Fire Safety Components of Building Codes

How to promote compliance by understanding resistance and flame spread, access and egress, fire services and equipment, and building exteriors and separation

Pacific Region Infrastructure Facility

The report is published by PRIF, a multi-partner coordination and technical assistance facility for improved infrastructure in the Pacific region. The PRIF development partners are the Asian Development Bank, Australian Department of Foreign Affairs and Trade, European Union, European Investment Bank, Japan International Cooperation Agency, New Zealand Ministry for Foreign Affairs and Trade, United States Department of State and the World Bank Group.

PRIF Coordination Office
c/o Asian Development Bank
Level 12, FHL Tower,
Corner of Gordon St and Thurston St,
Suva, Fiji

Phone: +679 3318101
Email: enquiries@theprif.org
Website: www.theprif.org

Published February 2026.
All tables and figures are provided by the author, unless otherwise specified.
Note: In this publication, "$" refers to United States dollars unless otherwise stated.

Introduction

Objective: This technical guide provides commentary and strategies on how building practitioners can satisfy the fire safety performance requirements of Pacific Island Building Codes; and how to account for water source reliability and/or availability of firefighting services.

Target Audience: Pacific Island Building Practitioners.

The Guide is divided into 5 parts

The purpose of Building Codes is to provide a minimum set of performance requirements for the design and construction of buildings to a tolerable level of safety to building occupants and the community. Part 1 demonstrates how building fire safety can be achieved.

Building Elements & Compartments. Managing the impact of a fire in a building, through the construction features and use of fire-resistant building materials is a critical component of building fire safety design. Part 2 demonstrates how the impact of fire-spread in buildings can be minimized.

Safeguarding occupants for the time required to egress a building during a fire or other emergency is a critical component of building fire safety design. Part 3 demonstrates how safeguarding occupants during a fire outbreak can be achieved.

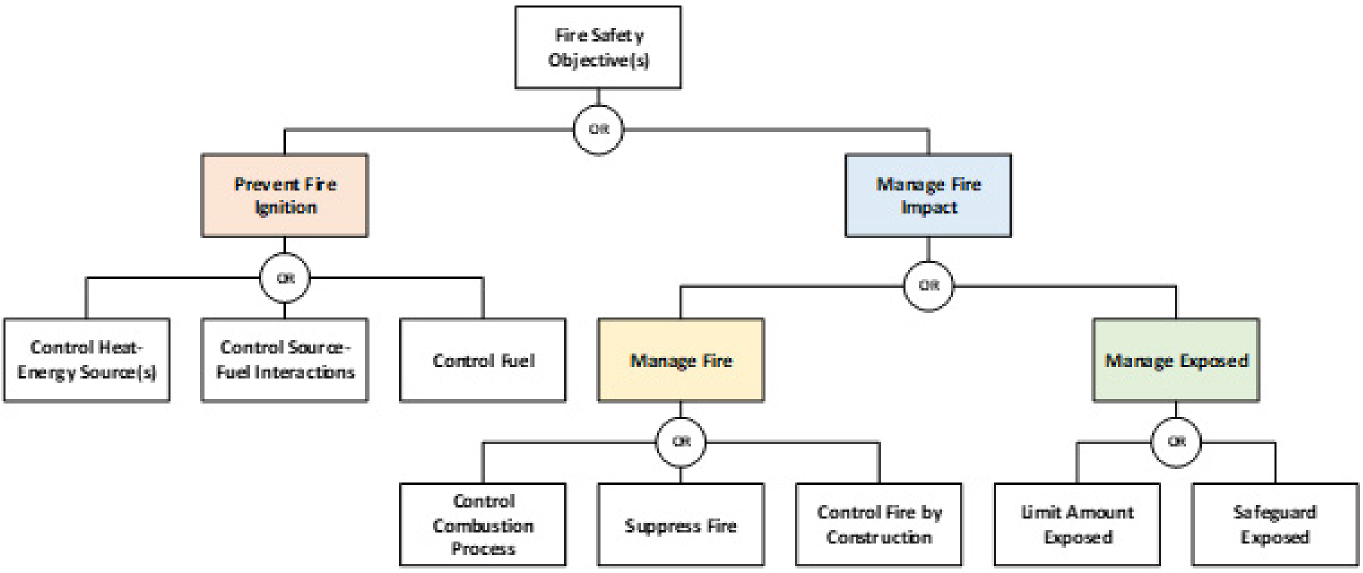
Managing the impact of a fire in a building through manual and automatic means of fire suppression is a critical option for building fire safety design. Part 4 describes appropriate manual and automatic means of fire suppression that can be utilized in both areas where water supply for fire suppression is robust and available and where water supply infrastructure may be unreliable, or water resources are limited.

Managing fire impact through control of construction materials and by taking steps to prevent ignition from one building to another are critical components of building fire safety design. Part 5 demonstrates how the threat of external fire from one building to another can be minimized.

PART 1: Purpose and Interactions[1]

Building Codes provide a minimum set of performance requirements for the design and construction of buildings to a tolerable level of safety to building occupants and the community. Building fire safety is achieved by implementing strategies that can be grouped into three basic areas: prevent fire ignition, control the size of fire if ignition occurs (i.e., manage the fire), and safeguard the occupants (i.e., manage the exposure of building occupants to fire). The interaction of these strategies is illustrated in the NFPA Firesafety Concepts Tree (FSCT)[2] shown in Figure 1.1.

Figure 1.1 Top Branches of the NFPA Fire Safety Concepts Tree (FSCT)



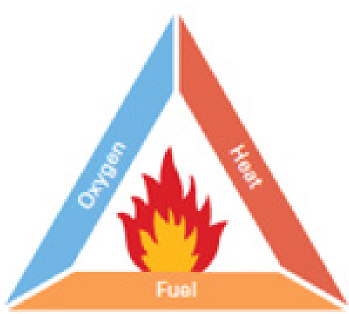
Source: ©NFPA

The aim of fire safety provisions within building codes is to draw from these strategies to deliver an integrated system of fire safety. This Guidance Note discusses these different strategies, and how they work together, to deliver an integrated fire safety system for a building. In order to better understand how the fire strategies work, it is helpful to have some fire fundamentals.

Fire Fundamentals

To have a fire there needs to be three fundamental components: heat (ignition source), fuel (combustible material) and oxygen. This is often referred to as the fire triangle, as illustrated in Figure 1.2. If you remove any of the components the combustion process will end. One can keep a fire from starting (or continuing to burn) by eliminating the initial heat source (ignition source), by controlling the materials (e.g., noncombustible materials) and/or their interaction with the heat source, or by removing oxygen. One can control the growth and spread of any fire that does ignite by removing the heat source (e.g., smothering or suppressing the fire) or by controlling the ability of additional fuel sources contributing to the fire (control by construction, which includes materials and limiting oxygen).

Figure 1.2 Fire Triangle



1 These Guidance Notes are not mandatory and provide general guidance for North and South Pacific which may utilize different standards. See National Building Code, and other country specific legislation for specific requirements

2 Top Branches of the Fire Safety Concepts Tree, NFPA 550, National Fire Protection Association, USA, all rights reserved.

Prevent Fire Ignition

While it may seem easy to control potential sources of fire ignition in buildings, in practice it can be difficult because of the building services and appliances. Globally, two of the most common ignition sources in buildings are related to facilities and services for cooking, and faults with electrical systems and equipment / appliances (Figure 1.3). In homes, cooking is one of the leading sources of fire ignition, especially heating sources that use open flame. This includes propane or other gas-burning appliances in formal construction and open fires in less formal construction. Electrical fires are common for a variety of reasons, including: poor electricity infrastructure, including inadequate protection on mains and connections into buildings and circuit breakers; poor or inadequate wiring within buildings, using improperly rated cabling, power points, switches, lamps and the like; poor quality electrical appliances, which may try to draw more power than can be safely handled.

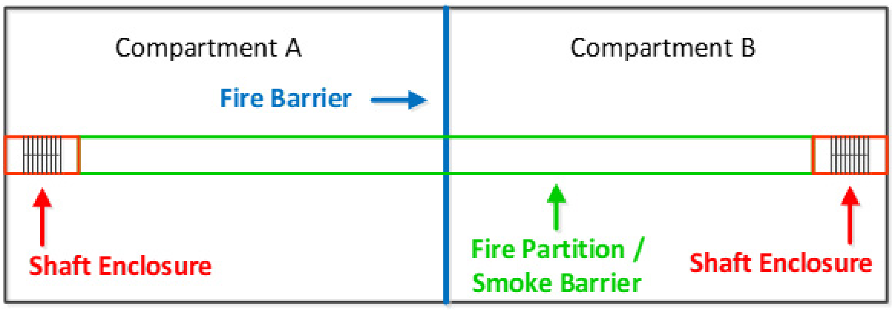
Figure 1.3 Fire involving overloaded electrical outlet / connections

Prevention of ignition is typically addressed in NBC provisions related to: electrical wiring requirements, requirements for test, certification and approval of electrical appliances and equipment, controls on fuel burning appliances and connections (e.g., propane), requirements for spacing of fuel burning appliances from combustible materials and construction, and installation of noncombustible barriers.

Manage Fire

It is not practicable to assume that all fires can be prevented. Many factors can lead to potential ignitions, including accidental ignitions, such as improperly discarded smoking material. As such, strategies must be included for managing any fire that may start. The options are to control combustion, control the fire through building construction features, or suppress the fire. Controlling combustion (burning) is difficult because building codes do not regulate most contents, except in specific buildings where the type and quantity of combustible or hazardous materials are limited (e.g., storage facilities, hardware stores). **Controlling fire by construction is common to most building codes.** This is often called passive fire protection. Passive fire protection is accomplished through use of a combination of non- or limited combustible structural elements, wall, floor and ceiling assemblies, and means to stop the spread of fire through openings, such as fire doors (Figure 1.4).

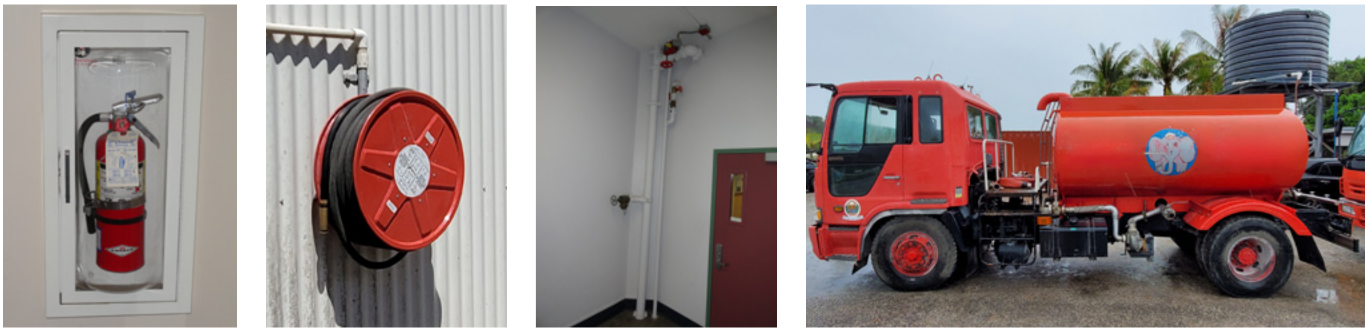
Figure 1.4 Fire/smoke compartments & barriers



A key aspect of managing fire by construction is that the materials used have been tested and approved to have a particular fire resistance rating (FRR) or fire resistance level (FRL). Requirements for FRR/FRL of building elements and exterior surfaces is a function of the size and use of the building, and the spacing between buildings. **Managing fire by construction is critical where firefighting water is limited.**

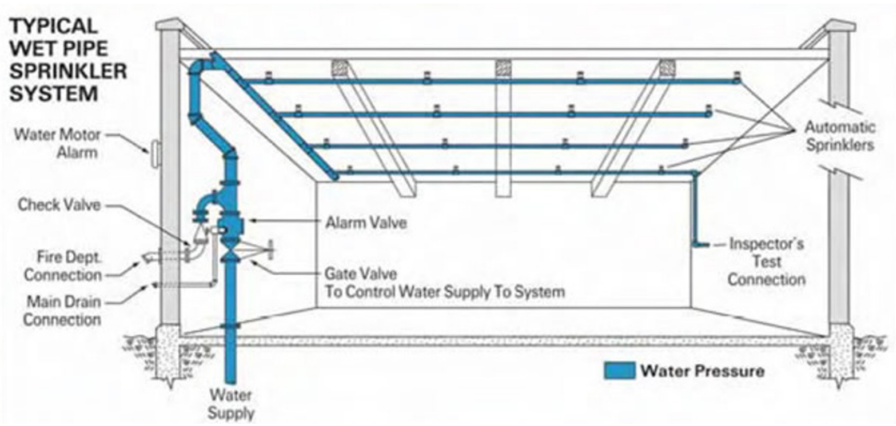
Controlling by suppression is typically broken down by manual and automatic. Suppression systems, along with fire detection systems, are often called active systems. **Manual fire suppression equipment** ranges from fire blankets (to smother a fire) to handheld fire extinguishers, hose reels, and firefighting equipment. Manual water suppression systems include interior hydrants and hose reels (Figure 1.5).

Figure 1.5 From left, fire extinguisher, fire hose reel, interior hydrant, fire water tank truck



Most building codes have requirements for manual fire suppression, especially in public buildings with vulnerable populations (e.g., hospitals), that have high occupant loads, are tall or complex, or which contain hazardous materials. **In cases where a reliable firefighter water supply is not available, alternative approaches may be needed.** This may mean more emphasis on limiting fire through construction and assuring safe means of escape. Note, however, that there is typically no requirement for water-based suppression systems in single detached dwellings (and fire extinguishers and fire blankets be warranted).

Figure 1.6 Illustration of wet fire sprinkler system



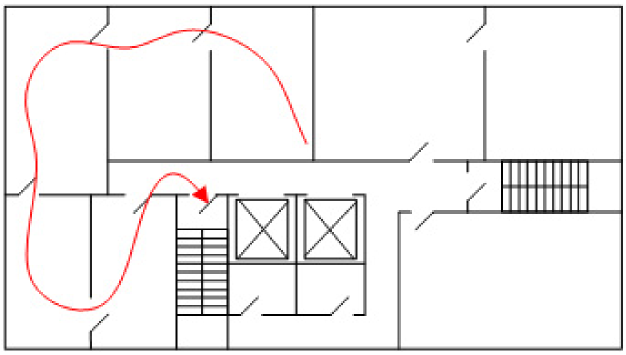
Automatic fire suppression is most commonly associated with automatic fire sprinkler systems (AFSS). AFSS may be wet, dry or deluge. Most common is wet systems. Wet systems involve a network of pipes throughout a building, supplied from a located (on site) water tank or municipal (reticulated) water supply network, to which automatic sprinkler heads are attached. The sprinkler heads are individually heat actuated, either via a glass bulb or fusible link, designed to melt at a given temperature. Once the temperature reaches the required level at a sprinkler head, the bulb breaks (or link melts), the plug dislodges and water flows over the deflector in a spray pattern. Deluge systems are design to flow water from all sprinkler heads simultaneously within defined sprinkler zones. Such systems may be used in high-hazard buildings (Figure 1.6).

AFSS are typical in complex buildings and hazardous material storage, where large numbers of people may be at risk, it may require a long time for emergency evacuation, the fire can create a community hazard, and/or firefighting operations may be difficult. Note: AFSS components may be prone to corrosion in the saltwater environment and alternatives may be warranted, including control of fire by construction. If a reliable water supply is not available, a local water tank may be needed. If AFFS are used, comprehensive inspection, test and maintenance (ITM) procedures and plans are needed. If alternative designs are needed, it may require following the 'performance' or 'alternate design' approach in the NBC.

Manage Exposed People

There are two basic approaches to managing exposure of people to fire in buildings: (1) limit the total number of occupants in building, room or floor of a building, and/or (2) safeguarding occupants from fire and its effects (temperature, smoke, toxic gases) for the total time required for them to exit to a safe place. Being able to quickly detect and notify occupants of a fire is important to getting them moving to safety as soon as possible. Providing protected egress (escape) routes is essential.

Figure 1.7 Exit travel path

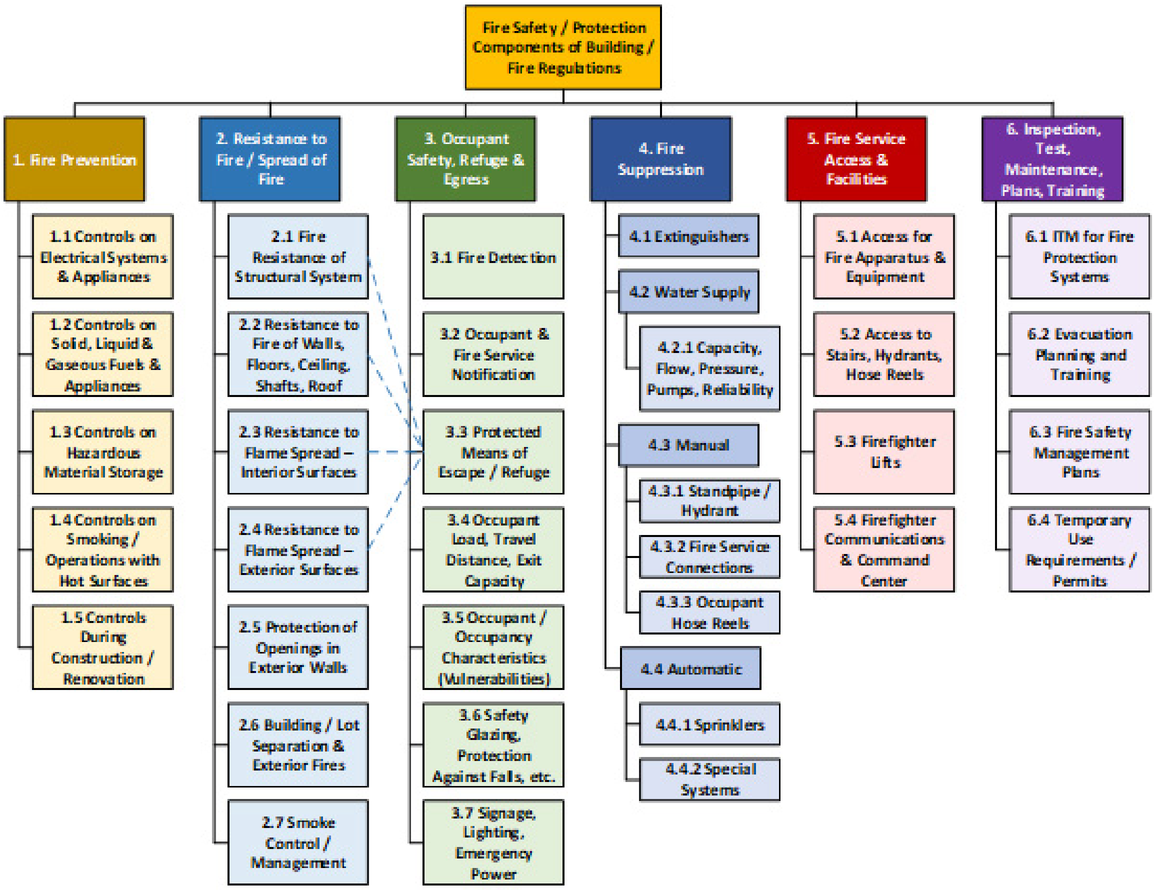


Safeguarding occupants is accomplished through NBC provisions related to maximum occupant load, means of fire notification, number and location of exits, limitations on travel distances to reach a place of safety inside or outside of the building, means to help people identify exits, and means to protect the escape (egress) pathways (Figure 1.7).

How Fire Safety is Addressed within Building Codes

As overviewed above, the concepts of controlling fire ignition, managing the fire, and managing those exposed to fire, can be addressed within six fundamental strategies that from the basic tenets of NBC fire safety provisions and good fire safety design. The six strategies are illustrated in Figure 1.8. Not every strategy is required by NBCs for every building, but compensation is typically needed if a strategy is missing.

Figure 1.8 Mapping of typical fire safety / protection provisions within building codes



Source: World Bank

Building Code & Design Considerations in Areas with Limited Water Supply

It is not always practicable to meet every building code provision for fire, especially when fire suppression water supply is unreliable / nonexistent. In such cases:

- First, check whether the NBC applies. In some NBCs, complex buildings are out of scope for the NBC.
- Detached dwellings likely have no fire suppression water requirement.
- For commercial and public buildings, check use, area, and height requirements for when fire suppression systems are needed.
- When fire suppression water supply is limited, FRR/FRL construction and separation are the primary means to manage fire spread in and between buildings. If building materials are combustible, separation distance is essential. Safe paths of egress are critical, and early detection and warning are very important.
- If fire suppression systems are required by the NBC, but water supply is unavailable or unreliable, a 'performance solution' or 'alternative design' option may be needed. This is the alternative pathway allowed by the code. See the other parts of this guide for strategies that may be helpful.
- If local capacity is currently less than needed for ITM of critical fire and life safety systems, this needs to be considered in the design and & safety management plans.
- See Figure 1.9 for a decision chart for key fire issues.

For more information, and additional guidance, see:

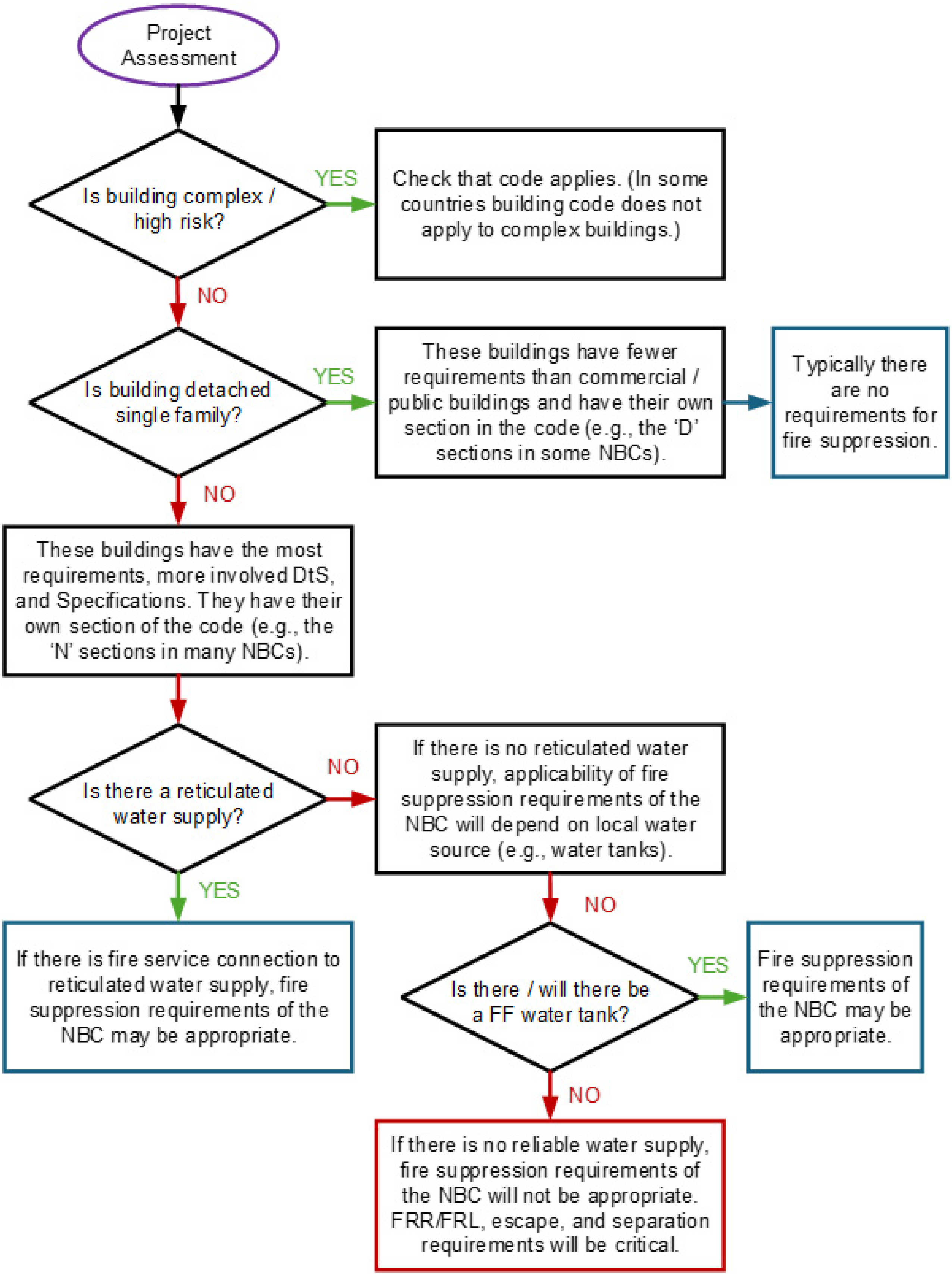
https://openknowledge.worldbank.org/entities/publication/4f2b16ea-9b8f-5317-aee2-afad9161e7e3

https://openknowledge.worldbank.org/entities/publication/aae2fad1-e013-4fc9-a1d5-e050bce618ce

https://www.abcb.gov.au/sites/default/files/resources/2022/Handbook-Fire-safety-verification-method.pdf

https://www.abcb.gov.au/resource/guideline/australian-fire-engineering-guidelines-afeg

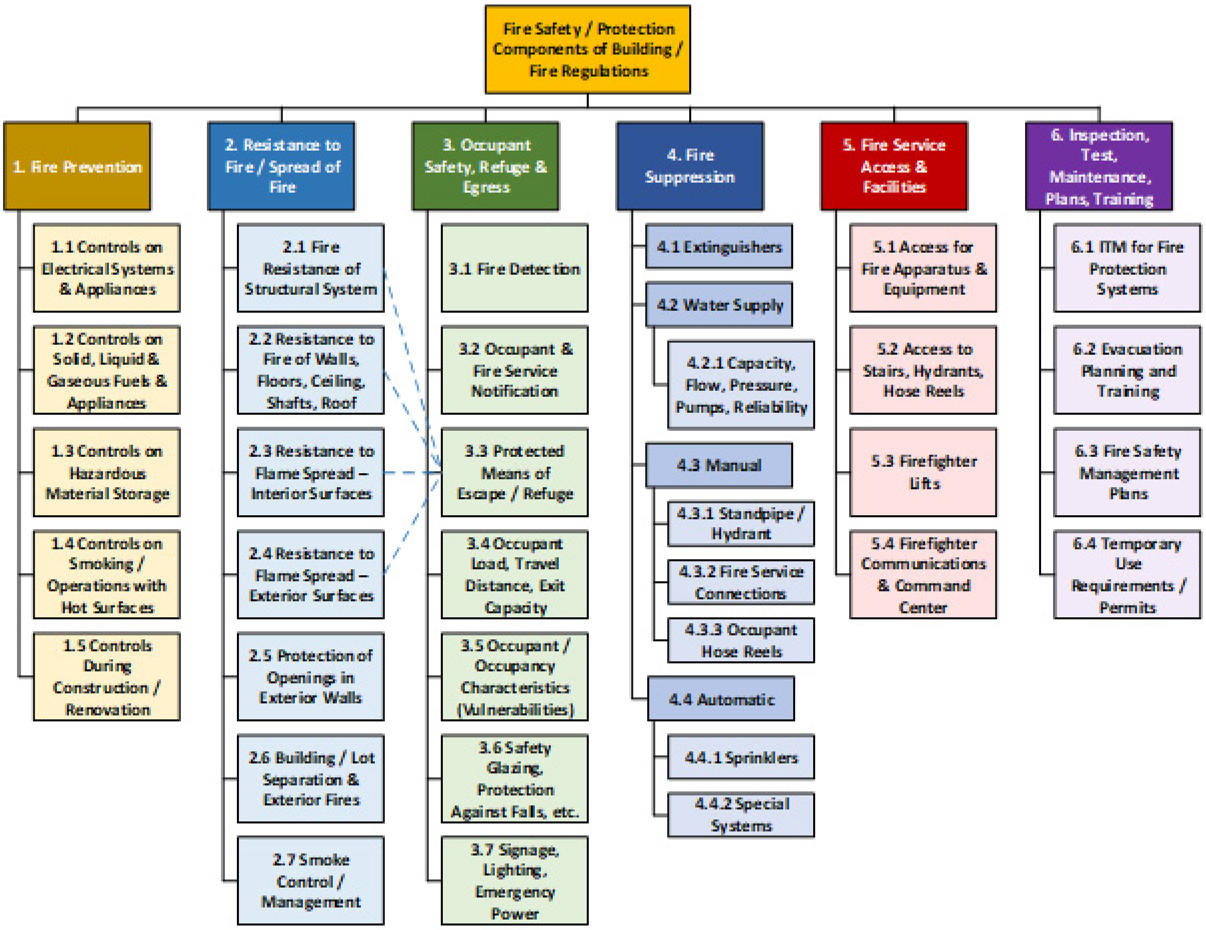
Figure 1.9 Decision chart for key fire issues, especially with limited water



PART 2: Fire Resistance and Flame Spread: Building Elements & Compartments

Managing the impact of a fire in a building, through the construction features and materials of a building (e.g., structural system and materials, walls, roof, etc.), is a critical component of building fire safety design. Managing fire impact through construction is one strategy included in building codes and good fire safety design, as reflected in Figure 2.1 under the heading **Resistance to Fire / Spread of Fire**.[3]

Figure 2.1 Mapping of typical fire safety / protection provisions within building codes



Source: World Bank

Ideally, all strategies presented in Figure 2.1 are available and work together to provide an integrated approach to building fire safety (see Part 1). However, in areas where water supplies for firefighting are limited or nonexistent, the design, construction, and ongoing maintenance of building construction features used for managing fire impact become critical to achieving fire safety objectives. If there is no reticulated water supply that includes connections for fire suppression water for buildings or for the fire service, and there is not a local water storage option (e.g., on site tank for fire suppression water), then the resistance to fire and fire spread that is achieved through building construction features and materials is the reliable means for fire containment.

Without a reliable source of fire suppression water, failure to provide adequate measures to resist the spread of fire in a building can result in complete loss of a building, whether a simple detached dwelling or a complex

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multi-story structure. Adequate measures to resist the spread of fire in a building are reflected in building codes as compartment barriers / separating elements and structural elements with defined fire resistance ratings (FRRs) or fire resistance levels (FRLs), appropriate fire sealant and fire stop materials at joints and penetrations of compartments boundaries, and protection of openings in compartment barriers, vertical shafts, and similar spaces. See figures 2.2 and 2.3 for examples of fires at informal and formal structures.

Figure 2.2 Fully involved fire of informal construction building

Source: © Justin Sullivan (2018) used with permission.

Figure 2.3 Timber frame building fire (formal construction)

Source: Captain John Bonadio, Waltham Fire Department. Permission to publish courtesy of Waltham, Massachusetts Fire Department.

Fire Resistance Ratings / Levels (FRR/FRL)

Building codes make reference to the need for construction materials, in particular structural systems and wall, ceiling, floor and roof assemblies, to be tested and rated for their ability to resist the increased temperatures associated with a fire for a defined period of time without failing to perform their intended function. This is generally referred to as fire resistance ratings (FRRs) or fire resistance levels (FRLs). To provide a common approach for establishing FRRs/FRLs, standard test methods have been developed that describe the application of a specific time-temperature profile to a building element, product, system or assembly, in a specially designed test furnace. The FRR/FRL is determined based on how long the material performs before it fails under the criteria established within the test method (Figures 2.4 and 2.5).

FRRs/FRLs are typically expressed in terms of minutes or hours, depending on the standard used (e.g., 15-minute, 30-minute, 60-minute, 90-minute, ..., or 1-hour, 2-hour, 3-hour...). Standard test methods for fire resistance include the International Organization for Standardization (ISO) Standard 834, Australian Standard

Figure 2.4 Time-Temperature Curve

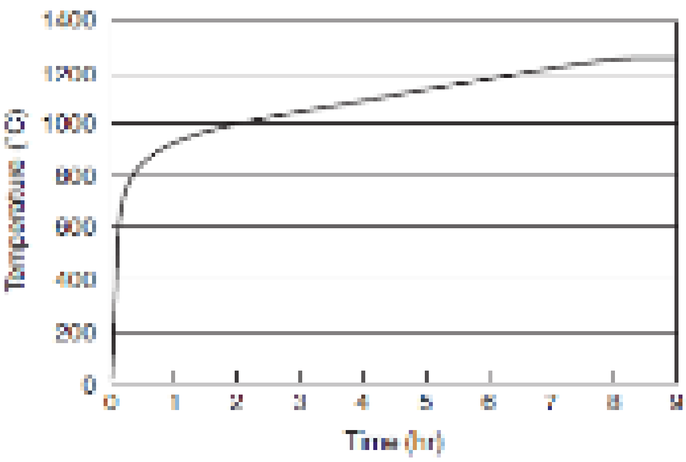


Figure 2.5 Door in fire test furnace

(AS) AS 1530.4, and ASTM E119. The determination of what FRR/FRL is required for different building elements, products, systems or assemblies is typically defined in building regulations (codes) or associated compliance documents[4].

In general, the FRR/FRL that is required by a building code for a building element, product, system or assembly increases based on the relative importance of that building feature to the overall fire performance of a building.

Typically, smaller buildings with limited number of occupants, such as dwellings (e.g., Figure 2.6), will have far lower FRR/FRL requirements than larger, public buildings, in which more people may be at risk in case of fire or post-fire collapse. As buildings get larger, taller, more complex, containing more people (e.g., Figure 2.7) and/or housing materials that may pose a risk (e.g., storage buildings), requirements for FRR/FRL typically increase. In these buildings of higher importance or risk, primary structural systems (e.g., columns, beams) and fire separation walls and shaft walls will have higher fire resistance requirements than non-structural partitions and other walls not forming part of the egress system. This concept generally holds true whether fire protection requirements are established based on regulatory provisions or engineering analysis (i.e., more important elements are required to resist temperatures longer than less important elements).

Within building regulations, FRRs/FRLs are generally required for load bearing elements, such as columns, beams, trusses and joists, floor and ceiling assemblies, fire walls used to separate buildings or major building uses, and certain types/classes of interior partitions which are intended to restrict the spread of fire within or between floors (also known as fire compartments, fire cells, and similar) and into the exit system.

Compartment Barriers / Separating Elements

While the concept of using compartment barriers / separating elements for the control of fire and smoke spread is easy to understand, the descriptions and definitions of the various levels of compartmentation are numerous, and it can sometimes be difficult to understand why the differences exist. This is further complicated by the use of different terms for the same function in different countries.[5]

Figure 2.6 Simple construction

Figure 2.7 Exemplar complex / high risk construction

In brief, the concept is that building elements with defined FRRs/FRLs are used to (a) create barriers that restrict fire spread to and from one portion of a building to another, and (b) resist fire sufficiently long to allow occupants for escape without being exposed to dangerous conditions. In general, this requires some level of FRR/FRL for walls, floors and ceilings, and that all openings within walls, floors and ceilings should be protected with a fire-protective assembly (e.g., fire door or other protective means).

4 In countries which have performance-based building regulations (codes), details such as FRR/FRL are often not defined within the regulation. However, as a companion to the regulation, there is typically a compliance document (CD) (or approved document (AD), deemed-to-satisfy solution (DtS)) of some sort which provides one or more means of complying with the regulation, and such compliance documents often provide guidance on FRR/FRL requirements for various building elements.

5 For example, a fire area in the International Building Code, as used as a basis of the building code in the Marshall Islands, is essentially the same as a fire compartment in the Australian National Construction Code, which is the basis for building codes in Kiribati, Nauru and elsewhere. However, requirements in the NBCs or DtS for FRR/FRL of compartment barriers, allowable floor areas, and protection of openings, can differ by code.

Figure 2.8 Illustration of fire barrier separating compartments

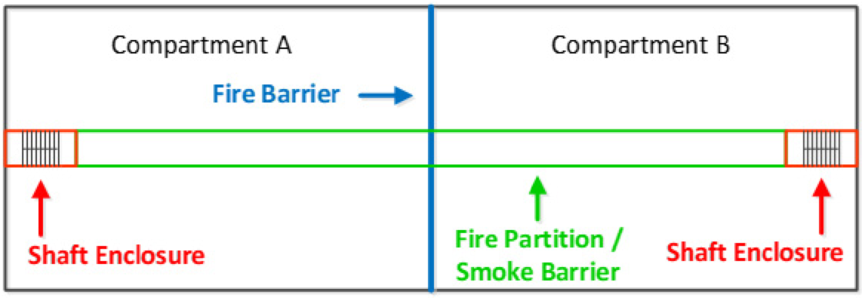


Figure 2.9 Incomplete fire barrier

Fire barriers are often used to create smaller fire areas within a building or to provide egress through a protected exit system. This is illustrated in Figure 2.8, where the floor of the building is separated into two compartments by a fire barrier (or fire wall), which would have a FRR/FRL requirement, fire partitions that may also have a FRR/FRL to create a safe path of escape through the compartments to protected exit stairs, which in turn are located within a vertical shaft with FRR/FRL rated construction and doors.

A critical consideration is that all penetrations and openings between barriers, shafts and partitions, including doors, ducts and plenums, should be fire sealed / protected, by materials, systems or components which match the barrier FRR/FRL. Concealed spaces, if breached by fire, can provide a route for the spread of fire, hot gases and smoke. Care should therefore be taken to provide barriers against the spread of fire, hot gases and smoke, and to restrict the use of combustible materials (other than allowed by the NBC), in concealed spaces. An example of incomplete fire barriers / unsealed penetrations is shown in Figure 2.9. where brick wall does not extend fully to the roof or side wall.

Early Fire Hazard Indices / Flame Spread & Smoke Production

A significant concern in buildings is flame spread along the surface of a material , especially for ceiling and wall linings on the interior and on the external wall / façade surface and roof. Examples include plywood, wood planks, plastics, some ACMs, and thatched roofs (Figure 2.10).

Figure 2.10 Surface flame spread

Combustible surface lining materials can facilitate the rapid spread of flame, and emit smoke and toxic products of combustions, and are therefore typically limited in quantity and/or prohibited in several building use groups, in particular within means of egress and on exterior walls of tall buildings.

There is a wide range of approaches and test standards for surface flame spread. For interior ceiling and wall finishes, examples include AS/NZS 1530.3 and ASTM E84.

Key Considerations where Fire Suppression Water is Lacking

Once a fire occurs in a building, it can only be managed by controlling the fire through construction (passive fire protection) or by suppressing the fire (part of active fire protection systems). Materials with appropriately tested and certified FRRs/FRLs and flame spread ratings/hazard indices are often required in NBCs as follows (Table 2.1)

Table 2.1: Flame spreading rates/Hazard indices

Passive FP Feature	Detached Dwelling	Other Residential	Public Buildings
Requirement for FRR/FRL of structural elements	No, with separation	Yes	Yes
Requirement for FRR/FRL of interior separating elements	Yes, if more than 1 story	Yes	Yes
Requirement for smoke barriers	No	Yes	Yes
Requirement for flame spread ratings	Yes (sarking)	Yes	Yes

As buildings increase in size, occupant load, and/or hazard, the criticality of resistance to fire and control of fire spread via construction increases in importance. Requirements for FRRs/FRLs increase proportionally.

Use of properly certified / listed / approved product increases confidence and should be used wherever possible.

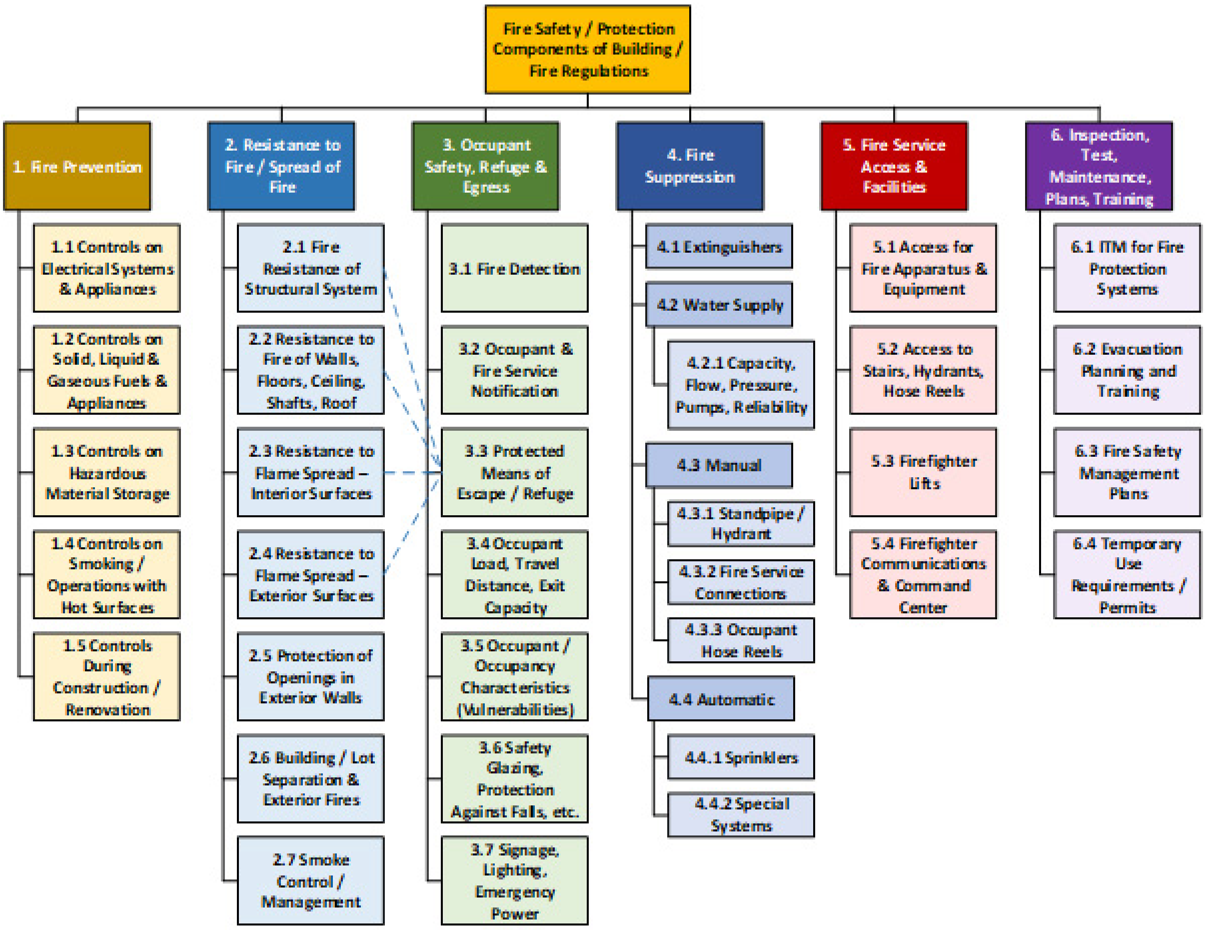
Careful attention to compliance with material selection, installation, and ongoing ITM is essential to maintain expected performance.

Use of FRR/FRL construction increases in importance where fire suppression water and capability are lacking or non-existent.

PART 3: Access and Egress[6]

Safeguarding occupants for the time required to egress a building during a fire or other emergency is a critical component of building fire safety design. This involves providing means to notify occupants of a fire and providing fire-protected escape routes and refuge areas (when needed). Consideration is also given to occupant characteristics, such as age and mobility. Key requirements for egress design are identified under the heading Occupant Safety, Refuge & Egress in Figure 3.1.

Figure 3.1 Mapping of typical fire safety / protection provisions within building codes



Source: World Bank

Ideally, all strategies in Figure 3.1 are available and work together to provide an integrated approach to building fire safety (see Part 1). However, in areas where water supplies for firefighting are limited or nonexistent, the design, construction, and ongoing maintenance of building construction features used for managing fire impact become critical to facilitating safe egress. Building features to control the spread of fire and smoke are the only ways in which to safeguard occupants. Note that for most single detached dwellings, there are few requirements, other than having early detection (smoke alarm) and short travel distance to the outside. For commercial and public buildings, there are typically more requirements, as more protection is needed as the number of occupants, area, stories in the building, and complexity increase.

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Egress / Means of Escape Fundamentals

The means of egress (means of escape) describes the path of travel that a building occupant encounters, starting with any occupiable point in a building, and ending when they reach a public way outside of the building (e.g., public walkway, street, alley, etc.).

In some NBCs, means of egress is described in terms of three fundamental components. The exit access, which is unprotected or has limited protection, includes the portion of the building between any occupied point and an exit. The exit, which provides a protected path of egress within the building between the exit access and to point where one leaves the building. The exit discharge is the transition point to outside the building where occupants leave an exit and reach a public way.

The means of egress components can be visualized with the help of Figure 3.2, which is a generalized representation of a three-story public building. The top illustration reflects a typical floor, highlighting the corridor (pink), which is part of the exit access system (path to get to an exit) and two exits, which on upper floors of a building are protected stairways (blue). The middle illustration is an elevation, or side view, showing the corridors (exit access) on floors 1 and 2 (pink), the exits, shown in this view as vertical stairway enclosures (blue), and an exit passageway (green) on the ground floor, which is a protected path to the outside. The bottom illustration shows how an exit stairway may discharge directly to the outside (top right) or connect to an exit passageway (green, lower left), which in turn discharges outside.

Figure 3.2 Building egress components

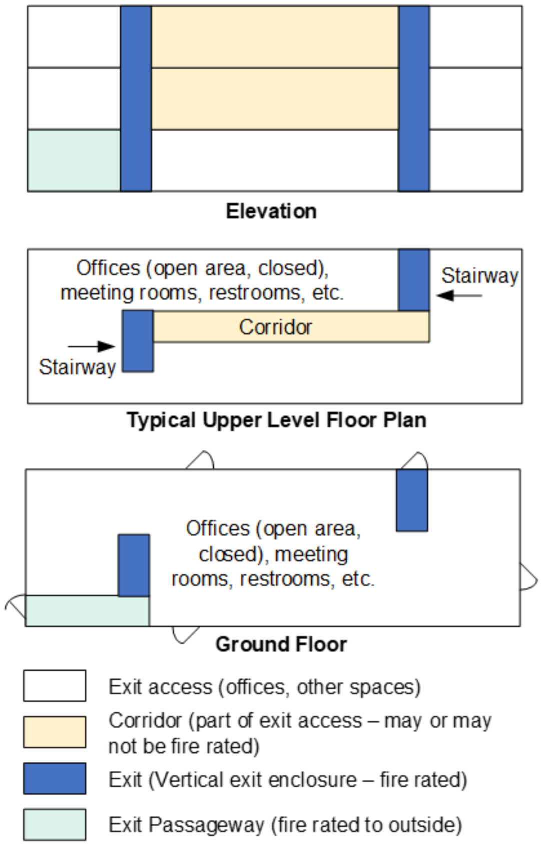
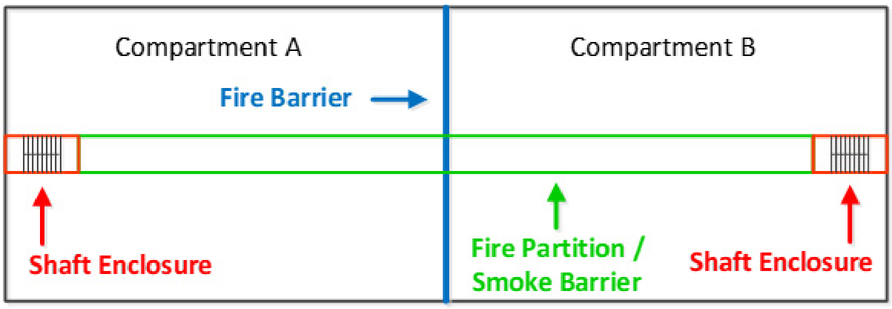


Figure 3.3 Fire rated components associated with egress system



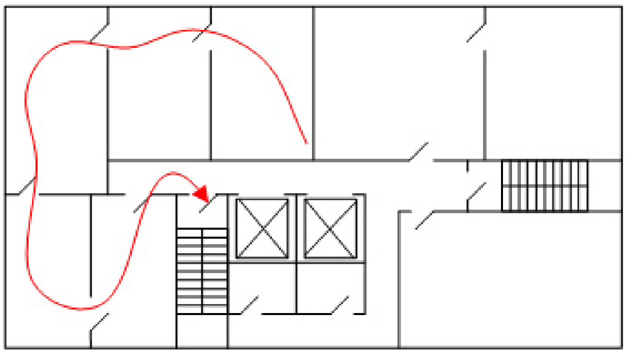
In public buildings, some exit access components, such as corridors, have requirements for FRR/FRL construction and other safety features to help maintain safe environments while occupants exit the space. Exits are constructed of FRR/FRL components as they need to provide a protected environment until occupants leave the building (see Figure 3.3).

Means of egress should be designed, constructed and maintained to be obvious, continuous, direct and unobstructed, with exit signage and emergency lighting.

Travel Distance, Number, Arrangement and Capacity

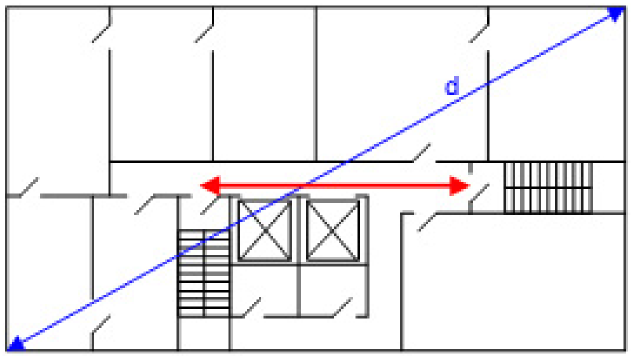
The number, arrangement and capacity of exits required for portions of a building, and for the entire building (all spaces), are largely a function of the use / occupancy classification of the building, travel distance to an exit, the occupant load, and the expected characteristics of the occupants (e.g., age, ability, etc.). Protection of the exits is dependent upon these factors, as well as on the size of the building (height and area) and fire safety systems installed.

Figure 3.5 Path of travel (red line)



In egress system design, travel distance and exit separation are important because of the time required for occupants to reach an exit and the potential hazards occupants may face along the way. Occupant load is important due to factors such as occupant density and related reduction in movement speed occupant density and flow through corridors, down or up stairs, and through doorways, and the number of persons at risk during an event (e.g., fire, earthquake).

Figure 3.6 Exit remoteness



Occupant load calculation is typically based on area per person criteria established in DtS or prescriptive requirements of NBCs. So too are criteria for travel distance, exit separation, required width and number of exits, stair geometry, and the like.

Factors that influence allowable travel distance include location and number of exits (per building, per floor in a building), FRR/FRL of exit access components, and presence of an automatic sprinkler system (travel distances are typically allowed to be longer in sprinklered buildings). Travel distance is generally measured from the most remote point, along travelable paths (e.g., around obstructions, through doorways) to the point of entering an exit (e.g., door to protected stairwell, door to the exterior), as shown in the red curved line in Figure 3.5. Exit remoteness should consider dimensions of the floorplate, travel distance and number of exits. Generally, it is recommended that exits be separated by at least 1/2 the diagonal dimension of the floor plate (may be 1/3 if the building is sprinkler protected). This is illustrated in Figure 3.6.

Occupant Characteristics

Occupant characteristics reflect those attributes of the expected occupants which may be important to response, decision-making and vulnerability to hazards events.

Egress provisions in NBCs take into account such factors as occupant age, ability, familiarity with the building and exits, occupant roles and responsibilities (e.g., caregiver, fire warden), particularly where delays may be associated with waiting for a responsible person to indicate the need to evacuate the building, and the presence and number of sensitive or vulnerable populations (e.g., hospitals).

For public buildings, NBCs include provisions for access and egress for persons with physical and other physical and mental impairments (e.g., ramps, tactile signs).

Height and Construction

Building height is important with respect to availability of exits, travel distance, travel time and the ability for emergency personnel to undertake operations. Stairs are required for exits, and walking speeds are slower on stairs than on horizontal surfaces. Building construction is important in providing occupants safety from fire as they escape.

As buildings get taller, more emphasis is placed on fire resistance and limiting fire spread (see Part 2). This is particularly important when fire suppression water is limited or non-existent, there are no automatic fire suppression systems installed in the building, and/or where fire service response is limited or unavailable.

Signage, Pathway Marking and Communications

To help facilitate safe egress during emergencies, exit signage, pathway marking and illumination, and fire safety and communications systems play significant roles. This starts with detecting fires, notifying and communicating with occupants, providing clear indication of exit pathways, notifying emergency responders, providing smoke control or management for tenability, suppressing or controlling fires, preventing the passage of smoke or fire from one compartment to another, and providing for emergency responder communications. In areas with unreliable electrical power and/or emergency power, the use of photoluminescent exit signage and egress path markers should be considered.

Means of Egress Summary

Driving Feature	Impacts on Fire Safety	Building Design Considerations
Occupant load and characteristics	Speed of movement, flow through openings, ability to self-evacuate	Number of exits, exit capacity, protection of exit access and exit enclosures, exit discharge.
Occupant characteristics based on abilities and impairments	Ability for persons of all abilities to safely evacuate a building in case of fire	Specific design parameters for stairs, ramps, doors, hardware, areas of refuge, lifts, and suitable audible, visual and tactile communication
Time required to reach an exit / refuge area	Exit access components, number and location of exits	Total travel distance should be such that safe egress is facilitated
Exit separation – providing alternate exits in case of fire or blockage	Ability to safely reach an exit if one is compromised by fire or other event	Exits should not be grouped together – adequate separation is needed to allow access in case one exit is compromised
Ability to readily find and follow egress pathways without obstruction	Occupants should expect easily identified exits, unrestricted movement, easy opening and unlocked doors, regular walking surfaces, lighting	Aisles, aisle accessways, corridors, doors, hallways, stairs, steps, ramps, surfaces, exit passages should be sized to maintain unobstructed and unrestricted flow; signage, illumination, pathway marking should be readily identifiable and understood
Ability for occupants to remain safe for the period of time required to safely reach the exterior	The longer it takes occupants to reach an exit the more protection is needed – particularly where occupants have limited movement ability	Protection of exit access, exit enclosures, exit passageways, horizontal exits, exit stairways, vertical exit enclosures, occupant load, building size and layout, building type / construction

Key Considerations where Fire Suppression Water is Lacking

In areas where water resources for firefighting are limited or non-existent, it is critical to safeguard occupants through compartmentation using materials with appropriate FRRs/FRLs, reduce occupant load, travel distances, increased number of exits, and facilitate appropriate exits and/or areas of refuge for people with disabilities.

As such, exit design considerations may be prioritized as follows (Table 3.1).

Table 3.1: Exit Design Considerations

Exit Feature	Detached Dwelling	Other Residential	Public Buildings
Required FRR/FRL of separating elements	No	Yes	Yes
Requirement for smoke barriers	No	Yes	Yes
Requirement for flame spread ratings	No	Yes	Yes
Requirement for exit direct to outside	Yes	Yes	Yes
More than one protected exit	No	Yes	Yes
Accessible exits (especially public buildings)	Yes	Yes	Yes
Appropriate occupant load limits	N/A	Yes	Yes
Smoke alarm for early warning*	Yes	Yes	N/A
Fire detection and alarm system*	No	Yes	Yes

**Care should be taken when considering smoke alarms or fire detection and alarm systems in areas of high salt and corrosive environments and low ITM capacity.*

As buildings increase in size, occupant load, and/or hazard, the criticality of resistance to fire and control of fire spread via construction while occupants escape increases in importance. This is particularly true when firefighting water and fire service response is limited or non-existent.

When firefighting water and fire service response is limited or non-existent, the 'performance' or 'alternative' option for compliance may be required to increase safety.

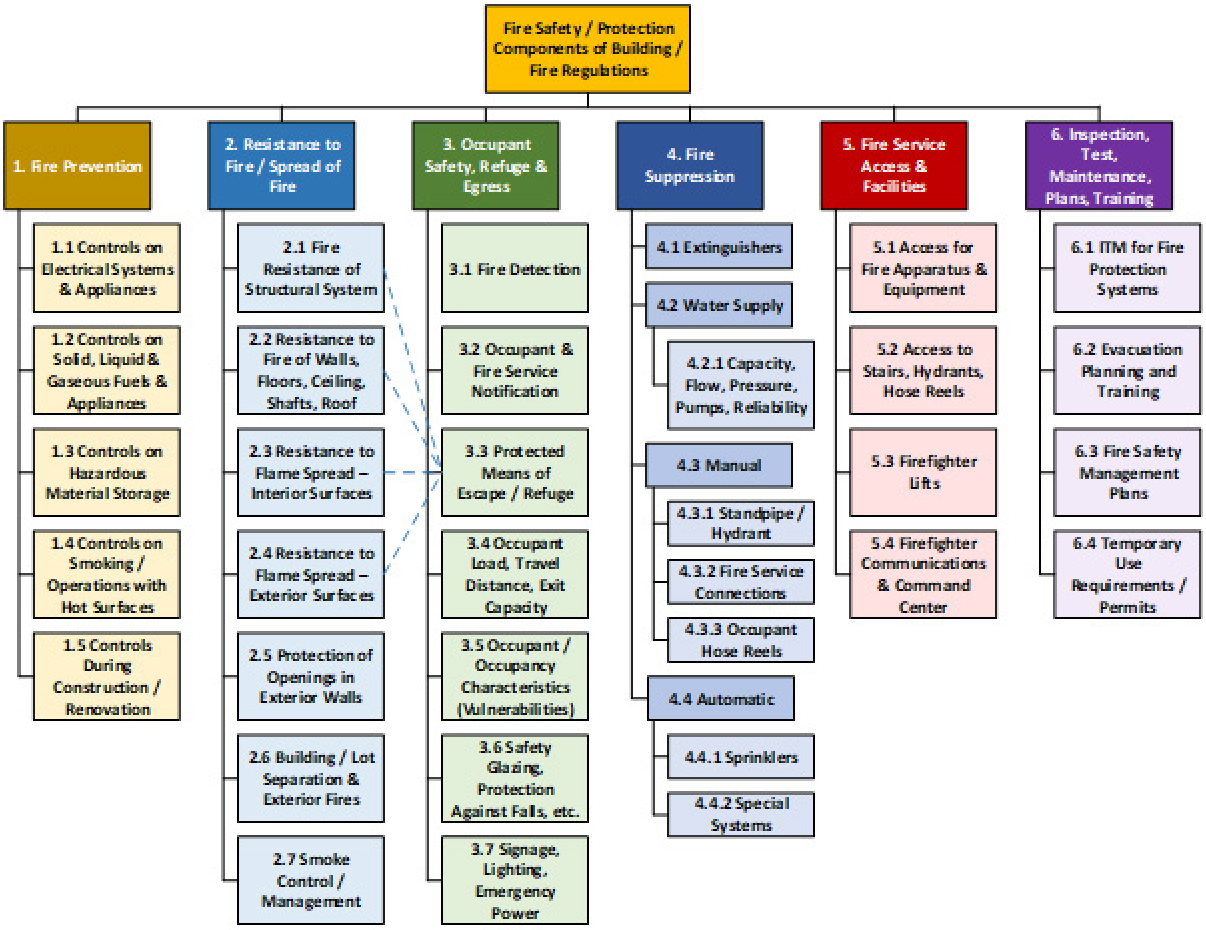
Use of properly certified / listed / approved product increases confidence and should be used wherever possible.

Careful attention to compliance with material selection, installation, and ongoing ITM is essential to maintain expected performance.

PART 4: Fire Services and Equipment[7]

Managing the impact of a fire in a building through manual and automatic means of fire suppression is a critical option for building fire safety design. In areas where water supply for fire suppression is robust and available, several different types of fire suppression systems may be used, as listed under the heading **Fire Suppression** in Figure 4.1.

Figure 4.1 Mapping of typical fire safety / protection provisions within building codes



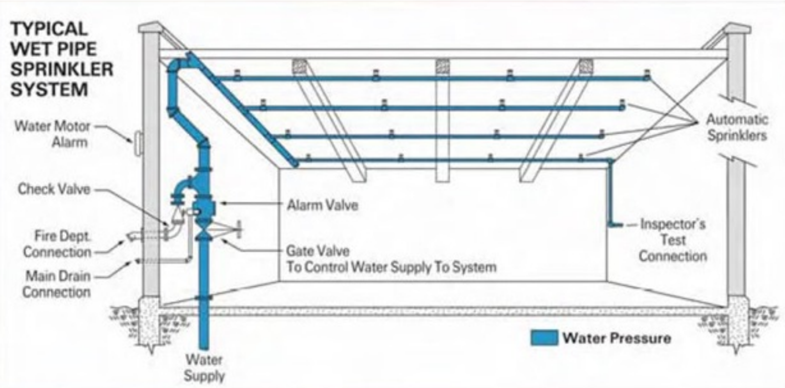
Source: World Bank

Ideally, all strategies reflected in Figure 4.1 are available and work together to provide an integrated approach to building fire safety (see Part 1). However, **in areas where water supplies for firefighting are limited or nonexistent,** the siting, design, construction, and ongoing maintenance of building construction features used for managing fire impact become critical to achieving fire safety. If there is no reticulated water supply that includes connections for fire suppression water for buildings or for the fire service, and there is not a local water storage option (e.g., on site tank for fire suppression water), then the resistance to fire and fire spread that is achieved through building construction features and materials, and separation distance, are the only reliable means for fire containment. **When firefighting water and fire service response is limited or non-existent, NBC requirements for suppression systems may not be applicable, and the 'performance' or 'alternative' option for compliance may be required for building design and approval.**

7 These Guidance Notes are not mandatory and provide general guidance for North and South Pacific which may utilize different standards. See National Building Code, and other country specific legislation for specific requirements

Automatic Fire Suppression Systems

Figure 4.2 Illustration of fire sprinkler system



In complex or high-risk buildings, automatic suppression systems help contain the size and impact of a fire without manual (e.g., fire service) intervention. The most common automatic fire suppression system is the automatic fire sprinkler system (AFSS). AFSS are comprised of a network of pipes throughout a building, supplied from a local (on site) water tank or municipal (reticulated) water supply network, to which automatic sprinkler heads are attached. Systems may be wet (water in pipes), dry (water not normally in pipes) and deluge (water flows from all heads at the same time). In normal wet and dry systems, sprinkler heads are individually heat actuated. The glass bulb or fusible link holds a plug in place, which keeps water from flowing until it melts (Figure 4.2).

Once the activation temperature is reached at a sprinkler head, the bulb breaks (or link melts), the water pipe is unblocked, and water flows.

In order to have a reliable AFSS, a reliable fresh or grey water supply is needed, and adequate capacity to conduct regular inspection, testing and maintenance (ITM) is required. Automatic fire sprinkler systems should be avoided when a reliable fresh or grey water supply is not available. In such cases, building fire protection relies primarily on building elements with suitable FRR/FRL (Part 2) and adequate egress systems (Part 3). Caution should also be used with AFSS due to the corrosive nature of the salt air and salt water environment. This may require specially protected piping and other components, which can impact cost.

Manual Fire Suppression Systems

Manual fire suppression systems include all systems and components which require human intervention and action, whether trained fire service, trained fire brigade, or trained building occupant. These systems include internal standpipe (hydrant) systems, interior hose systems, and portable fire extinguishers (Figure 4.3).

Figure 4.3 From left, fire extinguisher, fire hose reel, interior hydrant, fire water tank truck

Standpipe (interior hydrant) systems are comprised of vertical risers and branch lines the distribute water to various points in a building. **Such systems are generally used in tall or large floor-plate buildings, where it is more challenging to fight fires from outside of the building.** Outlets will typically be a combination of on/off valve and fire service connection, which should be matched to the threads on hoses used by the local fire service. In tall buildings, such systems will include pressure reducing valves to regulate pressure to appropriate levels at each floor.

Not all buildings require systems to support firefighting operations. Check the NBC for applicability. If required, and firefighting water and fire service response is limited or non-existent, NBC requirements for suppression systems may not be applicable, and the 'performance' or 'alternative' option for compliance may be required for building design and approval, e.g., following strategies in other parts of this guidance document.

Some NBCs require interior hose systems for use either by fire fighters or trained building occupants. These systems are often characterized by small diameter, rigid hose on hose reels. In rigid hose systems the user can turn on the water and then move toward the fire with water in the hose. In some cases, interior hose systems have folded or rolled flat flexible hose, which needs to be first extended before the water supply is turned on. Portable fire extinguishers discharge small amounts of water, gaseous or chemical fire extinguishing agents when activated. Portable fire extinguishers are rated based on the suitability of the extinguishing agent for the expected hazard (e.g., paper, liquid fuel, electricity). Unproven / uncertified items like fire suppression balls should be avoided. **It is critical that only systems with proper test certifications are used** (Figure 4.4).

Figure 4.4 Damaged fire hose reel

A significant challenge with all suppression systems is that they require continuous inspection, testing and maintenance (ITM) to assure they will work when needed. If this cannot be achieved, attention must be given to fire resistance, building separation and adequate means of escape as critical items. Furthermore, interior hydrant systems and hose reel systems should use fresh water from a reticulated system, fresh water tank, or swimming pool. If a fresh water supply is not available, saltwater or brackish water could be used. However, saltwater and brackish water will corrode metal components and fittings, and brackish water sprayed in buildings will cause similar concerns. This could cause significant damage and corrosion of materials.

Fire Suppression Water Supplies

In locations where there is no water authority piped mains system, the water supply infrastructure is unreliable, or water shortages can be expected due to climatic conditions (e.g., drought), on-site storage is an option. In some cases, the use of fresh water from a dedicated fire suppression water pond, rainwater catchment tank, or other outside source may be considered, but only if suitable controls are placed on screening of debris and the water supply (source) can be considered suitably reliable (e.g., it would be inappropriate to rely on a source that cannot be expected to meet demands) and appropriate maintenance and treatment is provided (Figure 4.5).

Figure 4.5 Emergency water tank in bidibidi.

Source: Asikironalio, Creative Commons 4.0

Inside of the building, a series of check valve, backflow prevention valves, and other controls are used to isolate the fire suppression water from potable supplies.

The efficacy of any water-based suppression system is directly linked to the availability, appropriateness and reliability of the water supply. When assessing building fire suppression system needs, the type of system, source of water, and reliability of the system must be considered, especially where water supply infrastructure may be unreliable or water resources are limited. Fire suppression water flow rates, pressures and minimum supply (quantity or time) requirements will be established by relevant design and installation standards for suppression systems and water supplies. These need to be checked for adequacy.

Local fresh water storage for firefighting is a consideration for complex / high-risk buildings, including large residential, such as hotel resorts. This option is used in Vanuatu, for example, in at least one resort. In addition, a common water storage tank may be considered for groupings of buildings, such as in a town or village center, to aid in firefighting operations. **As a last resort, saltwater or brackish water can be used for firefighting.** However, saltwater and brackish water will corrode metal components and fittings, and brackish water sprayed in buildings will cause similar concerns.

Brackish water is used for firefighting in Kiribati, for example. Any time fire suppression equipment is used, including fire trucks, they require thorough cleaning with clean water. Ongoing ITM is a particular challenge with saltwater systems.

Fire Detection, Alarm and Communication Systems

Fire detection, alarm and communications systems provide for the opportunity to detect fire through a wide range of automatic fire detection devices, provide a means for manual fire alarm initiation, provide for a range of alarm signaling capabilities (audible (voice or non-voice) and visual), and provide interfaces with other fire protection systems (such as smoke control systems). This should be considered for large and/or complex public buildings. Detached dwellings and sole living units are recommended to have single station (self-contained) smoke alarms.

Smoke control and management systems

In **large / complex buildings,** smoke control systems may be used for restricting the passage of smoke from one area to another. Smoke control systems need to be closely coordinated with passive fire protection systems. Smoke management systems are used to exhaust smoke from a particular space, such as a warehouse or atrium, and may employ natural ventilation or mechanical exhaust.

The aim is of these systems are to restrict or remove smoke for some period of time. Key aspects include the design fire size, level at which smoke layer needs to be maintained and for how long, availability of make-up air, and location and size of vents or exhaust ducts and fans. **These systems are typically engineered.**

Electrical Power Service

Most active fire and life safety systems in a building – from fire detection and alarm systems to smoke and heat exhaust systems – require electrical power. **It is important that designs consider reliable emergency back-up power if primary power is unreliable or unavailable.**

Table 4.1: Key Considerations where Fire Suppression Water is Lacking

Active FP system	Detached Dwelling	Other Residential	Public Buildings
Requirement smoke alarms & CO alarms	Yes	Yes	No
Requirement for system smoke detectors, manual pulls, and fire alarm control unit	No	(1)	(1)
Requirement for fire extinguishers	No	(1)	(1)
Requirement for manual hose reels	No	(1)	(1)
Requirement for smoke control / exhaust	No	(2)	(2)
Requirement for interior fire hydrants	No	(3)	(3)
Requirement for automatic sprinklers	No	(4)	(4)
Requirement for local water supply	No	(5)	(5)

1. Requirements for fire detection and alarm systems, fire extinguishers, and manual hose reels should consider corrosion impacts and ITM capacity. See for example https://www.icorr.org/souces-of-information/
2. Requirements for smoke control / management generally limited to high risk buildings (high occupant load, high hazard).
3. Requirements for interior hydrants generally limited to high risk buildings (high occupant load, high hazard).
4. Automatic sprinklers not recommended unless design, installation, and ITM funded by international partner.
5. Rainwater / grey water for fire suppression recommended for consideration in town centers and dense construction.

Corrosion is a challenge due to frequent precipitation, high salt content, warm temperatures, high relative humidity, and persistent wind. Metallic materials experience high corrosion rates that result in reduced service life. This is a particular challenge for fire suppression systems.

While brackish water can be used for manual firefighting, the corrosive nature can cause damage to pipes, valves, pumps and the like. Brackish water is not recommended for building fire sprinkler systems.

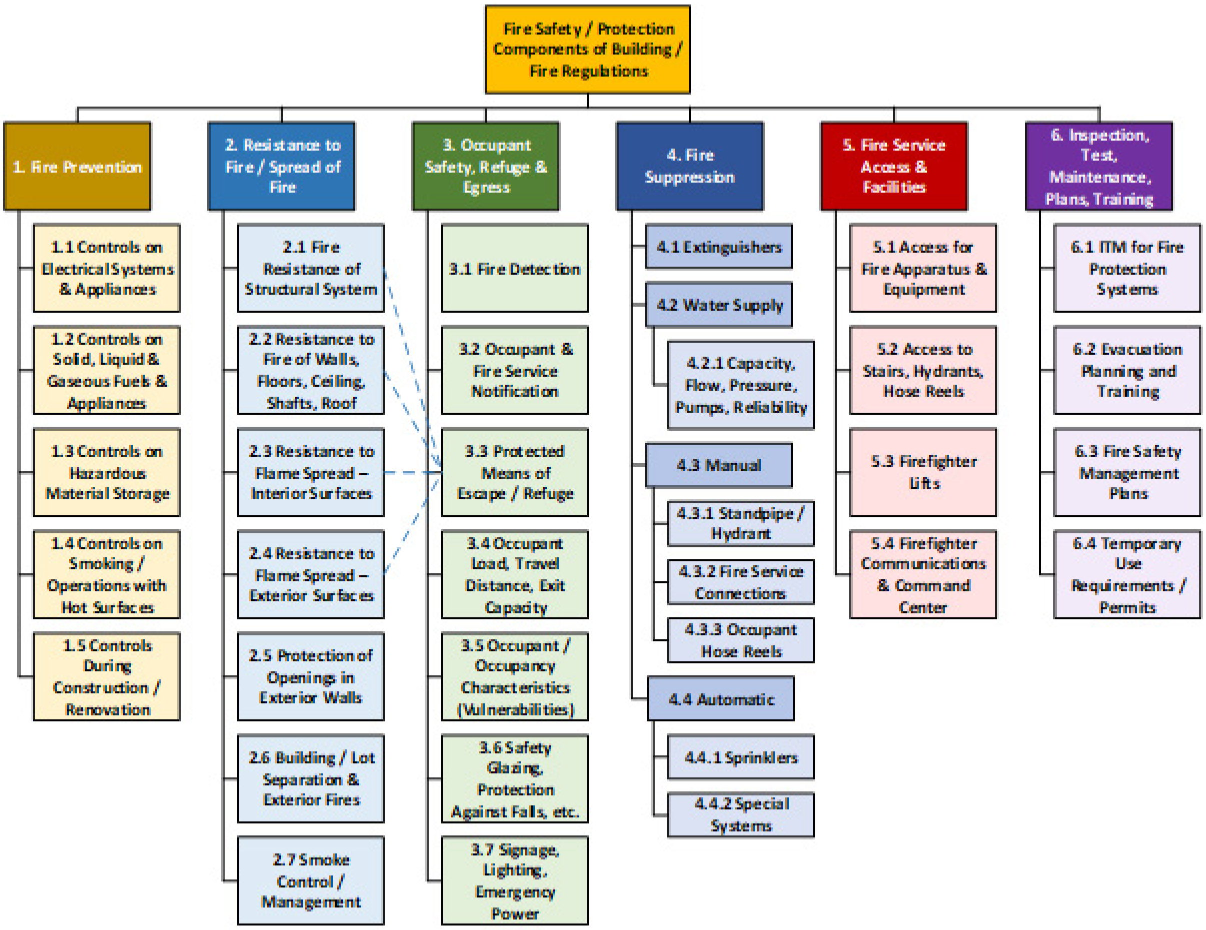
Where practicable, water for firefighting should be made available in town centers and areas of dense construction. Fresh water, without salt content, is preferred due to corrosion. Water-based fire suppression systems are not recommended for dwellings.

When firefighting water and fire service response is limited or non-existent, the 'performance' or 'alternative' option for compliance may be required. In such cases, more.

PART 5: Building Exteriors, Separation and External Fire Threats[8]

Managing fire impact through control of construction materials and by taking steps to prevent ignition from one building to another are critical components of building fire safety design. This is particularly true in where the water supply for fire suppression is lacking or nonexistent. In this case, building construction and separation distance are the primary methods of fire control. These concepts are built into building codes, as reflected under the heading Resistance to Fire / Spread of Fire in Figure 5.1.

Figure 5.1 Mapping of typical fire safety / protection provisions within building codes



Source: World Bank

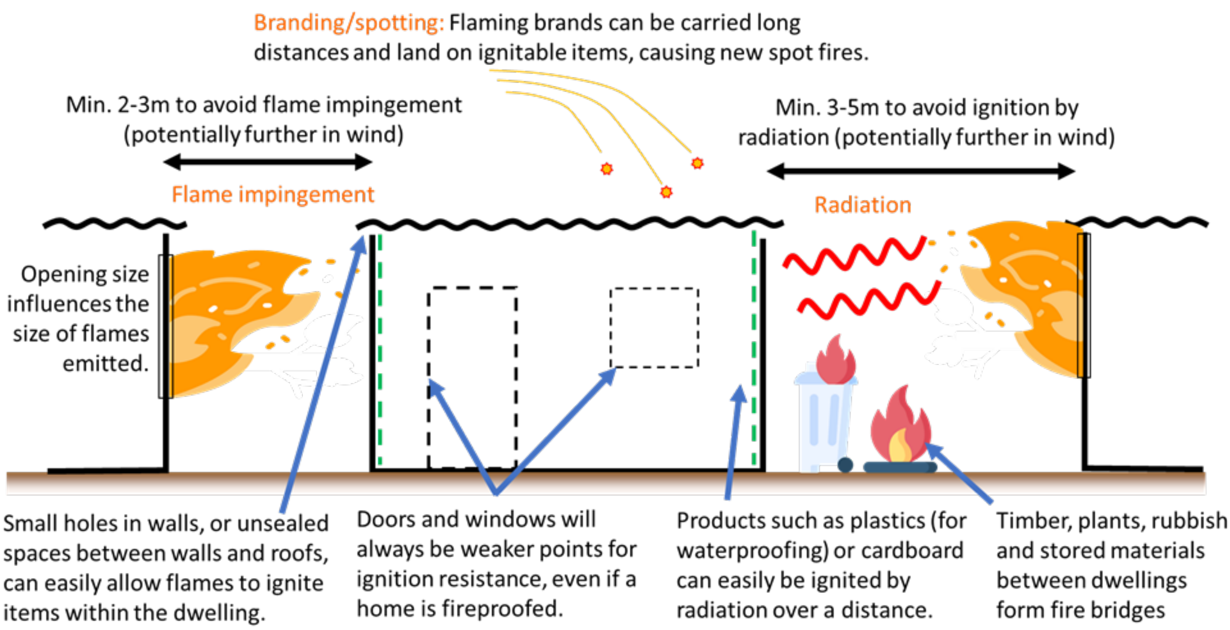
Ideally, all strategies presented in Figure 5.1 are available and work together to provide an integrated approach to building fire safety (see Part 1). **However, in areas where water supplies for firefighting are limited or nonexistent, the siting, design, construction, and ongoing maintenance of building construction features used for managing fire impact, and separation distance between buildings, become critical to achieving fire safety.**

8 These Guidance Notes are not mandatory and provide general guidance for North and South Pacific which may utilize different standards. See National Building Code, and other country specific legislation for specific requirements

Building Exteriors

With respect to exterior walls and roof assemblies, flame impingement can be important in such situations as flame extension into or out of an opening, such as an open window. Depending on building geometry, flames extending out an opening could come in contact with a surface, which if combustible could ignite, or could otherwise cause damage depending on the material (e.g., flame impingement could cause breakage of glass in window opening or façade). Similar responses can result from thermal radiation emanating from the flame as well (i.e., ignition of materials, breakage of glass). The reverse situation is also of concern; that is, where direct flame impingement or thermal radiation from exterior fire threats, such as from adjacent buildings, exterior combustibles (e.g., trash, stored combustible materials), or wildland fires, could result in ignition on the exterior or interior of the building of concern. In addition, in areas prone to wildland fires, additional threats exist in terms of burning embers / brands, which may come to rest on combustible surfaces, in some cases being driven by winds through screening and other protective measures. These concepts are reflected in Figure 5.2.

Figure 5.2 Fire-building interactions



Source: Stellenbosch University, used with permission.

To address these concerns there are two primary strategies: provide adequate separation distance between the building of concern and other buildings, property and vegetation, or protect the exterior wall and roof assemblies through choice of materials, limitation in openings, and/or protection of openings. Figure 5.3 illustrates the concept of separation distance between buildings on the same lot (property) or adjacent lots, particularly when the exterior walls and roof assemblies are combustible or have unprotected openings.

Separation not only helps to reduce the likelihood of building-to-building ignition but allows access for fire service apparatus, where available. In some cases, the distance will be impacted by building shapes or features, such as projection (as in a roof overhang). In such cases, distances may need to be increased, since the overhang could trap hot gases and result in a more intense (hotter) fire. The required distances may be set by regulation or calculation.

Figure 5.3 Building separation concepts

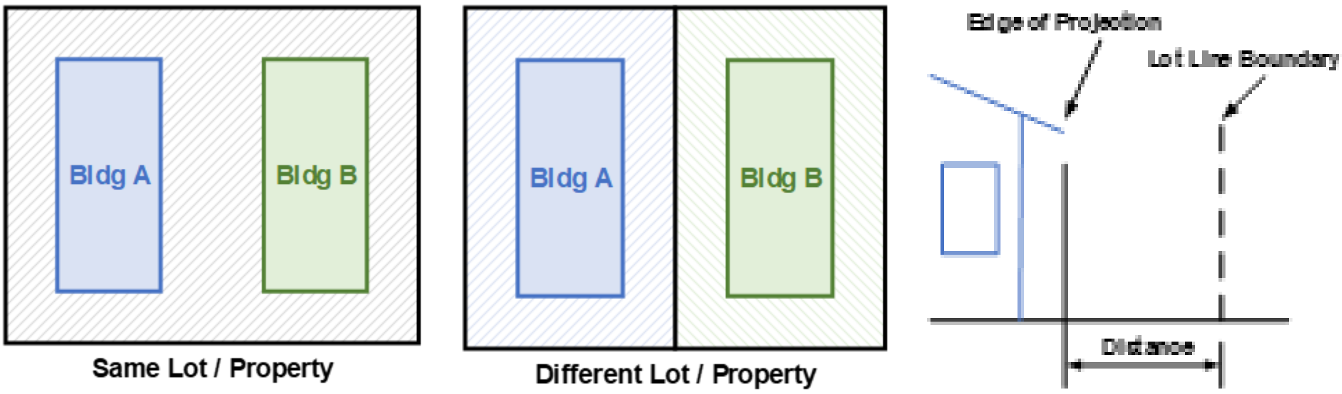
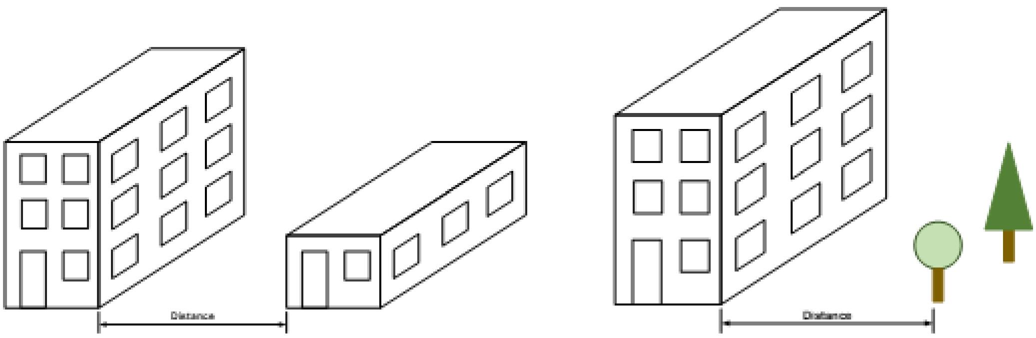


Figure 5.4 illustrates issues associated with unprotected openings (windows, in this case), which play a role in distances from other properties and from vegetation (in areas prone to wildland fires). There may also be concerns with the height of adjacent buildings, especially with respect to roof construction, but also from general fire exposure. With respect to roof construction, the lower building in the diagram below could be exposed to radiant energy from a fire in the taller building, which would impact the fire resistance requirements for the roof of the lower building and/or the protection of openings in the exposed sides of each building. The reverse is also a concern. If the lower building has a combustible roof, the radiant energy could ignite combustibles inside of the taller building, especially if the windows are open / unprotected. The same is true with vegetation. Slopes and wind direction are also key concerns.

A building fire at a lower level on a slope can ignite a building higher on the slope due to flame extension. The risk of this increases with wind blowing up the slope, tilting the flame to higher buildings.

Figure 5.4 Building separation concepts for building-to-building fire spread and external fire threats



Given the wide range of construction materials, exterior wall materials, and roof materials, there are numerous ways to address the above concerns. These include building code requirements for exterior construction material fire performance and separation distance. Fire engineering analysis of thermal radiation exposure can be used to assess different combinations of building construction, exterior materials and distance.

Wildland / Vegetation Fires & External Exposure Fires

Fires that start in vegetation and spread to inhabited areas is a growing threat in many parts of the world. With climate change resulting in increased temperatures, extended droughts, and increased wind speeds, the potential for fires in the wildland to extend into populated areas is increasing. This can happen any time there is a combination of dry vegetation and combustible buildings, whether a single building on a single lot, or in a town center with many buildings that are closely spaced.

In addition to the external building fire protection approaches outlined above (material selection, building spacing), further protection for against wildfire and external fire threats includes the additional of metal screening to prevent embers from impacting windows or penetrating openings, such as eaves and roof vents, prohibiting combustible decks and fences, and further increasing separation distance to other buildings and vegetation (grasses, bushes, and trees).

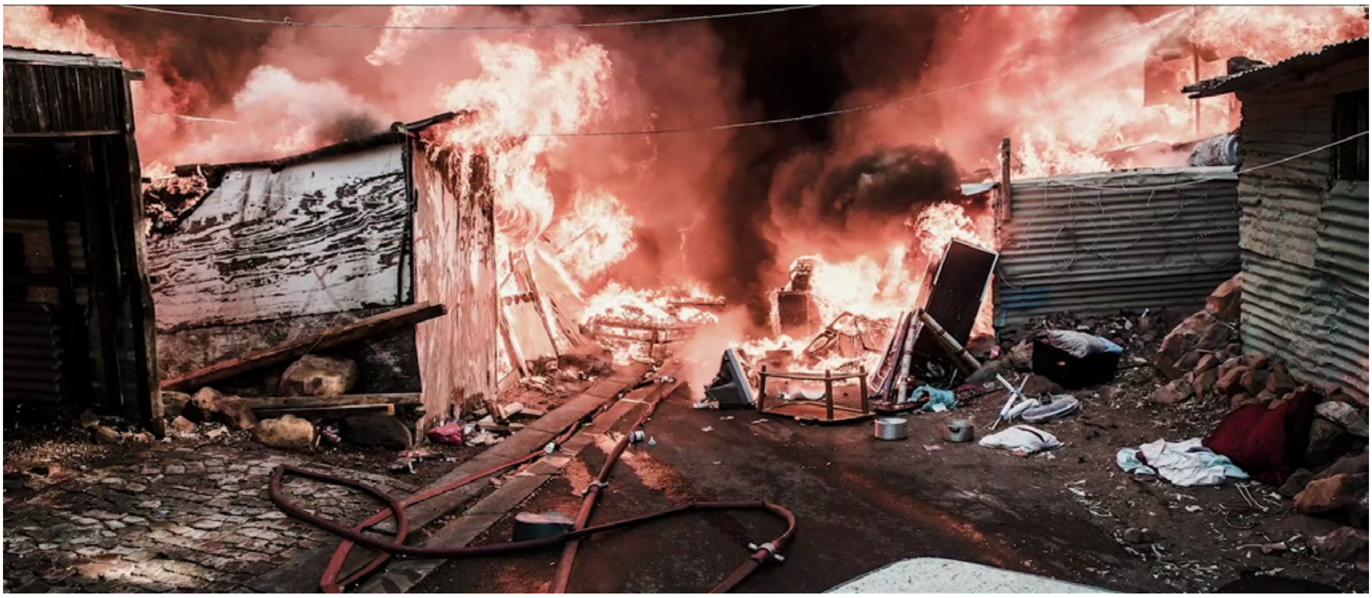
Informal / Unregulated Construction

A particular type of external fire threat that creates significant challenges is informal or unregulated construction. While some forms of informal or unregulated construction falls outside of the scope of building codes (e.g., informal settlements, unregulated shelters), there can also be aspects of building additions or expansions to code-regulated buildings for which permits and/or other permissions have not been obtained. Figure 5.5 reflects an example of information construction.

Figure 5.5 Informal construction, timber frame, closely spaced near vegetation

As in the structures shown in Figure 5.5, informal construction often involves use of materials that are readily available, which can include scrap lumber, thatched roofs, corrugated metal, and other such materials. When such materials are used to construct an informal shelter, an expansion to a formal building, a carport, or a shed or outbuilding, and if there is inadequate spacing between the structures, there is a significant chance of fire spread between buildings, should a fire occur. If there is use of open flame cooking, or informal or inappropriate electrical wiring, the fire risk increases. The results as illustrated in Figure 5.6 can be catastrophic, especially if water for firefighting is limited, or there is no fire service, or the combination.

Figure 5.6 Multiple informal shelters burning



Source: ©Justin Sullivan (2018), used with permission.

Key Considerations where Fire Suppression Water is Lacking

In areas where water resources for firefighting are limited or non-existent, the primary building feature for controlling fire spread is through compartmentation using materials of with appropriate FRRs/FRLs, as discussed in Part 2. In addition, protection of building exteriors, protection of openings in building exterior, and adequate separation distance from other fuel sources (e.g., buildings, debris, vegetation, etc.) is critical (Table 5.1).

Table 5.1: Passive Fire Prevention

Passive FP Feature	Detached Dwelling	Other Residential	Public Buildings
Requirement for FRR/FRL of external walls	No	Maybe (depends on separation distance)	Maybe (depends on separation distance)
Requirement for minimum distance from lot lines	Yes	Yes	Yes
Requirement for minimum distance from other buildings	Yes	Yes	Yes
Requirement for controlling vegetation	Desirable	Desirable	Desirable

As noted in Part 2, small buildings for storage and other uses associated with dwellings typically do not require FRR/FRLs, which means building separation is important.

For complex and tall buildings, requirements for FRR/FRL increase, as should exterior FRRs/FRLs, especially if separation distances are limited. In the Pacific Island context, these buildings may be as low as 3 stories and/or with large footprints or occupant loads.

When firefighting water and fire service response is limited or non-existent, the ‘performance’ or ‘alternative’ option for compliance may be needed to determine appropriate separation distance, fire resistance and egress needs to assure fire safety. As noted in Part 2, small buildings for storage and other uses associated with dwellings typically do not require FRR/FRLs, **which means building separation is important.**

For complex and tall buildings, requirements for FRR/FRL increase, as should exterior FRRs/FRLs, especially if separation distances are limited. **In the Pacific Island context, these buildings may be as low as 3 stories and/or with large footprints or occupant loads.**

When firefighting water and fire service response is limited or non-existent, the ‘performance’ or ‘alternative’ option for compliance may be needed to determine appropriate separation distance, fire resistance and egress needs to assure fire safety.

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