Singapore Civil Defence Force

Singapore Fire Safety Engineering Guidelines 2025

1st edition: 2015
2nd edition: 2025

Published by:
Singapore Civil Defence Force
91 Ubi Avenue 4
Singapore 408827

With inputs from:
Home Team Science and Technology Agency

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CHAPTER 1

1.0 INTRODUCTION

The Singapore Fire Safety Engineering Guidelines (SFEG) provides a means for Fire Safety Engineers (FSEs) to carry out Performance-Based (PB) designs to meet the objectives of the Fire Code (Code of Practice for Fire Precautions in Buildings). Where the design of fire safety works deviates from the prescribed or deemed-to-satisfy requirements stipulated in the Fire Code, the FSE may embark on an alternative solution i.e. PB approach to address these deviations.

The root and sub objectives for the PB design to achieve are stipulated in Fire Code 2013 and can be found in SCDF website and Annex J. FSE shall be cognizant of these objectives when developing their PB design method.

The SFEG therefore seeks to guide the FSEs and Peer Reviewers in preparing the relevant documents for submission to SCDF. The documents to be prepared by the FSE include the (1) Fire Safety Engineering Design Brief (FEDB), (2) Fire Safety Engineering Report (FER) and the (3) Operations and Maintenance (O&M) Manual while that of Peer Reviewer includes the Peer Reviewer's Report (PRR).

This SFEG comprises two main parts, namely:

> Part 1: PB regulatory framework, fire engineering design concepts, submission documentation requirements, administrative and technical guidelines.
>
> Part 2: Common alternative solutions to prescribed requirements and the general design approaches to address them.

While the latter part outlines the general design approaches to common alternative solutions from prescribed requirements, these are not mandated approaches and users are advised to apply them with care in view that buildings differ in terms of its design layout, fire load, occupant characteristics, etc.

Similarly, care must be exercised by the user when using any information in this document. SCDF shall not be held responsible for any wrongful design or misuse of information arising from the use of this document.

1.1 REGULATORY FRAMEWORK

1.1.1 A FSE is required to be appointed for the preparation of alternative solutions as part of the building plan submission to SCDF.

1.1.2 The FSE is required to produce a preliminary report - Fire Safety Engineering Design Brief (FEDB) to be submitted to SCDF for in-principle agreement (IPA).

The FEDB outlines the proposed fire safety engineering approach, methodology, and software tools etc.

1.1.3 The FEDB will be assessed by SCDF. Upon the in-principle agreement of the FEDB, the FSE can proceed to prepare the Fire Safety Engineering Report (FER) and the Operations and Maintenance Manual (O&M Manual).

1.1.4 After the preparation of the above documents by the FSE, the Peer Reviewer (to be engaged by the owner so as to avoid conflict of interest) shall assess the documents and ensure that the alternative solution is incorporated in the Building and M&E plans. The Peer Reviewer shall produce a report of his assessment in a Peer Reviewer's Report.

1.1.5 The Project QP is responsible for collating all the above documents for plans submission to SCDF. The alternative solution shall be endorsed by the FSE. QPs who are also qualified FSEs may endorse in the capacity of both the QP and the FSE.

1.1.6 The submitted plans and documents may be selected by SCDF for subsequent audit checks. Upon completion of the fire safety works, the owner is required to engage a Registered Inspector who is another FSE to inspect the performance-based aspects of the fire safety works. The flowchart below illustrates the process for the Performance-Based plan submission.

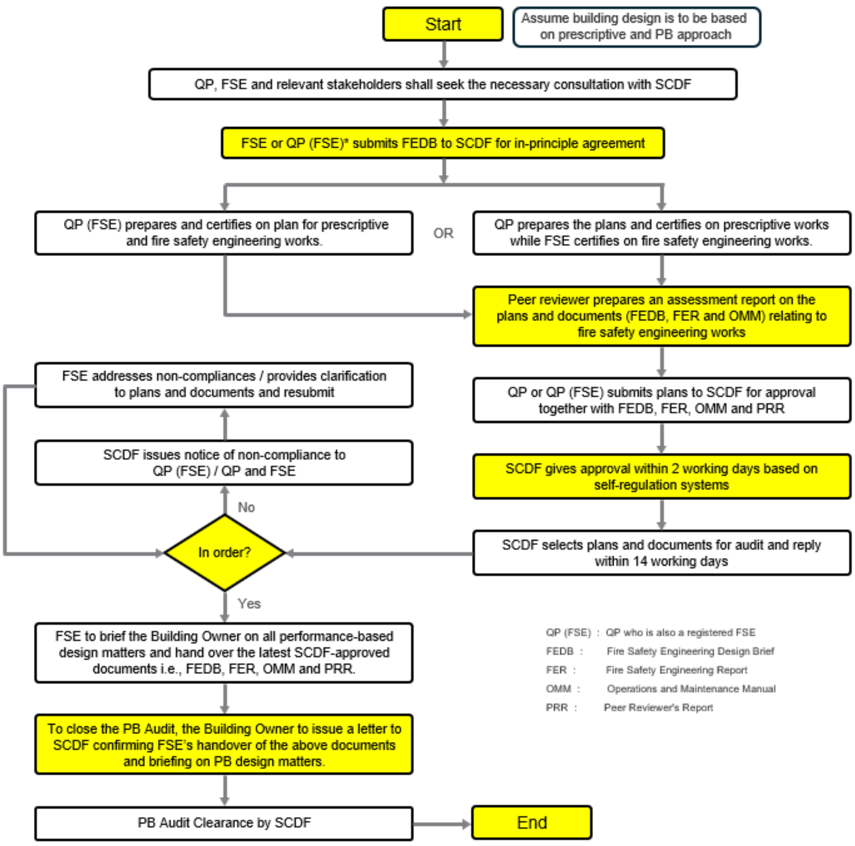

Figure 1.1 : The Performance-Based Plan Submission Framework

1.1.7 For fire safety engineering designs involving structural solution, the owner must engage a FSE who is also a Professional Engineer (PE) in the civil/structural engineering discipline. If the FSE is not a PE (civil/structural), the owner will need to engage a PE (civil/structural) to work together with the FSE. The Peer Reviewer would also need to be a PE in the civil/structural engineering discipline. If he/she is not a PE (civil/structural), then the review shall also be endorsed by another independent PE (civil/structural).

1.2 DEFINITIONS

1.2.1 The abbreviations listed in the following table are used in this Guideline: -

Abbreviation	Definition
† BS	British Standard / BS EN
† CP	Code of Practice
† NFPA	National Fire Protection Association
† SS	Singapore Standard

† latest version shall be used.

1.2.2 Alternative solution
Engineering solution for the fire safety works to satisfy any fire performance requirements in the Fire Code, being a solution that is based on:

a. A deterministic or probabilistic analysis of fire scenarios or both types of analysis or

b. A quantitative or qualitative assessment of design alternatives or both against the fire performance requirements in the Fire Code

1.2.3 Available Safe Egress Time (ASET)
"ASET" refers to the time available for escape for occupants. This is the calculated time interval between the time of ignition of a fire and the time at which conditions become such that the occupant is estimated to be incapacitated (i.e., unable to take effective action to escape to a place of safety).

1.2.4 Computational fluid dynamics (CFD)
"CFD" refers to the computational method that solves equations to represent the movement of fluids in an environment.

1.2.5 Design fire
"Design fire" refers to the quantitative description of assumed fire characteristics within the design scenario.

1.2.6 Design fire scenario

"Design fire scenario" refers to the specific scenario which defines the specific characteristics of the building, occupants and fire that are pertinent to the fire safety engineering analysis.

1.2.7 Detection time

"Detection time" refers to the time interval between ignition of a fire and its detection by an automatic or manual system or people.

1.2.8 Evacuation time

"Evacuation time" refers to the time interval between the time of warning of a fire being transmitted to the occupants and the time at which the occupants of a specified part of a building or the whole building are able to enter a place of safety.

1.2.9 Fire decay

"Fire decay" is the stage of fire development after a fire has reached its maximum intensity and during which the heat release rate and the temperature of the fire are decreasing.

1.2.10 Fire growth

"Fire growth" refers to the stage of fire development during which the heat release rate and the temperature of the fire are increasing.

1.2.11 Fuel load

"Fuel load" refers to the fire load quantity of heat which can be released by the complete combustion of all the combustible materials in a volume, including the facings of all bounding surfaces (Joules).

1.2.12 Fire safety engineering

"Fire safety engineering" is the application of engineering methods based on scientific principles to the development or assessment of designs in the built environment through the analysis of specific design scenarios or through the quantification of risk for a group of design scenarios.

1.2.13 Fractional effective dose (FED)

"FED" is the fraction of the dose (of toxic gases or thermal effects) that would render a person of average susceptibility incapable of escape.

1.2.14 Heat of combustion

"Heat of combustion" is the thermal energy produced by combustion of unit mass of a given substance (kJ/g).

1.2.15 Heat release per unit area

"Heat release rate per unit area" refers to the rate of thermal energy production per unit area generated (Qr) by combustion (kW/m^2). For purpose of calculating the fire perimeter or fire size for non-sprinkler-controlled fire, the values are given in Table 1.1.

Building Use	Heat release rate per unit area, Qr (kW/m²)
Industrial	260
Storage	500
Offices	290
Shops	550
Horel rooms	249

Table 1.1 : Commonly used values of heat release rate (Fire Code & CIBSE Guide E)

1.2.16 Heat release rate (HRR)

"HRR" is the rate of thermal energy production generated by combustion (kW or MW.

1.2.17 Optical density of smoke

"Optical density of smoke" is the measure of the attenuation of a light beam passing through smoke expressed as the logarithm to the base 10 of the opacity of smoke.

1.2.18 Pre-movement time

"Pre-movement time" is the time interval between occupants being informed to evacuate and the time in which they begin to travel to a safe location.

1.2.19 Registered Inspector

A "Registered Inspector" is a person who is registered under the Fire Safety Act to be qualified and competent to inspect fire safety works in buildings to ascertain the degree of compliance of fire safety requirements.

1.2.20 Required Safe Egress Time (RSET)

"RSET" is the time required for escape. This is the calculated time period required for the occupants to travel from their location at the time of fire ignition to a place of safety.

1.2.21 Response Time Index (RTI)

"RTI" is the measure of the reaction time to a fire phenomenon of the sensing element of a fire safety device.

CHAPTER 2

2.0 FIRE SCENARIOS

This chapter sets out fire scenarios and sensitivity analyses that the FSE is required to consider (qualitatively and/or quantitatively), depending on alternative solution(s) proposed. Refer to Part 2 of the SFEG to determine which fire scenarios to apply.

These scenarios may not be exhaustive and that FSE would need to consider other scenarios where appropriate.

2.1 Base case

Design fire scenarios are representative of typical(s) fire within the occupancy considering its usage, population size, fuel load and ignition sources, ventilation, means of escape provisions, etc

Depending on the scope of the performance-based assessment, there could be more than one base case design fire scenario. The design fire locations shall be located at the most onerous/credible locations.

SCDF may also request for other base case analysis to be conducted, depending on the nature of the project and the extent of the alternative solutions.

2.2 Sensitivity analysis

Sensitivity analysis shall be conducted to test the robustness of the proposed design. These mandatory studies as described below (where applicable) may not be exhaustive and the FSE is to propose all relevant sensitivity analysis in the FEDB.

FSE to tabulate the different sensitivity tests considered for each base case fire scenario and explain why (if any) the scenario is not applicable for a particular base case. SCDF may also request for other sensitivity analyses to be conducted, depending on the nature of the project and the extent of the alternative solutions.

2.2.1 Sensitivity Test 1 – Buoyancy test

a. A 1 MW fire to test buoyancy for natural smoke control system.

2.2.2 Sensitivity Test 2 – Wind effects

a. One side of vents (side with the most openings) is assumed to fail, i.e., vents modelled to be in closed position or subjected to wind effects that may negatively affect smoke venting for natural smoke control system.

2.2.3 Sensitivity Test 3 – Fan efficiency

a. To assume n-1 fans operating during fire mode, where n is the number of duty fans. (Not required if there are 2 or more standby fans).

b. Alternatively, a 20% increase in fire size (peak HRR) can be adopted in lieu of fan failure.

2.2.4 Sensitivity Test 4 – Increase in fire growth rate

a. Fire is assumed to grow at a faster rate using t-squared fire e.g. from medium to fast or from fast to ultrafast.

2.2.5 Sensitivity Test 5 – Fire rendering an exit unusable

a. A fire starts in the vicinity of an escape route and can potentially block an exit. Applies to premises/spaces where there are at least 2 exits.

b. FSE should consider the largest exit or the most-utilized exit to be blocked.

c. FSE would need to consider this if the alternative solution involves means of escape and/or engineered smoke control.

2.2.6 Sensitivity Test 6 – Delay in detection time

a. Failure of primary smoke/fire detection system (i.e. the first device that detects the smoke/fire).

b FSE would need to consider this if the alternative solution involves means of escape and/or engineered smoke control.

2.2.7 Sensitivity Test 7 – Smouldering Fire

a. This scenario addresses the concern regarding a slow, smouldering fire that poses a threat to sleeping occupants such fires may fill the rooms with toxic gases but may not be large enough to be detected by fire alarms or other occupants.

b. Would typically be considered if the alternative solution involves sleeping occupancies. Subject to SCDF request on a case-by-case basis.

2.3 Summary of fire scenarios

FSE shall provide a summary of all fire scenarios assessed in table format, including base case and sensitivity analysis, in the fire engineering reports. The deviation addressed by each fire scenario shall be indicated

FSE shall also provide justification with a sensitivity test table to explain how certain sensitivity tests are chosen/considered by the FSE for each fire scenario.

CHAPTER 3

3.0 AVAILABLE SAFETY EGRESS TIME (ASET)

As part of the performance-based analysis, ASET is compared against RSET after applying the relevant safety factor. The factors that affect the ASET are discussed below. As not all input parameters can be accurately predicted, safety factors are applied to the analysis to cater to these uncertainties

3.1 Fire hazards

The FSE would need to identify all possible fire hazards within the scope of his/her study and determine which would be selected as design fires

3.2 Design fires

Depending on the scope and objectives of the fire engineering analysis, the design fires would generally fall into two main categories, which are pre and post flashover fires.

3.2.1 Pre-Flashover fires are generally used for most design fires unless the design involves structural fire engineering analysis (where post flashover fires are used). For pre-flashover fire scenarios, the minimum details to be documented are as follows.

a Type and nature of fuel. The FSE would need to document the fuels present in the area of study. This includes the location, storage method, quantity or any other special characteristics/considerations.

b Type of smoke plumes

(1) **Axis-symmetric plumes at the centre of room of fire origin**

Such plumes produce lower smoke entrainment rates and higher smoke temperatures and are generally applicable to all fire scenarios.

(2) **Corner plumes at corner of room of fire origin**

Such plumes produce lower smoke entrainment rates and are applicable to corner spaces that are most remote from ventilation openings/exhaust points.

(3) **Under a balcony/Spill plume, window plumes and balcony/line plumes**

Such plumes produce higher smoke entrainment rates and lower smoke temperatures and are applicable to spaces containing intermediate/multiple levels such as atrium spaces and multi-storey buildings.

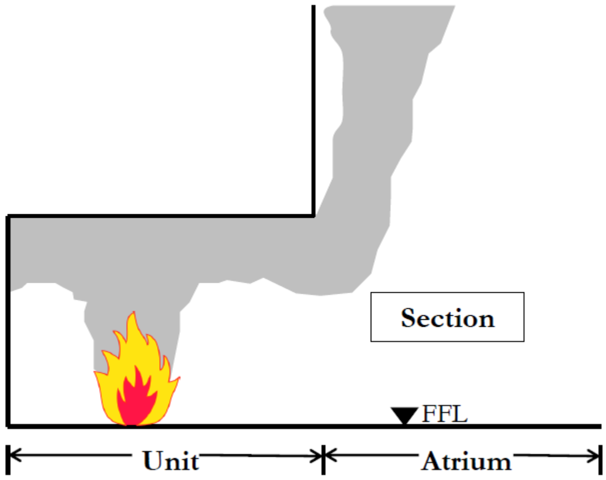

Figure 3.1 : Spill plume

c **Fire size/growth rate**

The fire growth rate generally depends on the type of fuel load, which can be generally characterised by the building usage e.g. residential, commercial, etc. In the event a building has different fuel loads e.g., due to mixed occupancies, the FSE is advised to adopt a more conservative fire growth rate or seek a consultation with SCDF. (Refer to Table 3.1)

d **Method of determining fire size**

In most cases, the design fire size can be determined by the active fire protection systems that are installed.

(1) If automatic sprinkler system is installed, fire size can be determined based on 2nd ring of sprinkler activation.

(2) If alternative water suppression systems are installed in lieu of sprinklers, fire size can be determined-based on the following:

(i) Pre-action sprinklers

Total time taken to activate (i) automatic fire detection system (e.g. smoke or heat detectors, flame detectors, air-sampling detectors, beam detectors, etc) including the time for the water to fill the pipework (water flow lag) and (ii) sprinkler system.

(ii) Deluge system

Time taken to activate automatic fire detection system (e.g. smoke or heat detectors, flame detectors, beam detectors, etc) and for the water to be discharged.

(iii) Water monitor system

Time taken to activate automatic fire detection system (e.g. flame detectors, etc) and for the water to be discharged.

Based on the product specifications, FSE shall determine the minimum fire size that would activate the water monitor system. Thereafter, FSE shall then apply a safety factor (minimum 2) and include the delay time for water to be discharged to determine the fire size to be modelled. The delay time can be obtained from the specification and test report of the water monitor provided by the manufacturer. The delay time shall be verified and recorded during testing and commissioning. FSE shall include the fire size justification in the fire engineering reports.

For sprinkler protected buildings, where water monitor systems are installed in areas that are within the effective height of sprinklers, the design fire size shall be based on 2nd ring sprinkler activation, rather than water monitor system activation.

(3) If the building/space is not protected by automatic sprinklers or other water-based fire protection systems, the fire size to be determined by fuel load and burning area.

(4) Annex A gives a general guide to how fire size can be determined under various conditions.

e Soot yield

FSE may adopt a soot yield, which refers to mass of soot generated during combustion divided by the mass loss of the test specimen, not lower than 0.1, unless he/she has justification to adopt other values.

The default soot yield value for industrial buildings and warehouses shall be 0.1. FSE may propose a different value only if the type of fuel load in the building is of specifically known usage during operation and does not change over its occupancy period.

Table 3.1 : Design Fire Characteristics (Pre-Flashover)	
Location / Usage	**Fire growth rate**
Areas of special/high hazard or Industrial (performance requirements also provided under prescribed Code of Practice for Fire Precautions in Buildings)	- Depends on fuel load burning - Pool fires (e.g. fuel, etc) will be nearly instantaneous High rack storage potentially between Fast t^2 to Ultrafast t^2; potentially t^3
Back of house areas / service areas	Depends on fuel load burning but generally Fast t^2
Retail	Fast t^2
F&B (restaurants, food courts, coffee shops, hawker centres, fast food outlets)	Fast t^2
Car parks in general, including Ductless Jet Fan (DJF) system	Fire growth rate for vehicles shall be instantaneous. With sprinkler protection, the total HRR for the following types of vehicles are as follows : 4 MW for cars/forklifts 10 MW for general goods vehicle 20 MW for buses/coaches
Offices, homes/apartments, and dormitories	Fast t^2
School classrooms, lecture halls, museums	Medium t^2
Places of assembly (auditorium, theatres, performing arts)	Seating – Medium t^2 Stage - Fast t^2 If there is no control on the type of materials used for scenery, staging props (i.e. use of polystyrene, polyurethane, non-fire-retardant drapes and curtains, etc), stage – Ultrafast t^2
Exhibition (e.g. convention, expos, etc)	Fast or Ultrafast t^2, depending on items exhibited
Recreational, amusement, night entertainment	Fast t^2 If there is no control on the type of materials used for scenery, staging props (i.e. use of polystyrene, polyurethane, non-fire-retardant drapes and curtains, etc), stage – Ultrafast t^2

3.2.2 Post-Flashover (Structural fire engineering analysis)

a Ventilation Controlled

In a post-flashover fire, the heat release rate can be limited by the amount of air that can enter the fire affected compartment.

Ventilation controlled heat release rate, Q_v :

$Q_v = 1.5 \times A_v \times h^{1/2}$

Where:

A_v is total area of wall openings (m^2)
h is the weighted average height of openings (m)

b Time-Temperature Curves

References can also be made to other guidance documents including time-temperature curves, e.g. parametric, ISO 834 standard curve, etc.

3.3 Acceptance criteria

Where the fire engineering assessment requires an assessment of human tenability to be made, the following limits of acceptability will apply:

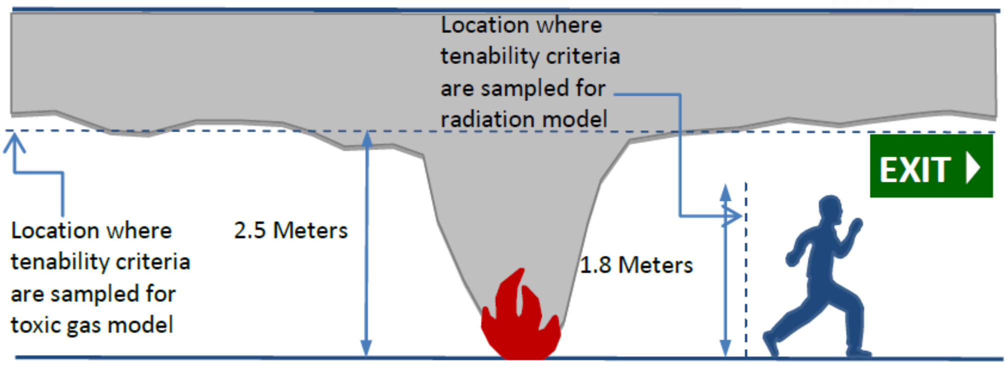

Figure 3.2 : Tenability criteria to be sampled at 2.5m from the finish floor level.

3.3.1 Smoke Temperature – The upper layer smoke temperature shall not exceed 200 ^oC measured at 2.5 m height from finished floor level and the lower layer smoke temperature shall not exceed 60 ^oC.

3.3.2 Radiation – Where occupants are expected to egress past a fire, the radiative heat flux shall not exceed 2.5 kW/m^2.

3.3.3 Visibility at 2.5 m above the floor level shall be greater than 10m.

3.3.4 Fractional Effective Dose (FED)

Where the FED is proposed to be used as an acceptance criterion, for example, in situation where the ceiling is low and the use of acceptance criteria 3.3.1 and 3.3.3 is not feasible, the FSE would need to justify for FED criterion to be adopted in the design and subject to SCDF's agreement. Fractional Effective Dose (FED) for toxic gases shall not exceed 0.3.

3.4 Computational Fluid Dynamics (CFD) modelling

In carrying out the CFD modelling, the following steps are recommended:

3.4.1 Define fire modelling goals

To state clearly that the results of the CFD modelling shall be used to justify the performance-based design.

3.4.2 Characterise the fire scenarios

Characterise the relevant fire scenarios from fire ignition, growth, detection, fire suppression and smoke control (if applicable). Selected scenarios should represent a complete set of fire conditions that are important to test the robustness of the proposed fire engineering design. These are discussed further below:

a Enclosure

Define the enclosure being studied in the CFD modelling. The enclosure details should include the identity of the enclosures that belong in the fire model analysis, the physical dimensions of the enclosures included in the fire model, and the boundary conditions of each enclosure

b Fire Locations

The fire locations used in the CFD modelling shall follow the proposed fire locations established from earlier sections of this guideline.

c Fire Characteristics

The source fire is the critical input for the fire scenario and is often described as the "ignition source." The source fire is typically characterised by a heat release rate though other important aspects include the physical dimensions of the burning object, its composition, and its behaviour when burning.

d Minimum details needed to describe the fire are:

(1) Heat Release Rate (HRR)
(2) Fire growth rate (for T-square fire)
(3) HRR per unit area

(4) Fire perimeter
(5) Soot yield
(6) Heat of combustion
(7) Type of smoke plume
(8) Sprinkler or non-sprinkler-controlled
(9) Toxic substances (for FED analysis if allowed)

The HRR chart is to be included in the FEDB, FER and Peer Reviewer's Report to demonstrate the fire characteristics. The fire characteristics used in the CFD modelling shall follow the fire hazards identified and design fire(s) established in Table 3.1 of this guideline.

3.4.3 Selecting the CFD software

Given the availability of different CFD models, the FSE is responsible to assess its suitability for use in the fire engineering study. Whilst this set of guidelines is written predominantly for FDS considering its wide use in the fire engineering fraternity in Singapore, they also apply in a similar manner to other CFD models.

A list of commonly used CFD software is as follows:

a Fire Dynamic Simulator (FDS)
b Fluent
c Phoenics

Use of any CFD software not listed above shall be justified by FSE. The use of any particular CFD software (including its version) must be reflected in the FEDB, FER and Peer Reviewer's Report.

3.4.4 Computational domain

The computational domain should be as close as reasonably practicable to the actual enclosure. Simplification (such as modelling a slightly curved wall as a straight wall) can be accepted if it does not adversely affect outcome of the CFD modelling.

Where inlet and/or exhaust vents are located at the domain boundaries, FSE must include an additional 5m buffer outwards to account for the aerodynamics of the vents.

Where wind effects are being modelled, the domain should be extended correspondingly to take this into consideration.

3.4.5 Boundary conditions

Assumptions on the type of surface and material properties such as ambient temperature and properties of surfaces must be included. In situations where adiabatic/inert surfaces are assumed, justification on why such assumptions is considered appropriate must be included.

Assumptions on ambient temperature & external wind effect for the areas being modelled must be included.

As a guide, ambient temperature in air-conditioned spaces can be taken to be 24 ^{o}C while that of non-air-conditioned spaces, 32 ^{o}C.

Should other temperatures be adopted, FSE will provide the justifications.

3.4.6 Mesh and grid resolution

The type of meshing i.e. structured vs unstructured and grid resolution can have significant impact on the accuracy of CFD computation, particularly for large eddy simulation models.

In the case of FDS, FSE must state whether single mesh or multi-mesh is to be used. Other information includes screenshots to illustrate the mesh set up, the mesh boundaries and the respective grid resolution. The recommended fine grid resolution should follow the FDS user guide. Fine grid shall extend at least 5m (in x, y and z direction) from the edge of burner in all directions. Progressive increase in grid resolution shall follow aspect ratio of 1:2.

FSE shall document the specification of mesh grid(s) in the report in alignment with fire modelling input parameters.

3.4.7 Duration of simulation

For steady-state CFD modelling, the simulation should be iterated until the results converge.

For transient CFD modelling, the simulation should continue until steady-state condition is observed. As a guide the fire size should reach the design fire size. Temperature and visibility readings should be taken to demonstrate that the readings have stabilised.

The duration of the simulation shall be adequate to demonstrate that life safety criteria (e.g. ASET/RSET with safety factor) can be met, or minimum 1200 s, whichever arrives first.

3.4.8 Smoke management systems

Relevant smoke management system i.e. engineered smoke control system, smoke purging system or smoke vents must be included in the CFD modelling.

For the case of engineered smoke control / purging system, the following information shall be provided

a Ductwork layout (Deeper than 10% of floor height)
b Beams (Deeper than 10% of floor height)
c Extraction grilles
d Make-up air paths
e Heat/Smoke detectors (where applicable)
f Sprinkler heads (where applicable)
g Storage racks. FSE may assume a reasonable racking structure if the actual design is not known yet.

The actual system design layout must also be included for comparison with the CFD model.

For the case of natural smoke vents, the following information shall be provided:

a Smoke vents and replacement air inlet's location including orientation and aerodynamic free area
b Smoke detectors (where applicable)
c Sprinkler heads (where applicable)

In the FER, the FSE is to include all relevant architectural plan & elevations for comparison with the CFD model.

FSE shall state the assumptions with respect to ramping up the operation of the smoke management system. As a general guide, the smoke management system is at 0% capacity at start of simulation and should reach full design capacity in accordance with the Fire Code requirements.

3.4.9 Fire detection system

Fire and smoke detectors must be included in the CFD model if they are provided to the actual spaces.

3.4.10 Fire suppression systems

It shall be assumed that the fire is maintained at the design fire size and not mitigated by the suppression system in the modelling study.

3.4.11 Visibility factor

When modelling visibility in CFD modelling, FSE shall adopt a visibility factor (C-factor) of 3 to ensure sufficient level of life safety.

3.4.12 Documenting the output

a FSE to include output quantities for visibility, temperature and velocity. Additional output quantities e.g. carbon monoxide, heat flux, FED may be required depending on the scope of the performance-based design.

b In addition to slice files/snapshots, other output parameters such as radiometers, thermocouples, etc shall be included in the FER as the slice files may not capture all the relevant details.

c For slice parameter, FSE must include slices in all three planes (x, y and z-planes).

(1) At least 3 slices of X-plane & Y-plane with one cut along the centreline of the fire origin. Include additional slices at critical areas in the model. More slices may be required if a spill plume forms part of the analysis.

(2) At least 2 slices of Z-plane at 1.7m (estimated human height level), and 2.5m above the finished floor level. Include additional slices at critical areas in the model. Where the mesh does not match, FSE shall provide slices at the next higher/available height (i.e. 1.8m and 2.6m).

(3) For the X, Y and Z planes, the slice/snapshot shall be taken at :
(i) At the 8-minute mark
(ii) ASET timing
(iii) RSET timing (with safety factor)
(iv) Steady state (If it is earlier than RSET with safety factor)
(v) At the 20-minute mark (if no failure shown beyond (iii)
(vi) Any other slices that SCDF or the FSE deems fit.

(4) Any legends accompanying the modelling outputs shall be legible

d Include the following CFD results in the FER.

(1) Graphic overall heat release rate output
(2) Visibility readings
(3) Temperature readings
(4) FED readings (if applicable)
(5) Visibility, temperature and FED readings should be taken at the reference height as defined under the tenability acceptance criteria.

e Modelling source codes

Where the fire engineering report contains CFD modelling, the source codes of all design fire scenarios shall be submitted together with the fire engineering report. This also applies to the Peer Reviewer's Reports.

3.5 Zone modelling

Zone models can be adopted to determine ASET. However, the compartment size limits for the use of zone models shall be according to the maximum reservoir sizes stated in the Fire Code, or the size limits stipulated by the respective software user manual, whichever is lower.

In projects where zone models are used to determine ASET, SCDF may still require the FSE to conduct CFD simulation.

A list of commonly used zone modelling software is as follows:

a. CFAST
b. Branzfire/B-Risk

Use of any zone modelling software not listed above shall be justified by FSE. The use of any particular zone modelling software (including its version) must be reflected in the FEDB, FER and Peer Reviewer's Report.

3.6 Validation of CFD and zone models

If the proposed software is new or has limited application in Singapore, SCDF may require validation of the software before being allowed for use. The current ways of validating CFD and zone models are:

a. validation against fire tests and;

b. validation against literature and past fires and;

c. validation against other models and third-party validation.

3.7 Replacement air for smoke control systems

Replacement air for engineered smoke control shall be provided fully by natural means. Where mechanical replacement air is proposed by FSE for SCDF's consideration, e.g., high containment facilities, laboratories that handle biological agents or toxins, clean room, deep underground infrastructure like rock cavern, tunnel, the following shall apply:

3.7.1 Limits

Maximum of 50% of the required replacement can be provided by mechanical means.

3.7.2 Standby fans

At least 2 standby fans (n+2) shall be provided for each mechanical replacement air system, such that in the event any fan fails, the required replacement air rate will still be met. The standby fan shall be automatically activated in the event the duty fan fails.

3.7.3 Interlocking the smoke extract fans with the replacement air fans.

The smoke extract fans shall interlock with the replacement air fans such that in the event the extract fan fails, the replacement air fans shall be adjusted accordingly. This is to avoid over-pressurising the affected area and push the smoke to unaffected areas.

3.7.4 Time for standby fans to be fully operational

The time taken for the make-up air system as part of a smoke ventilation system within a smoke zone to be fully operational shall not exceed 60 secs from the time of activation.

3.7.5 Injection Points

Location of replacement air injection points shall be marked up clearly in the report.

3.8 Determining the Available Safe Egress Time (ASET)

ASET is determined when the area/space under the fire engineering assessment fails any tenability criteria.

If there is any observation of smoke logging in CFD result slice files which FSE deems not affecting the ASET, FSE shall provide justification.

Some examples of such situation include:

3.8.1 Extent of spill plume is limited to vicinity of the room of fire origin.

3.8.2 If the means of egress is well defined, the remaining clear width of the egress route is sufficient for safe egress.

3.8.3 Smoke logging condition is some distance away from exit points.

3.8.4 For an open space where the means of egress is not clearly defined, the smoke logged area within the space is transient and its scale does not adversely impact egress.

3.8.5 Tenability has been achieved after increasing smoke exhaust rate.

CHAPTER 4

4.0 REQUIRED SAFE EGRESS TIME (RSET)

Required safe egress time or RSET is the time required for escape. This is the calculated time required for occupants to travel from their location at the time of ignition of fire to a place of safety. The RSET would need to be less than the ASET, with relevant safety factors applied.

$$RSET = (t_d + t_n + t_{pre}) + (t_{trav} \text{ and/or } t_{flow})$$

where:
t_d = detection time from deterministic modelling
t_n = time from detection to notification of occupants
t_{pre} = time from notification until evacuation begins
t_{trav} = time spent moving toward a place of safety, and
t_{flow} = time spent in congestion controlled by flow characteristics

4.1 Detection time (t_d)

Time interval between ignition of a fire and its detection by an automatic or manual system. The detection time shall be based on the activation of the 1st ring of the detector system. The following methods can be used to estimate the detection time (t_d)

a. Based on CFD modelling conducted with the detectors/sprinklers above a fire using approved fire models.

b. Based on Alpert's[11] ceiling jet correlation or other relevant methods.

c. Based on zone models.

4.1.1 For automatic detection, the input parameters used in the modelling study shall be the same as the properties of the detectors/sprinklers used in the design as well as the layout of the detectors/sprinkler.

a. Response Time Index (RTI) of sprinkler/detector.

b. Activation temperature (T_{act}) of sprinkler/detector.

c. C-factor for sprinklers.

d. Optical density at alarm for smoke detectors.

e. Radial distances adopted shall be based on a code-compliant (Code of Practice for Installation and Servicing of Electrical Fire Alarm System /

Code of Practice for Automatic Fire Sprinkler System / NFPA, etc.) system design.

Where there are no automatic fire detection systems installed, manual/human detection time can be estimated based on smoke layer height reaching 10% of the room height.

4.2 Notification Time (t_n)

This is the time required for building management to confirm with DECAM companies whether the fire alarm is a false alarm, or a confirmed fire and this time is taken to be 120 seconds. FSE to justify if other timings are adopted.

4.3 Pre-movement time (t_{pre})

Pre-movement time is the time interval between occupants being informed to evacuate and the time in which they begin to travel to a safe location. Refer to Table F-1 in Annex F.

Annex F presents a detailed explanation on some of these factors involved in estimating the pre-movement times. Any of the pre-movement times obtained from New Zealand document, C/VM2[2] in Table A6-1 can be used in the egress design and the FSE would need to justify his/her choice.

4.4 Movement time (t_{trav} or t_{flow})

The time taken by occupants to move to a place of safety is determined by the longer timing of travel time (t_{trav}), or flow time (t_{flow}):

4.4.1 Travel Time

The time taken to move to the doorway of the exit staircase (e.g., analysing egress from compartment/floor) or the final exit door (analysing total building evacuation)

a For horizontal travel, the travel time will be calculated based on the estimated walking speed. Horizontal travel speed can be calculated using equation below

$$S = k - akD$$

Where

- S is horizontal travel speed (m/s)
- k is 1.4 for horizontal travel
- a is 0.266
- D is the occupant density of the affected space (persons/m^2)

Horizontal travel time is then calculated using equation below:

$t_{trav} = L_{trav} / S$

Where

L_{trav} is the maximum travel distance (m)

b For vertical travel, the values used for the factor k are a function of the stair riser and thread as shown in Table 4.1.

Table 4.1 : Constants relating to horizontal and stair travel (extracted from PD-7974 Part 6)

Exit route element		**k**	**Speed**
Corridor, aisle, ramp, doorway		1.40	1.19
Riser (mm)	Tread (mm)		
191	254	1.00	0.85
178	279	1.08	0.95
165	305	1.16	1.00
165	330	1.23	1.05

c Table 4.2 and 4.3 also lists some typical travel speeds for occupants of different levels of mobility, both for horizontal travel as well as vertical travel via staircase.

Table 4.2 : Typical horizontal travel speeds for occupants of different mobility levels

Speed Of Horizontal Surface				
Subject Group	Mean	Standard Deviation	Range	Inerquartile Range
All Disabled	1.00	0.42	0.10-1.77	0.71-1.28
With Locomotion Disabilities	0.80	0.32	0.24-1.68	0.57-1.02
No Aid	0.95	0.32	0.24-1.68	0.70-1.02
Crutches	0.94	0.30	0.63-1.35	0.67-1.24
Walking Sticks	0.81	0.38	0.26-1.60	1.49-1.08
Rollator	0.57	0.29	0.10-1.02	0.34-0.83
No Locomotion Disability	1.25	0.32	0.82-1.77	1.05-1.34
Electric Wheelchair	0.89	-	0.13-1.77	-
Manual Wheelchair	0.69	0.35	0.13-1.35	0.38-0.94
Manual Wheelchair	0.36	0.14	0.11-0.70	0.20-0.47
Assisted Wheelchair	1.30	0.94	0.84-1.98	1.02-1.59
Assisted Ambulant	0.78	0.34	0.21-1.40	0.58-0.92

Source:Table 3-13.2 from Section 3, Chapter 13: "Movement Of People: The Evacuation Timing", The SFPE Handbook of Fire Protection Engineering, 3rd Edition, NFPA Inc., Quincy, Massachusetts, 2002

Table 4.3 : Typical travel speeds along staircase for occupants of different mobility levels

Speed On Stairs				
Subject Group	Mean	Standard Deviation	Range	Interquartile Range
Ascent				
With Locomotion Disabilities	0.38	0.14	0.13-0.62	0.26-0.52
No Aid	0.43	0.13	0.14-0.62	0.35-0.55
Crutches	0.22	-	0.19-0.31	0.26-0.45
Walking Stick	0.35	0.11	0.18-0.49	-
Rollator	0.14			
Without Disabilities	0.70	0.24	0.55-0.82	0.55-0.78
Descendent				
With Locomotion Disabilities	0.33	0.16	0.11-0.70	0.22-0.45
No Aid	0.36	0.14	0.11-0.70	0.2-0.47
Crutches	0.22	-	-	-
Walking Stick	0.32	0.12	0.11-0.49	0.24-0.46
Rollator	0.16	-	-	-
Without Disabilities	0.70	0.26	0.45-1.10	0.53-0.90

Source: Table 3-13.3 from Section 3, Chapter 13: "Movement Of People: The Evacuation Timing", The SFPE Handbook of Fire Protection Enginnering,3rd Edition , NFPA Inc., Quincy, Massachusetts, 2002

4.4.2 Flow Time

Time taken for all the occupants to flow through a restriction, typically a doorway, when queuing is necessary.

a The flow rate of persons passing through a particular point along an exit route can be calculated using the equation below

$$F_c = (1-aD)kDW_e$$

Where:

F_c is the calculated flow rate (persons/s)

D is the occupant density near flow constriction (persons/m^2)

W_e is the effective width of component being traversed (m)

k and a are defined in Section 4.4.a above.

b The effective width for various exit route elements can be determined from Table 4.4, by subtracting the boundary layer on each side from the measured exit width. For doorways that are not mechanically held open, a maximum flow rate of 50 persons/min/door leaf is recommended for design.

Table 4.4: Boundary layer width used to determine effective width

Exit Route Element	Boundary Layer On Each Side(m)
Stairway-walls or side tread	0.15
Railing or handrail	0.09
Theatre Chairs, Stadium Bench	0.00
Corridor wall and ramp wall	0.20
Obstacle	0.10
Wide Concours, passageway	0.46
Door, Archway	0.15

SFPE Handbook of Fire Protection Engineering, edition 3 (Table 3.14.1)

c For flows through a doorway, the occupant density to be determined using equation below can be estimated to be 1.9 persons/m^2. This value can be referred from the New Zealand Document C/VM2[2] document.

The flow time can then be determined from the flow rate using equation.

t_{flow} = Number of occupants / F_c

4.5 Evacuation Models

Hand calculations to determine movement time may be allowed for occupancies with a lower occupant loading, such as factories and warehouses.

However, for buildings/spaces with large occupant loads such as in shopping centres, exhibition halls, offices and places of public resort and the like, evacuation modelling would be required by SCDF.

4.5.1 Validation of models

If the proposed software is new or has limited application in Singapore, SCDF may require validation of the software before being allowed for use. The current ways of validating evacuation models are:

a validation against code requirements; (e.g. NFPA 130) and;

b validation against fire drills or other people movement experiments/trials and;

c validation against literature on past evacuation experiments (flow rates, etc) and;

d validation against other models and third-party validation.

4.5.2 Approved evacuation software

A list of commonly used evacuation modelling software is as follows:

a. Simulation of Transient Evacuation and Pedestrian Movements (STEPS)
b. Pathfinder
c. Simulex
d. Exodus
e. MassMotion

Use of any evacuation modelling software not listed above shall be justified by FSE. The use of any particular evacuation modelling software (including its version) must be reflected in the FEDB, FER and Peer Reviewer Report.

CHAPTER 5

5.0 FIRE ENGINEERING REPORTS

All fire engineering reports need to be endorsed by FSE. Fire engineering reports that are "DRAFT", "PRELIMINARY" or not endorsed by FSE will not be recognised by SCDF. If other disciplines were also involved in the performance-based design (e.g. PE Civil) they shall also endorse on the fire engineering reports.

FSE to remove all document restrictions (e.g. prohibiting highlighting or copying) as SCDF officers may need to process the reports (e.g. highlighting/copying) for presentation purposes.

Drawings (including mark-up drawings) shall be in pdf format and not editable for ease of reading and review.

5.1 At the Building Plan approval stage, the following (simply termed as the "PB Package") must be submitted to initiate the Performance-Based audit process. FSE to name the documents accordingly for easy identification:

a Declaration form

b Fire Engineering Design Brief (FEDB)

c Fire Engineering Report (FER), including any letter of undertaking.

d Peer Reviewer's Report (PRR)

e Operations and Maintenance Manual (OMM)

f Source codes for all simulations carried out

g Mark-up drawings (may be formatted as part of the FER)

5.2 Where a fire engineering report is submitted to support a waiver application, the following documents must be submitted together with the waiver application.

a Fire Engineering Report (FER), including any letter of undertaking.

b Source codes for all simulations carried out

5.3 MARKED UP DRAWINGS

Fire safety provisions that form part of the performance-based design strategy should be highlighted on the respective architectural or Building Plan (BP) and/or Mechanical and Electrical (M&E) plans that are submitted to SCDF for approval. This is to facilitate the audit and documentation of the performance-based strategy by SCDF.

These fire safety provisions to be included in the plan submissions fall into these broad categories

5.3.1 Architectural items in the BP submission

The following information to be included in this category but not limited to:

a. Table/summary of architectural alternative solutions

b. Area/floor(s) under the performance-based study to be indicated (via clouding or other means

c. Mark out non-compliances (e.g., length the path of extended travel distance/s)

d. Details of occupant loading and egress capacity for all affected floors

e. Fire shutters, smoke curtains/barriers

f. Floor to floor height

g. Compartmentation lines, including fire resistance rating

h. Natural vent openings and their sizes/areas (m^2)

i. Replacement air doors/windows/vents and their sizes/areas (m^2)

j. Waivers and consultations applied for and summary of the waiver decision (if any)

5.3.2 M&E items in the M&E plan submission

The following information to be included this category but not limited to:

a. Table/summary of M & E alternative solutions

b. Smoke control system detail

c. Area/floor(s) under the performance-based study to be indicated (via clouding or other means)

d. Smoke zones

e. Smoke curtains/barriers

f. Waivers and consultations applied for and summary of the waiver decision (if any)

5.3.3 Breakdown of the M&E plan

The mark ups for M&E plan can be further broken down to the following:

a. Mechanical ventilation

(1) Fan capacity and to also indicate duty and standby fans

(2) Extract points

(3) Replacement air doors/windows/vents and their sizes/areas (m^2)

(4) Demarcation of smoke zones

b. Fire protection

(1) Sprinkler/Water monitor coverage, etc

(2) Sprinkler details (Discharge rate, Response Time Index, etc)

5.3.4 Mark-up Drawings for FEDB & FER Submissions

Mark-up drawings are to be part of all fire engineering reports. These drawings should capture all alternative solutions and fire safety provisions that support the performance-based design. It should also capture all the elements of the FSE's trial design concept in their alternative design.

Mark-up drawings would be used by SCDF when deliberating on the performance-based fire safety issues for FEDB and FER approval.

5.3.5 Unlike the drawings for the formal building plan/M&E plan submission, the Mark-up drawings need not be broken up into the architectural and M&E sets. However, the reference set must include all performance-based floors and relevant elevations/sections. Items to be marked up on the mark-up drawings include (but not limited to):

a. Details of all alternative solutions (alternative solutions are to be numbered, (e.g. D1, D2, etc).

b. Design fire scenarios. FSE to mark location and fire size of all fire scenarios, including sensitivity studies. All design fires to be numbered (e.g. BC01, SS01, etc).

c. Floor height/s

d. Fire shutters and smoke curtains

e. Compartment walls/boundaries, including fire resistance rating

f. Occupant Loading and Egress Capacity

g. If they are alternative solutions and form part of the performance-based design solution, the reference drawings should show

   (1) How reservoir length/area is measured

   (2) Paths of extended travel distance

   (3) Paths of extended travel distance for internal discharge

h. Mechanical ventilation fans and ductwork. To indicate how many duty fans operate during fire emergency and how many standby fans are there. Ductwork to be shown clearly.

i. Differentiate separate smoke control zones

j. Smoke control activation matrix

k. Path(s) of replacement air. To also show openings on the elevation

l. Path(s) for natural smoke exhaust. To also show openings on the elevation if it is a naturally ventilated smoke control system

m. Sprinkler details (e.g., temperature rating / RTI / Discharge density)

n. Beam detector location, if any

FSE should apply the appropriate presentation style (font/line colours) consistently so that important details can be identified clearly.

5.3.6 For drawings to be submitted at the Building Plan approval stage (together with the FER, PRR & O&M Manual) the submission could contain both (1) the formal BP/M&E set of drawings for approval and the (2) set of mark-up drawings. The design team may choose to combine both sets into a single set of drawings that would be used for approval and presentation/deliberation by SCDF.

Mark-up drawings must be endorsed by the FSE.

5.3.7 The above mark ups need not be in a single drawing as long as all relevant details are captured

5.3.8 Other administrative requirements include:

a. To indicate : **FEDB Mark-up Drawing** or "**FER Mark-up Drawing**" at the top right-hand corner (if the formal submission drawings are separate from the reference drawings

b. Soft copies of mark-up drawings submitted shall be in pdf format. They can be compiled as part of the FER/FEDB report or a separate file/document.

c. Waiver of fire safety requirements applied for, including the waiver reference numbers and summary of the waiver decision(s) (if any).

d. Consultation reference numbers if QP/FSE has sought consultation.

CHAPTER 6

6.0 OPERATIONS & MAINTENANCE (O&M) MANUAL

The O&M Manual explains what the building operator and senior fire safety manager (Senior FSM) should do to maintain and operate the fire safety systems.

It also gives instructions to the building operator on the restrictions placed on the contents in the building e.g. daily operations, addition & alteration works to the building and change of use of the building, based on FSE's assumptions and design considerations.

The O&M Manual can also be used to communicate to the tenants and occupants about these restrictions and their responsibilities. It can also be used as a guide for future renovations and changes to the building. The updated O&M Manual must be given to the owner/client (together with the fire engineering report) after the performance-based audit is closed.

A copy of O&M Manual shall be kept in the FCC or management office (if no FCC) for ease of reference.

6.1 The cover page shall clearly state that the O&M Manual is prepared for:

a. Building Owner/Managing Committee/Agent
b. Facilities Director/Manager
c. Senior Fire Safety Manager / Company Emergency Response Team (CERT)

6.2 Role & responsibilities of building operator

State the role and responsibilities of the building operator and senior fire safety manager (Senior FSM), if applicable, in ensuring that the components of the performance-based design are in place, operating properly and a label, "This building has performance-based fire safety design" to be affixed to the main fire alarm panel or zone chart.

This is to alert or remind the building owner and QPs that this is a performance-based building and the Operations and Maintenance Manual must be understood before undertaking any addition and alteration works.

Design considerations and limitations with potential impact to life safety or building operations shall be stipulated for the building owner to adopt. Amendments or deviations from the requirements in the operations and maintenance manual may affect the performance-based analysis and solutions.

6.3 Future Addition & Alteration (A/A) Works

State what the building operator needs to do with respect to compliance to the existing Fire Safety Design if there are A&A Works in the future. A letter of no objection from the FSE or QP shall be required as part of the QP's submission if the A/A works clearly do not affect the Performance-Based (PB) design of the building. See SCDF circular on "Certification by QP for A/A Plans Involving Performance-Based Fire Safety Designs" dated 10th October 2013 (Annex G).

6.4 Affected Areas with PB design

The scope and floor plan of the affected area(s) with PB design shall be clearly shown and demarcated from the other areas that were designed based on prescribed code requirements.

The following information shall be included in the O&M Manual:

6.4.1 Smoke control strategy and Engineered Smoke Control System (ESCS) plan. For illustrations of ESCS components, reference can be made to the contractor's sub-system O&M Manual.

6.4.2 Any aspects of evacuation plan affected by Performance-based design.

6.5 Identification of sub-systems

Identify and describe the relevant sub-systems (sequencing, critical design features) for the project and their interaction with each other. Some examples are:

a. Fire detection
b. Fire protection
c. Emergency warning
d. Occupant evacuation
e. Smoke management
f. Electromagnetic lock

Where applicable, the above-mentioned sub-systems shall be included for inspection and maintenance as part of the process of obtaining Fire Certificate (FC) for the building.

The O&M Manual shall specify that the building operator is advised to inform the QP that this is a performance-based design building

6.6 Maintenance plan

Commissioning, maintenance and subsequent yearly testing and inspection plans shall be developed in accordance with the minimum requirements of the relevant codes of practice and manufacturer's guidelines. If the performance-based design requires a higher level of servicing such as higher frequency of maintenance, the FSE shall highlight the additional requirements in the O&M Manual.

6.7 Documentation of inspections/testing and their results shall be maintained with the building records. FSE shall emphasise the need to maintain inspection records.

6.8 FSEs would need to conduct a briefing to the client/end user/building operator on all performance-based issues when the Fire Engineering Report is cleared. Official letter must be submitted to SCDF from the client stating that they have been briefed by the FSE and received the O&M Manual. The template can be found on the SCDF website.

6.9 Restrictions

List the restrictions placed on the building operations. These restrictions may include content in the building, building use/purpose/activity and occupancy, and reliability and maintenance of systems. For example:

a. Storage height
b. Storage content
c. Limitation on transport vehicle in warehouse
d. Commercial activity in certain parts of the building
e. Activity with potential change in occupant type and hazard group

6.10 Compensatory actions

Highlight compensatory actions that must be taken if a fire protection system is impaired (e.g. requires servicing or maintenance, causing it to be out of service temporarily) or removed from service. Any impairment or removal of fire protection system may be subject to total review of the fire safety systems by an FSE.

6.11 Relevant circulars

FSE to include all relevant circulars affecting buildings with performance-based design. These include

a. Certification by QP for A/A plans involving Performance-Based fire safety designs dated 18 Oct 2013; and

b. Identification of buildings with Performance-Based fire safety designs & certification by QP for A/A plans dated 5th June 2012.

6.12 Credentials and Endorsement of FSE

Include name, credentials and endorsement of the FSE who prepared the manual. FSE shall also include contact details (email and phone number).

CHAPTER 7

7.0 PEER REVIEWER

The Peer Reviewer is another FSE, engaged by the building developer/owner, who is responsible to check the adequacy of the performance-based solution prepared by the FSE. The Peer Reviewer is required to submit an official report, i.e., Peer Reviewer's Report (PRR) to SCDF detailing his comments on the FSE's work. It is expected of the Peer Reviewer to conduct a separate fire and/or evacuation modelling to verify the design solution proposed by the FSE, preferably using different software from that used by the FSE.

In addition, the Peer Reviewer should comment on the assumptions, fire safety engineering approach, methodology, design parameters and software tools in the FER, etc proposed by the FSE. The Peer Reviewer will also need to endorse on the relevant declaration form when submitting the Peer Reviewer's Report.

The Peer Reviewer shall have no vested interest in the project that is being reviewed, or any involvement thereof which may be construed as a conflict of interest. As the Peer Reviewer must be independent from the project FSE, the Peer Reviewer should only be involved after the FSE had completed the FER.

7.1 Role of Peer Reviewer

7.1.1 To review the robustness of the fire engineering study by the FSE, including reviewing design objectives, assumptions, methodologies, input parameters used by FSE.

7.1.2 To review the fire engineering analysis performed for consistency between FEDB and FER. If there are inconsistencies, the Peer Reviewer needs to document the reasons and highlight the inconsistencies clearly in the Peer Reviewer Report.

The Peer Reviewer would also need to review and comment on the source codes of all modelling studies, the Operations & Maintenance Manual and any other reports/documents that form part of the performance-based assessment.

7.1.3 To perform independent sensitivity analysis (e.g. increasing fire size, increasing soot yield, increasing fire perimeter to reduce buoyancy, introduce MV failure, reduce walking speed, reduce awareness factor of exits, increase pre-movement times, etc)

7.1.4 Peer Reviewers should not be restricted or influenced in their design preference. Peer Reviewers may determine their own technical approaches and acceptance criteria which may be different from the FSEs.

7.2 Stage of involvement of Peer Reviewer

Peer Reviewers shall only be involved after the FSE had completed the FER in order to maintain the level of independency.

7.3 Modelling for Sensitivity Analysis

Peer Reviewers shall use a validated modelling tool to conduct independent assessment. The validated modelling tool shall preferably be different from that used by the FSE.

In the event that the Peer Reviewer uses the same modelling tool, the required pre-processing for setting up the model must be independently performed by the Peer Reviewer.

7.4 Dispute resolution

Any dispute or difference in opinion (e.g. technical approaches, acceptance criteria, etc.) arising between the FSE and Peer Reviewer should be discussed and resolved between the FSE and Peer Reviewer. In the event that a common resolution cannot be reached, the concerns must be brought to SCDF for resolution.

8.0 REGISTERED INSPECTOR (FSE)

8.1 Scope of work needs a Registered Inspector (FSE)

For projects containing alternative solutions, the areas under the performance-based assessment must be inspected by a SCDF registered RI, who must also be an FSE. His scope of work involves the checking of on-site installation of fire safety engineering works for compliance with the approved PB plans, FER and Operations & Maintenance Manual and to surface irregularities to SCDF. As such, performance-based projects would require RI (FSE), RI (Arch) and RI (M&E).

8.1.1 If the RI (Arch) is also an FSE, he/she can be responsible for both the fire safety works listed in Part I of the First Schedule of the Fire Safety (Registered Inspector) Regulations and the performance-based works of the project. See Annex H.

8.1.2 If the RI (M&E) is also an FSE, he/she can be responsible for both the fire safety works listed in Part II of the First Schedule of the Fire Safety (Registered Inspector) Regulations and the performance-based works of the project. See Annex H.

9.0 FIRE ENGINEERING ASSESSMENT IN SUPPORT OF WAIVER APPLICATIONS

Where waivers are sought for the clauses from the Fire Code, which are listed in Annex K, it is mandatory that these waiver applications must be supported by fire engineering assessment(s) endorsed by a Fire Safety Engineer. Unlike a full performance-based plan submission process where fire engineering design brief and Peer Reviewer Report are required, this process only requires a fire engineering assessment to be conducted by a FSE to provide scientific based evidence in support of the waiver application.

The list is not exhaustive. It will be updated according to the prevailing Fire Code. Refer to SCDF website for the latest version.

9.1 Assessment of residential corridors (for relevant clauses listed in Annex K)

Assessment of residential corridors shall generally follow the following methodology.

9.1.1 Main door of unit of fire origin.

The main door shall open for 60 seconds after the unit is 20% smoke filled. This represents occupants escaping from the unit. The main door shall close thereafter. The main door shall open for 120 seconds if:

a The floor is served by a single exit staircase or

b The corridor under assessment is at the discharge floor

9.1.2 Acceptance criteria for the residential corridor

Acceptance criteria shall be met at 180 seconds after the main door open, at a height of 2m above the floor level. (Z = 2 m). The criteria are:

a Visibility for the whole corridor shall exceed 10m and

b Temperature for the whole corridor shall be less than 60 ^{o}C

See timeline below

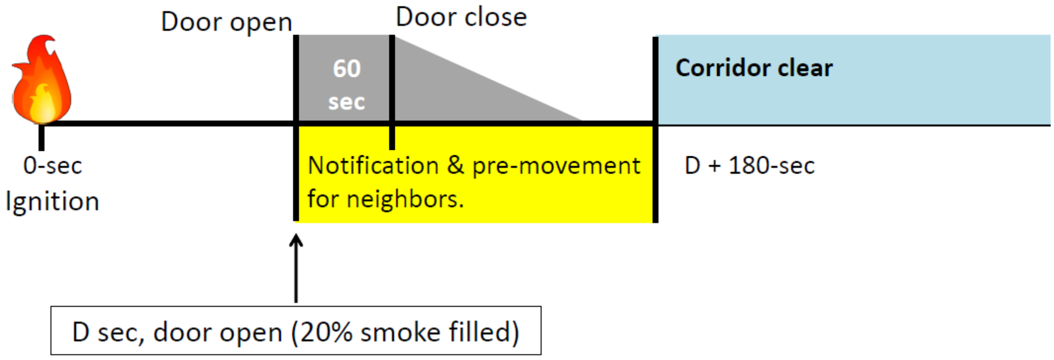

Figure 9.1 : Timeline for residential corridor assessment.

9.1.3 Fire size

The fire shall be a 13MW fast t^2 growing fire. This fire size shall be adopted for all fire engineering assessments involving non-sprinkler protected residential units.

9.1.4 Soot yield

The soot yield shall be 0.06 kg/kg. The soot yield shall be increased to 0.1 kg/kg if

a The floor is served by a single exit staircase or

b The corridor under assessment is at the discharge floor

9.1.5 Wind effects

FSE shall include wind effect study for applicable fire scenarios. FSE needs to determine and justify the wind direction and speed adopted.

9.1.6 Windows and glazing facade

Where there are windows in the unit on fire, the windows shall be modelled as closed at the start of the simulation. If the windows do break mid-way through the simulation, FSE needs to justify this timing based on the type of windows/glass used with technical data sheet for the glass. The time the window/glass breaks shall be shown clearly in the timeline of the fire scenario. FSE may also model the windows as closed for the duration of the simulation. This needs to be stated clearly.

9.2 Assessment of non-residential corridors(for relevant clauses listed in Annex K)

The assessment of non-residential corridors may be based on the methodology above for residential corridors with the following changes.

9.2.1 Main door of unit of fire origin

The opening of the main door shall be based on:

a If the main door is not a fire rated door, the door shall be modelled open throughout the simulation.

b If the main door is fire rated, it shall open

(1) When the detectors within the unit detect the fire, followed by suitable pre-movement time

(2) If there are no detectors within the unit, the main door shall open after the unit is 20% smoke filled

(3) The duration of door opening shall be determined by FSE. A safety factor of 2 shall be applied to the door opening time. If it is a sensitivity study, a safety factor of 1.2 shall be applied to the door opening time.

9.2.2 Acceptance criteria for the corridor

Acceptance criteria shall be met at all times at a height of 2.5 m above the floor level. (Z = 2.5 m).

9.2.3 Fire size

Fire size shall be determined and proposed by the FSE.

9.2.4 Soot yield

FSE may adopt a soot yield, which refers to mass of soot generated during combustion divided by the mass loss of the test specimen, not lower than 0.1, unless he/she has justification to adopt other values.

9.2.5 Wind effects

Where applicable, FSE shall include wind effect study for all fire scenarios. FSE needs to determine and justify the wind direction and speed adopted.

9.3 Assessment of exit staircases (for relevant clauses listed in Annex K)

The FSE shall propose suitable methodologies based on how the exit staircase may be affected by smoke. Separate fire scenarios are required if the exit staircase can be affected from smoke through the smoke stop lobby and smoke rising up through the air well from a unit that opens into the air well.

9.3.1 Acceptance criteria for staircases

Acceptance criteria shall be met at all times in the whole exit staircase

a. Visibility shall be more than 10 m measured at 2 m above each staircase landing.

b. Temperature shall be less than 60 °C measured at 2 m above each staircase landing.

c. Fractional Effective Dose (FED) shall be less than 0.3 for the duration of the simulation. The duration of the simulation shall be determined based on total building evacuation. FED shall be measured at 2 m above landing/ground where occupants may traverse. FSE to clearly show where FED is measure throughout the whole staircase.

9.3.2 Wind effects

Where applicable, FSE shall include wind effect study for applicable fire scenarios. FSE needs to determine and justify the wind direction and speed adopted.

9.4 Non fire rating of secondary steel beams (membrane action)

Where the structural design involves non fire rating of secondary steel beams in a sprinkler-protected building, the design shall comply to the Steel Construction Institute (SCI) Publications P288 and P390 for Fire Safety Design of Multi-storey Steel-framed buildings with Composite Slabs. The approach shall be used in conjunction with SCI Publication 390 titled "TSLAB v3.0 User Guidance and Engineering Update" and its accompanying software TSLAB v3.0. Refer to Annex M.

9.4.1 Waiver application

The approaches in P288 and P390 falls under the self-regulation framework and shall be regularised through a prescriptive waiver application.

9.4.2 Structural plans and calculations

The structural plans and calculations of the affected beams is to be prepared and endorsed by the PE(Civil) and submitted together with the BP plan by the Architecture QP. The affected beams need to be shown clearly.

9.4.3 Architectural plans

The Architecture (or BP) plans shall contain notes (similar to notes on waivers) to include a general statement indicating that there are structural plans based on

P288 and P390. The notes should be clear on whether there is a performance-based assessment (E.g. design based on parametric temperature time curve)

9.4.4 Should the designer choose to adopt standard ISO fire curve, this is deemed as a prescriptive submission. The PE (Civil) shall submit the report, calculation, and drawings as an additional attachment to building plans via the architect QP to SCDF. The architect QP shall indicate on building plans for areas where the structural beams have fire protection omitted.

a Declaration by PE (Civil) on the submission plans

I, _______PE Registration number _________being a qualified person, hereby certify that the omission of fire protection to the structural steel as shown on these plans have been designed in accordance with the provisions of the Code of Practice for Fire Precautions in Building 2018, P288 - Fire Safe Design A New Approach to Multi-storey Steel-Framed Buildings (Second edition) and P390 - TSLAB V3.0 User Guidance and Engineering Update

b The PE (Civil) shall clearly mark the beam(s) with omission of fire protection in the drawings. Any additional features such as increase thickness of fire protection shall be clearly described and marked up.

9.4.5 Use of parametric temperature time curve in the structural design

Should the parametric temperature time curve be used in the structural assessment, a Fire Safety Engineer is needed to establish the various fire scenarios based on varying fuel load densities and ventilation conditions. In this instance, the structural design shall be regularised through the full performance-based framework.

a The structural PE (FSE) shall submit the report, calculation, and drawings as an additional attachment to building plans via the architect QP to SCDF. If the structural PE is not an FSE, he/she is allowed to work together with FSE and co-endorse on the submission documents. The same arrangement is applicable to the Peer Reviewer (i.e., FSE(PE) or FSE+PE).

The architect QP shall indicate on building plans for areas where the structural beams have fire protection omitted.

b Declaration on submission plans by PB (Civil).

I, _______ PE Registration number _________being a qualified person, hereby certify that the omission of fire protection to the structural steel as shown on these plans have been designed in accordance with the provisions of the <<Insert relevant Code of Practice for Fire Precautions

in Building >>, P288 - Fire Safe Design A New Approach to Multi-storey Steel-Framed Buildings (Second edition) and P390 - TSLAB V3.0 User Guidance and Engineering Update

c Declaration on submission plans by FSE.

I, _______ FSE Registration number _________being a registered fire safety engineer, hereby certify that the parametric temperature-time curve has been designed according to BS EN 1991-1-2, Annex A, P288 - Fire Safe Design A New Approach to Multi-storey Steel-Framed Buildings (Second edition) and P390 - TSLAB V3.0 User Guidance and Engineering Update

d If the PB (Civil) is also an FSE, the declaration shall be as such.

I, _______ PE and FSE Registration numbers _________being a qualified person and a registered fire safety engineer, hereby certify that the omission of fire protection to the structural steel as shown on these plans have been designed in accordance with the provisions of the <<Insert relevant Code of Practice for Fire Precautions in Building >>,, Annex A P288 - Fire Safe Design A New Approach to Multi-storey Steel-Framed Buildings (Second edition) and P390 - TSLAB V3.0 User Guidance and Engineering Update, and the parametric temperature-time curve has been designed according to BS EN 1991-1-2

9.5 Ductless Jet Fan (DJF) system for carparks

Where the alternative solutions involve only issues pertaining to ductless jet fan design, the design team may apply for a waiver that is supported by a fire engineering assessment. The Fire Engineering Report shall be prepared by a Fire Safety Engineer.

9.5.1 Acceptance criteria

a Refer to Fire Code Cl. 7.4.4.g(1)(b) for acceptance criteria for carpark provided with ductless jet fan system (DJF).

b In the event ‘visibility ⩾ 25 m’ criterion cannot be achieved for spaces beyond the maximum allowable 1000 m^2 smoke-logged area, FSEs can consider use of emergency illumination and subject to the following:
(1) the illumination shall have at least an average of 10.8 lux along the path of egress measured at floor level during hot smoke test on site.
(2) smoke temperature not more than 60 ºC and visibility of at least 10 m at 1.7 m AFFL; and

(3) at least 1 viable route for firefighters within the smoke-logged area, where smoke temperature not more than 250ºC and visibility of at least 5 m at 1.7 m AFFL.

9.5.2 Soot yield

Soot yield shall not be lower than 0.1 kg/kg, unless FSE has justification to adopt other values. For vehicle fires, soot yield for general car parks shall not be lower than 0.07 kg/kg.

9.5.3 Additional requirements for adopting emergency illumination approach

a FSE shall provide tabulation of designed lux level for the affected carpark floor(s) in the fire engineering report.

b FSE, RI and QP shall be jointly responsible for the outcome of the assessment of lux level measurements.

CHAPTER 10

10.0 METHODS OF ASSESSMENT FOR COMMON DEVIATIONS

This chapter recommends methods to assess common deviations. It covers:

a. Objectives to be achieved
b. Design fire scenarios
c. Tenability limits
d. Acceptance criteria
e. Sensitivity analysis

The methods of assessment listed serve as a guide and the FSE shall still be responsible for the design solution.

The root and sub objectives for the PB design to achieve are stipulated in Fire Code 2013 and can be found in SCDF website and Annex J.

10.1 EXAMPLE 1

Smoke Control [Enlarged smoke reservoir (area, length), or Atrium design (width, area)] or Enlarged Fire Compartment

10.1.1 Root objectives

The root objectives are:

a R2.1 - Occupants must be able to escape to a safe place, directly or through a protected exit, before untenable conditions are reached during a fire emergency.

b R2.2 - Fire-fighters must be provided with adequate means of access for firefighting and rescue operations within the building.

c R7.1 - Maintain tenable conditions for evacuation of occupants and protect them from injury arising from the effects of fire.

d R7.2 - Provide smoke management in the building for firefighting operations.

10.1.2 Sub objectives

The sub objectives are:

a S2.9 - Provisions for adequate ventilation for means of escape.

b S2.13 - Provisions for adequate time for occupant escape from building.

c S2.14 - Provisions for safe movement of people within the means of escape.

d S7.1 - Provisions for ventilation for life safety purposes such that in the event of a fire, evacuation routes are maintained: -

(1) below thermal threshold for human tenability; and

(2) at visibility levels adequate for occupant evacuation; and

(3) below toxicity threshold for human tenability for the period of time required for escape.

e S7.2 - Provisions for ventilation to maintain safe conditions in the means of escape for evacuees for the period of time required for escape.

Table 10.1 : Design fires (sprinkler protected building)

Usage	**Location**	**Size**	**Remarks**
Factory / warehouse / large space or compartment	Centre of space or credible location	Proposed by FSE (E.g. use of 2nd ring sprinkler activation)	
	In-rack	Proposed by FSE	
	Loading / Unloading Bay	10 MW truck fire (as prescribed by the fire code) or higher (if deemed necessary by FSE)	
Atrium	Centre	Proposed by FSE	Axis-Symmetric plume
	Shop/unit	5MW (as prescribed by the fire code) or other appropriate fire size as proposed by FSE.	Axis-Symmetric plume or spill plume.

Table 10.2 : Fire size proposed by FSE based on DETACT T2, FPETool or Firecalc

Usage	**Growth Rate**	**Remarks**
Factory/warehouse	Ultra-fast	2^{nd} ring sprinkler activation
Warehouse (in-rack sprinklers)	Ultra-fast	Next higher level of sprinkler activation
Usage other than industrial.	Fast/Ultra-fast	2^{nd} ring sprinkler activate.

Table 10.3 : Tenability Limits

	Tenability Criteria
Smoke layer 2.5m above relevant Finished Floor Level (FFL)	Visibility > 10 m Temperature < 200 ^{o}C
Smoke layer drops below 2.5m above relevant FFL	Temperature < 60 ^{o}C

Table 10.4 : Acceptance Criteria

Scenario	
Base case	≥ 2 Safety Factor (ASET/RSET)
Sensitivity analysis	≥ 1.2 Safety Factor (ASET/RSET)
	Base cases for healthcare occupancies or projects deemed appropriate by SCDF (e.g. of national and cultural importance such as airport, Large-scale indoor gardens, National Art Galleries/Museums, etc.) shall achieve perpetual tenability.

Table 10.5 : Determining RSET

Time for	**Method**
Detection	Refer to Section 4.1.
Notification time	Refer to Section 4.2.
Pre-movement	Refer to Section 4.3.
Movement	Refer to Section 4.4.

Table 10.6 : Sensitivity Analysis (ASET/RSET ≥ 1.2)

Sensitivity study	**Affects**	**Remarks**
Natural Ventilation : 1 MW fire	ASET	(i) Test buoyancy of smoke.
Natural ventilation: Design fire size is based on base case design fire.	ASET	1 side of exhaust vents fail. Side with most vents or adverse wind effect.
Mechanical ventilation: Design fire size is based on based case design fire.	ASET	(i)Fan failure (See Section 2.2) or increase fire size by 20%
Increase in fire growth rate	ASET	E.g. From fast to ultrafast
Delay in detection	RSET	Failure of main means of detection
1 exit blocked (or more)	RSET	Most utilized exit or exits depends on closeness of exits
Extended pre-movement time	RSET	Value to be doubled

10.2 EXAMPLE 2

Extended 2-way travel distance or Inadequate egress capacity

10.2.1 Root objectives

The root objectives are :

a R2.1 - Occupants must be able to escape to a safe place, directly or through a protected exit, before untenable conditions are reached during a fire emergency.

b R2.2 - Fire-fighters must be provided with adequate means of access for firefighting and rescue operations within the building.

c R7.1 - Maintain tenable conditions for evacuation of occupants and protect them from injury arising from the effects of fire.

d R7.2 - Provide smoke management in the building for firefighting operations.

10.2.2 Sub objectives

The sub objectives are:

a S2.9 - Provisions for adequate ventilation for means of escape.

b S2.13 - Provisions for adequate time for occupant escape from building.

c S2.14 - Provisions for safe movement of people within the means of escape.

d S7.1 - Provisions for ventilation for life safety purposes such that in the event of a fire, evacuation routes are maintained: -

(1) below thermal threshold for human tenability; and

(2) at visibility levels adequate for occupant evacuation; and

(3) below toxicity threshold for human tenability for the period of time required for escape.

e S7.2 - Provisions for ventilation to maintain safe conditions in the means of escape for evacuees for the period of time required for escape.

Table 10.7 : Design fires (sprinkler protected)

Usage	**Location**	**Size**	**Remarks**
Factory / warehouse / large space or compartment	Centre of space or credible location	Proposed by FSE	
	In-rack	Proposed by FSE	
	Loading / Unloading Bay	10 MW truck fire (as prescribed by the fire code) or higher (if deemed necessary by FSE)	
Atrium	Centre	Proposed by FSE	Axis-Symmetric plume
	Shop/unit	5MW (as prescribed by the fire code) or other appropriate	Axis-Symmetric plume or spill plume

		fire size as proposed by FSE	

Table 10.8 : Fire size proposed by FSE based on DETACT T2, FPETool or Firecalc

Usage	**Growth rate**	**Remarks**
Factory/warehouse	Ultrafast	2nd ring sprinkler activation
Warehouse (in-rack sprinklers)	Ultrafast	Next higher level of sprinkler activation
Usage other than industrial.	Fast/Ultrafast	2nd ring sprinkler activation

Table 10.9 : Tenability Limits

	Tenability Criteria
Smoke layer 2.5 m above relevant FFL	Visibility > 10m Temperature < 200 ^{o}C
Smoke layer drops below 2.5 m above relevant FFL	Temperature < 60 ^{o}C

Table 10.10 : Acceptance Criteria

Scenario	
Base case	≥ 2 Safety Factor (ASET/RSET)
Sensitivity analysis	≥ 1.2 Safety Factor (ASET/RSET)
	Base cases for healthcare occupancies or projects deemed appropriate by SCDF (e.g. of national and cultural importance such as airport, Large-scale indoor gardens, National Art Galleries/Museums, etc.) shall achieve perpetual tenability.

Table 10.11 : Determining RSET

Time for	Method
Detection	Refer to Section 4.1.
Notification time	Refer to Section 4.2
Pre-movement	Refer to Section 4.3.
Movement	Refer to Section 4.4.

Table 10.12 : Sensitivity Analysis (ASET/RSET ≥ 1.2)

Sensitivity study	Affects	Remarks
Natural Ventilation: 1 MW fire	ASET	Test buoyancy of smoke.
Natural ventilation: Design fire size is based on base case design fire.	ASET	1 side of exhaust vents fail. Side with most vents or adverse wind effect.
Mechanical ventilation: Design fire size is based on based case design fire.	ASET	Fan failure (See Section 2.2) or increase fire size by 20%
Increase in fire growth rate	ASET	E.g. From fast to ultrafast
Delay in detection	RSET	Failure of main means of detection
1 exit blocked (or more)	RSET	Most utilized exit or exits depends on closeness of exits
Extended pre-movement time	RSET	Value to be doubled

10.3 EXAMPLE 3

Internal discharge of exit staircase

10.3.1 Root objectives

The root objectives are:

a R2.1 - Occupants must be able to escape to a safe place, directly or through a protected exit, before untenable conditions are reached during a fire emergency.

b R2.2 - Fire-fighters must be provided with adequate means of access for firefighting and rescue operations within the building.

c R7.1 - Maintain tenable conditions for evacuation of occupants and protect them from injury arising from the effects of fire.

d R7.2 - Provide smoke management in the building for firefighting operations.

10.3.2 Sub objectives

The sub objectives are:

a S2.9 - Provisions for adequate ventilation for means of escape.

b S2.13 - Provisions for adequate time for occupant escape from building.

c S2.14 - Provisions for safe movement of people within the means of escape.

d S7.1 - Provisions for ventilation for life safety purposes such that in the event of a fire, evacuation routes are maintained: -

(1) below thermal threshold for human tenability; and

(2) at visibility levels adequate for occupant evacuation; and

(3) below toxicity threshold for human tenability for the period of time required for escape.

e S7.2 - Provisions for ventilation to maintain safe conditions in the means of escape for evacuees for the period of time required for escape.

Table 10.13 : Design fires (sprinkler protected)

Usage	**Location**	**Size**	**Remarks**
Atrium	Centre	Proposed by FSE	Axis-Symmetric plume
	Shop/unit	5MW (as prescribed by the fire code) or other appropriate fire size as proposed by FSE	Spill plume.
Shopping Centre / Office / Mixed Use	Unit/s affecting egress path	5MW (as prescribed by the fire code) or other appropriate fire size as proposed by FSE	To determine impact of radiation on escaping occupants
All others	Area with deviation	Proposed by FSE	

Table 10.14 : Fire size proposed by FSE based on DETACT T2, FPETool or Firecalc

Usage	**Growth Rate**	**Remarks**
All others	Fast/Ultrafast	2nd ring sprinkler activation

Table 10.15 : Tenability Limits

	Tenability Criteria
Radiation at egress path to external	Radiation < 2.5 kW/m^2
Smoke layer 2.5m above relevant FFL	Visibility > 10 m Temperature < 200 ^oC
Smoke layer drops below 2.5m above relevant FFL	Temperature < 60 ^oC

Table 10.16 : Acceptance Criteria

Scenario	
Base case	≥ 2 Safety Factor (ASET/RSET) Radiation along evacuation route < 2.5 kW/m^2
Sensitivity analysis	≥ 1.2 Safety Factor (ASET/RSET)
	Base cases for healthcare occupancies or projects deemed appropriate by SCDF (e.g. of national and cultural importance such as airport, Large-scale indoor gardens, National Art Galleries/Museums, etc.) shall achieve perpetual tenability.

Table 10.17 : Determining RSET

Time for	Method
Detection	Refer to Section 4.1.
Notification time	Refer to Section 4.2.
Pre-movement	Refer to Section 4.3.
Movement	Refer to Section 4.4.

Table 10.18 : Sensitivity Analysis (ASET/RSET ≥ 1.2)

Sensitivity study	Affects	Remarks
Natural Ventilation: 1 MW fire	ASET	(i) Test buoyancy of smoke
Natural ventilation: Design fire size is based on base case design fire.	ASET	1 side of exhaust vents fail. Side with most vents or adverse wind effect.
Mechanical ventilation: Design fire size is based on based case design fire.	ASET	(i)Fan failure (See Section 2.2) or increase fire size by 20%
Increase in fire growth rate	ASET	E.g. From fast to ultrafast
Delay in detection	RSET	Failure of main means of detection

1 exit blocked (or more)	RSET	Most utilized exit or exits depends on closeness of exits
Extended pre-movement time	RSET	Value to be doubled

10.4 EXAMPLE 4

Insufficient set back distance from notional boundary.

10.4.1 Root objectives

The root objectives are:

a R3.1 - Prevent the untimely collapse of buildings due to the effects of fire that would affect the safe egress of the building occupants.

b R3.2 - Prevent spread of fire to adjacent properties due to the effects of a fire in the building.

10.4.2 Sub objectives

The sub objectives are :

a S3.7 - Provisions for prevention of spread of fire to adjacent buildings.

Table 10.19 : Design fires (sprinkler protected)

Usage	**Location**	**Size**	**Remarks**
N.A.	Relevant compartment	Proposed by FSE. Could be based on : • Specific fuel load; • 2nd ring sprinkler activation ; • 10 MW heavy goods vehicle or • 84 kW/m^2 or 168 kW/m^2 depending on usage.	

Table 10.20 : Acceptance Criteria

Scenario	
Base case	Radiation receiving plane on site/notional boundary < 12.6 kW/m^2

Table 10.21 : Sensitivity Analysis

Sensitivity study	**Affects**	**Remarks**
Increase in fire growth rate	Radiant heat flux from fire source	Increase fire size by 50%.

10.5 EXAMPLE 5

Omission or Reduction of Fire rating of element of structure. Structural engineer is to carry out structural analysis with thermal input from FSE. The PE(Civil) shall co-endorse with the FSE on all fire engineering reports/assessment involving structural assessment.

10.5.1 Root objectives

The root objectives are:

a R3.1 - Prevent the untimely collapse of buildings due to the effects of fire that would affect the safe egress of the building occupants.

b R3.3 - The building shall remain structurally stable to allow adequate time for fire-fighters to conduct their firefighting and rescue operations.

10.5.2 Sub objectives

The sub objectives are:

a S3.1 - Provision of elements of structure with appropriate fire resistance with respect to :-

(1) the fire severity; and
(2) firefighting and rescue operations; and
(3) the occupant evacuation time; and
(4) enclosure characteristics and configurations; and
(5) the height of building; and

(6) occupancy characteristics; and
(7) different fire risk levels.

b S3.2 - The construction and use of building materials should be of the type and method appropriate to the intended performance.

c S3.9 - Provisions for reasonable measures to prevent premature structural collapse of the building due to fire.

Table 10.22 : Design fires (sprinkler protected)

Usage	**Location**	**Size**	**Remarks**
Area of concern	Close to structural member in question	Proposed by FSE	Based on post flashover fires. Refer to Clause 3.2(b) on computation of post flashover fires.

Table 10.23 : Acceptance Criteria

Scenario		
Base case	(i)	Load-Capacity ratio ≤ 1. Structural engineer is to carry out structural analysis with thermal input from FSE. Annex I describe the steps to determine the load capacity ratio.
	(ii)	Smoke temperature less than limiting steel temperature.
Sensitivity	Structure shall not fail due to failure of two or more key structural member(s) and increase fire size by 50%	

10.6 EXAMPLE 6

Ductless Jet Fan (DJF) system for car parks.

Where the alternative solutions involve only issues pertaining to ductless jet fan design for car parks, the design team may apply for a waiver that is supported by a fire engineering assessment. The Fire Engineering Report shall be prepared by a Fire Safety Engineer.

10.6.1 Root objectives

The root objectives are:

a R7.2 - Provide smoke management in the building for firefighting operations.

10.6.2 Sub objectives – N.A.

Table 10.24 : Design fires (sprinkler protected)

Usage	Location	Size	Remarks
Vehicle/ Car park	Least favourable location i.e. longest smoke path that is away from openings.	20MW coach/bus parking area	Fire growth is instantaneous
		10 MW truck fire (as prescribed by the fire code) or higher if deemed necessary by FSE.	Fire growth is instantaneous
		4MW car fire/forklift fire (as prescribed by the fire code) or higher if deemed necessary by FSE.	Fire growth is instantaneous

Table 10.25 : Acceptance Criteria

Scenario	
Base case	Refer to Section 9.5.
Sensitivity Analysis	Failure of a group of jet fans nearest to the fire

10.7 EXAMPLE 7 Mass Engineered Timber

A fire safety performance-based (PB) approach shall be adopted in the design of any engineered timber building where its habitable height exceeds 12m. The engineering timber building shall be fully protected by an automatic sprinkler system. Essential escape provisions such as staircase shafts and lift shafts of engineered timber building shall be constructed of non-combustible materials which achieve the necessary fire resistance rating.

10.7.1 Root objectives

The root objectives are:

a R3.1 - Prevent the untimely collapse of buildings due to the effects of fire that would affect the safe egress of the building occupants.

b R3.3 – The building shall remain structurally stable to allow adequate time for fire-fighters to conduct their firefighting and rescue operations.

10.7.2 Sub objectives

The sub objectives are:

a S3.2 – The construction and use of building materials should be of the type and method appropriate to the intended performance.

b S3.9 – Provisions for reasonable measures to prevent premature structural collapse of the building due to fire.

The performance-based approach shall adopt a quantitative analysis based on non-sprinkler-controlled fires. The roles and responsibilities of the FSE and PE (Civil) are shown in the flow chart below.

See the flowchart below for roles and responsibilities of FSE and PE (Civil).

Figure 10.1 : Flowchart for roles and responsibilities of FSE and PE (Civil)

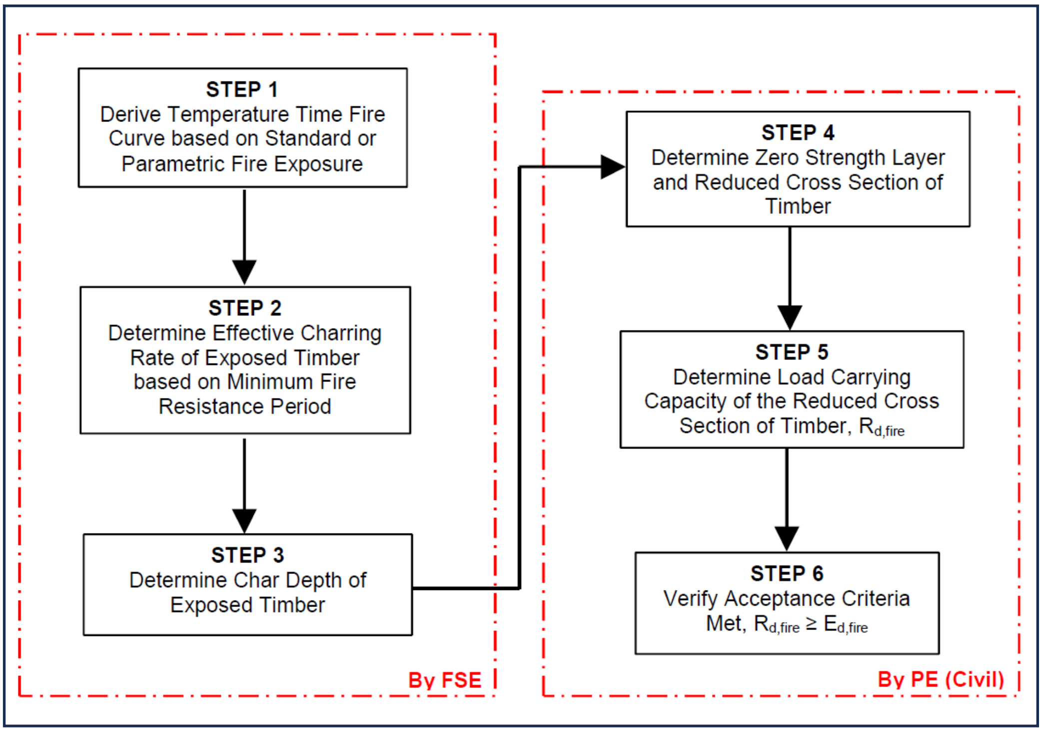

Table 10.26 : Determination of Time-Temperature Fire Curves

Scenario	Type of Time-Temperature Fire Curve	Standard / Methodology
Base Case	Standard time-temperature fire exposure.	ISO 834-1:1999
Sensitivity Analysis	Parametric time-temperature fire exposure. For timber that delaminates, cooling phase shall be ignored.	Eurocode 1 SS EN 1991-1-2:2008 EN 1991-1-2:2002

10.7.3 Base case and sensitivity analysis

Base case and sensitivity analysis using ISO 834 and Eurocode 1 standards to derive the temperature-time fire curves are compulsory. The largest charred depth from base and sensitivity analysis shall be used. When establishing charring rates for base case and in absence of literature, only test reports from SAC approved laboratories shall be used.

10.7.4 Limitations in Eurocode 1

When limitations in Eurocode 1 are exceeded (i.e. height of compartment > 4m, opening factor $0.02 \leq O \leq 0.2$ and/or fire load density: $50 \leq X \leq 1000$ MJ/m^2), the FSE shall justify that exceeding these limitations would result in a more onerous outcome. Otherwise, the FSE shall replace the sensitivity analysis with one of the alternative methodologies as shown in Table 10.27 to derive the time-temperature fire curves. The largest charred depth obtained from base, sensitivity or alternative method shall be used.

The limitations stated above are based on the current version of Eurocode 1. In future, if there are any updates to Eurocode 1 which affects these limitations, the FSE shall take those limitations into account.

Table 10.27 : Alternative methods for sensitivity analysis

Alternative Methods	Type of Time-Temperature Fire Curve	Standard/ Methodology
1	Methodologies from internationally recognised publications such as SFPE Handbook.	E.g. National Bureau of Standards NBSIR 83-2712
2	Derived from Computational Fluid Dynamics (CFD).	Software's such as FDS and Fluent could be used.

a National Bureau of Standards NBSIR 83-2712

Alternative method 1 using NBSIR 83-2712 could be used for predicting gas temperatures within a compartment. A few examples have been considered in the publication to show the versatility of the formulas and its general level of accuracy.

b Using CFD

For analysis using CFD simulations (i.e. alternative method 2), the FSE shall meet the general guidelines stipulated in Table 10.28.

Table 10.28 : General Guidelines for CFD Modelling

No	**General Guidelines for CFD Modelling**
1	Grid independence analysis shall be carried out and presented in the fire safety engineering report. The FSE shall justify the cell size to be used.
2	Appropriate CFD software shall be used which is able to model complex algorithms and reactions of non-sprinkler controlled, fuel controlled, ventilation controlled and/or flash over fires. FSE to review and consider whether the CFD software can model timber pyrolysis accurately.
3	All input parameters, type, locations and orientation of thermocouples and devices used in the CFD models shall be presented and justified in the fire engineering design brief (FEDB).
4	The CFD domain shall include the relevant fire compartment. CFD domain considering only the room of fire origin may not be adequate if the room of fire origin is not fire compartmented.
5	Materials of compartment shall be modelled to the actual building construction materials used.
6	The extent and choice of fuel bed and how fire spreads on the fuel bed shall be presented in the FEDB.
7	Fire spread via timber and other combustible materials shall be considered.
8	Fuel load contribution from charred timber, delamination of cross laminated timber and fire regrowth phase shall be considered.
9	Design fire size shall follow a non-sprinkler-controlled fire scenario. All factors adopted such as fuel load density, soot yield, effective heat transfer coefficient, duration of fire and added fuel from delaminated timber etc shall be justified.
10	For timbers that delaminate, the decay or cooling phase of the fire could be ignored.
11	The resultant heat release rate (HRR) shall be checked against ventilation controlled HRR hand calculations to ensure that the output HRR is in line with expectations.
12	The use of CFD modelling is ~~s~~ subject to SCDF's acceptance.

CFD results are to be supported by alternative method calculations or research to show applicability of results to the specific project.

c Other methodologies

Apart from NBSIR 83-2712 or CFD, FSE may propose other methodology from internationally recognised published documents (e.g. SFPE Handbook) to derive the time-temperature fire curve subject to SCDF's acceptance.

Table 10.29 : Acceptance Criteria

Scenario	**Acceptance Criteria**
Base and sensitivity cases	To adopt relevant structural codes, for example: $R_{d,fire} \geq E_{d,fire}$, where $R_{d,fire}$ is the resistance moment of reduced cross-section of timber after charring and $E_{d,fire}$ is the design bending moment on reduced cross-section of timber after charring. PE(Civil) to include any applicable safety factors from the structural codes.

The FEDB and FSER shall be endorsed by the FSE and PE (Civil).

REFERENCES

1. Singapore Civil Defence Force, Code of Practice for Fire Precautions in Buildings 2013

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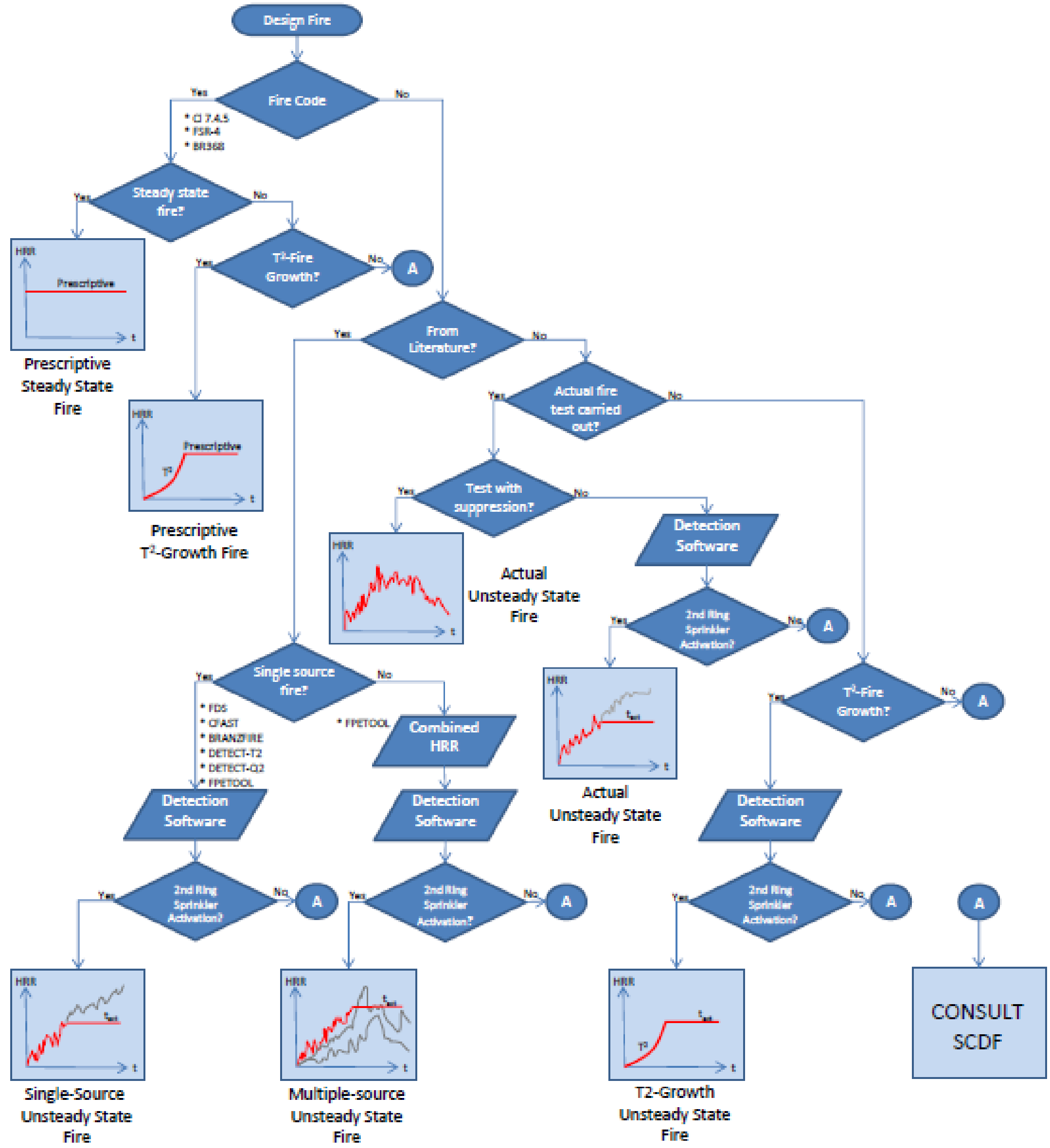
Annex A – Methods of determining fire size



Annex B – Table of Fire Hazards

Usage	**Potential Fuel Load**	**Potential Ignition Sources**	**Hazards presented**	**Potential mitigation measures**
Areas of special/high hazard	Fuel or other or other flammable or combustible liquids storage rooms High hazard plant rooms High voltage switch rooms Heating appliances Kitchen appliances	Electrical, e.g. short-circuit of electrical appliances, wiring or switch boards From equipment, e.g. motors overheating Explosive or highly flammable/ignitable contents or activities	Fire hazards posed to occupants considered high Potential extreme event, such as explosion or uncontrolled fire to impact areas remote from fire	Clause 3.2.5 and Table 6.4A of the Fire Code
Back of house areas / service areas	Electrical and mechanical plant rooms Small ancillary usage (e.g. offices) Staff-only areas like changing rooms, etc	Electrical, e.g. short-circuit of electrical appliances, wiring or switch boards From equipment, e.g. motors overheating Smoking, e.g. ignition from cigarettes or matches	Flexibility in type of goods/commodities Illegal storage may impact means of escape and/or fire compartmentation	Fire compartmentation Automatic sprinkler protection Smoke purging / engineered smoke control
Shop (department stores, shopping centres, supermarkets, business and trades)	Commodities Display goods Storage	Electrical, e.g. short-circuit of electrical appliances or wiring Smoking, e.g. ignition from cigarettes or matches Overheating of electrical equipment Arson	Flexibility in type of goods/commodities Depending on type of shop and stacking arrangement, fire hazard can range from low to high (e.g. high rack storage). May connect multiple floors and/or have high populations (shopping centres)	Fire compartmentation Automatic sprinkler protection Engineered smoke control

Usage	Potential Fuel Load	Potential Ignition Sources	Hazards presented	Potential mitigation measures
F&B (restaurants, food courts, coffee shops, hawker centres, fast food outlets)	Furniture and furnishings Rubbish bins Kitchen appliances Storage	Electrical, e.g. short-circuit of electrical appliances or wiring Overheating of electrical equipment, e.g. display lightings 'Open flame' cooking appliances in kitchens Smoking, e.g. ignition from cigarettes or matches Arson	Flexibility in type of furniture and layout Potential extreme event, such as explosion (gas cylinder/tanks/supply) to impact areas remote from fire May have high populations; e.g. food courts	Fire compartmentation Kitchen suppression systems Automatic sprinkler protection Engineered smoke control
Car parks	Cars, motorcycles, vans Larger vehicles (load/unloading area)	Electrical, e.g. short-circuit of electrical appliances or wiring Overheating of electrical equipment Arson	May include high fuel load larger vehicles	Fire compartmentation Automatic sprinkler protection Smoke purging / Jet fan ductless system
Offices	Furniture Electronic equipment Paper, books	Electrical, e.g. short-circuit of electrical appliances or wiring Overheating of electrical equipment	Flexibility in type of furniture and layout	Fire compartmentation Automatic sprinkler protection
Places of assembly (auditorium, theatres, performing arts)	Theatrical/stage scenery, hangings and other props (fly tower) Electrical equipment and lighting Fixed seating Performers' instruments/props	Performances using pyrotechnics, flame effects or similar Electrical, e.g. short-circuit of electrical appliances or wiring Overheating of electrical equipment Smoking, e.g. ignition from cigarettes or matches Arson	Scenery can include props made from highly combustible materials; e.g. plastics Seats to be tested to BS 5852 as specified clause 2.8.3 (g) of the Code of Practice for Fire Precautions in Buildings 2013. High populations and densities	Fire compartmentation Automatic sprinkler protection Smoke venting or engineered smoke control

Usage	**Potential Fuel Load**	**Potential Ignition Sources**	**Hazards presented**	**Potential mitigation measures**
Exhibition	Exhibits may include temporary booths/setups and displays (electronics, vehicles, roadshows, sales, etc)	Overheating of electrical equipment Smoking, e.g. ignition from cigarettes or matches Arson	Flexibility in type of goods/commodities Flexibility in type of furniture and layout	Fire compartmentation Automatic sprinkler protection Engineered smoke control
Recreational, amusement, night entertainment	Furniture Theatrical/stage scenery, hangings and other props	Performances using pyrotechnics, flame effects or similar Overheating of electrical equipment Smoking, e.g. ignition from cigarettes or matches Arson	Scenery can include props made from highly combustible materials; e.g. plastics High populations and densities	Fire compartmentation Automatic sprinkler protection Engineered smoke control

Annex C – Enclosure Fire Models

(a) General

There are generally two classes of computer models for analysing enclosure fire developments; Stochastic or Probabilistic models and Deterministic models.

(i) Stochastic model generally treats fire growth as a series of sequential events or states using established mathematical rules for the transition from one event to another. Probabilities are assigned to each transfer points based on analysis from experimental data, historical fire incident data or computer model results. The context of this model is not covered under this guide. Consultation with SCDF is required for the use of Stochastic model.

(ii) Deterministic models use interrelated mathematical expressions based on physics and chemistry to describe a compartment fire. The most common type of Deterministic model is the zone model, which solves the conservation equations in control volume(s). The other type of Deterministic model which gains popularity is the field model, which solves the fundamental equations of mass, momentum and energy in control volumes in subdivided grids.

(b) Zone Models

(i) Zone models are designed to predict the conditions resulting from a fire in an enclosure. These models solve the equations based on the zone assumptions within an enclosure. It provides a faster and a more accurate estimate of fire conditions than manual calculations methods. Most of the zone models can be run on personal computers. It is relatively simplicity, which permits inclusion of more phenomena in a given zone model without becoming overwhelmed by complexity. This also means that it may run far more rapidly and inexpensive.

(ii) It provides estimates of the fire conditions for each of the layers as a function of time. No zone model is the best for all applications. While most of the zone model are based on the similar fundamental principles, there is a significant variation features among the different zone models. The decision to use a model is dependent upon the understanding of the assumptions and its limitations for the particular model. Most importantly, the selected model must be validated with results comparing experiment data.

(iii) Application and limitations:

(1) Simple geometry that can be simplified into a simple box, best applies to an enclosure which dimensions (width and length) are similar.

(2) Large compartment is to be divided into multiple virtual compartments

(3) Radiation effects is not a primary consideration factor in the design

(4) Predicting sprinkler activation time and estimating ventilation rates

(5) Not well suited for comprehensive analyses involving the time-dependant interactions of multiple physical and chemical processes in developing fires

(6) Primarily one-dimensional, and divides the spaces of interest into a few zones

(7) Analyses of zone models assume two layers of uniform temperature and conditions; a hot upper zone and a cooler lower layer. Interaction of smoke with localised smoke logged conditions is not addressed, i.e. compartment volumes are strongly stratified

(8) Different zone models may yield quite a different result

(9) Not accurate in modelling long corridors, very large compartments or compartments involve radiation feedback of energy

(10) Smoke movement cannot be predicted

(11) Cannot generate pictorial results that describes a more realistic fire condition

(iv) Zone models are intended to be used to review the smoke transport with a wide variety of fire scenarios. Some of the limits to the inputs in the softwares are reproduced from the various references and listed below. The list of softwares shown is not exhaustive with a few commonly used software for zone model presented. It is important to understand the physics and assumptions on which the software is based in order to evaluate and interpret the results.

Table C-1 – Limitations of CFAST and BRANZFIRE

S/N	Description	CFAST	BRANZFIRE
1	Maximum simulation time	86,400s [12]	
2	Maximum number of compartments	100 [12]	10 [16]
3	Maximum number of horizontal flow (door/window) vent connections that can be included in a single test case	2500 [12]	
4	Maximum number of vertical flow (ceiling/floor) vent connections which can be included in a single test case	2500 [12]	
5	Maximum total number of connections between compartments and mechanical ventilation systems which can be included in a single test case	2500 [12]	
6	Total number of fans that can be included in a single test case	1250 [12]	
7	Maximum number of fires which can be included in a single test case	2500 [12]	
8	Maximum number of data points for a single fire definition	199 [12]	
9	Maximum number of data points in a variable cross-sectional area definition for a single compartment	199 [12]	
10	Maximum number of material thermal property definitions which can be included in a single thermal database fire	2500 [12]	
11	Maximum number of targets which can be included in a single test case. In addition, the CFAST model includes a target on the floor of each compartment in the simulation and one for each object fire in simulation	2500 [12]	
12	Maximum number of detectors/sprinklers which can be included in a single test case	2500 [12]	
13	Maximum single compartment size		1,200m^2 [15]
14	Maximum total virtual compartments size		5,000m^2 [15]
15	Maximum compartment height	Ceiling Jet 0.58m to 22m [18]	12m [14]
16	Maximum compartment volume		60,000m^3 [15]
17	Maximum length of compartment		25m [4]
18	Maximum fire size	Ceiling Jet only 0.62MW to 33MW	

S/N	Description	CFAST	BRANZFIRE
19	Minimum fire size within room of fire origin (This limit is not to be used as a limit to a specific design fire)	0.1 kW/m^3 [3]	
20	Maximum fire size within room of fire origin (This limit is not to be used as a limit to a specific design fire)	1000 kW/m^3 [13]	
21	Maximum ratio of area of vents connecting one compartment to another to the volume of the compartment	< $2m^{-1}$ [13]	
22	Corridor Scenario – aspect ratios as follows: * $(L/W)_{max}$ * $(L/H)_{max}$ * $(W/H)_{min}$	 L/W > 5 [13] L/H > 6 [13] W/H < 0.2 [13]	
23	Special consideration for Corridor with use of corridor flow and non-corridor flow algorithm for comparison - aspect ratios as follows: * $(L/W)_{max}$ * $(L/H)_{max}$ * $(W/H)_{min}$	 3 <L/W< 5 [13] 3 <L/H< 6 [13] 0.2<W/H<0.4 [13]	
24	Single Zone compartment scenario – aspect ratios as follows: * $(L/W)_{max}$ * $(L/H)_{max}$ * $(W/H)_{min}$	 L/W < 3 [13] L/H < 3 [13] W/H > 0.4 [13]	

(v) List of Approved Zone Models:
- CFAST
- BRANZFIRE
- To seek consensus from SCDF for the use of other zone models

(c) Field Models

(i) The field model solves fundamental Navier-Stokes equations using numerical method, commonly known as computational fluid dynamics (CFD). It allows study of extremely complicated problems even with irregular and complex geometry. The primary advantage of a field model is that it can provide detailed information on the fluid motions in three-dimensions as compared with zone model (except one-dimensionally). In general, a more powerful computer than desktop personal computer will be required to run CFD.

(ii) It computes the mass, momentum and energy conditions of the fire conditions for each of the cell within the grid or mesh as a function of time. Like the zone model, no field model is the best for all applications. Most of the field models are based on the similar fundamental principles but there is a significant variation features among the different field models. Understanding of the assumptions and its limitations for the particular model is required in order to select the appropriate field model to be used. Again, most importantly, the selected model must be validated with results comparing experiment data.

(iii) Application and limitations:

(1) No constraint in using field model for any geometry

(2) Detail analyses required

(3) Experience users with knowledge of fluid dynamics codes

(4) Powerful computer required to run CFD

(5) Large data storage for results

(6) Long computing time

(7) Results are grid dependant; i.e. Solution is less ideal for coarser and very fine grids or mesh

(iv) List of Approved Field Models:

- Fire Dynamic Simulator (FDS)
- FLUENT
- To seek consensus from SCDF for the use of other field models

Annex D – Notification time

(a) The following describes typical design notification times, depending on the types of alarm systems present and the evacuation strategies being adopted:

(i) From C/VM2 document Cl 3.2.2

- t_n = 30 s for premises adopting standard evacuation strategies;
- For non-standard evacuation strategies (i.e., 2-stage, management investigating, etc), t_n will have to take into account any extended timeframe.

(ii) From PD7974 Part 6:2004 Annex A

- If the building is fitted with automatic fire detection systems with immediate fire alarm, then t_n = 0 s;
- If the building is fitted with automatic fire detection system involving a pre-alarm to building management, and thereafter either (1) a manually activated warning sounded throughout affected area, or (2) if pre-alarm is not cancelled after a fixed delay, then a general alarm will be sounded. In such cases, the notification time can be taken as:
- t_n = 2 min to 5 min + time taken for voice alarm to be spoken twice.
- If the building is fitted with only local automatic alarm near the fire location or is not fitted with any automatic alarm at all, occupants will be notified of fire only via manually activated general warning system. In such cases, notification time may be long: t_n = long and unpredictable.

(iii) From SS CP10 : 2005

- Cl 1.4.3.3 Fire extinguishing alarm initiating devices.
- Flow switches, pressure switches and the like associated with fixed fire extinguishing systems that are used to initiate an alarm, shall be individually connected under separate alarm zones on the fire alarm panel. Flow switches used shall incorporate time-delay devices to avoid false alarm due to water surges.
- Initiation of the alarm signal shall occur within 90s of water flow at the alarm-initiating device when flow occurs that is equal to or greater than that from a single sprinkler of the smallest orifice size installed in the system.
- Cl 2.5.11 Alarm verification feature (AVF).

- To reduce the effects of transient environmental conditions, which may cause various types of detectors to be activated, an automatic fire alarm system may be provided with an alarm verification feature, subject to the approval of the relevant authority.

- Such an alarm verification feature, if provided, shall operate in the following manner. Upon activation of a detector in any zone, the fire alarm system shall go into an alarm retard state for a period not exceeding 20s at the control unit. After the expiry of this period, the fire alarm system shall go into an alarm confirmation state for a period not less than 120s and not exceeding 300s. Only when the same detector or another detector within the same zone or panel is activated during this alarm confirmation period, shall the fire alarm system go into full operation.

- Cl 2.7.2 Detectors. The delay between activation of a heat detector and activation of the general alarm shall not exceed 10s.

Annex E – Warning systems

(a) Alerting people with warning systems (Source: C/VM2)

Where only manual systems are installed, occupants are assumed to be aware of the fire when the ceiling jet has traversed the entire length of the space from a fire at the opposite end of the space. No additional pre-movement time need be included. The time required for the ceiling jet to completely traverse the ceiling can either be determined using CFD modelling or by the following relationship if zone modelling is used.

(i) For storage height ≤ 5.0m (ultrafast fire growth):
$t_d = 10 + 2.4L$ when $L \leq 1.4w$, and
$t_d = 10 + w + 1.7L$ when $1.4w < L \leq 4w$,

and

For storage height > 5.0m (ultrafast fire growth):
$t_d = 25 + 1.7L$ when $L \leq 1.4w$, and
$t_d = 25 + w + L$ when $1.4w < L \leq 4w$,

where:
w = width of space in meters (shortest dimension)
L = length of space in meters (longest dimension)

Annex F – Pre-movement time

(a) In essence, pre-movement time depends primarily upon the design behavioural scenario, the fire safety management level and building complexity. The New Zealand document, i.e. C/VM2 attempts to prescribe the pre-movement times for various building usage groups, occupant alertness, familiarity and proximity to fire origin. However, these pre-movement times obtained from C/VM2 do not take into account the behavioural modifiers (e.g. detection and alarm quality, level of fire safety management and building complexity) in determining pre-movement times.

(b) The level of fire safety management can be significant in reducing pre-movement times. Pre-movement times and their corresponding distributions have been found to be very short when fire safety management is of a high standard and when staff is well-trained [Purser, Bensilum & Purser 2002].

Table F-1 Comparison of pre-movement time.

Description of building use	Pre-movement activity time(s)
Building where the occupants are considered awake, alert and familiar with the building (eg, office, warehouse not open to the public)	
Enclosure of origin	30
Remote from the enclosure of origin	60
Building where the occupants are considered awake, alert and unfamiliar with the building (eg, retail shops, exhibition spaces, restaurants)	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of the origin (standard alarm signal)	120
Enclosure of origin (voice alarm signal)	30
Remote from the enclosure of origin (voice alarm signal)	60
Building where the occupants are considered sleeping and familiar with the building (eg, apartments)	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of origin (standard alarm signal)	300
Building where the occupants are considered sleeping and unfamiliar with the building (eg, hotels and motels)	
Enclosure of origin	60
Remote from the enclosure of origin (standard alarm signal)	600
Remote from the enclosure of origin (voice alarm signal)	300
Building where the occupants are considered awake and under the care of trained staff (eg, day care, dental office, clinic)	
Enclosure of origin (independent of alarm signal)	60
Remote from the enclosure of origin (independent of alarm signal)	120
Building where the occupants are considered sleeping and under the care of trained staff (eg, hospitals and rest homes)	
Enclosure of origin (assume staff will respond to the room of origin first)	60 s for staff to respond to alarm then 120 s (per patient per 2 staff)[1]
Remote from the enclosure of origin (independent of alarm signal)	1800
Remote from the enclosure of origin (independent of alarm signal) where occupants are unable to be move due to the procedure or other factor	1800 or as per specific requirements, whichever is the greater
Spaces within buildings which have only focused activities (eg, cinemas, theatres and stadiums)	
Space origin (occupants assumed to start evacuation travel immediately after detection and notification time or when fire in their space reaches 500 kW, which occurs first)	0
NOTE: **1. This allows 120 s to move each patient from their room to the next adjacent firecell. This includes time for staff to prepare the patient and transport them to the adjacent firecell, and then to return to evacuate another patient. The commentary document for this Verification Method gives details of staff to patient ratios.**	

SINGAPORE CIVIL DEFENCE FORCE

Our Ref. : CD/FSSD/12/02/03/01

Your Ref :

Date : 18 Oct 2013

HQ Singapore Civil Defence Force
91 Ubi Avenue 4
Singapore 408827
Tel : 68481457
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Registrar, Board of Architects (BOA)
Registrar, Professional Engineers Board (PEB)
President, Singapore Institute of Architects (SIA)
President, Institution of Engineers, Singapore (IES)
President, Association of Consulting Engineers, Singapore (ACES)

Dear Sir/Mdm

CERTIFICATION BY QUALIFIED PERSON FOR A/A PLANS INVOLVING PERFORMANCE-BASED FIRE SAFETY DESIGNS

SCDF issued a circular (ref: CD/FSSD/12/02/03/01) on 5 Jun 2012 to inform the building industry that qualified persons (QPs) who carry out any addition & alteration (A/A) works to an existing Performance–Based (PB) building, are required to obtain a letter of no objection from a fire safety engineer (FSE), if the A/A works do not affect the PB design. If the works affect the PB design, a FSE has to be engaged for submission of PB plans to SCDF.

2. QPs have suggested to allow them to issue the letter of no objection instead of FSEs, especially for cases where the A/A works clearly do not affect the Performance–Based (PB) design of the building.

3. SCDF has no objection to the suggestion. However, QPs are expected to do their due diligence in referring to the relevant PB documents before issuing the letter of undertaking. Please note that there could be several PB projects carried out for the PB building in question and as such, the QP would have to make reference to all the different sets of PB documents. QPs who undertake the certification, will take full responsibility if the A/A works are subsequently found to have affected the original PB designs. If the QP is doubtful whether the proposed A/A works affect the PB designs, he/she is strongly advised to consult the FSE.

4. The Operations and Maintenance (O&M) Manual is one of the PB documents prepared by the FSEs for submission to SCDF. One of the purposes of the manual is to serve as a guide for building operators on future renovations and changes made to the building. However, this aspect on demarcation is usually not included in the manual submitted by the FSEs. SCDF would therefore like to remind FSEs to clearly demarcate the areas where future A/A works can be carried out without affecting the PB design of the building so as to facilitate such works.

5. These requirements shall take immediate effect. Please convey the contents of this circular to members of your Institution/Association/Board. The circular is available in CORENET-e-Info: http://www.corenet.gov.sg/einfo.

6. For any inquiry or clarification, please contact Maj Chong Kim Yuan at DID: 6848 1476 or email address: Chong_Kim_Yuan@scdf.gov.sg.

Yours faithfully,

(transmitted via e-mail)

MAJ Lee Kok Chuen
Secretary, FSSD Standing Committee
for Commissioner
Singapore Civil Defence Force

cc

CEO, BCA
CEO, URA
CEO, HDB
CEO, JTC
CE, LTA
CE, SPRING Singapore
President, REDAS
President, IFE
President, SISV
President, FSMAS
All members of FSSD Standing Committee

Annex H – First Schedule of the Fire Safety (Registered Inspector) Regulations

FIRST SCHEDULE
SCOPE OF FIRE SAFETY WORKS TO BE INSPECTED BY APPROPRIATE REGISTERED INSPECTORS

A registered inspector who —

(*a*) is an architect registered under the Architects Act 1991 or a professional engineer in the civil or structural engineering discipline registered under the Professional Engineers Act 1991 shall inspect and, unless otherwise provided, test the fire safety works listed in Part I;

(*b*) is a professional engineer in the mechanical or electrical engineering discipline registered under the Professional Engineers Act 1991 shall inspect and test the fire safety works listed in Part II;

(*c*) is an architect registered under the Architects Act 1991 or a professional engineer in the civil or structural engineering discipline registered under the Professional Engineers Act 1991 must inspect the fire safety works listed in Part III;

(*d*) is a professional engineer in the mechanical or electrical engineering discipline registered under the Professional Engineers Act 1991 must test the fire safety works listed in Part III; or

(*e*) is a fire safety engineer must inspect and test any part of the fire safety works listed in Part I, II or III that uses an alternative solution

PART I

(*1*) Fire Protection Systems:

(*a*) Fire extinguishers
(*b*) Dry risers (testing not required).
(*c*) Manual fire alarm call points, sounding devices and indicating panel (testing not required).
(*d*) Exit and directional signs.
(*e*) Emergency lighting (self-contained light fittings only).
(*f*) Hose reels (direct Public Utilities Board supply).

(*2*) Structural Fire Precautions:

(*a*) Compartment walls and floors.
(*b*) Elements of structure.
(*c*) External walls.
(*d*) Separating walls.
(*e*) Protected shafts.
(*f*) Protection of openings (excluding fire dampers).
(*g*) Exit staircase.
(*h*) Concealed spaces.
(*i*) Fire stopping.
(*j*) Restriction of flame spread.
(*k*) Roofs.

(*3*) Means of Escape.

(*4*) Site planning and external fire fighting provisions:

(*a*) Fire fighting vehicles and equipment access (access opening and hard standing/access way).
(*b*) Rising mains access.
(*c*) Hydrants and private hydrants (testing not required).
(*d*) Fire Command Centre.

(*4A*) Regulated fire safety products:
(a) A fire-rated partition (including a compartment wall, a protected shaft enclosing lift, and a protected shaft enclosing staircase or services).
(*b*) A fire-rated floor.
(*c*) A fire-rated ceiling (including any compartmentation or protection to a steel beam that supports a reinforced concrete floor and any protection to timber or steel flooring).
(*d*) A fire-rated enclosure or fire-rated spraying material (including protection to a steel structure, protection to a firefighting system or protection to a building service).
(*e*) Any fire-stopping material (including fire-rated collar).
(*f*) A fire-rated glass block or glass partition.
(*g*) An exit sign powered by radioactive material.
(*h*) Any self-contained emergency lighting.
(*i*) A standby fire hose.
(*j*) An auditorium seat.
(*k*) A fire-rated door (including door closer).
(*l*) A bin or linen chute door.
(*m*) A fire-rated lift landing or dumb waiter door.
(*n*) A fire-rated hatch door.
(*o*) A portable fire extinguisher.
(*p*) Any intumescent coating system (for protection to a steel structure).
(*q*) Any raised floor panel.
(*r*) Any material for wall, ceiling or floor construction.
(*s*) Any thermal insulation material.
(*t*) Any finishing material for a wall or ceiling.
(*u*) Any plastic finishing material for a floor.
(*v*) Any roof covering material.
(*w*) A composite panel (cladding to an external wall).
(*x*) Any UPVC window frame material.
(*y*) Any engineered timber.
(*z*) A solar photo-voltaic (PV) roof-mounted module.
(*za*) Any cold-room material (whether fire-rated or not)

(*5*) Any other endorsements made on the approved building plans.

PART II

(*1*) Fire Protection Systems:

(*a*) Sprinkler systems.
(*b*) Automatic fire alarm systems, including testing of manual alarm systems.
(*c*) Lift systems.
(*d*) Hose reels (pump supply).

(*e*) Wet risers.
(*f*) Dry risers and internal hydrants (testing only).

(*2*) Mechanical ventilation/air-conditioning systems, including dampers and fire resisting construction of ductworks.

(*3*) Smoke control systems (both mechanical and venting systems).

(*4*) Pressurization systems.

(*5*) Emergency lighting.

(*6*) Voice communication systems and Fire Command Centre facilities.

(*7*) Standby generator systems.

(*8*) Integrated fire fighting and protection systems testing under both fire alarm activation and power failure condition.

(*8A*) Regulated fire safety products:
(*a*) A fire pump.
(*b*) A fire-rated duct system.
(*c*) A fire-extinguishing system for kitchen hoods.
(*d*) A fire damper.
(*e*) A fire-resistant cable

(*9*) Any other endorsements made on mechanical ventilation and fire protection plans.

(version in force from 31/12/2021)

Annex I – Determining Load/Capacity Ratio for Structural Steel

Step 1 - Calculating temperature of structural member in fire condition using CFD modelling and hand calculations (higher temperature to be adopted).

Step 2 - Calculating the Structural Capacity under Elevated Temperatures in accordance with SS EN 1993-1-2 (Eurocode 3: Design of steel structures – Part 1-2: General rules – Structural fire design).

The following capacity components at elevated temperatures are calculated (where appropriate):

- Design resistance of a tension member, N
- Design buckling resistance of a compression member, Nb
- Design moment resistance, M
- Design lateral torsional buckling resistance Moment, Mb
- Design shear resistance, V
- Design buckling resistance, R (subjected to combined bending and axial Compression)

Step 3 - Obtaining the Fire Load on the Structure

Structural engineers have developed the structural model for further analysis

The resultant loadings due to fire shall be determined in accordance to SS EN 1990 (Eurocode - Basis of structural design), SS EN 1991-1-1 (Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings) and SS EN 1991-1-2 (Eurocode 1: Actions on structures - Part 1-2: General actions – Actions on structures exposed to fire).

The load combination adopted for structural fire design shall be documented in FEDB/FER.

Step 4 – Verify Load/Capacity Ratio (as per SS EN 1993-1-2)

Perform load/capacity ratio check for each structural members including beams, columns, bracings if applicable and connections using the values from Step 2 and Step 3: Load-Capacity ratio ≤ 1.

CHAPTER 2

MEANS OF ESCAPE

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R2.1 Occupants must be able to escape to a safe place, directly or through a protected exit, before untenable conditions are reached during a fire emergency.

R2.2 Fire-fighters must be provided with adequate means of acc
ess for fire fighting and rescue operations within the building.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S2.1 Provisions for appropriate alternative means of escape.

S2.2 Provisions for adequate capacity of means of escape.

S2.3 Provisions for avoidance of fire occurrence in means of escape.

S2.4 Provisions for adequate protection against transmission of heat and infiltration of smoke into means of escape.

S2.5 Provisions for early warning to and communication with occupants in a fire emergency.

S2.6 Provisions for means of escape appropriate to the occupants' profile and the building's functions and characteristics.

S2.7 Provisions for accessibility of means of escape.

S2.8 Provisions for visibility & illumination of means of escape.

S2.9 Provisions for adequate ventilation for means of escape.

S2.10 Provisions for directing occupants to means of escape.

S2.11 Provisions for temporary refuge for healthcare occupancies.

S2.12 Provisions for reliability of means of escape.

S2.13 Provisions for adequate time for occupant escape from building.

S2.14 Provisions for safe movement of people within the means of escape.

CHAPTER 3

STRUCTURAL FIRE PRECAUTIONS

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R3.1 Prevent the untimely collapse of buildings due to the effects of fire that would affect the safe egress of the building occupants.

R3.2 Prevent spread of fire to adjacent properties due to the effects of a fire in the building.

R3.3 The building shall remain structurally stable to allow adequate time for fire-fighters to conduct their fire-fighting and rescue operations.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S3.1 Provision of elements of structure with appropriate fire resistance with respect to :-

(i) the fire severity; and

(ii) fire fighting and rescue operations; and

(iii) the occupant evacuation time; and

(iv) enclosure characteristics and configurations; and

(v) the height of building; and

(vi) occupancy characteristics; and

(vii) different fire risk levels.

S3.2 The construction and use of building materials should be of the type and method appropriate to the intended performance.

S3.3 Provisions for reasonable and adequate measures to limit the development of fire.

S3.4 Provisions for prevention of spread of fire from and to high fire risk areas.

S3.5 Provisions for the protection of building fire systems to enable their proper functioning during a fire emergency.

S3.6 Provisions for prevention of spread of fire from storey to storey.

S3.7 Provisions for prevention of spread of fire to adjacent buildings.

S3.8 Provisions to minimise risk of fire initiation and limit fire and smoke spread in concealed spaces.

S3.9 Provisions for reasonable measures to prevent premature structural collapse of the building due to fire.

CHAPTER 4

SITE PLANNING & EXTERNAL FIRE FIGHTING PROVISIONS

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R4.1 Provide space at the building site to enable effective mounting of fire fighting and rescue operations.

R4.2 Provide reliable and adequate water supply to enable effective fire-fighting operations.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S4.1 Provision for adequate and appropriate access for effective manoeuvring of fire fighting appliances at the building site for fire-fighting purposes.

S4.2 Provision for adequate structural provisions for accessways to sustain the operational loads of the fire appliances.

S4.3 Provision for adequate and appropriate provision of external entry locations on the building facade for fire-fighting and rescue operations.

S4.4 Provision for proper identification of fire fighting access at the building site and external entry locations for fire fighters on building facade.

S4.5 Provision for appropriate siting of reliable and adequate hydrant water supplies and related facilities at the building site.

CHAPTER 5

ELECTRICAL POWER SUPPLIES

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R5.1 Provide automatic backup power supply for continuity of services required for life safety and fire-fighting and rescue operations during a fire emergency.

SUB-OBJECTIVES

There are no sub-objectives for this chapter.

CHAPTER 6

FIRE FIGHTING SYSTEMS

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R6.1 Provide appropriate and adequate fire-fighting facilities for occupants to perform initial fire-fighting.

R6.2 Provide appropriate and adequate fire fighting facilities for fire-fighters to conduct their fire-fighting operations.

R6.3 Provide appropriate and adequate means of alerting occupants and locating of the fire by fire-fighters.

R6.4 Provide, where appropriate, adequate fire suppression systems commensurate with the level of fire safety intended for the building.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S6.1 Provisions for fire-fighting systems for initial fire fighting by occupants shall be installed appropriate to:-

(i) the nature of the fire hazard in relation to use of the building; and

(ii) the layout and footprint of the floor of the building.

S6.2 Fire fighting systems, including the necessary accessories for fire-fighting operations shall be installed appropriate to:-

(i) the nature of the hazard; and

(ii) the anticipated fire severity; and

(iii) the layout and footprint of the floor of the building; and

(iv) the height above and depth below ground of the building; and

(v) the use of the building; and

(vi) the location, accessibility and availability of the systems.

S6.3 Fire suppression systems to control the spread of fire shall be installed appropriate to:-

(i) the nature of the fire hazard; and

(ii) the anticipated fire severity; and

(iii) the fuel and storage configuration; and

(iv) the height above and depth below ground of the building; and

(v) the use of the building.

S6.4 Provisions for appropriate and adequate detection and warning systems to alert occupants, alarm monitoring agents and fire service shall be installed appropriate to:-

(i) the occupant characteristics; and

(ii) the nature of the hazard; and

(iii) the anticipated fire severity; and

(iv) the layout and footprint of the floor of the building; and

(v) the height above and depth below ground of the building; and

(vi) the use of the building; and

(vii) locating the fire.

CHAPTER 7

MECHANICAL VENTILATION AND SMOKE CONTROL SYSTEM

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R7.1 Maintain tenable conditions for evacuation of occupants and protect them from injury arising from the effects of fire.

R7.2 Provide smoke management in the building for fire-fighting operations.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S7.1 Provisions for ventilation for life safety purposes such that, in the event of a fire, evacuation routes are maintained :-

(i) below thermal threshold for human tenability; and

(ii) at visibility levels adequate for occupant evacuation; and

(iii) below toxicity threshold for human tenability

for the period of time required for escape.

S7.2 Provisions for ventilation to maintain safe conditions in the means of escape for evacuees for the period of time required for escape.

S7.3 Provisions for adequate ventilation for the storage of flammable and explosive substances or equipment emitting flammable vapour, to prevent undesirable accumulation of such flammable vapour.

S7.4 The installation and operation of the mechanical ventilation systems shall

(i) have minimal contribution to the spread of fire and smoke in the building; and

(ii) have no adverse effects on the operation of other life safety or fire suppression systems.

S7.5 Provisions for appropriate and adequate ventilation to

(i) rooms housing essential fire fighting facilities which are dependent on it for their continued operation; and

(ii) fire command centre in which emergency personnel operate.

CHAPTER 8

OTHER SYSTEMS

ROOT OBJECTIVES

The primary intentions of this chapter are encapsulated in the following statements:-

R8.1 Enable the safe escape of occupants from a building during a fire emergency by having adequate and appropriate

(i) lighting; and

(ii) means of identifying exit routes.

R8.2 Enable the continual use of fire fighting facilities by providing adequate and appropriate lighting for the duration of the fire emergency.

R8.3 Early warning to occupants of impending danger posed by a fire in the building.

R8.4 Enable effective fire–fighting by providing means of communication for fire-fighters in a building during a fire emergency.

SUB-OBJECTIVES

The following criteria define the conditions necessary to fulfil the intentions of this chapter:-

S8.1 Provisions for lighting at appropriate locations to enable occupants to have adequate visibility for safe evacuation, with considerations for:-

(i) the use of the building; and

(ii) the distance of travel to common escape routes

S8.2 Provisions for adequate and appropriate means to enable occupants to

(i) clearly identify exit locations; and

(ii) be guided to such exit locations

during a fire emergency in the building.

S8.3 Provisions for adequate and appropriate means of relaying information and instructions to the occupants during a fire emergency in a building, with considerations for:-

(i) the use of the building; and

(ii) the occupant load of the building; and

(iii) the floor area of the building; and

(iv) the height of the building; and

(v) basement conditions; and

(vi) the characteristics of the occupants.

S8.4 Provisions for adequate and appropriate means of communication for fire-fighting and rescue operations in the building, with considerations for:-

(i) the use of the building; and

(ii) the occupant load of the building; and

(iii) the floor area of the building; and

(iv) the height of the building; and

(v) basement conditions.

SCDF The Life Saving Force
SINGAPORE CIVIL DEFENCE FORCE

Your Ref : **Our Ref:** CD/FSSD/12/02/03/01

Date : 30 December 2015

Registrar, Board of Architects
Registrar, Professional Engineers Board
President, Singapore Institute of Architects
President, Institution of Engineers, Singapore
President, Association of Consulting Engineers, Singapore

Dear Sir/Mdm

CONDUCT OF FIRE ENGINEERING ASSESSMENT IN SUPPORT OF FIRE SAFETY WAIVER APPLICATION

Under the Fire Safety Act, plans of fire safety works submitted by the Qualified Person (QP) shall be in compliance with the prevailing Fire Code. In the event of any deviation from code requirements, a waiver application must be submitted to SCDF.

2. While the assessment of some waiver issues by SCDF is relatively straightforward, others may require fire engineering assessment to substantiate the waiver application so as to provide an objective assessment of the fire safety outcomes. However, presently in many instances, these fire engineering assessments are not carried out by the applicant.

3. In light of the above, SCDF has identified specific clauses in the Fire Code (see Annex A), where it is mandatory that these waiver applications must be supported by fire engineering assessment(s). Unlike a full performance-based plan submission process where fire engineering design brief and engagement of peer reviewer is necessary, this process only requires an additional fire engineering assessment to be conducted by a fire safety engineer in support of the waiver application.

SCDF – A member of the Home Team

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4. This list which can also be accessed via SCDF's website (http://www.scdf.gov.sg/building-professionals/downloads) may not be exhaustive and SCDF may still require and will advise accordingly for fire engineering assessment to be carried out for waiver issues that fall outside the list.

5. This circular shall take effect for waiver application submitted to SCDF from 30 June 2016 and is also available in CORENET-e-Info: http://www.corenet.gov.sg/einfo. Please convey the contents of this circular to members of your Board / Institution / Association. For any inquiry or clarification, please contact: MAJ Bryan Ng at DID: 68481443 or Email: bryan_ng@scdf.gov.sg.

Yours faithfully,

(transmitted via e-mail)

MAJ Tan Chung Yee
Fire Safety & Shelter Department
for Commissioner
Singapore Civil Defence Force

cc

CEO, BCA
CEO, URA
CEO, HDB
CEO, JTC
CE, LTA
CE, SPRING Singapore
President, REDAS
President, IFE
President, SISV
President, FSMAS
President, SCAL
Honorary Secretary, SPM
SCDF Fire Safety Standing Committee
Fire Code Review Committee

Annex A

Fire Safety Waivers to be substantiated with Fire Engineering Studies

SN	Waiver Clauses to be substantiated with fire engineering studies	Fire Code Requirements
1	1.2.1(A) Minimum air well size	To assess if the smaller air well size (10 to 14m) is sufficient for the ventilation of staircase
2	2.2.13(a) 2.2.13(b) (i) (iii) (iv) Smoke free approach to exit staircase	To assess if the non-compliance of the following is sufficient for smoke free approach: • Min width of 6m for air well and not less than $93m^2$ • At least 15% of floor area and not more than 9m from any part of the lobby • Cross ventilated corridor with at least 50% of the superficial area of the opposing external wall and any part of the corridor shall not be more than 13m from the opening
3	2.2.15 (c) External corridor serving area of refuge	To assess the deficiency of the external corridor serving the area of refuge
4	2.3.2 (c) External Exit Passageway 2.3.2 (d) Internal Exit Passageway	To assess if the non-compliance in the design and ventilation requirement of external exit passageway will affect egress of occupants To assess if the non-provision of 15% ventilation opening will affect egress of occupants
5	2.3.3 (a) (iii) Unprotected opening from internal staircase (1.5m horizontally and 3m vertically)	To assess the effect on the shortfall of the 1.5m horizontal and 3m vertical setback to ventilation opening of internal staircase
6	2.3.3 (b) (ii) Unprotected opening from external staircase (3m horizontally and 3m vertically)	To assess the effect on the shortfall of the 3m horizontal and vertical setback to external staircase
7	2.3.3 (c) (i) (ii) (iii) Protection at the staircase discharge	To assess the safety at the discharge point if the design deviates from code requirement: <u>Residential</u> • 50% of the staircase can discharge into covered circulation space with no commercial activity and not more than 10m to the exterior

		• Must be within sight to exterior and provided with 2 alternative routes • Not more than 4 residential units at the circulation space Discharge point to be cross ventilated with 50% permanent opening at each end <u>Others</u> • Not more than 5m to exterior from open sided external corridor (all staircases) • For sprinkler building, 50% of the discharge can be into circular space without commercial activity and not more than 10m to the exterior • Where there is commercial activity, a minimum 10m separation distance to be maintained between escape path and the commercial activities. The circulation space must have engineered smoke system or properly compartmented
8	2.3.3 (f) Ventilation requirement for exit staircase	To assess the effect on the shortfall of the 10% ventilation opening on the egress of occupants
9	2.4.5 (f) Smoke free approach to exit staircase for residential occupancy	To assess the effect on the shortfall of the ventilation width for the smoke free approach: • Ventilation opening to be minimum width of 2000mm and minimum height of 1200mm
10	2.4.8 Smoke free approach to exit staircase for residential occupancy via external corridor concept	To assess if the non-compliance in the design and ventilation requirement of external corridor will affect egress of occupants
11	2.4.13 Common internal corridor - means of ventilation for residential occupancy	To assess the effect on the ventilation for the common internal corridor if the design deviates from code requirement: • Ventilation opening to be at least 15% of floor area and not more than 9m from any part of the common internal corridor. • For a cross ventilated corridor design, fixed openings at opposing external wall to

		be at least 50% of the superficial area of the walls and no part of the corridor shall be more than 13m away from the ventilation opening
12	2.5.1 (iv) (4) (5) (6) Internal access corridor to patient accommodation ward	To assess the effect on the ventilation for the internal corridor if the design deviates from code requirement
13	2.5.1 (v) (1) (3) External corridor to patient accommodation ward	To assess the effect on the ventilation for the external corridor if the design deviates from code requirement
14	2.7.1 (c) Ventilation requirement for internal corridor (hotels, boarding houses, serviced apartments, hostels, backpackers hotel)	To assess the effect on the ventilation for the internal corridor if the design deviates from code requirement: • Cl 2.2.13 (b) (i) & (iv) • Min width of 6m for air well and not less than 93m^2 • At least 15% of floor area and not more than 9m from any part of the lobby • Cross ventilated corridor with at least 50% of the superficial area of the opposing external wall and any part of the corridor shall not be more than 13m from the opening
15	2.7.2 External corridor design (hotels, boarding houses, serviced apartments, hostels, backpackers hotel)	To assess the effect on the ventilation for the external corridor if the design deviates from code requirement
16	2.9.3 (c) (d) (e) Ventilation requirement for internal corridor serving workers' dormitories	To assess the effect on the ventilation for the internal corridor if the design deviates from code requirement: • Fixed opening of at least 15% of the floor area and not less than 3.5m and be positioned on opposite side of the corridor for cross ventilation • Ventilation opening in the external wall shall not be more than 12m from any part of corridor
17	2.9.4 External corridor serving workers' dormitories	To assess the effect on the ventilation for the external corridor if the design deviates from code requirement
18	3.2.8 (c) (i) (ii) Compartmentation requirement for open sided car park	To assess the effect on the compartmentation if the design deviates from code requirement: • 50% permanent fixed openings evenly distributed along the perimeter walls and on every floor/deck. No part of the floor shall be more than 12m from the openings on the perimeter walls

Annex L - List of Fire Code deviations that cannot be addressed using a PB approach

Situations Deemed Unsuitable for Use of Performance-Based (PB) Approach

S/No	Category	Nature of deviations & related clauses
1	There is no suitable fire engineering methodology available and relevant to attain the fire safety objectives.	• Use of PB to assess fire-fighting provisions and ease of fire-fighting, fire lift, etc o Chapter 4 of Fire Code 2018. o Clause 6.6 of Fire Code 2018 on lifts e.g. compartmentation of fire lifts, etc. • Deviations involving provisions for Person With Disabilities (PWD) o Clause 2.4 of Fire Code 2018. • Variation in occupant load density o Table 1.4B of Fire Code 2018 on occupant load factors • Maximum width (2m) of each exit staircase o Clause 2.2.8 of Fire Code 2018
2	The consequences of the Fire Code deviation (regardless of whether there is a PB methodology to address the Fire Code deviation) are considered severe.	• Use of PB to assess the provision of single staircase internal discharge for residential development - o Clause 2.3.3(c)(3) of Fire Code 2018. o Clause 9.2.1(a)(10)(a) of Fire Code 2018 • Provide single staircase instead of multiple staircases o Clause 2.2.11 of Fire Code, and its related clauses in other parts of the Fire Code. • Remoteness of exits o Clause 2.3.12 of Fire Code 2018 • Cases involving provisions intended for redundancy e.g. provision of standby fans for engineered smoke control systems o Clause 7.4.5(m) of Fire Code 2018. • Omission of Smoke Stop Lobby and Fire Lift Lobby o Clause 2.2.13 b. of Fire Code 2018
3	The risk is not easily quantifiable, i.e. fire risks involving probabilities.	• Non-compliance to one-way travel distances or dead-end distance (There is a chance for the sole means of escape to be disrupted, leading to severe consequences.) o Clause 2.2.6 and Table 2.2A of Fire Code 2018. o Exception: The extended one-way distance is protected. • Omission of exit staircase protection for more than one side of the staircase (A much higher chance for exit staircase to be compromised)

Updated on 06 Sept 2023 with consultation with the SFEG Committee

S/No	Category	Nature of deviations & related clauses
		o Clause 2.3.3(a)(1) of Fire Code 2018. • There are more than 2 doors opening into internal exit passageway (this increases the chances of smoke infiltrating the exit passageway. o Clause 2.3.2(b)(2) of Fire Code 2018. • No direct access to exit staircases for childcare occupancies (to safeguard children's escape and prevent them from disorientating when exposed to common egress routes without authoritative guidance) o Clause 9.3.2(d)(3) of Fire Code 2018 • There are no dedicated staircases for cinema occupancies exceeding 200 persons (Occupants may be disorientated during egress, and there may be a sudden surge of cinema patrons into common escape areas, leading to congestion and affecting other occupants) o Clause 9.7.3(b)(2) of Fire Code 2018 o Can consider PB solution if there is at least one dedicated staircase solely for cinema patrons • More than 4 residential units opening into discharge floor of residential development having not more than 50% of staircases discharging internally - o Clause 2.3.3(c)(3)(d) of Fire Code 2018.
4	The proposal does not align with prescriptive-based fire safety design policies.	• Omission of both sprinklers system & fire rating o Sections 3.3 and 6.4 of Fire Code 2018 o Discourage stacked deviations • Proposals to adopt mechanical ventilation for smoke stop lobbies in residential developments o Clause 2.2.13(b)(7)(b) of Fire Code 2018 o Lead to potential future requests for removal/non-maintenance of ventilation systems by condominium management • Omission of sprinklers or fire alarm systems (Such systems are crucial for fire suppression as well as to provide early warning to occupants.) o Clause 6.3 of Fire Code 2018 & SS 645 o Clause 6.4 of Fire Code 2018 & CP 52 o Exceptions – PB can be considered only in situations when the fuel load is clearly limited based on building owner's operating processes, and there are site constraints which cannot be resolved.

S/No	Category	Nature of deviations & related clauses

		• Compartmentation exceeds one-storey for areas above 24m in habitable height (Undesirable situation – fires can spread to multiple floors at high levels, making it difficult for emergency responders to mitigate)
		  o Clause 3.2.4(b) of Fire Code 2018
		  o Exceptions – PB can be considered for large internal open spaces and unenclosed open-sided situations such as atriums, vehicle ramps, open-sided terraces, etc. There is lesser risk to occupants and emergency responders as smoke can easily disperse.
		
		• More than 50% of exit staircases for new sprinkler-protected buildings discharge internally *(For premises requiring multiple exit staircases)*
		  o Clause 2.3.3(c)(2) of Fire Code 2018
		  o For new erections, it will be much easier for new buildings to design for proper discharge of exit staircases at the outset. This deviation should not be encouraged unless there are site constraints which cannot be overcome.
		
		• Delay in activation of engineered smoke control system (ESCS) – e.g. use of sprinklers instead of smoke detectors to activate ESCS
		  o Clause 7.4.5 k. (1) of Fire Code 2018
		  o ESC should be activated early so as to prevent occupants from being exposed to more severe fire risk.
		  o Exceptions – PB can be considered for such deviations in vehicle workshops, parking areas, loading bays and driveways where there is a buildup of exhaust smoke.
		
		• Maximum compartmentation size and storage height in Table 9.8A of Fire Code 2018.
		
		• Shortfall of separation distance between petrol service station and commercial/residential premises
		  o Clause 9.6.2(a)(2) of Fire Code 2018

SCDF
The Life Saving Force
SINGAPORE CIVIL DEFENCE FORCE

Your Ref : **Our Ref:**CD/FSSD/12/02/03/01

Date : 16 Sep 2016

Registrar, Board of Architects
Registrar, Professional Engineers Board
President, Singapore Institute of Architects
President, Institution of Engineers, Singapore
President, Association of Consulting Engineers, Singapore

Dear Sir/Mdm

SCI PUBLICATIONS P288 AND P390 FOR FIRE SAFETY DESIGN OF MULTI-STOREY STEEL-FRAMED BUILDINGS WITH COMPOSITE SLABS

Currently, the Fire Code requires any element of structure to have fire resistance in compliance with Clauses 3.3 and 3.4. Fire protection is thus required for structural steel elements, including secondary steel beams.

2. The SCI Publication P288 titled "Fire Safety Design: A new approach to multi-storey steel-framed buildings" allows a Performance-Based (PB) approach to fire safety design of multi-storey steel-framed buildings with composite slabs. The publication provides information on building structural behaviour and identifies steel members which do not require fire protection. It is used in conjunction with SCI Publication 390 titled "TSLAB v3.0 User Guidance and Engineering Update" and its accompanying software TSLAB v3.0. Many buildings in UK have since benefited from the application of SCI Publications P288 and P390, resulting in reduced fire protection cost and improved construction productivity (e.g. no fire protection required for secondary steel beams).

3. SCDF does not have objection to the adoption of such design approach by building practitioners provided the building is sprinkler-protected and the unprotected beams shall be designed and detailed with embedded shear studs. Building

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practitioners are also advised to use the SCI Publications P288 and P390 together with the Design Commentary published by Nanyang Technological University (Annex A). Such plans of fire safety works shall be submitted to SCDF under the PB regulatory system.

4. Please convey the contents of this circular to members of your Board / Institution /Association. This circular is also available in CORENET-e-Info: http://www.corenet.gov.sg/einfo. For any clarification, please contact: LTC Chong Kim Yuan at DID: 68481476 or email: Chong_Kim_Yuan @ scdf.gov.sg.

Yours faithfully,

(transmitted via e-mail)
MAJ Tan Chung Yee
Fire Safety & Shelter Department
for Commissioner
Singapore Civil Defence Force

Distribution list

CEO, BCA
CEO, URA
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SCDF Fire Safety Standing Committee
Fire Code Review Committee

SCDF
The Life Saving Force
SINGAPORE CIVIL DEFENCE FORCE

Your Ref :

Our Ref: CD/FSSD/12/02/03/01

Date : 10 Aug 2016

Registrar, Board of Architects
Registrar, Professional Engineers Board
President, Singapore Institute of Architects
President, Institution of Engineers, Singapore
President, Association of Consulting Engineers, Singapore

Dear Sir/Mdm

AMENDMENT TO FIRE CODE – FIRE SAFETY REQUIREMENTS FOR ENGINEERED TIMBER[1] BUILDING CONSTRUCTION

In Mar 2014, SCDF had issued a circular to allow the use of cross laminated timber for building construction, subject to a list of conditions imposed to mitigate the fire risks arising from such combustible construction[2]. Following a recent review undertaken to support greater productivity efforts in the use of engineered timber, and further developments overseas regarding the use of engineered timber for construction, SCDF has revised the list of conditions for engineered timber building construction.

2. The revised fire safety requirements for engineered timber building construction can be found in Annex A.

3. This circular shall take effect on 10 August 2016, and will supersede the earlier circular dated 6 March 2014 on Fire Safety Requirements for Cross Laminated Timber Building Construction.

[1] Engineered timber refers to mass timber products that are manufactured according to established standards accepted by SCDF. Examples of mass timber products are cross laminated timber (CLT) and glued laminated timber (GLT) structural elements manufactured in accordance with EN 16351 and EN 14080 respectively.
[2] Clause 3.15.2 of the Fire Code requires all elements of structure to be constructed of non-combustible materials. A circular was issued on 6 Mar 2014 to relax this requirement and allow CLT (which is a combustible material) to be used as elements of structure of a building, subject to certain conditions.

SCDF – A member of the Home Team

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4. Please convey the contents of this circular to members of your Institution/Association/Board. The circular is made available in CORENET-e-Info: http://www.corenet.gov.sg. For any enquiry or clarification, please contact LTC Tong Hong Haey at 68481448 or email him at Tong_Hong_Haey@scdf.gov.sg.

Yours faithfully,

(transmitted via e-mail)

MAJ Tan Chung Yee
Fire Safety & Shelter Department
for Commissioner
Singapore Civil Defence Force

cc

CEO, BCA
CEO, URA
CEO, HDB
CEO, JTC
CE, SPRING Singapore
President, REDAS
President, IFE
President, SISV
President, FSMAS
President, SCAL
Honorary Secretary, SPM
SCDF Fire Safety Standing Committee
Fire Code Review Committee

FIRE SAFETY REQUIREMENTS FOR ENGINEERED TIMBER BUILDING CONSTRUCTION

Pre-design stage

(a) The Qualified Person (QP) responsible for the design of the engineered timber building project shall inform SCDF of the project prior to the design and construction of the project.

(b) The QP responsible for the design of the engineered timber building project shall ensure that the engineered timber product is listed in accordance with the requirements of the product listing scheme.

Building design

(c) The habitable height[3] of any healthcare occupancy[4] in an engineered timber building shall not exceed 12m, including mezzanine levels.

(d) A fire safety performance-based (PB) approach shall be adopted in the design of any engineered timber building where its habitable height exceeds 12m.

(e) The engineered timber building shall be fully protected by an automatic sprinkler system.

i. Exception: Sprinkler systems can only be exempted under the following circumstances:

(1) Alternative fire protection measures (eg. fully encapsulated timber elements) are provided to minimise fire damage to the timber structures, in lieu of the sprinkler system, and
(2) The building does not exceed 12m in habitable height, and
(3) The building is protected by an automatic fire alarm system compliant with CP 10 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems, and
(4) The building does not contain any healthcare occupancy.

[3] The habitable height is the height measured from the lowest level of fire engine accessway or access road to the finished floor level of the highest habitable floor.
[4] Healthcare occupancy refers to premises intended as the accommodation areas of a healthcare development such as hospital or nursing home. Occupants in healthcare premises often require some form of assistance during evacuation in fire emergencies.

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(f) Where an automatic sprinkler system is required, the system shall be designed in accordance with CP 52 Code of Practice for automatic fire sprinkler system requirements. The automatic sprinkler system shall not be shared among different engineered timber buildings if the latter is under different occupier. If the external facade of the engineered timber building is unable to meet the stated performance in the prevailing Fire Code for prevention of external fire spread, the external facade shall be required to be protected by a deluge system in accordance to CP 52, or any other suppression system that is shown to be effective in preventing vertical fire spread.

(g) The use of engineered timber for elements of structure shall be permitted only for areas above the floor slab of the ground floor. The ground floor slab and basement floors below it shall not have elements of structure constructed using engineered timber.

(h) Essential escape provisions such as staircase shafts and lift shafts of an engineered timber building shall be constructed of non-combustible materials which achieve the necessary fire resistance rating.

   i. Exception: Engineered timber can only be used as elements of structure for essential escape provisions under the following circumstances:

      (1) The surfaces of engineered timber elements shall be protected by fire-rated board so that the composite element is able to achieve the necessary fire rating, and
      (2) The building does not exceed 12m in habitable height, and
      (3) The building does not contain any healthcare occupancy, and
      (4) This exception shall not apply to staircase shelters designed to comply with the Technical Requirements for Storey Shelters.

(i) Essential facilities for fire safety and fire-fighting operations (such as Fire Command Centre, fire pump rooms, generator rooms, and smoke-stop/fire-fighting lobbies) shall be separated from other areas of the engineered timber building project by non-combustible material or encapsulated engineered timber[5], either of which must achieve the necessary fire resistance rating.

(j) The use of flammable gas cylinders for cooking is not permitted in the engineered timber building premises if the engineered timber building has access to piped-gas supply for cooking.

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[5] Engineered timber elements protected with fire-rated boards.

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(k) Where the usage of the building potentially involves the use of flammable gas cylinders (either for cooking, storage, factory production, etc) which may result in explosions, the use of engineered timber as elements of structure is not allowed unless the engineered timber building is designed to take into account the explosive actions based on EN 1991[6] or other relevant internationally recognised standards, so as to manage the impact of such explosions on the building structure.

(l) Residential engineered timber building projects shall fully comply with the technical requirements for household and storey shelters.

(m) The engineered timber building project shall comply with the design & fire test performance requirements stipulated in European (EN) standards which include BS EN 1995, BS EN 1363, BS EN 1365 & other internationally recognised standards deemed appropriate and necessary by SCDF. In addition, the engineered timber building shall also comply with all other requirements in the prevailing Fire Code.

Building under construction

(n) During the construction stage, the QP responsible for the engineered timber building project shall ensure that the engineered timber project work site complies with the Fire Safety Requirements for Buildings Under Construction in the prevailing Fire Code. In addition, there shall be no smoking or use of naked flames within the engineered timber project worksite.

Maintenance of automatic fire detection/suppression systems

(o) Where automatic fire detection/suppression systems are installed, the engineered timber building owner shall undertake to engage a QP to conduct annual inspection of these systems and to submit inspection reports to SCDF[7].

General compliance

(p) Compliance with all the above requirements for an engineered timber building project does not exempt the owner of the engineered timber building from the need to obtain the necessary permits or approval of plans from the relevant authorities, including SCDF.

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[6] Although single occupancy houses not exceeding 4 storeys are exempted from such assessment of explosive actions in EN 1991, this exemption shall not apply for such engineered timber buildings in Singapore.
[7] See Fire Safety (Fire Certificate)(Designated Buildings) Order 2016.

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