways has a major influence on the crowding that occurs in escape routes. Flows of people though means of escape has been extensively studied and

much is known about how long it will take people to get out of sports stadiums or tall buildings, for example, using the available exits.

People Behaviour

In designing means of escape, it is easy to fall into the trap of assuming that people will all move to escape as soon as they become aware of the fire. In practice, there is a range of behaviours that people might engage in depending on how sure they are that there is a fire, what they are doing at the time and where they are physically located in the building.

In office environments, with a fire detection and alarm system and staff familiar with the evacuation procedures, it might be reasonable to assume that people will move quickly to escape. In shops, people may attempt to complete transactions before leaving, or wait for staff to confirm that the alarm is genuine. In situations where the information available is unclear, people may choose to investigate further. Even when they are sure there is a fire, people may choose to fight it, or indeed to watch it if they feel that there is minimal personal threat. In domestic environments, people may decide to find family members before evacuating or collect personal valuables.

The times taken for people to decide to start evacuating may well exceed the time it would normally take them to evacuate. It is important, therefore, that the possible variations in human behaviour are taken into account when undertaking building design work.

Design for Fire Spread

Protecting Escape Routes

The first objective of the BC in respect of fire spread, Clause C3.1(a), is to safeguard people from injury or illness whilst evacuating a building during fire. The third objective, Clause C3.1(c), concerns the protection of other property from the effects of fire.

Flame spread

The performance requirements of the BC require that fire spread on interior surfaces shall be controlled. In respect of surface finishes, a fire engineer would not normally depart from the prescriptive requirements in the approved documents.

Separation of Firecells

By definition, fire separations must be provided between firecells. Fire separations are required by the BC to have a fire resistance rating. Fire resistance is defined in such a way that it must be determined in the standard test for fire resistance, or in accordance with a specific calculation method, verified by experimental data from standard fire resistance tests. In other words, alternative solutions for fire resistance that do not relate to the test are not allowed under the BC.

It may be required to design firecells to resist burnout of the contents of the firecell (S-rating). Alternatively, a firecell may only be required not to fail within a given time (F-rating).

Protection of other Property

Where a property adjoins another property or sleeping accommodation, fire separations are required by the performance requirements. See note above concerning fire separations.

Where properties are separated by distance (as opposed to being separated by a fire separation), the potential for fire spread is by radiation from the burning building to the adjacent one. There are fire engineering calculations that can be carried out to demonstrate that the separation is sufficient to avoid fire spread.

Design for Structural Stability

Introduction

Many construction materials change their properties when they become hot. Depending on what the material is being used for, the change in the material may cause the building structure to weaken, and even give rise to structural collapse. The first objective of the BC, in respect of structural stability, Clause C4.1(a), is to safeguard people from injury due to loss of structural stability in a fire.

Avoidance of Collapse

The performance requirements of the BC require that structural elements have fire resistance to avoid structural collapse in a fire. Fire resistance must be determined in the standard test for fire resistance, or in accordance with a specific calculation method verified by experimental data from standard fire resistance tests. In other words, alternative solutions for fire resistance that do not relate to the test are not allowed under the BC.

Steel

Steel loses its strength as its temperature increases. Most structural design in steel would have built in factors of safety. All materials weaken with increasing temperature and steel is no exception. Strength loss for steel is generally accepted to begin at about 300ºC and increases rapidly after 400ºC. By 550ºC steel retains about 60% of its room temperature yield strength. It is known that fires can reach temperatures of over 1000°C, and fire protection of steel is often a necessary feature of building design.

Concrete

When heated, concrete tends to flake off – a process known as spalling. If the spalled concrete exposes the steel reinforcing rods within the concrete, the structure can lose its strength much quicker. The phenomenon of spalling can in some cases be quite explosive in nature. Usually concrete structural elements are designed by prescriptive rules that avoid the reinforcement being compromised.

Timber

When heated timber undergoes charring that progresses from the exposed surface. The char has no structural strength, but it can insulate the underlying timber. There are techniques that may be used to calculate the fire resistance rating of timber structural elements. Calculations may be used to show that large timber structural elements may be sufficient to provide the necessary fire resistance rating.

Design of Facilities for Firefighters

Building Code Requirements

Several parts of the BC mention provision of facilities for Firefighters:

- Clause C2.1(b) on means of escape provisions states that they must also facilitate fire rescue operations
- Clause C3.1(b) on fire spread provides that there must be protection to Fire Service personnel during firefighting operations

- Clause C4.2(b) on structural stability states that buildings shall be constructed to allow Fire Service personnel adequate time to undertake rescue and firefighting operations.

Engineering Design

Fire Engineers must consider the needs of firefighters when designing buildings for fire safety. The prescriptive requirements set out in the Approved Documents are generally followed in respect of Fire Service access and protection of staircases and other paths that will be used for firefighting and rescue purposes. Any variations to these requirements would generally be referred to the district Area Manager at the building design stage.

Fire Brigade Intervention Model

Please refer to the Fire Brigade Intervention Model chapter for further information.

Further Reading

- Fire engineering Design Guide, Spearpoint, Michael, 3rd edition, Christchurch, N.Z. , New Zealand Centre for Advanced Engineering, 2008

- SFPE Handbook of Fire Protection Engineering, DiNenno, Philip J, 4th edition, Quincy, MA, NFPA: Society of Fire Protection Engineers, 2008

- Department of Building and Housing (DBH) website http://www.dbh.govt.nz/