Section 5 – Fire Safety Sub-systems

Clause G5.1 Introduction

The framework of fire safety "sub-systems" should be used to assess, evaluate and document all the fundamental aspects of an Alternative Solution for a building.

The sub-systems form a set of parameters that must be considered for all Alternative Solutions. The interaction of the sub-systems and their direct correlations with the Performance Requirements should be identified for setting the design principles and the basis of the assessment fundamentals. All sub-systems must be considered even though some of them fully comply with the Deemed-to-Comply provisions. The sub-systems are described below:

Sub-system 1: Fire Initiation and Development - fire science principles and fundamentals.

Sub-system 2: Smoke Development, Spread and Control - assessment of smoke development is required to assess life safety, considering smoke movement, visibility and smoke layer temperature.

Sub-system 3: Fire Detection, Warning and Automatic Suppression - active fire safety provisions relevant to the fire hazard, to relevant standards, with regular inspection, testing and maintenance carried out to ensure the systems are operable at all times.

Sub-system 4: Fire Spread, Impact and Control - fire spread can be limited by the fire safety provisions installed. Assessing fire development, pre-flashover and post flashover fires is required for assessment of life safety and the impact of fire on property.

Sub-system 5: Occupant Characteristics and Evacuation - prediction of occupants' behaviour and egress must be based on analysis of occupant characteristics and the fire safety provisions provided.

Sub-system 6: Fire Service Intervention - interaction of firefighters must be considered.

Commentary

The fire safety sub-systems provide a framework for carrying out a fire engineering design. All sub-systems should be examined in a holistic manner. Some of the sub-system aspects may fully comply with the Deemed-to-Comply provisions and hence may need little justification, whereas other sub-systems may have significant non-compliances and require substantial assessment but all must be considered.

Sub-system 1 - Fire Initiation and Development

Fire initiation and development is a fundamental of any performance-based assessment for fire safety. Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) fire compartment characteristics;

(b) fire load density;

(c) expected fuel configuration;

(d) ignition sources;

(e) expected design fires;

(f) rate of heat release;

(g) fire compartment ventilation and limitations;

(h) development of smoke;

(i) calculation of temperature in smoke layer; and

(j) time to reach flashover or if flashover is reached.

Assessment should be based on considering the likelihood of fire occurrence and not just assuming a fire occurs. In general, due to the lack of data and tools, a probabilistic assessment on absolute terms (e.g. probability of fire deaths per year) cannot be undertaken.

The approach must be based on realistic assessment of the likely fire growth rate, likely fire size and rate of fire spread through a fire compartment, based on the ventilation available.

Commentary

To understand the likelihood of a fire developing and growing, statistical information is required on the location of a fire, how it develops and the effectiveness of active fire suppression systems etc.

Sub-system 2 - Smoke Development

The interaction of occupants with smoke is a fundamental for assessment of life safety. The assessment should be based on smoke layer height and visibility, with consideration of toxicity, where appropriate. The acceptance criteria for life safety with regard to smoke are to be based on:

(a) smoke movement and layer height;

(b) smoke visibility; and

(c) smoke layer temperature.

Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) occupant characteristics;

(b) fire compartment characteristics;

(c) fire load density;

(d) expected fuel configuration;

(e) expected design fires;

(f) rate of heat release;

(g) fire compartment ventilation and limitations;

(h) effects of elevated temperatures on elements of building construction;

(i) calculation of temperature in smoke layer;

(j) smoke layer height and interface height;

(k) smoke visibility / optical density;

(l) effect of fire suppression systems on properties of the fire and smoke;

(m) smoke control equipment present, active and passive;

(n) relevant standards to be complied with; and

(o) maintenance and testing.

If a probabilistic method is undertaken, the data on the effectiveness of smoke control measures (both active and passive), elements of construction and fire suppression systems are required.

Sub-system 3 - Fire Detection, Warning and Automatic Suppression

To mitigate the hazards represented within the other sub-systems, active fire safety provisions are required. These provisions provide warning to the occupants and may also provide automatic suppression in case of fire.

Performance-based design is not expected to occur on a sub-system level, unless in special circumstances, e.g. specialised smoke management or fire suppression systems within tall atria.

Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) fire compartment characteristics;

(b) expected design fires;

(c) rate of heat release;

(d) calculation of temperature in smoke layer;

(e) smoke layer height and interface height;

(f) smoke visibility / optical density;

(g) types of smoke or heat detection equipment;

(h) types of automatic suppression systems;

(i) activation of smoke control measures through fire alarm panel;

(j) activation of other fire safety provisions through fire alarm panel;

(k) activation of warning systems to occupants;

(l) activation of alarm system to the Fire Services Department;

(m) smoke control equipment present, active and passive;

(n) relevant standards to be complied with; and

(o) maintenance and testing.

Commentary

An assessment of this sub-system requires a thorough understanding of the potential failure modes and likelihood of failures of the sub-system. The likelihood of failure or activation of a system is also reliant on the type of maintenance and testing carried out. This data are not available in Hong Kong at present.

Sub-system 4 - Fire Spread, Impact and Control

Fire spread can be limited by either active or passive fire safety provisions or a combination of both. Generally the fire barriers of a fire compartment will limit fire and smoke spread, as will the type of fuels present and internal linings. The other key system for fire control is the use of fire suppression systems, especially automatic sprinkler systems. Hose reels and extinguishers can also be used.

The Fire Services Department provides the last means of defence against fire spread within a fire compartment and between fire compartments or buildings. Assessing the impact of fire service intervention is also required.

Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) fire compartment characteristics;

(b) fire load density;

(c) expected fuel configuration;

(d) expected design fires;

(e) rate of heat release;

(f) influence of lining materials;

(g) ventilation and limitations;

(h) calculation of temperature in smoke layer;

(i) smoke control equipment present, active and passive;

(j) automatic alarm systems;

(k) automatic suppression systems;

(l) time to flashover or if flashover is reached;

(m) sealing of all penetrations;

(n) use of the time-equivalence concept;

(o) knowledge of inherent fire resistance performance;

(p) effects of elevated temperature on elements of construction;

(q) structural stability of load bearing building elements;

(r) relevant standards to be complied with;

(s) fire service intervention; and

(t) maintenance and testing.

Commentary

An assessment of this sub-system requires an understanding of the expected failure processes for fire seals, fire barriers, automatic systems and fire service intervention. Also the likelihood that occupants will extinguish a fire by using devices such as hand-held extinguishers or hose reels should be considered.

Sub-System 5 - Occupant Characteristics and Evacuation

Occupant escape from fire is made up of the following components:

(a) detection of fire and occurrence of the warning cue;

(b) recognition of the cue and pre-movement activities of occupants; and

(c) movement to a safe place.

Fire initiation is based on the fuel characteristics and ventilation, which is determined within sub-system 1. The time for detection of the fire and an alarm to be activated is developed within sub-system 3.

Recognition of an alarm or cue is dependent on the occupant characteristics within the fire compartment and also within the building as a whole. The ability to recognise an alarm and then act on it is dependent on the type of warning system provided, which is required to be tailored to the expected occupant characteristics.

Occupant movement is dependent on the mobility of the occupant, the number of occupants, number of exits, travel distance to exits and ability to make decisions as to which exit to choose.

Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) fire compartment characteristics;

(b) occupant characteristics, including physical and mental capabilities;

(c) occupant numbers and distribution;

(d) prior fire safety training for occupants;

(e) presence of a warden system and its effectiveness;

(f) established fire emergency organisational structure and procedures;

(g) frequency of false alarms;

(h) building layout and exit route characteristics;

(i) type of detection;

(j) occupant warning systems and mode of alarm;

(k) life safety protection systems;

(l) fire service access, search and rescue abilities; and

(m) maintenance and testing.

All components are times and together they equate to the total evacuation time. The total evacuation time is the Required Safe Egress Time, i.e. RSET.

Commentary

Pre-movement time is a very difficult value to estimate, given the reliance on the human characteristics, especially if the occupancy involves sleeping groups or persons who have paid to enter an area. Pre-movement times have been researched for many years and ranges of values have been established within the fire engineering field. This information is a very important input into the design process and the assumed values, the range of values and how they are applied are required to be justified.

Pre-movement time is therefore usually not a discrete value but a range of values, given that people react differently due to their own perceived risk and also their location to the fire event. Some occupants are of relatively long pre-movement times because they are remote from a fire event and hence are not directly at risk. Typically a range is considered appropriate, due to the uncertainty and expected range of pre-movement times that will be possible for any design or actual fire.

Data on how people may react in a fire in Hong Kong is also relevant, categorised for example by age group, sex, physical and mental capability, level of education, any prior fire training received, responsibility held at the time of fire, ability to recognise and respond to alarms etc. An assessment will be highly dependent on the human factors.

Sub-system 6 - Fire Service Intervention

Often the impact of the Fire Services Department is ignored with an assumption that firefighters would arrive after all occupants have evacuated. This is a very conservative approach as the Fire Services Department is often on the fire ground when occupants are still leaving the building.

One method of predicting fire service intervention is to utilise a design methodology that is provided by the Fire Services Department. This is often entitled as an “intervention model”. This is a formalised method for quantifying the operations of the Fire Services Department. It is typically an event-based methodology that considers the time taken for the various firefighting functions to be performed.

Information and inputs to the assessment of this sub-system that may be required as part of an Alternative Solution include:

(a) building and fire compartment characteristics;

(b) occupant characteristics and numbers;

(c) exit path characteristics;

(d) fire safety provisions;

(e) dispatch and routes details;

(f) EVA;

(g) ability for investigation;

(h) area and time for set-up;

(i) means of access available;

(j) availability of water supplies;

(k) prevention of spread of fire to other buildings; and

(l) fire control and extinguishment.

Commentary

Intervention Model of Fire Services Department

This section provides the Fire Services Department's intervention model with guidance on methodologies that may be adopted for quantifying the following:

(a) the arrival of the fire service at the fire scene;

(b) investigation by the fire service;

(c) fire service set-up;

(d) search and rescue;

(e) fire service attack;

(f) fire control; and

(g) fire extinguishment.

The components of fire service intervention that will need quantification may be grouped under two main headings:

(a) pre-fire control and extinguishment activities; and

(b) fire control and extinguishment.

The first group of activities relates mostly to the series of events that take place from the time the fire service is notified to the time it is ready to attack the fire. The effect of fire service activities does not lend itself easily to quantification and many aspects of the procedure will need to be based on qualitative judgement rather than numerical calculations.

Computer models may provide guidance on how to quantify fire control and extinguishment events and times. Other methods based on thermodynamics and heat transfer theory may also be utilized for this purpose. However, it will be necessary to utilize the expertise of the local fire service to validate many of the decision-based input parameters used.

The computer model should assume the following prioritized outcomes:

(a) the safety of building occupants who must be able to leave the building (or remain in refuge floor) without being subject to untenable conditions;

(b) the protection of firefighters who must have reasonable time to search for any trapped occupants, before conditions become hazardous to their safety occur; and

(c) the protection of adjacent fire compartments and buildings from fire spread due to radiation, flame impingement, flying brands or structural collapse.

The computer model should be used (in whole or in part) to generate the following information:

(a) the time taken for firefighters to reach a particular location in a building;

(b) the water flow rate required for fire extinguishment or control that is necessary to compensate for deletion of a sprinkler system;

(c) the required water flow rate and building separation necessary to prevent fire spread to adjoining property;

(d) the time firefighters will be inside a building for search and rescue activities during which firefighter tenability and structural stability should be maintained; and

(e) the robustness of the Alternative Solution.