# TENABILITY IN STAIRWELL OF HIGH-RISE OFFICE BUILDINGS

Submitted by

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## Abstract

The commonly adopted fire evacuation strategy for office buildings is total evacuation which involves simultaneous evacuation of all building occupants upon fire alarm activation. Total evacuation for building with high occupancy load will cause congestion within stairwell which often results in long queuing time at the stairwell door. Long queuing time on the fire floor causes the stairwell door to remain open for extensive period, and the smoke from the fire floor will enter the stairwell resulting in untenable conditions within the stairwell. This can have devastating effects on egressing occupants. This research utilises the state-of-the-art modelling tools such as FDS and FDS+Evac to study high-rise office building with two means of escape. The aim was to demonstrate that for certain building parameters, phased evacuation should be adopted instead of total evacuation to ensure an acceptable tenability level within the stairwells which permits safe evacuation of the occupants.

A total of 48 unique simulations were identified based on varying building parameters such as floor area, building height, fire protection system, evacuation strategy and ceiling height. Relevant New Zealand Building Code (NZBC) Compliance Documents such as C/AS5, C/VM2 and D1/AS1 were used as guidelines to define the various modelling parameters such as fire growth and combustion characteristics, fire safety systems, modelling rules, evacuation parameters and geometries to ensure the modelled building achieves the minimum NZBC requirements. The use of FDS+Evac for simulating evacuation timings without the effect of smoke was validated to some extent against hydraulic models and relevant trial evacuation experiments found in the literature.

The results demonstrate that for high-rise office buildings up to 20 storeys with floor area not exceeding 510 $m^2$ served by either conventional or scissor stairwell, the tenability within the stairwell can be maintained during total evacuation by having at least a Type 6 automatic fire sprinkler system. For high-rise office buildings between 10 to 20 storeys with floor area of 5000 $m^2$ or 2450 $m^2$ served by either conventional or scissor stairwell, those buildings are required be protected by Type 7 automatic fire sprinkler system with smoke detection and phased evacuation are also required to maintain tenability within the stairwell.

The effect of stair arrangement on the tenability in the stairwell is more evident in high-rise office buildings with high occupancy load where scissor stairwell is found to be worse than conventional stairwell. This is due to the nature of scissor stair arrangement which forces smoke to flow up the stairwell in a corkscrew manner, concentrating smoke along a specific path. This phenomenon is found to be detrimental to the tenability conditions in the stairwell.

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## Definitions

| | |
|---|---|
| *ASET FED* | Available safe egress time based on $FED_{gas}$ threshold ($FED_{gas}$ > 0.3) |
| *ASET VIS* | Available safe egress time based on visibility threshold (VIS < 5 m or VIS < 10 m) |
| *Conventional stairs* | Single set of staircase within a stairwell shaft |
| *Coupled simulation* | Simultaneous running of FDS and FDS+Evac within a single simulation |
| *Decoupled simulation* | FDS and FDS+Evac simulation are conducted separately and independently |
| *$FED_{gas}$* | Fractional effective dose of narcotic gas at any specified locations within the computational domain |
| *High ceiling* | Floor to ceiling height of 3.3 m |
| *Large floor* | Large open plan office floor area |
| *LH* | Layer height measured from the ceiling at any specified locations within the computational domain (m) |
| *LLT* | Lower layer temperature at any specified locations within the computational domain ($^{o}$C) |
| *Low ceiling* | Floor to ceiling height of 2.7 m |
| *Medium floor* | Medium open plan office floor area |
| *NZBC* | New Zealand Building Code |
| *Phased Evacuation* | Specific to this study – The evacuation of occupants on the fire floor is prioritised over other occupants in the rest of the building (i.e. Fire floor occupants to completely evacuate floor of fire origin) |

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| *Place of safety* [4] | Place of safety means either –<br>(a) a *safe place*; or<br>(b) a place that is inside a building and meets the following requirements:<br>i. the place is constructed with fire separations that have fire resistance sufficient to withstand burnout at the point of the fire source; and<br>ii. the place is in a building that is protected by an automatic fire sprinkler system that complies with NZS 4541 or NZS 4515 as appropriate to the building's use; and<br>iii. the place is designed to accommodate the intended number of persons; and<br>iv. the place is provided with sufficient means of escape to enable the intended number of persons to escape to a safe place that is outside a building. |
| *RSET* [6] | Required safe egress time to reach a place safety or relative safety |
| *Safe place* [4] | A place, outside of and in the vicinity of a single building unit, from which people may safely disperse after escaping the effects of a fire. It may be a place such as a street, open space, public space or an adjacent building unit. |
| *Scissor stairs* | Two intertwined staircases within a stairwell shaft |
| *Small floor* | Small open plan office floor area |
| *TEMP* | Temperature at any specified locations within the computational domain ($^{o}C$) |
| *Total Evacuation* | Simultaneous evacuation of all occupants in a building during the event of an emergency |

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| *Type 6* [4] | Automatic fire sprinkler system |
| *Type 7* [4] | Automatic fire sprinkler system with smoke detection and alarm system |
| *ULT* | Upper layer temperature at any specified locations within the computational domain ($^oC$) |
| *VIS* | Visibility at any specified locations within the computational domain (m) |

## Nomenclature

| | |
|---|---|
| $A_f$ | Floor area of enclosure ($m^2$) |
| *a* [6] | Constant for evacuation speed and flow calculation (0.266 for speed in m/s and density in persons/$m^2$) |
| *α* [72] | Experimental constant used in FDS+Evac for calculating walking speed in smoke (0.706 $m^2\ s^{-1}$) |
| *β* [72] | Experimental constant used in FDS+Evac for calculating walking speed in smoke (-0.057 $m^2\ s^{-1}$) |
| C [6] | Sprinkler C-factor ($m^{1/2}\ s^{1/2}$) |
| $c_p$ | Specific heat of air at ambient (kJ/kg K) |
| *D* | Density of population (persons/$m^2$) |
| *D** [59] | Characteristic fire diameter |
| *δx* [59] | Mesh size (m) |
| $F_d$ [6] | Evacuation flow through doorway (persons/s) |
| $F_s$ [6] | Evacuation flow in stairs (persons/s) |
| *g* | Gravitational constant (m/$s^2$) |
| $H_e$ | Average height of enclosure (m) |
| $\Delta H_c$ | Heat of Combustion (MJ/kg) |
| *k* [6] | Constant for evacuation speed and flow calculation (value varies based on the exit route element – corridor, aisle, ramp, doorway and stairs) |
| $K_s$ [32] | Extinction coefficient (1/m) |
| $\rho_a$ | Density of air at ambient (kg/$m^3$) |
| $\dot{Q}$ | Fire heat release rate (kW) |

| | |
|---|---|
| $\dot{Q}^*$ [48] | Non-dimensional heat release rate |
| RTI [6] | Response time index ($m^{1/2}$ $s^{1/2}$) |
| $S$ | Travel speed of occupant (m/s) |
| $T_a$ | Ambient temperature (K) |
| $T_{act}$ | Sprinkler activation temperature ($^oC$) |
| $t_d$ | Detection time determined from deterministic modelling [s] |
| $t_n$ | Time from detection to notification of the occupants [s] |
| $t_{pre}$ | Time from notification until evacuation begins [s] |
| $v_i^0$ | Unimpeded walking speed (m/s) |
| $v_{i,min}^0$ | Minimum walking speed (m/s) |
| $W$ | Effective width of constriction (m) |
| $Y_{CO}$ | Pre-flashover Carbon Monoxide yield (kg/kg) |
| $Y_{CO2}$ | Carbon Dioxide yield (kg/kg) |
| $Y_{H2O}$ | Water yield (kg/kg) |
| $Y_{soot}$ | Pre-flashover soot yield (kg/kg) |

# 1. Introduction

## 1.1 Overview

Stairwell in high-rise buildings serves as an important route of egress for occupants to evacuate the building in the event of a fire. Smoke logging of stairwells can have serious consequences during building fires especially for high-rise buildings with significant occupant load. A few examples of fires in high-rise buildings where smoked-logged stairwells contributed to fire fatalities are the MGM Grand Hotel Fire [1], Cook County Administration Building [2] and The Forest Laneway Fire [2]. Thus, it is important to protect the stairwell from fire and the ingress of smoke.

The building code typically requires protection to be provided to the stairwell by complete fire separation and effectively forming a vertical safe path. A vertical safe path is achieved by providing adequate fire resistance rating (FRR) to the solid partition forming the stairwell shaft which creates a complete fire and smoke separation between the stairwell and the rest of the building. However, in the event of an emergency evacuation, the fire and smoke rated construction of the stairwell will inevitably be compromised as the occupants attempt to evacuate the floor spaces. In particular, buildings with high occupancy loads will often have queuing at the stairwell doors which keeps the doors open thus allowing smoke from the fire floor to infiltrate the stairwell over the queuing period. Depending on various building/fire/egress parameters, the amount of smoke infiltrating the stairwell may be sufficient to compromise the tenability within the stairwell, especially for occupants egressing from the floors above as smoke accumulates and fills the volume above the fire floor due to buoyancy.

In this study, six main parameters that can have impact on smoke filling of the stairwell are identified to be (1) building geometries, (2) fire location, (3) fire characteristics, (4) fire protection systems, (5) building occupancy type and (6) evacuation strategy:

- **Building geometries** refers to the physical attributes of the building such as the floor area, width of escape routes, stairs arrangement (conventional stairs or scissor stairs), building height, ceiling height of the floor space etc.
- **Fire location** relates to the location of the fire within a floor space, as well as the location of the fire floor within the entire building.

- **Fire characteristics** are associated with the heat release rate (HRR), species production and heat of combustion.
- **Fire protection systems** refer to the presence of any active or passive fire protection. Passive fire protection includes compartmentalisation of the building through the use of fire-resistance rated constructions. Active fire protection comprises manual or automatic fire detection and suppression. Active fire protection can have an effect on the evacuation time as well as the maximum fire size (for e.g. – activation of sprinkler head is assumed to control the HRR of fire).
- **Building occupancy type** will determine the maximum number and capabilities of the occupants expected to occupy a given floor area, and this will have an impact on the evacuation time.
- **Evacuation strategy** refer to different egress strategies that can be adopted to evacuate the occupants from a building in the event of an emergency.

In order to demonstrate high-rise building with high occupancy load (for e.g. office) can be susceptible to smoke filling of the stairwell, an egress hand calculation was carried out based on the method prescribed in the SFPE Handbook [3] on a 20-storey office building with 123 people/floor using a stairwell. The queuing time at the stairwell door was found to be in the order of 40 minutes. Consider the case where the fire floor is the floor with the longest queuing time, smoke from the fire floor will infiltrate the stairwell for the duration (40 minutes) of queuing. In addition, simultaneous evacuation of the occupants will result in stairwell doors on all floors opening at roughly the same time thereby reducing the effectiveness of stairwell pressurisation system which is typically installed in the stairwell of high-rise building.

Qualitatively, permitting smoke to fill the stairwell for a long duration is highly unfavourable especially for occupants above the fire floor. However, quantitative analysis will need to be carried out to determine the extent of this problem, accounting for the different building/fire/egress parameters mentioned above. The impetus of this research is to quantify the impact of building/fire/egress parameters on the occupants' ability to safely evacuate from the stairwells of a high rise building.

## 1.2 Research Objective

High-rise buildings are typically used as offices, accommodation or mixed-use such as retail/offices or retail/accommodation. For mixed-use high-rise building, it is common for retail spaces to occupy the lower floors for accessibility whereas offices/accommodation tend to occupy the upper floors. One of the major challenges around fire safety of high-rise buildings is to get occupants out of their building safely in the event of an emergency. High-rise office buildings tend to be more challenging compared to high-rise accommodation buildings from a fire safety perspective simply due to the occupancy load of office buildings being much greater than that of the accommodation buildings. A higher occupancy load will lead to longer and more complex evacuation process.

This research focuses solely on high-rise office buildings due to their challenging nature from a fire safety perspective. The objective of this research is to investigate and identify the combinations of building parameters that results in untenable condition for the egressing occupants in the event of a fire within high-rise office buildings. The scope of this research is confined to high-rise office buildings with two means of escape comprising a conventional stairwell and a scissor stairwell allowing the smoke filling characteristics of different stair arrangements to be investigated. This research adopts a fully analytical approach through the use of the-state-of-the-art computer modelling tools.

Given that there is a wide range of building parameters which may potentially affect the tenability in a high-rise building, the scope of this research has been refined to vary only the following building parameters listed in order to create a number of unique simulations.

- Floor area
- Building height
- Fire protection system
- Evacuation strategy
- Floor ceiling height

The following New Zealand Building Code (NZBC) compliance documentations are used as guidelines for defining the various modelling parameters such as fire growth and combustion characteristics, fire protection systems, modelling rules, evacuation parameters and building geometries. This is to ensure that the case study buildings meet the minimum NZBC requirements.

- C/AS5 – Acceptable Solution for Buildings used for Business, Commercial and Low Level Storage [4]
- D1/AS1 – Acceptable Solution for Access Routes [5]
- C/VM2 – Verification Method: Framework for Fire Safety Design [6]

The intention of this study is to provide information to assist the Fire Engineering stakeholders to make informed decision on the optimum strategy to evacuate high-rise office building based on the research outcome deduced from the analysis. The quantitative outcomes of this research are intended to be used by Fire Engineering stakeholders as reference to make informed decision to further develop the framework for fire safety design.

## 1.3 Modelling & Analysis Approach

Each simulation in this study has two main components – fire and evacuation. The modelling approach is to choose a fire and an evacuation model which are readily available and suitable for the study of each simulation.

The fire model is designed to numerically predict the fire-induced conditions in an enclosure as a function of time. The output from the fire model provides information on the tenability conditions within the modelled enclosure. Based on defined tenability criteria, the available safe egress time (ASET) can be determined from the fire model. ASET is the calculated time interval from the time of ignition of a fire to the time when the enclosure conditions result in the incapacitation of the occupants. The tenability criteria defined in NZBC's C Clauses are presented below in italics and are adopted without prejudice in this research.

> *C4.3 The evacuation time must allow occupants of a building to move to a place of safety in the event of a fire so that occupants are not exposed to any of the following:*

*a) a fractional effective dose of carbon monoxide greater than 0.3;*

*b) a fractional effective dose of thermal effect greater than 0.3;*

*c) conditions where, due to smoke obscuration, visibility is less than 10 m except in rooms of less than 100 $m^2$ where visibility may fall to 5 m.*

*C4.4 Clause C4.3 (b) and (c) do not apply where it is not possible to expose more than 1000 people in a firecell protected with an automatic fire sprinkler system.*

Evacuation modelling is used to simulate the movement of occupants to obtain evacuation timings. The output from evacuation model allows the required safe egress time (RSET) to be determined. RSET is defined as the calculated time period required for an individual occupant to travel from their location at the time of ignition to a place of safety (Refer to Definitions). RSET is defined by Equation 1 as given in C/VM2 for detailed egress modelling and is used as a basis for evacuation timings in this research.

$$RSET = (t_d + t_n + t_{pre}) + (t_{trav} \text{ or } t_{flow}) \qquad \text{(Equation 1)}$$

*Where*

$t_d$ = *detection time determined from deterministic modelling*

$t_n$ = *time from detection to notification of the 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*

The ASET/RSET analysis is the chosen comparative approach for evaluating the pass/fail of each simulations in regards to life safety. For ASET > RSET, the occupants are expected to have safely evacuated without being overcome by the effects of fire and/or smoke. Conversely, if ASET < RSET, the occupants are expected to be incapacitated by the effect of fire and/or smoke before they can safely evacuate.

## 1.4 Outline of this Research

Chapter 2 presents a brief background on high-rise office buildings, evacuation strategy for high-rise and the review of fire and evacuation models within the literature. The decision to use FDS for fire modelling and FDS+Evac for egress modelling are also presented in this chapter.

Chapter 3 presents a total of six building parameters – (1) floor area, (2) building height, (3) active fire protection systems, (4) evacuation strategy, (5) floor ceiling height, and (6) stair arrangements which form the scope of this research. The selected variables for each parameter are discusses and the total number of unique simulations based on the variables for each parameters are determined.

Chapter 4 describes the detailed model set-up for FDS and FDS+Evac respectively. Detailed model set-up of FDS includes fire location, fire protection systems, model leakages, model geometries and location of measuring devices. For FDS+Evac, the detailed model set-up includes evacuation model geometries and evacuation parameters such as occupant body types, travelling speeds and pre-evacuation times.

Chapter 5 begins with presenting preliminary modelling results and the relevant analysis and ends with the comparison between FDS+Evac preliminary modelling results, hydraulic calculations and relevant literature values. Preliminary modelling is comprised of evacuation only modelling (without the effects of fire) and fire only modelling (without evacuation). Evacuation only modelling is required to obtain second-order estimate of the stairwell door opening duration. Fire only modelling is conducted to obtain detection time which affects the initial stairwell door opening time.

Chapter 6 compares the results of coupled and decoupled simulations (evacuation of occupants with and without the effects of fire) for a number of most onerous simulations. This is due to research constraints where not all simulations are practically able to be completed as coupled simulations. This chapter also presents results and analysis for two simulations which are deemed representative of the rest of the simulations.

Chapter 7 discusses the findings from the modelling results and analysis of each unique simulation. The discussion focuses on the tenability conditions and evacuation within the fire floor, floor above and stairwells.

Chapter 8 concludes this research and provides recommendations for future works.

# 2. Background and Models Selection

## 2.1 High-rise Office Buildings

### 2.1.1 History and Definitions

High rise buildings began to appear around the 1880's [7], and one of the first high-rise office building was constructed in 1889 reaching a height of 309 feet (94 m) [8]. Since then, high-rise office buildings began to grow dramatically, doubling and tripling in height. One of the main factors enabling increasing heights has been the improvements in construction technology, and the drive is to create great efficiencies in the use of real estate by providing office space for more people per square meter of land. However, these benefits have created a number of challenges in the event of an emergency, due to increased consequences of a disaster and long evacuation time of the occupants.

Over the years, not only the exterior construction has improved, the interior designs and fuel loads within high-rise office buildings have also changed significantly. Offices containing wooden desks and metal filing cabinets in the earlier days have now been replaced by modular offices which contains plastic products [9]. These innovations have contributed to faster fire growth, higher HRR and higher species yield (CO and soot production) which directly impact the tenability conditions. Consequently, these current interior features have increased the exposure of occupants to toxic and smoke-filled environments which rapidly challenges the required safe egress time given the shorter available safe egress time. These undesirable fire properties of plastic products have to be accounted for to ensure safe fire design of modern high-rise office buildings.

The current definition of high-rise building according to NFPA 101, *The Life Safety Code, 2015 Edition, Section 3.3.36.7* [10] is "a building where the floor of an occupiable story is greater than 75 ft (23 m) above the lowest level of fire department vehicle access". Confederation of Fire Protection Association-Europe (CFPA-Europe) [9] defines high-rise as a building with height ranging from a cut-off point of over 72 feet (22 m) to the highest point of over 164 feet (50 m) for office buildings. Other definition includes that of O'Hagan [7] which defines high-rise as building that lacks viable exterior access to upper floors for fire-fighting and over 100 feet (30 m). A less quantitate definition is provided by General Services Administration (GSA) [11] which states that high-rise buildings are those that are beyond the reach of fire brigade equipment where it provides potential for significant stack effect as well as requiring unreasonable evacuation time.

### 2.1.2 Safety Concerns

There are many situations that would trigger the evacuation of a high-rise office building with fire being one of the main causes. Pauls [12] noted that fire is usually considered the most probable reason for rapid evacuation of all or part of a building; however, other emergency conditions such as bomb threats, tornadoes, or loss of electricity might also lead to evacuation. The review of data according to the National Research Council Canada [12] has shown that for the past twenty-seven years, evacuation of high-rise office buildings has been primarily due to fire incidents and terrorism attacks.

Throughout the existence of high-rise office buildings, there have been a number of recorded fatal high-rise office fire incidents [13]. A study by Cowlard *et al.* [14] surveyed a total of 50 tall buildings between 10 to 110 storeys to establish the failure rates of critical elements to fire safety strategies within tall building. Some of the renowned fire in high-rise office buildings included in the survey are: Interstate Bank Building, One Meridian Plaza, and Cook County Administration Building which all reported to have premature loss of stairwell tenability. The common denominator for smoke-logged stairwell in those buildings is due to openings from the floor levels into the stairwell with one of the floor levels being the fire floor [15, 16, 17]. The openings are in the form of ventilation openings or stairwell doors on the fire floor. Those openings effectively permit the stairwell to function as chimney which is detrimental to the tenability conditions within the stairwell.

The means of escape, specifically the number of escape route is a safety concern for high-rise office buildings because it governs the duration for the occupants to clear the building during evacuation. NFPA 101 [18] requires two means of egress to be provided for occupancy load up to 500 per floor. Beyond 500 occupants but less than 1000 occupants, at least three escape routes shall be provided and beyond 1000 occupants, at least four escape routes shall be provided. These requirements are consistent with that specified within the NZBC C/AS5 document.

The distance of travel relating to fatigue of the occupants is another area of concern for high-rise building but it has not been considered extensively in the current fire engineering practice. Lo and Will [19] have authored a paper addressing the fatigue in travelling down stairs in high-rise buildings. They suggested that an area of refuge should be provided on every 18 floors to enable egressing occupants to rest during the evacuation of the building.

### 2.1.3 Evacuation Process

The primary emergency egress route in a high-rise building is the stairwell, through which occupants can escape from the building in case of a disaster such as fire. When attempting to evacuate a high-rise building, there are two primary phases involved – (1) travel time to stair and (2) time taken to descend the stairs to final exit or a place of safety which includes queuing at the door into the stair, within the stair and/or at the final exit. The first phase, especially for an open plan office building is relatively straightforward, where the occupants are expected to travel at maximum speed towards the stairs given the typical relatively low office density of 10 $m^2$/person [4]. The second phase is more complex, and it involves merging flow within the stairwell and subsequently flow through the final exit door.

There have been numerous studies on the evacuation process in stairwell by means of experiments, computer modelling and post incident analysis. According to Proulx [20], the factors affecting the evacuation efficiency in stairwell include staircase geometry, population density, simultaneous evacuation from several floors, and counter-flow. Study by Gwynne *et al.* [21] revealed that travel speed in stairwell is affected by the number of steps, angle of stairway, depth of tread, height of riser, and the presence and location of handrails. High population density in the stairwell due to evacuation from multiple floors will result in merging flow which is dependent on the merging behaviour of occupants and this flow and social aspects have not been researched in detail [22]. A number of studies have reported different trends of merging, for instance, occupants in stairs may dominate over occupants entering the stairs [23, 24, 25], and vice versa [26]. There are also cases where neither dominate, and the occupants on the floor and those in the stairs proceed down the stairs with a merging ratio of approximately 50:50 [27]. Stairwell merging flow in this research is accounted for simply by adopting the people movement algorithm built into the chosen evacuation model. Detailed study of the impact of merging flow is outside the scope of this research.

The ideal evacuation from a high-rise building is such that the occupants are not exposed to the effect of fire or smoke. However, this is not always possible with high-rise buildings, and human behavior studies [28, 29, 30, 31] have shown that people are willing to move through smoke. Nevertheless, studies have found that the presence of smoke or poor visibility will slow the movement of people. This is reported by Jin [32] in the experimental study on the effect of visibility and irritant smoke on people's movement. For light extinction coefficient between 0.1/m to 1.0/m, Jin found that the movement speed decreases rapidly from 1 m/s to 0.3 m/s as the visibility worsened. The reduction in speed was found to be more rapid in the presence of irritant than non-irritant smoke. Frantzich and Nilsson [33] conducted an experimental study on the effect of artificial smoke and irritant on people's movement for light extinction coefficient between 2.0/m to 8.0/m. The experiments were conducted in a tunnel with and without illumination. The experimental results showed that the walking speed of occupants in the tunnel with illumination clearly reduced from 0.8 m/s to 0.2 m/s as the extinction coefficient increases. As for the tunnel without illumination, there was no clear trend between the walking speed of occupants and the extinction coefficient. Figure 2-1 shows the experimental results obtained from Jin's and Frantzich and Nilsson's experiments.

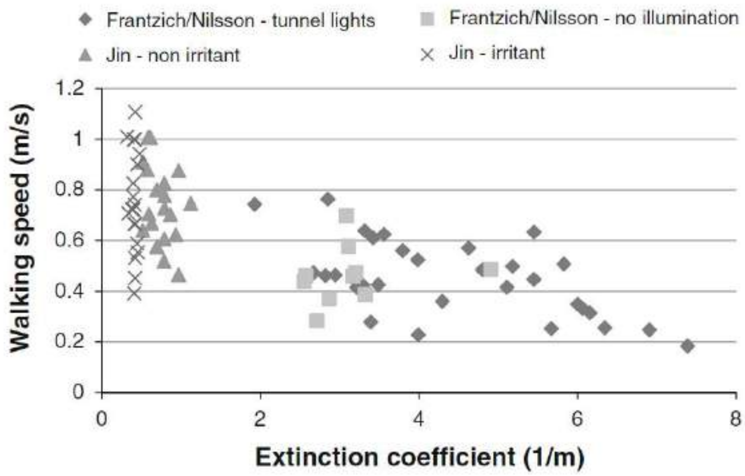


Figure 2-1: Walking speed as a function of extinction coefficient obtained in Jin's experiments and Frantzich and Nilsson's experiments [34]

Based on the literatures, it is acknowledged that evacuation down a stairwell is a complex phenomenon with numerous governing factors which may result in a high level of uncertainty on the evacuation duration. Overall, the factors which influence the evacuation in stairs can be divided into two categories. The first is the engineering variables describing occupant movement in stairwell which can be approximated and quantified with a numerical model. The second is the human behavioral factors which are difficult to quantify due to natural variation and social interaction amongst humans. Peacock *et al.* [35] suggested that the human behavior aspect may have significant influence on stairwell evacuation where engineering variables were demonstrated to have limited influence and further research is needed to better understand the human behavioral aspect. This research focuses solely on the engineering variables and it shall be noted that the study of human behavioral factors lie outside the scope of this research.

## 2.2 Evacuation Strategy

The evacuation dynamics of a high-rise building are affected by the use of the building and the evacuating population. For example, office occupancy are generally better prepared to evacuate the building since they are typically trained through evacuation drills and they are awake, alert and responsible mainly for themselves [36]. In addition, the fire safety systems in an office building are expected to be well-maintained to alert people of an emergency situation.

During a fire emergency, the standard procedure is to evacuate down a building. The study by Ronchi and Nilsson [37] identifies three main strategies for evacuating high-rise building. These evacuation strategies are (1) total evacuation (or simultaneous full evacuation), (2) phased evacuation (or staged), and (3) defend-in-place evacuation. The application of different evacuation strategies is dependent upon the characteristics of the building (e.g., egress components available, compartmentation, etc.), the population involved and the nature of the scenario and hazard involved.

**Total evacuation** strategy involves the evacuation of all building occupants at the same time from a building to the designated area of safety [38]. This strategy is simple and easy to carry out but may cause significantly higher density in the means of escape of high-rise building. Due to the possible large population involved, this will have two adverse effects on life safety of egressing occupants, (1) the simultaneous opening of stairwell doors and (2) the extended opening duration of these doors. Simultaneous opening of stairwell doors will reduce the effectiveness of compartmentation and stairwell pressurization system, allowing the smoke to spread to floors above the fire. Extended opening time of stairwell doors will allow smoke to infiltrate the stairwell from the fire floor, potentially compromising the tenability within the stairwell. An analytical study on a seven storey building and a twenty-one story building was carried out by Klote [39] to assess the effect of door opening on the tenability of pressurized stairwells. The study shows that for stairwell doors propped open on fire floor as well as floors above, the stairwell pressurization system would not be able to maintain tenable condition inside the stairwell.

In situation where total evacuation is deemed undesirable, **phased evacuation** can be implemented where the evacuation of occupants in the most critical floor (e.g. fire floor) and floors nearby are prioritized. This strategy will require sequenced communication systems within the building to ensure the effectiveness of the evacuation process. If deployed successfully, phased evacuation will help decrease the queuing time by optimizing the flow of occupants in the means of escape. As the occupants on the critical floors are able to evacuate unimpeded (by occupants from the rest of the building), phased evacuation would ensure that the stairwell doors on the critical floor are only opened for the minimum duration. This minimizes the amount of smoke entering the stairwell. For the case where stairwell pressurization system is present, phased evacuation will ensure the opening of the stairwell doors are in a controlled manner which allows the designate pressure within the stairwell to be maintained thereby ensuring that the stairwell is kept relatively smoke free.

**The defend-in-place** strategy allows the building occupants to remain inside the building until the fire is extinguished or the rescuers have arrived. This strategy is typically used within buildings occupied by people with disabilities or mobility impairments where evacuation would present more harm to the individual. Those buildings would have additional safeguard features such as refuge floors/areas to accommodate their occupants during a fire incident. Refuge area is a temporary staging area during egress which provides a relatively safe environment to the occupants while the fire-fighting and rescue efforts are being carried out. This strategy is usually not necessary for office buildings as office occupants are alert, awake and mainly responsible for themselves which imply that they are more prepared to evacuate the building than staying in place [36].

## 2.3 Fire Models

Fire models are useful for determining ASET for the occupants in a building during the event of a fire. The two computer fire models that are most widely used in fire research and fire design are Zone model and Computational Fluid Dynamics (CFD) model. Both models are implemented as computer programs designed to numerically predict the fire-induced conditions within an enclosure as a function of time.

### 2.3.1 Zone Models

The most common type of zone model is a two-zone model where the simulated space is divided into two homogeneous layers, a hot upper layer and a relatively cool lower layer (See Figure 2-2).

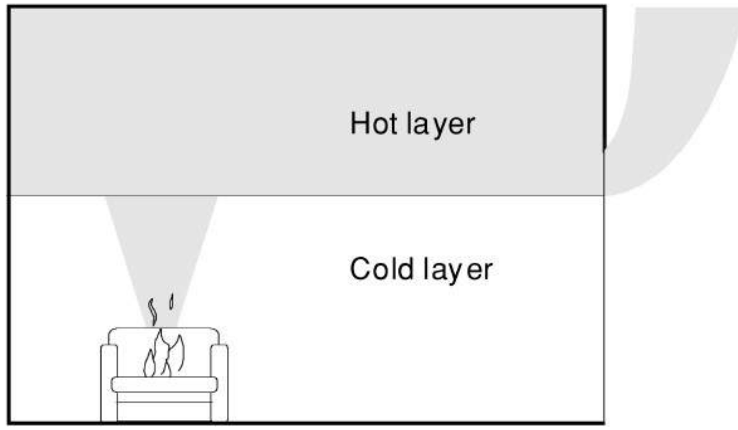


Figure 2-2: Two-zone modelling of a fire in an enclosure [40]

Zone model is developed using principles of mass and energy conservation to predict various phenomena associated with enclosure fires. The equations for mass and energy conservation are solved numerically for both zones at every time step. In a zone model, the properties of temperature, density and species concentrations are assumed to be consistent throughout each zone at any given time. In-depth details relating to zone model concepts are described by Quintiere [41].

In reality, when a fire occurs within a room, it induces a fire plume where the smoke will rise to the ceiling and spread across the ceiling in all direction to form a well-stratified hot smoke layer. Since zone models do not deal with conservation of momentum, the hot layer within zone model is assumed to form instantaneously. This scenario is considered to be a good approximation for small enclosures [42]. However, for large enclosures, the use of zone model is not always appropriate or effective, and these models are known to have certain limitations [43, 44, 45].

The advantage of zone models is that the computational run times are relatively short on modern computers when compared to the CFD models. Combustion Science & Engineering, Inc. [46] compiled a list of some common zone models that are still being actively supported:

- ARGOS [47]
- B-RISK [48]
- CFAST/FAST [49]

### 2.3.2 CFD Models

In CFD models (also commonly known as field models), the space of interest or fire enclosure is represented by computational mesh where the obstructions modelled conform to the user specified mesh. In essence, the volume of space within the user defined simulation domain is divided into sub-volumes (also known as mesh) where the basic laws of mass, momentum and energy conservation are applied to each control volume. Figure 2-3 shows a visual representation of CFD models for a fire in an enclosure.

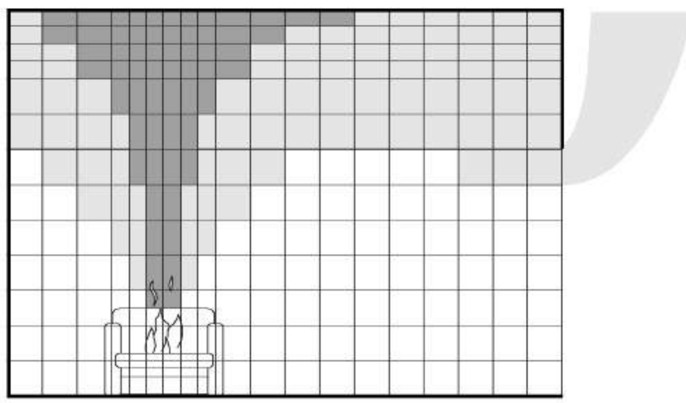

Figure 2-3: Computational fluid dynamics models divide the enclosure into a large number of sub-volumes (grid) [40]

The governing equations that are central to any CFD code is the Navier-Stokes equation which are the basic equations applicable to viscous and heat conducting fluid exhibiting low speed, thermally driven behaviour. Additional and more in-depth details of enclosure fire modelling using CFD models are explained by McGrattan and Miles [50] and Cox [51].

The ability of CFD models to discretise the computational domain into a large number of grids allows a more detail study of fluid flow and heat transfer as a function of time at specific locations (dependent on the resolution of the specific grid) within the enclosure of interest. CFD modelling approach are useful when simulated geometries and obstructions are complex and improved resolution is desired to capture the subsequent changes on fluid flow behavior. Despite the advantages, CFD model demands a higher background knowledge from its users and also computer processors with greater computing capacity which adds to additional cost and time of simulation and result analysis.

Combustion Science & Engineering, Inc. [52] have compiled a list of CFD models and the models that are still actively supported include:

- Fire Dynamic Simulator or FDS [53]
- FIRE3D [54]
- SMARTFIRE [55]
- KAMELEON FIREEX [56]

### 2.3.3 Fire Model Selection

From fire modelling perspective, each simulation presents complex modelling features such as stair geometry and smoke spread through floor and stair shaft. As such, computer fire models are the chosen tools to obtain accurate results and also to capture the details of these fire phenomena. Hand calculations are not considered for fire processes as they are deemed over-simplified for complex geometries, time-consuming and not expected to provide additional value to the study.

The most commonly used zone model and CFD model in the New Zealand Industry are B-RISK [48] and FDS [53] respectively as they are well validated and readily available (open source) for download at no cost. Since both software are also constantly being updated and actively supported, they are considered for selection. In order to select the modelling tool deemed most appropriate for this study, the features and limitations of each software are compared and evaluated.

B-RISK is a zone model developed by Building Research Association of New Zealand (BRANZ) [57] in New Zealand. A number of studies on the limitations of B-RISK had been carried out by Wade and Robbins [42] and Bong [44] which presented the comparisons between B-RISK and FDS, and the comparison between B-RISK and experimental data sets. Two parameters of interest were investigated – (1) non-dimensional HRR, $\dot{Q}^*$ and (2) dimensionless shape factor, *SF*.

The non-dimensional HRR, $\dot{Q}^*$ is defined by Zukoski [58] and is given in Equation 2:

$$\dot{Q}^* = \frac{\dot{Q}}{\rho_a c_p T_a \sqrt{g} H_e^{5/2}} \qquad \text{(Equation 2)}$$

For ambient conditions, taking $g$ = 9.81 m/s$^2$, $\rho_a$ = 1.2 kg/m$^3$, $c_p$ = 1.0 kJ/(kg K), $T_a$ = 293 K, Equation 2 can be rewritten as Equation 3 where it can be clearly seen that $\dot{Q}^*$ relates to the HRR of the fire and the height of the enclosure.

$$\dot{Q}^* = \frac{\dot{Q}}{1110 H_e^{5/2}} \qquad \text{(Equation 3)}$$

Shape factor, *SF* is defined by Klote and Milke [43] and is given in Equation 4 which relates the floor area to the height of the enclosure.

$$SF = \frac{A_f}{H_e^2} \qquad \text{(Equation 4)}$$

Based upon those studies, a paper by Wade [45] recommended the following limits relating to non-dimensional HRR, $\dot{Q}^*$ and dimensionless shape factor, *SF*:

- *For $\dot{Q}^* \leq 0.15$ and $0.4 \leq SF \leq 70$, a single-room two-zone model is considered satisfactory.*
- *For $\dot{Q}^* \leq 0.15$ and $SF > 70$, a multi-room two-zone model (with virtual rooms) is considered satisfactory with each room having a shape factor of $0.4 \leq SF \leq 70$.*

B-RISK is not suitable to be used for simulating stairwells of high-rise building as the *SF* tends to fall outside the recommended *SF* range due to large height to floor area ratio. The $\dot{Q}^*$ limit in B-RISK is not expected to be exceeded for any simulation in this research as the office building is sprinkler protected which controls the HRR of the fire at sprinkler activation.

B-RISK as a zone model can only model compartments as rectilinear compartments where important geometries within the stairwells such as stair steps and landings cannot be captured using zone model. Zone modelling of stairwell treats the stairwell as a tall room and therefore, when smoke enters a stairwell, zone model assumes instantaneous formation of smoke layer at the very top of the stairwell. This approximation of smoke distribution is far from reality as smoke will actually flow around the obstructions and at the same time up the stairwell. For certain tall buildings, the smoke may stagnate as it reaches certain height due to the loss of buoyancy when cooled. Such details cannot be captured within a zone model which makes it undesirable to be used for the modelling of tenability and smoke movement in stairwell.

FDS is a CFD model developed by National Institute of Standards and Technology (NIST) in the United States. Within the FDS Validation Guide [59], it is recommended that a $D^*/\delta x$ ratio between 4 and 16 shall be adopted to accurately model the fire and smoke behaviour within the simulation domain. $D^*/\delta x$ ratio between 4 and 16 was shown to adequately resolve plume dynamics, along with other geometrical characteristics of the models according to the validation studies in the FDS Validation Guide documentation. The characteristic fire diameter $D^*$ is defined by Equation 5.

$$D^* = \left(\frac{\dot{Q}}{\rho_a c_p T_a \sqrt{g}}\right)^{\frac{2}{5}} \qquad \text{(Equation 5)}$$

Where $\delta x$ is the size of the mesh and for ambient conditions, constant value of $g$ = 9.81 m/s$^2$, $\rho_a$ = 1.2 kg/m$^3$, $c_p$ = 1.0 kJ/(kg K) and $T_a$ = 293 K can be used. Equation 5 determines $D^*$ which is used to compute the recommended mesh size based on the fire size, $\dot{Q}$ (kW) at the time of interest (i.e, at maximum HRR or RSET time).

This study's primary focus is to quantify the tenability conditions (such as visibility and $FED_{gas}$) within the stairwells, specifically at each floor level of the stairwell. In addition to that, investigation of the smoke movement characteristic in stairwell with different stair arrangements is also part of the scope of this study. Those smoke flow details which B-RISK fails to resolve are automatically included within FDS being a field model. The smoke flow effect can be visualised using Smokeview [60]. A recent study by Hadjisophocleous and Jia [61] demonstrate that FDS is capable of modelling fire development and smoke movement in a high rise building. The study uses FDS to predict smoke movement, $O_2$, $CO_2$ concentrations and temperature in stair shaft and upper floors of an experimental 10-storey building. Results from the FDS model were compared with actual experimental data for the building and good agreement was found between the modelling and experimental results. Overall, the study has shown that FDS is suitable for studying tenability and smoke movement in stairwell.

FDS is better suited for this study as the user will only need to ensure that the mesh size chosen is within the recommended limit. For this research, FDS v6.1.2 is selected as the most suitable fire modelling tool for this study (note that v6.1.2 was the most current version at the time this study was carried out).

### 2.3.4 D*/δx analysis

According to FDS User Guide [59], D*/δx ratio between 4 and 16 is recommended to accurately resolve the simulated flow field for various fire scenarios. Equation 5 is used for calculating the D*/δx ratio. From Equation 5, D* is dependent only on the maximum HRR of the fire. The results (Table 5-11) from Section 5.4 show that low ceiling produces shorter sprinkler activation time compared to high ceiling for the identical floor area. Since fire is assumed to be capped at sprinkler activation, low ceiling scenarios have lower capped HRR which is expected to give smaller D*/δx ratio and thus smaller mesh size. Therefore, the low ceiling scenario for different floor areas are examined in this analysis. The mesh size, δx chosen for modelling the floor space in FDS is 0.3 m.

According to Table 5-11 in Section 5.4, the sprinkler activation time for large floor is 209 s. This gives a peak HRR of $0.0469 \times 209^2 = 2048$ kW. Using Equation 5 yields,

$$D^* = \left(\frac{2048}{1.2\times1.005\times293\times\sqrt{9.81}}\right)^{2/5} = 1.279$$

For δx = 0.3 m, D*/ δx = 4.3 (between 4 and 16)

According to Table 5-11 in Section 5.4, the sprinkler activation time for medium floor is 203 s. This gives a peak HRR of $0.0469 \times 203^2 = 1933$ kW. Using Equation 5 yields,

$$D^* = \left(\frac{1933}{1.2\times1.005\times293\times\sqrt{9.81}}\right)^{2/5} = 1.250$$

For δx = 0.3 m, D*/ δx = 4.2 (between 4 and 16)

According to Table 5-11 in Section 5.4, the sprinkler activation time for small floor is 175 s. This gives a peak HRR of $0.0469 \times 175^2 = 1436$ kW. Using Equation 5 yields,

$$D^* = \left(\frac{1436}{1.2\times1.005\times293\times\sqrt{9.81}}\right)^{2/5} = 1.110$$

For δx = 0.3 m, D*/ δx = 3.7 (outside of 4 and 16)

Based on the calculations above, it is found that D*/δx for all small floor lies slightly outside of the recommended range. For the purpose of this study, it is deemed not feasible to refine the mesh as it will result in impractically long simulation run time. The duration of most of the simulations are in the region of weeks to months and any refinement of the grid size will only further extend the simulation run time beyond the practical realm. In addition, D*/δx being slightly outside the recommended range is not expected to cause significant inaccuracy for the results obtained.

## 2.4 Evacuation Models

Evacuation models are useful for estimating RSET of the occupants and comparison between ASET and RSET will determine whether occupants are able to safely evacuate the building and vice versa in the event of a fire. Evacuation calculations are progressively becoming a part of performance-based analyses to demonstrate whether the level of life safety provided in a buildings is adequate [62]. Hand calculations and computational evacuation models are the two ways to obtain evacuation timings.

### 2.4.1 Hand Calculations

Typically, hand calculations are based on the equations given in the Society of Fire Protection Engineers (SFPE) Handbook [63] to calculate the travel and flow time of evacuation from any location within the building. The main focus of the calculations is on points of constriction throughout the building (e.g. doorway, corridor and stairwell) where the calculations determine the time for occupants to traverse these points, and to a place of safety.

These calculations essentially represent the occupants as particles that follow simple rule such as density dependent travel/flow speed. Apart from density, other human behaviour factors such as interactions between individuals, effect of fire and decision making processes of the individuals are unaccounted and variations among occupants not considered. Hand calculations are simple and enable RSET to be ascertained quickly. The RSET found are expected to be reasonable for simple building with minimal constrictions and low occupancy load. However, for more complex building which has multiple constrictions, merging flows, high occupancy load and mix occupancy type, the assumptions made using hand calculations may not be valid, resulting in inferior estimation of the evacuation time.

### 2.4.2 Computer Models

In order to address the limited application of hand calculations for complex evacuation processes, computer models have been developed to simulate phenomena such as distributed pre-movement time, effect of merging or counter-flow, and changes in flow rate due to different capabilities of occupants. Evacuation computer models enable a more detailed study of the evacuation process.

A recent study by Kuligowski *et al*. [64] provides a comprehensive model review of 26 evacuation models with the purpose of giving guidance to users in selecting the model or models appropriate for their study. Some prior evacuation model review works such as those performed by NIST [65], Gwynne *et al.* [66], Watts [67] and Friedmann [68] are useful and shall be referred to for evacuation models that have not been updated in the period between the original review and Kuligowski's work.

The review by Kuligowski is extensive and it covers main features for each model such as the model availability, modelling method, model structure and perspective, methods for simulating movement and behaviour of occupants, use of fire data, visualisation methods, use of computer aided drawings (CAD), and validation methods. The review also covers special features of the models which includes counterflow, blocked exits, fire conditions affecting behaviour, toxicity effects, group designations, occupants with disabilities, delays/pre-evacuation times, elevator use, and route choice of occupants. Further detailed elaboration of each main and special features can be found in the paper. The comparison between the main and special features of all the evacuation models provide insightful information which allows them to weigh the pros and cons of each model before selecting the most appropriate model to be used.

Out of the 26 evacuation models reviewed by Kuligowski, the evacuation models which are still actively supported according to Combustion Science & Engineering, Inc. [69] are:

- ❖ buildingEXODUS [70]
- ❖ PATHFINDER [71]

Some other evacuation models that are not listed by Combustion Science & Engineering, Inc. but are actively supported are FDS+Evac [72] and EvacuatioNZ [73]. FDS+Evac is a sub-model (evacuation module) embedded within FDS developed at VTT Technical Research Centre of Finland. EvacuatioNZ is currently under development at the University of Canterbury. For these reasons, both software have been considered for selection in this research.

### 2.4.3 Evacuation Model Selection

From egress modelling perspective, each simulation presents complex modelling features such as queuing and merging flow in the stairwell. As such, computer models are chosen as the primary tools to capture the details of these egress phenomena and predict the movement of people. However, it shall be noted that hand calculations (hydraulic models) for evacuation processes will be carried out to validate the evacuation computer model used in this study.

The review study by Kuligowski *et al.* [64] has provided some insight into selecting the appropriate evacuation computer model for this study. The paper identified that more than a dozen out of the 26 models are available to the public for free or a fee. The evacuation computer models that are readily available to be used in this study are identified to be FDS+Evac [72] and EvacuatioNZ [73].

FDS+Evac is an evacuation sub-model embedded within FDS, and given this existing coupling between fire and egress models, FDS+Evac is considered for use in this study. FDS+Evac uses an agent based approach where each agent within the model is treated as an individual entity, using stochastic properties for assigning their main characteristics, such as walking speed, pre-evacuation times and familiarity with exits. The movement of agents is simulated using two-dimensional planes representing the floors of the building. The algorithm behind the egress movement is based upon the method described by Helbing *et al.* [74, 75, 76], and solves an equation of motion for each agent in a continuous two-dimensional space and time. The equation of motion considers forces acting on the agents comprising of both physical forces, contact forces, and psychological forces which are exerted by surroundings or other agents.

FDS+Evac can interface with FDS allowing for simultaneous simulation of fire and evacuation processes where the effects of fire and smoke on occupants can be studied.

EvacuatioNZ is an evacuation software currently being developed at the University of Canterbury. EvacuatioNZ uses a coarse network approach where the floor plan is separated into nodes for which occupants can move [77] through the path connecting the nodes. A node will have characteristic such as space size defined whilst the path will contain the characteristic of egress components such as width of doors or staircases, and the travel distance between nodes. A model within EvacuatioNZ is defined by six input files which can be classified into two aspects – physical and behaviour aspects. These input files will need to be written in Extensible Mark-up Language (XML). Tsai [78] in his study provided a detailed description of all six input files. EvacuatioNZ has probabilistic analysis capability where it uses Monte Carlo methods for generating spreads in evacuation time by varying the distribution (normal, log-normal, uniform, triangular or Weibull) of the input data such as travelling speed, pre-movement time etc.

From the review study by Kuligowski *et al.*, both FDS+Evac and EvacuatioNZ differ in terms of the modelling algorithm, the type of grid/structure and the movement of occupants. Nevertheless, both models are suitable for use on most buildings.

Based on literature reviews, it is found that there are currently more validation studies done on EvacuatioNZ compared to FDS+Evac for high-rise office building. Those studies involve the validation of the software model against the following:

- Fire drills or people movement experiments/trials
- Other models

An example of previous validation study done on EvacuatioNZ for high-rise office building includes work by Tsai [78] who validated EvacuatioNZ against trial evacuation of a 13-storey and 21-storey office buildings located in Canada and Australia respectively. A more recent validation study was conducted by Hay [79] who compared simulation results from EvacuatioNZ against trial evacuation of four office buildings. The four office buildings are – (1) 17-storey Manchester building in United Kingdom, (2) 29-storey Majestic building in Wellington, NZ, (3) 17-storey Unisys building in

Wellington, NZ, and (4) 11-storey office building located in Christchurch, NZ. Validation of EvacuatioNZ against other models such as FDS+Evac, Simulex [80] and Hand Calculations were carried out by Tan [81] on a 4-storey hypothetical office building. Although this office building is not considered as a high-rise by definition, the research still provides some useful information regarding validation of EvacuatioNZ.

In terms of high-rise office building, FDS+Evac was validated by Heliovaara *et al*. [82] against trial evacuation of a 7-storey office building. The study focused mainly on the evacuation down the stairs. In another study by Heliovaara [83], merging flow in stairs was investigated using FDS+Evac and compared to other model (buildingEXODUS) as well as experimental data of Takeichi *et al.* [84]. The results from FDS+Evac appeared to agree well with both buildingEXODUS and the experimental data.

FDS+Evac has a simultaneous fire model (FDS) which couples the fire and evacuation models whereas EvacuatioNZ only allows the user to input specific fire data at specified times throughout the evacuation. FDS+Evac as an agent-based model has the ability to track the movement as well as the incapacitation ($FED_{gas}$) of each occupants when coupled with FDS. This ability is an advantage as it allows a more accurate and realistic time to incapacitation of each agent to be determined.

FDS+Evac has both 2D and 3D visualisation capabilities combined with agent-based approach for movement of agents in a continuous two dimensional space. These capabilities of FDS+Evac allow observation of the evacuation simulation easily, and facilitate model troubleshoot by identifying any area of concerns. On the other hand, EvacuatioNZ only has a 2D visualisation capability combined with nodal approach for movement of agents. Although FDS+Evac may have limited studies in the area of validation compared to EvacuatioNZ, FDS+Evac appeared to have edge over EvacuatioNZ in the areas of fire effect, visualisation method and agent-based approach. For this research, FDS+Evac v2.5.0 is selected for this study (note that v2.5.0 was the most current version at the time this study was carried out).

Given FDS+Evac has only limited validation studies, the evacuation results obtained from selected simulations are compared against hand calculations (hydraulic models) and comparable experimental evacuation studies within the literature.

# 3. Simulation Scenarios

This chapter discusses in details the building parameters that are chosen for this study, and the range of these parameters to form unique simulations. In this research, the simple open plan high-rise office building featured in each simulation scenario is an idealised layout.

## 3.1 Building Parameters

From the research objective discussed in Section 1.2, the building parameters investigated in this study are the floor area, building height, active fire protection systems, evacuation strategy and ceiling height.

### 3.1.1 Floor Area

The NZBC C/AS5 [4] compliance document is used as guidance to identify the size of floor or area to be studied. In general, C/AS5 requires a building to have a minimum of two means of egress for up to 500 occupants on each floor, beyond which the building shall have three or more means of egress. Single mean of egress is acceptable if certain requirements are met (Refer to C/AS5 clause 3.13) and one of the primary requirements is that the occupant load on each floor does not exceed 50 people. This research focuses on evacuation with two means of escape as it is effectively the worst case scenario for occupant load between 51 and 500. Single mean of egress is outside the scope of this research as it is deemed less onerous from fire safety perspective due to the low occupant load.

The occupant density defined within C/AS5 for office space is 10 $m^2$/person which is a common density found in most standards and handbooks [85, 86, 10]. Applying this occupancy density value to the upper and lower occupant limits for two means of egress yields a floor area of 5000 $m^2$ (500 occupants) and 510 $m^2$ (51 occupants) respectively. The upper and lower floor area limits are the range of floor area that is considered in this study.

Minimum width requirements for escape routes are also specified within C/AS5, and it shall be no less than the larger of the two requirements for accessible routes:

a) 7 mm/person for horizontal travel and 9 mm/person for vertical travel

b) 1200 mm for horizontal travel and 1100 mm for vertical travel

The escape width requirements provide the third option for floor area of this study. The floor area is based on the maximum occupant load allowed by the minimum required horizontal and vertical travel escape width as per b) above. This equates to a floor area of 2450 $m^2$ using office occupant density value of 10 $m^2$/person. Calculations below demonstrate the determination of the floor area:

- Minimum horizontal travel width based on a) above – 1200 mm/7 mm/person = 171 person
- Minimum vertical travel width based on b) above – 1100 mm/9 mm/person = 122 person

From the calculations above, vertical travel width is more restrictive in terms of occupant load – 122.22 x 2 means of escape per floor ≈ 245 person/floor (rounded up). Based on density of 10 $m^2$/person, a floor area of 2450 $m^2$ is found. In accordance with C/AS5, the floor area of 2450 $m^2$ have the same minimum width requirements as the floor area of 510 $m^2$ even though the 2450 $m^2$ floor area has five times greater occupant load than that of 510 $m^2$ floor area.

Based on this assessment, a total of three floor areas – 5000 $m^2$, 2450 $m^2$ and 510 $m^2$ are included in this study. The floor areas will be referred as “large floor”, “medium floor” and “small floor”, respectively throughout this document.

### 3.1.2 Building Height

The scope of C/AS5 does not include any building that is over 20 storeys high and those will need to be assessed using verification method or performance based design according to the NZBC. This provides the upper limit of the building height assessed in this study.

One of the most common definition of high-rise is a building with the highest floor level located at a height of approximately 23 m vertically from the ground level. According to 2003 Facilities Standards (P100) [87], the minimum ceiling height for an office floor is 2.7 m. Assuming that ceiling height is equal to floor height (this is not practical but provides a lower limit of the height between floors), a 10 storeys building will have a height of approximately 27 m which is near the lower limit of “high-rise” category.

Based on this, 10 storeys building is chosen near the lower limit of building height to be assessed in this study.

### 3.1.3 Active Fire Protection Systems

Fire protection systems are categorized into two components – active and passive fire protection. Active fire protection are detection devices that operates by manual, mechanical or electrical means [88]. Some examples include sprinkler system, smoke detection and smoke control system. Conversely, passive fire protection are systems that relies on specific construction features and the use of materials, products and building elements that achieve certain fire performance requirements [88]. A typical example will be a fire wall. This study is focused solely on the active fire protection systems.

There are many choices of active fire protection system available in application and this study has focused on sprinkler and smoke detection system specifically. According to C/AS5, office building that is over 25 m tall or have more than 1000 occupants will require fire protection system in the form of sprinkler and smoke detection. Thus, one of the fire protection system options in this study is sprinkler and smoke detection. This combined system is also known as Type 7 fire alarm system in New Zealand Compliance Documents & Verification Method.

Although smoke detection system is a cost effective solution and provides early fire/smoke detection, the system is also prone to false alarm which can reduce its effectiveness (intentional disabling) and resulting in additional cost for building owner (security/fire service call-out). In some cases, it may be beneficial to use verification document or adopting performance based design to demonstrate on-going compliance with the building code without a smoke detection system. For this reason, this study has also considered high-rise building with sprinkler system only. This system is also known as Type 6 fire alarm system in New Zealand Compliance Documents & Verification Method.

In total, two types of active fire protection systems, comprising of a combined sprinkler and smoke detection system (Type 7), and a sprinkler only system (Type 6) are investigated in this study.

### 3.1.4 Evacuation Strategy

As discussed in Section 2.2, evacuation strategy is one of the building parameter that has been widely debated for high-rise building due to the different approaches available which are application specific, depending on the state of the building occupants. As previously discussed, total evacuation strategy which involves simultaneous evacuation of all occupants within the building upon sounding of the alarm is the most common evacuation strategy for office building. Total evacuation strategy is selected for this study to examine the impact this approach has on high-rise office building.

Another evacuation strategy that is selected for this study is phased evacuation where occupants on the critical floors (e.g. fire floor and floor immediately above) are given priority to fully evacuate before the evacuation for the rest of the building commences (if required). This evacuation strategy intentionally delays the evacuation of the occupants on the non-critical floors with the objective to minimize congestion within the stairwell. From a qualitative perspective, this strategy appears to be favorable for high-rise building where congestion in the stairwell is highly probable if total evacuation strategy is adopted. Congestion in the stairwell caused by total evacuation may delay the occupants on the fire floor from entering the stairwell and as a result, the stairwell door on the fire floor will be left open allowing the smoke to infiltrate the stairwell.

The phased evacuation strategy considered in this study is that of a simple phased evacuation where priority to evacuate is given to occupants on the fire floor only. Those occupants are given a certain duration to evacuate before the evacuation of the rest of the building will commence. The duration is determined based on the unimpeded flow of occupants through the stairwell door, and the design occupancy load of the fire floor. The objective is to get occupants off the fire floor in the quickest and easiest fashion so that the stairwell door will only be kept opened over a short duration, minimizing the amount of smoke infiltrating the stairwell.

### 3.1.5 Floor Ceiling Height

According to 2003 Facilities Standards (P100) [87], the recommended minimum ceiling height for office floor is 2.7 m. Ceiling height of less than 2.7 m, especially in an open plan office tend to have a claustrophobic effect which are not desirable.

Therefore, it is unlikely that high-rise open plan office building will have ceiling height less than 2.7 m. The minimum ceiling height of 2.7 m is considered as one of the variable for floor ceiling height.

A common ceiling height for office building is between 3 m to 3.5 m based on commonly observed office buildings. A ceiling height of 3.3 m is selected for this study based on the provision of using CFD model which will allow the ceiling height to be modelled by the smallest mesh specified. The minimum and typical ceiling height are also known as "low" and "high" ceiling respectively throughout this document.

### 3.1.6 Stair Arrangements

This study is focused on high-rise office building with two means of egress comprising two stairwells serving each floor. One of the stair shafts house a conventional stair which is a single staircase within the shaft. The other stair shaft houses a pair of scissor stairs which consisted of two intertwined staircases separated by partition within the shaft. While the scissor stairs have two means of egress, only one of the two intertwined stairs is used for evacuation and smoke filling giving a total of two means of egress for the building as a whole. The conventional and scissor stair arrangements are not variable in this study as both arrangements are incorporated together into all the simulations. In order to ensure both stair arrangements occupy the same footprint, it is found that the floor to floor height has to be set at 4.8 m. The purpose of studying conventional and scissor stairs is to investigate the smoke filling characteristic due to different stair arrangements.

## 3.2 Simulation Scenarios

Table 3-1 shows a summary of all the variables associated with each building parameter, applicable word definition of the variables and the total number of unique simulations obtained from the study of each variable.

Table 3-1: Summary of building parameters and variables

| Parameters | Simulation variables | Word Definition (Abbrev.) | No. |
|---|---|---|---|
| Floor area | 510 $m^2$; 2450 $m^2$; 5000 $m^2$ | Small (S); Medium (M); Large (L) | 3 |
| Building height | 10 Storeys; 20 Storeys | N/A (10); N/A (20) | 2 |
| Fire protection system | Sprinkler and smoke detection; Sprinkler only | Type 7 (T7); Type 6 (T6) | 2 |
| Evacuation strategy | Total[1]; Phased[2] | N/A (T); N/A (P) | 2 |
| Floor ceiling height | 2.7 m; 3.3 m | Low (2.7); High (3.3) | 2 |
| | | **Total Scenarios** | **48** |

[1] Total evacuation strategy refers to simultaneous evacuation of all occupants in a building.

[2] Phased evacuation (in this study) is where occupants on the fire floor are given a certain duration to evacuate before the evacuation of the rest of the building will commence. (Refer to Chapter 5 for further details)

From Table 3-1 above, a total of 48 unique simulations are generated based on the variables considered for each building parameter. Each unique simulation is summarised in Table 3-2.

Table 3-2: Summary of 48 simulations

| Run | Parameters | | | | |
|---|---|---|---|---|---|
| | **Floor Area** | **Building Height** | **Fire Protection System** | **Evacuation Strategy** | **Floor Ceiling Height** |
| L_20_T6_T_2.7 | Large | 20-storey | Type 6 | Total | Low |
| M_20_T6_T_2.7 | Medium | 20-storey | Type 6 | Total | Low |
| S_20_T6_T_2.7 | Small | 20-storey | Type 6 | Total | Low |
| L_10_T6_T_2.7 | Large | 10-storey | Type 6 | Total | Low |
| M_10_T6_T_2.7 | Medium | 10-storey | Type 6 | Total | Low |
| S_10_T6_T_2.7 | Small | 10-storey | Type 6 | Total | Low |
| L_20_T6_P_2.7 | Large | 20-storey | Type 6 | Phased | Low |
| M_20_T6_P_2.7 | Medium | 20-storey | Type 6 | Phased | Low |
| S_20_T6_P_2.7 | Small | 20-storey | Type 6 | Phased | Low |
| L_10_T6_P_2.7 | Large | 10-storey | Type 6 | Phased | Low |
| M_10_T6_P_2.7 | Medium | 10-storey | Type 6 | Phased | Low |
| S_10_T6_P_2.7 | Small | 10-storey | Type 6 | Phased | Low |
| L_20_T7_T_2.7 | Large | 20-storey | Type 7 | Total | Low |
| M_20_T7_T_2.7 | Medium | 20-storey | Type 7 | Total | Low |
| S_20_T7_T_2.7 | Small | 20-storey | Type 7 | Total | Low |
| L_10_T7_T_2.7 | Large | 10-storey | Type 7 | Total | Low |
| M_10_T7_T_2.7 | Medium | 10-storey | Type 7 | Total | Low |
| S_10_T7_T_2.7 | Small | 10-storey | Type 7 | Total | Low |
| L_20_T7_P_2.7 | Large | 20-storey | Type 7 | Phased | Low |
| M_20_T7_P_2.7 | Medium | 20-storey | Type 7 | Phased | Low |
| S_20_T7_P_2.7 | Small | 20-storey | Type 7 | Phased | Low |
| L_10_T7_P_2.7 | Large | 10-storey | Type 7 | Phased | Low |
| M_10_T7_P_2.7 | Medium | 10-storey | Type 7 | Phased | Low |
| S_10_T7_P_2.7 | Small | 10-storey | Type 7 | Phased | Low |
| L_20_T6_T_3.3 | Large | 20-storey | Type 6 | Total | High |
| M_20_T6_T_3.3 | Medium | 20-storey | Type 6 | Total | High |
| S_20_T6_T_3.3 | Small | 20-storey | Type 6 | Total | High |
| L_10_T6_T_3.3 | Large | 10-storey | Type 6 | Total | High |
| M_10_T6_T_3.3 | Medium | 10-storey | Type 6 | Total | High |
| S_10_T6_T_3.3 | Small | 10-storey | Type 6 | Total | High |
| L_20_T6_P_3.3 | Large | 20-storey | Type 6 | Phased | High |
| M_20_T6_P_3.3 | Medium | 20-storey | Type 6 | Phased | High |
| S_20_T6_P_3.3 | Small | 20-storey | Type 6 | Phased | High |
| L_10_T6_P_3.3 | Large | 10-storey | Type 6 | Phased | High |
| M_10_T6_P_3.3 | Medium | 10-storey | Type 6 | Phased | High |

| Run | Parameters | | | | |
|---|---|---|---|---|---|
| | Floor Area | Building Height | Fire Protection System | Evacuation Strategy | Floor Ceiling Height |
| S_10_T6_P_3.3 | Small | 10-storey | Type 6 | Phased | High |
| L_20_T7_T_3.3 | Large | 20-storey | Type 7 | Total | High |
| M_20_T7_T_3.3 | Medium | 20-storey | Type 7 | Total | High |
| S_20_T7_T_3.3 | Small | 20-storey | Type 7 | Total | High |
| L_10_T7_T_3.3 | Large | 10-storey | Type 7 | Total | High |
| M_10_T7_T_3.3 | Medium | 10-storey | Type 7 | Total | High |
| S_10_T7_T_3.3 | Small | 10-storey | Type 7 | Total | High |
| L_20_T7_P_3.3 | Large | 20-storey | Type 7 | Phased | High |
| M_20_T7_P_3.3 | Medium | 20-storey | Type 7 | Phased | High |
| S_20_T7_P_3.3 | Small | 20-storey | Type 7 | Phased | High |
| L_10_T7_P_3.3 | Large | 10-storey | Type 7 | Phased | High |
| M_10_T7_P_3.3 | Medium | 10-storey | Type 7 | Phased | High |
| S_10_T7_P_3.3 | Small | 10-storey | Type 7 | Phased | High |

# 4. Computer Models Set-up

## 4.1 FDS Model Set-up

### 4.1.1 Fire Location and Fire Protection Systems in FDS

For all simulations, a 3 m (length) x 3 m (width) x 0.3 m (depth) burner representing the fire was modelled in FDS at the centre of the floor space to maximise plume entrainment. The top surface of the burner was specified to be burning. The burner was elevated such that its base was 0.3 m above the floor level. In both 20-storey and 10-storey building, the fire was located within the middle floor (i.e, 5$^{th}$ floor for 10-storey building and 10$^{th}$ floor for 20-storey building). The fire was specified with the following characteristic as prescribed in Part 2 (Table 2.1) of C/VM2 [6].

**Fire Characteristics**

- Fire growth rate: 0.0469 $t^2$ (fast growth fire)
- Species:
  - Soot yield, $Y_{soot}$ = 0.07 kg/kg
  - Carbon Monoxide yield, $Y_{CO}$ = 0.04 kg/kg
  - Heat of combustion, $\Delta H_c$ = 20 MJ/kg
  - Fuel = $CH_2O_{0.5}$
- Radiative fraction: 0.35

Heat Release Rate per Unit Area (HRRPUA) for each scenario is in the range of 150 - 300 kW/m$^2$ which is lower than the specified range in C/VM2 (500 kW/m$^2$ – 1000 kW/m$^2$). A sensitivity analysis were carried out on the small and medium floor areas which are the worse cases for HRRPUA in terms of its deviation from the specified values in C/VM2. The analysis found that the tenability conditions in the floor space and stairwells are not sensitive to the range of the HRRPUA specified. Refer to Appendix A for the comparison of simulation results with different HRRPUA.

The fire protection system consists either of Type 7 or Type 6. The specified sprinkler for all simulations is quick response type with the following criteria/characteristic as per Part 3 (Table 3.2) of C/VM2.

| **Quick response sprinkler** |
| --- |
| ❖ RTI: 50 $m^{1/2}s^{1/2}$ |
| ❖ C = 0.65 $m^{1/2}s^{1/2}$ |
| ❖ $T_{act}$ = 68 $^{o}C$ (activation temperature) |
| ❖ Radial distance = 3.25 m |
| ❖ Distance below ceiling = 25 mm |

A total of four sprinkler heads were specified in the model with each sprinkler located at 3.25 m away from the fire, on all four sides of the fire as shown in Figure 4-1. It shall be noted that the distance of sprinkler head from the fire was taken to the closest edge rather than the centre of the fire for conservativeness.

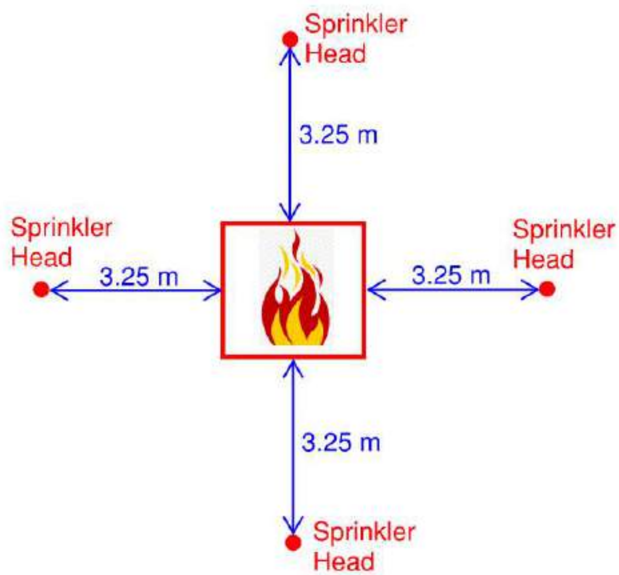


Figure 4-1: Locations of sprinkler head

The specified smoke detector characteristics were also based on the values provided in Table 3.2 of C/VM2 given as follow:

| **Smoke detector** |
| --- |
| ❖ Optical density at alarm = 0.097 $m^{-1}$ (21.65 %/m) |
| ❖ Radial distance = 7 m |
| ❖ Distance below ceiling = 25 mm |

The optical density at alarm of 0.097 $m^{-1}$ is considered to be the obscuration level outside the smoke detector. Thus, the specified smoke detectors consist of measurement points (also known as devices) that record the optical density at the specified location.

Similar to the arrangement of sprinklers, a total of four smoke detectors were specified in the model where each smoke detector was located at 7 m away from the fire, on all four sides of the fire as shown in Figure 4-2. It shall be noted that the distance of smoke detector from the fire was taken to the closest edge rather than the centre of the fire for conservativeness.

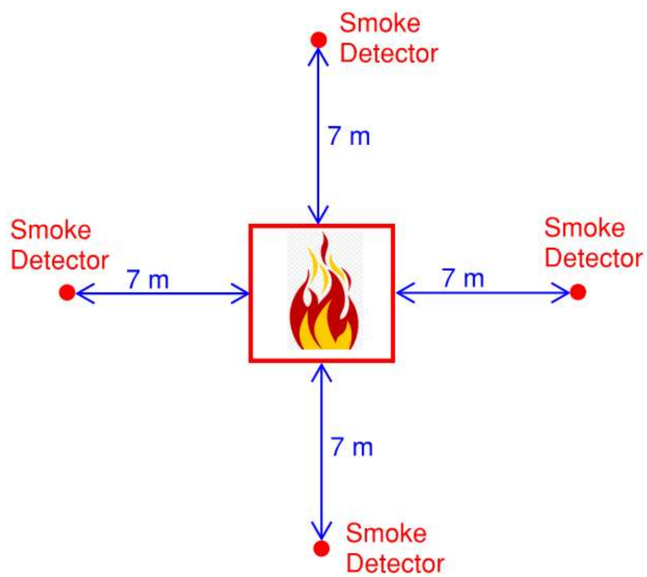


Figure 4-2: Locations of smoke detector

### 4.1.2 FDS Model Leakage

The leakage area to the outside in the floor spaces and stairwells were calculated by multiplying the wall area by 0.001 $m^2/m^2$ (lined wall) which is the leakage ratio in accordance with C/VM2 fire modelling rules. For the floor space, the calculated leakage area was modelled as four equal slots and positioned at four corners of the space, two at ceiling level and two at ground level. For the stairwells, the calculated leakage area was divided into two equal slots positioned at the top and bottom of the stairwell. The actual leakage areas modelled in FDS were rounded from the calculated leakage area to fit within the specified grid size. Consistent with C/VM2 fire modelling rules, the actual total leakage area modelled in FDS does not exceed 5 times that of the calculated leakage area.

All doors connecting the floor space to the stairwell (stairwell doors) were assumed to be fire rated and smoke control doors. In accordance with C/VM2 fire modelling rules, those doors have zero leakage area except for a 10 mm gap under the doors. Similarly, the actual leakage area was rounded to fit the smallest grid but not exceeding 5 times that of the calculated leakage area.

### 4.1.3 FDS Building Geometry

#### *4.1.3.1 Large Floor*

Large floor was modelled as a square floor space with width and length of 70.5 m. The maximum occupant load was assigned to be 500 on each floor.

For an open plan office, it is reasonable to assume that the number of occupants using each mean of escape is half of the total occupant load of 250 occupants. The minimum escape width for accessible routes according to C/AS5 [4] shall be no less than the larger of the two requirements:

a) 7 mm/person for horizontal travel and 9 mm/person for vertical travel
b) 1200 mm for horizontal travel and 1100 mm for vertical travel

Based on the requirements above, the minimum horizontal and vertical escape width for both stairwells were determined to ensure compliance with the building code requirements.

- ❖ The minimum horizontal escape width = 250 person x 7 mm/person = 1750 mm > 1200 mm
- ❖ The minimum vertical escape width = 250 person x 9 mm/person = 2250 mm > 1100 mm

From the calculations above, it can be observed that for large floor, the minimum width is governed by occupant load. Hence, stair landing and vertical stair width were modelled as 1800 mm and 2300 mm (both rounded to fit within grid) which is greater than the minimum width requirements for horizontal and vertical travel of 1200 mm and 1100 mm respectively. A sketch of the typical floor plan for the large floor, conventional stairs and scissor stairs which were modelled in FDS are shown in Figure 4-3.

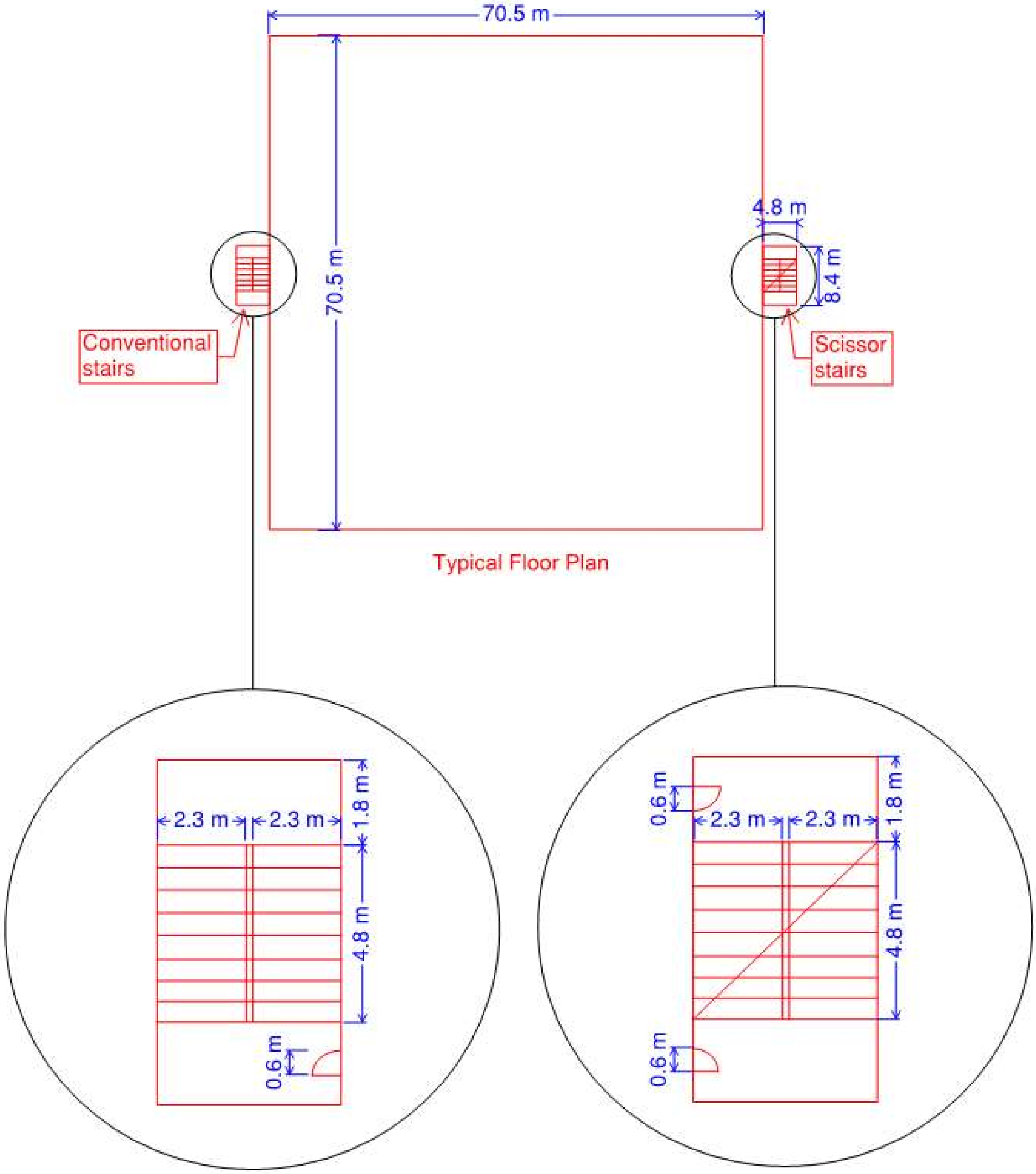


Figure 4-3: Large floor and stairs plan

#### *4.1.3.2 Medium Floor*

Medium floor was modelled as a square floor space with width and length of 49.5 m. The maximum occupant load was assigned to be 245 on each floor.

For an open plan office, it is reasonable to assume that the number of occupants using each mean of escape is half of the total occupant load of 123 occupants.

Based on the minimum escape width requirements of C/AS5 described in Section 4.1.3.1, the minimum horizontal and vertical escape width for both stairwells were determined to ensure compliance with the building code requirements.

- The minimum horizontal escape width = 123 person x 7 mm/person = 861 mm < 1200 mm
- The minimum vertical escape width = 123 person x 9 mm/person = 1107 mm > 1100 mm

From the calculations above, it can be observed that for medium floor, the minimum width is governed by minimum width requirements. Hence, stair landing and vertical stair width were modelled as 1650 mm and 1100 mm (both rounded to fit within grid). Stair landing width of 1650 mm is to satisfy with the clearances at door locations under D1/AS1 [5]. A sketch of the typical floor plan for the medium floor, conventional stairs and scissor stairs which were modelled in FDS are shown in Figure 4-4.

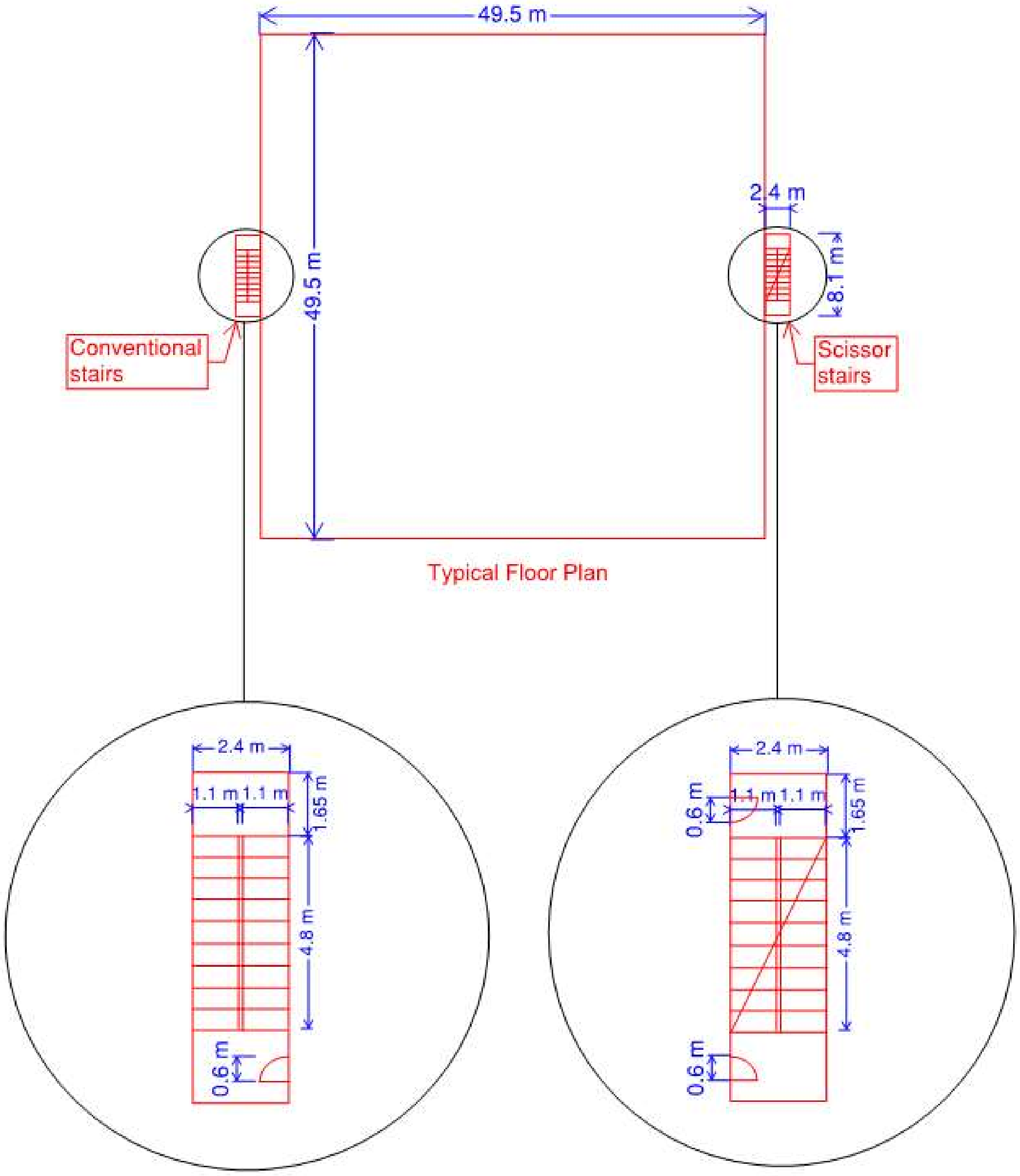


Figure 4-4: Medium floor and stairs plan

#### *4.1.3.3 Small Floor Area*

Small floor was modelled as a square floor space with width and length of 22.5 m. The maximum occupant load was assigned to be 51 on each floor.

For an open plan office, it is reasonable to assume that the number of occupants using each mean of escape is half of the total occupant load of 26 occupants.

Based on the minimum escape width requirements of C/AS5 described in Section 4.1.3.1, the minimum horizontal and vertical escape width for both stairwells were determined to ensure compliance with the building code requirements.

- The minimum horizontal escape width = 26 person x 7 mm/person = 182 mm < 1200 mm
- The minimum vertical escape width = 26 person x 9 mm/person = 234 mm > 1100 mm

From the calculations above, it can be observed that for small floor, the minimum width is governed by minimum width requirements. Hence, the dimension of the stair landing and vertical stair width were similar to that of medium floor. A sketch of the typical floor plan for the small floor, conventional stairs and scissor stairs which were modelled in FDS are shown in Figure 4-5.

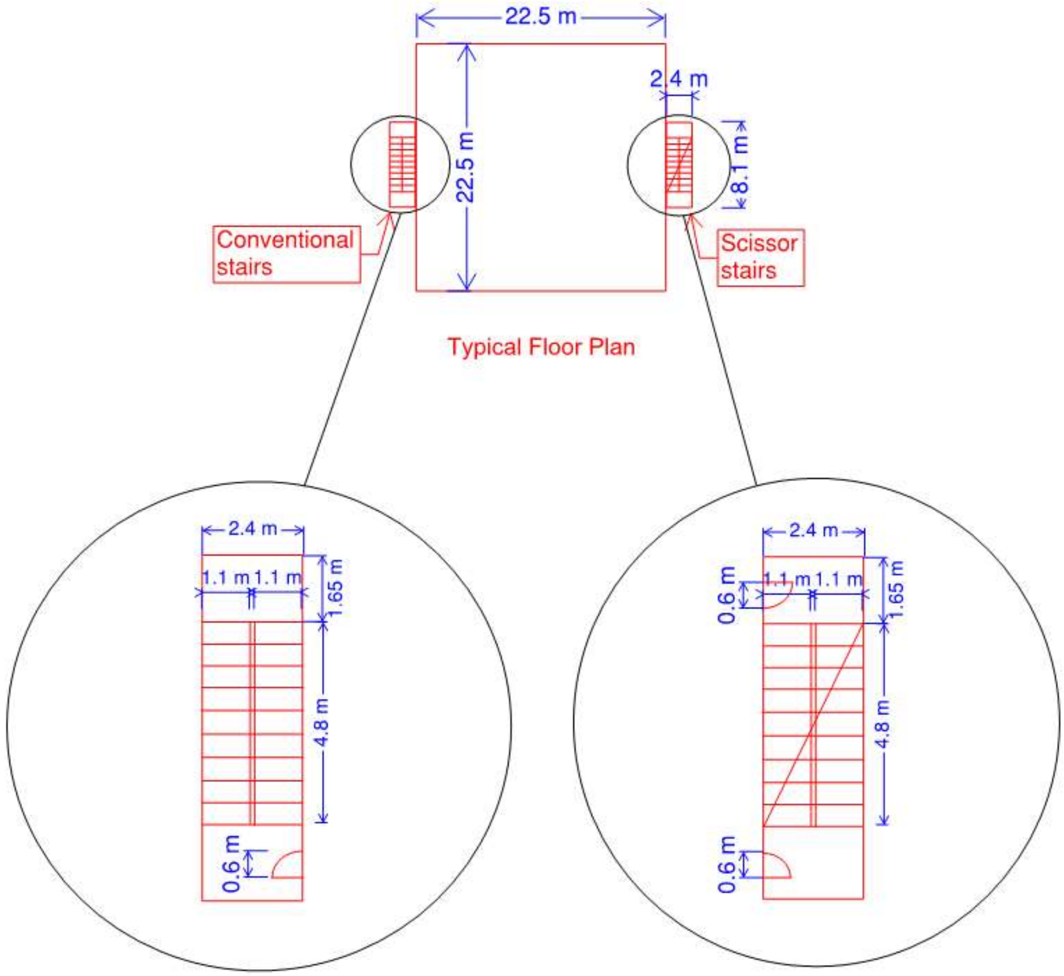


Figure 4-5: Small floor and stairs plan

#### *4.1.3.4 Typical FDS Building Geometry*

This section describes the typical FDS building geometry applicable for all simulations.

For all simulations, each floor was provided with two means of egress via the conventional and scissor stairs. While scissor stairs by nature have two means of egress, only one of the two intertwined stairs was utilised for evacuation and smoke filling.

For FDS smoke flow calculations, the stairwell doors were modelled as half-width (full width = 1000 mm, half width = 600 mm to fit within the grid) in accordance with the C/VM2 fire modelling rules.

In order to compare the smoke filling effect of two different stair arrangements (conventional and scissor stairs), both stair shaft were constructed to have equal volume. Based on requirements in D1/AS1, it was found that the minimum floor to floor height of 4.8 m is required to accommodate scissor stairs. The stair tread and riser were modelled at 300 mm and 150 mm respectively, satisfying the requirements of accessible stair. A sketch of the typical elevation for conventional and scissor stairs are shown in Figure 4-6.

Since floor-to-floor height was set at 4.8 m to accommodate scissor stairs, suspended ceiling was specified within the floor space to achieve the ceiling height of 2.7 m and 3.3 m within each floor space.

The modelled building components consisted of fire floor, a single floor above, conventional stairs and scissor stairs. FDS model for each simulation scenario utilised multi-mesh where the grid size used for the floor meshes was 300 mm while for the stairwells, a finer grid size of 150 mm was used. The multi-mesh approach for modelling of floor spaces and stairwells reduces computational time while still retain useful results. Finer mesh was used for the stairwells to resolve the smallest components which were the stair risers.

Furthermore, two floor levels rather than all the floor levels were modelled to reduce computational time. It was deemed more beneficial to have a large number of completed simulations which will allow meaningful conclusions to be drawn compared to having only a limited number of simulations with great amount of details (i.e, all floor spaces modelled). One floor above the fire floor was chosen to be modelled because it was expected to be the worst affected floor compared to any other floors above. This is because as smoke moves up the stairwell, it will diffuse into the floor spaces above due to the geometry of the stairs. Thus, as the smoke travels towards the top of the building, it would have been sufficiently diffused/diluted such that the tenability conditions on the upper floors are expected to be better than those floors below.

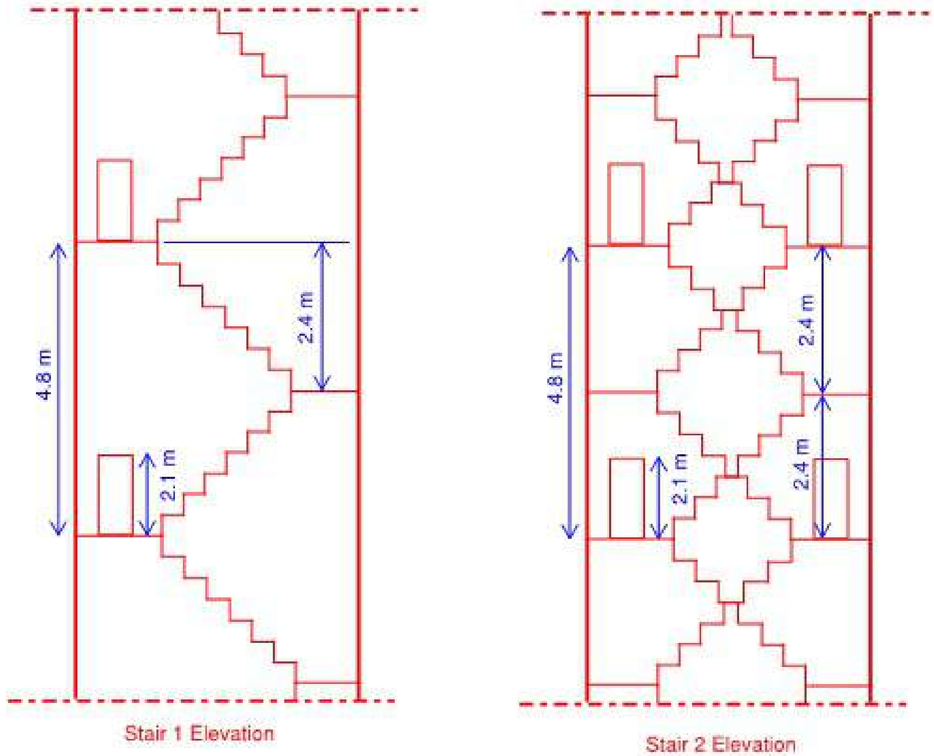


Figure 4-6: Conventional and scissor stairs typical elevations

### 4.1.4 Location of Devices in FDS

The tenability parameters that were monitored in the floor space (fire floor and floor above) were:

- Visibility (VIS)
- $FED_{gas}$ (FED)
- Layer Height (LH)
- Upper layer temperature (ULT)
- Lower layer temperature (LLT)
- Gas temperature (TEMP)

The tenability parameters that were monitored in the stairwell floor and intermediate landings were comprised of the following:

- Visibility (VIS)
- $FED_{gas}$ (FED)

❖ Gas temperature (TEMP)

Visibility, $FED_{gas}$ and Temperature were monitored at a height of 2 m above the floor/landing. As for layer height, upper layer temperature and lower layer temperature, these were determined from the continuous vertical temperature profile.

For large floor area, the distribution of the devices in the floor space, and within the conventional and scissor stairs are shown in Figure 4-7. Each device was labelled according to its XYZ coordinate in the FDS model and has the following form:

*Tenability parameters*_(*X*-*Y*-*Z*)

For example, the device located at position "A" of the floor space (Refer Figure 4-7) has x-coordinate of -28.2, y-coordinate of -5.4, and if the device is located on the fire floor ($10^{th}$) of a 20-storey building, the z-coordinate of the device is 4.8 m x 9 floors + 2 m (2 m above floor) = 45.2, where 4.8 m is the floor to floor height. If the device measures visibility, it will be labelled VIS_(-28.2--5.4-45.2).

From Figure 4-7, the devices are spaced 10 m apart in the floor space. As an example, the visibility device at position "B" is labelled VIS_(-18.2--5.4-45.2) whereas the visibility device at position "C" is labelled VIS_(-28.2--15.4-45.2)

Measurements such as layer height, upper layer temperature and lower layer temperature were measured across the floor to ceiling height of the floor space. Those devices are labelled such that their z-coordinate is that of the floor level (i.e, 4.8 m x 9 floors = 43.2 for the device located on the fire floor of a 20-storey building). As an example, the device at position "A" on the fire floor space of a 20-storey building that measures layer height will be labelled LH_(-28.2--5.4-43.2).

For conventional stairs, the x and y-coordinate of the device located on the stairwell floor landings are -0.9 and 2.4 respectively. As an example, a device that measures visibility on the stairwell fire floor landing of a 20-storey building is labelled VIS_ (-0.9-2.4-45.2). The x and y-coordinate of the device located on the stairwell intermediate landings are 5.7 and 2.4 respectively. As an example, a device that measures visibility on the stairwell fire floor intermediate landing of a 20-storey building is labelled VIS_ (5.7-2.4-47.6).

For scissor stairs, the x and y-coordinate of the device located on the stairwell floor landings are -0.9 and -73.2 respectively. As an example, a device that measures visibility on the stairwell fire floor landing of a 20-storey building is labelled VIS_ (-0.9--73.2-45.2). The x and y-coordinate of the device located on the stairwell intermediate landings are 5.7 and -73.2 respectively. As an example, a device that measures visibility on the stairwell fire floor intermediate landing of a 20-storey building is labelled VIS_ (5.7--73.2-47.6).

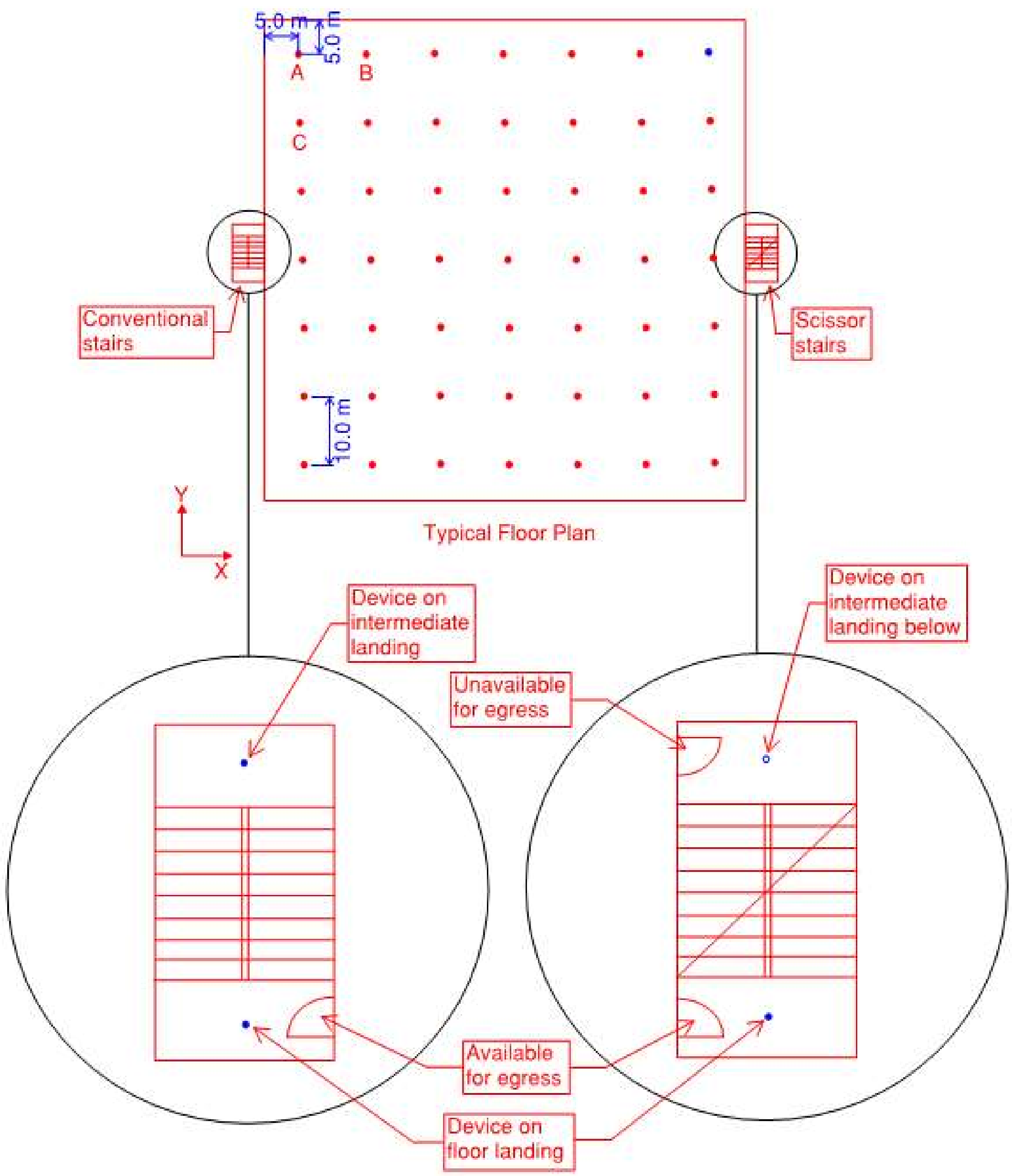


Figure 4-7: Location of devices for large floor area

For medium and small floor area, the same labelling convention as per that described for the large floor area were used. The spacing of the devices in the floor space were as per Figure 4-8 and Figure 4-9 for medium and small floor area respectively. The location of the devices within the conventional and scissor stairs of the medium and small floor area were located similar to that of the large floor area (i.e. at the centre of each landing).

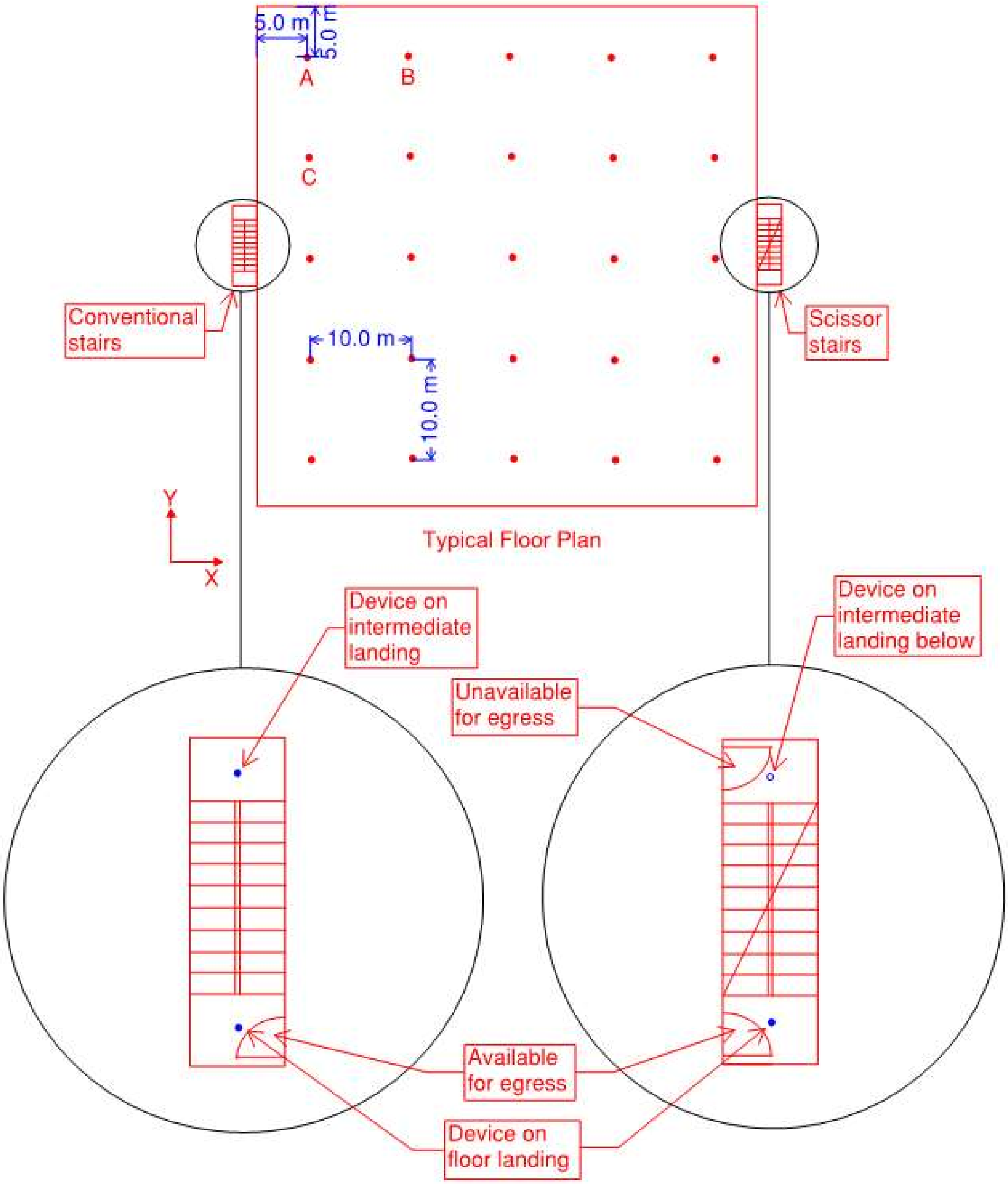


Figure 4-8: Location of devices for medium floor area

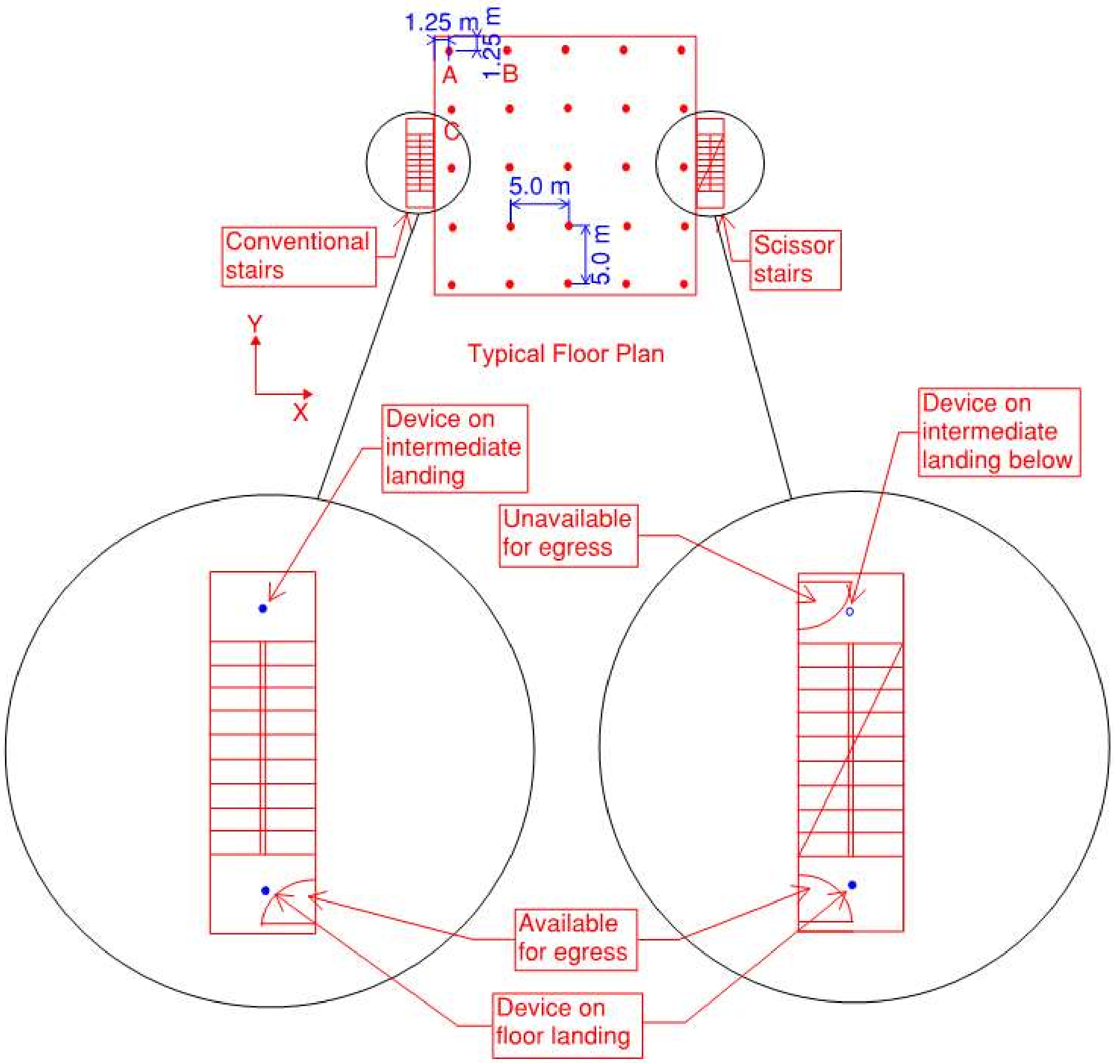


Figure 4-9: Location of devices for small floor area

Elevations showing the location of the devices in the floor and intermediate landings of conventional and scissor stairs typical to all floor areas are shown in Figure 4-10.

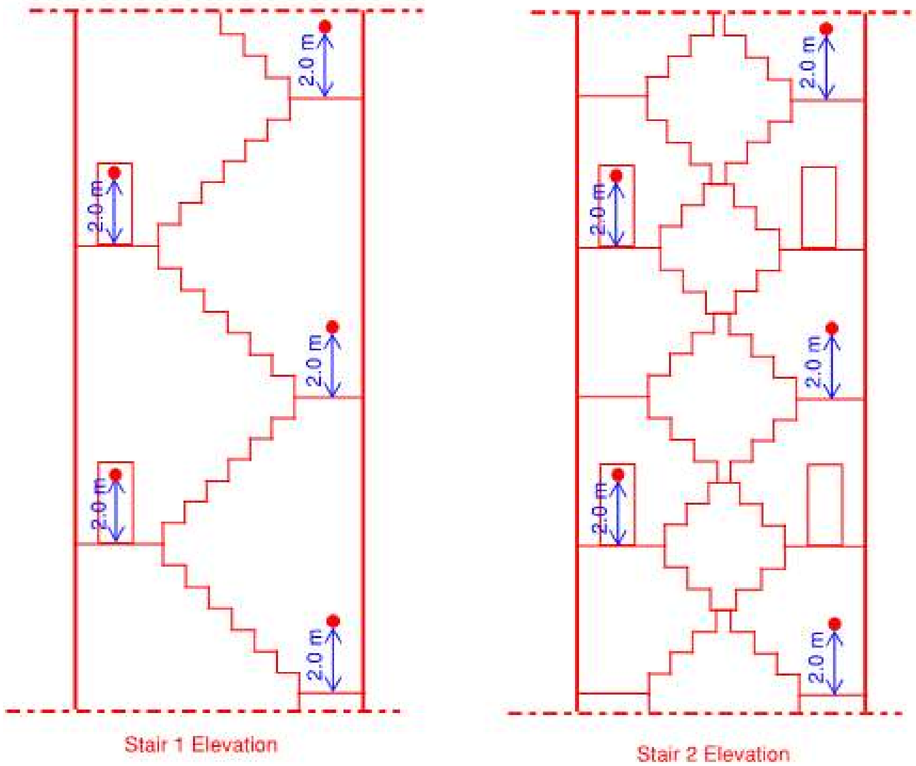


Figure 4-10: Location of devices in conventional and scissor stairs

## 4.2 FDS+Evac Model Set-up

### 4.2.1 FDS+Evac Geometry

Within the FDS+Evac model, the building components modelled were comprised of both stairwells and all the floors except for the ground level. It is assumed that occupants on the ground floor have escape routes which lead directly to the outside without passing through the stairs. Separate evacuation meshes are used to model each floor space and the associated conventional and scissor stair sections at every floor level. Therefore, for a 20-storey building, the total number of mesh was 59 meshes which consists of 20 meshes for conventional stair sections, 20 meshes for scissor stair sections, and 19 meshes for floors, as ground level was not modelled. Similarly, for a 10-storey building, the total number of mesh is 29 (10 meshes for conventional stairs, 10 meshes for scissor stairs and 9 meshes for floors). 100 mm grid size was utilised throughout the entire model.

The stairs within FDS+Evac were constructed using the EVSS namelist. EVSS namelist defines an incline in place of treads and risers of an actual stair which allows the occupants to traverse between stair levels. The incline can be set as horizontal to model the intermediate landings of stairwell.

The width of the stairwell doors and the final exit door were modelled as 1000 mm (full width) for egress. The method used for moving occupants from the floor space into the stairwell includes the use of DOOR namelist and ENTR namelist within FDS+Evac. The DOOR namelist defines a door for which the agents can pass through to adjacent space (e.g. stairs). The ENTR namelist defines an entry which restricts the movement of agents to one-way (i.e. from the floor space into the stairwell).

EVHO namelist was used to prevent FDS+Evac from placing occupants (or agents) within the vicinity of the fire. Obstructions specific to evacuation only were specified around the fire to prevent the occupants (or agents) from traversing through the fire during evacuation. These obstructions are not recognised by the smoke and fire calculations of FDS.

### 4.2.2 Evacuation Parameters

All agents specified were of "Adult" body type and have the following predefined body dimensions (Refer to Table 4-1) with uniform distribution in FDS+Evac. "Adult" body type were selected due to the fact that majority of office occupants are expected to be adults.

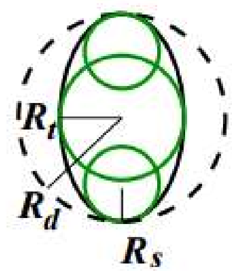


Figure 4-11: Body type parameters [72]

Table 4-1: Body type as defined in FDS+Evac (see Figure 4-11); $d_s = R_d - R_s$ [72]

| Body type | $R_d$ (m) | $R_t/R_d$ | $R_s/R_d$ | $d_s/R_d$ |
|---|---|---|---|---|
| Adult | 0.255 ± 0.035 | 0.5882 | 0.3725 | 0.6275 |
| Male | 0.270 ± 0.020 | 0.5926 | 0.3704 | 0.6296 |
| Female | 0.240 ± 0.020 | 0.5833 | 0.3750 | 0.6250 |
| Child | 0.210 ± 0.015 | 0.5714 | 0.3333 | 0.6667 |
| Elderly | 0.250 ± 0.020 | 0.6000 | 0.3600 | 0.6400 |

The maximum unimpeded horizontal and vertical travelling speeds of all the agents were specified with a constant value of 1.2 m/s and 1.05 m/s (accessible stair) respectively in accordance with Part 3 (Table 3.4) of C/VM2 [6]. These values were inputs in the FDS+Evac model for all simulations.

The detection time for each modelling scenario was obtained from FDS fire modelling and it was the time of sprinkler activation for scenarios with sprinkler protection only. For scenarios with sprinkler protection and smoke detection, the detection time was the earlier activation time of the two devices. The notification time was 30 s in accordance with C/VM2 to allow for polling of the fire protection system. FDS+Evac only simulates detection time and pre-evacuation time, thus, the notification time of 30 s was added to the pre-evacuation time for all scenarios.

Part 3 (Table 3.3) of C/VM2 was used for determining the pre-evacuation times for occupants in the enclosure of origin, and also those who are remote from the enclosure of origin. For an office building use, it is reasonable to assume that the occupants are awake, alert and familiar with the building. Therefore, according to Table 3.3 of C/VM2, the pre-evacuation time for occupants in the enclosure of origin and those remote from the enclosure of origin were 30 s and 60 s, respectively. By adding 30 s of notification time to the pre-evacuation time, the pre-evacuation time input for all scenarios were 60 s for the occupants in the enclosure of origin (fire floor) and 90 s for the occupants remote from enclosure of origin (other floors).

For exit selection within the model, half of the total occupants in a floor level were specified to only recognise the door leading into the conventional stair and the other half were specified to only recognise the door leading to the scissor stairs. This approach will ensure:

- ❖ An even distribution of occupants to the available exits for comparison of the effect of different stair arrangements on tenability conditions.
- ❖ Both stairwell doors on the fire floor to be opened for equal duration.
- ❖ Both stairwells to serve an equal number of occupants to avoid overloading of any one stairwell.

The type of agent specified for all scenarios was the default who will prioritise the use of all known doors, and if no known door is found, they will proceed to use the visible doors [89]. The characteristic of the default agent type allows the number of occupants using each stairwell to be split evenly. One of the two stairwell doors were specified to be known by half of the total occupants on a floor and the other stairwell door was specified to be known by the remaining half. The herding type of the agent for all scenarios was also set to the default in FDS+Evac [89]. The default agent herding type will allow agent to follow the flow field if no door is found. For coupled FDS and FDS+Evac simulation, the level above the floor where the smoke and FED information will affect each agent was 2 m for all scenarios.

## 4.3 Modelling Input Files

An exemplar input file with both FDS and FDS+Evac components can be found in Appendix B. The exemplar input file is that of M_20_T6_T_2.7 simulation scenario with the following building characteristics. Refer to Table 3-2 for the complete list of building characteristics for other scenarios.

| Run | Parameters | | | | |
|---|---|---|---|---|---|
| | **Floor Area** | **Building Height** | **Fire protection system** | **Evacuation strategy** | **Ceiling height** |
| M_20_T6_T_2.7 | Medium | 20-storey | Type 6 | Total | Low |

# 5. Preliminary Modelling

This chapter focuses on preliminary modelling which involves FDS+Evac (evacuation only) and FDS (fire only) modelling. Evacuation only modelling is required to be carried out to identify the following:

- ❖ Stairwell door opening duration which will be used as input for FDS in all simulations
- ❖ The full evacuation time which is useful for setting the FDS run time

Fire only modelling is required to determine the smoke detection time and sprinkler activation time so that the following can be modelled accurately within FDS:

- ❖ Stairwell door opening and closing time
- ❖ Capping fire HRR at sprinkler activation time

## 5.1 FDS+Evac Modelling (Evacuation Only)

It is important to note that the doors defined in FDS+Evac are different entity to that of FDS and they are independent of each other. The doors defined in FDS+Evac will only affect evacuation whereas the doors defined in FDS only affect the fire and smoke calculation. Thus, in this study, it is essential to conduct preliminary modelling to determine a second order estimation of the door opening duration to serve as input for the FDS modelling. Preliminary modelling consists of evacuation drills within FDS+Evac with no fire meshes. As such, no fire calculation is performed and only evacuation calculation is carried out. The door opening duration is required for the fire floor and floor above only as these floors were modelled in FDS.

Through examining the building parameters and their associated variables listed in Table 3-1, the door opening duration for fire floor and floor above are only affected by the floor area (large; medium; small), building height (10-storey; 20-storey) and evacuation strategy (total; phased). The remaining two parameters – fire protection system (Type 6; Type 7) and ceiling height (low; high) only affect the door opening and closing times but not the opening duration. The evacuation drills summarised in Table 5-1 were conducted to determine the door opening durations to be used in FDS modelling for all simulations.

Table 5-1: Evacuation only (drill) scenarios

| Evacuation Drill | Scenarios |
|---|---|
| 1 | large; 20-storey; total |
| 2 | medium; 20-storey; total |
| 3 | small; 20-storey; total |
| 4 | large; 10-storey; total |
| 5 | medium; 10-storey; total |
| 6 | small; 10-storey; total |
| 7 | large; 20-storey; phased |
| 8 | medium; 20-storey; phased |
| 9 | large; 10-storey; phased |
| 10 | medium; 10-storey; phased |

The following two sub-sections, 5.1.1 and 5.1.2 present the outcome of the preliminary modelling on door opening duration affected by floor areas, building height and evacuation strategy. The discussions focus on the two evacuation strategies – total and phased evacuation.

### 5.1.1 Total Evacuation Scenarios

For all total evacuation drill scenarios, the FDS+Evac model was set up such that the occupants on the fire floor started evacuating at time zero with the rest of the occupants in the building followed 30 s later. This 30 s time difference between the occupants in the floor of fire origin and the rest of the building is based on the difference in pre-evacuation time between the occupants on the fire floor (30 s) and those remote from the fire floor (60 s) given that the detection and notification time for total evacuation would be the same.

Due to the stochastic nature of the FDS+Evac, each evacuation drill was repeated 10 times. From the 10 evacuation drill simulated, the mean door opening duration for fire floor and floor above were determined and used as input in FDS modelling. Table 5-2 summarises the mean door opening duration for the fire floor and floor above for all the total evacuation scenarios examined.

Table 5-2: Mean door opening duration for fire floor and floor above (total evacuation)

| Evacuation Drill | Scenarios | No. of Runs | Door opening duration (s) | |
|---|---|---|---|---|
| | | | Fire floor | Floor above |
| 1 | large; 20-storey; total | 10 | 2591 | 2787 |
| 2 | medium; 20-storey; total | 10 | 2157 | 2163 |
| 3 | small; 20-storey; total | 10 | 33 | 65 |
| 4 | large; 10-storey; total | 10 | 1413 | 1299 |
| 5 | medium; 10-storey; total | 10 | 1038 | 914 |
| 6 | small; 10-storey; total | 10 | 33 | 53 |

From each evacuation drill scenario, the following were observed:

- Floor clearing pattern (see **Figure 5-1**)
- Stairwell floor clearing pattern (see **Figure 5-1**)
- Total evacuation time (see **Figure 5-1**)

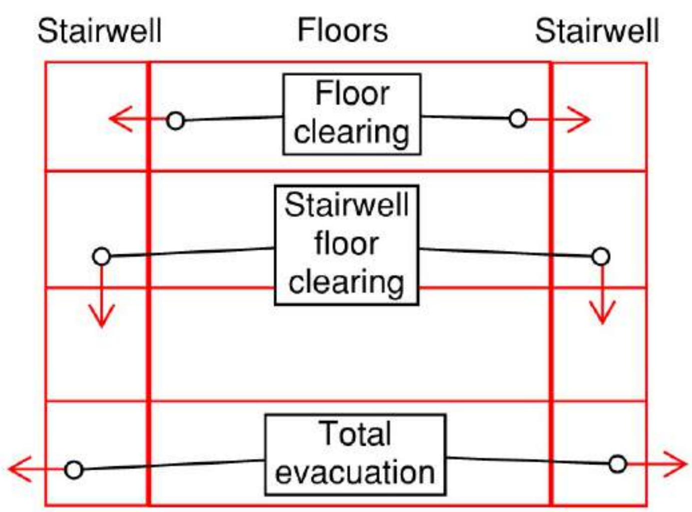


Figure 5-1: Illustration of floor clearing, stairwell floor clearing and total evacuation time

Figure 5-2 to Figure 5-7 show the mean time to clear each floor space for each evacuation drill scenario. The error bars indicate the maximum and minimum time to clear each floor based on 10 simulations. The mean time to clear the fire floor and floor above are indicated in those figures. The fire floor for each scenario is circled on the figure.

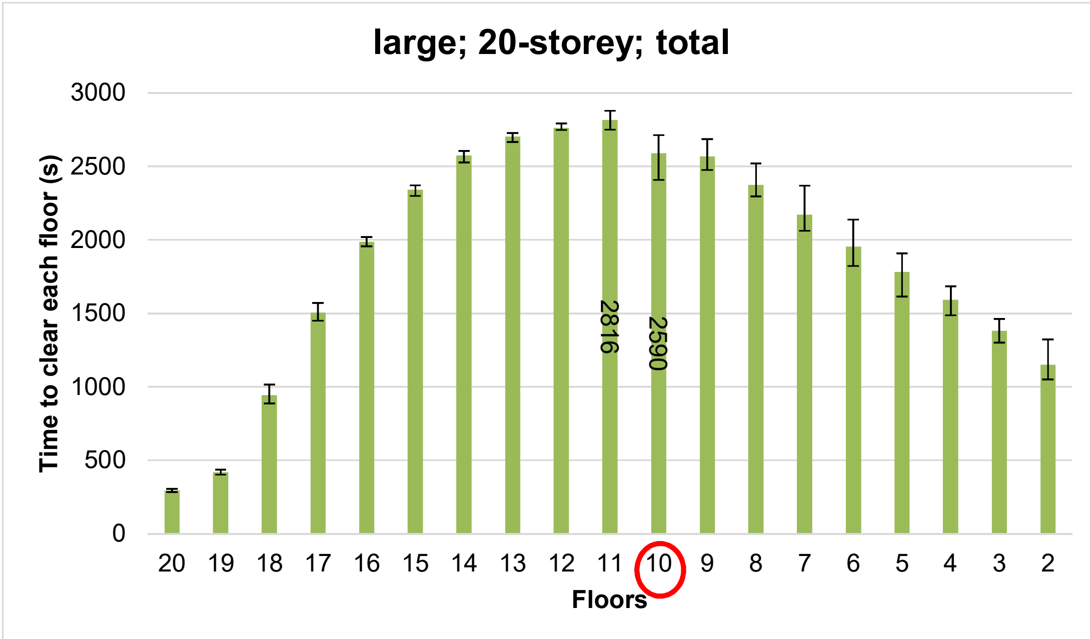


Figure 5-2: Time to clear each floor (large; 20-storey; total)

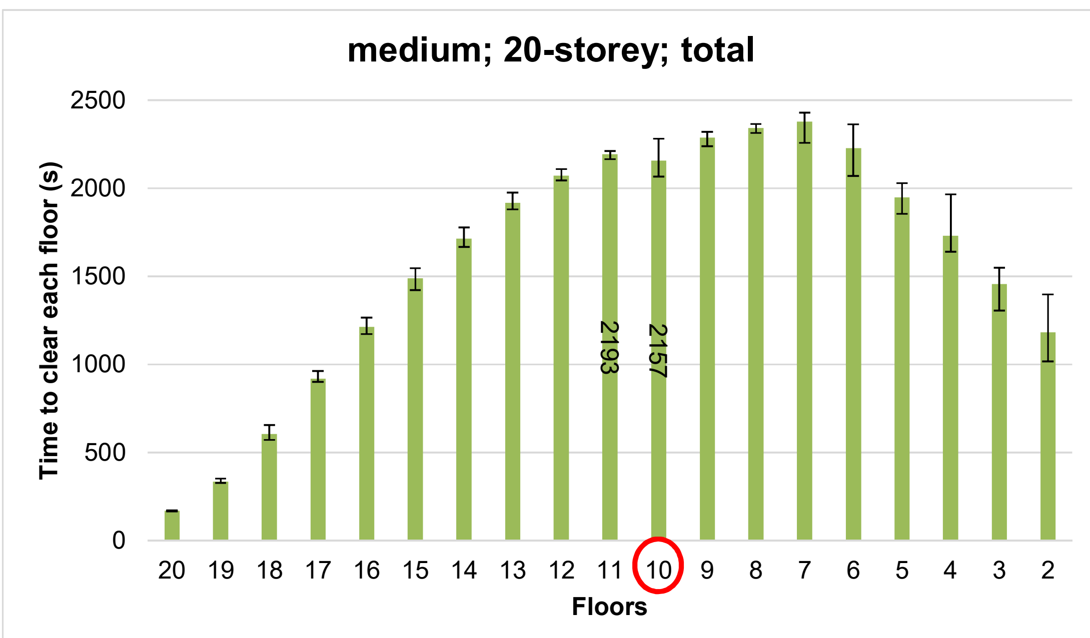


Figure 5-3: Time to clear each floor (medium; 20-storey; total)

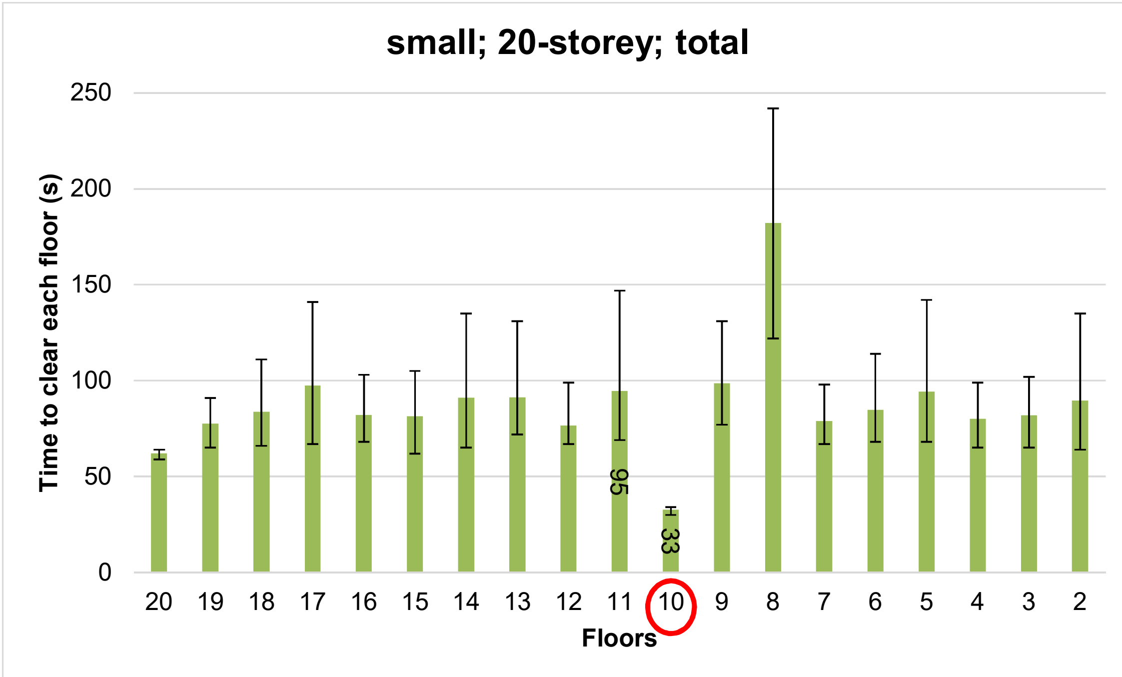


Figure 5-4: Time to clear each floor (small; 20-storey; total)

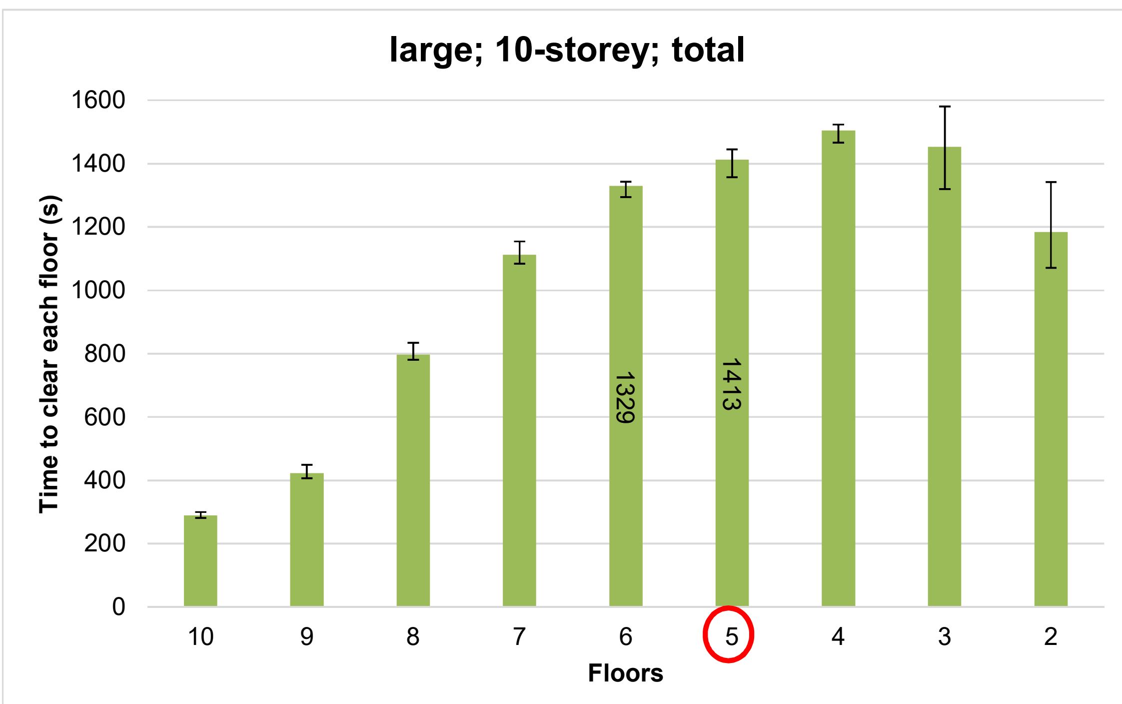


Figure 5-5: Time to clear each floor (large; 10-storey; total)

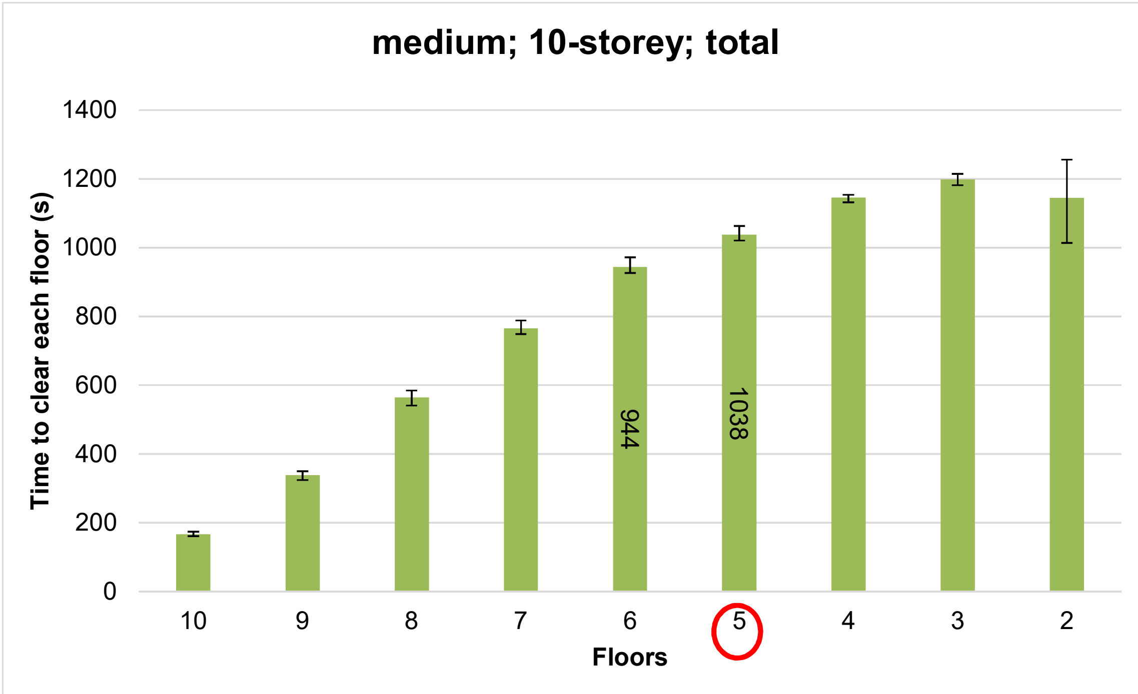


Figure 5-6: Time to clear each floor (medium; 10-storey; total)

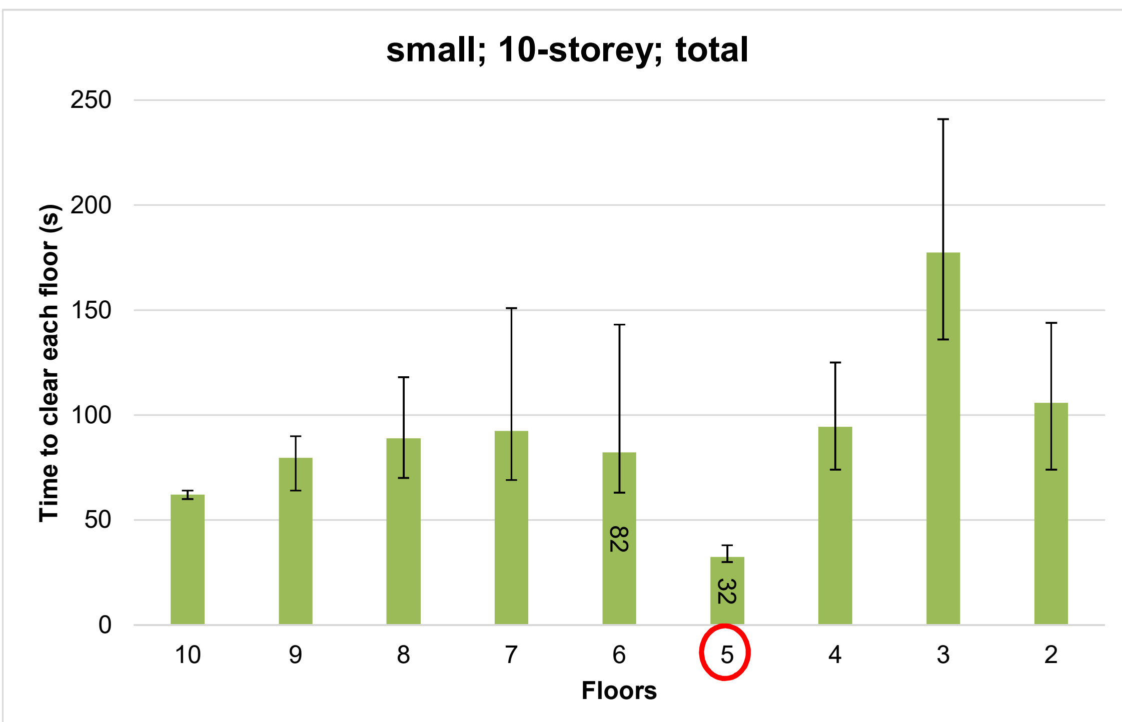


Figure 5-7: Time to clear each floor (small; 10-storey; total)

From Figure 5-2 to Figure 5-7, the results show that for large and medium floor area, the building's top floors clear the earliest, followed by the bottom floors while the middle floors, including the floor of fire origin require the longest evacuation time. For example, Figure 5-2 for 20 storey building with large floor utilising total evacuation shows $18^{th}$ – $20^{th}$ floors clearing within 1000 s, $2^{nd}$ – $6^{th}$ floors clearing between 1000 to 2000 s, and $7^{th}$ – $17^{th}$ floors clearing between 1500 to 3000 s. For small floor area, the results show a different floor clearing pattern to large and medium floor area. The fire floor clears the earliest due to its shorter pre-movement time of 30 s while the remaining floors clear within an identical duration, except for the floor located two floors below fire floor which has the longest evacuation time by approximately 80%. For example, Figure 5-4 for 20 storey building with small floor utilising total evacuation shows $10^{th}$ floor clearing within 33 s, remaining floors clearing between 60 to 100 s, except $8^{th}$ floor which took 180 s to clear. However, by taking into account the uncertainties, the remaining floors appear to take roughly the same time to clear.

Figure 5-8 to Figure 5-13 show the mean time to clear each stairwell floor space for each evacuation drill scenario. The errors bars indicate the maximum and minimum time to clear each floor based on 10 simulations. Two different stair configurations, conventional and scissor stairs were investigated. The mean time to clear each floor of both stairwells are indicated in those figures. The stairwell floor for each scenario with which the fire floor opens into is circled on the figure.

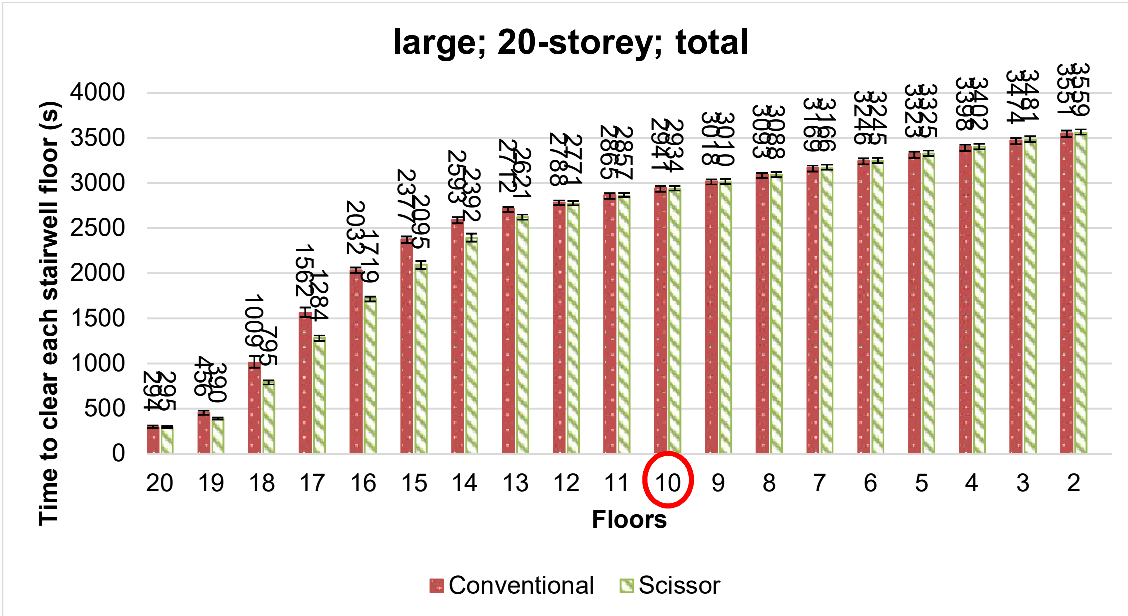


Figure 5-8: Time to clear floors of conventional and scissor stairs (large; 20-storey; total)

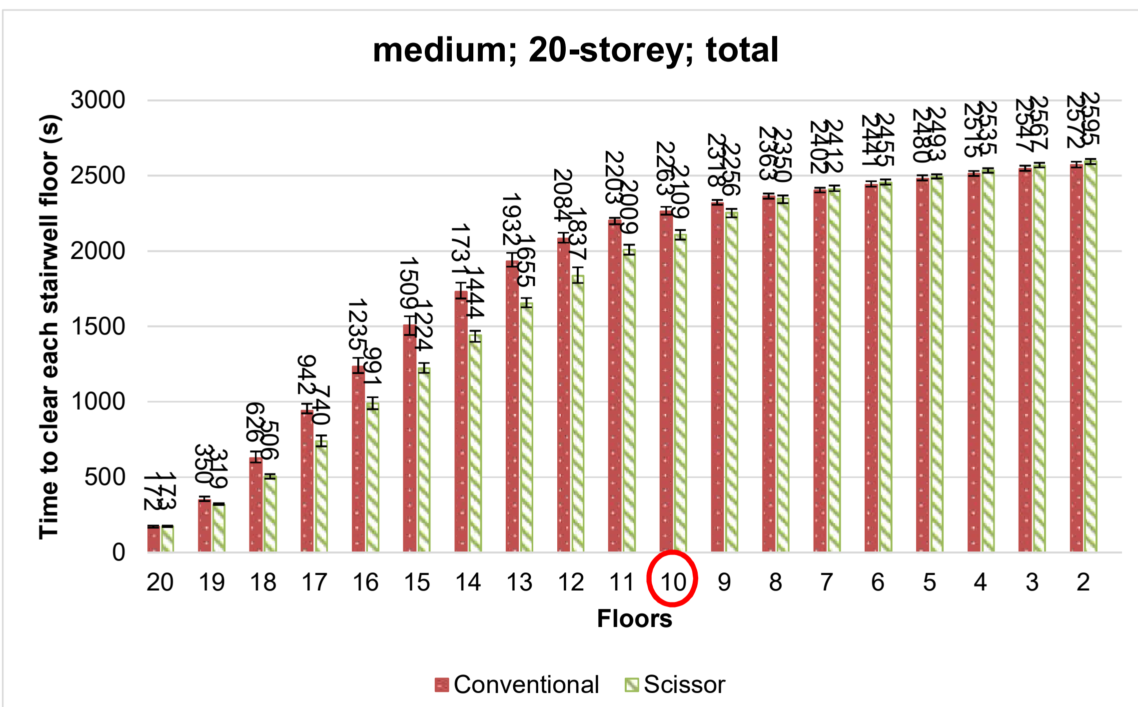


Figure 5-9: Time to clear floors of conventional and scissor stairs (medium; 20-storey; total)

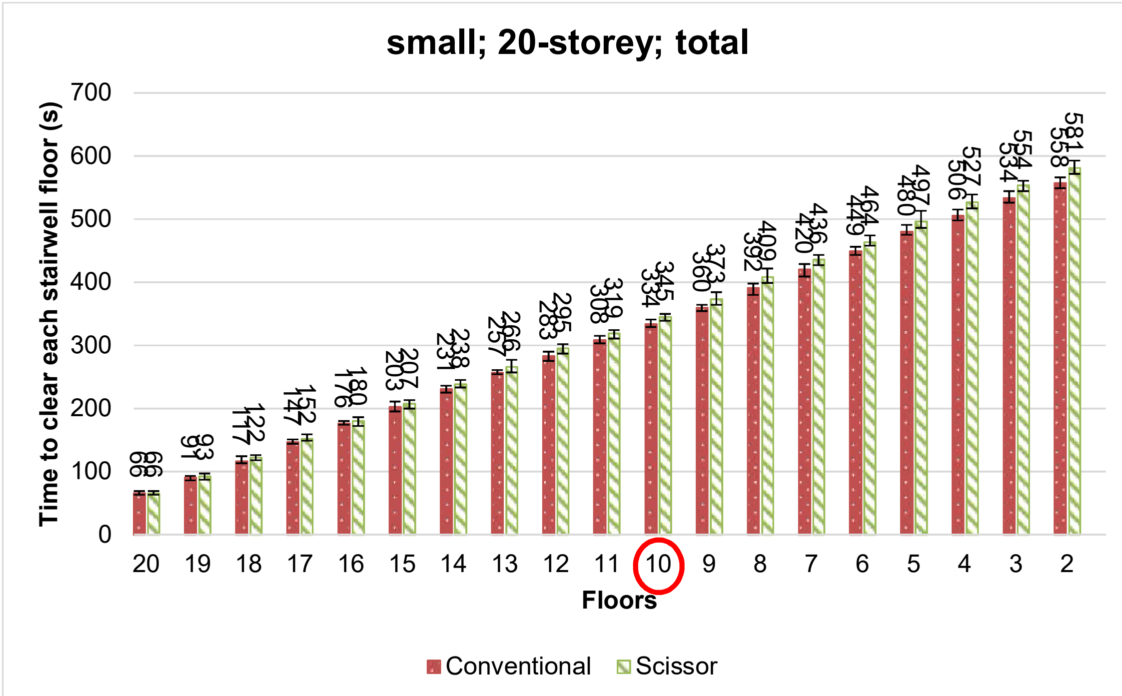


Figure 5-10: Time to clear floors of conventional and scissor stairs (small; 20-storey; total)

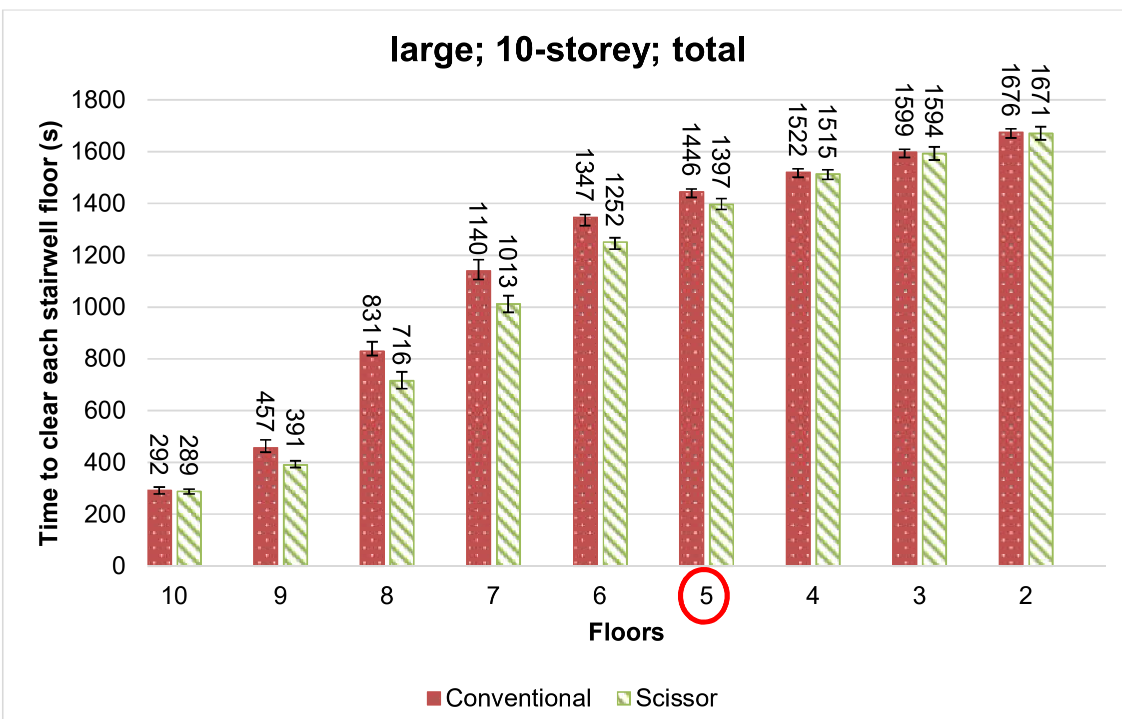


Figure 5-11: Time to clear floors of conventional and scissor stairs (large; 10-storey; total)

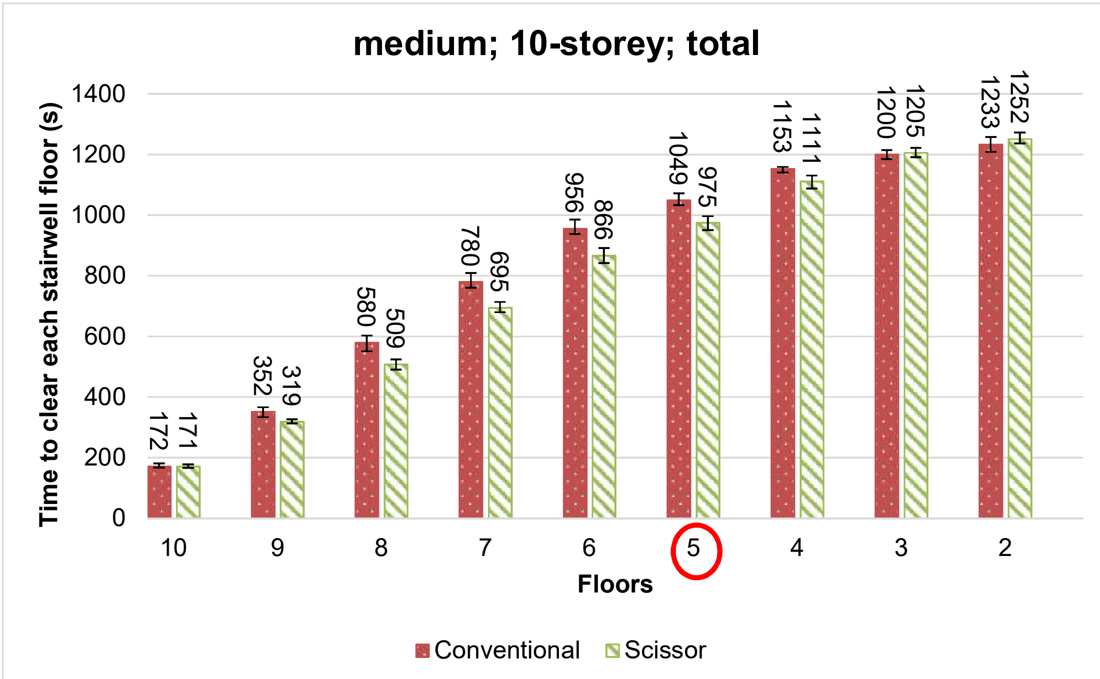


Figure 5-12: Time to clear floors of conventional and scissor stairs (medium; 10-storey; total)

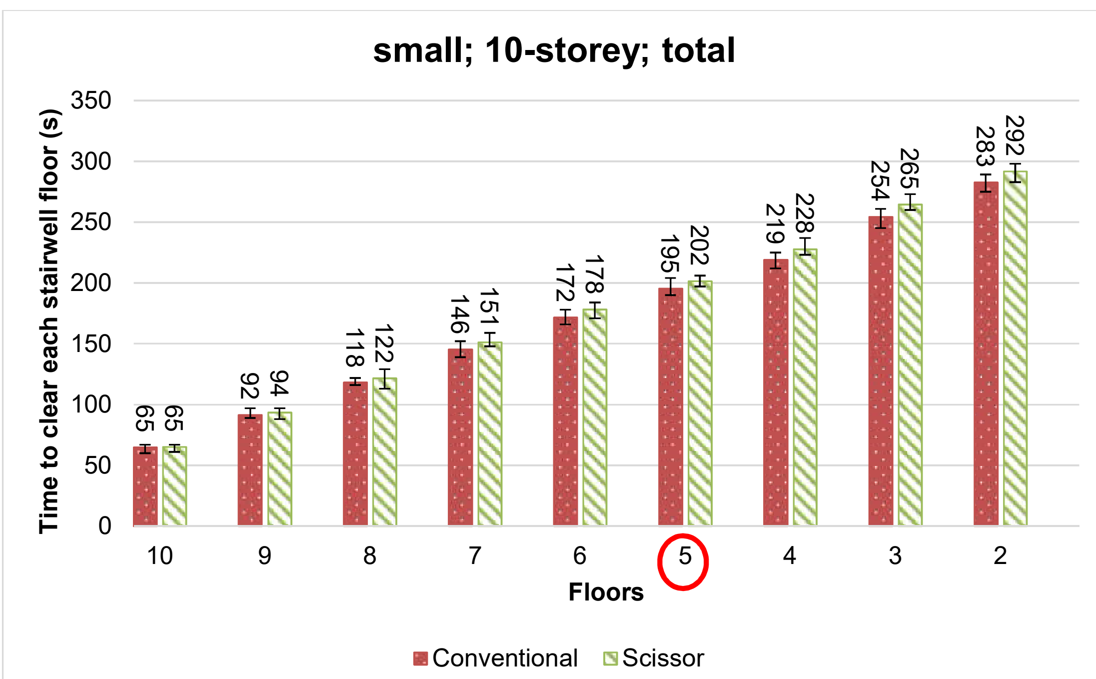


Figure 5-13: Time to clear floors of conventional and scissor stairs (small; 10-storey; total)

From Figure 5-8 to Figure 5-13, the results show that for large and medium floor area, scissor stairs consistently clears at a slightly faster rate compared to conventional stairs over the middle floors. This phenomenon is noted to extend to more floors where medium floor area is simulated. For example, Figure 5-8 for 20 storey with large floor area utilising total evacuation shows scissor stair has higher clear rate between $13^{th}$ and $19^{th}$ floors while for medium floor area (Figure 5-9), this extends to between $9^{th}$ and $19^{th}$ floors. Similar trend is also noted for 10 storey scenarios as depicted in Figure 5-11 and Figure 5-12. Below the mentioned floors, both stairwells clear at the same rate until the completion of the evacuation.

The phenomenon where one stairwell clears at a faster rate compared to another over the middle floors is not within expectation since each stairwell served the same number of occupants and had identical construction within FDS+Evac (Refer to Appendix B). This issue was referred to the developer of FDS+Evac and it was suggested that each floor and its stairwell floors to be modelled as one evacuation mesh. By applying the suggested changes and re-running the FDS+Evac model for medium floor, 20 storey utilising total evacuation, the following differences (compared to the results for evacuation drill 2 in Table 5-2) are observed:

- ❖ Floor clearing pattern – the floors clear from bottom to top for the FDS+Evac model with the suggested changes, as opposed to top few floors clearing first followed by bottom floors with the middle floors taking the longest to clear which is exhibited by the original FDS+Evac model presented above.
- ❖ Total evacuation time – the total evacuation time for the FDS+Evac model with the suggested changes is found to be considerably longer than the original FDS+Evac model by approximately 600 s.

According to the developer of FDS+Evac, the above differences are likely due to the different merging algorithm for different modelling approaches. For the case where the stair geometry is included within the floor meshes, the agents will “compete” at the stair and floor connection point, resulting in more agents being pushed into the stair landing on each floor. This can cause a reduction in the speed and specific flow in the stairs due to high occupancy density which ultimately led to longer total evacuation time. For the case where the stairs and floors are modelled as separate meshes, the DOOR to ENTR connection between the meshes will not allow agent to traverse into the stair if there is insufficient empty space in the stairs. Thus, with this modelling approach, the stairs will only have moderate occupant density resulting in higher specific flow and shorter total evacuation time. Based on this, the two approaches are likely to be the extremes in terms of total evacuation time and the reality could be somewhere in between.

It shall be noted that the suggested modelling approach did not successfully address the issue where one stairwell clears at a faster rate compared to another over the middle floors. This phenomenon is still observed in the FDS+Evac model with the suggested changes. Thus, it is recommended that further studies are to be carried out to identify the extent of the problem or limitation to the software.

Table 5-3 summarises the minimum, mean and maximum total evacuation time for each total evacuation drill scenario based on the author's FDS+Evac setup (i.e. suggested changes by the developer were not incorporated as it did not appear to improve the model).

Table 5-3: Total evacuation time for each total evacuation drill scenarios

| **Evacuation Drill** | **Scenario** | **Total Evacuation Time (s)** | | |
|---|---|---|---|---|
| | | **Min** | **Mean** | **Max** |
| 1 | large; 20-storey; total | 3623 | 3646 | 3669 |
| 2 | medium; 20-storey; total | 2596 | 2614 | 2630 |
| 3 | small; 20-storey; total | 590 | 599 | 611 |
| 4 | large; 10-storey; total | 1747 | 1761 | 1774 |
| 5 | medium; 10-storey; total | 1254 | 1270 | 1291 |
| 6 | small; 10-storey; total | 305 | 311 | 316 |

### 5.1.2 Phased Evacuation Scenarios

As previously mentioned in Section 3.1.4, the phased evacuation strategy is a simple phased evacuation where the occupants on the fire floor are given the priority to evacuate the floor of fire origin before the occupants in the rest of the building begin to evacuate. From the results depicted in Figure 5-4 and Figure 5-7, it is found that phased evacuation would not provide additional benefit to the overall evacuation process of the small floor area as the shorter pre-movement time of 30 s for the occupants on the fire floor is adequate to complete the evacuation on the fire floor before the occupants in the rest of the building start to evacuate. Thus, it is not necessary for small floor area to adopt phased evacuation strategy. This reduces the number of simulations shown in Table 3-2 to 40 simulations.

From FDS+Evac evacuation drill, the unimpeded flow through a 1 m wide door is approximately 55 people/min which is higher than the maximum flow of 50 people/min quoted in the literature [63]. This is not unexpected since the 50 people/min in the literature is based on a single door leaf with self-closer whereas in FDS+Evac, door obstructing people movement is not considered. In order to ensure that the fire floor will be completely cleared before the occupants in the rest of the building start to evacuate under phased evacuation, a conservative flow of 40 people/min is assumed to determine the door opening duration for modelling smoke flow in FDS. Based on this assumed flow, the duration for which occupants on the fire floor are allowed to evacuate unimpeded after detection, notification and pre-evacuation time can be calculated using Equation 6:

$$\frac{\text{Highest no.of occupants using each egress door}}{40\ \text{people/min}} \qquad \text{(Equation 6)}$$

Evacuation drill for phased evacuation scenarios are still required to determine the door opening duration for the floor above. All phased evacuation drill scenarios were set-up such that the occupants on the fire floor start evacuating at time zero, and the rest of the occupants in the building will only evacuate after the duration calculated using Equation 6, based on a conservative 40 people/min flow rate.

Due to the stochastic nature of the FDS+Evac, each phased evacuation drill was repeated up to 5 times only due to minimal variations between simulations (evident by the error bars). From the 5 evacuation drills, the mean door opening duration for floor above were determined and used as input in FDS modelling. Table 5-4 summarises the mean door opening duration for the fire floor and floor above for all the phased evacuation scenarios examined.

Table 5-4: Mean door opening duration for fire floor and floor above (phased evacuation)

| Evacuation Drill | Scenarios | No. of Runs | Highest no. of occupants using each egress door | Door opening duration (s) | |
|---|---|---|---|---|---|
| | | | | Fire floor | Floor above |
| 7 | large; 20-storey; phased | 5 | 250 | 375[1] | 2454 |
| 8 | medium; 20-storey; phased | 5 | 123 | 185[1] | 2072 |
| 9 | large; 10-storey; phased | 5 | 250 | 375[1] | 1126 |
| 10 | medium; 10-storey; phased | 5 | 123 | 185[1] | 818 |

[1] Duration is based on the assumed and conservative 40 people/min through stairwell door rather than the time it takes to clear the floor according to FDS+Evac simulations.

Similar to total evacuation, from each phased evacuation drill, the following were observed:

- Floor clearing pattern
- Stairwell floor clearing pattern
- Total evacuation time

Figure 5-14 to Figure 5-17 show the mean time to clear each floor space for each evacuation drill scenario. The error bars indicate the maximum and minimum time to clear each floor based on 5 simulations. The time to clear the fire floor and the mean time to clear the floor above are shown in those figures. Note that the fire floor is circled.

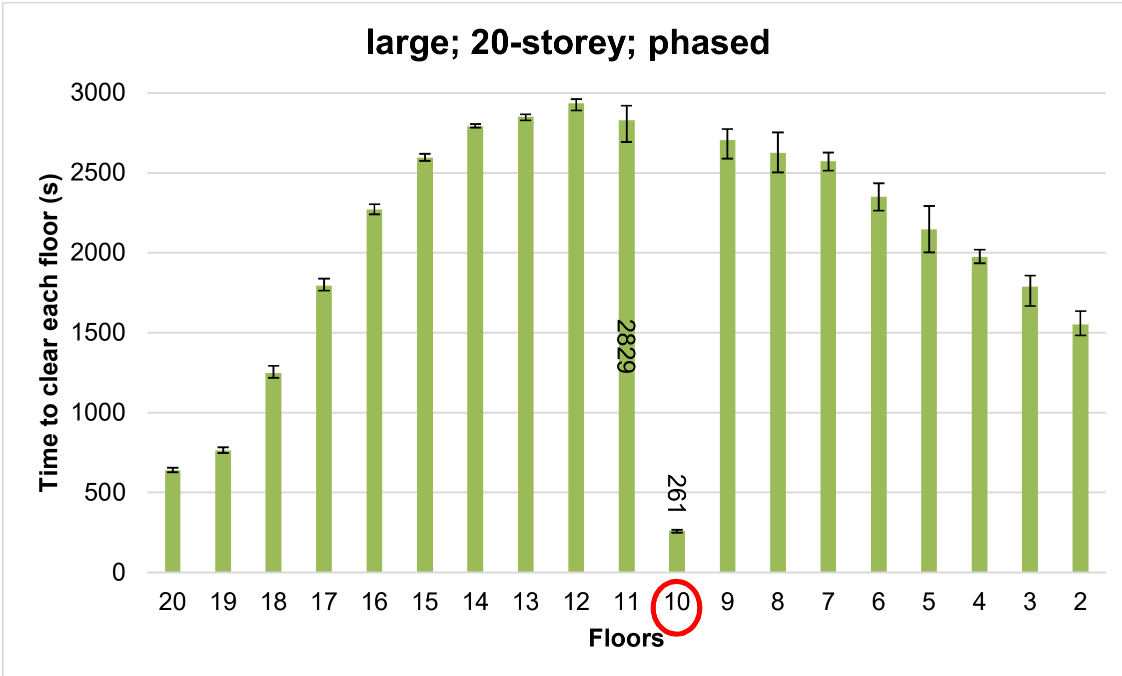


Figure 5-14: Time to clear each floor (large; 20-storey; phased)

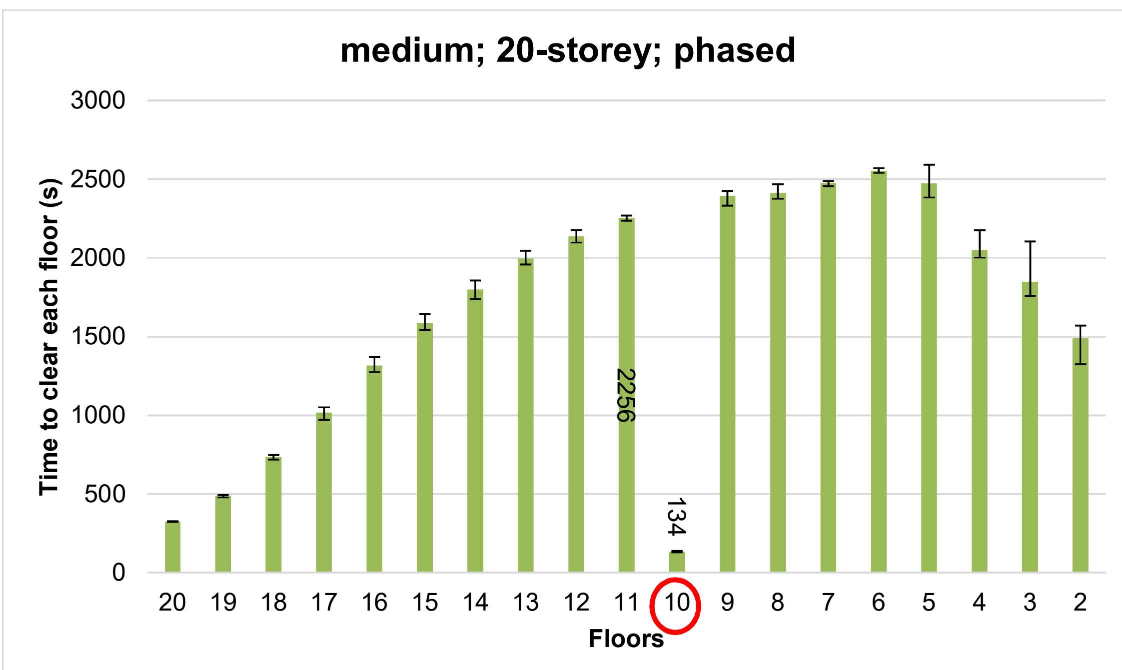


Figure 5-15: Time to clear each floor (medium; 20-storey; phased)


Figure 5-16: Time to clear each floor (large; 10-storey; phased)

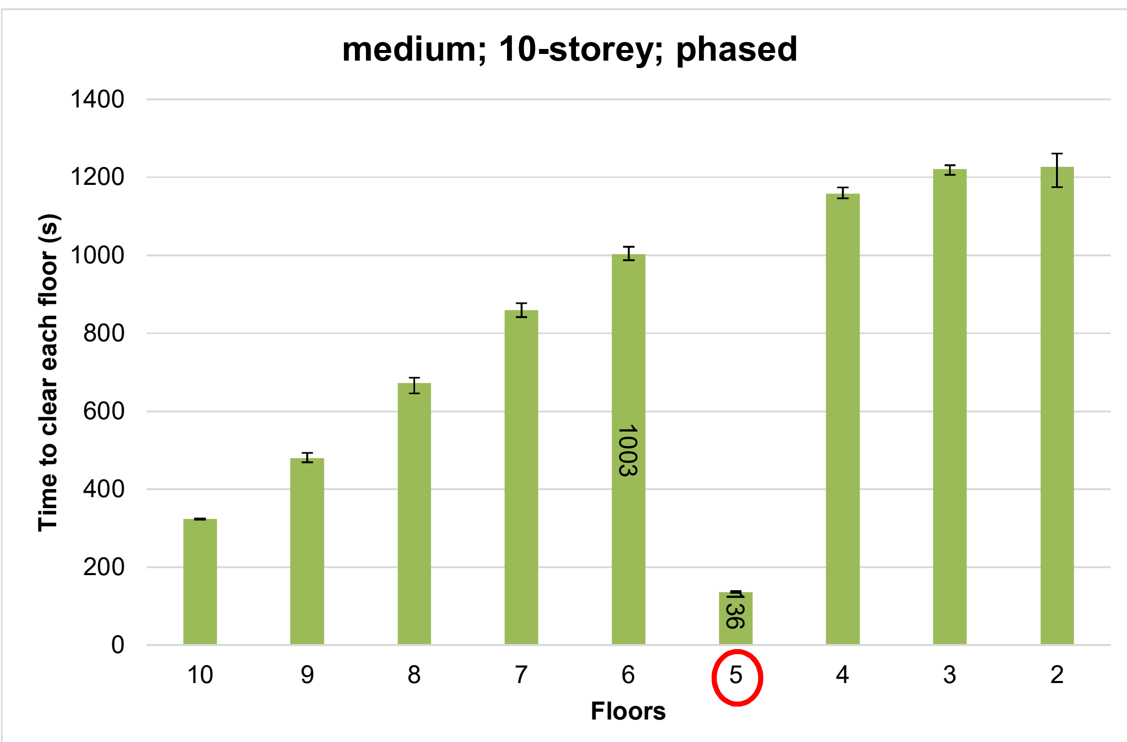


Figure 5-17: Time to clear each floor (medium; 10-storey; phased)

From Figure 5-14 to Figure 5-17 above, the results show that for large and medium floor area, the building's top floors clear the earliest, followed by the bottom floors while the middle floors require the longest evacuation time, except for the fire floor which is shortest due to phased evacuation. For example, Figure 5-14 for 20 storey building with large floor utilising phased evacuation shows 18$^{th}$ – 20$^{th}$ floors clearing within 1500 s, 2$^{nd}$ – 4$^{th}$ floors clearing between 1500 to 2000 s, and 5$^{th}$ – 17$^{th}$ floors clearing between 1500 to 3000 s except the fire floor (10$^{th}$) which took 261 s to clear. The fire floor clearing times shown in Figure 5-14 to Figure 5-17 from FDS+Evac are less than the fire floor clearing times summarised in Table 5-4 which are determined based on the assumed flow of 40 people/min. Therefore, the door opening time modelled for smoke flow is more conservative when compared to the door opening time from FDS+Evac.

Figure 5-18 to Figure 5-21 show the mean time to clear each stairwell floor space for each evacuation drill scenario. The errors bars indicate the maximum and minimum time to clear each stairwell floor based on 5 simulations. Two different stair configurations, conventional and scissor stairs were investigated. The mean time to clear each floor of both stairwells are indicated in those figures.

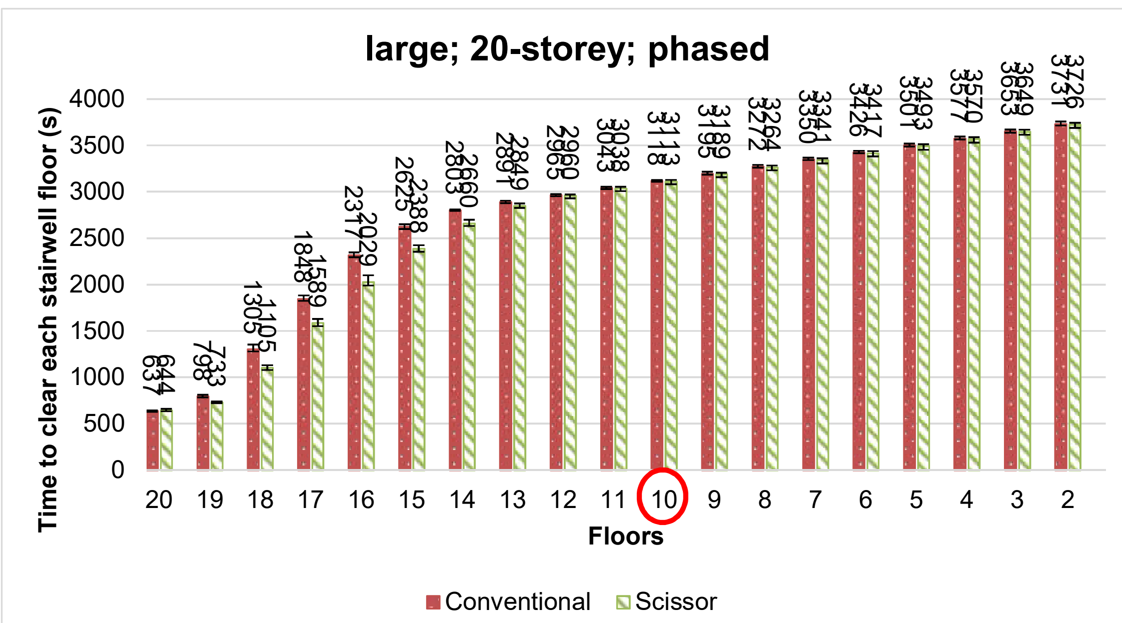


Figure 5-18: Time to clear floors of conventional and scissor stairs (large; 20-storey; phased evacuation)

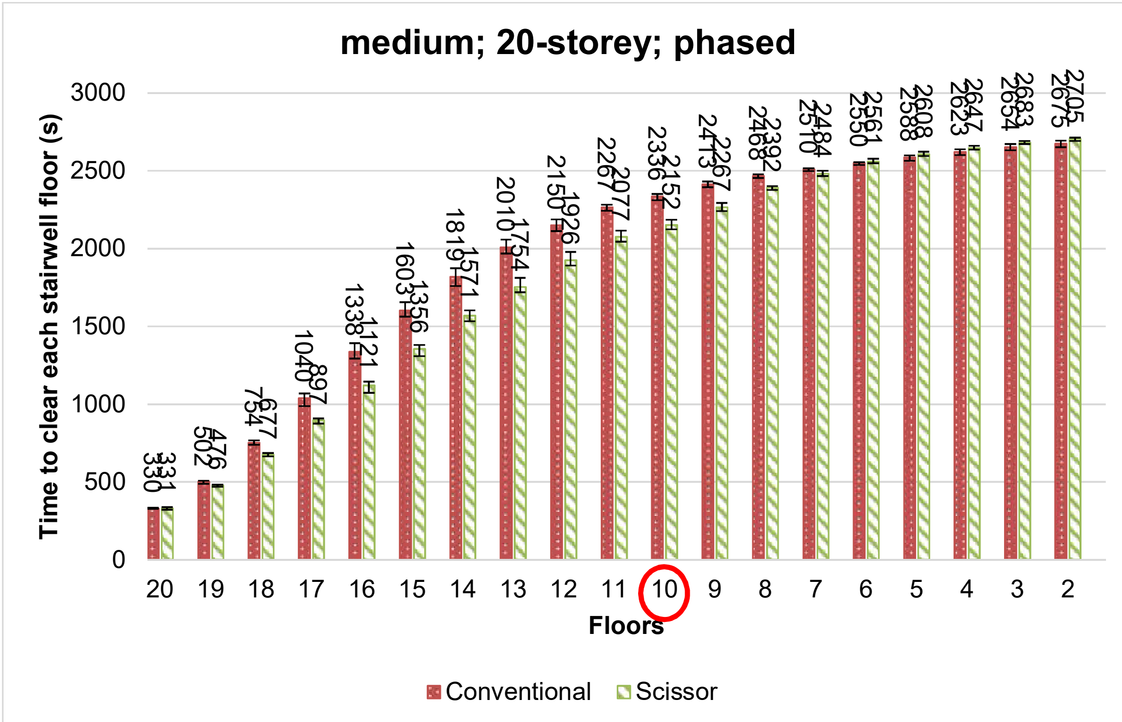


Figure 5-19: Time to clear floors of conventional and scissor stairs (medium; 20-storey; phased)


Figure 5-20: Time to clear floors of conventional and scissor stairs (large; 10-storey; phased)


Figure 5-21: Time to clear floors of conventional and scissor stairs (medium; 10-storey; phased)

From Figure 5-18 to Figure 5-21, the results show a similar trend which is discussed in Section 5.1.1 for total evacuation scenarios whereby the scissor stairs consistently clears at a faster rate compared to conventional stairs over middle floors and beyond.

Table 5-5 summarises the minimum, mean and maximum total evacuation time for each phased evacuation drill scenario.

Table 5-5: Total evacuation time for each phased evacuation drill scenarios

| Phased Evacuation Scenario | Total Evacuation Time (s) | | |
|---|---|---|---|
| | Min | Mean | Max |
| large; 20-storey; phased | 3806 | 3817 | 3833 |
| medium; 20-storey; phased | 2712 | 2722 | 2732 |
| large; 10-storey; phased | 1914 | 1927 | 1942 |
| medium; 10-storey; phased | 1282 | 1293 | 1302 |

## 5.2 Comparison between FDS+Evac and Hydraulic Models

The results for total evacuation drills from FDS+Evac model are compared against first and second order hydraulic model (hand calculations) as described in The SFPE Handbook [63] for validation of the computational evacuation model. The first order hydraulic model represents a simplified approach where it focuses mainly on the building component (e.g. doorway, corridor or stairwell) that places the most severe constraint on the flow of people, and uses this constraint to determine the movement time. The second order hydraulic model requires the calculation of the occupant flow between the building components which provide information on the occupant movement between the building components along the egress route. The subsequent sections demonstrate the calculations of the total evacuation time using the first and second order hydraulic models for 20-storey; large, medium and small floor office buildings. Due to the simplifying assumptions and limitations associated with the hydraulic models, the comparison of total evacuation time is made, and office floors and stairwell floors clearing time are not compared as these are not specifically calculated by the hydraulic models.

### 5.2.1 First Order Hydraulic Model

According to Table 3-13.5 in The SFPE Handbook [63], the maximum specific flow for doorway is given by 1.3 persons/s/m of effective width. The stairs in this study are accessible stairs, and according to Table 3-13.5 the maximum specific flow for accessible stair with 165 mm riser and 310 mm tread is 1.16 persons/s/m of effective width.

The main assumptions and limitations relating to first order hydraulic model are:

- ❖ The flow through constrictions (doorway and stairs) govern over the travel time (reasonable for this study due to high occupancy load on each floor).
- ❖ Maximum specific flow value for doorway and stairs assumes optimum density (1.9 persons/m$^2$) at the vicinity of the flow.
- ❖ Inability to account for occupants on fire floor evacuating 30 s earlier than the rest of the building.
- ❖ Inability to account for the time to clear floors due to merging flow in the stairwell.

**Small floor**

The door opening into the stairs on each floor measured 1 m in width and the stairs have a minimum required width of 1.1 m as discussed in Section 4.2.3.3. From Table 3-13.1 in the SFPE Handbook, the boundary layer width for doorway and stairs is 0.15 m. Therefore, the effective width of doorway and stairs are calculated to be 0.7 m (1 – 0.15 x 2) and 0.8 m (1.1 – 0.15 x 2) respectively.

Using the effective widths, the flow capacity through the door and the flow capability of the stairs are calculated as follow:

- Flow capacity through door, $F_d$ = 1.3 x 0.7 = 0.91 persons/s (this is the same for the final exit door at the bottom of the stairs as the final exit door width is also 1 m)
- Flow capability of stairs, $F_s$ = 1.16 x 0.8 = 0.928 person/s

From the above calculations, the flow capacity through door is less than that of the stairs. Thus, the flow is controlled by the door of each floor.

Equation 7 taken from the SFPE Handbook is used for calculating the speed of movement down the stairs:

$$S = k - akD \qquad \text{(Equation 7)}$$

Where
$S$ = speed along the line of travel (m/s)
$D$ = population density (persons/m$^2$)
$k$ = 1.23 m/s (for accessible stairs)
$a$ = 0.266

As mentioned previously, the density in the stairs is assumed to be an optimal value of 1.9 persons/m$^2$. The stairs travel speed is therefore $S$ = 1.23 – 0.266 x 1.23 x 1.9 = 0.6 m/s. The travel distance down one floor is calculated based on the dimension of the landings and stairs. For small floor, an occupant will have to travel 2.4 m along the landing, 5.4 m down the slope of the first flight of stairs, 2.4 m along the intermediate landing and 5.4 m down the slope of the second flight of stairs to get to the floor below. This gives a total distance of 5.4 x 2 + 2.4 x 2 = 15.6 m. The travel time between floors is therefore 15.6/0.6 = 26 s/floor.

Similar to the FDS+Evac model, it is assumed that on each floor which has a total of 51 occupants, 26 occupants will use one of the stairs and 25 occupants will use the other. Therefore, the total number of occupants using the slightly more occupied stair is 26 persons/floor x 19 floors = 494 occupants.

If all occupants in the building start evacuating at the same time (t = 0 s), each stairs can discharge 0.91 persons/s through the final exit door at ground level, it is estimated to take 494/0.91 = 543 s to flow down the stairs with an additional 26 s to account for the travel time from the first floor to the exit on the ground floor. This gives a total evacuation time of **543 + 26 = 569 s** for 20-storey, small floor office building.

**Medium floor**

From Section 4.2.3.2, the 20-storey office building with medium floor has the same width for doorway and stairs construction as the small floor. Therefore, the flow capacity through door and stairs as well as the travel time between floors are the same as that of small floor.

Similar to the FDS+Evac model, it is assumed that on each floor which has a total of 245 occupants, 123 occupants will use one of the stairs and 122 occupants will use the other. Therefore, the total number of occupants using the slightly more occupied stairs is 123 persons/floor x 19 floors = 2337 occupants.

If all occupants in the building start evacuating at the same time (t = 0 s), each stairs can discharge 0.91 persons/s out of the final exit, it is estimated to take 2337/0.91 = 2569 s to flow down the stairs with an additional 26 s to account for the travel time from the first floor to the exit on the ground floor. This gives a total evacuation time of **2569 + 26 = 2595 s** for 20-storey, medium floor office building.

**Large floor**

From Section 4.2.3.1, the 20-storey office building with large floor also has the same doorway width as the small and medium floor and therefore, the flow capacity through the door is also 0.91 persons/s. The width of the stairs for large floor is 2.3 m wide which gives an effective width of 2.3 – 0.15 x 2 = 2.0 m. Thus, the flow capability of stairs is calculated to be 1.16 x 2 = 2.32 persons/s which is larger than the flow capacity of the door, thus, the lesser flow of the doorway will govern.

The travel speed down the stairs remains the same (0.6 m/s) due to the assumed optimum density of 1.9 persons/$m^2$ in the stairs. As for the travel distance between floors, an occupant will have to travel 4.8 m along the landing, 5.4 m down the first flight of stairs, 4.8 m along the intermediate landing and 5.4 m down the second flight of stairs to get to the floor below. This gives a total distance of 5.4 x 2 + 4.8 x 2 = 20.4 m. The travel time between floors is calculated to be 20.4/0.6 = 34 s/floor.

Similar to the FDS+Evac model, it is assumed that each stairs serves 250 occupants from each floor. Hence, the total number of occupants using each stairs is 250 persons/floor x 19 floors = 4750 occupants.

If all occupants in the building started evacuating at the same time (t = 0 s), each stairs can discharge 0.91 persons/s out of the final exit, it is estimated to take 4750/0.91 = 5220 s to flow down the stairs with an additional 34 s to account for the travel time from the first floor to the exit on the ground floor. This gives a total evacuation time of **5220 + 34 = 5254 s** for 20-storey, large floor office building.

### 5.2.2 Second Order Hydraulic Model

Similar to that of the first order hydraulic model, the maximum specific flow for doorway and stairs obtained from SFPE Handbook are 1.3 persons/s/m and 1.16 persons/s/m respectively. The main assumptions and limitation relating to second order hydraulic model are as follow:

- The flow through constrictions (doorway and stairs) govern over the travel time (reasonable for this study due to high occupancy load on each floor).
- Maximum specific flow value for doorway and stairs assumes optimum density (1.9 persons/$m^2$) in the vicinity of the flow.
- For the purpose of the second order hydraulic model estimation, an assumption on which floors take dominance in entering the stairwell has to be made to set a boundary for the calculations [3]. Floor clearing pattern is assumed to be from the highest to the lowest floor (i.e. occupants on the top floors take precedence in entering the stairs).

**Small floor**

For doors and stairs with effective width of 0.7 m and 0.8 m respectively, $F_d$ = 0.91 persons/s and $F_s$ = 0.928 persons/s. Since $F_d < F_s$, $F_d$ will govern the evacuation.

The occupiable areas within the stairs consist of the landings and the steps. From Section 4.1.3.3, the area of a single landing is 2.4 x 1.65 = 3.96 m$^2$, and the area of a single flight of stairs is 1.1 x 5.4 (slope length) = 5.9 m$^2$. Within the stairwell of a 20-storey building, there are 39 landings (20 floor landings + 19 intermediate landings) and 38 flights of stairs. Therefore, the total occupiable area within a stairwell of a 20-storey small floor building is 3.96 x 39 + 5.9 x 38 = 379 m$^2$.

According to a study by Kuligowski *et al*. [90], it was found that the peak density within the stairwells based on 30 stairwells sampled [91] ranged from 0 persons/m$^2$ to 3.23 persons/m$^2$ with a mean of 1.87 persons/m$^2$ ± 0.16 persons/m$^2$. For the purpose of the second order hydraulic model calculations, it is assumed that the stairwell will be kept at a rounded mean peak density of 1.9 persons/m$^2$ throughout the evacuation. Therefore, the maximum number of occupants who can be present in the stairwell at any one time is 379 x 1.9 = 720 persons. However, one of the stairwells of the small floor will serve a total of 26 persons/floor x 19 floors = 494 persons which means that all occupants in the building can simultaneously be present in the stairwells.

In the FDS+Evac model, the occupants on the fire floor are set to evacuate at t = 0 s for a duration of 30 s before the rest of the building evacuates. This is accounted for in the second order hydraulic model where at t = 30 s, the number of occupants in the stairwell is 0.91 x 30 = 28 persons > 26 persons = 26 persons. All occupants are expected to be in the stairwell 26/0.91 = 29 s later. Since the stairwell will never be at optimum density, the actual density is used. At t = 30 + 29 = 59 s, the density in the stairwell is 494/379 = 1.3 persons/m$^2$. The revised flow in the stairs is given by Equation 8:

$$F_s = (1 - aD)kDW \qquad \text{(Equation 8)}$$

Where

$F_s$ = flow (persons/s)

$D$ = population density (persons/m$^2$)

$k$ = 1.23 m/s (for accessible stairs)

$a$ = 0.266

$W$ = effective width (m)

Using Equation 8, the revised flow in the stairs is $F_s$ = (1 – 0.266 x 1.3) x 1.23 x 1.3 x 0.8 = 0.837 persons/s. The new $F_s$ is less than $F_d$, and therefore, it will govern the evacuation from t = 59 s onwards. The time for all occupants in the stairwell to exit the building via the final exit is 494/0.837 = 590 s. The total evacuation time is therefore, **59 + 590 = 649 s**.

**Medium floor**

Similar to the small floor, the door and stairs effective width of 0.7 m and 0.8 m respectively, $F_d$ = 0.91 persons/s and $F_s$ = 0.928 persons/s. Since $F_d$ < $F_S$, $F_d$ will govern the evacuation. The stair layout for medium floor is the same as that of small floor. The total occupiable area is 379 $m^2$ and the maximum number of occupants who can be present in the stairwell at any one time is 720 persons based on an optimum density of 1.9 persons/$m^2$. As one of the stairwells of the medium floor will serve a total of 123 persons/floor x 19 floors = 2337 persons, this occupant load is greater than stair capacity which means the remaining occupant will not enter the stairwell until stair capacity becomes available.

In the FDS+Evac model, the occupants on the fire floor are set to evacuate at t = 0 s for a duration of 30 s before the rest of the building evacuates. This is accounted for in the second order hydraulic model where at t = 30 s, the number of occupants in the stairwell is 0.91 x 30 = 28 persons. After 30 s, the stairwell can take a maximum of 720 – 28 = 692 persons before the optimum density is reached. Assuming that the flow of occupants from each floor is identical, each floor will flow a total of 692/19 = 37 persons before the optimum density is reached in the stairwell. It is estimated to take 37/0.91 = 41 s to reach the optimum density in the stairwell. Hence, at 30 + 41 = 71 s the stairs are fully occupied.

With the stairwell at maximum capacity, it is assumed that the topmost floor occupants have precedence in entering the stairwell (i.e. the number of occupants evacuating the stairwell through the final exit door are replaced by the occupants from the topmost occupied floor). At t = 71 s, the number of occupants on topmost floor is 123 – 37 = 86 persons (one of the stairwell serves 123 persons from each floor). The time to clear the topmost floor is therefore, 86/0.91 = 95 s. The travel time between floors from first order hydraulic model is 26 s and this is the time calculated for the last occupant on the top floor to reach the floor landing of the floor below. Identical set of calculations is repeated for the subsequent floors and throughout the building. The cumulative calculations are computed using Excel (refer to Appendix C) and part of the calculations are presented as follow:

At t = 30 + 41 + 95 = 166 s – 20$^{th}$ level is cleared

At t = 166 + 26 = 192 s – last occupant from 20$^{th}$ level reaches 19$^{th}$ level landing

At t = 192 + 95 = 287 s – 19$^{th}$ level is cleared

At t = 287 + 26 = 313 s – last occupant from 19$^{th}$ level reaches 18$^{th}$ level landing

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At t = 1281 + 64 = 1345 s – 10$^{th}$ level is cleared (**Note reduced time)

At t = 1345 + 26 = 1371 s – last occupant from 10$^{th}$ level reaches 9$^{th}$ level landing

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.

At t = 2218 + 95 = 2313 s – 2$^{nd}$ level is cleared

At t = 2313 + 26 = 2339 s – last occupant from 2$^{nd}$ level reaches 1$^{st}$ level landing (out of building)

**For the fire floor, 28 occupants have evacuated between 0 s to 30 s before other floors started evacuation, 37 occupants have evacuated between 31 s to 71 s where stair reaches its capacity. Thus, there are 123 – 28 – 37 = 58 occupants remaining to clear when the queue reaches the fire floor.

The total evacuation time based on the calculations above is **2339 s.**

## Large floor

For door and stairs effective width of 0.7 m and 2.0 m respectively, $F_d$ = 0.91 persons/s and $F_s$ = 2.32 persons/s. Since $F_d$ < $F_S$, $F_d$ will govern the evacuation. The area of a single landing in stairwell of large floor building is 4.8 x 1.8 = 8.64 m$^2$, and the area of a single flight of stairs is 2.3 x 5.4 (slope length) = 12.42 m$^2$. Since there are 39 landings (20 floor landings + 19 intermediate landings) and 38 flights of stairs within a stairwell of a 20-storey building, the total occupiable area within a stairwell of a 20-storey large floor building is 8.64 x 39 + 12.42 x 38 = 809 m$^2$. The maximum number of occupants who can be present in the stairwell at any one time is 809 x 1.9 = 1537 persons based on the assumed optimum density of 1.9 persons/m$^2$. As one of the stairwells of the large floor will serve a total of 250 persons/floor x 19 floors = 4750 persons, this occupant load is greater than stair capacity which means the remaining occupant will not enter the stairwell until stair capacity becomes available.

In the FDS+Evac model, the occupants on the fire floor are set to evacuate at t = 0 s for a duration of 30 s before the rest of the building evacuates. This is accounted for in the second order hydraulic model where at t = 30 s, the number of occupants in the stairwell is 0.91 x 30 = 28 persons. After 30 s, the stairwell can take a maximum of 1537 – 28 = 1509 persons before the optimum density is reached. Assuming that the flow of occupants from each floor is identical, each floor will flow a total of 1509/19 = 80 persons before the optimum density is reached in the stairwell. It is estimated to take 80/0.91 = 88 s to reach the optimum density in the stairwell. Hence, at 30 + 88 = 118 s the stairs are fully occupied.

With the stairwell at maximum capacity, it is assumed that the topmost floor occupants have precedence in entering the stairwell (i.e. the number of occupants evacuating the stairwell through the final exit door are replaced entirely by occupants from the topmost occupied floor). At t = 118 s, the number of occupants on topmost floor is 250 – 80 = 170 persons (one of the stairwells serves 250 persons from each floor). The time to clear the topmost is therefore, 170/0.91 = 187 s. The travel time between floors calculated from first order hydraulic model is 34 s, and this is the time for the last occupant on the top floor to reach the floor landing of the floor below. Identical set of calculations is repeated for the subsequent floors and throughout the building. The cumulative calculations are computed using Excel (refer to Appendix C) and part of the calculations are presented as follow:

At t = 30 + 88 + 187 = 305 s – 20$^{th}$ level is cleared

At t = 305 + 34 = 339 s – last occupant from 20$^{th}$ level reaches 19$^{th}$ level landing

At t = 339 + 187 = 526 s – 19$^{th}$ level is cleared

At t = 526 + 34 = 560 s – last occupant from 19$^{th}$ level reaches 18$^{th}$ level landing

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At t = 2328 + 156 = 2484 s – 10$^{th}$ level is cleared (**Note reduced time)

At t = 2484 + 34 = 2518 s – last occupant from 10$^{th}$ level reaches 9$^{th}$ level landing

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At t = 4065 + 187 = 4252 s – 2$^{nd}$ level is cleared

At t = 4252 + 34 = 4286 s – last occupant from 2$^{nd}$ level reaches 1$^{st}$ level landing (out of building)

**For the fire floor, 28 occupants have evacuated between 0 s to 30 s before other floors started evacuation, 80 occupants have evacuated between 31 s to 118 s where stair reaches its capacity. Thus, there are 250 – 28 – 80 = 142 occupants remaining to clear when the queue reaches the fire floor.

The total evacuation time based on the calculations above is **4286 s**.

### 5.2.3 Comparison with FDS+Evac

Table 5-6 summarises the comparison of the total evacuation times between FDS+Evac, 1$^{st}$ order hydraulic model and 2$^{nd}$ order hydraulic model. The computed percentage differences are between the total evacuation time calculated using the hydraulic models (1$^{st}$ and 2$^{nd}$ order) and the mean total evacuation time of FDS+Evac. The comparison between the hydraulic models and FDS+Evac is shown in Figure 5-22 where the mean total evacuation times for FDS+Evac are plotted.

Table 5-6: Total evacuation timings for FDS+Evac and Hydraulic Models

| Scenario | Total evacuation time (s) | | | | | | |
|---|---|---|---|---|---|---|---|
| | FDS+Evac | | | Hydraulic model (1st order) | % Difference | Hydraulic Model (2nd order) | % Difference |
| | Min | Mean | Max | | | | |
| large; 20-storey; total | 3623 | 3646 | 3669 | 5254 | 30.6 | 4286 | 14.9 |
| medium; 20-storey; total | 2596 | 2614 | 2630 | 2595 | -0.7 | 2339 | -11.8 |
| small; 20-storey; total | 590 | 599 | 611 | 569 | -5.3 | 649 | 7.7 |
| | | | | Absolute difference | 12.2 | Absolute difference | 11.5 |

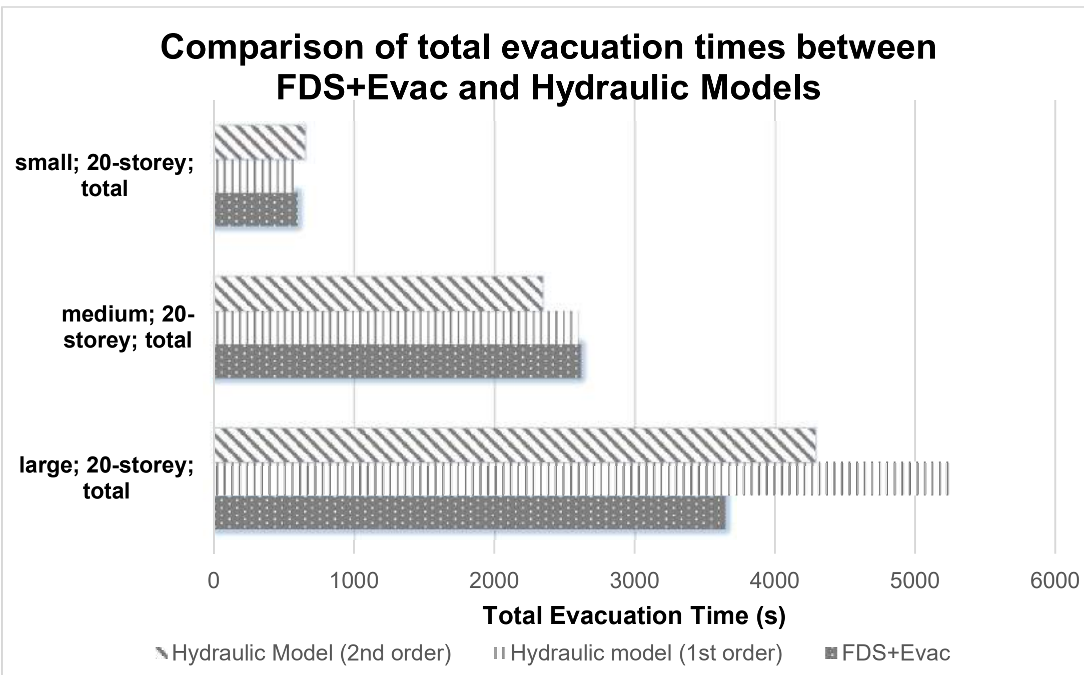


Figure 5-22: Comparison of total evacuation times between FDS+Evac and Hydraulic Models

From Table 5-6 and Figure 5-22 above, the result show that the total evacuation times for small floor are similar between FDS+Evac and both hydraulic models where the percentage difference is 5.3% and 7.7% for 1st order and 2nd order hydraulic model, respectively. The total evacuation time calculated using 1st order hydraulic model is close to that of FDS+Evac for medium floor with a percentage difference of 0.7%. However, for 2nd order hydraulic model, the percentage difference when compared to FDS+Evac is larger at 11.8% for medium floor. For large floor area, the results show that 1st order hydraulic model overestimates the total evacuation time when compared to FDS+Evac with a percentage difference of 30.6%. Similarly, the 2nd order hydraulic model also shows an overestimation with a percentage difference of 14.9%.

In terms of average absolute difference, 1st and 2nd order hydraulic models is similar at approximately 12%. From the analysis, the validation of FDS+Evac with hand calculations has showed the range of variation for RSET can vary from 0.7% to 30.6% given the inherent differences between the models, the underlying assumptions and the building features investigated. It is also within expectation that the variation will be greater for large floor areas because of the simplifying assumptions of hydraulic models do no account for merging effect within the stairwell.

## 5.3 Comparison between FDS+Evac and Literatures

The results obtained from the preliminary modelling are also compared against literature values comprising of actual trial evacuation experiments. Although these are different buildings in essence and it is not feasible to find actual trial evacuation experiments with similar building parameters for comparison, the analysis is believed to be useful to provide a qualitative assessment on FDS+Evac capability in simulating occupant egress from high-rise building.

From literature review, the following studies on actual trial evacuation by MacLennan [92] referred to in Hay's thesis [79] have been used for comparison.

- Manchester Building (Clean stair)
- Majestic Building (Main stair)
- Unisys Building (West stair)
- Christchurch Building (Stair B)

The comparison is a qualitative comparison where only total evacuation times are compared. Detailed descriptions including the building height, floor layout, stairs construction, and number of occupants for each building are reported in Hay's thesis.

In terms of three influential building features on egress, (1) the door width into stair, (2) the stair width and (3) the building height, Manchester Building (Clean stair) is found to be similar to simulated scenario for 10-storey building with small floor area utilising total evacuation. Table 5-7 shows a comparison between Manchester Building (Clean stair) and the closest FDS+Evac model (small; 10-storey; total).

Table 5-7: Comparison between Manchester Building (Clean Stair) and FDS+Evac model (small; 10-storey; total)

| Parameters | small; 10-storey; total (FDS+Evac) | Manchester (Clean stair) |
|---|---|---|
| No. of occupant per stairwell | 234 | 168 |
| Stair door width (m) | 1.00 | 1.07 |
| Stair width (m) | 1.10 | 0.96 |
| No. of storey | 10 | 17 |
| Floor-to-floor height (m) | 4.80 | 3.04 |
| Building height (m) | 48 | 52 |
| Total evacuation time (s) | 311 (mean) | 274[1] |

[1] The total evacuation time is an adjusted value where pre-movement time was subtracted for equal comparison.

The number of occupants using the stairwell of the Manchester Building is 40% less than that of the FDS+Evac model. Therefore, it is within expectation that the total evacuation time for the Manchester Building (Clean stair) is less than that of FDS+Evac model.

Based on the similarity for the three building features identified, Majestic (Main stair) is found to be close to simulated scenario for 20-storey building with small floor area utilising total evacuation. Table 5-8 shows a comparison between Majestic Building (Main stair) and the closest FDS+Evac model (small; 20-storey; total).

Table 5-8: Comparison between Majestic Building (Main Stair) and FDS+Evac model (small; 20-storey; total)

| Parameters | small; 20-storey; total | Majestic (Main stair) |
|---|---|---|
| No. of occupant per stairwell | 494 | 377 |
| Stair door width (m) | 1.00 | 0.87 |
| Stair width (m) | 1.10 | 1.00 |
| No. of storey | 20 | 23 |
| Floor-to-floor height (m) | 4.80 | 3.86 |
| Building height (m) | 96 | 89 |
| Total evacuation time (s) | 599 (mean) | 489[1] |

[1] The total evacuation time is an adjusted value where pre-movement time was subtracted for equal comparison.

The number of occupants using the stairwell of the Majestic Building is 30% less than that of the FDS+Evac model. Therefore, it is within expectation that the total evacuation time for the "Main stair" of Majestic Building is less than that of FDS+Evac model.

Similar to previous buildings, Unisys (East stair) is found to be close to simulated scenario for 10-storey building with small floor area utilising total evacuation. Table 5-9 shows a comparison between Unisys Building (East stair) and the closest FDS+Evac model (small; 10-storey; total).

Table 5-9: Comparison between Unisys Building (East Stair) and FDS+Evac model (small; 10-storey; total)

| Parameters | small; 10-storey; total | Unisys (East stair) |
|---|---|---|
| No. of occupant per stairwell | 234 | 312 |
| Stair door width (m) | 1.00 | 0.95 |
| Stair width (m) | 1.10 | 1.045 |
| No. of storey | 10 | 17 |
| Floor-to-floor height (m) | 4.80 | 3.00 |
| Building height (m) | 48 | 51 |
| Total evacuation time (s) | 311 (mean) | 466[1] |

[1] The total evacuation time is an adjusted value where pre-movement time was subtracted for equal comparison.

The number of occupants using the stairwell of the Unisys Building is approximately 30% more than that of the FDS+Evac model. Therefore, it is within expectation that the total evacuation time for the “East stair” of Unisys Building is greater than that of FDS+Evac model.

Christchurch Building (Stair B) and simulated scenario for 10-storey building with small floor utilising total evacuation are similar in terms of door width into stair and stair width. For building height, the FDS+Evac model is 1.5 times taller than the Christchurch Building. However, the number of occupants using the stairwell of the Christchurch Building is only 50% of the FDS+Evac model. Table 5-10 shows a comparison between Christchurch Building (Stair B) and the closest FDS+Evac model (small; 10-storey; total).

Table 5-10: Comparison between Christchurch Building (East Stair) and FDS+Evac model (small; 10-storey; total)

| **Parameters** | **small; 10-storey; total** | **Christchurch (Stair B)** |
|---|---|---|
| No. of occupant per stairwell | 234 | 122 |
| Stair door width (m) | 1.00 | 0.95 |
| Stair width (m) | 1.10 | 1.02 |
| No. of storey | 10 | 11 |
| Floor-to-floor height (m) | 4.80 | 3.00 |
| Building height (m) | 48 | 33 |
| Total evacuation time (s) | 311 (mean) | 233[1] |

[1] The total evacuation time is an adjusted value where pre-movement time was subtracted for equal comparison.

While the Christchurch Building has half the occupant load modelled in FDS+Evac model, the total evacuation time for Christchurch Building is not in proportion and is found to be 25% less than that of FDS+Evac model. This is likely due to the building height of the Christchurch Building being approximately 30% shorter which contributed to shorter travel distance and the low occupant loading resulting in the evacuation being governed by travel time rather than flow time where travel distance is more critical.

Overall, comparison with actual trial evacuation shows justifiable variation in total evacuation time that FDS+Evac can be used to obtain reasonable predictions on the total evacuation of high-rise building.

## 5.4 FDS Modelling (Detection Time)

Preliminary modelling is also required to determine the detection time for each modelling scenario. For a Type 7 system, the detection time is taken as the earlier of the activation of the two fire protection systems, sprinkler or smoke detector. For a Type 6 system, the detection time is taken as the activation of the sprinkler. The activation of sprinkler is assumed to occur when the sprinkler bulb temperature reaches 68 $^{o}$C with C-factor and RTI as per Section 4.1.1, and the activation of smoke detector is assumed to occur when the optical density outside the detector reaches 0.097 $m^{-1}$.

Through inspecting the building parameters and the associated variables, it is found that the detection time is only affected by the floor area (large; medium; small), the fire protection system (Type 7; Type 6), and the ceiling height (low; high).

Table 5-11 shows the simulated detection time for each scenario, and for each scenario, only the fire floor space was modelled to determine the detection time

Table 5-11: Scenarios for modelling detection time

| Scenarios | Detection time (s) | Type of Detection |
|---|---|---|
| large; Type 6; low | 209 | Sprinkler |
| medium; Type 6; low | 203 | Sprinkler |
| small; Type 6; low | 175 | Sprinkler |
| large; Type 7; low | 46 | Smoke Detector |
| medium; Type 7; low | 46 | Smoke Detector |
| small; Type 7; low | 46 | Smoke Detector |
| large; Type 6; high | 228 | Sprinkler |
| medium; Type 6; high | 221 | Sprinkler |
| small; Type 6; high | 187 | Sprinkler |
| large; Type 7; high | 49 | Smoke Detector |
| medium; Type 7; high | 47 | Smoke Detector |
| small; Type 7; high | 47 | Smoke Detector |

From Table 5-11, for scenarios with Type 6, the detection time for small floor area is considerably quicker compared to medium and large floor areas as the upper layer temperature increases at a faster rate due to reduced smoke filling volume for small floor. As for scenarios with Type 7, the detection time is similar irrespective of the floor area due to the activation of smoke detector which is based on optical density local to the detector. The increase in ceiling height results in an increase in detection time of approximately 8% and 6% for Type 6 and Type 7 respectively.

# 6. Modelling Results and Analysis

## 6.1 Fire Evacuations Vs Evacuation Drills

This section compares the evacuation of occupants with and without the effect of smoke (e.g. fire evacuations and evacuation drills). In order to incorporate the effect of smoke on people's movement, FDS and FDS+Evac simulations have to be conducted simultaneously as coupled simulation. FDS+Evac only simulations where smoke does not affect egress as FDS simulations are not conducted simultaneously are known as decoupled evacuation. This comparison study identifies simulations where the occupants egress is adversely affected by the presence of smoke.

The walking speed reduces as occupants traverse in smoke where visibility is limited. Based on the experiment conducted by Frantzich and Nilsson [33], the governing relationship is given by Equation 9 which is implemented into FDS+Evac:

$$v_i^0(K_s) = Max\ \left\{v_{i,min}^0\ , v_i^0\left(1 + \frac{\beta}{\alpha}K_s\right)\right\} \quad \text{(Equation 9)}$$

Where

$K_s$ = Extinction coefficient [$m^{-1}$]
$v_i^0$ = Unimpeded walking speed [m $s^{-1}$]
$\beta$ = -0.057 $m^2$ $s^{-1}$
$\alpha$ = 0.706 m $s^{-1}$
$v_{i,min}^0$ = minimum walking speed (0.1 x $v_i^0$ )

By examining all the simulations, simulation L_20_T6_T_2.7, M_20_T6_T_2.7, S_20_T6_T_2.7, L_10_T6_T_2.7, M_10_T6_T_2.7 and S_10_T6_T_2.7 are expected to have greater amount of smoke within the stairwell compared to other simulations. This is mainly due to the following reasons:

- Lower ceiling reducing smoke filling volume.
- Total evacuation strategy resulting in stair congestion which extends stair evacuation time.
- Longer evacuation time due to detection by sprinkler activation instead of smoke detection.

Therefore, the effect of smoke slowing down the movement of occupants (if any) would be expected to be most apparent in those simulations.

The comparison of coupled and decoupled evacuation for M_20_T6_T_2.7, S_20_T6_T_2.7, L_10_T6_T_2.7, M_10_T6_T_2.7 and S_10_T6_T_2.7 are presented in the following sections[1]. The evacuation durations compared are the following:

- Time to clear floors
- Time to clear stairwell floor for conventional stairs
- Time to clear stairwell floor for scissor stairs

For coupled evacuation, these evacuation durations are obtained from the outputs of FDS+Evac within the coupled FDS and FDS+Evac simulation. For decoupled evacuation, these evacuation durations for decoupled evacuation are obtained from the relevant evacuation drill scenario presented in Chapter 5 which initiates egress at t = 0 s. As such, the relevant detection, notification and pre-movement times for each scenario are included accordingly.

### 6.1.1 Coupled Vs Decoupled Evacuation for M_20_T6_T_2.7

Figure 6-1 shows the time to clear each floor space for coupled and decoupled evacuation of simulation scenario M_20_T6_T_2.7. Figure 6-2 and Figure 6-3 shows the time to clear conventional and scissor stair floors respectively for coupled and decoupled evacuation of simulation scenario M_20_T6_T_2.7.

[1] L_20_T6_T_2.7 coupled run incomplete due to extensive run time and interrupted simulation.

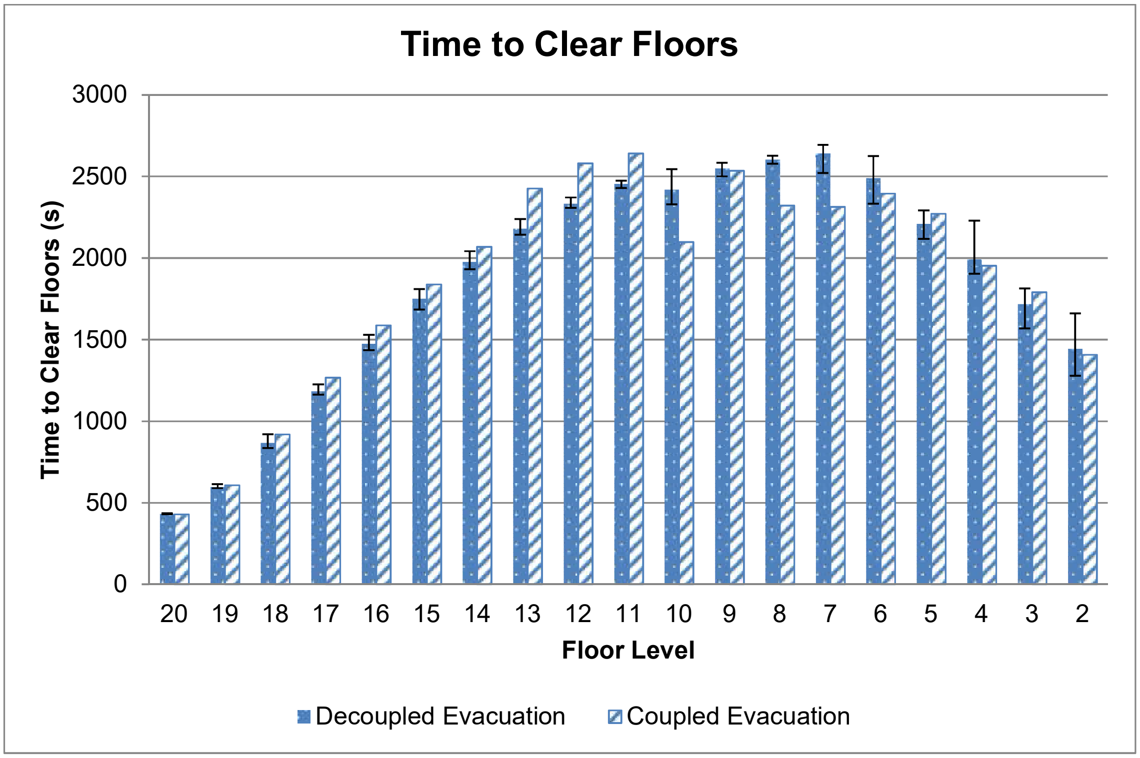


Figure 6-1: Time to clear floors (coupled vs. decoupled) for M_20_T6_T_2.7

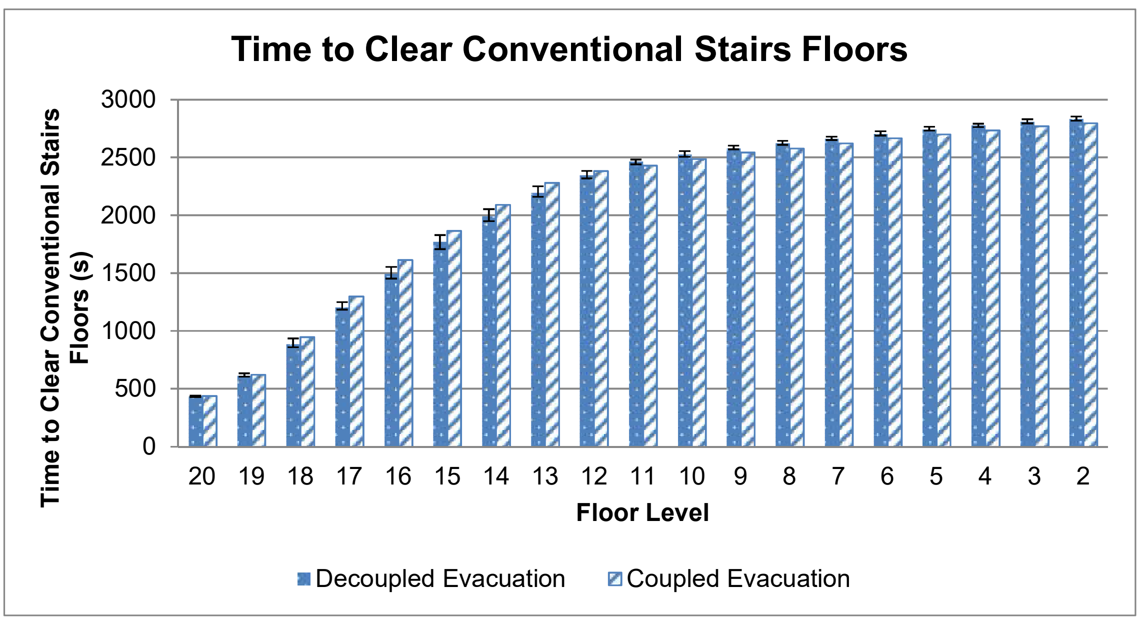


Figure 6-2: Time to clear conventional stairs floors (coupled vs. decoupled) for M_20_T6_T_2.7

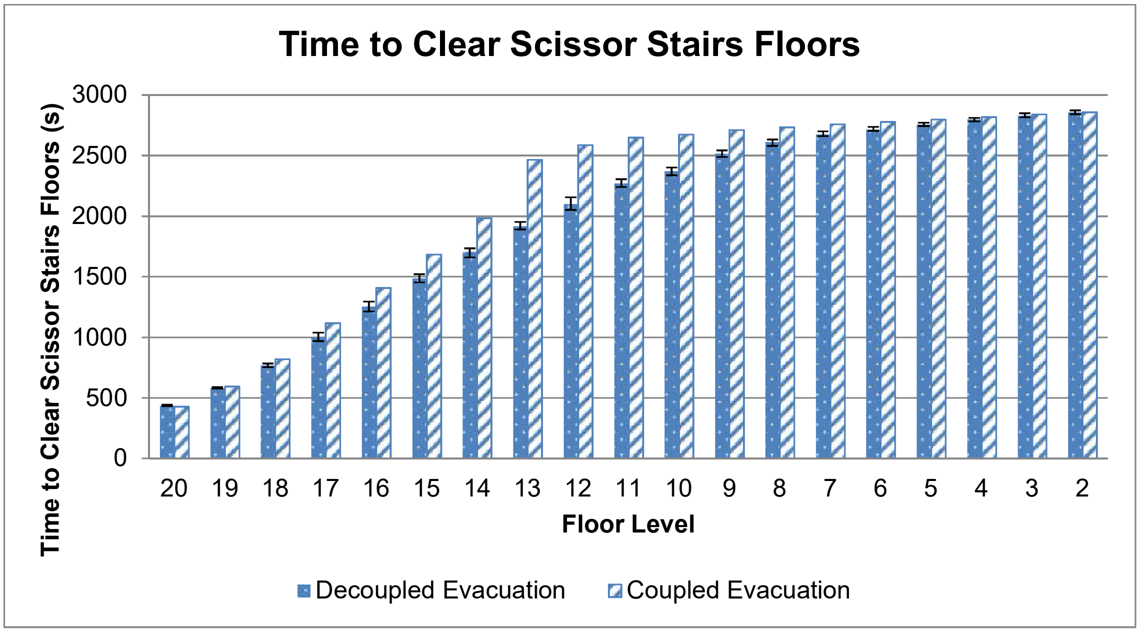


Figure 6-3: Time to clear scissor stairs floors (coupled vs. decoupled) for M_20_T6_T_2.7

From Figure 6-1, the results show that the three floors above the fire floor (10$^{th}$) have longer evacuation time when smoke affected occupant egress in coupled evacuation compared to the decoupled evacuation. The percentage of increased evacuation time for 13$^{th}$ to 11$^{th}$ floor is approximately 9% for coupled evacuation compared to decoupled evacuation. The percentage reduction of evacuation time for 10$^{th}$, 8$^{th}$ and 7$^{th}$ floor is approximately 12% for coupled evacuation compared to decoupled evacuation. The reduction in evacuation time for those floors could be due to reduced evacuation flow from upper floors caused by smoke risen to the upper levels.

From Figure 6-2, the results show that the movement of people in conventional stairs is similar with or without the effect of smoke. This is possibly due to the congestion within the stairwell having a greater effect in slowing occupant egress than the smoke itself. From Figure 6-3, the fire floor and three floors above exhibit longer time to clear when occupant's egress is affected by smoke. These results show that scissor stairs arrangement for M_20_T6_T_2.7 encourages the mixing of smoke in stairwell and this has impacted occupant egress by increasing egress time as much as 32%.

### 6.1.2 Coupled Vs Decoupled Evacuation for S_20_T6_T_2.7

Figure 6-4 shows the time to clear each floor space for coupled and decoupled evacuation of simulation scenario S_20_T6_T_2.7. Figure 6-5 and Figure 6-6 shows the time to clear conventional and scissor stair floors respectively for coupled and decoupled evacuation of simulation scenario S_20_T6_T_2.7.

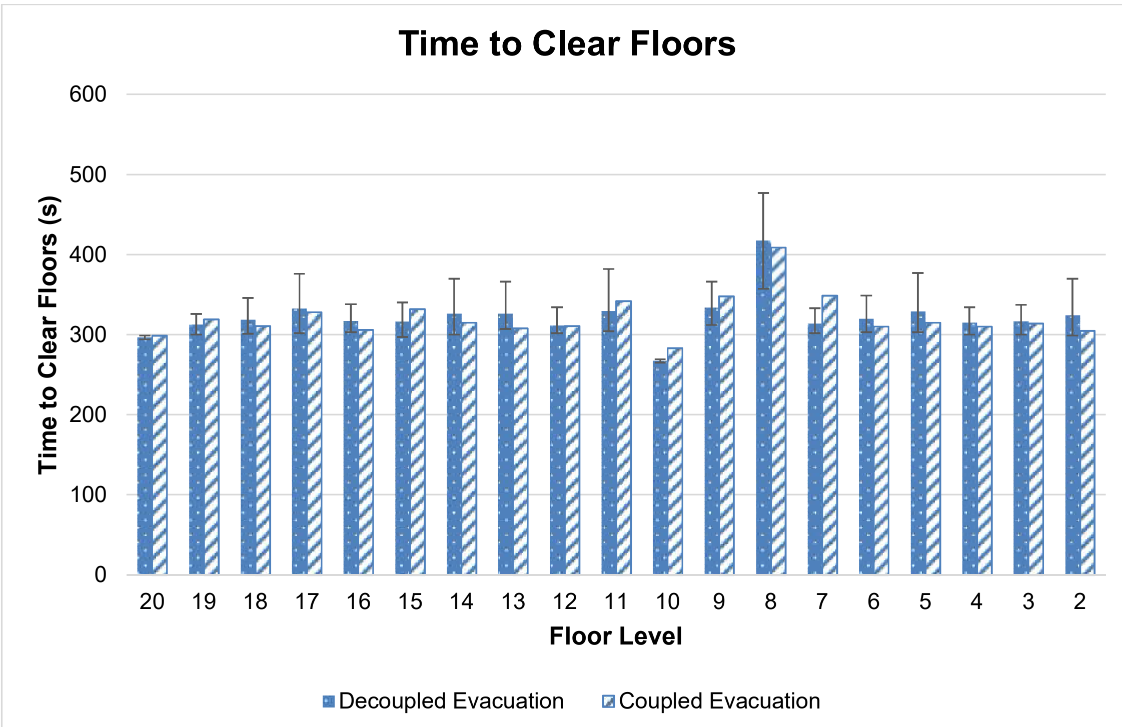


Figure 6-4: Time to clear floors (coupled vs. decoupled) for S_20_T6_T_2.7

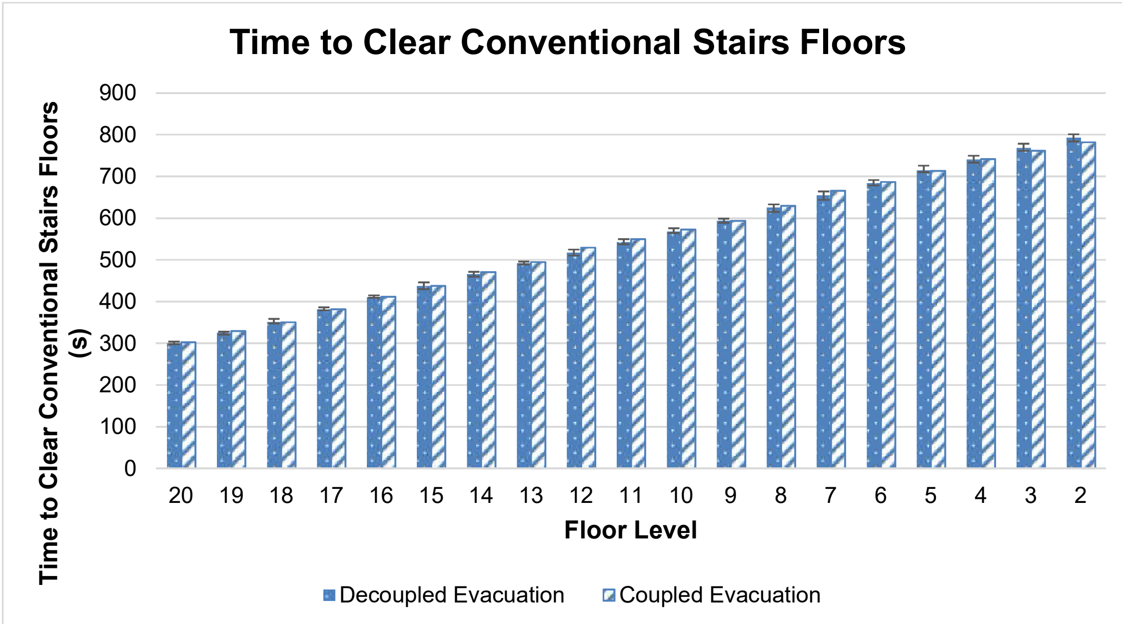


Figure 6-5: Time to clear conventional stairs floors (coupled vs. decoupled) for S_20_T6_T_2.7

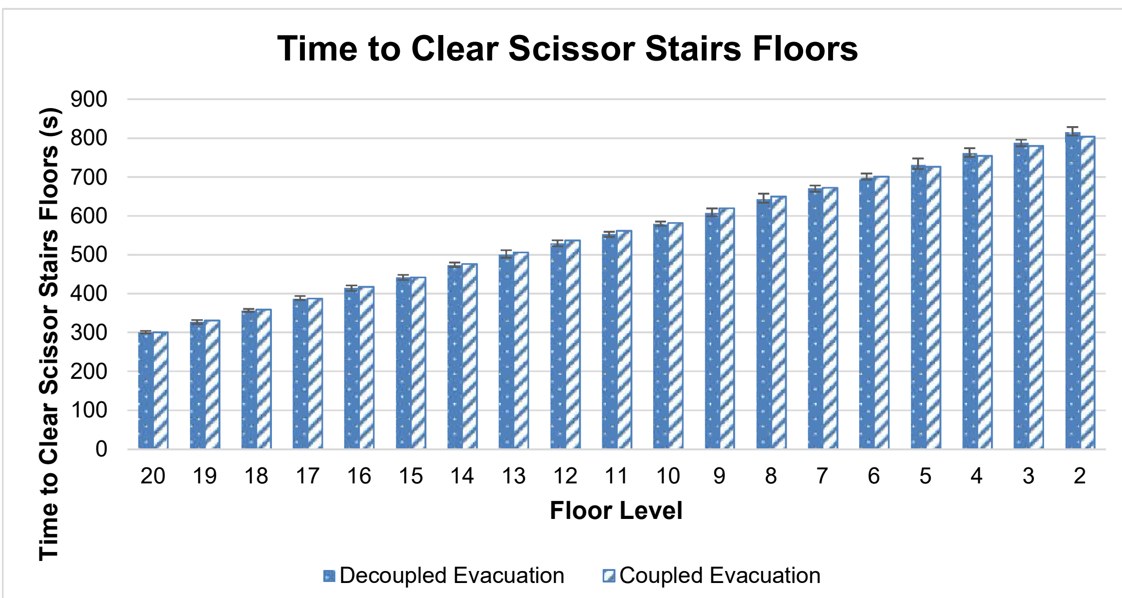


Figure 6-6: Time to clear scissor stairs floors (coupled vs. decoupled) for S_20_T6_T_2.7

From Figure 6-4 to Figure 6-6 above, the results show that the movement of people in the floor spaces, conventional and scissor stairs are comparable with or without the effect of smoke. This is due to low occupant load and short stairwell door opening duration which will limit the amount of smoke infiltrating the stair.

Similarly for L_10_T6_T_2.7, M_10_T6_T_2.7 and S_10_T6_T_2.7, the evacuations are found to be seemingly unaffected by the presence of smoke in the floor spaces as well as within the stairwells. For L_10_T6_T_2.7 and M_10_T6_T_2.7, this is likely due to congestion within the stairwell having a greater effect in slowing occupant egress than the smoke itself. As for S_10_T6_T_2.7, the reason behind occupant's egress unaffected by the presence of smoke is the same as per described for S_20_T6_T_2.7 above (limited smoke in the stairwell). Refer to Appendix D for fire evacuation versus evacuation drills comparison plots of scenario L_10_T6_T_2.7, M_10_T6_T_2.7 and S_10_T6_T_2.7.

### 6.1.3 Remark

From the analysis above, smoke effect on occupant egress is most pronounced for the medium floor, 20-storey building simulations. Theoretically, similar phenomena is expected for the large floor area, 20-storey building simulations as the stairwell door opening duration will be longer than that of medium floor, 20-storey building. Therefore, it can be reasonably deduced that any simulation involving large or medium floor area with 20-storey height should be conducted as coupled simulation. This is with exception to those simulations involving phased evacuation as the amount of smoke present in stairwell will be significantly reduced. This gives a total of 8 simulations which ideally should be conducted as coupled simulation. It is not essential for the remaining simulations to be conducted as coupled simulation.

## 6.2 Simulation Results and Analysis

All the simulations that are carried out in this study consist of a combination of coupled and decoupled simulations. Coupled simulation is where the FDS and FDS+Evac simulations are conducted simultaneously allowing the effect of fire and smoke to affect people's movement. Conversely, decoupled simulations are those where FDS and FDS+Evac simulations are carried out separately. It is important to note that only one (M_20_T6_T_2.7) out of 8 simulations identified in Section 6.1 above is completed as coupled simulation. It is found to be impractical for the rest to be completed as coupled simulation[1]. Despite being decoupled, those simulations are still be able to provide meaningful findings. Decoupling of those simulations are deemed not significant enough to result in a different conclusion being drawn.

The analysis for coupled simulations is straightforward where the tenability conditions from FDS simulation are compared against the evacuation timings from FDS+Evac from the same simulation. For decoupled simulation, the tenability conditions are compared against relevant evacuation drill scenario from the preliminary modelling described in Chapter 5 where the occupants on fire floor starts to evacuate at time zero. The reported evacuation timings in Chapter 5 for relevant evacuation drill scenario are required to be amended for each decoupled simulation. The amendments include adding the detection, notification and pre-evacuation time for the floor of fire origin onto the time to clear floors, the time to clear stairwell floors and the total evacuation time.

Out of 40 simulations, the results and analysis of two selected simulations are presented in Section 6.2.1 to 6.2.2. The two simulations are deemed representative of the rest of the simulations.

The method of analysis for ASET and RSET comparison is demonstrated through the selected simulations which are generic representation of the analysis of the remaining simulations. Refer to Appendix F for the detailed analysis of the rest of the simulations. An overall summary table showing the tenability conditions for all 40 simulations are presented at the end of this chapter.

The following tenability conditions are considered for all simulations as summarised in Table 6-1 and Table 6-2 for 20-storey and 10-storey building height respectively.

[1] 7 out of 8 simulations identified in Section 6.1 are not completed as coupled simulations due to the evacuation component of FDS and FDS+Evac simultaneous simulation cannot be restarted once terminated. Coupled simulation requires the simulation to be completed within a single run without interruption. 8 simulations identified in Section 6.1 have extensive run time (1-2 months) and were frequently interrupted by power outage due to the earthquake rebuild works occurring at the University of Canterbury at the time this study was carried out.

Table 6-1: Assessed tenability conditions for 20-storey building

| Tenability condition | Location |
|---|---|
| Visibility < 10 m | Fire floor ($10^{th}$ floor) |
| | Floor above ($11^{th}$ floor) |
| Visibility < 5 m | Conventional stairs all floor landings |
| | Scissor stairs all floor landings |
| $FED_{gas} > 0.3$ | Fire floor ($10^{th}$ floor) |
| | Floor above ($11^{th}$ floor) |
| | Conventional stairs all floor landings |
| | Scissor stairs all floor landings |

Table 6-2: Assessed tenability conditions for 10-storey building

| Tenability condition | Location |
|---|---|
| Visibility < 10 m | Fire floor ($5^{th}$ floor) |
| | Floor above ($6^{th}$ floor) |
| Visibility < 5 m | Conventional stairs all floor landings |
| | Scissor stairs all floor landings |
| $FED_{gas} > 0.3$ | Fire floor ($5^{th}$ floor) |
| | Floor above ($6^{th}$ floor) |
| | Conventional stairs all floor landings |
| | Scissor stairs all floor landings |

Note that only the visibility and $FED_{gas}$ device directly above the fire were ignored. The time to visibility < 10 m and $FED_{gas} > 0.3$ were based upon the first device (visibility and $FED_{gas}$) measuring < 10 m and > 0.3 respectively located on the floors, stairwell floors and intermediate landings.

The pre-analysed results for each simulation can be found in Appendix E. The pre-analysed results for the floor spaces consist of the plot of ***Visibility vs Time***, ***$FED_{gas}$ vs Time***, ***Gas Temperature vs Time***, ***Layer Height vs Time***, ***Upper Layer Temperature vs Time*** and ***Lower Layer Temperature vs Time*** for the fire floor and the floor above. The pre-analysed results for the stairwells (conventional and scissor stairs) consist of the plot of ***Visibility vs Time***, ***$FED_{gas}$ vs Time*** and ***Gas Temperature vs Time*** for all floors and intermediate landings within both stairwells.

### 6.2.1 Simulation Scenario M_20_T6_T_2.7

This is a **coupled** simulation and the simulation has the following building characteristic:

- ❖ Medium floor area
- ❖ 20-storey
- ❖ Type 6 system
- ❖ Total evacuation strategy
- ❖ Low ceiling height

Figure 6-7 shows a plot of Available Safe Egress Time (ASET) vs Required Safe Egress Time (RSET) for the floor of fire origin ($10^{th}$) and the floor above ($11^{th}$). RSET is the time taken to clear these floor spaces determined from FDS+Evac model in the coupled simulation. ASET is the time for visibility to be less than 10 m (ASET VIS) or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 in the floor spaces, whichever is the earlier.

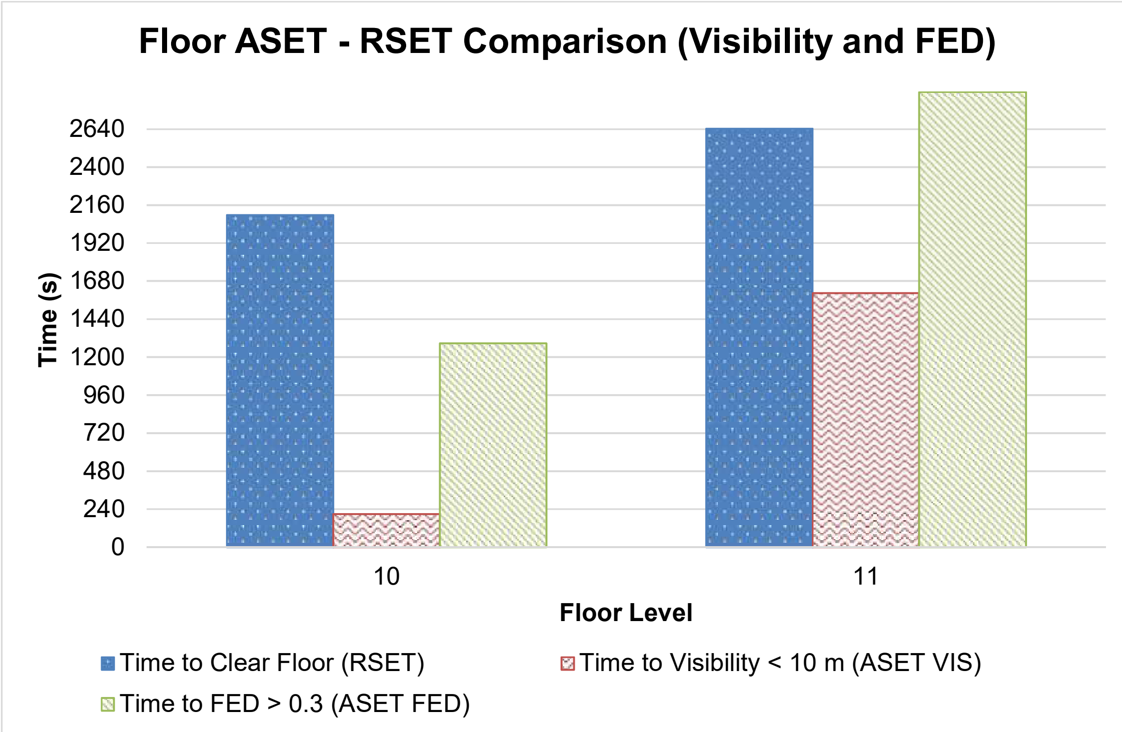


Figure 6-7: Floor space ASET-RSET comparison for M_20_T6_T_2.7

From Figure 6-7 above, the results show that the time to clear the fire floor (10$^{th}$) is longer than the time when visibility is less than 10 m and $FED_{gas}$ exceeds 0.3. For the floor above (11$^{th}$), the results show that the visibility is less than 10 m before the floor is cleared. The $FED_{gas}$ for the floor above never exceed 0.3 throughout the evacuation period.

Figure 6-8 shows a plot of ASET vs RSET for all floor landings above the fire floor, inclusive of fire floor landing for the conventional stairs. The results of stairwell floor level 10 to 20 are plotted and those for Level 0 to 9 are excluded because smoke is not present below the fire floor. RSET is the time taken to clear each stairwell floor landing determined from FDS+Evac model in the coupled simulation. ASET is the time for visibility (ASET VIS) to be less than 5 m or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 at each floor landing. The bars on ASET VIS represent the duration in which visibility is below 5 m.

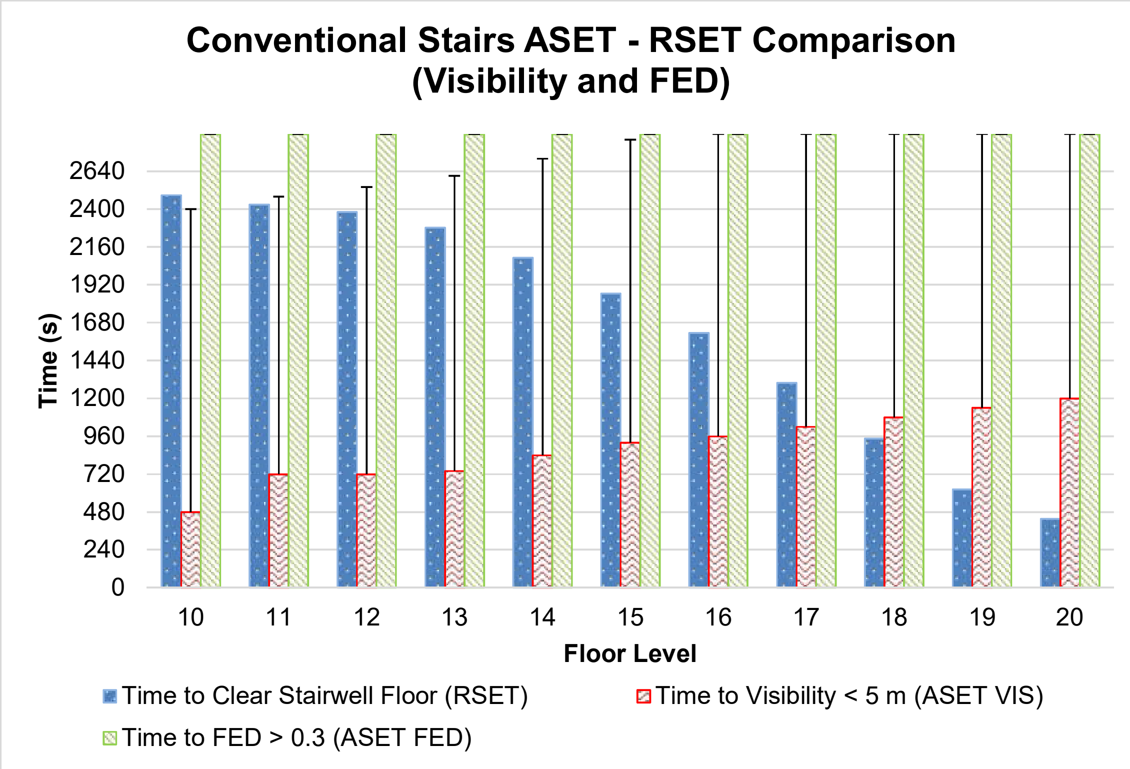


Figure 6-8: Conventional stairs ASET-RSET comparison for M_20_T6_T_2.7

From Figure 6-8, the results show that visibility is less than 5 m before 10th to 17th stairwell floors are cleared. For 18th to 20th stairwell floors, the occupants are able to evacuate those stairwell floor levels before visibility is less than 5 m. $FED_{gas}$ does not exceed 0.3 within the conventional stairs throughout the evacuation period.

Figure 6-9 shows a plot of ASET vs RSET for all floor landings above the fire floor, inclusive of fire floor landing for scissor stairs. The results of stairwell floor level 10 to 20 are plotted and those fore Level 0 to 9 are excluded because smoke is not present below the fire floor. RSET is the time taken to clear each stairwell floor landing determined from FDS+Evac model in the coupled simulation. ASET is the time taken for visibility (ASET VIS) to be less than 5 m or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 at each floor landing. The bars on ASET VIS represent the duration in which visibility is below 5 m.

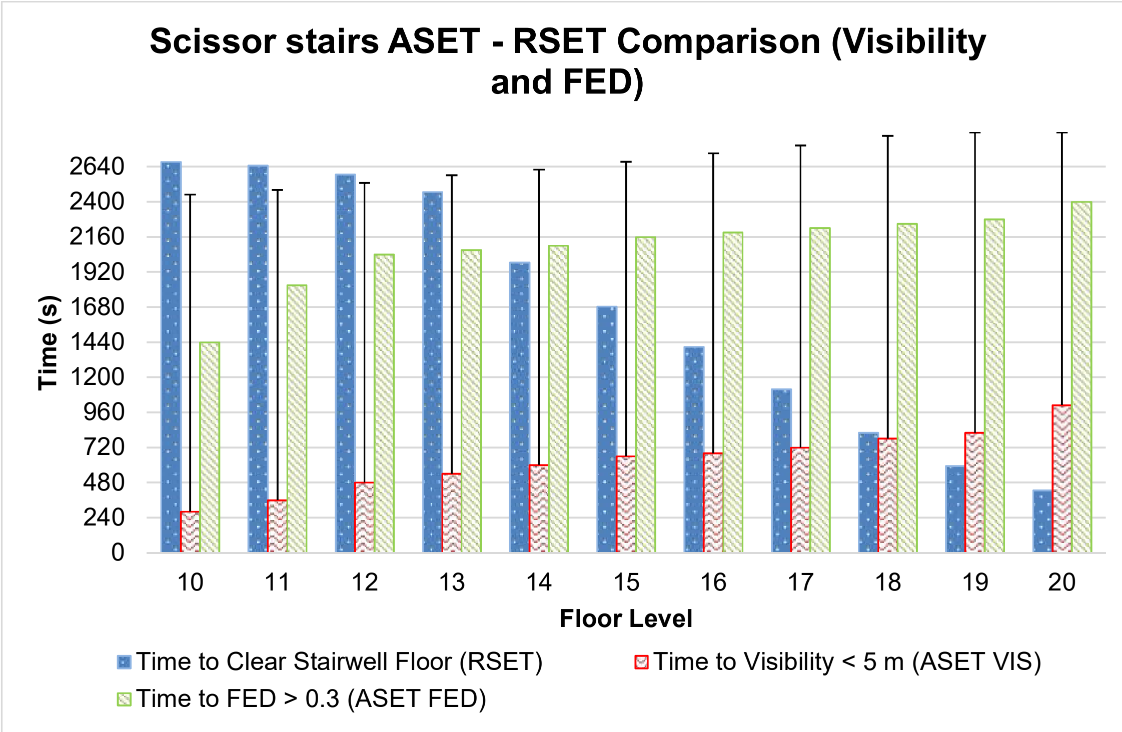


Figure 6-9: Scissor stairs ASET-RSET comparison for M_20_T6_T_2.7

From Figure 6-9 above, the results show that visibility is less than 5 m before 10th to 18th stairwell floors are cleared. For 19th and 20th stairwell floors, the occupants are able to evacuate those stairwell floor levels before visibility becomes less than 5 m. $FED_{gas}$ exceeds 0.3 for stairwell floor level 10 to 13 before those stairwell floors are vacated. For stairwell floor level 14 to 20, $FED_{gas}$ does not exceed 0.3 for the evacuation period of those floors.

Table 6-3 summarises the tenability conditions during the evacuation period for the fire floor, the floor above, and the conventional and scissor stairs.

Table 6-3: Tenability conditions summary for M_20_T6_T_2.7

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 2875 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 2098 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | Yes (1288)** |
| Maximum temperature | 90°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2643 s |
| Visibility < 10 m | Yes (1605/-)* |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2326 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 480 s/1920 s<br>11th – 720 s/1760 s<br>20th – 1200 s/>1675 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (2329 occupants)** | |
| Visibility < 5 m | Yes (10th to 18th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 280 s/2170 s<br>11th – 360 s/2120 s<br>20th – 1010 s/>1865 s*** |
| FED > 0.3 | Yes (10th to 13th floor) |
| Maximum temperature | 70°C (Fire Floor) |

* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

### 6.2.2 Simulation Scenario M_20_T6_P_2.7

This is a **decoupled** simulation and the simulation has the following building characteristic:

- Medium floor area
- 20-storey
- Type 6 system
- Phased evacuation strategy
- Low ceiling height

Figure 6-10 shows a plot of Available Safe Egress Time (ASET) vs Required Safe Egress Time (RSET) for the floor of fire origin ($10^{th}$) and the floor above ($11^{th}$). RSET is the time taken to evacuate these floor spaces. For the fire floor, being a phased evacuation scenario, the time to clear the floor space is based on 40 people/min flow through the stairwell door rather than that of the FDS+Evac model. Since each floor has two means of escape and the number of occupants are equally distributed (123 occupants per exit), the time to clear fire floor can be calculated as follow:

$$\text{RSET} = t_d + t_n + t_{pre} + \frac{123\, people}{40\, people/min} \times 60\, \frac{s}{min} = 203 + 30 + 30 + 185 = 448\, s$$

For the floor above, the time taken to clear floor space is obtained from the relevant evacuation drill scenario, namely medium; 20-storey; phased, as this simulation scenario is decoupled. From Figure 5-15, the time to clear floor above is found to be 2256 s. Since the evacuation drill scenarios do not incorporate detection, notification and pre-evacuation time of the fire floor, the actual time to evacuate floor above for this scenario is calculated to be:

$$\text{RSET} = t_d + t_n + t_{pre} + 2256 = 203 + 30 + 30 + 2256 = 2519\, s$$

ASET is the time for visibility to be less than 10 m (ASET VIS) or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 in the floor space, whichever is earlier.

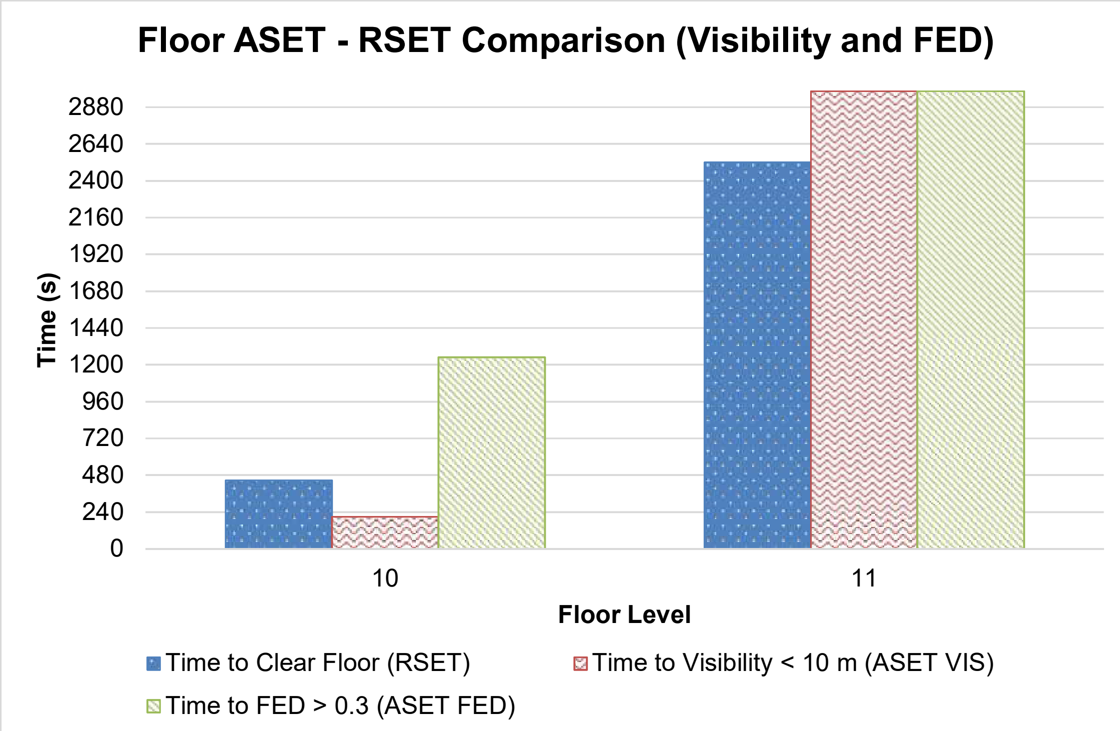


Figure 6-10: Floor space ASET-RSET comparison for M_20_T6_P_2.7

From Figure 6-10 above, the results show that the time to evacuate the fire floor (10th) is longer than the time when visibility is less than 10 m. This implies that occupants on the fire floor are not expected to fully evacuate the floor before visibility is reduced to below 10 m. However, occupants on the fire floor are able to fully evacuate the floor before $FED_{gas}$ exceeds 0.3. For the floor above (11th), the results show that the visibility is never less than 10 m and $FED_{gas}$ never exceeded 0.3 throughout the evacuation period.

Figure 6-11 shows a plot of ASET vs RSET for all floor landings above the fire floor, inclusive of the fire floor landing for conventional stairs. Stairwell floor level 10 to 20 are plotted and those for level 0 to 9 are excluded because smoke is not present below the fire floor. RSET is the time taken to clear each stairwell floor landing determined from relevant evacuation drill scenario (medium; 20-storey; phased). The time taken to clear each stairwell floor for conventional stairs in Figure 6-11 is taken from Figure 5-19 with detection, notification and pre-evacuation time of the fire floor for this scenario included.

ASET is the time taken for visibility (ASET VIS) to be less than 5 m or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 at each floor landing. The bars on ASET VIS represent the duration in which visibility is below 5 m.

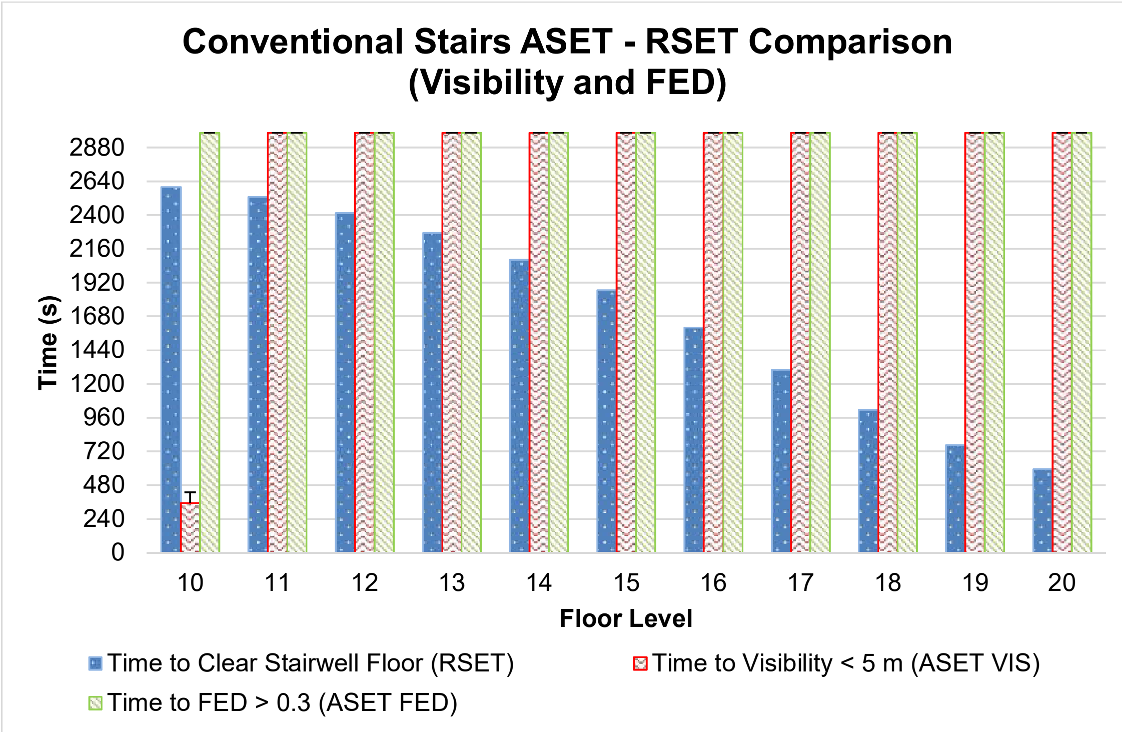


Figure 6-11: Conventional stairs ASET-RSET comparison for M_20_T6_P_2.7

From Figure 6-11 above, the results show that visibility is less than 5 m before 10th stairwell floor is cleared. For 11th to 20th stairwell floors, the occupants are able to clear those stairwell floor levels before visibility becomes less than 5 m. $FED_{gas}$ does not exceed 0.3 in conventional stairs throughout the evacuation period.

Figure 6-12 shows a plot of ASET vs RSET for all floor landings above the fire floor, inclusive of the fire floor landing for scissor stairs. Stairwell floor level 10 to 20 are and those for level 0 to 9 are excluded because smoke is not present below the fire floor. RSET is the time taken to clear each stairwell floor landing determined from relevant evacuation drill scenario (medium; 20-storey; phased). The time taken to clear each stairwell floor for scissor stairs in Figure 6-12 is taken from Figure 5-19 with detection, notification and pre-evacuation time of the fire floor for this scenario included.

ASET is the time for visibility (ASET VIS) to be less than 5 m or the time for $FED_{gas}$ (ASET FED) to exceed 0.3 at each floor landing. The bars on ASET VIS represent the duration in which visibility is below 5 m.

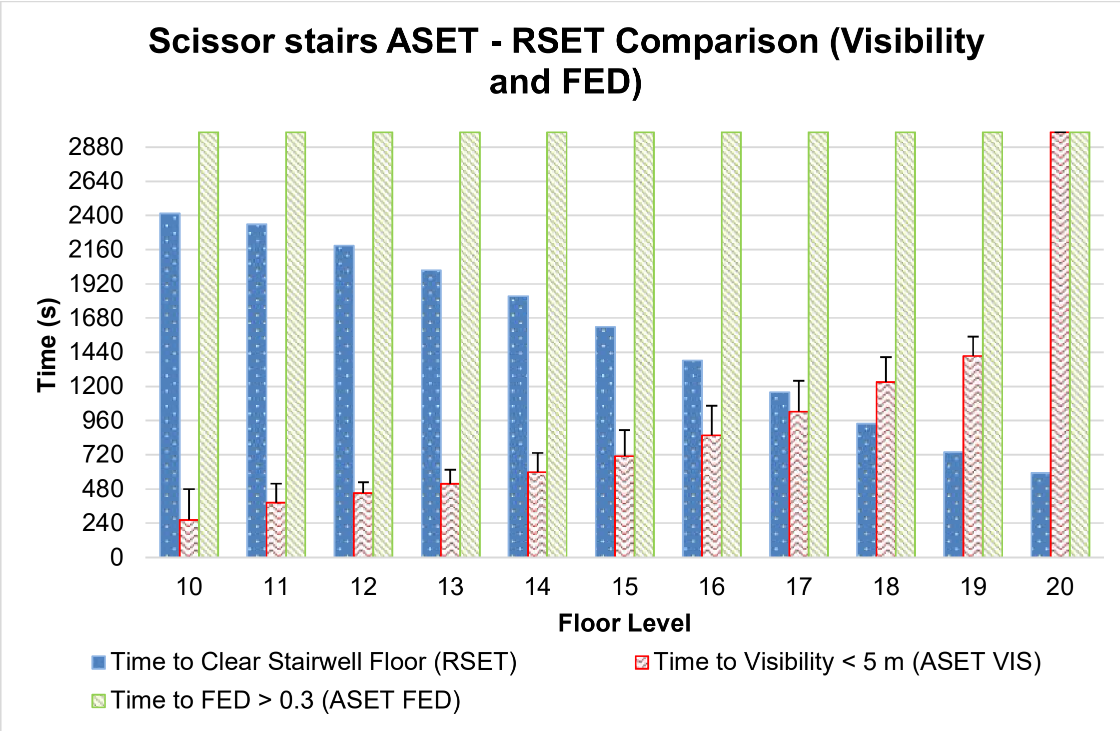


Figure 6-12: Scissor stairs ASET-RSET comparison for M_20_T6_P_2.7

From Figure 6-12 above, the results show that visibility is less than 5 m before 10th to 17th stairwell floors are cleared. For 18th to 20th stairwell floors, the occupants are able to evacuate those stairwell floor levels before visibility becomes less than 5 m. It is also observed that visibility on 20th stairwell floor never reduced to below 5 m throughout the evacuation period. $FED_{gas}$ does not exceed 0.3 in the scissor stairs throughout the evacuation period.

Table 6-4 summarises the tenability conditions during the evacuation period for the fire floor, the floor above, and the conventional and scissor stairs.

Table 6-4: Tenability conditions summary for _20_T6_P_2.7

| **Tenability conditions during occupied period**<br>Total Evacuation Time: 2986 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 448 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | No |
| Maximum temperature | 60°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2520 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes (10th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 355 s/75 s<br>11th – NEVER/0 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |
| **Scissor stairs (2329 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 265 s/215 s<br>11th – 385 s/133 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |

* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

### 6.2.3 Overall Summary Table

| | | Tenability Conditions During Occupied Period | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fire Floor | | | | Floor Above | | | | Conventional stairs | | | | Scissor stairs | | | | |
| Simulation scenario | Total Evacuation Time (s) | No. of occupants | Visibility < 10 m | FED > 0.3 | Maximum Temperature (ºC) | No. of occupants | Visibility < 10 m | FED > 0.3 | Maximum Temperature (ºC) | No. of occupants | Visibility < 5 m (floors affected) | FED > 0.3 (floors affected) | Maximum Temperature (ºC) | No. of occupants | Visibility < 5 m (floors affected) | FED > 0.3 (floors affected) | Maximum Temperature (ºC) | Coupled or Decoupled |
| L_20_T6_T_2.7 | 3915 | 500 | yes | yes | 70 | 500 | yes | no | 30 | 4750 | yes (11th to 16th) | no | 30 | 4750 | yes (10th to 17th) | yes (10th to 14th) | 50 | Decoupled |
| M_20_T6_T_2.7 | 2875 | 245 | yes | yes | 90 | 245 | yes | no | 30 | 2326 | yes (10th to 17th) | no | 50 | 2329 | yes (10th to 18th) | yes (10th to 13th) | 70 | Coupled |
| S_20_T6_T_2.7 | 822 | 51 | yes | no | 110 | 51 | no | no | 25 | 475 | no | no | 50 | 494 | yes (10th to 11th) | no | 100 | Coupled |
| L_10_T6_T_2.7 | 2008 | 500 | yes | no | 60 | 500 | no | no | 25 | 2253 | yes (6th to 7th) | no | 30 | 2247 | yes (5th to 7th) | no | 50 | Coupled |
| M_10_T6_T_2.7 | 1531 | 245 | yes | yes | 80 | 245 | no | no | 25 | 1098 | yes (5th to 8th) | no | 50 | 1107 | yes (5th to 8th) | no | 50 | Coupled |
| S_10_T6_T_2.7 | 533 | 51 | yes | no | 110 | 51 | no | no | 20 | 233 | no | no | 30 | 226 | yes (5th to 6th) | no | 60 | Coupled |
| L_20_T6_P_2.7 | 4086 | 500 | yes | no | 50 | 500 | no | no | 30 | 4750 | no | no | 30 | 4750 | yes (10th) | no | 40 | Decoupled |
| M_20_T6_P_2.7 | 2986 | 245 | yes | no | 60 | 245 | no | no | 30 | 2318 | yes (10th) | no | 45 | 2337 | yes (10th to 17th) | no | 45 | Decoupled |
| L_10_T6_P_2.7 | 2192 | 500 | yes | no | 45 | 500 | no | no | 25 | 2260 | no | no | 30 | 2240 | yes (5th) | no | 40 | Coupled |
| M_10_T6_P_2.7 | 1546 | 245 | yes | no | 50 | 245 | no | no | 25 | 1102 | yes (5th) | no | 50 | 1103 | yes (5th to 9th) | no | 50 | Coupled |
| L_20_T7_T_2.7 | 3752 | 500 | yes | yes | 65 | 500 | no | no | 30 | 4750 | yes (11th to 15th) | no | 27 | 4750 | yes (10th to 16th) | yes (10th to 12th) | 50 | Decoupled |
| M_20_T7_T_2.7 | 2721 | 245 | yes | yes | 87 | 245 | yes | no | 25 | 2318 | yes (10th to 16th) | no | 50 | 2337 | yes (10th to 17th) | yes (10th to 11th) | 70 | Decoupled |
| S_20_T7_T_2.7 | 693 | 51 | yes | no | 50 | 51 | no | no | 25 | 475 | no | no | 30 | 494 | no | no | 40 | Coupled |
| L_10_T7_T_2.7 | 1861 | 500 | yes | no | 50 | 500 | no | no | 25 | 2250 | yes (6th to 7th) | no | 30 | 2250 | yes (5th to 7th) | no | 45 | Coupled |
| M_10_T7_T_2.7 | 1365 | 245 | yes | no | 70 | 245 | no | no | 25 | 1098 | yes (5th to 7th) | no | 50 | 1107 | yes (5th to 8th) | no | 60 | Coupled |
| S_10_T7_T_2.7 | 410 | 51 | yes | no | 50 | 51 | no | no | 20 | 225 | no | no | 25 | 234 | no | no | 30 | Coupled |
| L_20_T7_P_2.7 | 3923 | 500 | yes | no | 45 | 500 | no | no | 30 | 4750 | no | no | 25 | 4750 | no | no | 35 | Decoupled |
| M_20_T7_P_2.7 | 2829 | 245 | yes | no | 45 | 245 | no | no | 30 | 2318 | no | no | 45 | 2337 | no | no | 40 | Decoupled |
| L_10_T7_P_2.7 | 2018 | 500 | yes | no | 40 | 500 | no | no | 25 | 2250 | no | no | 25 | 2250 | no | no | 35 | Coupled |
| M_10_T7_P_2.7 | 1377 | 245 | yes | no | 50 | 245 | no | no | 25 | 1098 | no | no | 40 | 1107 | no | no | 40 | Coupled |
| L_20_T6_T_3.3 | 3934 | 500 | yes | yes | 66 | 500 | no | no | 30 | 4750 | yes (11th to 15th ) | no | 30 | 4750 | yes (10th to 17th) | yes (10th to 12th) | 55 | Decoupled |
| M_20_T6_T_3.3 | 2896 | 245 | yes | yes | 95 | 245 | yes | no | 30 | 2318 | yes (10th to 17th) | no | 50 | 2337 | yes (10th to 17th) | yes (10th to 12th) | 70 | Decoupled |

| Simulation scenario | Total Evacuation Time (s) | Tenability Conditions During Occupied Period | | | | | | | | | | | | | | | | Coupled or Decoupled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fire Floor | | | | Floor Above | | | | Conventional stairs | | | | Scissor stairs | | | | |
| | | No. of occupants | Visibility < 10 m | FED > 0.3 | Maximum Temperature (ºC) | No. of occupants | Visibility < 10 m | FED > 0.3 | Maximum Temperature (ºC) | No. of occupants | Visibility < 5 m (floors affected) | FED > 0.3 (floors affected) | Maximum Temperature (ºC) | No. of occupants | Visibility < 5 m (floors affected) | FED > 0.3 (floors affected) | Maximum Temperature (ºC) | |
| S_20_T6_T_3.3 | 853 | 51 | yes | no | 110 | 51 | no | no | 25 | 501 | no | no | 30 | 468 | yes (10th to 11th) | no | 60 | Coupled |
| L_10_T6_T_3.3 | 2050 | 500 | yes | no | 55 | 500 | no | no | 25 | 2250 | yes (6th to 7th) | no | 30 | 2250 | yes (5th to 7th) | no | 50 | Decoupled |
| M_10_T6_T_3.3 | 1595 | 245 | yes | yes | 80 | 245 | no | no | 25 | 1058 | yes (5th to 8th) | no | 50 | 1147 | yes (5th to 8th) | no | 65 | Coupled |
| S_10_T6_T_3.3 | 553 | 51 | yes | no | 100 | 51 | no | no | 20 | 225 | no | no | 40 | 234 | yes (5th to 6th) | no | 80 | Coupled |
| L_20_T6_P_3.3 | 4105 | 500 | yes | no | 45 | 500 | no | no | 30 | 4750 | no | no | 30 | 4750 | yes (10th) | no | 35 | Decoupled |
| M_20_T6_P_3.3 | 3004 | 245 | yes | no | 57 | 245 | no | no | 30 | 2138 | yes (10th) | no | 45 | 2337 | yes (10th to 11th) | no | 45 | Decoupled |
| L_10_T6_P_3.3 | 2198 | 500 | yes | no | 45 | 500 | no | no | 25 | 2252 | no | no | 25 | 2248 | yes (5th) | no | 35 | Coupled |
| M_10_T6_P_3.3 | 1577 | 245 | yes | no | 55 | 245 | no | no | 25 | 1101 | yes (5th) | no | 50 | 1104 | yes (5th to 6th) | no | 50 | Coupled |
| L_20_T7_T_3.3 | 3755 | 500 | yes | yes | 68 | 500 | no | no | 30 | 4750 | yes (11th to 14th) | no | 25 | 4750 | yes (10th to 14th) | yes (10th to 12th) | 55 | Decoupled |
| M_20_T7_T_3.3 | 2722 | 245 | yes | yes | 95 | 245 | yes | no | 25 | 2318 | yes (10th to 17th) | no | 50 | 2337 | yes (10th to 17th) | yes (10th to 11th) | 70 | Decoupled |
| S_20_T7_T_3.3 | 708 | 51 | yes | no | 40 | 51 | no | no | 20 | 475 | no | no | 30 | 494 | no | no | 30 | Coupled |
| L_10_T7_T_3.3 | 1871 | 500 | yes | no | 55 | 500 | no | no | 25 | 2250 | yes (6th to 7th) | no | 30 | 2250 | yes (5th to 7th) | no | 50 | Decoupled |
| M_10_T7_T_3.3 | 1371 | 245 | yes | no | 75 | 245 | no | no | 25 | 1098 | yes (5th to 7th) | no | 50 | 1107 | yes (5th to 8th) | no | 60 | Coupled |
| S_10_T7_T_3.3 | 419 | 51 | yes | no | 40 | 51 | no | no | 20 | 225 | no | no | 25 | 234 | no | no | 30 | Coupled |
| L_20_T7_P_3.3 | 3926 | 500 | yes | no | 40 | 500 | no | no | 30 | 4750 | no | no | 25 | 4750 | no | no | 30 | Decoupled |
| M_20_T7_P_3.3 | 2830 | 245 | yes | no | 45 | 245 | no | no | 35 | 2318 | no | no | 35 | 2337 | no | no | 35 | Decoupled |
| L_10_T7_P_3.3 | 2036 | 500 | yes | no | 40 | 500 | no | no | 25 | 2250 | no | no | 25 | 2250 | no | no | 30 | Decoupled |
| M_10_T7_P_3.3 | 1389 | 245 | yes | no | 40 | 245 | no | no | 25 | 1098 | no | no | 35 | 1107 | no | no | 35 | Coupled |

# 7. Discussion

## 7.1 Fire Floor

From the overall summary table presented at the end of Chapter 6, it is observed that for all simulations regardless of the building parameters, visibility on the fire floor is less than 10 m before occupants are able to fully evacuate the floor.

Simulations with medium floor (10 or 20-storey), large floor (20-storey), total evacuation strategy and Type 6 system, $FED_{gas}$ exceeds 0.3 before occupants are able to fully evacuate the fire floor. The same is observed for simulations with medium or large floor, 20-storey, total evacuation strategy and Type 7 system. In short, providing early detection (Type 7) only is found to be sufficient for 10-storey building with medium floor to ensure $FED_{gas}$ does not exceed 0.3 during occupied period on the fire floor. However, it is not the case for 20-storey building with medium and large floor. Providing Type 7 system is insufficient for those scenarios as they will need to rely on phased evacuation to ensure safety of the occupants with respect to the $FED_{gas}$.

For small floor, the relatively shorter pre-evacuation time for occupants on the fire floor is sufficient for them to evacuate the floor before the rest of the building evacuates. Therefore, phased evacuation is deemed unnecessary. Whether or not early detection is provided is insignificant as the $FED_{gas}$ never exceeds 0.3 during evacuation period for all small floor scenarios.

For large and medium floor with Type 6 system and total evacuation, the maximum temperature at 2 m above fire floor is approximately 70°C and 95°C respectively. It is found that by providing Type 7 system, the maximum temperature is reduced slightly (5 to 10°C). If instead of early detection, phased evacuation is carried out, the maximum temperature is reduced to 50°C for large floor and 60°C for medium floor. However, if both Type 7 system and phased evacuation are provided, the maximum temperature is reduced to as low as 45°C for both large and medium floor.

For small floor, the temperature at 2 m above fire floor is found to have reached a maximum of 110°C during occupied period when Type 6 system is provided. However, when Type 7 system is provided, the maximum temperature is approximately 55°C during occupied period.

Compared to 10-storey building, occupants tend to spend longer time queuing on the fire floor in 20-storey building when total evacuation is carried out. From analysis, it is found that occupants on the fire floor of a 20-storey building are exposed to higher temperature of approximately 70°C (compared to 10-storey building with the same other building parameters) and is in the order of 10 - 15°C more.

Increasing the ceiling height from 2.7 m to 3.3 m is found to have little effect on the time to visibility less than 10 m and FED greater than 0.3 on the fire floor. It also had little or no effect on the maximum temperature in which occupants are exposed to on the fire floor during occupied period.

If the NZBC C4.3 and C4.4 are used to assess the fire floor of each simulation, visibility and thermal effect need not be considered as none of the simulations have more than 1000 people in a firecell protected with automatic fire sprinkler system. It is only required to ensure that occupants are not exposed to $FED_{gas}$ of greater than 0.3 throughout the evacuation. Table 7-1 summarises the recommended requirements (based on the studied building parameters) to ensure that tenability criteria ($FED_{gas}$ > 0.3) will not be exceeded on the fire floor for high-rise office building.

Table 7-1: Recommended requirements to meet tenability criteria ($FED_{gas}$ > 0.3) for fire floor

| **Floor Area** | **Building Height** | **Fire Protection System** | **Evacuation Strategy** | **Ceiling Height** |
|---|---|---|---|---|
| Small | 20 or 10-storey | Type 6 or Type 7 | Total or Phased | Low or High |
| Medium or Large | 10-storey | Type 7 | Total or Phased | Low or High |
| Medium or Large | 20-storey | Type 7 | Phased | Low or High |

## 7.2 Floor Above

Based on the overall summary table at the end of Chapter 6, simulations with medium or large floor, 20-storey and adopting total evacuation are found to have visibility on the floor above reduced to less than 10 m during occupied period. This is due to the congestion in the stairwell caused by total evacuation, resulting in long queuing time at the stairwell door of the fire floor and the floor above. This allows smoke from the fire floor to infiltrate not only the stairwell, but also the floor above. For the rest of the simulations, the stairwell door opening time is relatively short and the amount of smoke entering the floor above is not sufficient to cause visibility problem.

For all simulations regardless of any studied building parameters, $FED_{gas}$ on the floor above never exceeded 0.3 before occupants are able to fully evacuate the floor. The maximum temperature for all scenarios is found to have never exceeded 30°C on the floor above during occupied period.

The FDS modelling for all simulations is such that only one floor above fire floor is modelled and assessed due to limited computational resources as well as to ensure that all the simulations can be practically completed within the research timeframe. From careful consideration, floor directly above fire floor is expected to be worst affected compared to the rest of the floors above because as smoke rises within the stairwell, it will become more diluted. Thus, the tenability condition within all the other floors above the fire floor is not expected to be worse than the floor directly above fire floor.

Similar to that of the fire floor, assessment in accordance with NZBC C4.3 and C4.4 only requires that occupants are not exposed to $FED_{gas}$ of greater than 0.3 throughout the evacuation for sprinklered building. None of the simulation scenario has $FED_{gas}$ greater than 0.3 during the occupied period on the floor above. Thus, the floor above fire floor is deemed not to be under immediate danger for all building parameters that are considered in this research.

## 7.3 Stairwells

NZBC C4.3 and C4.4 guidelines around assessing tenability conditions in stairwell are somewhat vague and open to interpretation. According to NZBC C4.3 and C4.4, visibility and thermal effect need not be considered if a firecell protected with automatic fire sprinkler system does not contain more than 1000 people. However, for the case where the occupant load is more than 1000 people in a firecell, visibility shall be considered and it shall not be less than 10 m during occupied period except in rooms of less than 100 $m^2$ where visibility may fall to 5 m. It unclear whether the floor area of 100 $m^2$ refers to the footprint of the firecell/room or for the case of a stairwell, the area of all floor and intermediate landings.

In this study, the largest stairwell footprint area (large floor) is approximately 40 $m^2$ and the longer dimension of the stairwell is less than 10 m (8.4 m). It is deemed not justifiable to consider visibility of less than 10 m for the tenability criteria as occupants do not need to have visibility beyond 10 m to travel down stairs. In addition, the travel path down a stairwell is fairly straight-forward which again, negates the need for the occupants to be able to see beyond 10 m. Therefore, for the purpose of this study, the author chose to assess visibility of less than 5 m in stairwell that serves more than 1000 people. The requirement with regards to $FED_{gas}$ remained the same ($FED_{gas}$ > 0.3).

### 7.3.1 Conventional Stairs

For all simulations with small floor, visibility on any floor level in conventional stairs is never less than 5 m throughout the evacuation. This is because occupants on the fire floor are able to flow unimpededly into the stairwell without being affected by occupants on floors above which minimises the stairwell door opening time on the fire floor. Thus, the amount of smoke entering the stairwell is not sufficient to cause visibility problem.

Simulations with large or medium floor, adopting total evacuation, and 10-storey, it is found that visibility in conventional stairs reduced to less than 5 m for up to 4 floor levels during occupied period. This implies that some occupants on and above the fire floor have to move down the stairwell under poor visibility for over 4 floor levels. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 1000 s. For simulations with large or medium floor, adopting total evacuation, and 20-storey, it is found that visibility in conventional stairs is less than 5 m for up to 8 floor levels during occupied period. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 2000 s.

When phased evacuation is carried out, medium floor (10 or 20-storey) with Type 6 system is found to have visibility in conventional stairs of less than 5 m on only 1 floor level (fire floor level) with the duration of visibility less than 5 m in the order of approximately 80 s. The duration is relatively short because phased evacuation significantly reduced the stairwell door opening time on the fire floor and therefore also significantly reduces the amount of smoke flow into the stairwell. The short duration of visibility loss on one floor level is considered temporary and as the smoke moved up the stairwell, visibility on that floor level recovers to above 5 m. For the case where phased evacuation is adopted for simulations with medium floor (10 or 20-storey) and Type 7 system, visibility is found to be not less than 5 m on any floor level throughout the evacuation period.

Focussing on simulations with large floor and 10-storey or 20-storey, it is found that regardless of whether Type 6 or 7 system is provided, visibility is never less than 5 m on any of the floor level in conventional stairs as long as phased evacuation is adopted.

Simulation results show that tenability condition (visibility) in conventional stairs is worse for medium floor compared to large floor as more floors are affected for the same other building parameters. This can be explained by the fact that although large floor area has long queuing time at the stairwell door (due to higher occupancy load), the stairwell of large floor is considerably larger than that of medium floor and thereby providing more volume for smoke filling.

For all simulations, the results show that $FED_{gas}$ never exceeds 0.3 on any of the floor level in conventional stairs throughout the evacuation period. The maximum temperature rise in conventional stairs is approximately 50°C which occurred on the fire floor level. Since the temperature is relatively modest and only occurred over one floor level, it is not deemed to be particularly threatening to the occupants.

The increase in ceiling height from 2.7 m to 3.3 m in the floor spaces is found to prolong the time (in the order of 100 s to 150 s) it takes for visibility to first reduce to below 5 m and the maximum temperature in the stairwell is reduced by about 5 to 10°C. Overall, a 0.6 m increase in ceiling height has negligible effect on the tenability condition within conventional stairs.

If the conventional stairs are to be assessed based on the author's interpretation of NZBC C4.3 and C4.4, small floor comprising of any studied building parameters is unlikely cause tenability issue in the conventional stairwell serving it. The number of occupants in the stairwell of any small floor scenario never exceeds 1000 people and therefore, only $FED_{gas}$ is required to be assessed. It is found that $FED_{gas}$ never exceeds 0.3 throughout the evacuation for all small floor scenarios. However, for all medium and large floor scenarios, the number of occupants in stairwell exceeded 1000 which implied that both visibility and $FED_{gas}$ are required to be assessed. For medium floor, it is essential to provide Type 7 system for early detection as well as phased evacuation to ensure visibility and $FED_{gas}$ are kept within the tenability limits. For large floor, it is not necessary to provide early detection but it is essential that phased evacuation is adopted to ensure occupants can evacuate down a relatively smoke-free stairs.

Table 7-2 summarises the recommended requirements (based on the studied parameters) to ensure that tenability criteria (Visibility < 5 m; $FED_{gas}$ > 0.3) are not exceeded in the conventional stairs for high-rise office building.

Table 7-2: Recommended requirements to meet tenability criteria (Visibility < 5m; $FED_{gas}$ > 0.3) for conventional stairs

| Floor Area | Building Height | Fire Protection System | Evacuation Strategy | Ceiling Height |
|---|---|---|---|---|
| Small | 20 or 10-storey | Type 6 or Type 7 | Total or Phased | Low or High |
| Medium | 20 or 10-storey | Type 7 | Phased | Low or High |
| Large | 20 or 10-storey | Type 7 | Phased | Low or High |

### 7.3.2 Scissor Stairs

For simulations with small floor area and Type 7 system, visibility in the scissor stairs is not less than 5 m throughout the occupied period. When Type 6 system is provided instead, the results show that visibility is less than 5 m in scissor stairs for up to 2 floor levels. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 80 s.

Simulations with large or medium floor, 10-storey and adopting total evacuation, it is found that visibility is less than 5 m in scissor stairs on up to 4 floor levels. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 1250 s. For large or medium floor, 20-storey and adopting total evacuation, it is found that visibility in scissor stairs is less than 5 m for up to 9 floor levels during occupied period. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 2200 s.

When phased evacuation is adopted, simulations comprising medium floor with Type 6 system have visibility being less than 5 m in scissor stairs on up to 8 floor levels for 20-storey building and 5 floor levels for 10-storey building. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 200 s. For similar simulations but with large floor (instead of medium floor), visibility is found to be less than 5 m in scissor stairs on 1 floor level for 10-storey and 20-storey. The duration in which the visibility is lost (< 5m) on a single floor level is in the order of up to 280 s. Similar to that of conventional stairs, it is showed that tenability condition (visibility) in scissor stairs is worse for medium floor compared to large floor as more floors are affected for the same other building parameters.

When phased evacuation is adopted in conjunction with Type 7 system, it is found that visibility never reduces to below 5 m in scissor stairs for all simulations with large or medium floor.

From the simulation results, it is found that $FED_{gas}$ exceeds 0.3 on up to 5 floor levels in scissor stairs during occupied period for all medium or large floor, 20-storey and adopting total evacuation. For the rest of the simulations, it is found that $FED_{gas}$ never exceeds 0.3 on any of the floor level in scissor stairs throughout the evacuation period.

The maximum temperature in scissor stairs for small floor is found to be approximately 100°C on the fire floor level during occupied period. However, this only occurred over a short period of time (10 s) when the stairwell door is first opened and the temperature rapidly plummeted to 40°C within less than 60 seconds. This is likely to be due to the hot gas passing by detector it rises up the stairwell. For medium floor, the maximum temperature in scissor stairs on the fire floor level is found to be around 70°C when total evacuation is adopted. The maximum temperature dropped to 45°C when phased evacuation is adopted instead. As for large floor, the maximum temperature is 55°C when total evacuation is adopted and dropped to around 35°C when phased evacuation is adopted.

Similar to that of conventional stairs, the increase in ceiling height from 2.7 m to 3.3 m in the floor spaces is found to prolong the time (in the order of 50 s to 100 s) it takes for visibility to first reduce to less than 5 m and the maximum temperature in the stairwell is also reduced by about 5 to 10°C. Overall a 0.6 m increase in ceiling height has negligible effect on the tenability condition within scissor stairs.

If scissor stairs is to be assessed based on the author's interpretation of NZBC C4.3 and C4.4, small floor comprising of any studied building parameter is unlikely cause tenability issue in the scissor stairwell serving it. For large and medium floor (number of occupants in stairwell > 1000), it is essential to provide Type 7 system as well as adopting phased evacuation to ensure visibility and $FED_{gas}$ are kept within the tenability limits.

Table 7-3 summarises the recommended requirements (based on the studied building parameters) to ensure that tenability criteria (Visibility < 5 m; $FED_{gas}$ > 0.3) are not exceeded in the scissor stairs for high-rise office building.

Table 7-3: Recommended requirements to meet tenability criteria (Visibility < 5m; $FED_{gas}$ > 0.3) for scissor stairs

| **Floor Area** | **Building Height** | **Fire Protection System** | **Evacuation Strategy** | **Ceiling Height** |
|---|---|---|---|---|
| Small | 20 or 10-storey | Type 6 or Type 7 | Total or Phased | Low or High |
| Medium | 20 or 10-storey | Type 7 | Phased | Low or High |
| Large | 20 or 10-storey | Type 7 | Phased | Low or High |

## 7.4 General Summary

Assessment in accordance with NZBC C4.3 and C4.4 for small floor served by either conventional or scissor stairwell, the tenability limit ($FED_{gas}$ > 0.3 only) is never exceeded on the fire floor, the floor above as well as in the stairwells for all building parameter considered in this study.

Using NZBC C4.3 and C4.4 for the assessment of medium or large floor served by conventional stairwell or scissor stairwell, the tenability limits ($FED_{gas}$ > 0.3 for floor spaces; visibility < 5 m and $FED_{gas}$ > 0.3 for stairwells) are never exceeded for the fire floor, the floor above as well as in the stairwells if and only if phased evacuation is adopted and Type 7 system is provided.

Scissor stairwell is generally worse than conventional stairwell in terms of tenability conditions during an event of a fire. The time for visibility to first reduce to less than 5 m in scissor stairwell is found to be earlier (in the order of 200 s to 300 s) than that of conventional stairs for same location within the stairwell. It is also found that the duration in which visibility is lost in scissor stairs is longer (in the order of 200 s to 300 s) than that of conventional stairs for the same location within the stairwell. $FED_{gas}$ measurements at any location on scissor stairs fire floor and above are higher than that of conventional stairs. Scissor stairs is worse than conventional stairs due to the scissor stair arrangement which reduces the volume available for smoke filling by half. In this study, the amount of smoke flowing into conventional stairs and scissor stairs is roughly the same but since scissor stairs have less volume, the smoke concentration in scissor stairs is higher. In addition, the nature of scissor stair arrangement is such that smoke flows up the stairs in a corkscrew manner rather than diffusing in all direction like in conventional stairwell. This corkscrew smoke flow phenomenon concentrates the smoke along a specific path up the stairwell which has detrimental effect to the tenability conditions.

## 8. Conclusion

The most common form of strategy for fire evacuation of office building is that of total evacuation where simultaneous evacuation of occupants from all parts of a building will take place upon fire detection. The main objective of this research is to utilise the state-of-the-art modelling tools to show that for high-rise office building served by two stairwells possessing certain building parameters, adopting total evacuation can be detrimental to the evacuation and will result in tenability limits being exceeded before occupants can safely evacuate. This study aims to show that by adopting phased evacuation, where occupants under immediate threat (fire floor) are given the priority to fully evacuate the floor before the evacuation of the rest of the building commences, the tenability conditions in the high-rise office building (specifically in the stairwells) can be improved and kept within the tenability limits during evacuation.

The modelling tools are consisted of FDS and FDS+Evac. FDS is used as a numerical tool for solving fire driven fluid flow whereas FDS+Evac is used to determine the evacuation timings. The building parameters of interest to this study are – office floor area (small; medium; large), building height (10-storey and 20-storey), fire protection system (Type 6; Type 7), evacuation strategy (total; phased) and ceiling height (low; high). The phased evacuation in this study assumes a conservative flow of 40 people/min through the stairwell door for calculating the time to be allowed for occupants on the fire floor to evacuate before the rest of the building evacuates. Based on the number of variables considered for each building parameter, a total of 48 unique simulations are identified, assessed and analysed. Relevant New Zealand Compliance Documents such as C/AS5, C/VM2 and D1/AS1 are used to define the fire, fire protection system, modelling rules, evacuation parameters and geometry (floor and stairs) that satisfied the minimum requirements of NZBC.

Each simulation is initially intended to be ran as coupled run where FDS and FDS+Evac simulation are conducted simultaneously to allow for the effect of smoke on people’s movement. As the research progresses, it is found impractical to conduct all simulations as coupled simulation due to constraints such as frequent power outages, lack of resources (dedicated computers) and hard drive storage space to complete each simulation as coupled run. However, the inability to complete some of the simulations as coupled run is not deemed significant enough to result in a different conclusion being drawn. This is supported by the fact that the use of FDS+Evac for calculating evacuation timings without the effect of smoke (evacuation drill) is validated to some extent against hydraulic models and relevant trial evacuation experiments in the literature. Thus, the results and analysis associated with decoupled simulations can still provide meaningful insights.

For each simulation, the assessed tenability limits are in accordance with NZBC C4.3 and C4.4. For the floor space, ASET is determined at $FED_{gas}$ greater than 0.3 as each simulation scenario is sprinklered and has no more than 1000 occupants per floor (firecell). For the stairwells, ASET is determined at visibility less than 5 m or $FED_{gas}$ greater than 0.3 for stairwell serving more than 1000 occupants. For stairwell serving less than 1000 occupants, ASET is determined at $FED_{gas}$ greater than 0.3 only.

From the analysis of the simulation results, the following conclusions can be drawn:

- For office building with floor area not exceeding 510 $m^2$ (small floor) on each floor served by either conventional or scissor stairwell and up to 20 storeys, as long as the building is provided with at least a Type 6 system, the tenability within the stairwell are expected to be maintained. Type 7 system and phased evacuation are not deemed essential.
- For office building with floor area of 2450 $m^2$ (medium floor) on each floor served by either conventional or scissor stairwell and between 10 to 20 storeys, the building shall be provided with Type 7 system and adopting phased evacuation to maintain tenability in the stairwell.
- For office building with floor area of 5000 $m^2$ (large floor) on each floor served by either conventional or scissor stairwell and between 10 to 20 storeys, the building shall be provided with Type 7 system and adopting phased evacuation to maintain tenability in the stairwell.

Increasing the ceiling height in the floor space from 2.7 m to 3.3 m has little to no effect on the time to visibility less than 10 m and $FED_{gas}$ greater than 0.3 on the fire floor. It also has minimal effect on the maximum temperature in which occupants are exposed to on the fire floor during occupied periods. However, it is found that the increase in ceiling height prolonged the time (in the order of 50 to 200 s) it takes for visibility to first reduce to less than 5 m. Overall, a 0.6 m increase in ceiling height in the floor space has a negligible effect on the tenability conditions within the stairwells.

The analysis of all 40 unique simulations has also generated a number of interesting observations which are summarised below:

- ❖ The tenability limits that are considered for the stairwells (especially for large and medium floor) are more stringent compared to that of the floor space (visibility < 5 m and $FED_{gas}$ > 0.3 for stairwell and $FED_{gas}$ > 0.3 only for floor space). Therefore, it is expected that the tenability assessment of the stairwells (rather than the floor) will govern the selection of building parameters (fire protection system and evacuation strategy) to keep the tenability conditions within the limits in the stairwells.
- ❖ When visibility of less than 5 m is required to be assessed for the stairwells, the height of the building (10-storey or 20-storey) is found to be an insignificant building parameter. The height of the building is only significant when considering the $FED_{gas}$ of occupants in the floor spaces and stairwells.
- ❖ Scissor stairwell is less tenable than conventional stairwell in an event of a fire. This is due to the scissor stair arrangement having a reduced volume (by half) for smoke filling compared to conventional stairs occupying the same footprint. It is observed that for a scissor stair arrangement, smoke flows up the stairs in a corkscrew manner rather than diffusing in all direction as seen on conventional stairs. This corkscrew smoke flow phenomenon concentrates the smoke along a specific path up the stairwell which has detrimental effect on the tenability conditions.

## 8.1 Future works/Recommendations

The following are some future works that can be generated from this study:

- ❖ The method of determining $FED_{gas}$ of occupants utilised in this research is conservative but does not take into account the uptake of narcotic gas changes as the occupants move through spaces. If all simulations can be conducted as coupled runs (simultaneous running of FDS and FDS+Evac), $FED_{gas}$ of each occupant can be obtained from the coupled simulation through FDS+Evac. This is expected to result in longer ASET time and more correctly reflect the $FED_{gas}$ the occupants are exposed to in reality.

- ❖ Consider and investigate the presence of stairwell pressurisation system in conjunction with phased evacuation and how that will affect the requirements of other building parameters to achieve a code compliance building with respect to protection from fire.
- ❖ Determine the maximum floor area and building height for which phased evacuation is not required and total evacuation can be adopted without compromising the tenability within the stairwell.
- ❖ The use of other evacuation models such as EvacuatioNZ for calculating the evacuation timings of the simulations in this research. This will allow evacuation results obtained from different evacuation models to be compared and the uncertainties between different evacuation models can be evaluated.
- ❖ Further investigation will be required on the unusual phenomenon observed within FDS+Evac where scissor stairs consistently clears at a much faster rate compared to conventional stairs from the middle floor and up. This phenomenon is not expected since both stairwells are identical in terms of construction within FDS+Evac (escape width and boundary layer etc.) and they both served the same number of occupants.

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# Appendix A – Comparison of Different HRRPUA Values

An analysis was carried out to investigate the sensitivity of the specified HRRPUA value in FDS on the tenability condition within the floor space as well as the stairwells. C/VM2 specified a range of 500 - 1000 kW/m$^2$ for the HRRPUA for the design fire, however, in this research study; a range of 150 – 300 kW/m$^2$ was adopted.

The two simulations chosen for this analysis are consisted of simulation M_10_T6_T_2.7 and S_10_T6_T_2.7. S_10_T6_T_2.7 is chosen for the analysis because it represents the absolute worst case scenario in terms of the deviation of its HRRPUA value from that specified in C/VM2. M_10_T6_T_2.7 is chosen to better assess the sensitivity of HRRPUA value on the tenability condition in the stairwells due to longer stairwell door opening time.

### A1 M_10_T6_T_2.7

Figure A-1 to Figure A-12 compare the visibility and $FED_{gas}$ on the fire floor as well as the floor landings of both stairwells with a HRRPUA value of 215 kW/m$^2$ and 859 kW/m$^2$.

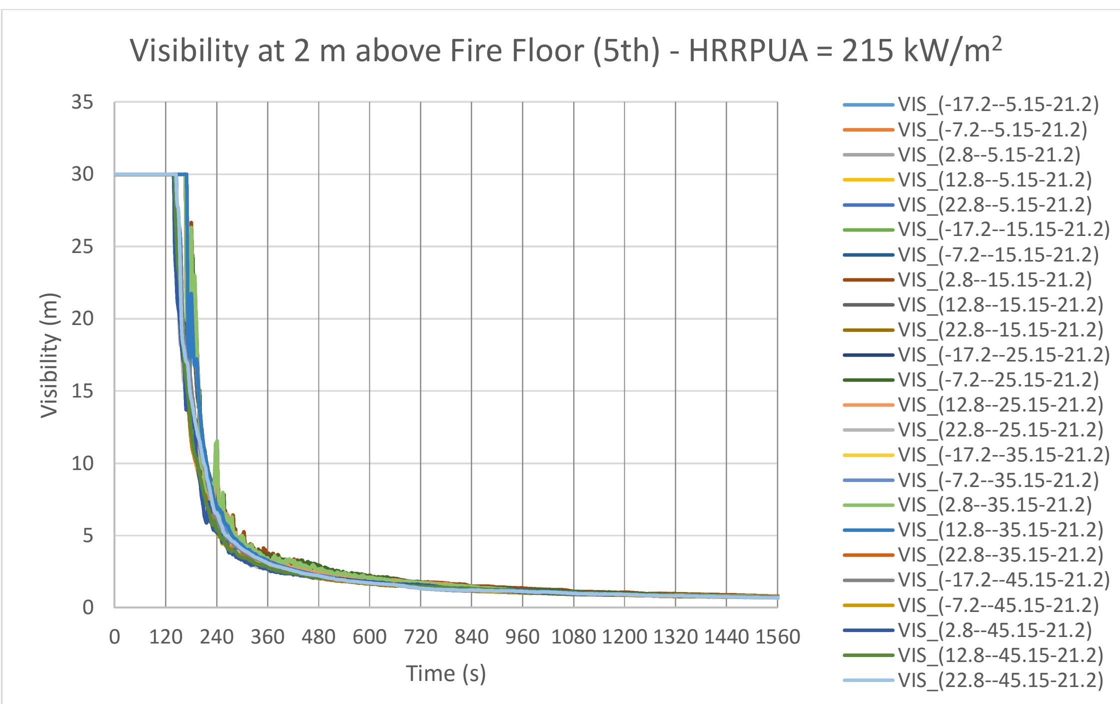


Figure A-1: Visibility vs Time for HRRPUA = 215 kW/m$^2$ on Fire Floor (5th)

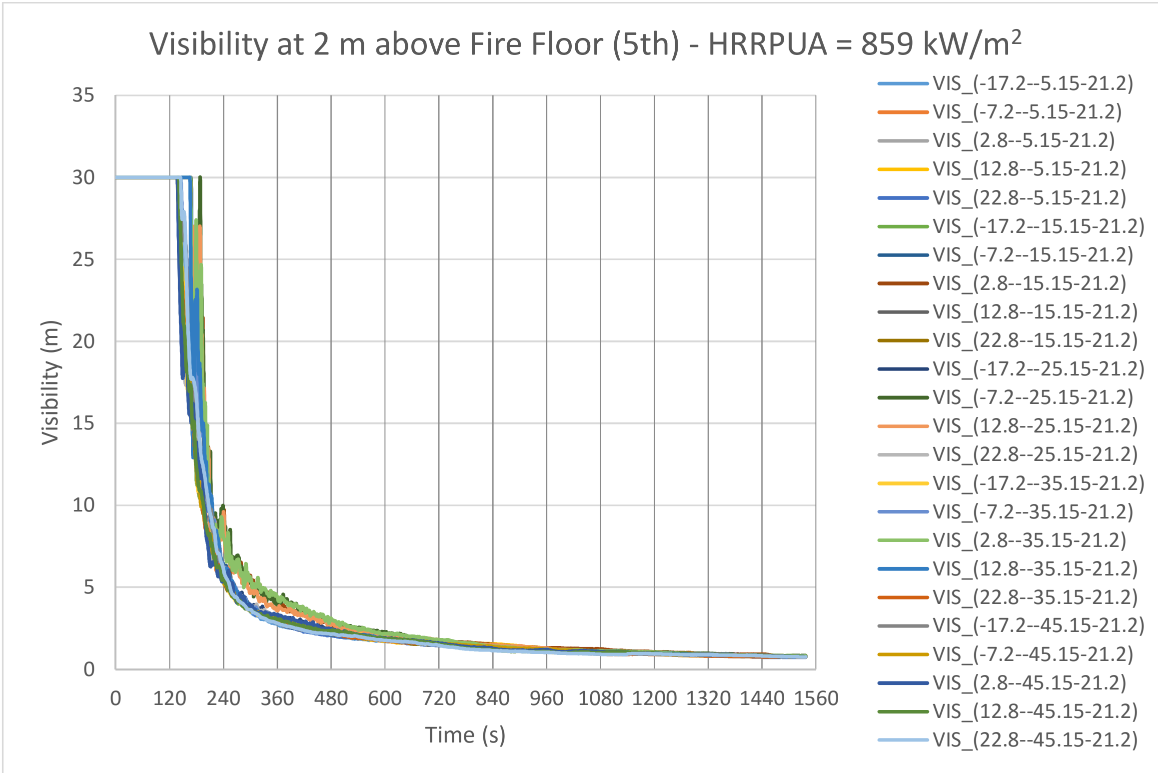


Figure A-2: Visibility vs Time for HRRPUA = 859 kW/m$^2$ on Fire Floor (5th)

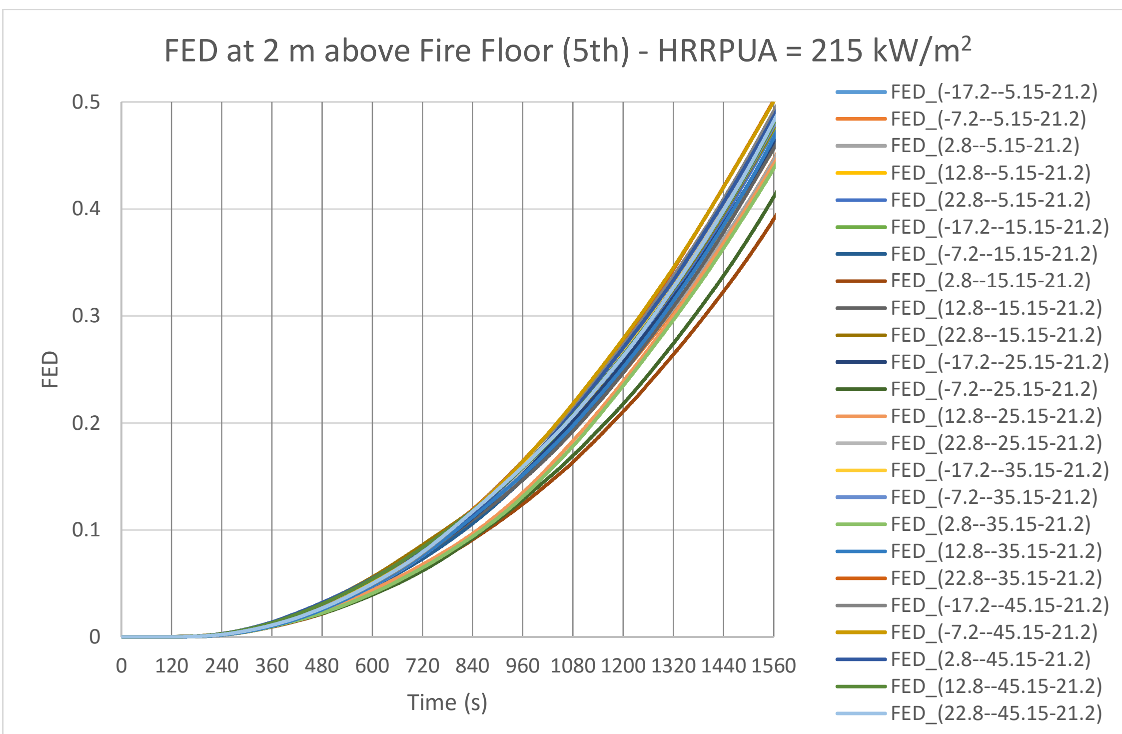


Figure A-3: FED vs Time for HRRPUA = 215 kW/m$^2$ on Fire Floor (5th)

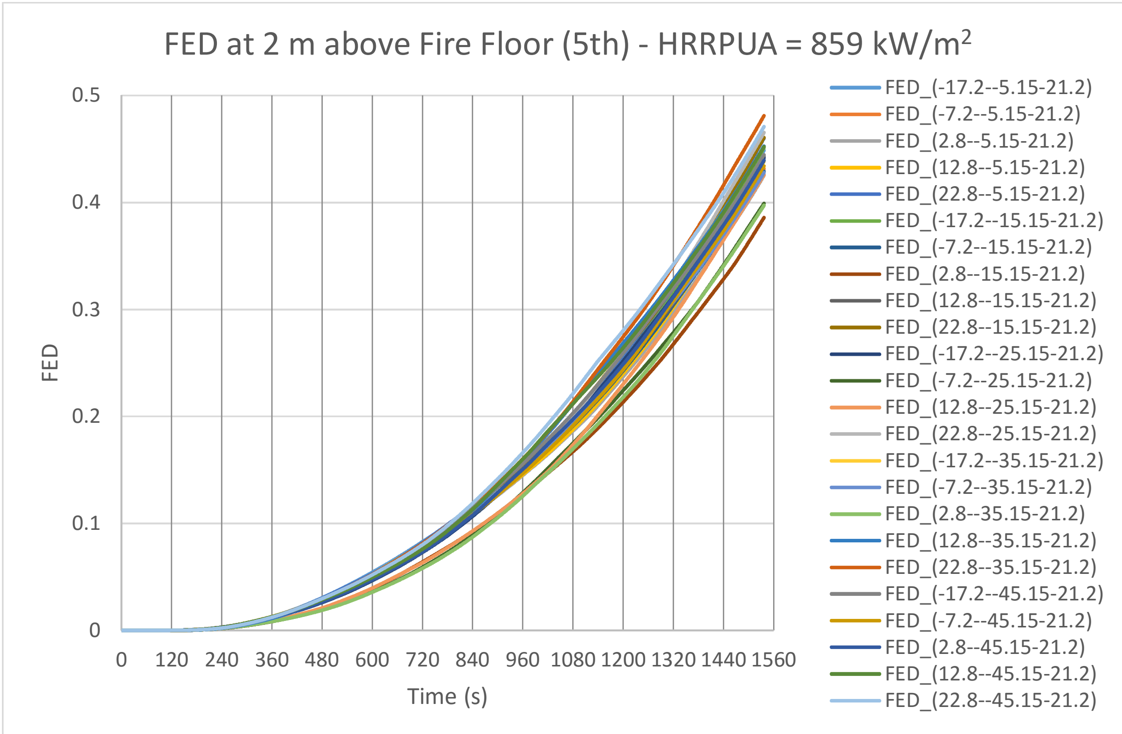


Figure A-4: FED vs Time for HRRPUA = 859 kW/m$^2$ on Fire Floor (5th)

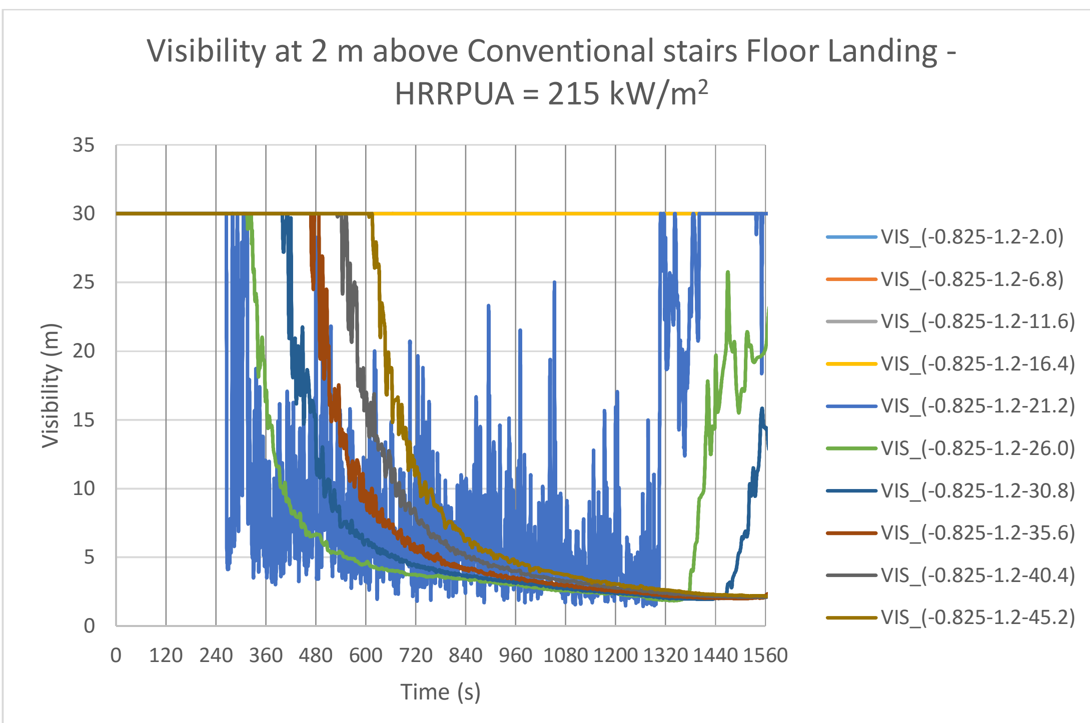


Figure A-5: Visibility vs Time for HRRPUA = 215 kW/m$^2$ on Conventional stairs Floor Landings

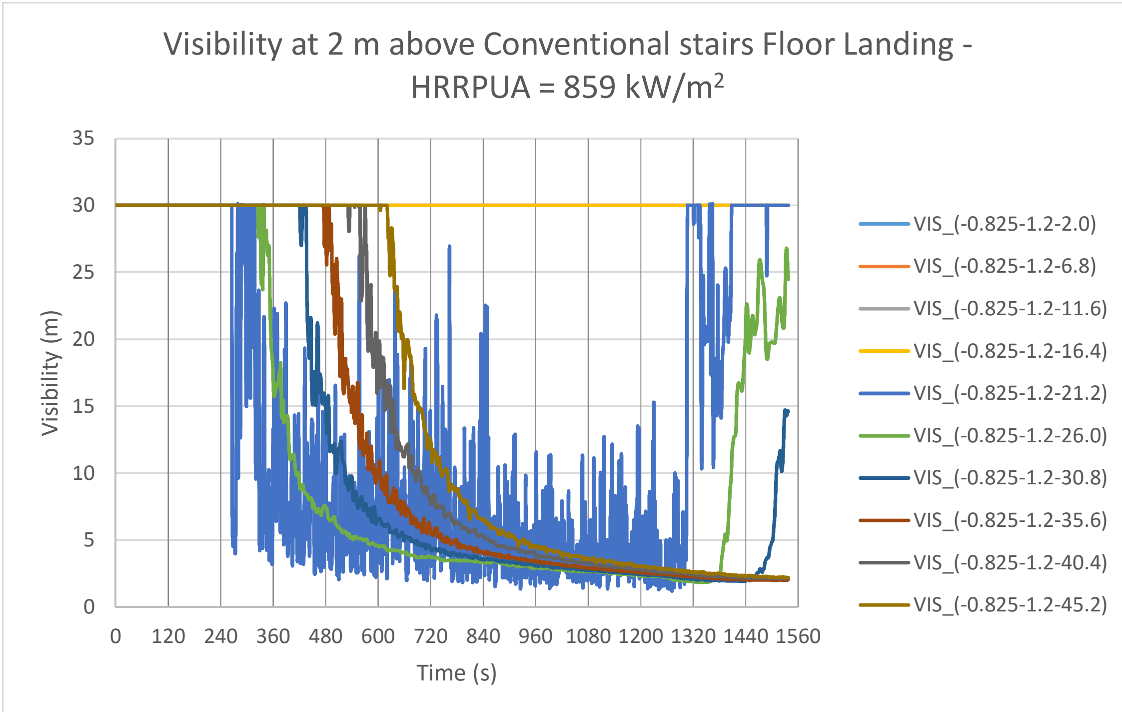


Figure A-6: Visibility vs Time for HRRPUA = 859 kW/m$^2$ on Conventional stairs Floor Landings

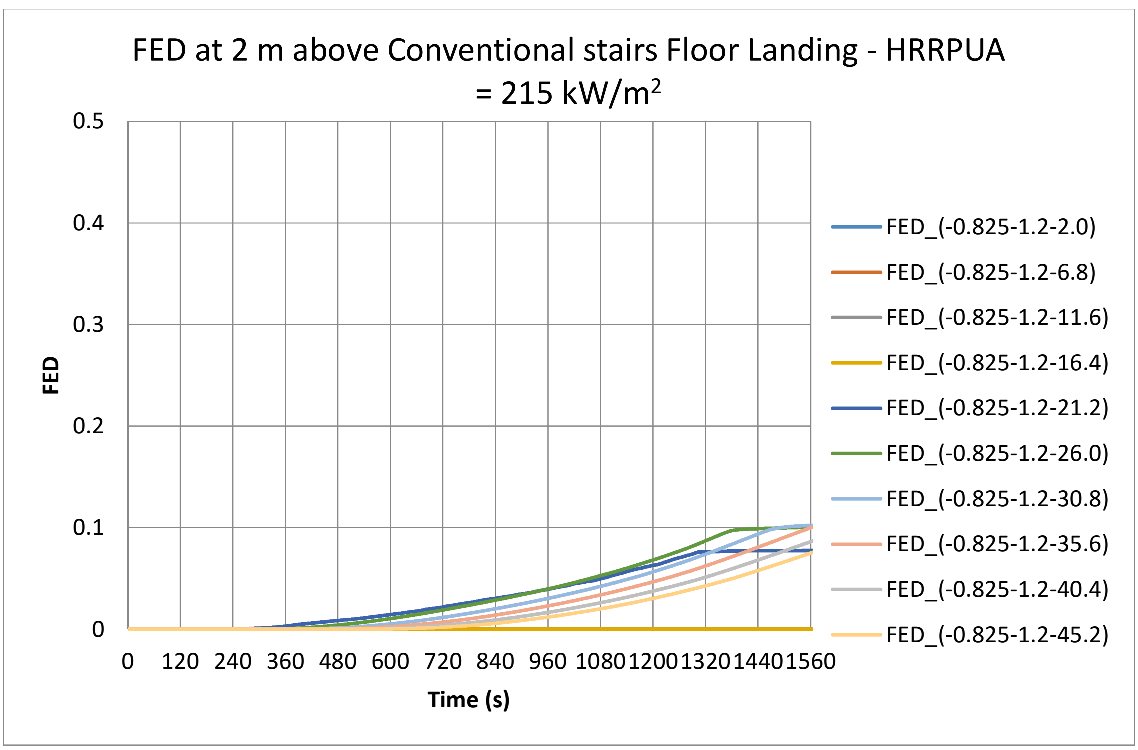


Figure A-7: FED vs Time for HRRPUA = 215 kW/m$^2$ on Conventional stairs Floor Landings

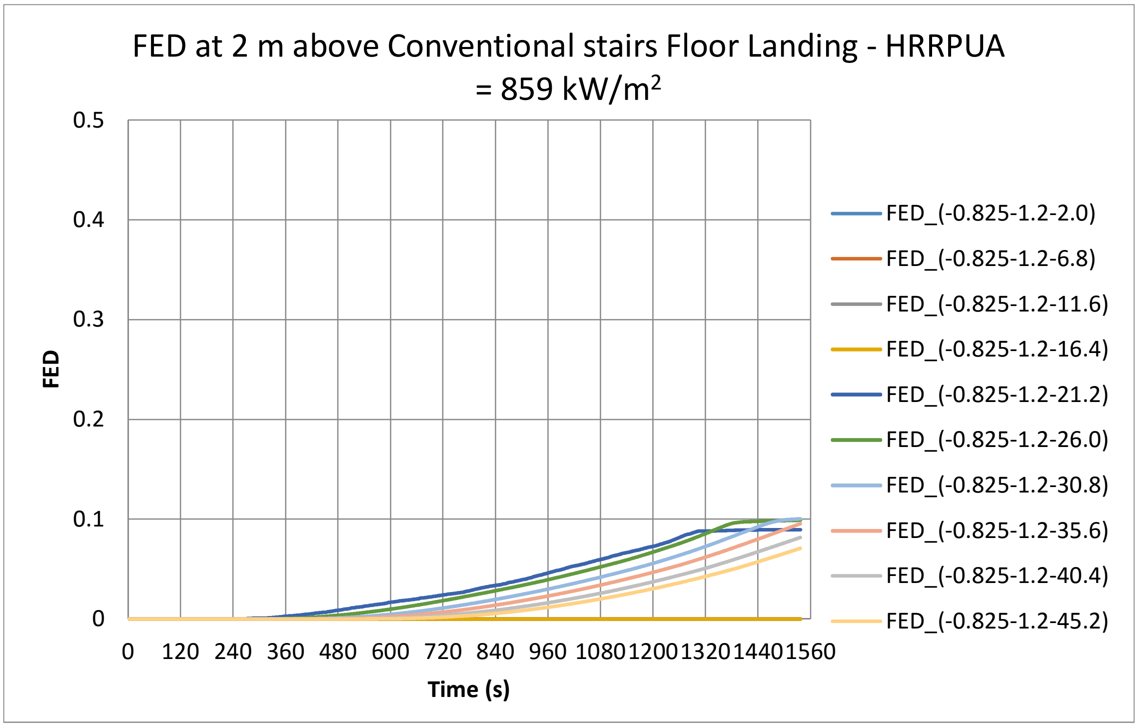


Figure A-8: FED vs Time for HRRPUA = 859 kW/m$^2$ on Conventional stairs Floor Landings

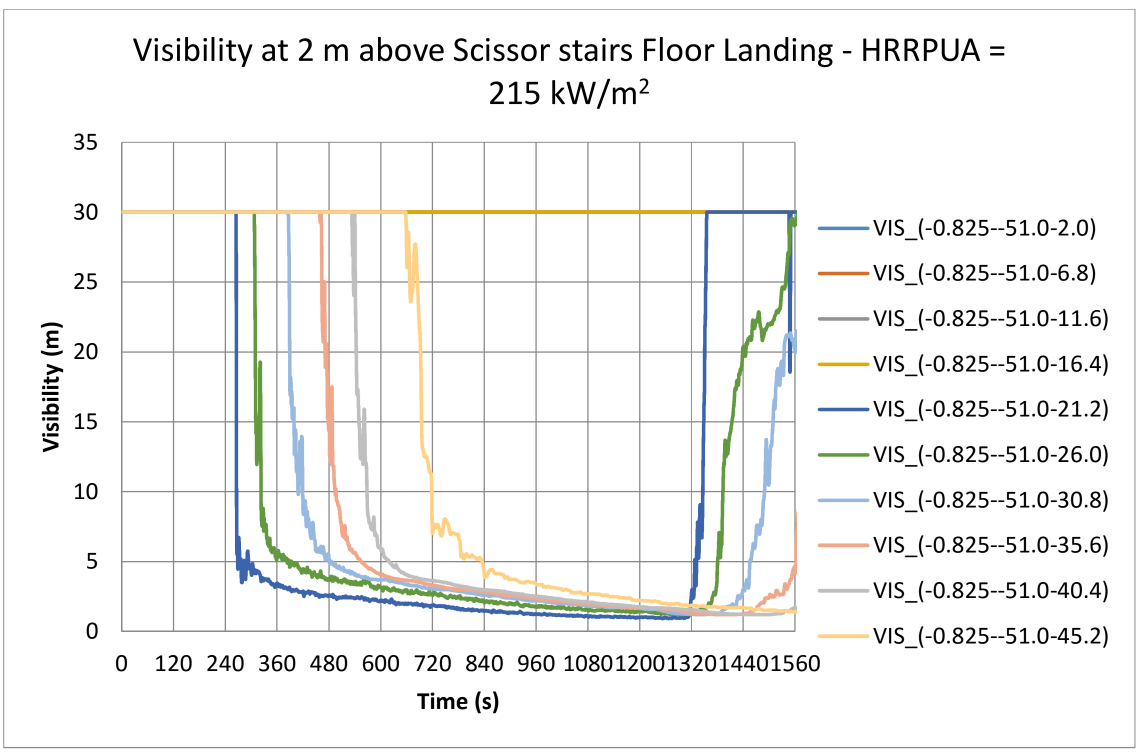


Figure A-9: Visibility vs Time for HRRPUA = 215 kW/m$^2$ on Scissor stairs Floor Landings

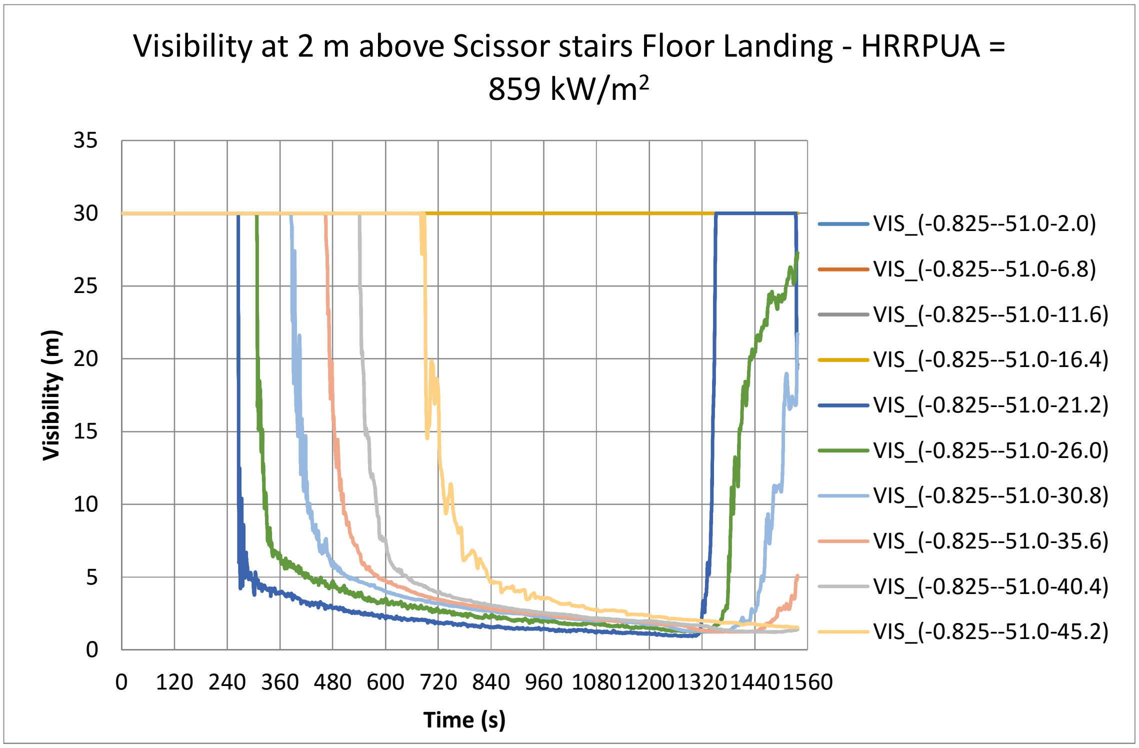


Figure A-10: Visibility vs Time for HRRPUA = 859 kW/m$^2$ on Scissor stairs Floor Landings

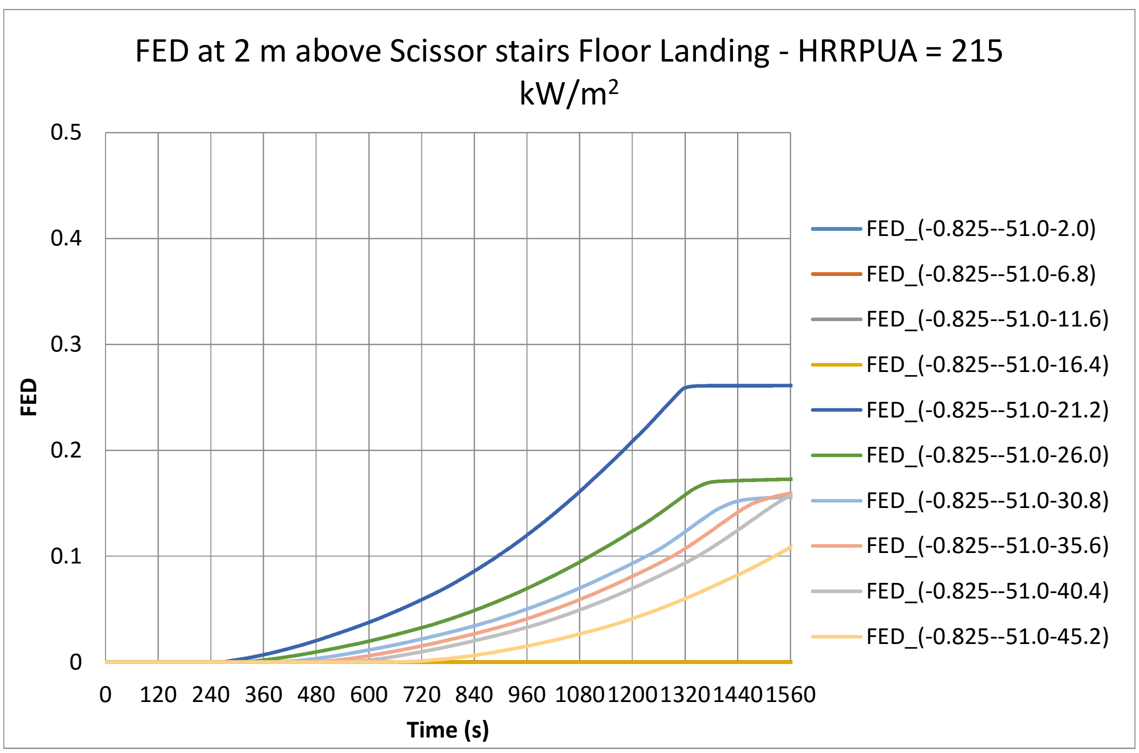


Figure A-11: FED vs Time for HRRPUA = 215 kW/m$^2$ on Scissor stairs Floor Landings

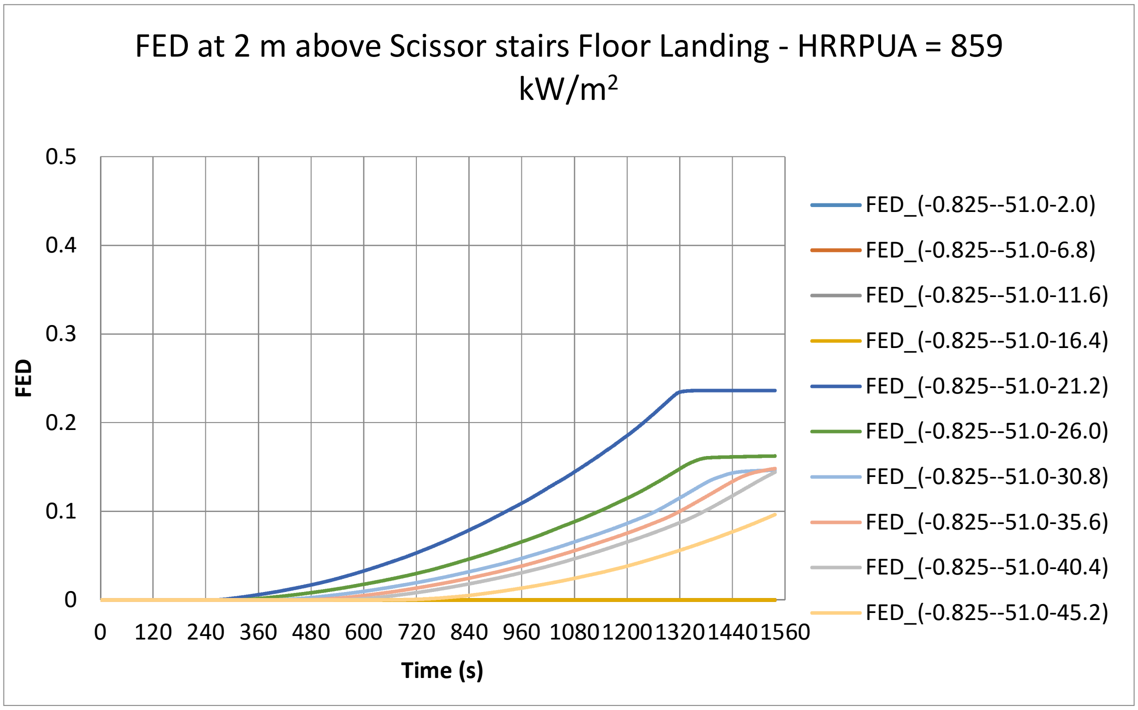


Figure A-12: FED vs Time for HRRPUA = 859 kW/m$^2$ on Scissor stairs Floor Landings

## A2 S_10_T6_T_2.7

Figure A-13 to Figure A-24 compare the visibility and $FED_{gas}$ on the fire floor as well as the floor landings of both stairwells with a HRRPUA value of 160 kW/m$^2$ and 638 kW/m$^2$.

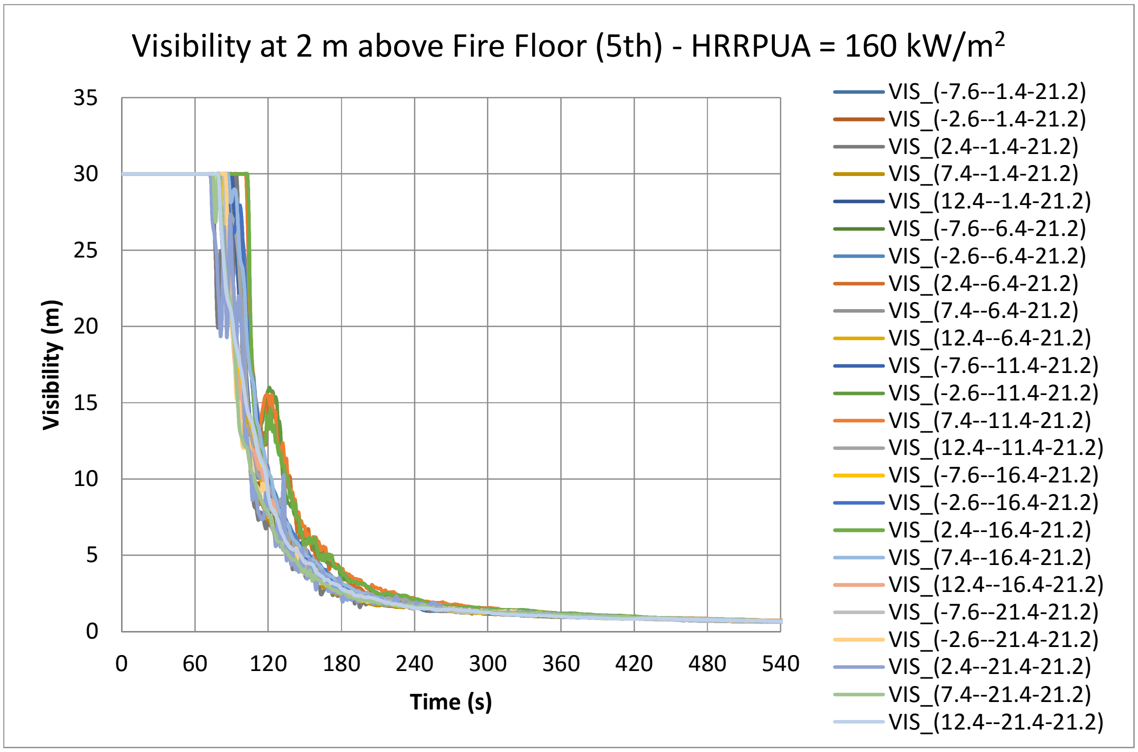


Figure A-13: Visibility vs Time for HRRPUA = 160 kW/m$^2$ on Fire Floor (5th)

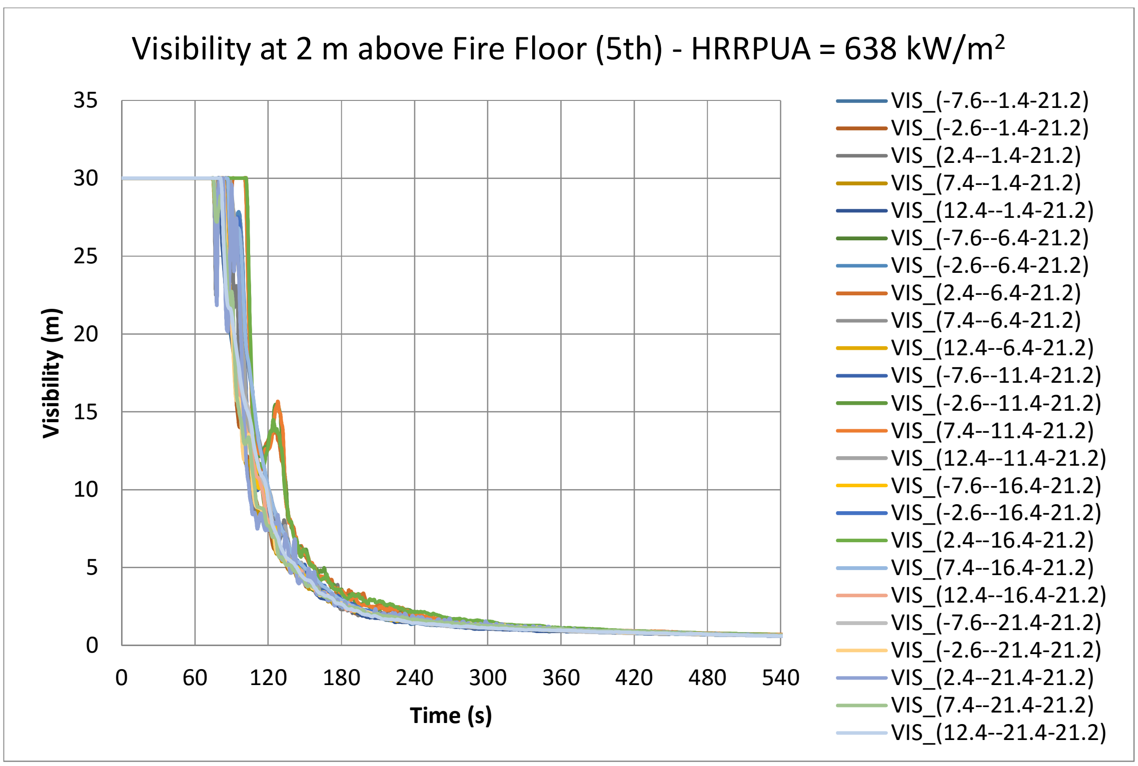


Figure A-14: Visibility vs Time for HRRPUA = 638 kW/m$^2$ on Fire Floor (5th)

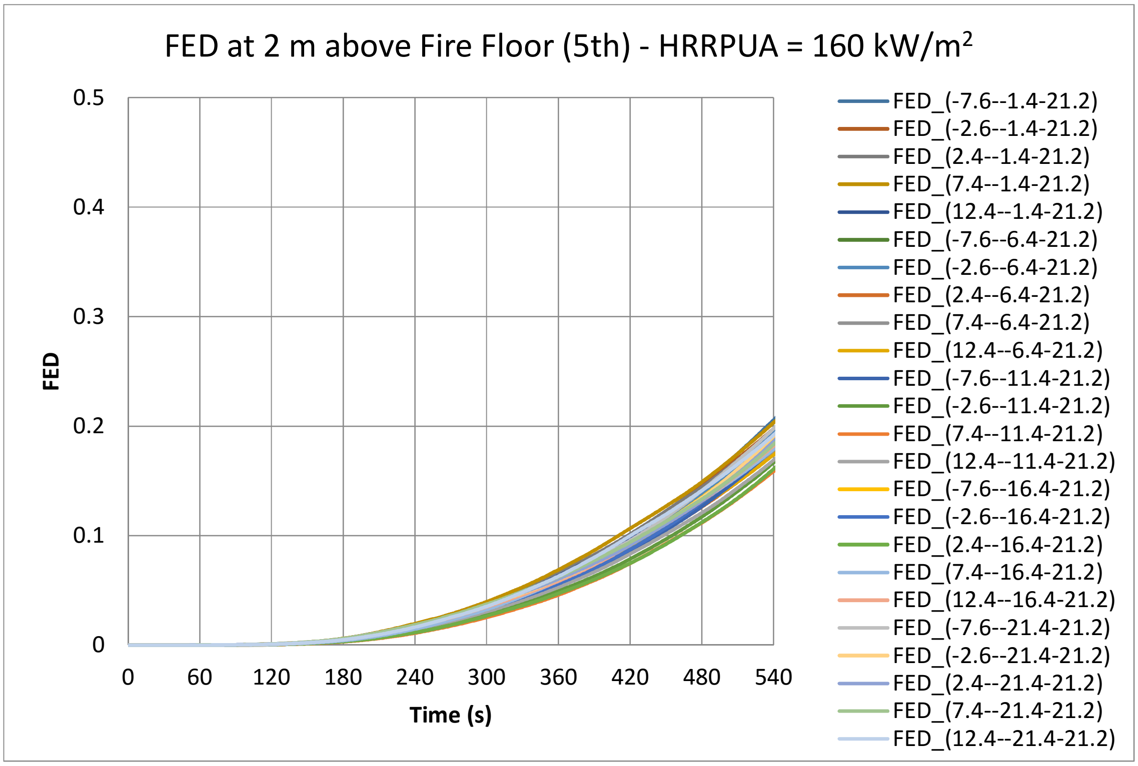


Figure A-15: FED vs Time for HRRPUA = 215 kW/m$^2$ on Fire Floor (5th)

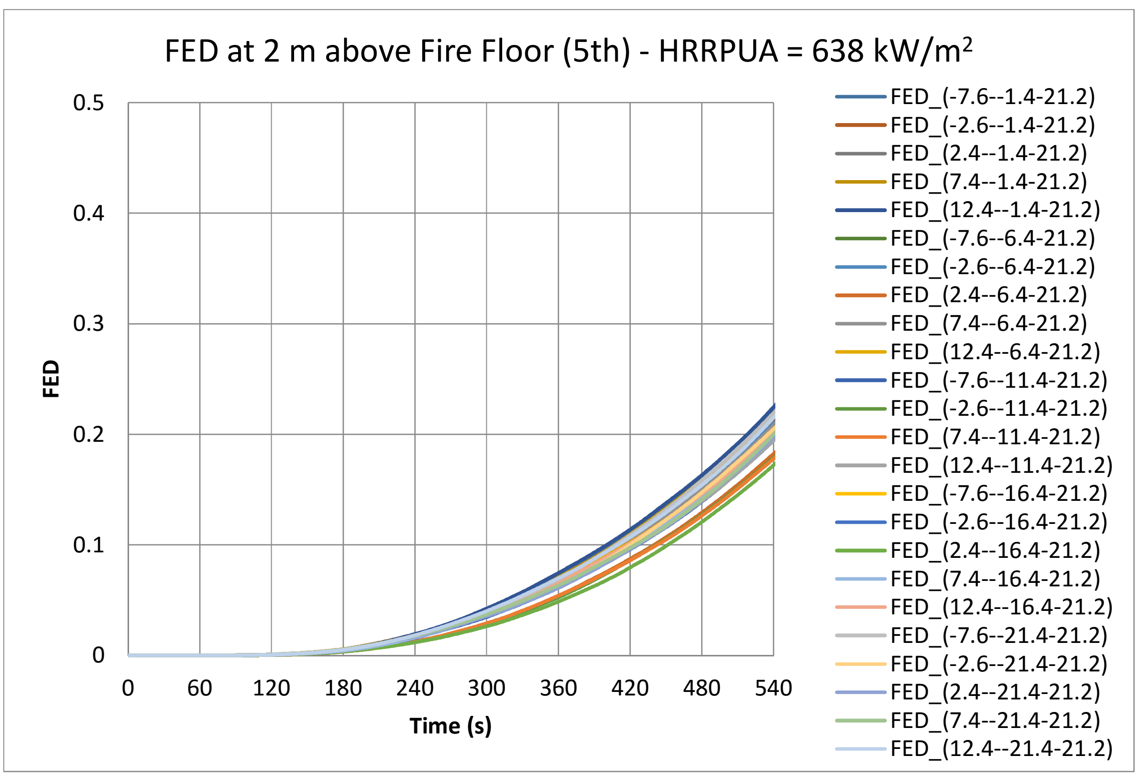


Figure A-16: FED vs Time for HRRPUA = 638 kW/m$^2$ on Fire Floor (5th)

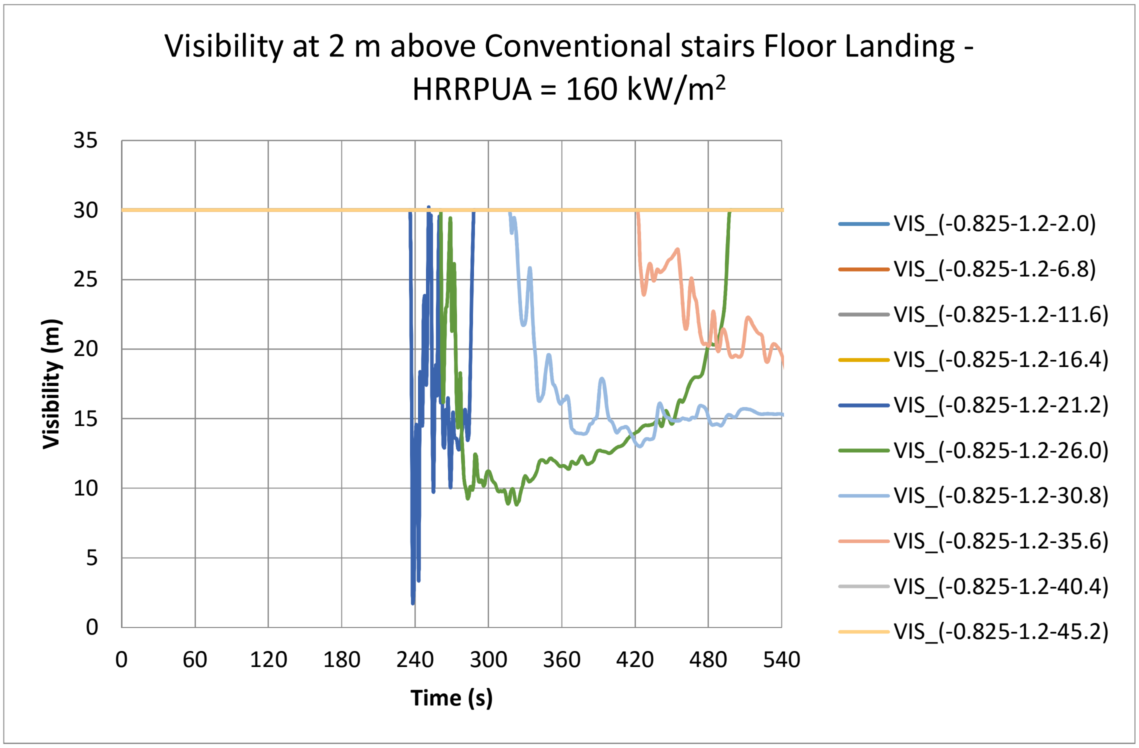


Figure A-17: Visibility vs Time for HRRPUA = 160 kW/m² on Conventional stairs Floor Landings

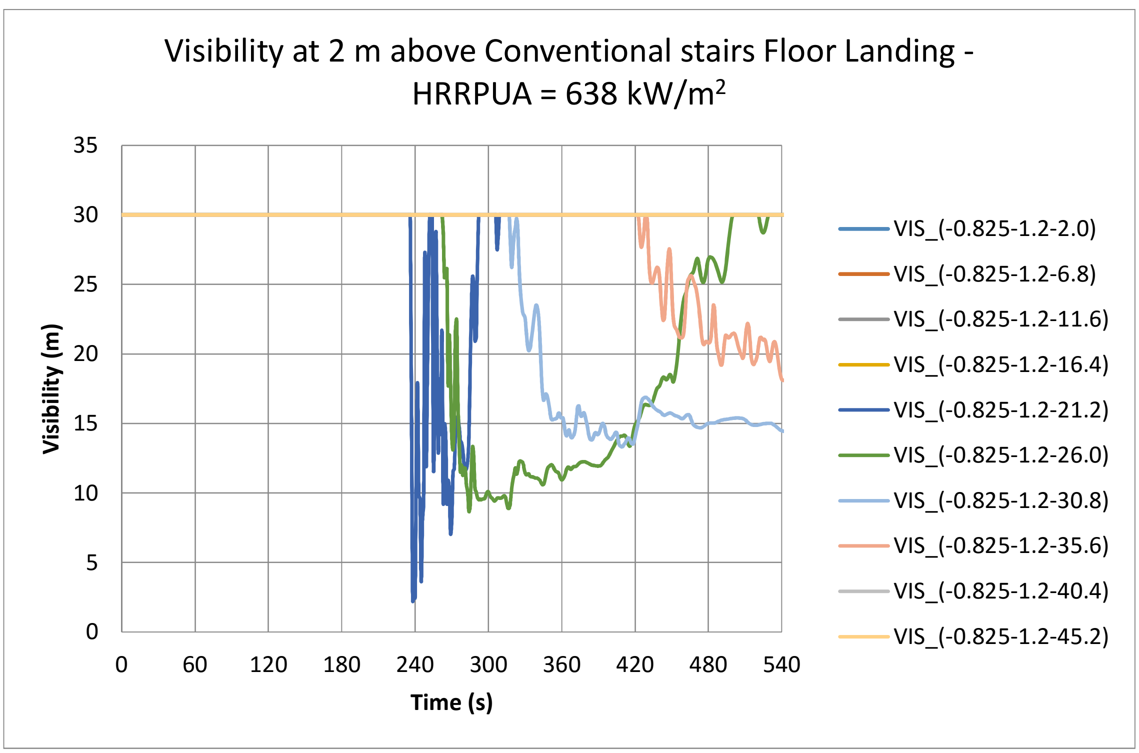


Figure A-18: Visibility vs Time for HRRPUA = 638 kW/m² on Conventional stairs Floor Landings

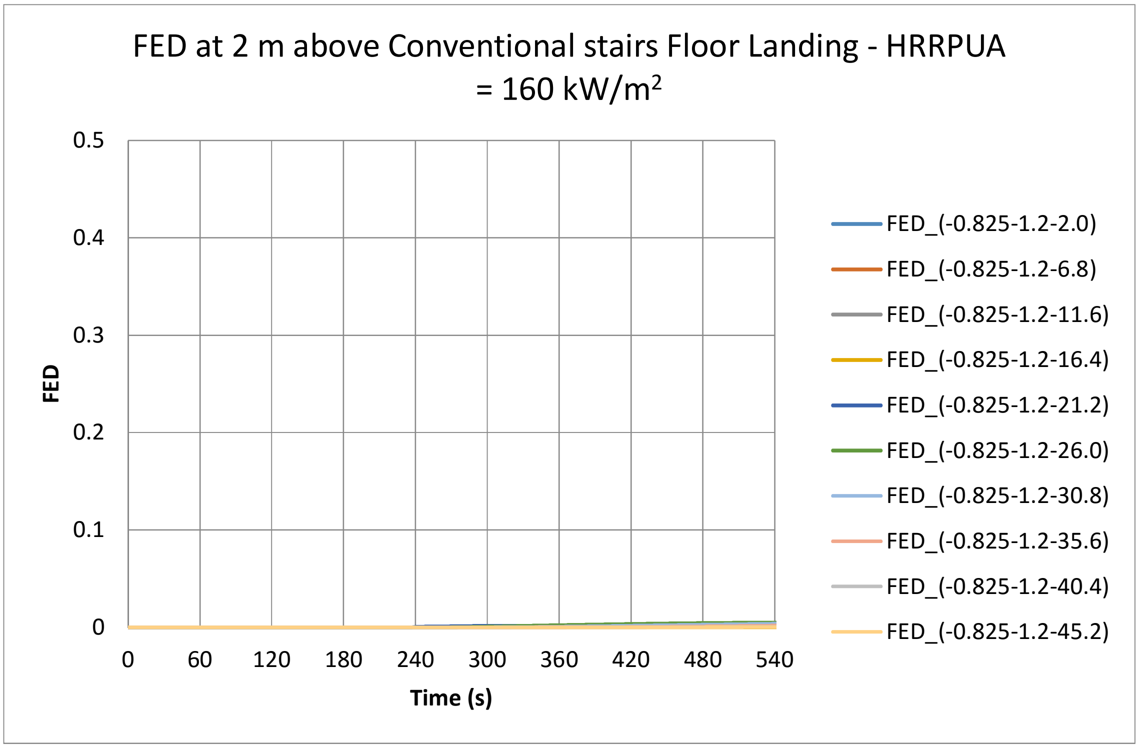


Figure A-19: FED vs Time for HRRPUA = 160 kW/m² on Conventional stairs Floor Landings

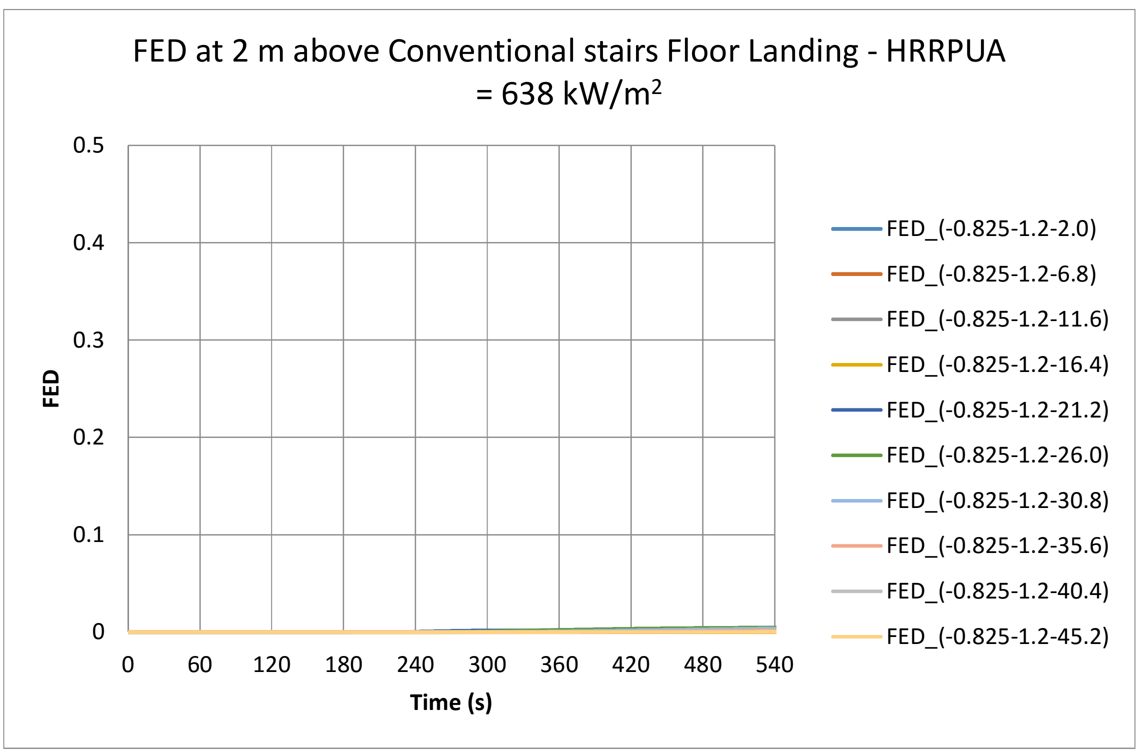


Figure A-20: FED vs Time for HRRPUA = 638 kW/m² on Conventional stairs Floor Landings

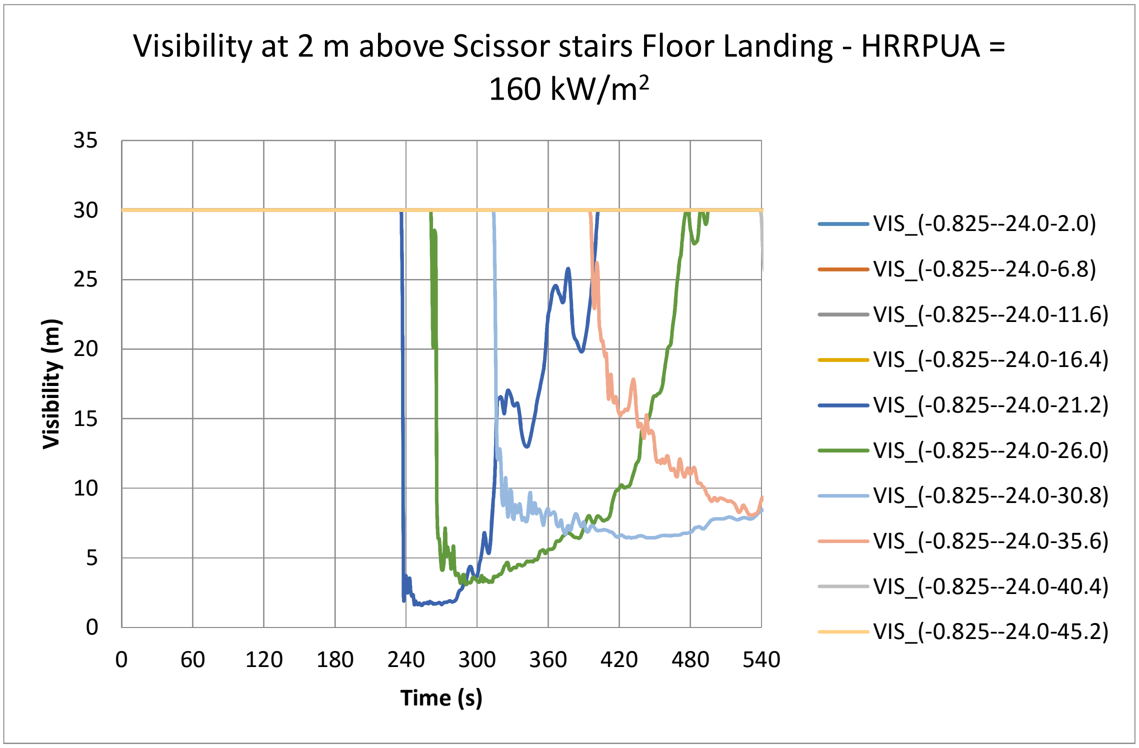


Figure A-21: Visibility vs Time for HRRPUA = 160 kW/m² on Scissor stairs Floor Landings

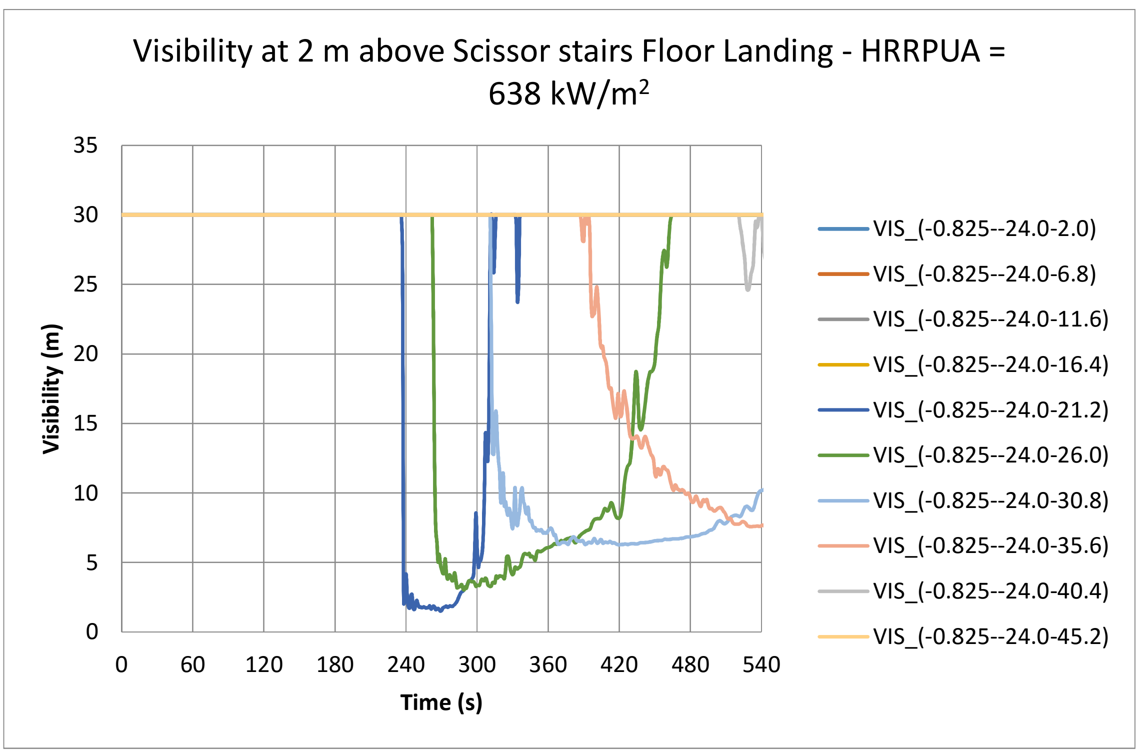


Figure A-22: Visibility vs Time for HRRPUA = 638 kW/m² on Scissor stairs Floor Landings

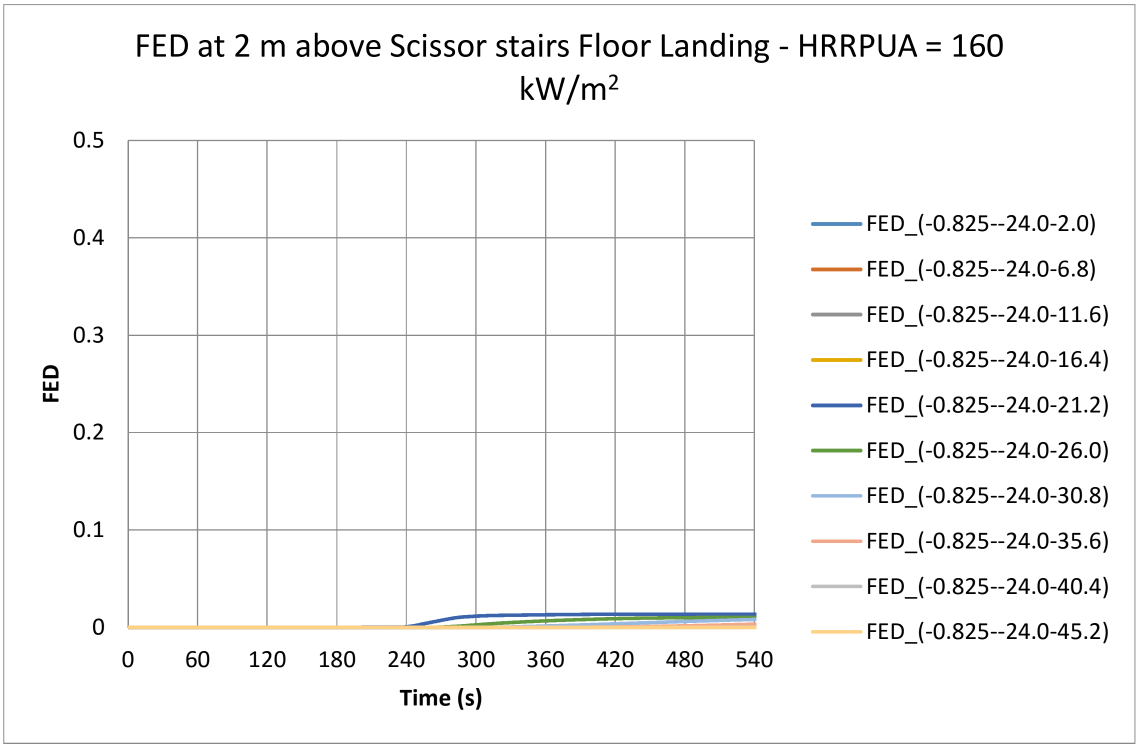


Figure A-23: FED vs Time for HRRPUA = 160 kW/m$^2$ on Scissor stairs Floor Landings

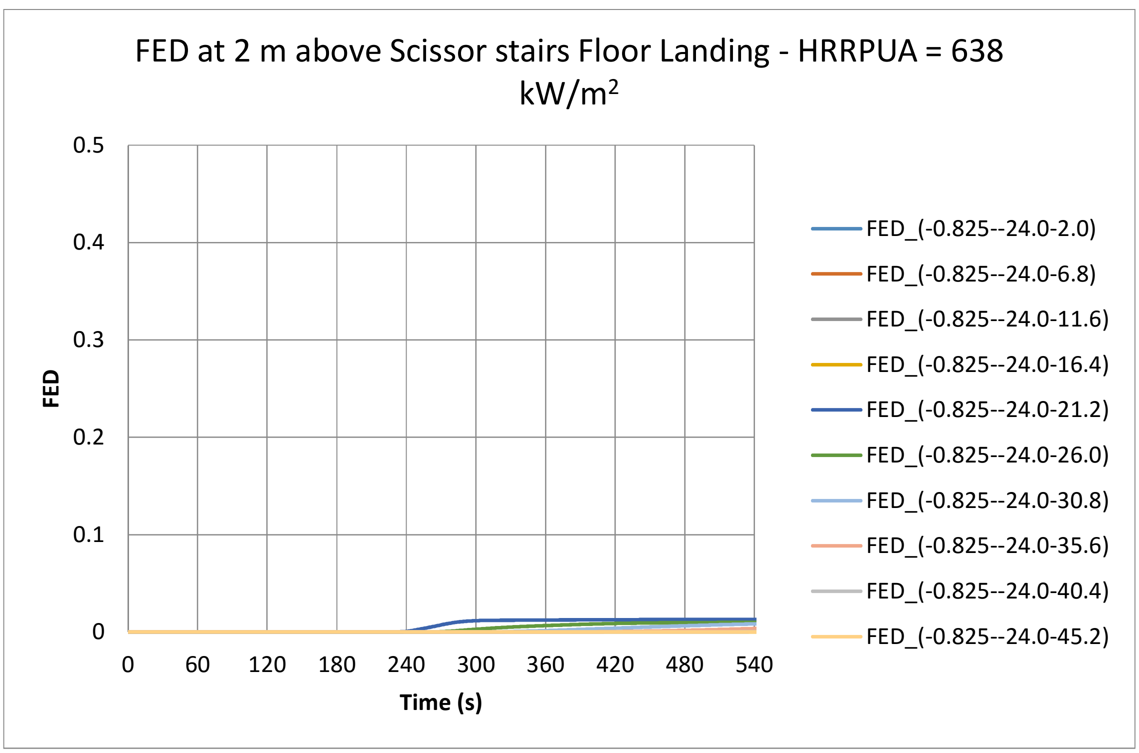


Figure A-24: FED vs Time for HRRPUA = 638 kW/m$^2$ on Conventional stairs Floor Landings

## A3 Overall Remark

From above, it can be observed that there is no noticeable difference in terms of the tenability conditions (visibility and $FED_{gas}$) in the floor space as well as the stairwells for HRRPUA values stated outside of the range prescribed in C/VM2. This implied that the measured tenability conditions are insensitive towards the specified HRRPUA values. Therefore, the range of HRRPUA (150 kW/m$^2$ – 300 kW/m$^2$) used in this research study is deemed acceptable.

# Appendix B – FDS and FDS+Evac Input Files

FDS+Evac version: FDS 6.1.2, Evac 2.5.0
Floor to floor height is 4.8 m for stairwell, floor to floor height is 2.7 m for office floor.
Building is 20 storeys tall, fire floor on 10th floor.
One floor above and one floor below fire floor will be modelled as well.
Office floor area is 2450 m2
Sprinkler system only
One out, all out evacuation

```
&HEAD CHID='DP002', TITLE='Simulation Run 2' /

Fire mesh for the staircase and floor
&MESH IJK=56,37,642, XB=-1.80,6.6, -3.15,2.40, -0.3,96.0 / 150 mm mesh for stair 1
&MESH IJK=165,145,33, XB= -22.2,27.3, -3.15,-46.65, 42.9,52.8 / 300 mm grid
&MESH IJK=56,37,642, XB=-1.80,6.6, -46.65,-52.20, -0.3,96.0 / 150 mm mesh for stair 2
&MESH IJK=68,10,33, XB= -22.2,-1.80, -3.15,-0.15, 42.9,52.8 / 300 mm grid
&MESH IJK=69,10,33, XB= 6.6,27.3, -3.15,-0.15, 42.9,52.8 / 300 mm grid
&MESH IJK=68,10,33, XB= -22.2,-1.8, -46.65,-49.65, 42.9,52.8 / 300 mm grid
&MESH IJK=69,10,33, XB= 6.6,27.3, -46.65,-49.65, 42.9,52.8 / 300 mm grid

&TIME TWFIN=3600./

*************Leakages*******************************************************************

&VENT XB=27.3,27.3, -49.65,-49.05, 45.6,45.9, SURF_ID='OPEN'/ leakage 1 for 10th floor
&VENT XB=27.3,27.3, -0.75,-0.15, 43.5,43.2, SURF_ID='OPEN'/ leakage 2 for 10th floor
&VENT XB=-22.2,-22.2, -49.65,-49.05, 45.6,45.9, SURF_ID='OPEN'/ leakage 3 for 10th floor
&VENT XB=-22.2,-22.2, -0.75,-0.15, 43.5,43.2, SURF_ID='OPEN'/ leakage 4 for 10th floor

&VENT XB=27.3,27.3, -49.65,-49.05, 50.4,50.7, SURF_ID='OPEN'/ leakage 1 for 11th floor
&VENT XB=27.3,27.3, -0.75,-0.15, 48.3,48.0, SURF_ID='OPEN'/ leakage 2 for 11th floor
&VENT XB=-22.2,-22.2, -49.65,-49.05, 50.4,50.7, SURF_ID='OPEN'/ leakage 3 for 11th floor
&VENT XB=-22.2,-22.2, -0.75,-0.15, 48.3,48.0, SURF_ID='OPEN'/ leakage 4 for 11th floor

&VENT XB=1.20,3.45, 2.4,2.4, 0.0,0.45, SURF_ID='OPEN'/ stair 1 bottom
&HOLE XB=1.20,3.45, 0.15,-0.30, 96.0,95.55 / stair 1 top
VENT XB=1.20,3.45, -0.15,-0.15, 96.0,95.55, SURF_ID='OPEN'/ stair 1 top

&VENT XB=1.65,2.85, -52.20,-52.20, 0.0,0.45, SURF_ID='OPEN'/ stair 2 bottom
&HOLE XB=1.20,3.45, -49.35,-49.95, 96.0,95.55 / stair 1 top
VENT XB=1.20,3.45, -49.65,-49.65, 96.0,95.55, SURF_ID='OPEN'/ stair 1 top
&VENT XB=1.65,2.85, -52.20,-52.20, 96.0,95.55, SURF_ID='OPEN'/ stair 2 top

&VENT XB=-1.80,6.6, -0.15,-3.15, 96.0,96.0, SURF_ID='OPEN'/ top vent open stair 1
&VENT XB=-1.80,6.6, -46.65,-49.65, 96.0,96.0, SURF_ID='OPEN'/ top vent open stair 2

&VENT XB=-1.80,6.6, -3.15,-3.15, 52.8,96.0, SURF_ID='OPEN'/ side vent open 12th floor and above stair 1
&VENT XB=-1.80,6.6, -3.15,-3.15, -0.3,42.9, SURF_ID='OPEN'/ side vent open 9th floor and below stair 1

&VENT XB=-1.80,6.6, -46.65,-46.65, 52.8,96.0, SURF_ID='OPEN'/ side vent open 12th floor and below stair 2
&VENT XB=-1.80,6.6, -46.65,-46.65, -0.3,42.9, SURF_ID='OPEN'/ side vent open 9th floor and below stair 2

*************Define the fire*********************************************************************

&REAC ID='CVM2', C=1., H=2., O=0.5, SOOT_YIELD=0.07, CO_YIELD=0.04
          HEAT_OF_COMBUSTION=20000. /
```

*******VM2 fire*********************************************************************

&SURF ID='BURNER', HRRPUA=500., RAMP_Q='framp'/ vm2 fast fire
&OBST XB=0.9,3.9, -23.4,-26.4, 43.5,43.8, SURF_IDS='BURNER', 'INERT', 'INERT'/ Fire location middle 3m x 3m

&RAMP ID='framp', T=0., F=0, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=30., F=0.00938, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=60., F=0.03752, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=90., F=0.08442, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=120., F=0.15008, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=150., F=0.2345, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=180., F=0.33768, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=210., F=0.45962, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=240., F=0.60032, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=270., F=0.75978, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=300., F=0.938, DEVC_ID='FREEZE TIME 1', DEVC_ID='FREEZE TIME 2', DEVC_ID='FREEZE TIME 3', DEVC_ID='FREEZE TIME 4'/
&RAMP ID='framp', T=330., F=1./

*********SPRINKLER AND SMOKE DETECTOR*********************************************************************

&PROP ID='QUICK RESP', QUANTITY='SPRINKLER LINK TEMPERATURE', RTI=50., C_FACTOR=0.65, ACTIVATION_TEMPERATURE=68. / VM2 SPRINKLER

&DEVC ID='SPRINKLER 1', XYZ=2.4, -29.65, 45.875, PROP_ID='QUICK RESP' / SPRINKLER LOCATION 3.25m radial distance
&DEVC ID='SPRINKLER 2', XYZ=2.4, -20.15, 45.875, PROP_ID='QUICK RESP' / SPRINKLER LOCATION
&DEVC ID='SPRINKLER 3', XYZ=-2.35, -24.9, 45.875, PROP_ID='QUICK RESP' / SPRINKLER LOCATION
&DEVC ID='SPRINKLER 4', XYZ=7.15, -24.9, 45.875, PROP_ID='QUICK RESP' / SPRINKLER LOCATION

&DEVC ID='FREEZE TIME 1', NO_UPDATE_DEVC_ID='SPRINKLER 1', QUANTITY='TIME', XYZ=0.0, -0.3, 45.875 /
&DEVC ID='FREEZE TIME 2', NO_UPDATE_DEVC_ID='SPRINKLER 2', QUANTITY='TIME', XYZ=0.0, -0.3, 45.875 /
&DEVC ID='FREEZE TIME 3', NO_UPDATE_DEVC_ID='SPRINKLER 3', QUANTITY='TIME', XYZ=0.0, -0.3, 45.875 /
&DEVC ID='FREEZE TIME 4', NO_UPDATE_DEVC_ID='SPRINKLER 4', QUANTITY='TIME', XYZ=0.0, -0.3, 45.875 /

&DEVC ID='SD1', QUANTITY='OPTICAL DENSITY', XYZ=2.4, -33.4, 45.875/ VM2 SMOKE DETECTOR
&DEVC ID='SD2', QUANTITY='OPTICAL DENSITY', XYZ=2.4, -16.4, 45.875/ VM2 SMOKE DETECTOR
&DEVC ID='SD3', QUANTITY='OPTICAL DENSITY', XYZ=-6.1, -24.9, 45.875/ VM2 SMOKE DETECTOR
&DEVC ID='SD4', QUANTITY='OPTICAL DENSITY', XYZ=10.9, -24.9, 45.875/ VM2 SMOKE DETECTOR

&DEVC ID='SD_5', PROP_ID='CLEARY', XYZ=2.4, -33.4, 45.875 /
&DEVC ID='SD_6', PROP_ID='CLEARY', XYZ=2.4, -16.4, 45.875 /

```
&DEVC ID='SD_7', PROP_ID='CLEARY', XYZ=-6.1, -24.9, 45.875 /
&DEVC ID='SD_8', PROP_ID='CLEARY', XYZ=10.9, -24.9, 45.875 /

&DEVC ID='SD_9', PROP_ID='HESKESTAD', XYZ=2.4, -33.4, 45.875 /
&DEVC ID='SD_10', PROP_ID='HESKESTAD', XYZ=2.4, -16.4, 45.875 /
&DEVC ID='SD_11', PROP_ID='HESKESTAD', XYZ=-6.1, -24.9, 45.875 /
&DEVC ID='SD_12', PROP_ID='HESKESTAD', XYZ=10.9, -24.9, 45.875 /

&PROP ID='CLEARY', QUANTITY='CHAMBER OBSCURATION',
        ALPHA_E=1.8, BETA_E=-1.1, ALPHA_C=1.0, BETA_C=-0.8,
        ACTIVATION_OBSCURATION=21.65 /

&PROP ID='HESKESTAD', QUANTITY='CHAMBER OBSCURATION', LENGTH=1.8,
        ACTIVATION_OBSCURATION=21.65 /

*****************************************************************************************************

&MISC EVACUATION_DRILL=.FALSE., SURF_DEFAULT='WALL', VISIBILITY_FACTOR=8.0,
RESTART=.FALSE./

&DUMP NFRAMES=3600., DT_DEVC=1.0, DT_HRR=1.0, DT_RESTART=30./

&SURF ID= 'EvacSurf', COLOR='NAVY', EVAC_DEFAULT=.TRUE. /

&MATL ID= 'CONCRETE'
   CONDUCTIVITY= 1.0
   SPECIFIC_HEAT= 0.88
   EMISSIVITY= 0.8
   DENSITY= 2200. /

&MATL ID='GIB'
   CONDUCTIVITY=0.2
   SPECIFIC_HEAT=0.9
   DENSITY=700./

&SURF ID='WALL'
  MATL_ID='GIB'
  TRANSPARENCY=1.0
  THICKNESS=0.015
  COLOR='PINK'/

&SURF ID='STAIRS'
  MATL_ID='CONCRETE'
  TRANSPARENCY=0.6
  THICKNESS=0.15
  COLOR='GRAY'/

&SURF ID='LANDING'
  MATL_ID='CONCRETE'
  TRANSPARENCY=0.7
  THICKNESS=0.15
  COLOR='GRAY'/

&SURF ID='FLOOR'
  MATL_ID='CONCRETE'
  THICKNESS=0.15
  COLOR='GRAY'/
```

******************STAIRS 1 GEO INCLUDING DOOR OPENING AND CLOSING****************************************

&OBST XB= -0.45, 6.45, -0.15,0.0, 43.2,52.8,  SURF_ID='WALL' / Wall between stairs 1 and 2 modelled floors
&OBST XB= -1.65, -0.45, -0.15,0.0, 50.1,52.8,  SURF_ID='WALL'/ Wall between stairs 1 and 2 modelled floors
&OBST XB= -1.65, -0.45, -0.15,0.0, 45.3,48.0,  SURF_ID='WALL'/ Wall between stairs 1 and 2 modelled floors
&OBST XB= -1.65, -1.05, -0.15,0.0, 48.0,50.1,  SURF_ID='WALL'/ Wall between stairs 1 and 2 modelled floors
&OBST XB= -1.65, -1.05, -0.15,0.0, 43.2,45.3,  SURF_ID='WALL'/ Wall between stairs 1 and 2 modelled floors

&OBST XB=-1.05,-0.45, -0.15,0.0, 48.0,50.1, CTRL_ID='Stair Door Remote', COLOR='BLUE' / Door 11th floor
&OBST XB=-1.05,-0.45, -0.15,0.0, 43.2,45.3, CTRL_ID='Stair Door Origin', COLOR='GREEN' / Door 10th floor

&OBST XB=-1.05,-0.45, -49.65,-49.80, 48.0,50.1, CTRL_ID='Stair Door Remote', COLOR='BLUE' / Door 11th floor
&OBST XB=-1.05,-0.45, -49.65,-49.80, 43.2,45.3, CTRL_ID='Stair Door Origin', COLOR='GREEN' / Door 10th floor

&HOLE XB=-1.05,-0.9, -49.35,-49.95, 48.0,48.15 / Door Leakage 11TH FLOOR
&HOLE XB=-1.05,-0.9, -49.35,-49.95, 43.2,43.35 / Door Leakage 10TH FLOOR

&HOLE XB=-1.05,-0.9, -0.45,0.15, 48.0,48.15 / Door Leakage 11TH FLOOR
&HOLE XB=-1.05,-0.9, -0.45,0.15, 43.2,43.35 / Door Leakage 10TH FLOOR

&DEVC ID='TIMER_ORIGIN', XYZ=0.0,1.2,45.6, QUANTITY='TIME'/
&CTRL ID='Stair Door Origin', FUNCTION_TYPE='CUSTOM', INPUT_ID='TIMER_ORIGIN', RAMP_ID='Open-Close_ORIGIN' /
&RAMP ID='Open-Close_ORIGIN', T= 0, F=-1 / Door Stair Opens
&RAMP ID='Open-Close_ORIGIN', T= 1, F=1 /Door Stair Close
&RAMP ID='Open-Close_ORIGIN', T= 263, F=1 / Door Stair still closed
&RAMP ID='Open-Close_ORIGIN', T= 264, F=-1 / Door Stair Opens
&RAMP ID='Open-Close_ORIGIN', T= 2418, F=-1 / Door Stair still Opened
&RAMP ID='Open-Close_ORIGIN', T= 2419, F=1 / Door Stair Close

&DEVC ID='TIMER_REMOTE', XYZ=0.0,-51.0,45.6, QUANTITY='TIME'/
&CTRL ID='Stair Door Remote', FUNCTION_TYPE='CUSTOM', INPUT_ID='TIMER_REMOTE', RAMP_ID='Open-Close_REMOTE' /
&RAMP ID='Open-Close_REMOTE', T= 0, F=-1 / Door Stair Opens
&RAMP ID='Open-Close_REMOTE', T= 1, F=1 /Door Stair Close
&RAMP ID='Open-Close_REMOTE', T= 293, F=1 / Door Stair still closed
&RAMP ID='Open-Close_REMOTE', T= 294, F=-1 / Door Stair Opens
&RAMP ID='Open-Close_REMOTE', T= 2451, F=-1 / Door Stair still Opened
&RAMP ID='Open-Close_REMOTE', T= 2452, F=1 / Door Stair Close

&OBST XB= -1.80,-1.65, -0.15,2.4, -0.3,96.0,  SURF_ID='WALL' / side wall (east and west) of the stairs
&OBST XB=  6.45, 6.60, -0.15,2.4, -0.3,96.0,  SURF_ID='WALL' / side wall (east and west) of the stairs
&OBST XB=  -1.80, 6.6, -0.15,0.0, 52.8,96.0,  SURF_ID='WALL' / south wall of the stairs 12th floor and up
&OBST XB=  -1.80, 6.6, -0.15,0.0, -0.3,43.2,  SURF_ID='WALL' / south wall of the stairs 9TH floor and down

******************STAIRS 2 GEO INCLUDING DOOR OPENING AND CLOSING****************************************

&OBST XB= -0.45, 6.45, -49.65,-49.80, 43.2,52.8,  SURF_ID='WALL' / Wall between stairs 2 and 2 modelled floors
&OBST XB= -1.65, -0.45, -49.65,-49.80, 50.1,52.8,  SURF_ID='WALL'/ Wall between stairs 2 and 2 modelled floors
&OBST XB= -1.65, -0.45, -49.65,-49.80, 45.3,48.0,  SURF_ID='WALL'/ Wall between stairs 2 and 2 modelled floors

```
&OBST XB= -1.65, -1.05, -49.65,-49.80, 48.0,50.1,  SURF_ID='WALL'/ Wall between stairs 2 and 2 modelled
floors
&OBST XB= -1.65, -1.05, -49.65,-49.80, 43.2,45.3,  SURF_ID='WALL'/ Wall between stairs 2 and 2 modelled
floors

&OBST XB= -1.80,-1.65, -49.65,-52.2, -0.3,96.0,  SURF_ID='WALL' / side wall (east and west) of the stairs
&OBST XB=  6.45, 6.60, -49.65,-52.2, -0.3,96.0,  SURF_ID='WALL' / side wall (east and west) of the stairs
&OBST XB=  -1.80, 6.6, -49.65,-49.80, 52.8,96.0,  SURF_ID='WALL' / north wall of the stairs 12th floor and up
&OBST XB=  -1.80, 6.6, -49.65,-49.80, -0.3,43.2,  SURF_ID='WALL' /north wall of the stairs 9TH floor and down
&OBST XB=  0.00, 4.80, -50.9,-51.1, -0.3,96.0,  SURF_ID='WALL' / scissor stairs divider
&OBST XB=  0.00, 0.15, -49.65,-50.9, 91.05,96.0,  SURF_ID='WALL' / scissor stairs divider
&OBST XB=  4.65, 4.80, -51.10,-52.2, 91.05,96.0,  SURF_ID='WALL' / scissor stairs divider

******************FLOOR GEO*********************************************************************

&OBST XB= -22.2, 27.3,  -0.15,-49.65, 42.9,43.2  SURF_ID='WALL' / FLOOR OF 10TH FLOOR
&OBST XB= -22.2, 27.3,  -0.15,-49.65, 48.0,47.7  SURF_ID='WALL' / FLOOR SEPARATION 10TH AND 11TH

&OBST XB= -22.2, 27.3,  -0.15,-49.65, 51.0,50.7  SURF_ID='WALL' / suspended ceiling 11th
&OBST XB= -22.2, 27.3,  -0.15,-49.65, 46.2,45.9  SURF_ID='WALL' / suspended ceiling 10th

***************STAIR 1 FDS GEOMETRY*****************************************************************

&MULT ID='Landing 1', DXB=0.00,0.00,0.00,0.00,4.8,4.8, N_LOWER=0, N_UPPER=19 / Landing Shift
&MULT ID='Landing 2', DXB=0.00,0.00,0.00,0.00,4.8,4.8, N_LOWER=0, N_UPPER=18 / Landing Shift

&OBST XB=-1.65,0.0, -0.15,4.8, -0.15,0.0, MULT_ID='Landing 1',SURF_ID='LANDING' /Landings Stair 1 at
doors
&OBST XB=4.8,6.45, -0.15,4.8, 2.25,2.4, MULT_ID='Landing 2',SURF_ID='LANDING' /Landings Stair 1
intermediate

&MULT ID='Stair 1', DXB=0.30,0.30, 0.00,0.00, 0.15,0.15, N_LOWER=0, N_UPPER=15 / Stair Shift +j & +k
&MULT ID='Stair 2', DXB=-0.30,-0.30, 0.00,0.00, 0.15,0.15, N_LOWER=0, N_UPPER=15 / Stair Shift +j & +k

&OBST XB=0.0,0.3, 0.0,1.2, 0.0,0.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 1-2
&OBST XB=4.8,4.5, 1.2,2.4, 2.4,2.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 1-2
&OBST XB=0.0,0.3, 0.0,1.2, 4.8,4.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 2-3
&OBST XB=4.8,4.5, 1.2,2.4, 7.2,7.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 2-3
&OBST XB=0.0,0.3, 0.0,1.2, 9.6,9.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 3-4
&OBST XB=4.8,4.5, 1.2,2.4, 12.0,12.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 3-4
&OBST XB=0.0,0.3, 0.0,1.2, 14.4,14.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 4-5
&OBST XB=4.8,4.5, 1.2,2.4, 16.8,16.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 4-5
&OBST XB=0.0,0.3, 0.0,1.2, 19.2,19.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 5-6
&OBST XB=4.8,4.5, 1.2,2.4, 21.6,21.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 5-6
&OBST XB=0.0,0.3, 0.0,1.2, 24.0,24.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 6-7
&OBST XB=4.8,4.5, 1.2,2.4, 26.4,26.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 6-7
&OBST XB=0.0,0.3, 0.0,1.2, 28.8,28.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 7-8
&OBST XB=4.8,4.5, 1.2,2.4, 31.2,31.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 7-8
&OBST XB=0.0,0.3, 0.0,1.2, 33.6,33.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 8-9
&OBST XB=4.8,4.5, 1.2,2.4, 36.0,36.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 8-9
&OBST XB=0.0,0.3, 0.0,1.2, 38.4,38.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 9-10
&OBST XB=4.8,4.5, 1.2,2.4, 40.8,40.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 9-10
&OBST XB=0.0,0.3, 0.0,1.2, 43.2,43.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 10-11
&OBST XB=4.8,4.5, 1.2,2.4, 45.6,45.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 10-11
&OBST XB=0.0,0.3, 0.0,1.2, 48.0,48.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 11-12
&OBST XB=4.8,4.5, 1.2,2.4, 50.4,50.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 11-12
&OBST XB=0.0,0.3, 0.0,1.2, 52.8,52.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 12-13
&OBST XB=4.8,4.5, 1.2,2.4, 55.2,55.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 12-13
```

```
&OBST XB=0.0,0.3, 0.0,1.2, 57.6,57.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 13-14
&OBST XB=4.8,4.5, 1.2,2.4, 60.0,60.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 13-14
&OBST XB=0.0,0.3, 0.0,1.2, 62.4,62.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 14-15
&OBST XB=4.8,4.5, 1.2,2.4, 64.8,64.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 14-15
&OBST XB=0.0,0.3, 0.0,1.2, 67.2,67.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 15-16
&OBST XB=4.8,4.5, 1.2,2.4, 69.6,69.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 15-16
&OBST XB=0.0,0.3, 0.0,1.2, 72.0,72.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 16-17
&OBST XB=4.8,4.5, 1.2,2.4, 74.4,74.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 16-17
&OBST XB=0.0,0.3, 0.0,1.2, 76.8,76.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 17-18
&OBST XB=4.8,4.5, 1.2,2.4, 79.2,79.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 17-18
&OBST XB=0.0,0.3, 0.0,1.2, 81.6,81.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 18-19
&OBST XB=4.8,4.5, 1.2,2.4, 84.0,84.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 18-19
&OBST XB=0.0,0.3, 0.0,1.2, 86.4,86.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 19-20
&OBST XB=4.8,4.5, 1.2,2.4, 88.8,88.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 19-20
```

***************STAIR 2 FDS GEOMETRY*************************************************************

SCISSOR STAIR 1

&OBST XB=-1.65,0.0, -49.65,-52.20, -0.15,0.0, MULT_ID='Landing 1',SURF_ID='LANDING' /Landings Stair 2_1 at doors
&OBST XB=4.8,6.45, -49.65,-52.20, 2.25,2.4, MULT_ID='Landing 2',SURF_ID='LANDING' /Landings Stair 2_1 intermediate

SCISSOR STAIR 2

&OBST XB=4.8,6.45, -49.65,-52.20, -0.15,0.0, MULT_ID='Landing 1',SURF_ID='LANDING' /Landings Stair 2_2 at doors
&OBST XB=-1.65,0.0, -49.65,-52.20, 2.25,2.4, MULT_ID='Landing 2',SURF_ID='LANDING' /Landings Stair 2_2 intermediate

SCISSOR STAIR 1

```
&OBST XB=0.0,0.3, -49.80,-51.00, 0.0,0.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 1-2
&OBST XB=4.8,4.5, -51.00,-52.20, 2.4,2.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 1-2
&OBST XB=0.0,0.3, -49.80,-51.00, 4.8,4.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 2-3
&OBST XB=4.8,4.5, -51.00,-52.20, 7.2,7.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 2-3
&OBST XB=0.0,0.3, -49.80,-51.00, 9.6,9.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 3-4
&OBST XB=4.8,4.5, -51.00,-52.20, 12.0,12.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 3-4
&OBST XB=0.0,0.3, -49.80,-51.00, 14.4,14.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 4-5
&OBST XB=4.8,4.5, -51.00,-52.20, 16.8,16.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 4-5
&OBST XB=0.0,0.3, -49.80,-51.00, 19.2,19.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 5-6
&OBST XB=4.8,4.5, -51.00,-52.20, 21.6,21.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 5-6
&OBST XB=0.0,0.3, -49.80,-51.00, 24.0,24.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 6-7
&OBST XB=4.8,4.5, -51.00,-52.20, 26.4,26.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 6-7
&OBST XB=0.0,0.3, -49.80,-51.00, 28.8,28.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 7-8
&OBST XB=4.8,4.5, -51.00,-52.20, 31.2,31.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 7-8
&OBST XB=0.0,0.3, -49.80,-51.00, 33.6,33.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 8-9
&OBST XB=4.8,4.5, -51.00,-52.20, 36.0,36.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 8-9
&OBST XB=0.0,0.3, -49.80,-51.00, 38.4,38.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 9-10
&OBST XB=4.8,4.5, -51.00,-52.20, 40.8,40.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 9-10
&OBST XB=0.0,0.3, -49.80,-51.00, 43.2,43.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 10-11
&OBST XB=4.8,4.5, -51.00,-52.20, 45.6,45.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 10-11
&OBST XB=0.0,0.3, -49.80,-51.00, 48.0,48.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 11-12
&OBST XB=4.8,4.5, -51.00,-52.20, 50.4,50.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 11-12
&OBST XB=0.0,0.3, -49.80,-51.00, 52.8,52.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 12-13
&OBST XB=4.8,4.5, -51.00,-52.20, 55.2,55.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 12-13
&OBST XB=0.0,0.3, -49.80,-51.00, 57.6,57.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 13-14
```

```
&OBST XB=4.8,4.5, -51.00,-52.20, 60.0,60.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 13-14
&OBST XB=0.0,0.3, -49.80,-51.00, 62.4,62.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 14-15
&OBST XB=4.8,4.5, -51.00,-52.20, 64.8,64.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 14-15
&OBST XB=0.0,0.3, -49.80,-51.00, 67.2,67.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 15-16
&OBST XB=4.8,4.5, -51.00,-52.20, 69.6,69.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 15-16
&OBST XB=0.0,0.3, -49.80,-51.00, 72.0,72.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 16-17
&OBST XB=4.8,4.5, -51.00,-52.20, 74.4,74.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 16-17
&OBST XB=0.0,0.3, -49.80,-51.00, 76.8,76.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 17-18
&OBST XB=4.8,4.5, -51.00,-52.20, 79.2,79.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 17-18
&OBST XB=0.0,0.3, -49.80,-51.00, 81.6,81.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 18-19
&OBST XB=4.8,4.5, -51.00,-52.20, 84.0,84.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 18-19
&OBST XB=0.0,0.3, -49.80,-51.00, 86.4,86.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 19-20
&OBST XB=4.8,4.5, -51.00,-52.20, 88.8,88.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 19-20
```

SCISSOR STAIR 2

```
&OBST XB=0.0,0.3, -49.80,-51.00, 2.4,2.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 1-2
&OBST XB=4.8,4.5, -51.00,-52.20, 0.0,0.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 1-2
&OBST XB=0.0,0.3, -49.80,-51.00, 7.2,7.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 2-3
&OBST XB=4.8,4.5, -51.00,-52.20, 4.8,4.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 2-3
&OBST XB=0.0,0.3, -49.80,-51.00, 12.0,12.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 3-4
&OBST XB=4.8,4.5, -51.00,-52.20, 9.6,9.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 3-4
&OBST XB=0.0,0.3, -49.80,-51.00, 16.8,16.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 4-5
&OBST XB=4.8,4.5, -51.00,-52.20, 14.4,14.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 4-5
&OBST XB=0.0,0.3, -49.80,-51.00, 21.6,21.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 5-6
&OBST XB=4.8,4.5, -51.00,-52.20, 19.2,19.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 5-6
&OBST XB=0.0,0.3, -49.80,-51.00, 26.4,26.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 6-7
&OBST XB=4.8,4.5, -51.00,-52.20, 24.0,24.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 6-7
&OBST XB=0.0,0.3, -49.80,-51.00, 31.2,31.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 7-8
&OBST XB=4.8,4.5, -51.00,-52.20, 28.8,28.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 7-8
&OBST XB=0.0,0.3, -49.80,-51.00, 36.0,36.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 8-9
&OBST XB=4.8,4.5, -51.00,-52.20, 33.6,33.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 8-9
&OBST XB=0.0,0.3, -49.80,-51.00, 40.8,40.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 9-10
&OBST XB=4.8,4.5, -51.00,-52.20, 38.4,38.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 9-10
&OBST XB=0.0,0.3, -49.80,-51.00, 45.6,45.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 10-11
&OBST XB=4.8,4.5, -51.00,-52.20, 43.2,43.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 10-11
&OBST XB=0.0,0.3, -49.80,-51.00, 50.4,50.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 11-12
&OBST XB=4.8,4.5, -51.00,-52.20, 48.0,48.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 11-12
&OBST XB=0.0,0.3, -49.80,-51.00, 55.2,55.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 12-13
&OBST XB=4.8,4.5, -51.00,-52.20, 52.8,52.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 12-13
&OBST XB=0.0,0.3, -49.80,-51.00, 60.0,60.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 13-14
&OBST XB=4.8,4.5, -51.00,-52.20, 57.6,57.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 13-14
&OBST XB=0.0,0.3, -49.80,-51.00, 64.8,64.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 14-15
&OBST XB=4.8,4.5, -51.00,-52.20, 62.4,62.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 14-15
&OBST XB=0.0,0.3, -49.80,-51.00, 69.6,69.75, MULT_ID='Stair 1',SURF_ID='STAIRS' / 15-16
&OBST XB=4.8,4.5, -51.00,-52.20, 67.2,67.35, MULT_ID='Stair 2',SURF_ID='STAIRS' / 15-16
&OBST XB=0.0,0.3, -49.80,-51.00, 74.4,74.55, MULT_ID='Stair 1',SURF_ID='STAIRS' / 16-17
&OBST XB=4.8,4.5, -51.00,-52.20, 72.0,72.15, MULT_ID='Stair 2',SURF_ID='STAIRS' / 16-17
&OBST XB=0.0,0.3, -49.80,-51.00, 79.2,79.35, MULT_ID='Stair 1',SURF_ID='STAIRS' / 17-18
&OBST XB=4.8,4.5, -51.00,-52.20, 76.8,76.95, MULT_ID='Stair 2',SURF_ID='STAIRS' / 17-18
&OBST XB=0.0,0.3, -49.80,-51.00, 84.0,84.15, MULT_ID='Stair 1',SURF_ID='STAIRS' / 18-19
&OBST XB=4.8,4.5, -51.00,-52.20, 81.6,81.75, MULT_ID='Stair 2',SURF_ID='STAIRS' / 18-19
&OBST XB=0.0,0.3, -49.80,-51.00, 88.8,88.95, MULT_ID='Stair 1',SURF_ID='STAIRS' / 19-20
&OBST XB=4.8,4.5, -51.00,-52.20, 86.4,86.55, MULT_ID='Stair 2',SURF_ID='STAIRS' / 19-20
```

***************Evacuation Meshes*******************************************************************
dx=dy=0.1 m

```
&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 5.7,5.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_2F', EVAC_Z_OFFSET=1.0 / mesh for 2ND
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 10.5,10.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_3F', EVAC_Z_OFFSET=1.0 / mesh for 3RD
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 15.3,15.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_4F', EVAC_Z_OFFSET=1.0 / mesh for 4th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 20.1,20.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_5F', EVAC_Z_OFFSET=1.0 / mesh for 5th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 24.9,25.1,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_6F', EVAC_Z_OFFSET=1.0 / mesh for 6th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 29.7,29.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_7F', EVAC_Z_OFFSET=1.0 / mesh for 7th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 34.5,34.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_8F', EVAC_Z_OFFSET=1.0 / mesh for 8th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 39.3,39.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_9F', EVAC_Z_OFFSET=1.0 / mesh for 9th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 44.1,44.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_10F', EVAC_Z_OFFSET=1.0 / mesh for 10th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 48.9,49.1,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_11F', EVAC_Z_OFFSET=1.0 / mesh for 11th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 53.7,53.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_12F', EVAC_Z_OFFSET=1.0 / mesh for 12th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 58.5,58.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_13F', EVAC_Z_OFFSET=1.0 / mesh for 13th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 63.3,63.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_14F', EVAC_Z_OFFSET=1.0 / mesh for 14th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 68.1,68.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_15F', EVAC_Z_OFFSET=1.0 / mesh for 15th
floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 72.9,73.1,
```

```
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_16F', EVAC_Z_OFFSET=1.0 / mesh for 16th floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 77.7,77.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_17F', EVAC_Z_OFFSET=1.0 / mesh for 17th floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 82.5,82.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_18F', EVAC_Z_OFFSET=1.0 / mesh for 18th floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 87.3,87.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_19F', EVAC_Z_OFFSET=1.0 / mesh for 19th floor

&MESH IJK=495,495,1, XB=-22.2,27.3, -0.15,-49.65, 92.1,92.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_20F', EVAC_Z_OFFSET=1.0 / mesh for 20th floor

***************Stair 1 mesh*********************************************************************

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  0.9, 1.1,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_1', EVAC_Z_OFFSET=1.0 / Evac mesh for ground/first floor

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  5.7,5.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_2', EVAC_Z_OFFSET=1.0 / Evac mesh for second floor

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  10.5, 10.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_3', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  15.3, 15.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_4', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  20.1, 20.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_5', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  24.9, 25.1,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_6', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  29.7, 29.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_7', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  34.5, 34.7,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_8', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  39.3,39.5,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_9', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  44.1,44.3,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_10', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  48.9,49.1,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_11', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  53.7, 53.9,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_12', EVAC_Z_OFFSET=1.0 / ....
```

```
&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  58.5, 58.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_13', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  63.3, 63.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_14', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  68.1, 68.3,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_15', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  72.9, 73.1,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_16', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  77.7, 77.9,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_17', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  82.5, 82.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_18', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  87.3, 87.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_19', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -0.10,2.50,  92.1, 92.3,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_20', EVAC_Z_OFFSET=1.0 / Evac mesh for
20th floor

*******Stairs 2 mesh*******************************************************************************

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  0.9, 1.1,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_1a', EVAC_Z_OFFSET=1.0 / Evac mesh for
ground/first floor

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  5.7,5.9,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_2a', EVAC_Z_OFFSET=1.0 / Evac mesh for
second floor

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  10.5, 10.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_3a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  15.3, 15.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_4a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  20.1, 20.3,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_5a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  24.9, 25.1,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_6a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  29.7, 29.9,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_7a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  34.5, 34.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_8a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  39.3,39.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_9a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  44.1,44.3,
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     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_10a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  48.9,49.1,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_11a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  53.7, 53.9,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_12a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  58.5, 58.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_13a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  63.3, 63.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_14a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  68.1, 68.3,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_15a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  72.9, 73.1,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_16a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  77.7, 77.9,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_17a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  82.5, 82.7,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_18a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  87.3, 87.5,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_19a', EVAC_Z_OFFSET=1.0 / ....

&MESH IJK=83,26,1, XB=-1.75,6.55, -49.7,-52.3,  92.1, 92.3,
     EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='EMesh_20a', EVAC_Z_OFFSET=1.0 / Evac mesh for
20th floor
************Stair 1 evss***************************************************

&EVSS XB=0.05,4.85, 0.0,1.1, 0.9, 1.1, IOR=-1, ID='Stair_1A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_1'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 0.9, 1.1, IOR=+1, ID='Stair_1B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_1'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 0.9, 1.1, IOR=+1, ID='Landing_1_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_1'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 0.8, 1.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 0.8, 1.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 0.8, 1.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 5.7,5.9, IOR=-1, ID='Stair_2A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_2'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 5.7,5.9, IOR=+1, ID='Stair_2B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_2'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 5.7,5.9, IOR=+1, ID='Landing_2_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_2'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 5.6,6.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 5.6,6.0, EVACUATION=.TRUE. /
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&HOLE XB=4.85,6.45, 0.0,2.4, 5.6,6.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 10.5,10.7, IOR=-1, ID='Stair_3A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_3'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 10.5,10.7, IOR=+1, ID='Stair_3B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_3'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 10.5,10.7, IOR=+1, ID='Landing_3_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_3'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 10.4,10.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 10.4,10.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 10.4,10.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 15.3, 15.5, IOR=-1, ID='Stair_4A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_4'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 15.3, 15.5, IOR=+1, ID='Stair_4B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_4'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 15.3, 15.5, IOR=+1, ID='Landing_4_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_4'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 15.2, 15.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 15.2, 15.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 15.2, 15.6, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 20.1, 20.3, IOR=-1, ID='Stair_5A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_5'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 20.1, 20.3, IOR=+1, ID='Stair_5B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_5'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 20.1, 20.3, IOR=+1, ID='Landing_5_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_5'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 20.0, 20.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 20.0, 20.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 20.0, 20.4, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 24.9, 25.1, IOR=-1, ID='Stair_6A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_6'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 24.9, 25.1, IOR=+1, ID='Stair_6B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_6'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 24.9, 25.1, IOR=+1, ID='Landing_6_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_6'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 24.8, 25.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 24.8, 25.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 24.8, 25.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 29.7, 29.9, IOR=-1, ID='Stair_7A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_7'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 29.7, 29.9, IOR=+1, ID='Stair_7B_1',
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     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_7'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 29.7, 29.9, IOR=+1, ID='Landing_7_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_7'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 29.6, 30.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 29.6, 30.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 29.6, 30.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 34.5, 34.7, IOR=-1, ID='Stair_8A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_8'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 34.5, 34.7, IOR=+1, ID='Stair_8B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_8'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 34.5, 34.7, IOR=+1, ID='Landing_8_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_8'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 34.4, 34.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 34.4, 34.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 34.4, 34.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 39.3, 39.5, IOR=-1, ID='Stair_9A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_9'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 39.3, 39.5, IOR=+1, ID='Stair_9B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_9'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 39.3, 39.5, IOR=+1, ID='Landing_9_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_9'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 39.2, 39.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 39.2, 39.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 39.2, 39.6, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 44.1, 44.3, IOR=-1, ID='Stair_10A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_10'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 44.1, 44.3, IOR=+1, ID='Stair_10B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_10'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 44.1, 44.3, IOR=+1, ID='Landing_10_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_10'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 44.0, 44.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 44.0, 44.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.65, 0.0,2.4, 44.0, 44.4, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 48.9, 49.1, IOR=-1, ID='Stair_11A_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_11'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 48.9, 49.1, IOR=+1, ID='Stair_11B_1',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_11'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 48.9, 49.1, IOR=+1, ID='Landing_11_1',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_11'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 48.8, 49.2, EVACUATION=.TRUE. /
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&HOLE XB=0.05,4.85, 1.3,2.4, 48.8, 49.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 48.8, 49.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 53.7, 53.9, IOR=-1, ID='Stair_12A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_12'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 53.7, 53.9, IOR=+1, ID='Stair_12B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_12'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 53.7, 53.9, IOR=+1, ID='Landing_12_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_12'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 53.6, 54.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 53.6, 54.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 53.6, 54.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 58.5, 58.7, IOR=-1, ID='Stair_13A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_13'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 58.5, 58.7, IOR=+1, ID='Stair_13B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_13'  /
&EVSS XB=4.85,6.4, 0.0,2.4, 58.5, 58.7, IOR=+1, ID='Landing_13_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_13'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 58.4, 58.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 58.4, 58.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 58.4, 58.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 63.3, 63.5, IOR=-1, ID='Stair_14A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_14'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 63.3, 63.5, IOR=+1, ID='Stair_14B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_14'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 63.3, 63.5, IOR=+1, ID='Landing_14_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_14'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 63.2, 63.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 63.2, 63.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 63.2, 63.6, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 68.1, 68.3, IOR=-1, ID='Stair_15A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_15'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 68.1, 68.3, IOR=+1, ID='Stair_15B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_15'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 68.1, 68.3, IOR=+1, ID='Landing_15_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_15'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 68.0, 68.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 68.0, 68.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 68.0, 68.4, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 72.9, 73.1, IOR=-1, ID='Stair_16A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_16'  /
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&EVSS XB=0.05,4.85, 1.3,2.4, 72.9, 73.1, IOR=+1, ID='Stair_16B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_16'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 72.9, 73.1, IOR=+1, ID='Landing_16_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_16'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 72.8, 73.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 72.8, 73.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 72.8, 73.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 77.7, 77.9, IOR=-1, ID='Stair_17A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_17'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 77.7, 77.9, IOR=+1, ID='Stair_17B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_17'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 77.7, 77.9, IOR=+1, ID='Landing_17_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_17'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 77.6, 78.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 77.6, 78.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 77.6, 78.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 82.5, 82.7, IOR=-1, ID='Stair_18A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_18'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 82.5, 82.7, IOR=+1, ID='Stair_18B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_18'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 82.5, 82.7, IOR=+1, ID='Landing_18_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_18'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 82.4, 82.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 82.4, 82.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 82.4, 82.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, 0.0,1.1, 87.3, 87.5, IOR=-1, ID='Stair_19A_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_19'  /
&EVSS XB=0.05,4.85, 1.3,2.4, 87.3, 87.5, IOR=+1, ID='Stair_19B_1',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_19'  /
&EVSS XB=4.85,6.45, 0.0,2.4, 87.3, 87.5, IOR=+1, ID='Landing_19_1',
    FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_19'  /
&HOLE XB=0.05,4.85, 0.0,1.1, 87.2, 87.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, 1.3,2.4, 87.2, 87.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, 0.0,2.4, 87.2, 87.6, EVACUATION=.TRUE. /

*****************Stairs 2 evss*****************************************

&EVSS XB=0.05,4.85, -49.8,-50.9, 0.9, 1.1, IOR=-1, ID='Stair_1A_2',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_1a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 0.9, 1.1, IOR=+1, ID='Stair_1B_2',
    FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
    HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_1a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 0.9, 1.1, IOR=+1, ID='Landing_1_2',
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      FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_1a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 0.8, 1.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 0.8, 1.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 0.8, 1.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 5.7,5.9, IOR=-1, ID='Stair_2A_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_2a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 5.7,5.9, IOR=+1, ID='Stair_2B_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_2a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 5.7,5.9, IOR=+1, ID='Landing_2_2',
      FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_2a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 5.6,6.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 5.6,6.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 5.6,6.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 10.5,10.7, IOR=-1, ID='Stair_3A_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_3a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 10.5,10.7, IOR=+1, ID='Stair_3B_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_3a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 10.5,10.7, IOR=+1, ID='Landing_3_2',
      FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_3a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 10.4,10.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 10.4,10.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 10.4,10.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 15.3, 15.5, IOR=-1, ID='Stair_4A_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_4a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 15.3, 15.5, IOR=+1, ID='Stair_4B_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_4a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 15.3, 15.5, IOR=+1, ID='Landing_4_2',
      FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_4a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 15.2, 15.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 15.2, 15.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 15.2, 15.6, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 20.1, 20.3, IOR=-1, ID='Stair_5A_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_5a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 20.1, 20.3, IOR=+1, ID='Stair_5B_2',
      FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
      HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_5a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 20.1, 20.3, IOR=+1, ID='Landing_5_2',
      FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
      HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_5a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 20.0, 20.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 20.0, 20.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 20.0, 20.4, EVACUATION=.TRUE. /
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&EVSS XB=0.05,4.85, -49.8,-50.9, 24.9, 25.1, IOR=-1, ID='Stair_6A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_6a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 24.9, 25.1, IOR=+1, ID='Stair_6B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_6a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 24.9, 25.1, IOR=+1, ID='Landing_6_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_6a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 24.8, 25.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 24.8, 25.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 24.8, 25.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 29.7, 29.9, IOR=-1, ID='Stair_7A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_7a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 29.7, 29.9, IOR=+1, ID='Stair_7B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_7a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 29.7, 29.9, IOR=+1, ID='Landing_7_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_7a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 29.6, 30.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 29.6, 30.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 29.6, 30.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 34.5, 34.7, IOR=-1, ID='Stair_8A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_8a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 34.5, 34.7, IOR=+1, ID='Stair_8B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_8a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 34.5, 34.7, IOR=+1, ID='Landing_8_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_8a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 34.4, 34.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 34.4, 34.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 34.4, 34.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 39.3, 39.5, IOR=-1, ID='Stair_9A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_9a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 39.3, 39.5, IOR=+1, ID='Stair_9B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_9a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 39.3, 39.5, IOR=+1, ID='Landing_9_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_9a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 39.2, 39.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 39.2, 39.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 39.2, 39.6, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 44.1, 44.3, IOR=-1, ID='Stair_10A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_10a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 44.1, 44.3, IOR=+1, ID='Stair_10B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_10a'  /
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&EVSS XB=4.85,6.45, -49.8,-52.2, 44.1, 44.3, IOR=+1, ID='Landing_10_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_10a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 44.0, 44.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 44.0, 44.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 44.0, 44.4, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 48.9, 49.1, IOR=-1, ID='Stair_11A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_11a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 48.9, 49.1, IOR=+1, ID='Stair_11B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_11a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 48.9, 49.1, IOR=+1, ID='Landing_11_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_11a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 48.8, 49.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 48.8, 49.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 48.8, 49.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 53.7, 53.9, IOR=-1, ID='Stair_12A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_12a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 53.7, 53.9, IOR=+1, ID='Stair_12B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_12a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 53.7, 53.9, IOR=+1, ID='Landing_12_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_12a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 53.6, 54.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 53.6, 54.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 53.6, 54.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 58.5, 58.7, IOR=-1, ID='Stair_13A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_13a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 58.5, 58.7, IOR=+1, ID='Stair_13B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_13a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 58.5, 58.7, IOR=+1, ID='Landing_13_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_13a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 58.4, 58.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 58.4, 58.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 58.4, 58.8, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 63.3, 63.5, IOR=-1, ID='Stair_14A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_14a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 63.3, 63.5, IOR=+1, ID='Stair_14B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_14a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 63.3, 63.5, IOR=+1, ID='Landing_14_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_14a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 63.2, 63.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 63.2, 63.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 63.2, 63.6, EVACUATION=.TRUE. /
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&EVSS XB=0.05,4.85, -49.8,-50.9, 68.1, 68.3, IOR=-1, ID='Stair_15A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_15a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 68.1, 68.3, IOR=+1, ID='Stair_15B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_15a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 68.1, 68.3, IOR=+1, ID='Landing_15_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_15a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 68.0, 68.4, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 68.0, 68.4, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 68.0, 68.4, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 72.9, 73.1, IOR=-1, ID='Stair_16A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_16a'  /
&EVSS XB=0.05,4.8, -51.1,-52.2, 72.9, 73.1, IOR=+1, ID='Stair_16B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_16a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 72.9, 73.1, IOR=+1, ID='Landing_16_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_16a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 72.8, 73.2, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 72.8, 73.2, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 72.8, 73.2, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 77.7, 77.9, IOR=-1, ID='Stair_17A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_17a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 77.7, 77.9, IOR=+1, ID='Stair_17B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_17a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 77.7, 77.9, IOR=+1, ID='Landing_17_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_17a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 77.6, 78.0, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 77.6, 78.0, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 77.6, 78.0, EVACUATION=.TRUE. /

&EVSS XB=0.05,4.85, -49.8,-50.9, 82.5, 82.7, IOR=-1, ID='Stair_18A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_18a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 82.5, 82.7, IOR=+1, ID='Stair_18B_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_18a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 82.5, 82.7, IOR=+1, ID='Landing_18_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_18a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 82.4, 82.8, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 82.4, 82.8, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 82.4, 82.8, EVACUATION=.TRUE. /


&EVSS XB=0.05,4.85, -49.8,-50.9, 87.3, 87.5, IOR=-1, ID='Stair_19A_2',
     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=0.0, MESH_ID='EMesh_19a'  /
&EVSS XB=0.05,4.85, -51.1,-52.2, 87.3, 87.5, IOR=+1, ID='Stair_19B_2',
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     FAC_V0_UP=0.875, FAC_V0_DOWN=0.875, FAC_V0_HORI=1.0,
     HEIGHT=4.8, HEIGHT0=2.4, MESH_ID='EMesh_19a'  /
&EVSS XB=4.85,6.45, -49.8,-52.2, 87.3, 87.5, IOR=+1, ID='Landing_19_2',
     FAC_V0_UP=1.0, FAC_V0_DOWN=1.0, FAC_V0_HORI=1.0,
     HEIGHT=2.4, HEIGHT0=2.4, MESH_ID='EMesh_19a'  /
&HOLE XB=0.05,4.85, -49.8,-50.9, 87.2, 87.6, EVACUATION=.TRUE. /
&HOLE XB=0.05,4.85, -51.1,-52.2, 87.2, 87.6, EVACUATION=.TRUE. /
&HOLE XB=4.85,6.45, -49.8,-52.2, 87.2, 87.6, EVACUATION=.TRUE. /

*************************************************************************

 Evacuation OBST (agents are forced to move inside the stairs)
 Note: The fire geometry does not have walls, because the fire
 mesh boundary is at the "inside walls".

******************EVAC GEO STAIRS 1******************************************

&OBST XB= -1.75, 6.55, -0.1,0.0, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB= -1.75, 6.55,  2.4,2.5, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB= -1.75,-1.65, -0.1,2.5, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB=  6.45, 6.55, -0.1,2.5, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB=  0.05, 4.85,  1.1,1.3, 0.0,96.0, EVACUATION=.TRUE., /

******************EVAC GEO STAIRS 2******************************************

&OBST XB= -1.75, 6.55, -49.70,-49.80, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB= -1.75, 6.55, -52.2,-52.3, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB= -1.75,-1.65, -49.70,-52.3, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB=  6.45, 6.55, -49.70,-52.3, 0.0,96.0, EVACUATION=.TRUE., /
&OBST XB=  0.05, 4.85, -50.9,-51.1, 0.0,96.0, EVACUATION=.TRUE., /

**********Stair 1****************************

&EXIT ID='Door_out_1', IOR=+2,
     COUNT_ONLY=.FALSE.,
     XB=-1.45, -0.45,   2.4,2.4,   0.9, 1.1, /
&DOOR ID='Door_in_1', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_2'
     XYZ=  0.2, 1.8,  1.0,
     XB=0.05, 0.05,   1.3,2.4,   0.9, 1.1, /

&DOOR ID='Door_out_2', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_1'
     XYZ= -0.2, 1.8, 5.8,
     XB=-0.05, -0.05,   1.3,2.4,   5.7, 5.9, /
&DOOR ID='Door_in_2', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_3'
     XYZ=  0.2, 1.8,  5.8,
     XB=0.05, 0.05,   1.3,2.4,   5.7, 5.9, /

&DOOR ID='Door_out_3', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_2'
     XYZ= -0.2, 1.8, 10.6,
     XB=-0.05, -0.05,   1.3,2.4,   10.5, 10.7, /
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&DOOR ID='Door_in_3', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_4'
     XYZ=  0.2, 1.8,  10.6,
     XB=0.05, 0.05,   1.3,2.4,   10.5, 10.7, /

&DOOR ID='Door_out_4', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_3'
     XYZ= -0.2, 1.8, 15.4,
     XB=-0.05, -0.05,   1.3,2.4,   15.3,15.5, /
&DOOR ID='Door_in_4', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_5'
     XYZ=  0.2, 1.8, 15.4,
     XB=0.05, 0.05,   1.3,2.4,   15.3,15.5, /

&DOOR ID='Door_out_5', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_4'
     XYZ= -0.2, 1.8, 20.2,
     XB=-0.05, -0.05,   1.3,2.4,   20.1,20.3, /
&DOOR ID='Door_in_5', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_6'
     XYZ=  0.2, 1.8, 20.2,
     XB=0.05, 0.05,   1.3,2.4,   20.1,20.3, /

&DOOR ID='Door_out_6', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_5'
     XYZ= -0.2, 1.8, 25.0,
     XB=-0.05, -0.05,   1.3,2.4,   24.9,25.1, /
&DOOR ID='Door_in_6', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_7'
     XYZ=  0.2, 1.8, 25.0,
     XB=0.05, 0.05,   1.3,2.4,   24.9,25.1, /

&DOOR ID='Door_out_7', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_6'
     XYZ= -0.2, 1.8, 29.8,
     XB=-0.05, -0.05,   1.3,2.4,   29.7,29.9, /
&DOOR ID='Door_in_7', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_8'
     XYZ=  0.2, 1.8, 29.8,
     XB=0.05, 0.05,   1.3,2.4,   29.7,29.9, /

&DOOR ID='Door_out_8', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_7'
     XYZ= -0.2, 1.8, 34.6,
     XB=-0.05, -0.05,   1.3,2.4,   34.5,34.7, /
&DOOR ID='Door_in_8', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_9'
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     XYZ=  0.2, 1.8, 34.6,
     XB=0.05, 0.05,   1.3,2.4,   34.5,34.7, /

&DOOR ID='Door_out_9', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_8'
     XYZ= -0.2, 1.80, 39.4,
     XB=-0.05, -0.05,   1.3,2.4,   39.3,39.5, /
&DOOR ID='Door_in_9', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_10'
     XYZ=  0.2, 1.80, 39.4,
     XB=0.05, 0.05,   1.3,2.4,   39.3,39.5, /

&DOOR ID='Door_out_10', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_9'
     XYZ= -0.2, 1.80, 44.2,
     XB=-0.05, -0.05,   1.3,2.4,   44.1,44.3, /
&DOOR ID='Door_in_10', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_11'
     XYZ=  0.2, 1.80, 44.2,
     XB=0.05, 0.05,   1.3,2.4,   44.1,44.3, /

&DOOR ID='Door_out_11', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_10'
     XYZ= -0.2, 1.80, 49.0,
     XB=-0.05, -0.05,   1.3,2.4,   48.9,49.1, /
&DOOR ID='Door_in_11', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_12'
     XYZ=  0.2, 1.80, 49.0,
     XB=0.05, 0.05,   1.3,2.4,   48.9,49.1, /

&DOOR ID='Door_out_12', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_11'
     XYZ= -0.2, 1.80, 53.8,
     XB=-0.05, -0.05,   1.3,2.4,   53.7,53.9, /
&DOOR ID='Door_in_12', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_13'
     XYZ=  0.2, 1.80, 53.8,
     XB=0.05, 0.05,   1.3,2.4,   53.7,53.9, /

&DOOR ID='Door_out_13', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_12'
     XYZ= -0.2, 1.80, 58.6,
     XB=-0.05, -0.05,   1.3,2.4,   58.5,58.7, /
&DOOR ID='Door_in_13', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_14'
     XYZ=  0.2, 1.80, 58.6,
     XB=0.05, 0.05,   1.3,2.4,   58.5,58.7, /
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&DOOR ID='Door_out_14', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_13'
     XYZ= -0.2, 1.80, 63.4,
     XB=-0.05, -0.05,   1.3,2.4,   63.3,63.5, /
&DOOR ID='Door_in_14', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_15'
     XYZ=  0.2, 1.80, 63.4,
     XB=0.05, 0.05,   1.3,2.4,   63.3,63.5, /

&DOOR ID='Door_out_15', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_14'
     XYZ= -0.2, 1.80, 68.2,
     XB=-0.05, -0.05,   1.3,2.4,   68.1,68.3, /
&DOOR ID='Door_in_15', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_16'
     XYZ=  0.2, 1.80, 68.2,
     XB=0.05, 0.05,   1.3,2.4,   68.1,68.3, /

&DOOR ID='Door_out_16', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_15'
     XYZ= -0.2, 1.80, 73.0,
     XB=-0.05, -0.05,   1.3,2.4,   72.9,73.1, /
&DOOR ID='Door_in_16', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_17'
     XYZ=  0.2, 1.80, 73.0,
     XB=0.05, 0.05,   1.3,2.4,   72.9,73.1, /

&DOOR ID='Door_out_17', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_16'
     XYZ= -0.2, 1.80, 77.8,
     XB=-0.05, -0.05,   1.3,2.4,   77.7,77.9, /
&DOOR ID='Door_in_17', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_18'
     XYZ=  0.2, 1.80, 77.8,
     XB=0.05, 0.05,   1.3,2.4,   77.7,77.9, /

&DOOR ID='Door_out_18', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_17'
     XYZ= -0.2, 1.80, 82.6,
     XB=-0.05, -0.05,   1.3,2.4,   82.5,82.7, /
&DOOR ID='Door_in_18', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_19'
     XYZ=  0.2, 1.80, 82.6,
     XB=0.05, 0.05,   1.3,2.4,   82.5,82.7, /

&DOOR ID='Door_out_19', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_18'
```

```
     XYZ= -0.2, 1.80, 87.4,
     XB=-0.05, -0.05,   1.3,2.4,   87.3,87.5, /
&DOOR ID='Door_in_19', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_20'
     XYZ=  0.2, 1.80, 87.4,
     XB=0.05, 0.05,   1.3,2.4,   87.3,87.5, /

&DOOR ID='Door_out_20', IOR=+1,
     COLOR='RED',
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_19'
     XYZ= -0.2, 1.8, 92.2,
     XB=-0.05, -0.05,   1.3,2.4,  92.1,92.3, /

**********Stair 2 SCISSOR STAIRS****************************************************************

&EXIT ID='Door_out_1a', IOR=-2,
     COUNT_ONLY=.FALSE.,
     XB=-1.45, -0.45,   -52.2,-52.2,   0.9, 1.1, /
&DOOR ID='Door_in_1a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_2a'
     XYZ=  0.2, -51.6,  1.0,
     XB=0.05, 0.05, -51.1,-52.2,   0.9, 1.1, /

&DOOR ID='Door_out_2a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_1a'
     XYZ= -0.2, -51.6, 5.8,
     XB=-0.05, -0.05, -51.1,-52.2,   5.7, 5.9, /
&DOOR ID='Door_in_2a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_3a'
     XYZ=  0.2, -51.6,  5.8,
     XB=0.05, 0.05, -51.1,-52.2,   5.7, 5.9, /

&DOOR ID='Door_out_3a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_2a'
     XYZ= -0.2, -51.6, 10.6,
     XB=-0.05, -0.05,   -51.1,-52.2,   10.5, 10.7, /
&DOOR ID='Door_in_3a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_4a'
     XYZ=  0.2, -51.6,  10.6,
     XB=0.05, 0.05,   -51.1,-52.2,   10.5, 10.7, /

&DOOR ID='Door_out_4a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_3a'
     XYZ= -0.2, -51.6, 15.4,
     XB=-0.05, -0.05,   -51.1,-52.2,   15.3,15.5, /
&DOOR ID='Door_in_4a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_5a'
     XYZ=  0.2, -51.6, 15.4,
     XB=0.05, 0.05,   -51.1,-52.2,   15.3,15.5, /
```

```
&DOOR ID='Door_out_5a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_4a'
     XYZ= -0.2, -51.6, 20.2,
     XB=-0.05, -0.05,   -51.1,-52.2,   20.1,20.3, /
&DOOR ID='Door_in_5a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_6a'
     XYZ=  0.2, -51.6, 20.2,
     XB=0.05, 0.05,   -51.1,-52.2,   20.1,20.3, /

&DOOR ID='Door_out_6a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_5a'
     XYZ= -0.2, -51.6, 25.0,
     XB=-0.05, -0.05,   -51.1,-52.2,   24.9,25.1, /
&DOOR ID='Door_in_6a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_7a'
     XYZ=  0.2, -51.6, 25.0,
     XB=0.05, 0.05,   -51.1,-52.2,   24.9,25.1, /

&DOOR ID='Door_out_7a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_6a'
     XYZ= -0.2, -51.6, 29.8,
     XB=-0.05, -0.05,   -51.1,-52.2,   29.7,29.9, /
&DOOR ID='Door_in_7a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_8a'
     XYZ=  0.2, -51.6, 29.8,
     XB=0.05, 0.05,   -51.1,-52.2,   29.7,29.9, /

&DOOR ID='Door_out_8a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_7a'
     XYZ= -0.2, -51.6, 34.6,
     XB=-0.05, -0.05,   -51.1,-52.2,   34.5,34.7, /
&DOOR ID='Door_in_8a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_9a'
     XYZ=  0.2, -51.6, 34.6,
     XB=0.05, 0.05,   -51.1,-52.2,   34.5,34.7, /

&DOOR ID='Door_out_9a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_8a'
     XYZ= -0.2, -51.6, 39.4,
     XB=-0.05, -0.05,   -51.1,-52.2,   39.3,39.5, /
&DOOR ID='Door_in_9a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_10a'
     XYZ=  0.2, -51.6, 39.4,
     XB=0.05, 0.05,   -51.1,-52.2,   39.3,39.5, /

&DOOR ID='Door_out_10a', IOR=+1,
     EXIT_SIGN=.TRUE.,
```

```
    TO_NODE= 'Door_in_9a'
    XYZ= -0.2, -51.6, 44.2,
    XB=-0.05, -0.05,   -51.1,-52.2,   44.1,44.3, /
&DOOR ID='Door_in_10a', IOR=-1,
    EXIT_SIGN=.FALSE.,
    TO_NODE= 'Door_out_11a'
    XYZ=  0.2, -51.6, 44.2,
    XB=0.05, 0.05,   -51.1,-52.2,   44.1,44.3, /

&DOOR ID='Door_out_11a', IOR=+1,
    EXIT_SIGN=.TRUE.,
    TO_NODE= 'Door_in_10a'
    XYZ= -0.2, -51.6, 49.0,
    XB=-0.05, -0.05,   -51.1,-52.2,   48.9,49.1, /
&DOOR ID='Door_in_11a', IOR=-1,
    EXIT_SIGN=.FALSE.,
    TO_NODE= 'Door_out_12a'
    XYZ=  0.2, -51.6, 49.0,
    XB=0.05, 0.05,   -51.1,-52.2,   48.9,49.1, /

&DOOR ID='Door_out_12a', IOR=+1,
    EXIT_SIGN=.TRUE.,
    TO_NODE= 'Door_in_11a'
    XYZ= -0.2, -51.6, 53.8,
    XB=-0.05, -0.05,   -51.1,-52.2,   53.7,53.9, /
&DOOR ID='Door_in_12a', IOR=-1,
    EXIT_SIGN=.FALSE.,
    TO_NODE= 'Door_out_13a'
    XYZ=  0.2, -51.6, 53.8,
    XB=0.05, 0.05,   -51.1,-52.2,   53.7,53.9, /

&DOOR ID='Door_out_13a', IOR=+1,
    EXIT_SIGN=.TRUE.,
    TO_NODE= 'Door_in_12a'
    XYZ= -0.2, -51.6, 58.6,
    XB=-0.05, -0.05,   -51.1,-52.2,   58.5,58.7, /
&DOOR ID='Door_in_13a', IOR=-1,
    EXIT_SIGN=.FALSE.,
    TO_NODE= 'Door_out_14a'
    XYZ=  0.2, -51.6, 58.6,
    XB=0.05, 0.05,   -51.1,-52.2,   58.5,58.7, /

&DOOR ID='Door_out_14a', IOR=+1,
    EXIT_SIGN=.TRUE.,
    TO_NODE= 'Door_in_13a'
    XYZ= -0.2, -51.6, 63.4,
    XB=-0.05, -0.05,   -51.1,-52.2,   63.3,63.5, /
&DOOR ID='Door_in_14a', IOR=-1,
    EXIT_SIGN=.FALSE.,
    TO_NODE= 'Door_out_15a'
    XYZ=  0.2, -51.6, 63.4,
    XB=0.05, 0.05,   -51.1,-52.2,   63.3,63.5, /

&DOOR ID='Door_out_15a', IOR=+1,
    EXIT_SIGN=.TRUE.,
    TO_NODE= 'Door_in_14a'
    XYZ= -0.2, -51.6, 68.2,
    XB=-0.05, -0.05,   -51.1,-52.2,   68.1,68.3, /
```

```
&DOOR ID='Door_in_15a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_16a'
     XYZ=  0.2, -51.6, 68.2,
     XB=0.05, 0.05,   -51.1,-52.2,   68.1,68.3, /

&DOOR ID='Door_out_16a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_15a'
     XYZ= -0.2, -51.6, 73.0,
     XB=-0.05, -0.05,   -51.1,-52.2,   72.9,73.1, /
&DOOR ID='Door_in_16a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_17a'
     XYZ=  0.2, -51.6, 73.0,
     XB=0.05, 0.05,   -51.1,-52.2,   72.9,73.1, /

&DOOR ID='Door_out_17a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_16a'
     XYZ= -0.2, -51.6, 77.8,
     XB=-0.05, -0.05,   -51.1,-52.2,   77.7,77.9, /
&DOOR ID='Door_in_17a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_18a'
     XYZ=  0.2, -51.6, 77.8,
     XB=0.05, 0.05,   -51.1,-52.2,   77.7,77.9, /

&DOOR ID='Door_out_18a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_17a'
     XYZ= -0.2, -51.6, 82.6,
     XB=-0.05, -0.05,   -51.1,-52.2,   82.5,82.7, /
&DOOR ID='Door_in_18a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_19a'
     XYZ=  0.2, -51.6, 82.6,
     XB=0.05, 0.05,   -51.1,-52.2,   82.5,82.7, /

&DOOR ID='Door_out_19a', IOR=+1,
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_18a'
     XYZ= -0.2, -51.6, 87.4,
     XB=-0.05, -0.05,   -51.1,-52.2,   87.3,87.5, /
&DOOR ID='Door_in_19a', IOR=-1,
     EXIT_SIGN=.FALSE.,
     TO_NODE= 'Door_out_20a'
     XYZ=  0.2, -51.6, 87.4,
     XB=0.05, 0.05,   -51.1,-52.2,   87.3,87.5, /

&DOOR ID='Door_out_20a', IOR=+1,
     COLOR='RED',
     EXIT_SIGN=.TRUE.,
     TO_NODE= 'Door_in_19a'
     XYZ= -0.2, -51.6, 92.2,
     XB=-0.05, -0.05,   -51.1,-52.2,  92.1,92.3, /
```

```
****************From floor into stairwell 1********************************

&DOOR ID='NORTHDOOR_1', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_1',
     MESH_ID='EMesh_2F',
     XB= -1.40,-0.40, -0.15,-0.15, 5.7,5.9 /

&ENTR ID='NORTHENTR_1', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_2',
     XB= -1.45,-0.45,  0.0,0.0,  5.7,5.9 /

&DOOR ID='NORTHDOOR_2', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_2',
     MESH_ID='EMesh_3F',
     XB= -1.40,-0.40, -0.15,-0.15, 10.5,10.7 /

&ENTR ID='NORTHENTR_2', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_3',
     XB= -1.45,-0.45,  0.0,0.0,  10.5,10.7 /

&DOOR ID='NORTHDOOR_3', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_3',
     MESH_ID='EMesh_4F',
     XB= -1.40,-0.40, -0.15,-0.15, 15.3,15.5 /

&ENTR ID='NORTHENTR_3', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_4',
     XB= -1.45,-0.45,  0.0,0.0,  15.3,15.5 /

&DOOR ID='NORTHDOOR_4', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_4',
     MESH_ID='EMesh_5F',
     XB= -1.40,-0.40, -0.15,-0.15, 20.1,20.3 /

&ENTR ID='NORTHENTR_4', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_5',
     XB= -1.45,-0.45,  0.0,0.0,  20.1,20.3 /

&DOOR ID='NORTHDOOR_5', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_5',
     MESH_ID='EMesh_6F',
     XB= -1.40,-0.40, -0.15,-0.15, 24.9,25.1 /

&ENTR ID='NORTHENTR_5', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_6',
     XB= -1.45,-0.45,  0.0,0.0,  24.9,25.1 /

&DOOR ID='NORTHDOOR_6', IOR=+2,
```

```
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_6',
     MESH_ID='EMesh_7F',
     XB= -1.40,-0.40, -0.15,-0.15, 29.7,29.9 /

&ENTR ID='NORTHENTR_6', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_7',
     XB= -1.45,-0.45,  0.0,0.0,  29.7,29.9 /

&DOOR ID='NORTHDOOR_7', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_7',
     MESH_ID='EMesh_8F',
     XB= -1.40,-0.40, -0.15,-0.15, 34.5,34.7 /

&ENTR ID='NORTHENTR_7', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_8',
     XB= -1.45,-0.45,  0.0,0.0,  34.5,34.7 /

&DOOR ID='NORTHDOOR_8', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_8',
     MESH_ID='EMesh_9F',
     XB= -1.40,-0.40, -0.15,-0.15, 39.3,39.5 /

&ENTR ID='NORTHENTR_8', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_9',
     XB= -1.45,-0.45,  0.0,0.0,  39.3,39.5 /

&DOOR ID='NORTHDOOR_9', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_9',
     MESH_ID='EMesh_10F',
     XB= -1.40,-0.40, -0.15,-0.15, 44.1,44.3 /

&ENTR ID='NORTHENTR_9', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_10',
     XB= -1.45,-0.45,  0.0,0.0,  44.1,44.3 /

&DOOR ID='NORTHDOOR_10', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_10',
     MESH_ID='EMesh_11F',
     XB= -1.40,-0.40, -0.15,-0.15, 48.9,49.1 /

&ENTR ID='NORTHENTR_10', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_11',
     XB= -1.45,-0.45,  0.0,0.0,  48.9,49.1 /

&DOOR ID='NORTHDOOR_11', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_11',
     MESH_ID='EMesh_12F',
```

```
     XB= -1.40,-0.40, -0.15,-0.15, 53.7,53.9 /

&ENTR ID='NORTHENTR_11', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_12',
     XB= -1.45,-0.45,  0.0,0.0,  53.7,53.9 /

&DOOR ID='NORTHDOOR_12', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_12',
     MESH_ID='EMesh_13F',
     XB= -1.40,-0.40, -0.15,-0.15, 58.5,58.7 /

&ENTR ID='NORTHENTR_12', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_13',
     XB= -1.45,-0.45,  0.0,0.0,  58.5,58.7 /

&DOOR ID='NORTHDOOR_13', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_13',
     MESH_ID='EMesh_14F',
     XB= -1.40,-0.40, -0.15,-0.15, 63.3,63.5 /

&ENTR ID='NORTHENTR_13', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_14',
     XB= -1.45,-0.45,  0.0,0.0,  63.3,63.5 /

&DOOR ID='NORTHDOOR_14', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_14',
     MESH_ID='EMesh_15F',
     XB= -1.40,-0.40, -0.15,-0.15, 68.1,68.3 /

&ENTR ID='NORTHENTR_14', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_15',
     XB= -1.45,-0.45,  0.0,0.0,  68.1,68.3 /

&DOOR ID='NORTHDOOR_15', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_15',
     MESH_ID='EMesh_16F',
     XB= -1.40,-0.40, -0.15,-0.15, 72.9,73.1 /

&ENTR ID='NORTHENTR_15', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_16',
     XB= -1.45,-0.45,  0.0,0.0,  72.9,73.1 /

&DOOR ID='NORTHDOOR_16', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_16',
     MESH_ID='EMesh_17F',
     XB= -1.40,-0.40, -0.15,-0.15, 77.7,77.9 /

&ENTR ID='NORTHENTR_16', IOR=+2,
```

```
     COLOR='GREEN',
     MESH_ID='EMesh_17',
     XB= -1.45,-0.45,  0.0,0.0,  77.7,77.9 /

&DOOR ID='NORTHDOOR_17', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_17',
     MESH_ID='EMesh_18F',
     XB= -1.40,-0.40, -0.15,-0.15, 82.5,82.7 /

&ENTR ID='NORTHENTR_17', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_18',
     XB= -1.45,-0.45,  0.0,0.0,  82.5,82.7 /

&DOOR ID='NORTHDOOR_18', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_18',
     MESH_ID='EMesh_19F',
     XB= -1.40,-0.40, -0.15,-0.15, 87.3,87.5 /

&ENTR ID='NORTHENTR_18', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_19',
     XB= -1.45,-0.45,  0.0,0.0,  87.3,87.5 /

&DOOR ID='NORTHDOOR_19', IOR=+2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'NORTHENTR_19',
     MESH_ID='EMesh_20F',
     XB= -1.40,-0.40, -0.15,-0.15, 92.1,92.3 /

&ENTR ID='NORTHENTR_19', IOR=+2,
     COLOR='GREEN',
     MESH_ID='EMesh_20',
     XB= -1.45,-0.45,  0.0,0.0,  92.1,92.3 /


****************From floor into stairwell 2*********************************


&DOOR ID='SOUTHDOOR_1', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_1',
     MESH_ID='EMesh_2F',
     XB= -1.40,-0.40, -49.65,-49.65, 5.7,5.9 /

&ENTR ID='SOUTHENTR_1', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_2a',
     XB= -1.45,-0.45,  -49.80,-49.80,  5.7,5.9 /

&DOOR ID='SOUTHDOOR_2', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_2',
     MESH_ID='EMesh_3F',
     XB= -1.40,-0.40, -49.65,-49.65, 10.5,10.7 /
```

```
&ENTR ID='SOUTHENTR_2', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_3a',
     XB= -1.45,-0.45,  -49.80,-49.80,  10.5,10.7 /

&DOOR ID='SOUTHDOOR_3', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_3',
     MESH_ID='EMesh_4F',
     XB= -1.40,-0.40, -49.65,-49.65, 15.3,15.5 /

&ENTR ID='SOUTHENTR_3', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_4a',
     XB= -1.45,-0.45,  -49.80,-49.80,  15.3,15.5 /

&DOOR ID='SOUTHDOOR_4', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_4',
     MESH_ID='EMesh_5F',
     XB= -1.40,-0.40, -49.65,-49.65, 20.1,20.3 /

&ENTR ID='SOUTHENTR_4', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_5a',
     XB= -1.45,-0.45,  -49.80,-49.80,  20.1,20.3 /

&DOOR ID='SOUTHDOOR_5', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_5',
     MESH_ID='EMesh_6F',
     XB= -1.40,-0.40, -49.65,-49.65, 24.9,25.1 /

&ENTR ID='SOUTHENTR_5', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_6a',
     XB= -1.45,-0.45,  -49.80,-49.80,  24.9,25.1 /

&DOOR ID='SOUTHDOOR_6', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_6',
     MESH_ID='EMesh_7F',
     XB= -1.40,-0.40, -49.65,-49.65, 29.7,29.9 /

&ENTR ID='SOUTHENTR_6', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_7a',
     XB= -1.45,-0.45,  -49.80,-49.80,  29.7,29.9 /

&DOOR ID='SOUTHDOOR_7', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_7',
     MESH_ID='EMesh_8F',
     XB= -1.40,-0.40, -49.65,-49.65, 34.5,34.7 /

&ENTR ID='SOUTHENTR_7', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_8a',
```

```
     XB= -1.45,-0.45,  -49.80,-49.80,  34.5,34.7 /

&DOOR ID='SOUTHDOOR_8', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_8',
     MESH_ID='EMesh_9F',
     XB= -1.40,-0.40, -49.65,-49.65, 39.3,39.5 /

&ENTR ID='SOUTHENTR_8', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_9a',
     XB= -1.45,-0.45,  -49.80,-49.80,  39.3,39.5 /

&DOOR ID='SOUTHDOOR_9', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_9',
     MESH_ID='EMesh_10F',
     XB= -1.40,-0.40, -49.65,-49.65, 44.1,44.3 /

&ENTR ID='SOUTHENTR_9', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_10a',
     XB= -1.45,-0.45,  -49.80,-49.80,  44.1,44.3 /

&DOOR ID='SOUTHDOOR_10', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_10',
     MESH_ID='EMesh_11F',
     XB= -1.40,-0.40, -49.65,-49.65, 48.9,49.1 /

&ENTR ID='SOUTHENTR_10', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_11a',
     XB= -1.45,-0.45,  -49.80,-49.80,  48.9,49.1 /

&DOOR ID='SOUTHDOOR_11', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_11',
     MESH_ID='EMesh_12F',
     XB= -1.40,-0.40, -49.65,-49.65, 53.7,53.9 /

&ENTR ID='SOUTHENTR_11', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_12a',
     XB= -1.45,-0.45,  -49.80,-49.80,  53.7,53.9 /

&DOOR ID='SOUTHDOOR_12', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_12',
     MESH_ID='EMesh_13F',
     XB= -1.40,-0.40, -49.65,-49.65, 58.5,58.7 /

&ENTR ID='SOUTHENTR_12', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_13a',
     XB= -1.45,-0.45,  -49.80,-49.80,  58.5,58.7 /

&DOOR ID='SOUTHDOOR_13', IOR=-2,
```

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     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_13',
     MESH_ID='EMesh_14F',
     XB= -1.40,-0.40, -49.65,-49.65, 63.3,63.5 /

&ENTR ID='SOUTHENTR_13', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_14a',
     XB= -1.45,-0.45,  -49.80,-49.80,  63.3,63.5 /

&DOOR ID='SOUTHDOOR_14', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_14',
     MESH_ID='EMesh_15F',
     XB= -1.40,-0.40, -49.65,-49.65, 68.1,68.3 /

&ENTR ID='SOUTHENTR_14', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_15a',
     XB= -1.45,-0.45,  -49.80,-49.80,  68.1,68.3 /

&DOOR ID='SOUTHDOOR_15', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_15',
     MESH_ID='EMesh_16F',
     XB= -1.40,-0.40, -49.65,-49.65, 72.9,73.1 /

&ENTR ID='SOUTHENTR_15', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_16a',
     XB= -1.45,-0.45,  -49.80,-49.80,  72.9,73.1 /

&DOOR ID='SOUTHDOOR_16', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_16',
     MESH_ID='EMesh_17F',
     XB= -1.40,-0.40, -49.65,-49.65, 77.7,77.9 /

&ENTR ID='SOUTHENTR_16', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_17a',
     XB= -1.45,-0.45,  -49.80,-49.80,  77.7,77.9 /

&DOOR ID='SOUTHDOOR_17', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_17',
     MESH_ID='EMesh_18F',
     XB= -1.40,-0.40, -49.65,-49.65, 82.5,82.7 /

&ENTR ID='SOUTHENTR_17', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_18a',
     XB= -1.45,-0.45,  -49.80,-49.80,  82.5,82.7 /

&DOOR ID='SOUTHDOOR_18', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_18',
     MESH_ID='EMesh_19F',
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     XB= -1.40,-0.40, -49.65,-49.65, 87.3,87.5 /

&ENTR ID='SOUTHENTR_18', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_19a',
     XB= -1.45,-0.45,  -49.80,-49.80,  87.3,87.5 /

&DOOR ID='SOUTHDOOR_19', IOR=-2,
     COLOR='GREEN', EXIT_SIGN=.FALSE.,
     TO_NODE= 'SOUTHENTR_19',
     MESH_ID='EMesh_20F',
     XB= -1.40,-0.40, -49.65,-49.65, 92.1,92.3 /

&ENTR ID='SOUTHENTR_19', IOR=-2,
     COLOR='GREEN',
     MESH_ID='EMesh_20a',
     XB= -1.45,-0.45,  -49.80,-49.80,  92.1,92.3 /

*****************************************************************************************************
&EVAC ID='EvacAdult_2A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 5.7,5.9,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_1',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 2nd floor agents 122 ppl

&EVAC ID='EvacAdult_2B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 5.7,5.9,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_1',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 2nd floor agents 123 ppl

&EVAC ID='EvacAdult_3A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 10.5,10.7,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_2',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 3rd floor agents 122 ppl

&EVAC ID='EvacAdult_3B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 10.5,10.7,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_2',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 3rd floor agents 123 ppl

&EVAC ID='EvacAdult_4A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 15.3,15.5,
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     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_3',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 4th floor agents 122 ppl

&EVAC ID='EvacAdult_4B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 15.3,15.5,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_3',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 4th floor agents 123 ppl

&EVAC ID='EvacAdult_5A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 20.1,20.3,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_4',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 5th floor agents 122 ppl

&EVAC ID='EvacAdult_5B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 20.1,20.3,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_4',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 5th floor agents 123 ppl

&EVAC ID='EvacAdult_6A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 24.9,25.1,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_5',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 6th floor agents 122 ppl

&EVAC ID='EvacAdult_6B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 24.9,25.1,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_5',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 6th floor agents 123 ppl

&EVAC ID='EvacAdult_7A',
     NUMBER_INITIAL_PERSONS= 122,
     XB= -22.2, 27.3, -0.15, -49.65, 29.7,29.9,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='NORTHDOOR_6',
     KNOWN_DOOR_PROBS=1.0,
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```
    PERS_ID='AGENTS_REMOTE' / 7th floor agents 122 ppl

&EVAC ID='EvacAdult_7B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 29.7,29.9,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_6',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 7th floor agents 123 ppl

&EVAC ID='EvacAdult_8A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 34.5,34.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_7',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 8th floor agents 122 ppl

&EVAC ID='EvacAdult_8B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 34.5,34.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_7',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 8th floor agents 123 ppl

&EVAC ID='EvacAdult_9A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 39.3,39.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_8',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 9th floor agents 122 ppl

&EVAC ID='EvacAdult_9B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 39.3,39.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_8',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 9th floor agents 123 ppl

&EVAC ID='EvacAdult_10A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -22.35, 44.1,44.3,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_9',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_ORIGIN' / 10th floor agents 122 ppl

&EVAC ID='EvacAdult_10B',
    NUMBER_INITIAL_PERSONS= 123,
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    XB= -22.2, 27.3, -27.45, -49.65, 44.1,44.3,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_9',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_ORIGIN' / 10th floor agents 123 ppl

&EVAC ID='EvacAdult_11A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 48.9,49.1,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_10',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 11th floor agents 122 ppl

&EVAC ID='EvacAdult_11B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 48.9,49.1,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_10',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 11th floor agents 123 ppl

&EVAC ID='EvacAdult_12A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 53.7,53.9,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_11',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 12th floor agents 122 ppl

&EVAC ID='EvacAdult_12B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 53.7,53.9,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_11',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 12th floor agents 123 ppl

&EVAC ID='EvacAdult_13A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 58.5,58.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_12',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 13th floor agents 122 ppl

&EVAC ID='EvacAdult_13B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 58.5,58.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_12',
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    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 13th floor agents 123 ppl

&EVAC ID='EvacAdult_14A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 63.3,63.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_13',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 14th floor agents 122 ppl

&EVAC ID='EvacAdult_14B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 63.3,63.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_13',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 14th floor agents 123 ppl

&EVAC ID='EvacAdult_15A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 68.1,68.3,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_14',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 15th floor agents 122 ppl

&EVAC ID='EvacAdult_15B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 68.1,68.3,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_14',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 15th floor agents 123 ppl

&EVAC ID='EvacAdult_16A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 72.9,73.1,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_15',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 16th floor agents 122 ppl

&EVAC ID='EvacAdult_16B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 72.9,73.1,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_15',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 16th floor agents 123 ppl

&EVAC ID='EvacAdult_17A',
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    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 77.7,77.9,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_16',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 17th floor agents 122 ppl

&EVAC ID='EvacAdult_17B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 77.7,77.9,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_16',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 17th floor agents 123 ppl

&EVAC ID='EvacAdult_18A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 82.5, 82.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_17',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 18th floor agents 122 ppl

&EVAC ID='EvacAdult_18B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 82.5, 82.7,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_17',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 18th floor agents 123 ppl

&EVAC ID='EvacAdult_19A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 87.3,87.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='NORTHDOOR_18',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 19th floor agents 122 ppl

&EVAC ID='EvacAdult_19B',
    NUMBER_INITIAL_PERSONS= 123,
    XB= -22.2, 27.3, -0.15, -49.65, 87.3,87.5,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
    KNOWN_DOOR_NAMES='SOUTHDOOR_18',
    KNOWN_DOOR_PROBS=1.0,
    PERS_ID='AGENTS_REMOTE' / 19th floor agents 123 ppl

&EVAC ID='EvacAdult_20A',
    NUMBER_INITIAL_PERSONS= 122,
    XB= -22.2, 27.3, -0.15, -49.65, 92.1,92.3,
    AVATAR_COLOR= 'BLUE',
    AGENT_TYPE=2,
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     KNOWN_DOOR_NAMES='NORTHDOOR_19',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 20th floor agents 122 ppl

&EVAC ID='EvacAdult_20B',
     NUMBER_INITIAL_PERSONS= 123,
     XB= -22.2, 27.3, -0.15, -49.65, 92.1,92.3,
     AVATAR_COLOR= 'BLUE',
     AGENT_TYPE=2,
     KNOWN_DOOR_NAMES='SOUTHDOOR_19',
     KNOWN_DOOR_PROBS=1.0,
     PERS_ID='AGENTS_REMOTE' / 20th floor agents 123 ppl

&PERS ID='AGENTS_ORIGIN',
     DEFAULT_PROPERTIES='ADULT',
     VELOCITY_DIST=0,
     VEL_MEAN=1.2,
     PRE_EVAC_DIST=0,
     PRE_MEAN=60.,
     HUMAN_SMOKE_HEIGHT=2.0,
     DET_EVAC_DIST=0,
     DET_MEAN=203.,
     DENS_INIT=0.0,
     OUTPUT_FED=.TRUE.
     COLOR_METHOD=0, I_HERDING_TYPE=0, /

&PERS ID='AGENTS_REMOTE',
     DEFAULT_PROPERTIES='ADULT',
     VELOCITY_DIST=0,
     VEL_MEAN=1.2,
     PRE_EVAC_DIST=0,
     PRE_MEAN=90.,
     HUMAN_SMOKE_HEIGHT=2.0,
     DET_EVAC_DIST=0,
     DET_MEAN=203.,
     DENS_INIT=0.0,
     OUTPUT_FED=.TRUE.
     COLOR_METHOD=0, I_HERDING_TYPE=0, /

*) Added herding behaviour for agents.
 EVAC-namelist:
 AGENT_TYPE: Default is 2
   1 rational agents (visible doors and known doors equal)
   2 known doors first, then the visible ones (like in the manual)
   3 herding (choose the door that the others are using if no known doors given)
 PERS-namelist: I_HERDING_TYPE=0 (default)
  0: default herding (follow the default flow field if no door found)
  1: keep the first choice (follow the default flow field if no door found)
  2: do not move, if no door found
  3: do not move, if no door found + keep the first choice
  (keep the first choice: If the agent does know/see any door then it tries
   to check the other agents.  If it finds this way a door, then it does not
   try anymore to find any other door. The other mode of operation is that
   the agent constantly sees what the others are doing around and changes
   its mind accordingly, if no known or visible door available.)

&EVHO ID='fire',
     FYI='human not allowed close to the fire',
```

XB= -0.1,4.9, -22.35,-27.45, 44.1,44.3 /

Created obstructions in Evac only to prevent human walking past
the fire during evacuation, this will not affect the fire calculations

&OBST XB= -0.1, -0.1, -22.35,-27.45, 43.2,48.0, EVACUATION=.TRUE., /
&OBST XB= 4.9, 4.9, -22.35,-27.45, 43.2,48.0, EVACUATION=.TRUE., /
&OBST XB= -0.1, 4.9, -22.35,-22.35, 43.2,48.0, EVACUATION=.TRUE., /
&OBST XB= -0.1, 4.9, -27.45,-27.45, 43.2,48.0, EVACUATION=.TRUE., /

***************DEVICES IN FIRE FLOOR***********************************************************************

DEVICE LABELLED ACROSS AND THEN DOWN

***************VISIBILITY******************************************************

&DEVC XYZ=-17.2,-5.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-17.2--5.15-45.2)'/
&DEVC XYZ=-7.2,-5.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-7.2--5.15-45.2)'/
&DEVC XYZ=2.8,-5.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(2.8--5.15-45.2)'/
&DEVC XYZ=12.8,-5.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(12.8--5.15-45.2)'/
&DEVC XYZ=22.8,-5.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(22.8--5.15-45.2)'/

&DEVC XYZ=-17.2,-15.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-17.2--15.15-45.2)'/
&DEVC XYZ=-7.2,-15.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-7.2--15.15-45.2)'/
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&DEVC XYZ=12.8,-15.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(12.8--15.15-45.2)'/
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&DEVC XYZ=-17.2,-25.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-17.2--25.15-45.2)'/
&DEVC XYZ=-7.2,-25.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-7.2--25.15-45.2)'/
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&DEVC XYZ=-17.2,-35.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-17.2--35.15-45.2)'/
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&DEVC XYZ=12.8,-35.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(12.8--35.15-45.2)'/
&DEVC XYZ=22.8,-35.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(22.8--35.15-45.2)'/

&DEVC XYZ=-17.2,-45.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-17.2--45.15-45.2)'/
&DEVC XYZ=-7.2,-45.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(-7.2--45.15-45.2)'/
&DEVC XYZ=2.8,-45.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(2.8--45.15-45.2)'/
&DEVC XYZ=12.8,-45.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(12.8--45.15-45.2)'/
&DEVC XYZ=22.8,-45.15,45.2, QUANTITY='VISIBILITY', ID='VIS_(22.8--45.15-45.2)'/

***************FED*******************************************************************

&DEVC XYZ=-17.2,-5.15,45.2, QUANTITY='FED', ID='FED_(-17.2--5.15-45.2)'/
&DEVC XYZ=-7.2,-5.15,45.2, QUANTITY='FED', ID='FED_(-7.2--5.15-45.2)'/
&DEVC XYZ=2.8,-5.15,45.2, QUANTITY='FED', ID='FED_(2.8--5.15-45.2)'/
&DEVC XYZ=12.8,-5.15,45.2, QUANTITY='FED', ID='FED_(12.8--5.15-45.2)'/
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&DEVC XYZ=12.8,-15.15,45.2, QUANTITY='FED', ID='FED_(12.8--15.15-45.2)'/

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&DEVC XYZ=22.8,-15.15,45.2, QUANTITY='FED', ID='FED_(22.8--15.15-45.2)'/

&DEVC XYZ=-17.2,-25.15,45.2, QUANTITY='FED', ID='FED_(-17.2--25.15-45.2)'/
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&DEVC XYZ=-17.2,-35.15,45.2, QUANTITY='FED', ID='FED_(-17.2--35.15-45.2)'/
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&DEVC XYZ=-17.2,-45.15,45.2, QUANTITY='FED', ID='FED_(-17.2--45.15-45.2)'/
&DEVC XYZ=-7.2,-45.15,45.2, QUANTITY='FED', ID='FED_(-7.2--45.15-45.2)'/
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&DEVC XYZ=12.8,-45.15,45.2, QUANTITY='FED', ID='FED_(12.8--45.15-45.2)'/
&DEVC XYZ=22.8,-45.15,45.2, QUANTITY='FED', ID='FED_(22.8--45.15-45.2)'/

***************TEMPERATURE*******************************************************

&DEVC XYZ=-17.2,-5.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-17.2--5.15-45.2)'/
&DEVC XYZ=-7.2,-5.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-7.2--5.15-45.2)'/
&DEVC XYZ=2.8,-5.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(2.8--5.15-45.2)'/
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&DEVC XYZ=22.8,-5.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(22.8--5.15-45.2)'/

&DEVC XYZ=-17.2,-15.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-17.2--15.15-45.2)'/
&DEVC XYZ=-7.2,-15.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-7.2--15.15-45.2)'/
&DEVC XYZ=2.8,-15.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(2.8--15.15-45.2)'/
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&DEVC XYZ=2.8,-35.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(2.8--35.15-45.2)'/
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&DEVC XYZ=22.8,-35.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(22.8--35.15-45.2)'/

&DEVC XYZ=-17.2,-45.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-17.2--45.15-45.2)'/
&DEVC XYZ=-7.2,-45.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-7.2--45.15-45.2)'/
&DEVC XYZ=2.8,-45.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(2.8--45.15-45.2)'/
&DEVC XYZ=12.8,-45.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(12.8--45.15-45.2)'/
&DEVC XYZ=22.8,-45.15,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(22.8--45.15-45.2)'/

***************LAYER HEIGHT*******************************************************

&DEVC XB=-17.2,-17.2, -5.15,-5.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--5.15-43.2)'/
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&DEVC XB=2.8,2.8, -5.15,-5.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(2.8--5.15-43.2)'/
&DEVC XB=12.8,12.8, -5.15,-5.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(12.8--5.15-43.2)'/
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&DEVC XB=22.8,22.8, -5.15,-5.15, 43.2,45.9 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--5.15-43.2)'/

&DEVC XB=-17.2,-17.2, -15.15,-15.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--15.15-43.2)'/
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&DEVC XB=12.8,12.8, -15.15,-15.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(12.8--15.15-43.2)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 43.2,45.9 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--15.15-43.2)'/

&DEVC XB=-17.2,-17.2, -25.15,-25.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--25.15-43.2)'/
&DEVC XB=-7.2,-7.2, -25.15,-25.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-7.2--25.15-43.2)'/
&DEVC XB=2.8,2.8, -25.15,-25.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(2.8--25.15-43.2)'/
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&DEVC XB=22.8,22.8, -25.15,-25.15, 43.2,45.9 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--25.15-43.2)'/

&DEVC XB=-17.2,-17.2, -35.15,-35.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--35.15-43.2)'/
&DEVC XB=-7.2,-7.2, -35.15,-35.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-7.2--35.15-43.2)'/
&DEVC XB=2.8,2.8, -35.15,-35.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(2.8--35.15-43.2)'/
&DEVC XB=12.8,12.8, -35.15,-35.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(12.8--35.15-43.2)'/
&DEVC XB=22.8,22.8, -35.15,-35.15, 43.2,45.9 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--35.15-43.2)'/

&DEVC XB=-17.2,-17.2, -45.15,-45.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--45.15-43.2)'/
&DEVC XB=-7.2,-7.2, -45.15,-45.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(-7.2--45.15-43.2)'/
&DEVC XB=2.8,2.8, -45.15,-45.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(2.8--45.15-43.2)'/
&DEVC XB=12.8,12.8, -45.15,-45.15, 43.2,45.9, QUANTITY='LAYER HEIGHT', ID='LH_(12.8--45.15-43.2)'/
&DEVC XB=22.8,22.8, -45.15,-45.15, 43.2,45.9 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--45.15-43.2)'/

***************UPPER LAYER TEMPERATURE*********************************************************

&DEVC XB=-17.2,-17.2, -5.15,-5.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--5.15-43.2)'/
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&DEVC XB=2.8,2.8, -5.15,-5.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(2.8--5.15-43.2)'/
&DEVC XB=12.8,12.8, -5.15,-5.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(12.8--5.15-43.2)'/
&DEVC XB=22.8,22.8, -5.15,-5.15, 43.2,45.9 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--5.15-43.2)'/

&DEVC XB=-17.2,-17.2, -15.15,-15.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--15.15-43.2)'/
&DEVC XB=-7.2,-7.2, -15.15,-15.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-7.2--15.15-43.2)'/
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&DEVC XB=12.8,12.8, -15.15,-15.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(12.8--15.15-43.2)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 43.2,45.9 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--15.15-43.2)'/

&DEVC XB=-17.2,-17.2, -25.15,-25.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--25.15-43.2)'/
&DEVC XB=-7.2,-7.2, -25.15,-25.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-7.2--25.15-43.2)'/
&DEVC XB=2.8,2.8, -25.15,-25.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(2.8--25.15-43.2)'/
&DEVC XB=12.8,12.8, -25.15,-25.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(12.8--25.15-43.2)'/
&DEVC XB=22.8,22.8, -25.15,-25.15, 43.2,45.9 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--25.15-43.2)'/

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&DEVC XB=-17.2,-17.2, -35.15,-35.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--35.15-43.2)'/
&DEVC XB=-7.2,-7.2, -35.15,-35.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-7.2--35.15-43.2)'/
&DEVC XB=2.8,2.8, -35.15,-35.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(2.8--35.15-43.2)'/
&DEVC XB=12.8,12.8, -35.15,-35.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(12.8--35.15-43.2)'/
&DEVC XB=22.8,22.8, -35.15,-35.15, 43.2,45.9 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--35.15-43.2)'/

&DEVC XB=-17.2,-17.2, -45.15,-45.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--45.15-43.2)'/
&DEVC XB=-7.2,-7.2, -45.15,-45.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-7.2--45.15-43.2)'/
&DEVC XB=2.8,2.8, -45.15,-45.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(2.8--45.15-43.2)'/
&DEVC XB=12.8,12.8, -45.15,-45.15, 43.2,45.9, QUANTITY='UPPER TEMPERATURE', ID='ULT_(12.8--45.15-43.2)'/
&DEVC XB=22.8,22.8, -45.15,-45.15, 43.2,45.9 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--45.15-43.2)'/

***************LOWER LAYER TEMPERATURE******************************************************

&DEVC XB=-17.2,-17.2, -5.15,-5.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--5.15-43.2)'/
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&DEVC XB=2.8,2.8, -5.15,-5.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(2.8--5.15-43.2)'/
&DEVC XB=12.8,12.8, -5.15,-5.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--5.15-43.2)'/
&DEVC XB=22.8,22.8, -5.15,-5.15, 43.2,45.9 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--5.15-43.2)'/

&DEVC XB=-17.2,-17.2, -15.15,-15.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--15.15-43.2)'/
&DEVC XB=-7.2,-7.2, -15.15,-15.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-7.2--15.15-43.2)'/
&DEVC XB=2.8,2.8, -15.15,-15.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(2.8--15.15-43.2)'/
&DEVC XB=12.8,12.8, -15.15,-15.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--15.15-43.2)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 43.2,45.9 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--15.15-43.2)'/

&DEVC XB=-17.2,-17.2, -25.15,-25.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--25.15-43.2)'/
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&DEVC XB=22.8,22.8, -25.15,-25.15, 43.2,45.9 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--25.15-43.2)'/

&DEVC XB=-17.2,-17.2, -35.15,-35.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--35.15-43.2)'/
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&DEVC XB=22.8,22.8, -35.15,-35.15, 43.2,45.9 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--35.15-43.2)'/

&DEVC XB=-17.2,-17.2, -45.15,-45.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--45.15-43.2)'/
&DEVC XB=-7.2,-7.2, -45.15,-45.15, 43.2,45.9, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-7.2--45.15-43.2)'/
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&DEVC XB=22.8,22.8, -45.15,-45.15, 43.2,45.9 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--45.15-43.2)'/

***************DEVICES IN 11TH FLOOR*************************************************************************

DEVICE LABELLED ACROSS AND THEN DOWN

***************VISIBILITY*******************************************************

&DEVC XYZ=-17.2,-5.15,50.0, QUANTITY='VISIBILITY', ID='VIS_(-17.2--5.15-50.0)'/
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***************FED**********************************************************************

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***************TEMPERATURE*******************************************************

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&DEVC XYZ=22.8,-45.15,50.0, QUANTITY='TEMPERATURE', ID='TEMP_(22.8--45.15-50.0)'/

***************LAYER HEIGHT*******************************************************

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&DEVC XB=22.8,22.8, -5.15,-5.15, 48.0,50.7 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--5.15-48.0)'/

&DEVC XB=-17.2,-17.2, -15.15,-15.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--15.15-48.0)'/
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&DEVC XB=12.8,12.8, -15.15,-15.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(12.8--15.15-48.0)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 48.0,50.7 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--15.15-48.0)'/

&DEVC XB=-17.2,-17.2, -25.15,-25.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--25.15-48.0)'/
&DEVC XB=-7.2,-7.2, -25.15,-25.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(-7.2--25.15-48.0)'/
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&DEVC XB=-17.2,-17.2, -35.15,-35.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--35.15-48.0)'/
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&DEVC XB=22.8,22.8, -35.15,-35.15, 48.0,50.7 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--35.15-48.0)'/

&DEVC XB=-17.2,-17.2, -45.15,-45.15, 48.0,50.7, QUANTITY='LAYER HEIGHT', ID='LH_(-17.2--45.15-48.0)'/
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&DEVC XB=22.8,22.8, -45.15,-45.15, 48.0,50.7 QUANTITY='LAYER HEIGHT', ID='LH_(22.8--45.15-48.0)'/

***************UPPER LAYER TEMPERATURE*******************************************************

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48.0)'/
&DEVC XB=22.8,22.8, -5.15,-5.15, 48.0,50.7 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--5.15-
48.0)'/

&DEVC XB=-17.2,-17.2, -15.15,-15.15, 48.0,50.7, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--
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48.0)'/
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48.0)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 48.0,50.7 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--15.15-
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48.0)'/
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48.0)'/
&DEVC XB=22.8,22.8, -25.15,-25.15, 48.0,50.7 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--25.15-
48.0)'/

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48.0)'/
&DEVC XB=22.8,22.8, -35.15,-35.15, 48.0,50.7 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--35.15-
48.0)'/

DEVC XB=-17.2,-17.2, -45.15,-45.15, 48.0,50.7, QUANTITY='UPPER TEMPERATURE', ID='ULT_(-17.2--45.15-
48.0)'/
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48.0)'/
&DEVC XB=22.8,22.8, -45.15,-45.15, 48.0,50.7 QUANTITY='UPPER TEMPERATURE', ID='ULT_(22.8--45.15-
48.0)'/

***************LOWER LAYER TEMPERATURE*******************************************************

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48.0)'/
&DEVC XB=12.8,12.8, -15.15,-15.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--15.15-
48.0)'/
&DEVC XB=22.8,22.8, -15.15,-15.15, 48.0,50.7 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--15.15-
48.0)'/

&DEVC XB=-17.2,-17.2, -25.15,-25.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--
25.15-48.0)'/
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&DEVC XB=-7.2,-7.2, -25.15,-25.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-7.2--25.15-48.0)'/
&DEVC XB=2.8,2.8, -25.15,-25.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(2.8--25.15-48.0)'/
&DEVC XB=12.8,12.8, -25.15,-25.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--25.15-48.0)'/
&DEVC XB=22.8,22.8, -25.15,-25.15, 48.0,50.7 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--25.15-48.0)'/

&DEVC XB=-17.2,-17.2, -35.15,-35.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--35.15-48.0)'/
&DEVC XB=-7.2,-7.2, -35.15,-35.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-7.2--35.15-48.0)'/
&DEVC XB=2.8,2.8, -35.15,-35.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(2.8--35.15-48.0)'/
&DEVC XB=12.8,12.8, -35.15,-35.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--35.15-48.0)'/
&DEVC XB=22.8,22.8, -35.15,-35.15, 48.0,50.7 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--35.15-48.0)'/

&DEVC XB=-17.2,-17.2, -45.15,-45.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-17.2--45.15-48.0)'/
&DEVC XB=-7.2,-7.2, -45.15,-45.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(-7.2--45.15-48.0)'/
&DEVC XB=2.8,2.8, -45.15,-45.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(2.8--45.15-48.0)'/
&DEVC XB=12.8,12.8, -45.15,-45.15, 48.0,50.7, QUANTITY='LOWER TEMPERATURE', ID='LLT_(12.8--45.15-48.0)'/
&DEVC XB=22.8,22.8, -45.15,-45.15, 48.0,50.7 QUANTITY='LOWER TEMPERATURE', ID='LLT_(22.8--45.15-48.0)'/

***************DEVICES IN STAIR 1**************************************************************************

***************VISIBILITY*******************************************************

FLOOR FROM 1ST TO 20TH FLOOR THEN LANDING FROM 1ST TO 20TH FLOOR

&DEVC XYZ=-0.825,1.2,2.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-2.0)'/ FLOOR
&DEVC XYZ=-0.825,1.2,6.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-6.8)'/
&DEVC XYZ=-0.825,1.2,11.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-11.6)'/
&DEVC XYZ=-0.825,1.2,16.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-16.4)'/
&DEVC XYZ=-0.825,1.2,21.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-21.2)'/
&DEVC XYZ=-0.825,1.2,26.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-26.0)'/
&DEVC XYZ=-0.825,1.2,30.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-30.8)'/
&DEVC XYZ=-0.825,1.2,35.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-35.6)'/
&DEVC XYZ=-0.825,1.2,40.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-40.4)'/
&DEVC XYZ=-0.825,1.2,45.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-45.2)'/
&DEVC XYZ=-0.825,1.2,50.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-50.0)'/
&DEVC XYZ=-0.825,1.2,54.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-54.8)'/
&DEVC XYZ=-0.825,1.2,59.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-59.6)'/
&DEVC XYZ=-0.825,1.2,64.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-64.4)'/
&DEVC XYZ=-0.825,1.2,69.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-69.2)'/
&DEVC XYZ=-0.825,1.2,74.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-74.0)'/
&DEVC XYZ=-0.825,1.2,78.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-78.8)'/
&DEVC XYZ=-0.825,1.2,83.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-83.6)'/
&DEVC XYZ=-0.825,1.2,88.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-88.4)'/
&DEVC XYZ=-0.825,1.2,93.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825-1.2-93.2)'/

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&DEVC XYZ=5.625,1.2,4.4, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-4.4)'/ LANDINGS
&DEVC XYZ=5.625,1.2,9.2, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-9.2)'/
&DEVC XYZ=5.625,1.2,14.0, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-14.0)'/
&DEVC XYZ=5.625,1.2,18.8, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-18.8)'/
&DEVC XYZ=5.625,1.2,23.6, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-23.6)'/
&DEVC XYZ=5.625,1.2,28.4, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-28.4)'/
&DEVC XYZ=5.625,1.2,33.2, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-33.2)'/
&DEVC XYZ=5.625,1.2,38.0, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-38.0)'/
&DEVC XYZ=5.625,1.2,42.8, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-42.8)'/
&DEVC XYZ=5.625,1.2,47.6, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-47.6)'/
&DEVC XYZ=5.625,1.2,52.4, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-52.4)'/
&DEVC XYZ=5.625,1.2,57.2, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-57.2)'/
&DEVC XYZ=5.625,1.2,62.0, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-62.0)'/
&DEVC XYZ=5.625,1.2,66.8, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-66.8)'/
&DEVC XYZ=5.625,1.2,71.6, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-71.6)'/
&DEVC XYZ=5.625,1.2,76.4, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-76.4)'/
&DEVC XYZ=5.625,1.2,81.2, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-81.2)'/
&DEVC XYZ=5.625,1.2,86.0, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-86.0)'/
&DEVC XYZ=5.625,1.2,90.8, QUANTITY='VISIBILITY', ID='VIS_(5.625-1.2-90.8)'/

***************FED*******************************************************

&DEVC XYZ=-0.825,1.2,2.0, QUANTITY='FED', ID='FED_(-0.825-1.2-2.0)'/ FLOOR
&DEVC XYZ=-0.825,1.2,6.8, QUANTITY='FED', ID='FED_(-0.825-1.2-6.8)'/
&DEVC XYZ=-0.825,1.2,11.6, QUANTITY='FED', ID='FED_(-0.825-1.2-11.6)'/
&DEVC XYZ=-0.825,1.2,16.4, QUANTITY='FED', ID='FED_(-0.825-1.2-16.4)'/
&DEVC XYZ=-0.825,1.2,21.2, QUANTITY='FED', ID='FED_(-0.825-1.2-21.2)'/
&DEVC XYZ=-0.825,1.2,26.0, QUANTITY='FED', ID='FED_(-0.825-1.2-26.0)'/
&DEVC XYZ=-0.825,1.2,30.8, QUANTITY='FED', ID='FED_(-0.825-1.2-30.8)'/
&DEVC XYZ=-0.825,1.2,35.6, QUANTITY='FED', ID='FED_(-0.825-1.2-35.6)'/
&DEVC XYZ=-0.825,1.2,40.4, QUANTITY='FED', ID='FED_(-0.825-1.2-40.4)'/
&DEVC XYZ=-0.825,1.2,45.2, QUANTITY='FED', ID='FED_(-0.825-1.2-45.2)'/
&DEVC XYZ=-0.825,1.2,50.0, QUANTITY='FED', ID='FED_(-0.825-1.2-50.0)'/
&DEVC XYZ=-0.825,1.2,54.8, QUANTITY='FED', ID='FED_(-0.825-1.2-54.8)'/
&DEVC XYZ=-0.825,1.2,59.6, QUANTITY='FED', ID='FED_(-0.825-1.2-59.6)'/
&DEVC XYZ=-0.825,1.2,64.4, QUANTITY='FED', ID='FED_(-0.825-1.2-64.4)'/
&DEVC XYZ=-0.825,1.2,69.2, QUANTITY='FED', ID='FED_(-0.825-1.2-69.2)'/
&DEVC XYZ=-0.825,1.2,74.0, QUANTITY='FED', ID='FED_(-0.825-1.2-74.0)'/
&DEVC XYZ=-0.825,1.2,78.8, QUANTITY='FED', ID='FED_(-0.825-1.2-78.8)'/
&DEVC XYZ=-0.825,1.2,83.6, QUANTITY='FED', ID='FED_(-0.825-1.2-83.6)'/
&DEVC XYZ=-0.825,1.2,88.4, QUANTITY='FED', ID='FED_(-0.825-1.2-88.4)'/
&DEVC XYZ=-0.825,1.2,93.2, QUANTITY='FED', ID='FED_(-0.825-1.2-93.2)'/

&DEVC XYZ=5.625,1.2,4.4, QUANTITY='FED', ID='FED_(5.625-1.2-4.4)'/ LANDINGS
&DEVC XYZ=5.625,1.2,9.2, QUANTITY='FED', ID='FED_(5.625-1.2-9.2)'/
&DEVC XYZ=5.625,1.2,14.0, QUANTITY='FED', ID='FED_(5.625-1.2-14.0)'/
&DEVC XYZ=5.625,1.2,18.8, QUANTITY='FED', ID='FED_(5.625-1.2-18.8)'/
&DEVC XYZ=5.625,1.2,23.6, QUANTITY='FED', ID='FED_(5.625-1.2-23.6)'/
&DEVC XYZ=5.625,1.2,28.4, QUANTITY='FED', ID='FED_(5.625-1.2-28.4)'/
&DEVC XYZ=5.625,1.2,33.2, QUANTITY='FED', ID='FED_(5.625-1.2-33.2)'/
&DEVC XYZ=5.625,1.2,38.0, QUANTITY='FED', ID='FED_(5.625-1.2-38.0)'/
&DEVC XYZ=5.625,1.2,42.8, QUANTITY='FED', ID='FED_(5.625-1.2-42.8)'/
&DEVC XYZ=5.625,1.2,47.6, QUANTITY='FED', ID='FED_(5.625-1.2-47.6)'/
&DEVC XYZ=5.625,1.2,52.4, QUANTITY='FED', ID='FED_(5.625-1.2-52.4)'/
&DEVC XYZ=5.625,1.2,57.2, QUANTITY='FED', ID='FED_(5.625-1.2-57.2)'/
&DEVC XYZ=5.625,1.2,62.0, QUANTITY='FED', ID='FED_(5.625-1.2-62.0)'/
&DEVC XYZ=5.625,1.2,66.8, QUANTITY='FED', ID='FED_(5.625-1.2-66.8)'/
&DEVC XYZ=5.625,1.2,71.6, QUANTITY='FED', ID='FED_(5.625-1.2-71.6)'/
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&DEVC XYZ=5.625,1.2,76.4, QUANTITY='FED', ID='FED_(5.625-1.2-76.4)'/
&DEVC XYZ=5.625,1.2,81.2, QUANTITY='FED', ID='FED_(5.625-1.2-81.2)'/
&DEVC XYZ=5.625,1.2,86.0, QUANTITY='FED', ID='FED_(5.625-1.2-86.0)'/
&DEVC XYZ=5.625,1.2,90.8, QUANTITY='FED', ID='FED_(5.625-1.2-90.8)'/

***************TEMPERATURE*******************************************************

&DEVC XYZ=-0.825,1.2,2.0, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-2.0)'/ FLOOR
&DEVC XYZ=-0.825,1.2,6.8, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-6.8)'/
&DEVC XYZ=-0.825,1.2,11.6, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-11.6)'/
&DEVC XYZ=-0.825,1.2,16.4, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-16.4)'/
&DEVC XYZ=-0.825,1.2,21.2, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-21.2)'/
&DEVC XYZ=-0.825,1.2,26.0, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-26.0)'/
&DEVC XYZ=-0.825,1.2,30.8, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-30.8)'/
&DEVC XYZ=-0.825,1.2,35.6, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-35.6)'/
&DEVC XYZ=-0.825,1.2,40.4, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-40.4)'/
&DEVC XYZ=-0.825,1.2,45.2, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-45.2)'/
&DEVC XYZ=-0.825,1.2,50.0, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-50.0)'/
&DEVC XYZ=-0.825,1.2,54.8, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-54.8)'/
&DEVC XYZ=-0.825,1.2,59.6, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-59.6)'/
&DEVC XYZ=-0.825,1.2,64.4, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-64.4)'/
&DEVC XYZ=-0.825,1.2,69.2, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-69.2)'/
&DEVC XYZ=-0.825,1.2,74.0, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-74.0)'/
&DEVC XYZ=-0.825,1.2,78.8, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-78.8)'/
&DEVC XYZ=-0.825,1.2,83.6, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-83.6)'/
&DEVC XYZ=-0.825,1.2,88.4, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-88.4)'/
&DEVC XYZ=-0.825,1.2,93.2, QUANTITY='TEMPERATURE', ID='TEMP_(-0.825-1.2-93.2)'/

&DEVC XYZ=5.625,1.2,4.4, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-4.4)'/ LANDINGS
&DEVC XYZ=5.625,1.2,9.2, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-9.2)'/
&DEVC XYZ=5.625,1.2,14.0, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-14.0)'/
&DEVC XYZ=5.625,1.2,18.8, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-18.8)'/
&DEVC XYZ=5.625,1.2,23.6, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-23.6)'/
&DEVC XYZ=5.625,1.2,28.4, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-28.4)'/
&DEVC XYZ=5.625,1.2,33.2, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-33.2)'/
&DEVC XYZ=5.625,1.2,38.0, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-38.0)'/
&DEVC XYZ=5.625,1.2,42.8, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-42.8)'/
&DEVC XYZ=5.625,1.2,47.6, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-47.6)'/
&DEVC XYZ=5.625,1.2,52.4, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-52.4)'/
&DEVC XYZ=5.625,1.2,57.2, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-57.2)'/
&DEVC XYZ=5.625,1.2,62.0, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-62.0)'/
&DEVC XYZ=5.625,1.2,66.8, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-66.8)'/
&DEVC XYZ=5.625,1.2,71.6, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-71.6)'/
&DEVC XYZ=5.625,1.2,76.4, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-76.4)'/
&DEVC XYZ=5.625,1.2,81.2, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-81.2)'/
&DEVC XYZ=5.625,1.2,86.0, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-86.0)'/
&DEVC XYZ=5.625,1.2,90.8, QUANTITY='TEMPERATURE', ID='TEMP_(5.625-1.2-90.8)'/

***************DEVICES IN STAIR 2**************************************************************************

***************VISIBILITY*******************************************************

FLOOR FROM 1ST TO 20TH FLOOR THEN LANDING FROM 1ST TO 20TH FLOOR

&DEVC XYZ=-0.825,-51.0,2.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-2.0)'/ FLOOR
&DEVC XYZ=-0.825,-51.0,6.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-6.8)'/
&DEVC XYZ=-0.825,-51.0,11.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-11.6)'/
&DEVC XYZ=-0.825,-51.0,16.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-16.4)'/

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&DEVC XYZ=-0.825,-51.0,21.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-21.2)'/
&DEVC XYZ=-0.825,-51.0,26.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-26.0)'/
&DEVC XYZ=-0.825,-51.0,30.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-30.8)'/
&DEVC XYZ=-0.825,-51.0,35.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-35.6)'/
&DEVC XYZ=-0.825,-51.0,40.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-40.4)'/
&DEVC XYZ=-0.825,-51.0,45.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-45.2)'/
&DEVC XYZ=-0.825,-51.0,50.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-50.0)'/
&DEVC XYZ=-0.825,-51.0,54.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-54.8)'/
&DEVC XYZ=-0.825,-51.0,59.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-59.6)'/
&DEVC XYZ=-0.825,-51.0,64.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-64.4)'/
&DEVC XYZ=-0.825,-51.0,69.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-69.2)'/
&DEVC XYZ=-0.825,-51.0,74.0, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-74.0)'/
&DEVC XYZ=-0.825,-51.0,78.8, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-78.8)'/
&DEVC XYZ=-0.825,-51.0,83.6, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-83.6)'/
&DEVC XYZ=-0.825,-51.0,88.4, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-88.4)'/
&DEVC XYZ=-0.825,-51.0,93.2, QUANTITY='VISIBILITY', ID='VIS_(-0.825--51.0-93.2)'/

&DEVC XYZ=5.625,-51.0,4.4, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-4.4)'/ LANDINGS
&DEVC XYZ=5.625,-51.0,9.2, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-9.2)'/
&DEVC XYZ=5.625,-51.0,14.0, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-14.0)'/
&DEVC XYZ=5.625,-51.0,18.8, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-18.8)'/
&DEVC XYZ=5.625,-51.0,23.6, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-23.6)'/
&DEVC XYZ=5.625,-51.0,28.4, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-28.4)'/
&DEVC XYZ=5.625,-51.0,33.2, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-33.2)'/
&DEVC XYZ=5.625,-51.0,38.0, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-38.0)'/
&DEVC XYZ=5.625,-51.0,42.8, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-42.8)'/
&DEVC XYZ=5.625,-51.0,47.6, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-47.6)'/
&DEVC XYZ=5.625,-51.0,52.4, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-52.4)'/
&DEVC XYZ=5.625,-51.0,57.2, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-57.2)'/
&DEVC XYZ=5.625,-51.0,62.0, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-62.0)'/
&DEVC XYZ=5.625,-51.0,66.8, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-66.8)'/
&DEVC XYZ=5.625,-51.0,71.6, QUANTITY='VISIBILITY', ID='VIS_(5.625--51.0-71.6)'/
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&DEVC XYZ=5.625,-51.0,81.2, QUANTITY='FED', ID='FED_(5.625--51.0-81.2)'/
&DEVC XYZ=5.625,-51.0,86.0, QUANTITY='FED', ID='FED_(5.625--51.0-86.0)'/
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***************TEMPERATURE*******************************************************

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***************SLICE FILES*****************************************************************

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&SLCF PBY=1.8, QUANTITY='VISIBILITY' / Slice at stair 1
&SLCF PBY=-50.4, QUANTITY='VISIBILITY' / Slice at stair 2
&SLCF PBY=-51.6, QUANTITY='VISIBILITY' / Slice at stair 2

&SLCF PBZ=45.2, QUANTITY='TEMPERATURE' / Slice at 2 m above fire floor 10th floor
&SLCF PBZ=50.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 11th floor
&SLCF PBY=0.6, QUANTITY='TEMPERATURE' / Slice at stair 1
&SLCF PBY=1.8, QUANTITY='TEMPERATURE' / Slice at stair 1
&SLCF PBY=-50.4, QUANTITY='TEMPERATURE' / Slice at stair 2
&SLCF PBY=-51.6, QUANTITY='TEMPERATURE' / Slice at stair 2

Stair 1 and 2 (Floors and landing slice files)

***********Floors**********************************************************

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&SLCF PBZ=21.2, QUANTITY='VISIBILITY' / Slice at 2 m above 5th floor stair
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&SLCF PBZ=30.8, QUANTITY='VISIBILITY' / Slice at 2 m above 7th floor stair
&SLCF PBZ=35.6, QUANTITY='VISIBILITY' / Slice at 2 m above 8th floor stair
&SLCF PBZ=40.4, QUANTITY='VISIBILITY' / Slice at 2 m above 9th floor stair
&SLCF PBZ=54.8, QUANTITY='VISIBILITY' / Slice at 2 m above 12th floor stair
&SLCF PBZ=59.6, QUANTITY='VISIBILITY' / Slice at 2 m above 13th floor stair
&SLCF PBZ=64.4, QUANTITY='VISIBILITY' / Slice at 2 m above 14th floor stair
&SLCF PBZ=69.2, QUANTITY='VISIBILITY' / Slice at 2 m above 15th floor stair
&SLCF PBZ=74.0, QUANTITY='VISIBILITY' / Slice at 2 m above 16th floor stair
&SLCF PBZ=78.8, QUANTITY='VISIBILITY' / Slice at 2 m above 17th floor stair
&SLCF PBZ=83.6, QUANTITY='VISIBILITY' / Slice at 2 m above 18th floor stair
&SLCF PBZ=88.4, QUANTITY='VISIBILITY' / Slice at 2 m above 19th floor stair
&SLCF PBZ=93.2, QUANTITY='VISIBILITY' / Slice at 2 m above 20th floor stair

&SLCF PBZ=2.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 1st floor stair
&SLCF PBZ=6.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 2nd floor stair
&SLCF PBZ=11.6, QUANTITY='TEMPERATURE' / Slice at 2 m above 3rd floor stair
&SLCF PBZ=16.4, QUANTITY='TEMPERATURE' / Slice at 2 m above 4th floor stair
&SLCF PBZ=21.2, QUANTITY='TEMPERATURE' / Slice at 2 m above 5th floor stair
&SLCF PBZ=26.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 6th floor stair
&SLCF PBZ=30.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 7th floor stair
&SLCF PBZ=35.6, QUANTITY='TEMPERATURE' / Slice at 2 m above 8th floor stair
&SLCF PBZ=40.4, QUANTITY='TEMPERATURE' / Slice at 2 m above 9th floor stair
&SLCF PBZ=54.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 12th floor stair
&SLCF PBZ=59.6, QUANTITY='TEMPERATURE' / Slice at 2 m above 13th floor stair
&SLCF PBZ=64.4, QUANTITY='TEMPERATURE' / Slice at 2 m above 14th floor stair

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&SLCF PBZ=69.2, QUANTITY='TEMPERATURE' / Slice at 2 m above 15th floor stair
&SLCF PBZ=74.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 16th floor stair
&SLCF PBZ=78.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 17th floor stair
&SLCF PBZ=83.6, QUANTITY='TEMPERATURE' / Slice at 2 m above 18th floor stair
&SLCF PBZ=88.4, QUANTITY='TEMPERATURE' / Slice at 2 m above 19th floor stair
&SLCF PBZ=93.2, QUANTITY='TEMPERATURE' / Slice at 2 m above 20th floor stair

***********Landings**********************************************************

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&SLCF PBZ=18.8, QUANTITY='VISIBILITY' / Slice at 2 m above 4th floor landing
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&SLCF PBZ=33.2, QUANTITY='VISIBILITY' / Slice at 2 m above 7th floor landing
&SLCF PBZ=38.0, QUANTITY='VISIBILITY' / Slice at 2 m above 8th floor landing
&SLCF PBZ=42.8, QUANTITY='VISIBILITY' / Slice at 2 m above 9th floor landing
&SLCF PBZ=47.6, QUANTITY='VISIBILITY' / Slice at 2 m above 10th floor landing
&SLCF PBZ=52.4, QUANTITY='VISIBILITY' / Slice at 2 m above 11th floor landing
&SLCF PBZ=57.2, QUANTITY='VISIBILITY' / Slice at 2 m above 12th floor landing
&SLCF PBZ=62.0, QUANTITY='VISIBILITY' / Slice at 2 m above 13th floor landing
&SLCF PBZ=66.8, QUANTITY='VISIBILITY' / Slice at 2 m above 14th floor landing
&SLCF PBZ=71.6, QUANTITY='VISIBILITY' / Slice at 2 m above 15th floor landing
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&SLCF PBZ=81.2, QUANTITY='VISIBILITY' / Slice at 2 m above 17th floor landing
&SLCF PBZ=86.0, QUANTITY='VISIBILITY' / Slice at 2 m above 18th floor landing
&SLCF PBZ=90.8, QUANTITY='VISIBILITY' / Slice at 2 m above 19th floor landing

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&SLCF PBZ=14.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 3rd floor landing
&SLCF PBZ=18.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 4th floor landing
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&SLCF PBZ=71.6, QUANTITY='TEMPERATURE' / Slice at 2 m above 15th floor landing
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&SLCF PBZ=86.0, QUANTITY='TEMPERATURE' / Slice at 2 m above 18th floor landing
&SLCF PBZ=90.8, QUANTITY='TEMPERATURE' / Slice at 2 m above 19th floor landing

&TAIL /
```

# Appendix C – Second Order Hydraulic Model

## C1 Medium floor

SUM =D24+$B$3

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Time to clear each floor (except 10th level) | 95 | s | Time (s) | Event |
| 2 | Time to travel between floors | 26 | s | 0 | 10th level starts evacuating |
| 3 | Time to clear 10th level | 64 | s | 30 | 28 persons in stairwell; rest of building starts to evacuate |
| 4 | | | | 71 | Stairwell filled to optimum density |
| 5 | | | | 166 | 20th level clear |
| 6 | | | | 192 | Queue on 19th level landing |
| 7 | | | | 287 | 19th level clear |
| 8 | | | | 313 | Queue on 18th level landing |
| 9 | | | | 408 | 18th level clear |
| 10 | | | | 434 | Queue on 17th level landing |
| 11 | | | | 529 | 17th level clear |
| 12 | | | | 555 | Queue on 16th level landing |
| 13 | | | | 650 | 16th level clear |
| 14 | | | | 676 | Queue on 15th level landing |
| 15 | | | | 771 | 15th level clear |
| 16 | | | | 797 | Queue on 14th level landing |
| 17 | | | | 892 | 14th level clear |
| 18 | | | | 918 | Queue on 13th level landing |
| 19 | | | | 1013 | 13th level clear |
| 20 | | | | 1039 | Queue on 12th level landing |
| 21 | | | | 1134 | 12th level clear |
| 22 | | | | 1160 | Queue on 11th level landing |
| 23 | | | | 1255 | 11th level clear |
| 24 | | | | 1281 | Queue on 10th level landing |
| 25 | | | | =D24+$B | 10th level clear |
| 26 | | | | 1371 | Queue on 9th level landing |
| 27 | | | | 1466 | 9th level clear |
| 28 | | | | 1492 | Queue on 8th level landing |
| 29 | | | | 1587 | 8th level clear |
| 30 | | | | 1613 | Queue on 7th level landing |
| 31 | | | | 1708 | 7th level clear |
| 32 | | | | 1734 | Queue on 68th level landing |
| 33 | | | | 1829 | 6th level clear |
| 34 | | | | 1855 | Queue on 5th level landing |
| 35 | | | | 1950 | 5th level clear |
| 36 | | | | 1976 | Queue on 4th level landing |
| 37 | | | | 2071 | 4th level clear |
| 38 | | | | 2097 | Queue on 3rd level landing |
| 39 | | | | 2192 | 3rd level clear |
| 40 | | | | 2218 | Queue on 2nd level landing |
| 41 | | | | 2313 | 2nd level clear |
| 42 | | | | 2339 | Queue on 1st level landing (out of building |

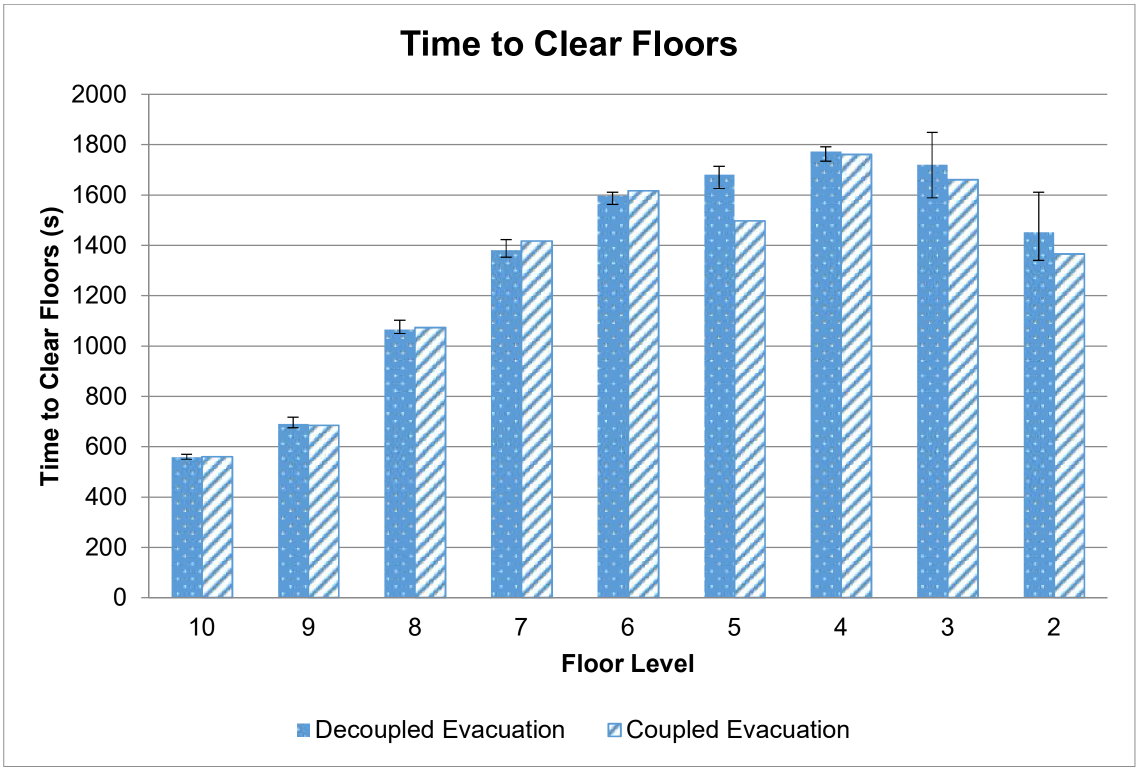
## C2 Large floor

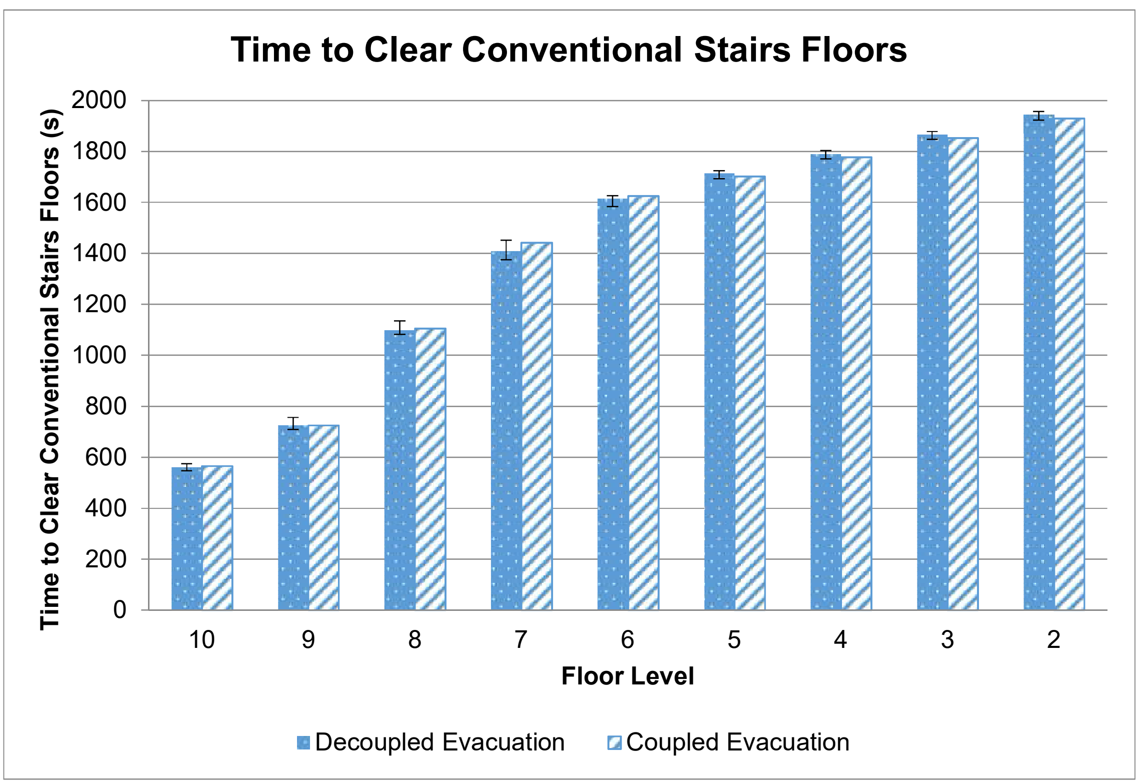
SUM | =D24+$B$3

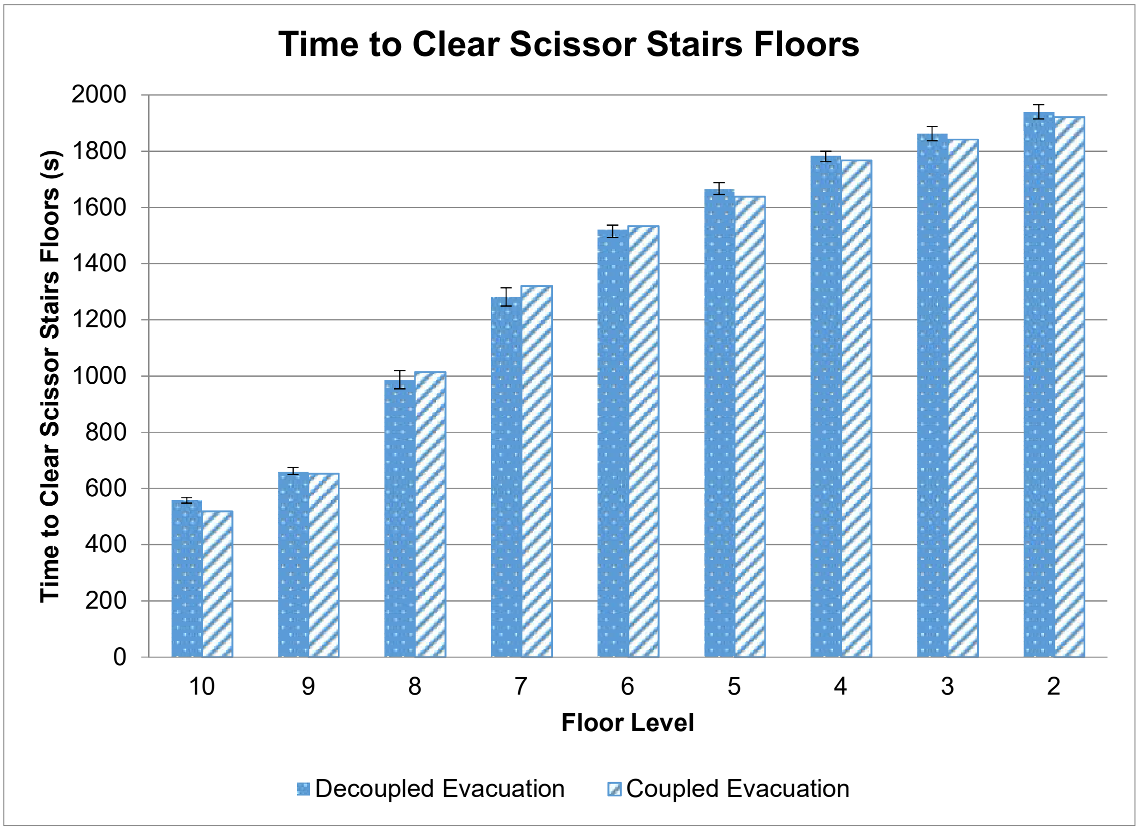
| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Time to clear each floor (except 10th level) | 187 | s | Time (s) | Event |
| 2 | Time to travel between floors | 34 | s | 0 | 10th level starts evacuating |
| 3 | Time to clear 10th level | 156 | s | 30 | 28 persons in stairwell; rest of building starts to evacuate |
| 4 | | | | 118 | Stairwell filled to optimum density |
| 5 | | | | 305 | 20th level clear |
| 6 | | | | 339 | Queue on 19th level landing |
| 7 | | | | 526 | 19th level clear |
| 8 | | | | 560 | Queue on 18th level landing |
| 9 | | | | 747 | 18th level clear |
| 10 | | | | 781 | Queue on 17th level landing |
| 11 | | | | 968 | 17th level clear |
| 12 | | | | 1002 | Queue on 16th level landing |
| 13 | | | | 1189 | 16th level clear |
| 14 | | | | 1223 | Queue on 15th level landing |
| 15 | | | | 1410 | 15th level clear |
| 16 | | | | 1444 | Queue on 14th level landing |
| 17 | | | | 1631 | 14th level clear |
| 18 | | | | 1665 | Queue on 13th level landing |
| 19 | | | | 1852 | 13th level clear |
| 20 | | | | 1886 | Queue on 12th level landing |
| 21 | | | | 2073 | 12th level clear |
| 22 | | | | 2107 | Queue on 11th level landing |
| 23 | | | | 2294 | 11th level clear |
| 24 | | | | 2328 | Queue on 10th level landing |
| 25 | | | | =D24+$B | 10th level clear |
| 26 | | | | 2518 | Queue on 9th level landing |
| 27 | | | | 2705 | 9th level clear |
| 28 | | | | 2739 | Queue on 8th level landing |
| 29 | | | | 2926 | 8th level clear |
| 30 | | | | 2960 | Queue on 7th level landing |
| 31 | | | | 3147 | 7th level clear |
| 32 | | | | 3181 | Queue on 68th level landing |
| 33 | | | | 3368 | 6th level clear |
| 34 | | | | 3402 | Queue on 5th level landing |
| 35 | | | | 3589 | 5th level clear |
| 36 | | | | 3623 | Queue on 4th level landing |
| 37 | | | | 3810 | 4th level clear |
| 38 | | | | 3844 | Queue on 3rd level landing |
| 39 | | | | 4031 | 3rd level clear |
| 40 | | | | 4065 | Queue on 2nd level landing |
| 41 | | | | 4252 | 2nd level clear |
| 42 | | | | 4286 | Queue on 1st level landing (out of building |

# Appendix D – Fire Evacuations Vs Evacuation Drills

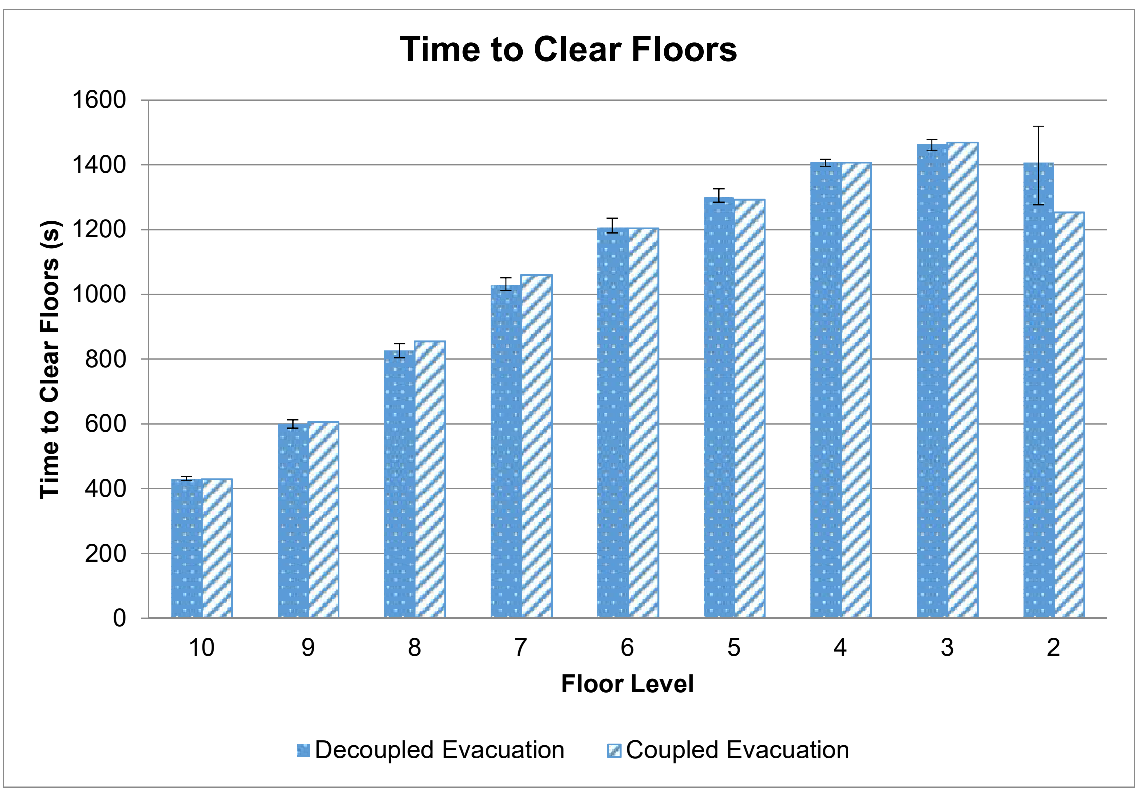
## D1 Coupled Vs. Decoupled (L_10_T6_T_2.7)

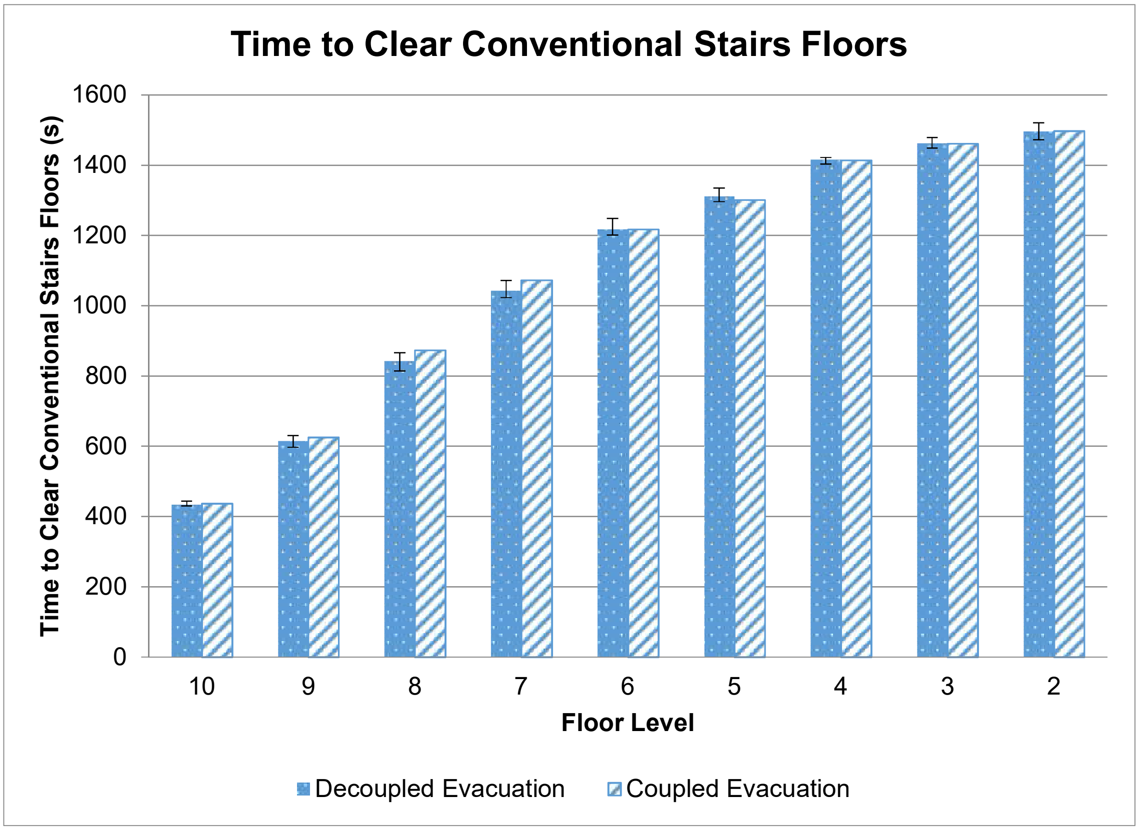


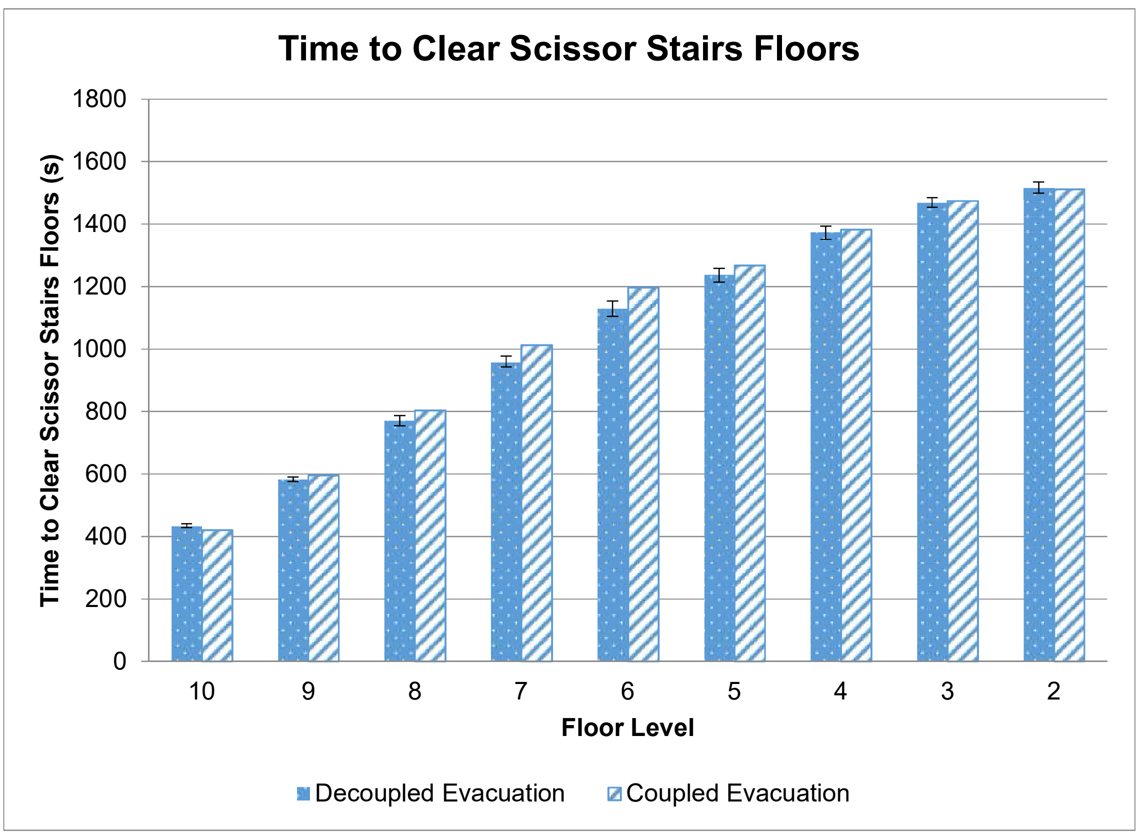





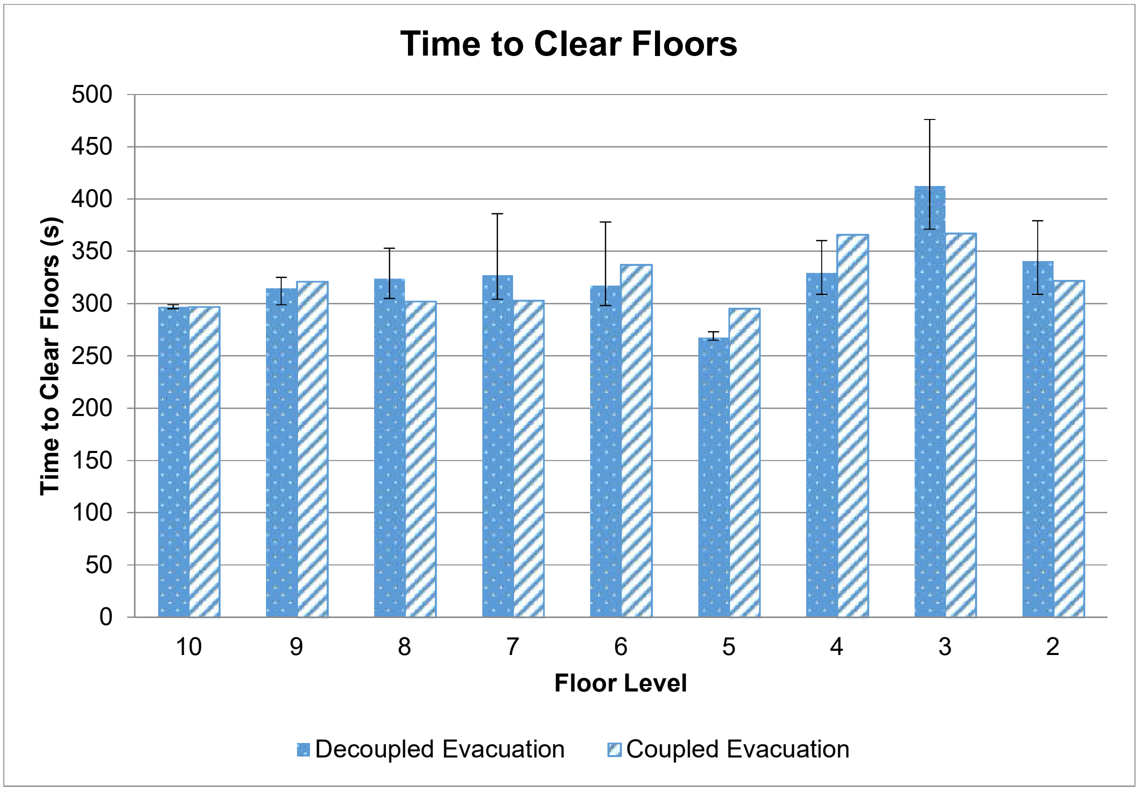

**D2 Coupled Vs. Decoupled (M_10_T6_T_2.7)**

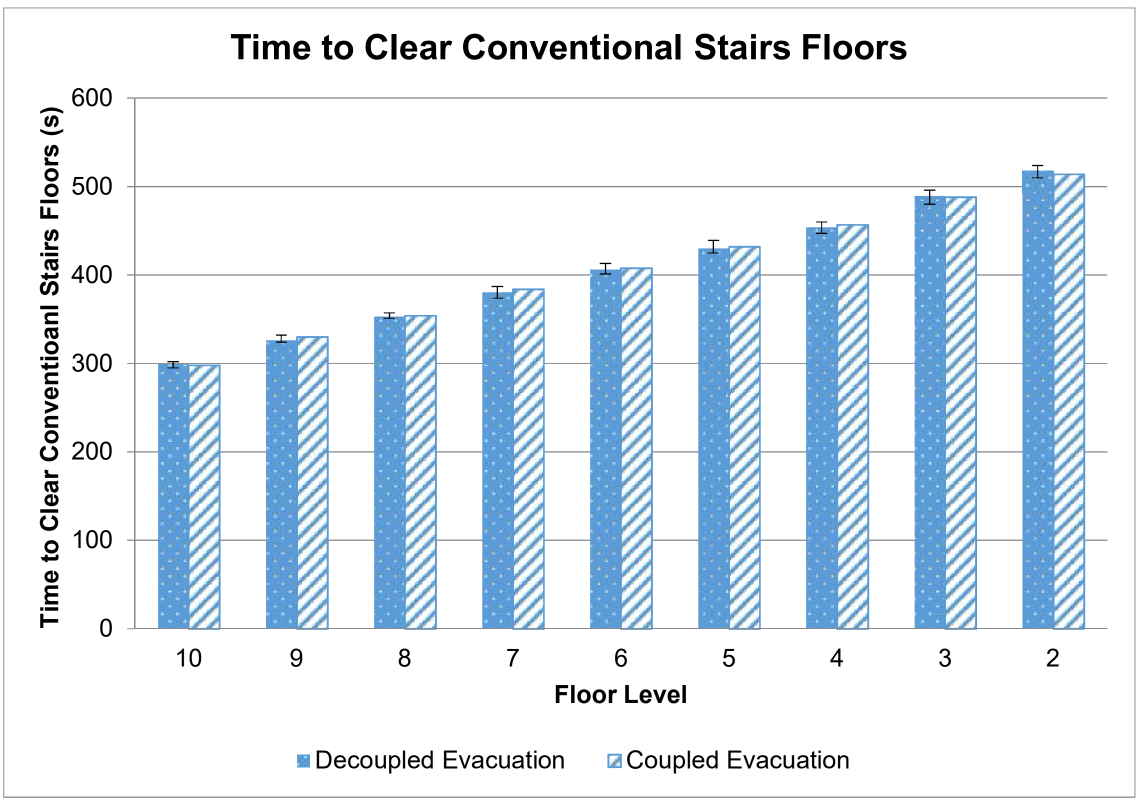


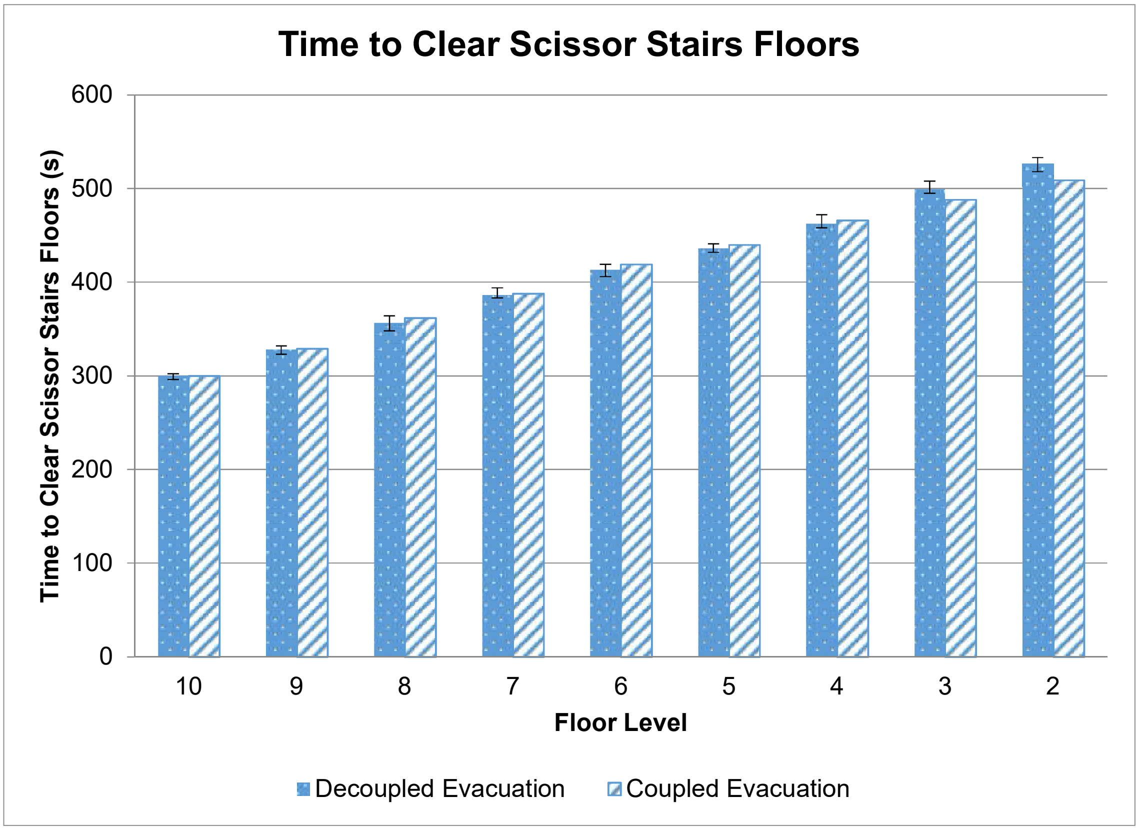

Time to Clear Conventional Stairs Floors
Time to Clear Conventional Stairs Floors (s)
1600
1400
1200
1000
800
600
400
200
0
10
9
8
7
6
5
4
3
2
Floor Level
Decoupled Evacuation
Coupled Evacuation


Time to Clear Scissor Stairs Floors
Time to Clear Scissor Stairs Floors (s)
1800
1600
1400
1200
1000
800
600
400
200
0
10
9
8
7
6
5
4
3
2
Floor Level
Decoupled Evacuation
Coupled Evacuation

## D3 Coupled Vs. Decoupled (S_10_T6_T_2.7)






## D4 Overall Remark

It is evident from the analysis that the movement of people in the floor spaces, conventional and scissor stairs for simulations L_10_T6_T_2.7, M_10_T6_T_2.7 and S_10_T6_T_2.7 are comparable with or without the effect of smoke. This is likely due to congestion within the stairwell having a greater slowing effect than the smoke.

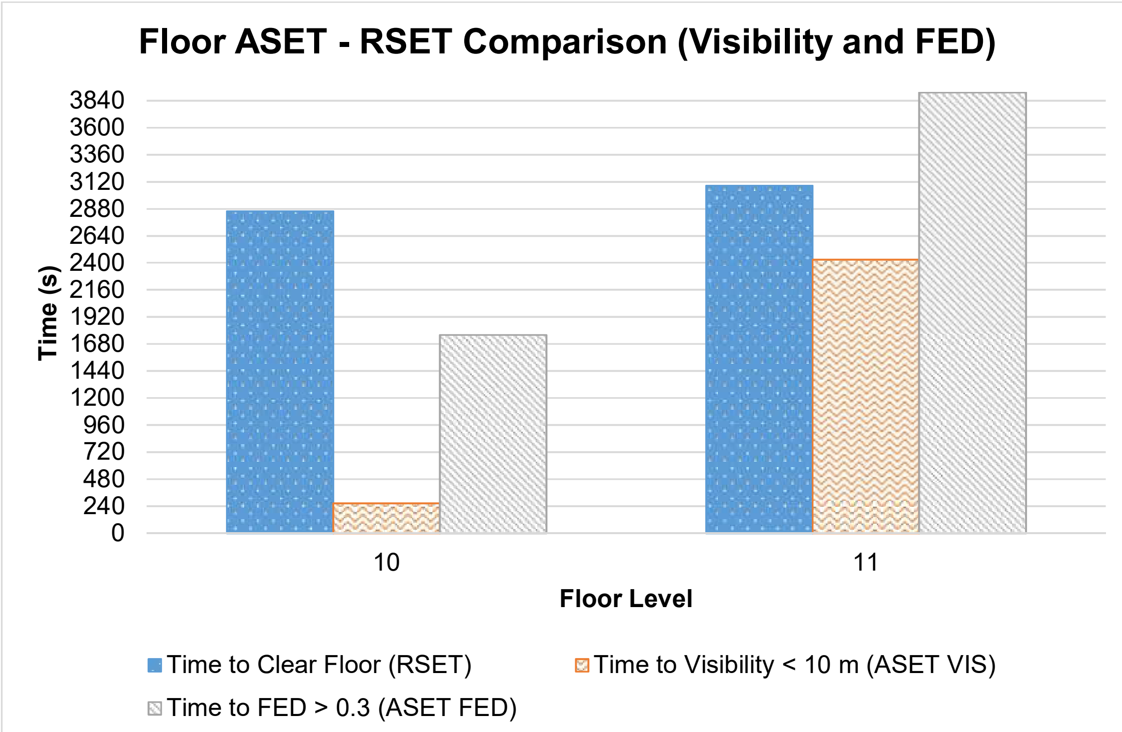
## Appendix E – Simulation Pre-analysed Results

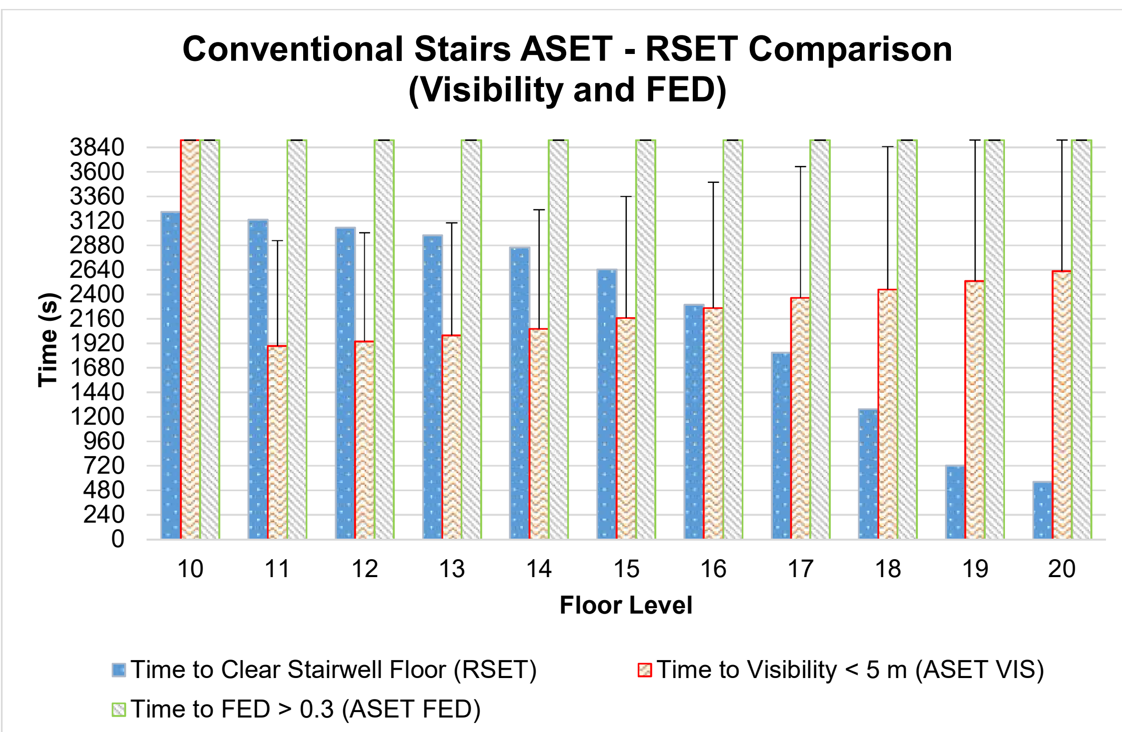
Due to the size of the simulation pre-analysed results, it is not practical to include them within this thesis report. The simulation pre-analysed results are stored on external hard drives. Please contact **Charles Fleischmann** to request for a copy.

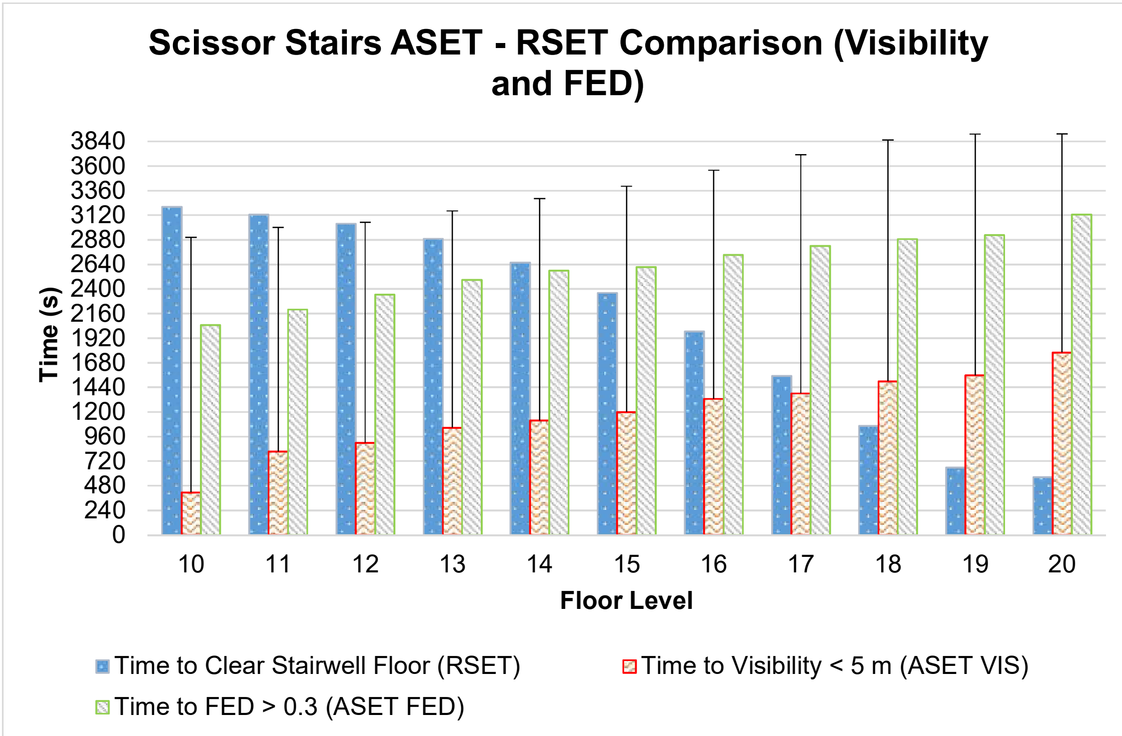
Contact email: charles.fleischmann@canterbury.ac.nz

# Appendix F – Analysis of Simulations

## F1 L_20_T6_T_2.7




Scissor Stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
0
240
480
720
960
1200
1440
1680
1920
2160
2400
2640
2880
3120
3360
3600
3840
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 3915 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 2860 s |
| Visibility < 10 m | Yes (266/-)* |
| FED > 0.3 | Yes (1760)** |
| Maximum temperature | 70°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 3086 s |
| Visibility < 10 m | Yes (2430/-)* |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (11th to 16th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 11th – 1895 s/1031 s<br>12th – 1940 s/1062 s<br>20th – 2629 s/>1286 s*** |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 416 s/2487 s<br>11th – 816 s/2184 s<br>20th – 1782 s/>2133 s*** |
| FED > 0.3 | Yes (10th to 14th floor) |
| Maximum temperature | 50°C (Fire Floor) |

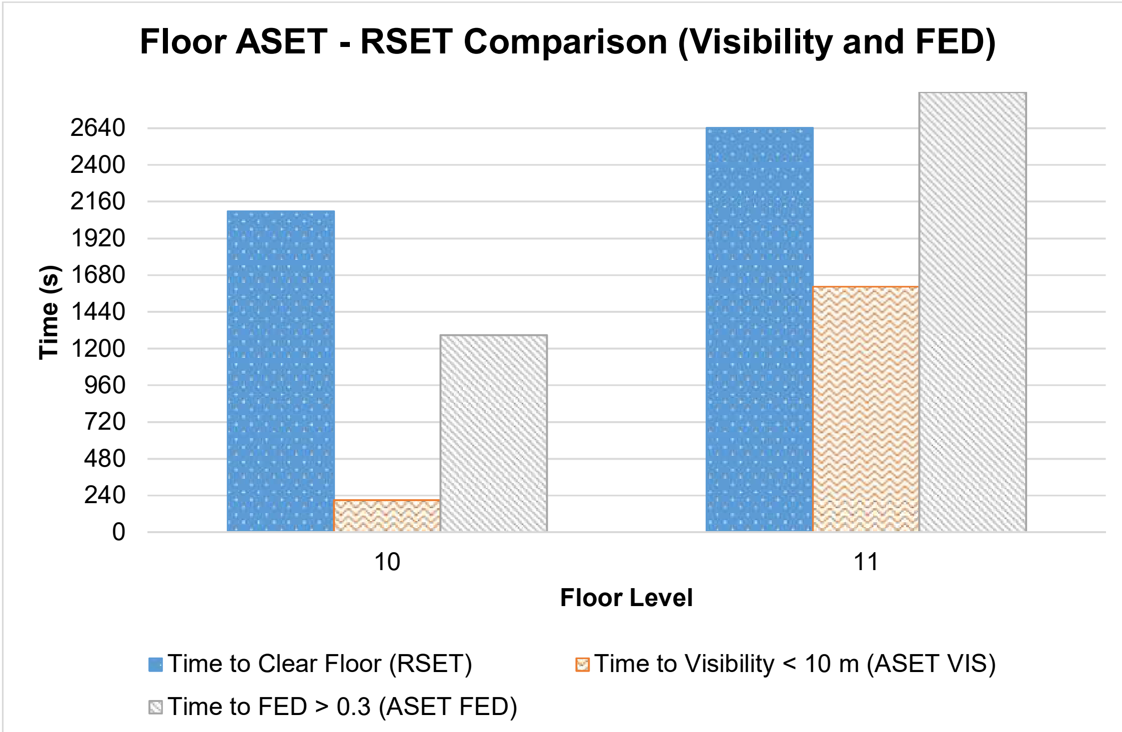
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

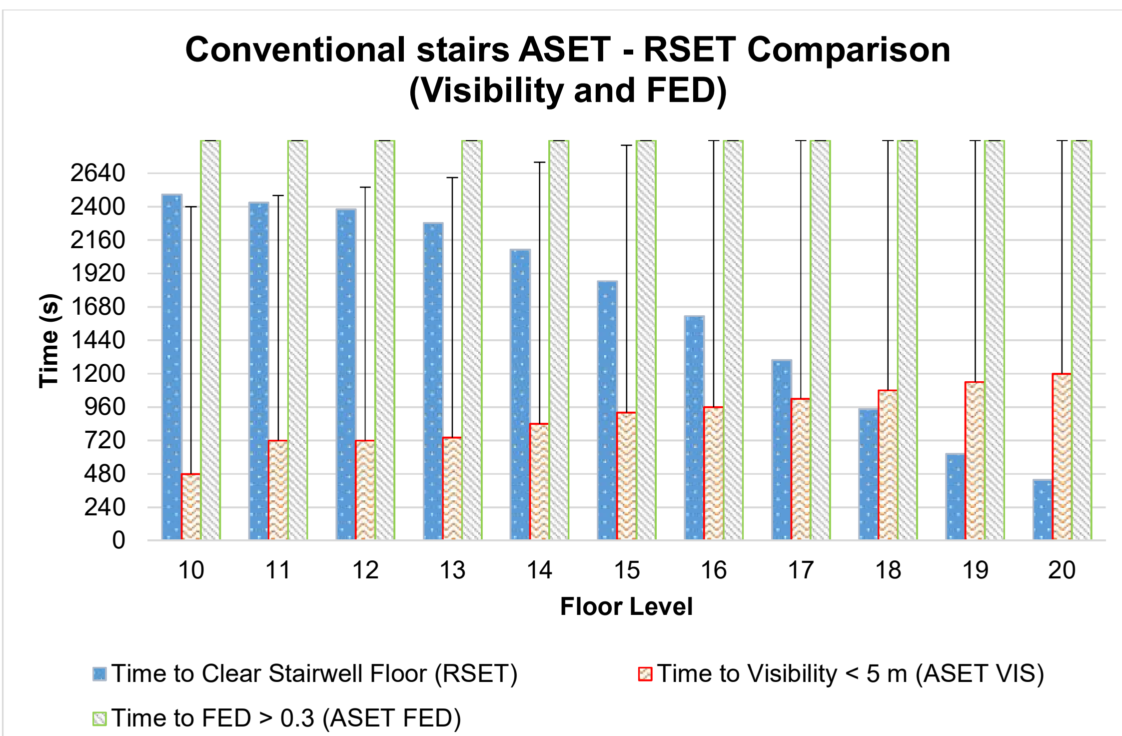
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

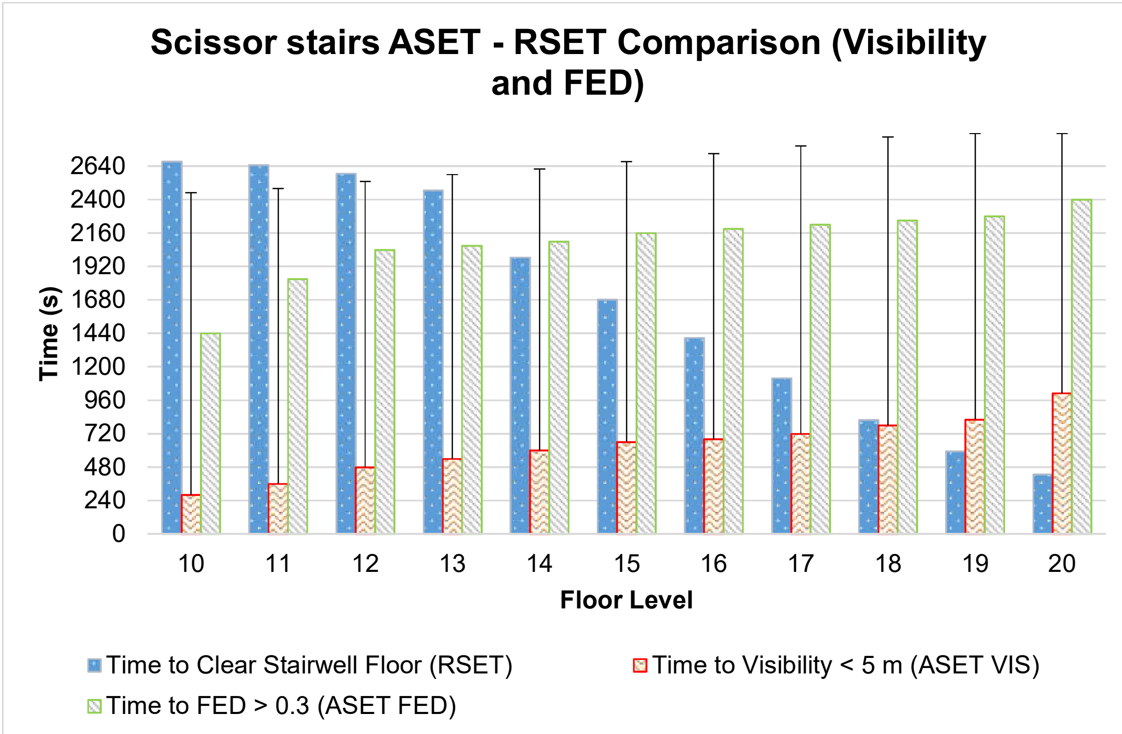
**F2 M_20_T6_T_2.7**



Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)


Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| | |
|---|---|
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 2875 s<br>Coupled Simulation | |
| **Fire Floor (10th floor)** | |
| Time to Clear | 2098 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | Yes (1288)** |
| Maximum temperature | 90°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2643 s |
| Visibility < 10 m | Yes (1605/-)* |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2326 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 480 s/1920 s<br>11th – 720 s/1760 s<br>20th – 1200 s/>1675 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (2329 occupants)** | |
| Visibility < 5 m | Yes (10th to 18th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 280 s/2170 s<br>11th – 360 s/2120 s<br>20th – 1010 s/>1865 s*** |
| FED > 0.3 | Yes (10th to 13th floor) |
| Maximum temperature | 70°C (Fire Floor) |

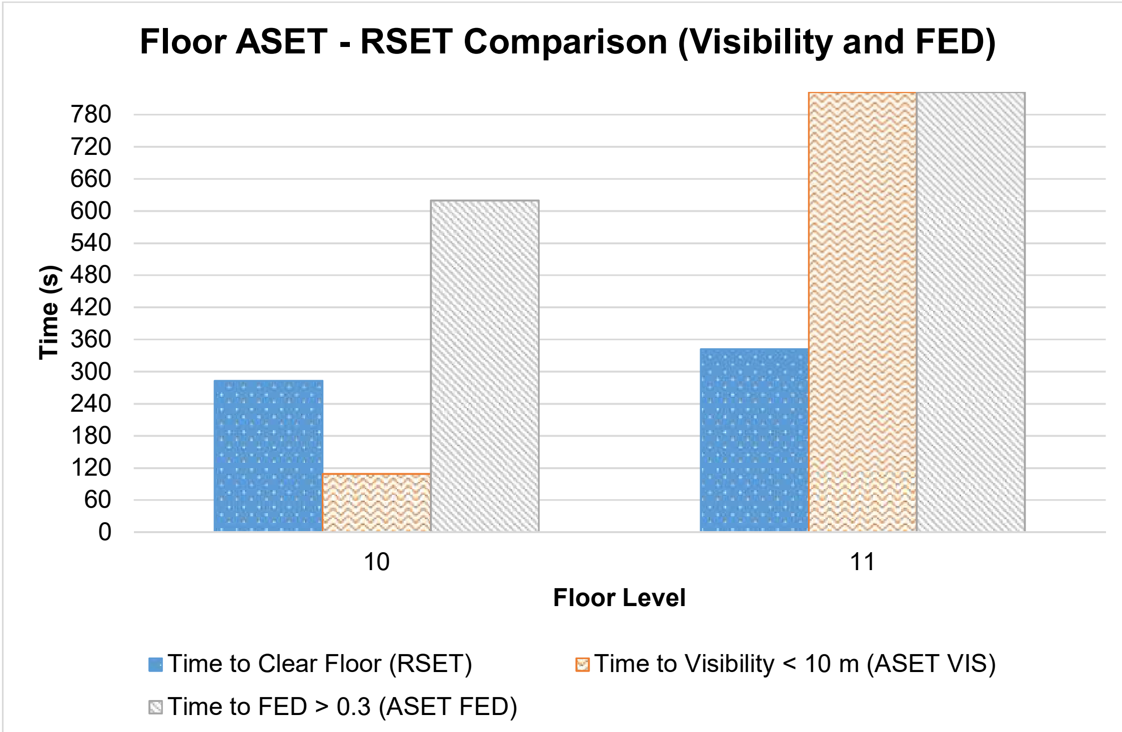
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

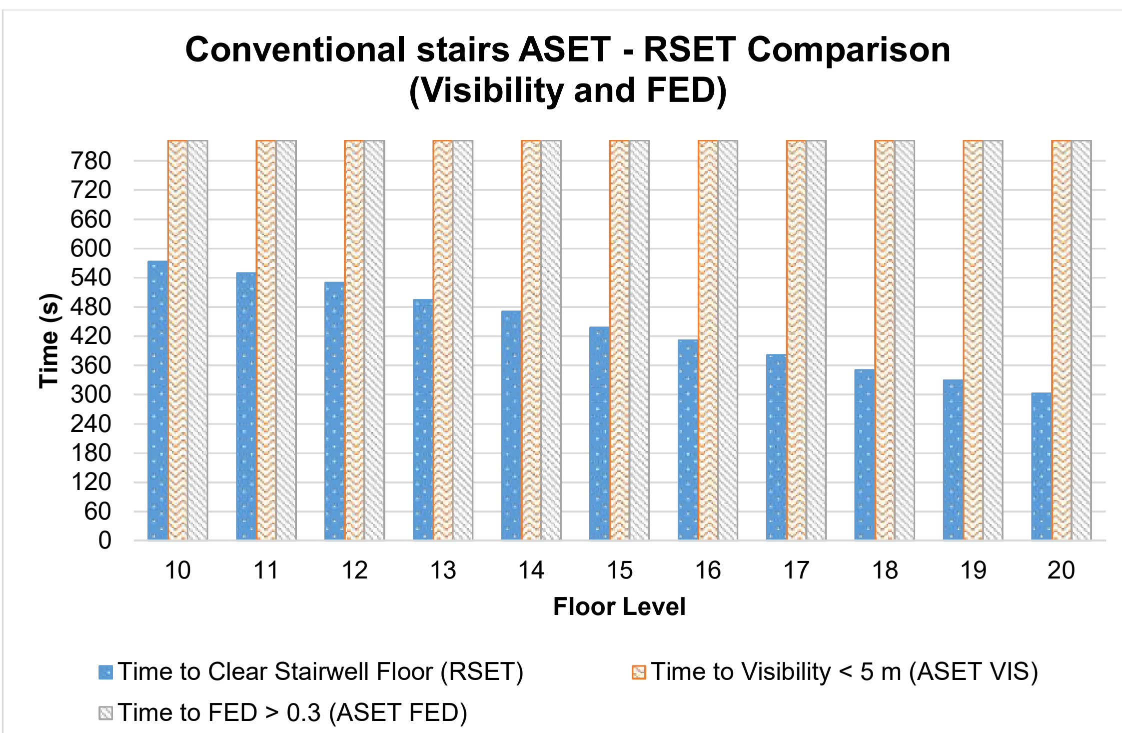
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

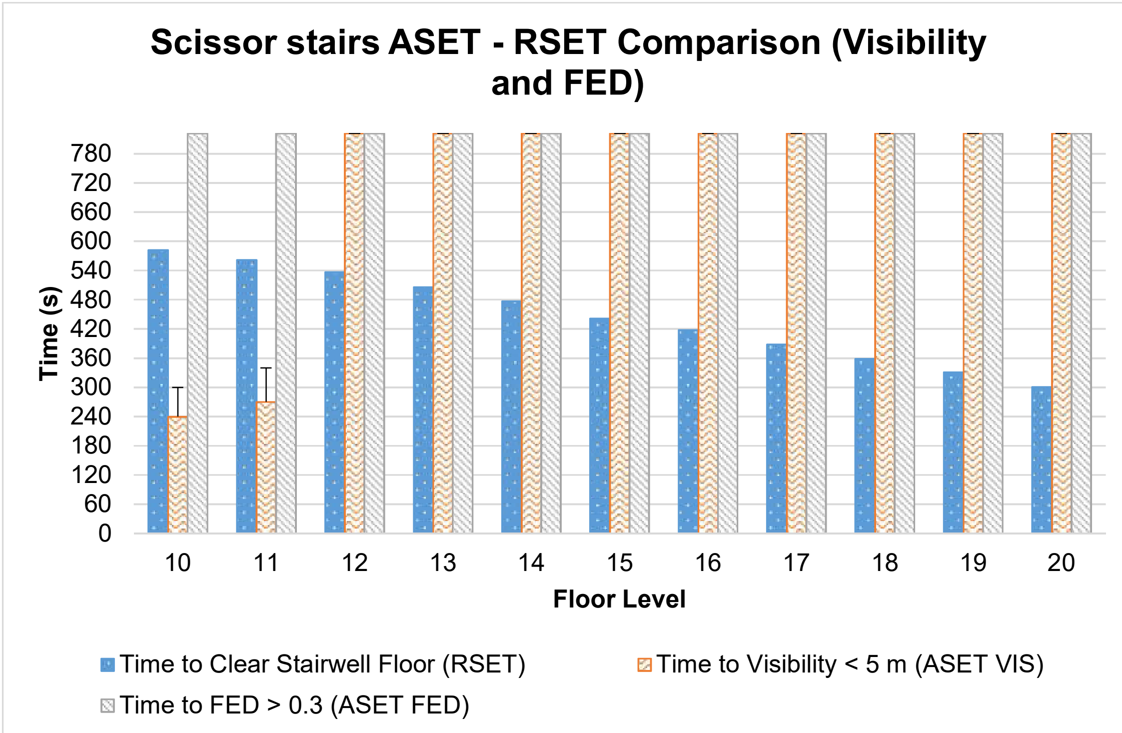
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F3 S_20_T6_T_2.7**


Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
780
720
660
600
540
480
420
360
300
240
180
120
60
0
10
11
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)


Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
780
720
660
600
540
480
420
360
300
240
180
120
60
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

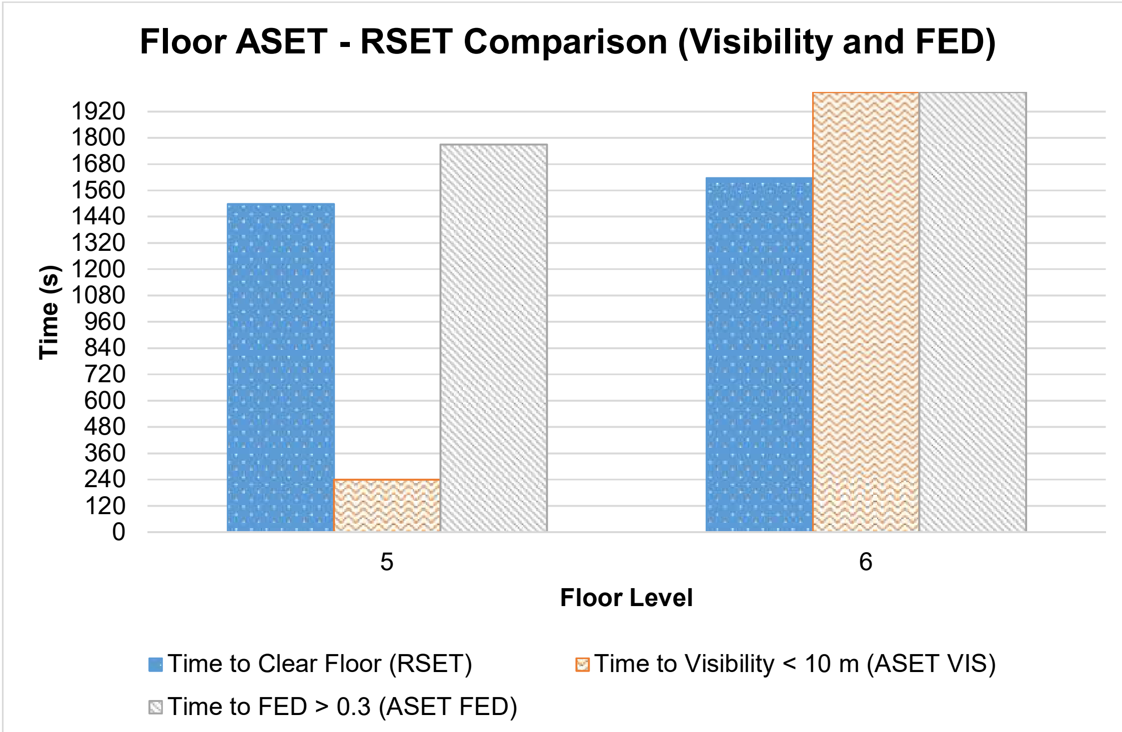

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
0
60
120
180
240
300
360
420
480
540
600
660
720
780
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| Tenability conditions during evacuation period<br>Total Evacuation Time: 822 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 283 s |
| Visibility < 10 m | Yes (109/-)* |
| FED > 0.3 | No |
| Maximum temperature | 110°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 342 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (475 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (494 occupants)** | |
| Visibility < 5 m | Yes (10th and 11th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 240 s/60 s<br>11th – 270 s/70 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 100°C (Fire Floor) |

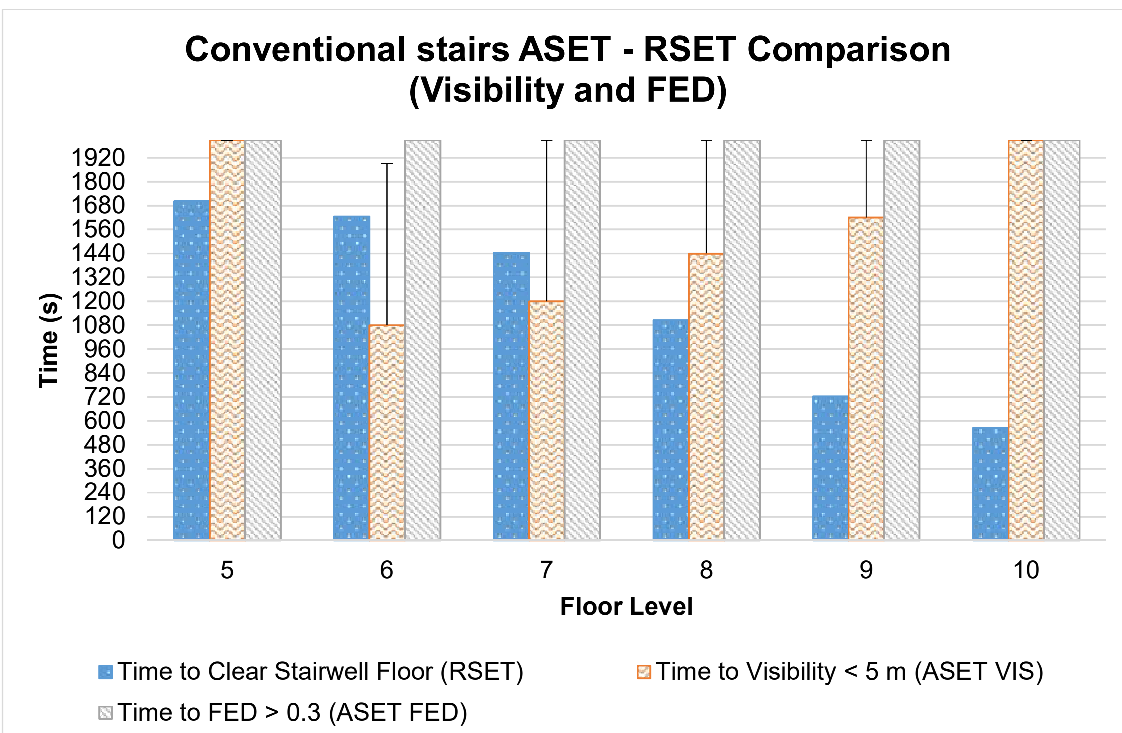
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

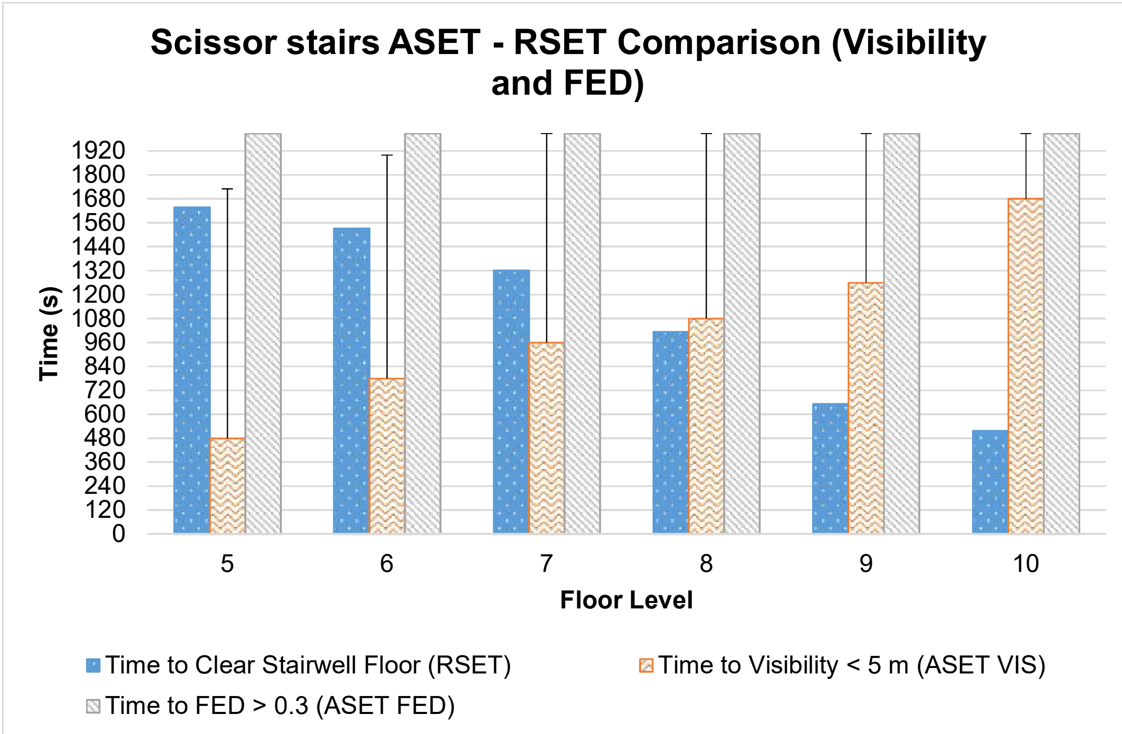
**F4 L_10_T6_T_2.7**



Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)



Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

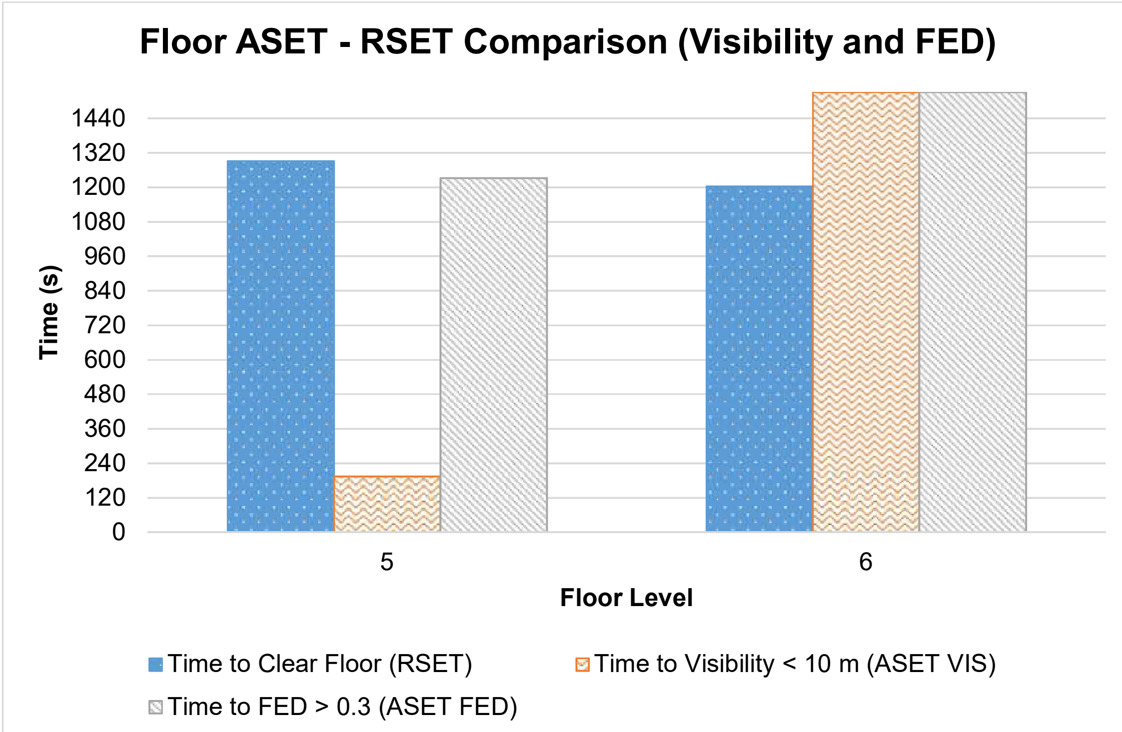
| Tenability conditions during evacuation period<br>Total Evacuation Time: 2008 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear | 1498 s |
| Visibility < 10 m | Yes (240/-)* |
| FED > 0.3 | No |
| Maximum temperature | 60°C |
| **Floor Above (6th floor)** | |
| Time to Clear | 1618 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2253 occupants)** | |
| Visibility < 5 m | Yes (6th and 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – NEVER/0 s<br>6th – 1080 s/810 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (2247 occupants)** | |
| Visibility < 5 m | Yes (5th to 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 480 s/1250 s<br>6th – 780 s/1120 s<br>10th – 1680 s/>328 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |

* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

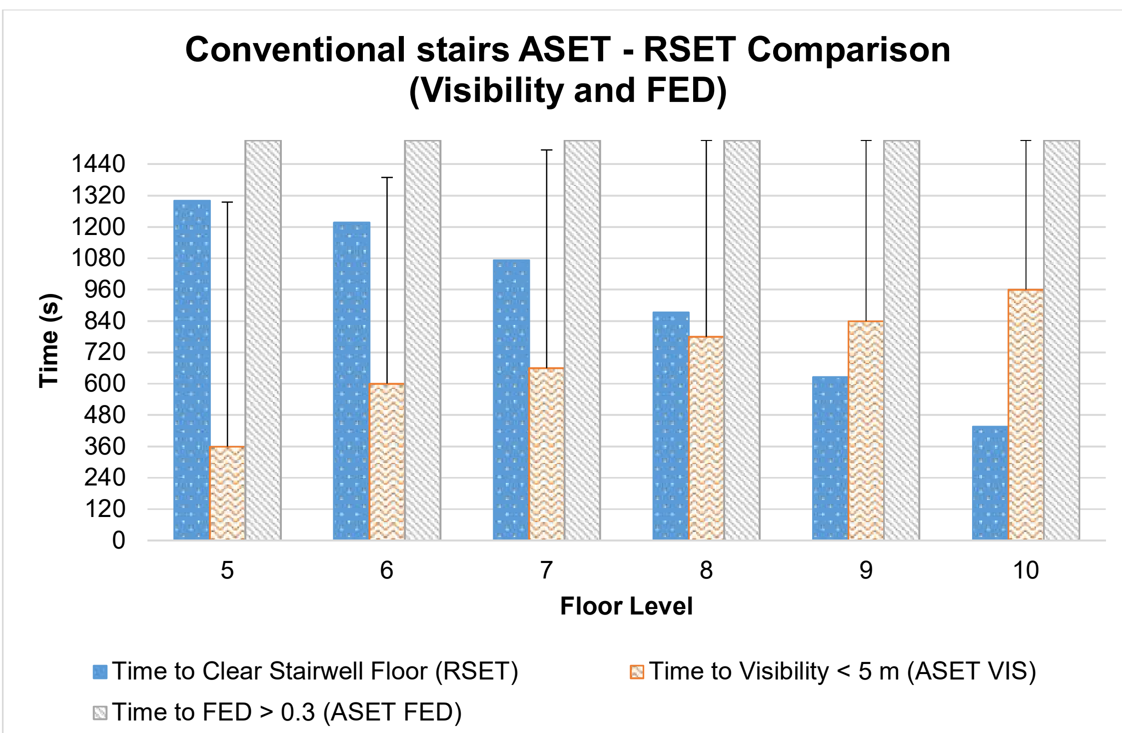
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

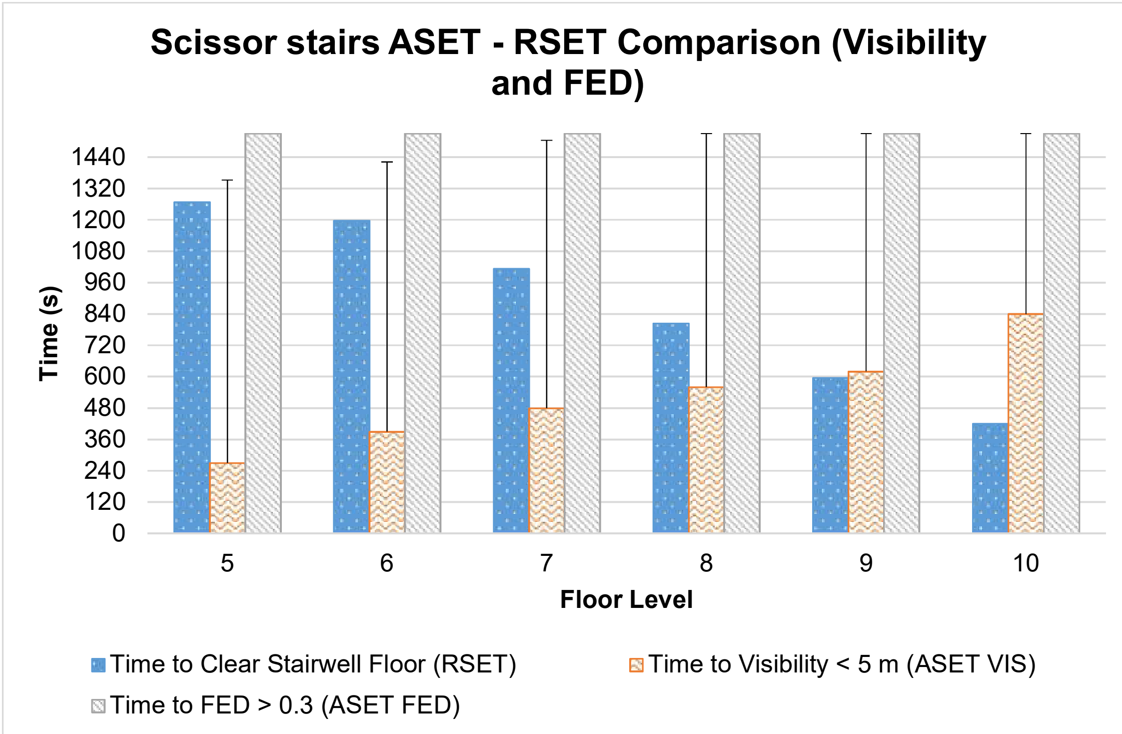
**F5 M_10_T6_T_2.7**



Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)



Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 1531 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor ($5^{th}$ floor)** | |
| Time to Clear | 1292 s |
| Visibility < 10 m | Yes (195/-)* |
| FED > 0.3 | Yes (1232)** |
| Maximum temperature | 80$^{o}$C |
| **Floor Above ($6^{th}$ floor)** | |
| Time to Clear | 1204 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25$^{o}$C |
| **Conventional stairs (1098 occupants)** | |
| Visibility < 5 m | Yes ($5^{th}$ and $8^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $5^{th}$ – 360 s/935 s;<br>$6^{th}$ – 600 s/790 s;<br>$10^{th}$ – 960 s/>571 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50$^{o}$C (Fire Floor) |
| **Scissor stairs (1107 occupants)** | |
| Visibility < 5 m | Yes ($5^{th}$ to $8^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $5^{th}$ – 270 s/1082 s<br>$6^{th}$ – 390 s/1032 s;<br>$10^{th}$ – 840 s/>691 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50$^{o}$C (Fire Floor) |

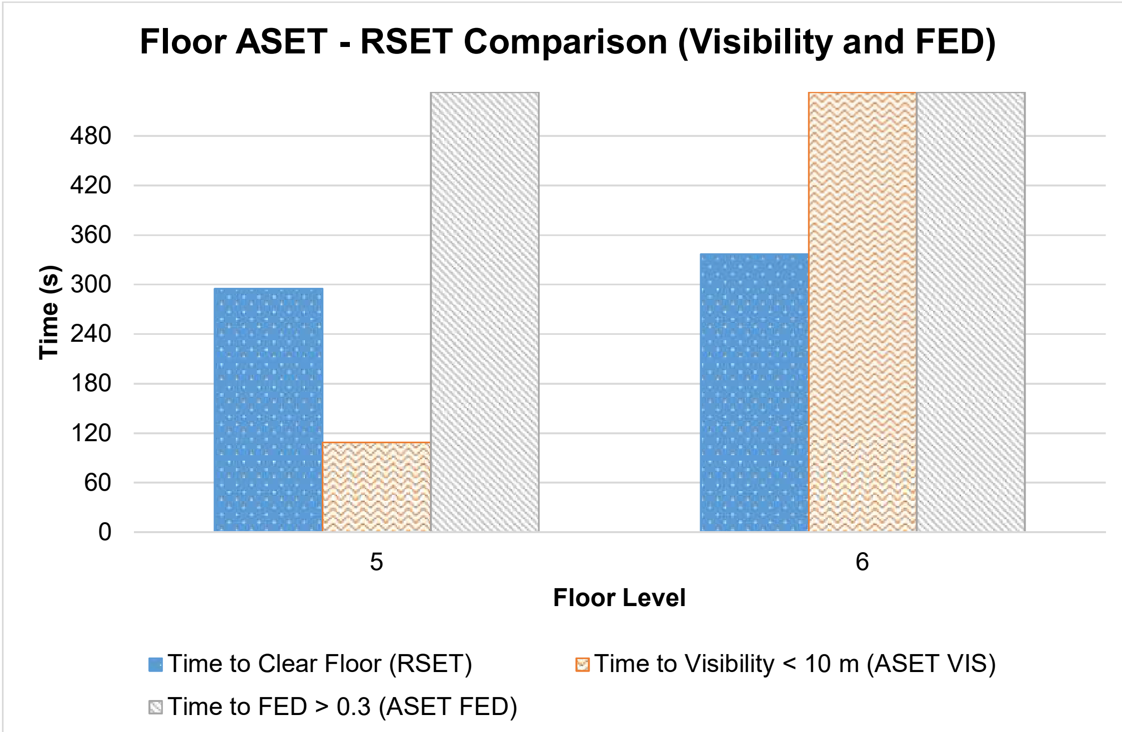
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

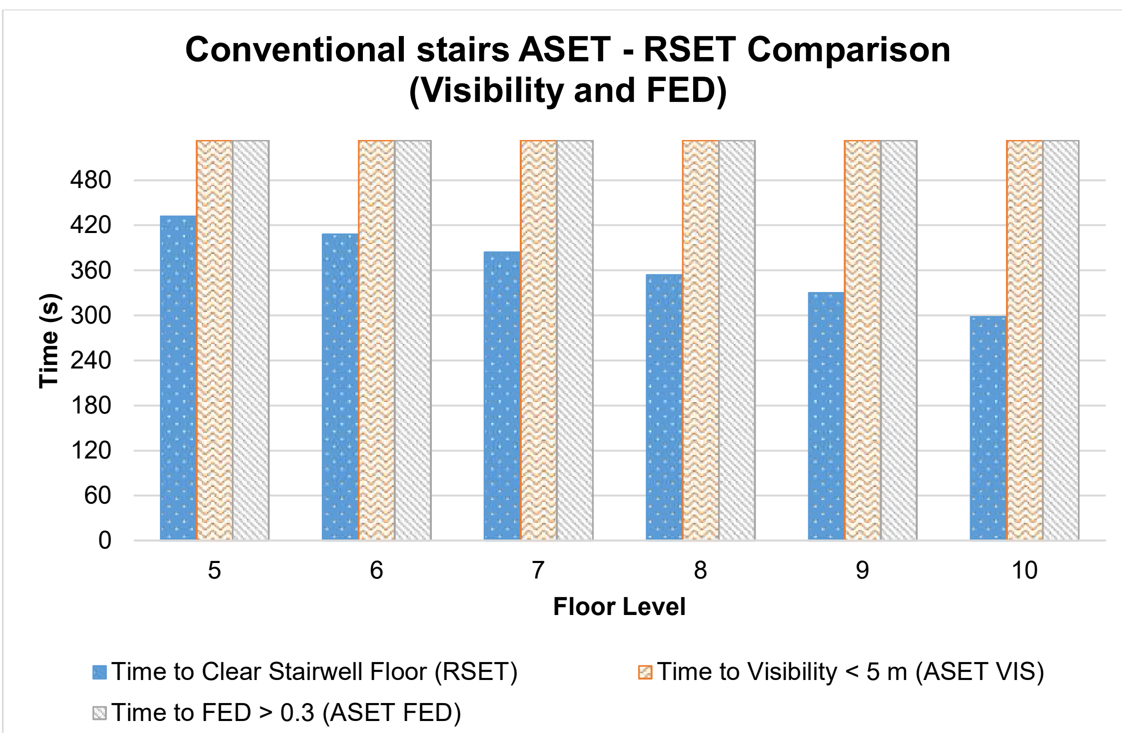
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

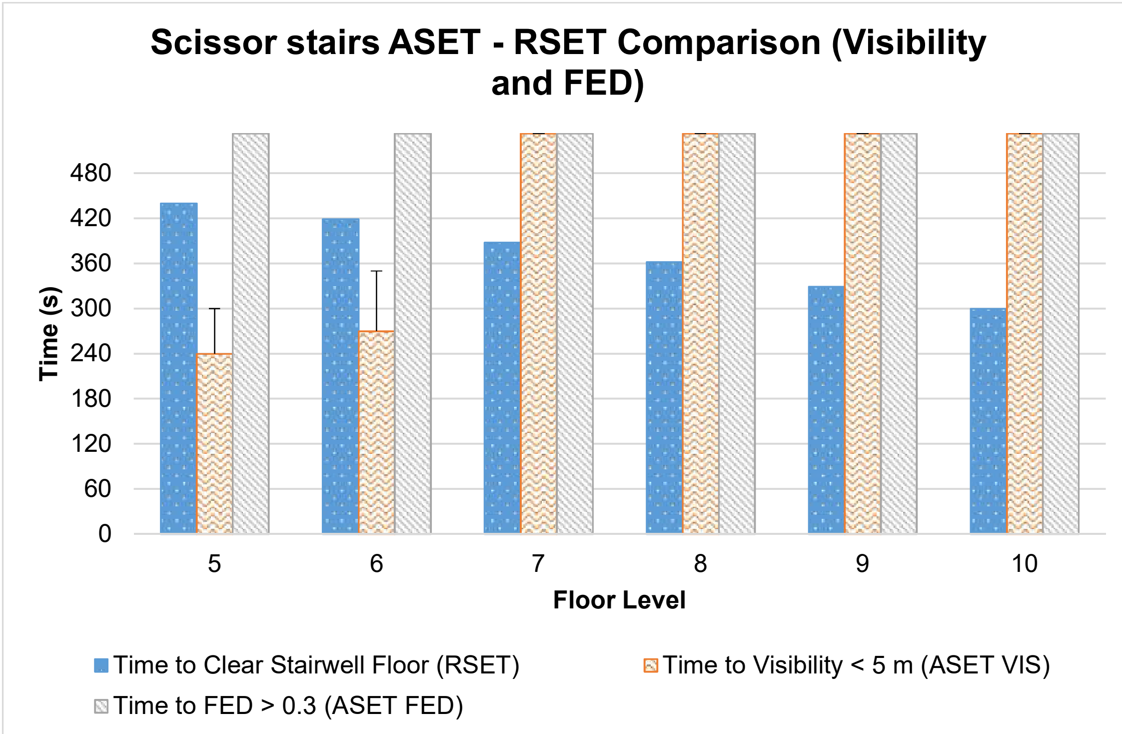
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F6 S_10_T6_T_2.7**


Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
480
420
360
300
240
180
120
60
0
5
6
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)


Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
480
420
360
300
240
180
120
60
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

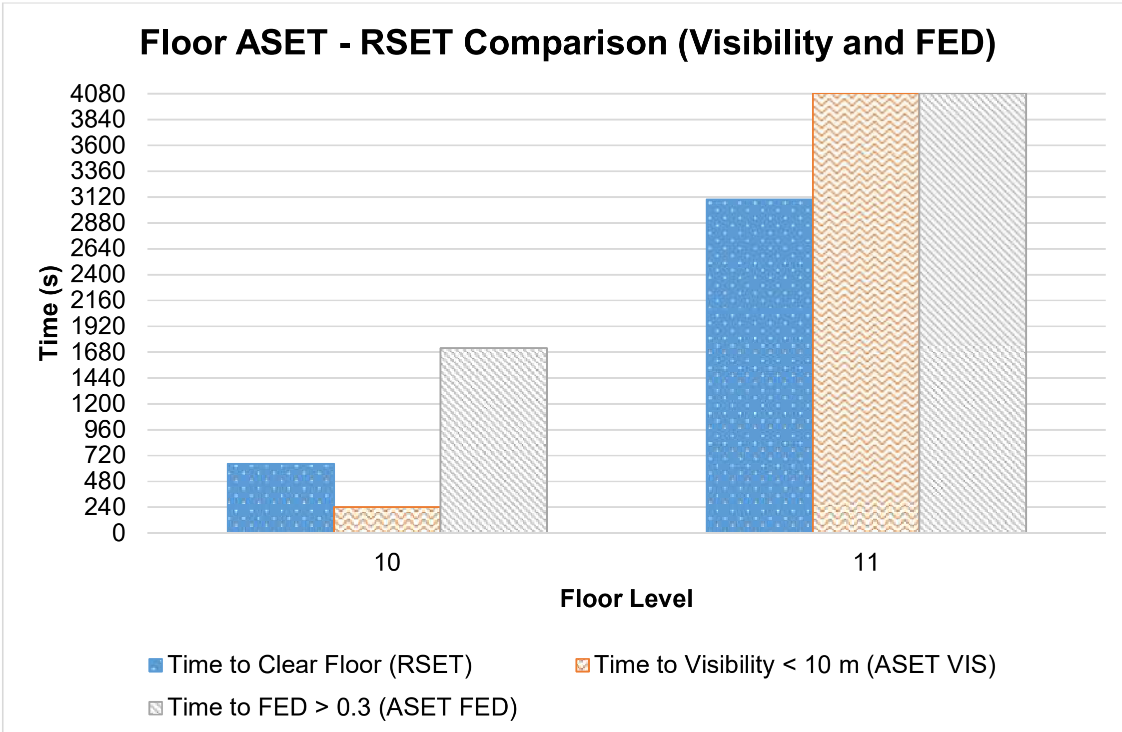

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
480
420
360
300
240
180
120
60
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| Tenability conditions during evacuation period<br>Total Evacuation Time: 533 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 295 s |
| Visibility < 10 m | Yes (109/-)* |
| FED > 0.3 | No |
| Maximum temperature | 110°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 337 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 20°C |
| **Conventional stairs (233 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (226 occupants)** | |
| Visibility < 5 m | Yes (5th to 6th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 240 s/60 s<br>6th – 270 s/80 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 60°C (Fire Floor) |

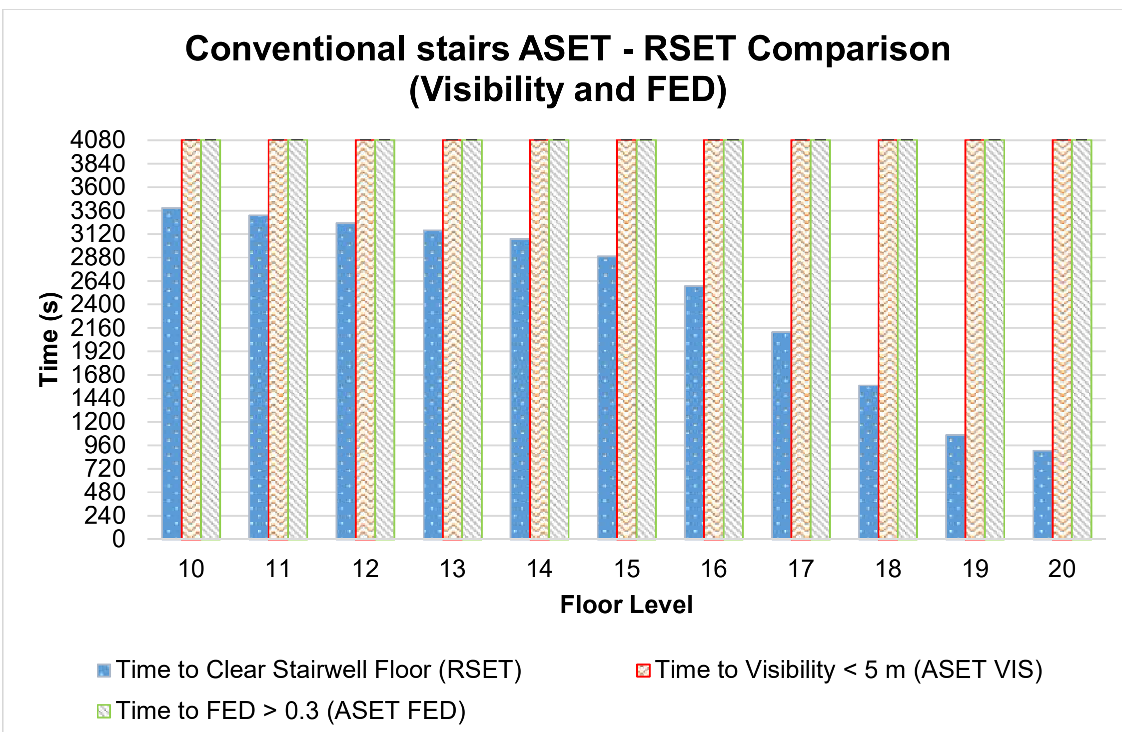
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

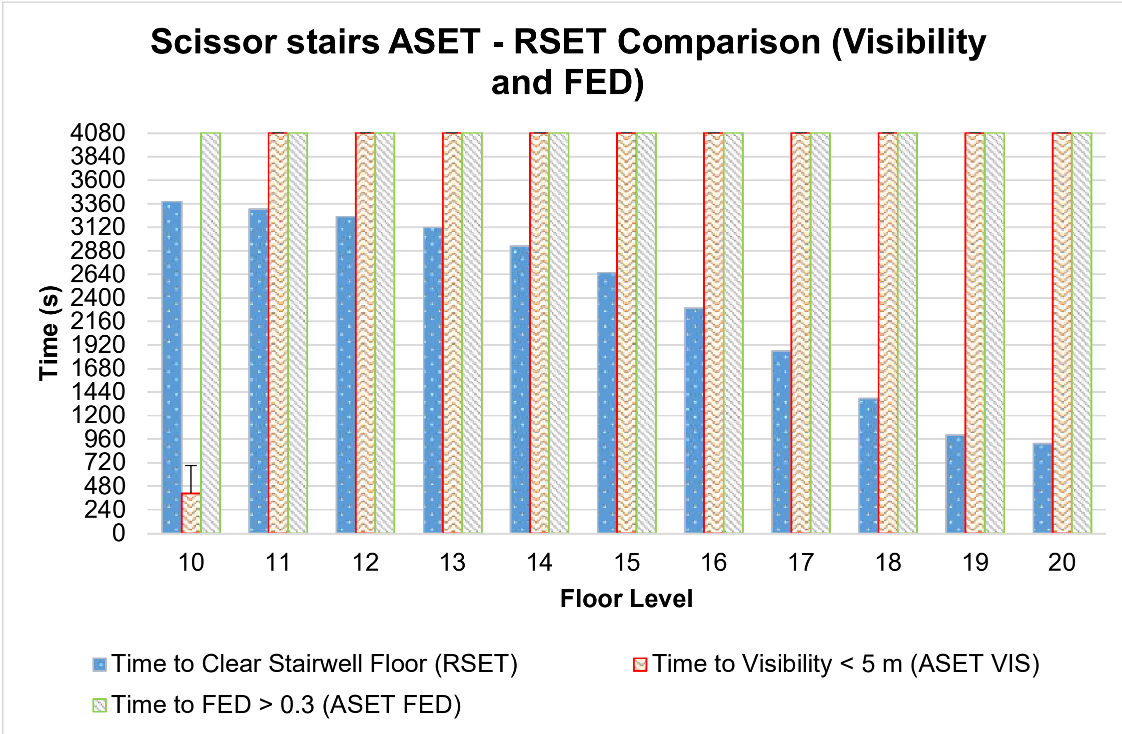
**F7 L_20_T6_P_2.7**



Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
4080
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
4080
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

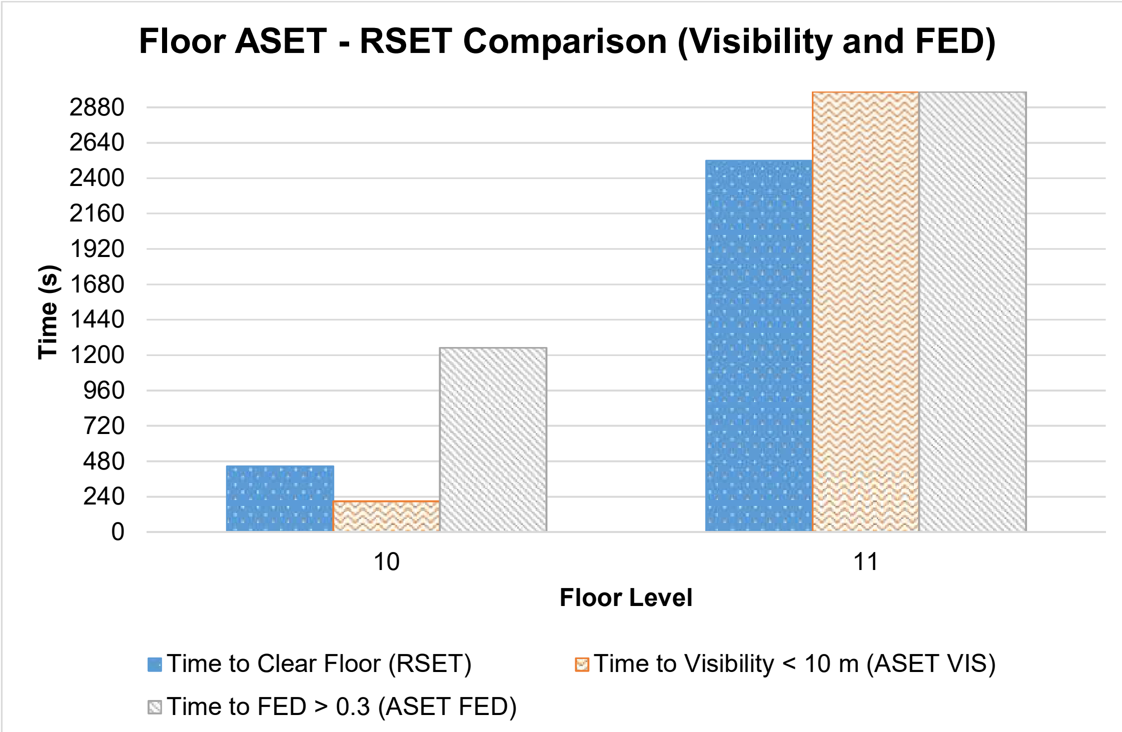

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
4080
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

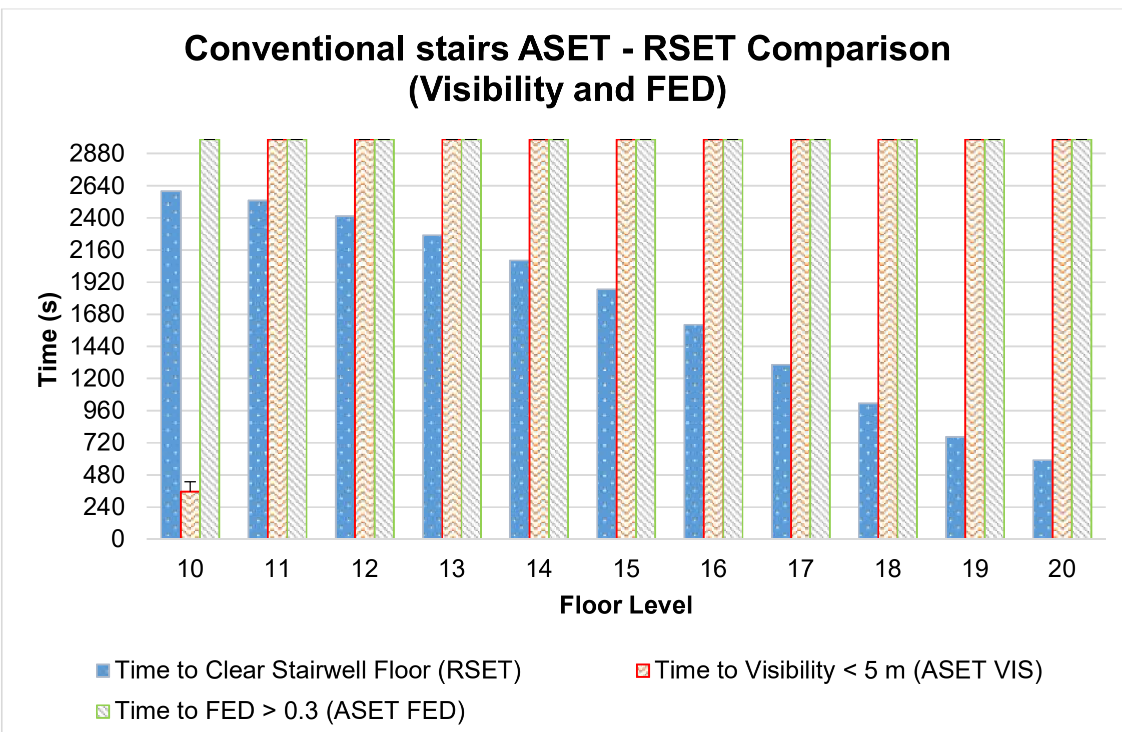
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 4086 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 644 s |
| Visibility < 10 m | Yes (243/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 3098 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (10th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 407 s/280s<br>11th – NEVER/0 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |

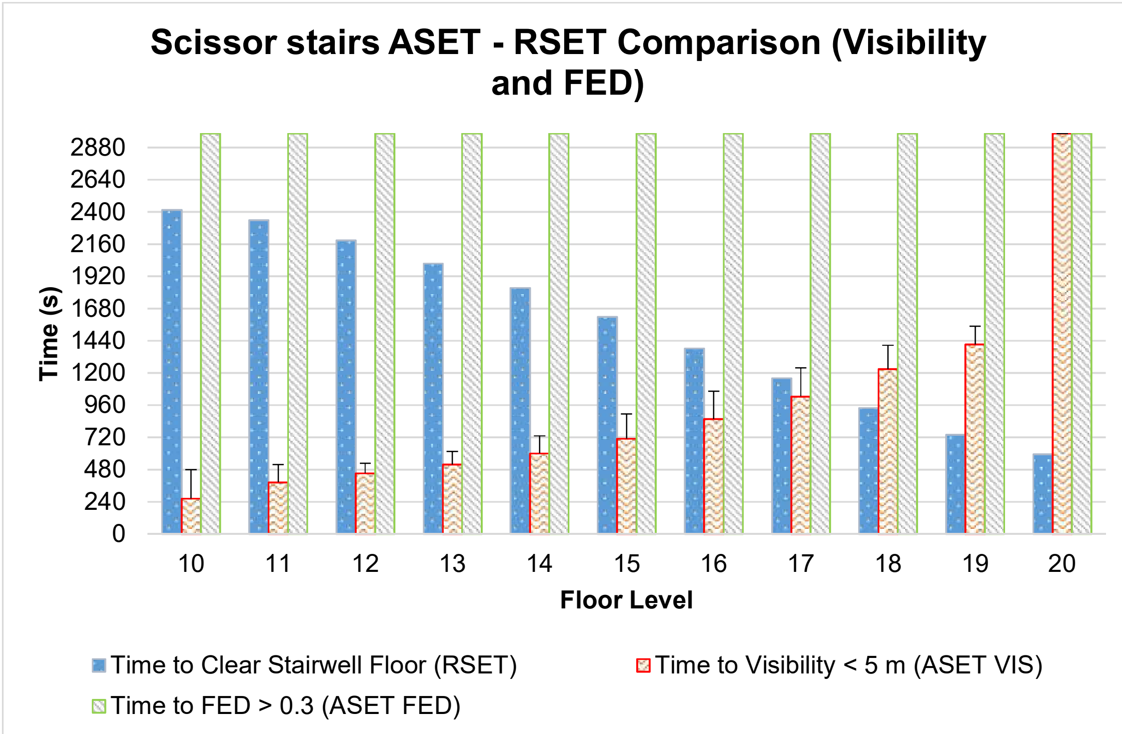
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F8 M_20_T6_P_2.7**


Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)


Conventional stairs ASET - RSET Comparison
(Visibility and FED)
Time (s)
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)



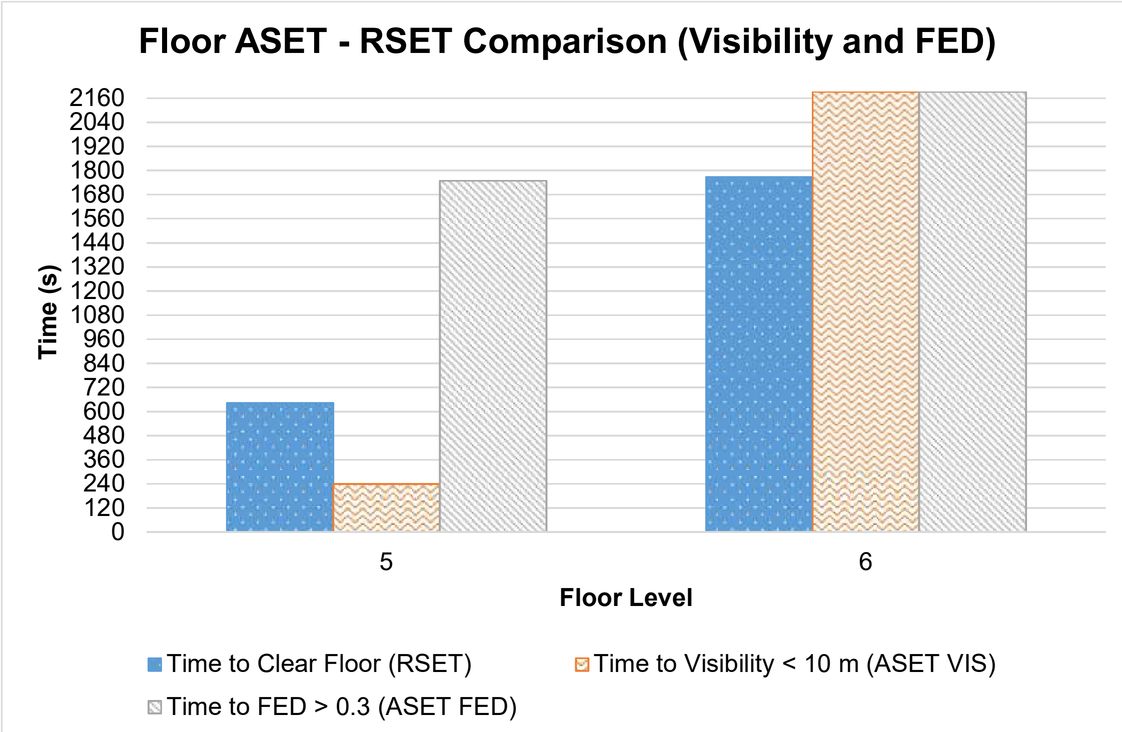
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| Tenability conditions during evacuation period<br>Total Evacuation Time: 2986 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 448 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | No |
| Maximum temperature | 60°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2520 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes (10th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 355 s/75 s<br>11th – NEVER/0 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 265 s/215 s<br>11th – 385 s/133 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |

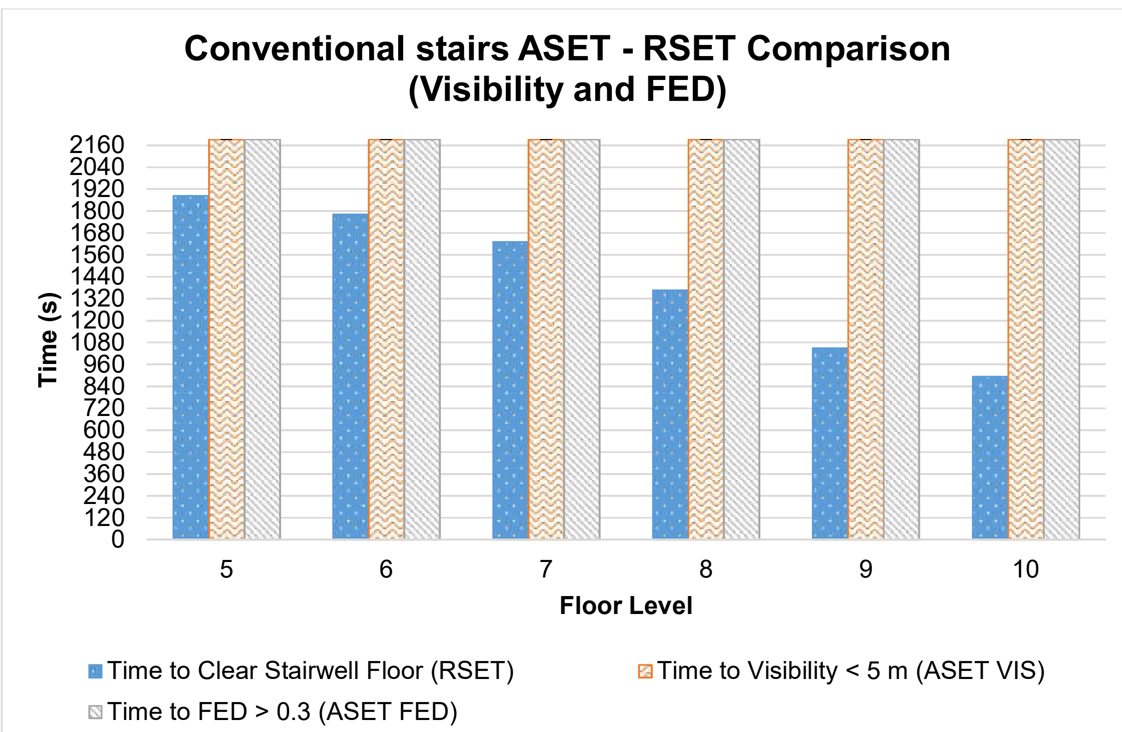
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

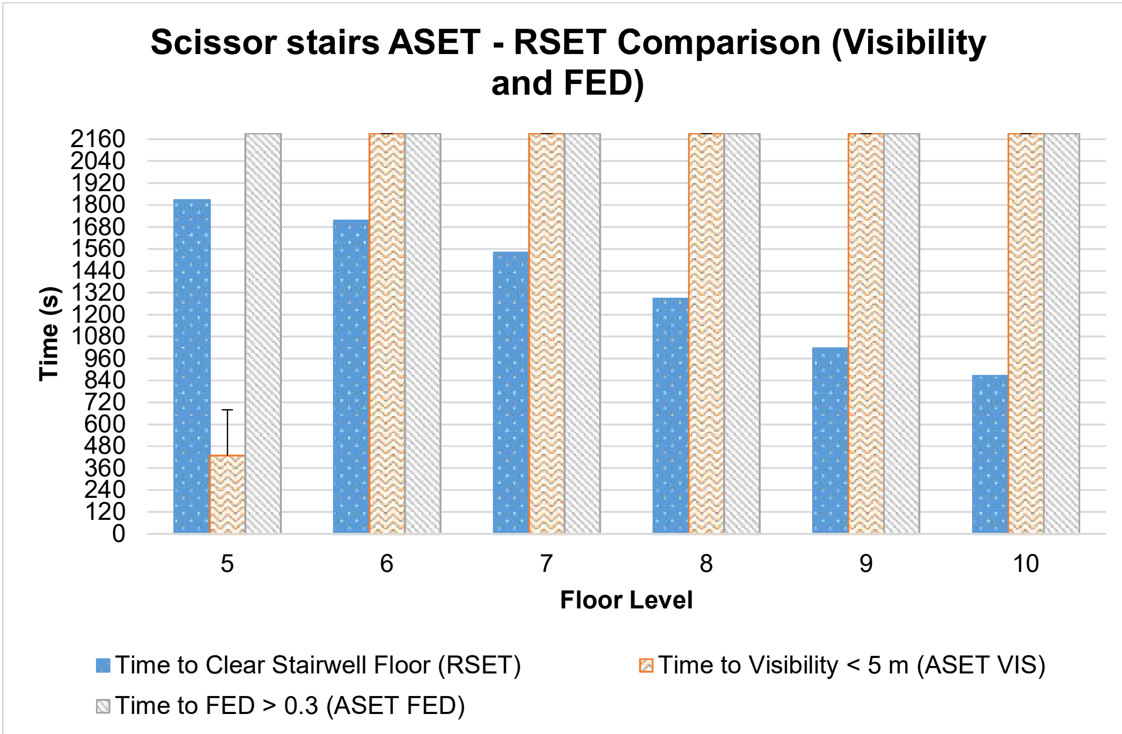
**F9 L_10_T6_P_2.7**



Floor ASET - RSET Comparison (Visibility and FED)
Time (s)
2160
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
Floor Level
Time to Clear Floor (RSET)
Time to Visibility < 10 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

Conventional stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2160
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

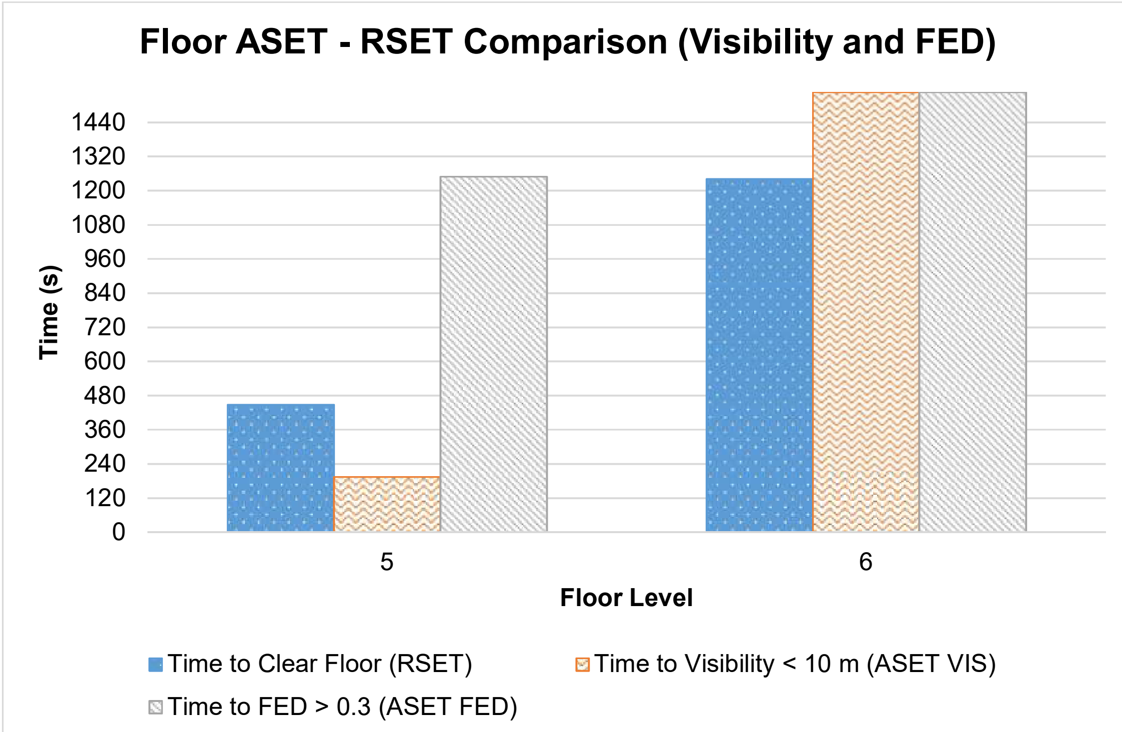

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2160
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

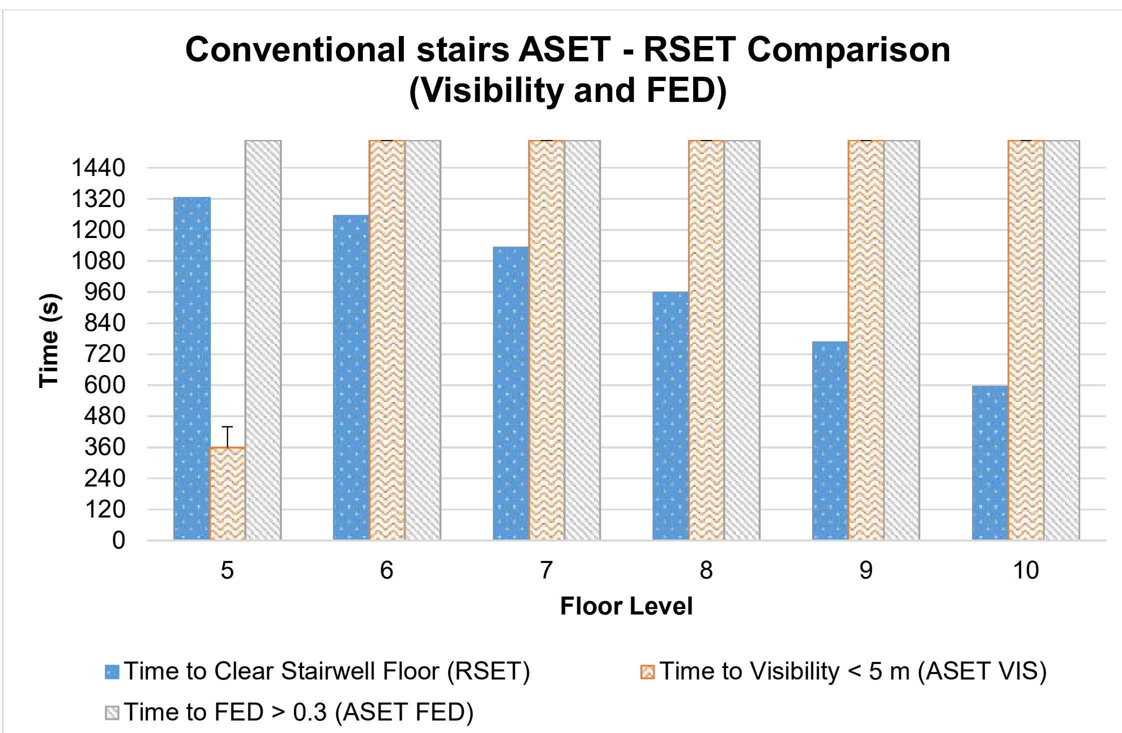
| Tenability conditions during evacuation period<br>Total Evacuation Time: 2192 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 644 s |
| Visibility < 10 m | Yes (240/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1769 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2260 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (2240 occupants)** | |
| Visibility < 5 m | Yes (5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 430 s/250 s<br>6th – NEVER/0 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |

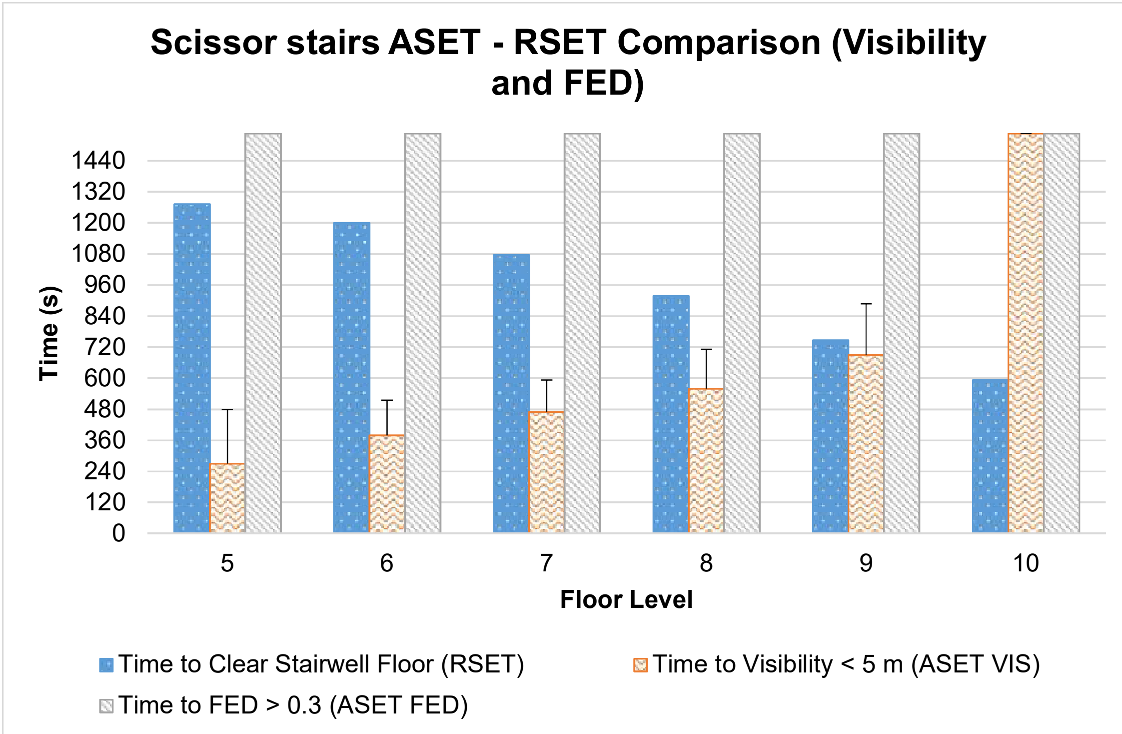
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F10 M_10_T6_P_2.7**





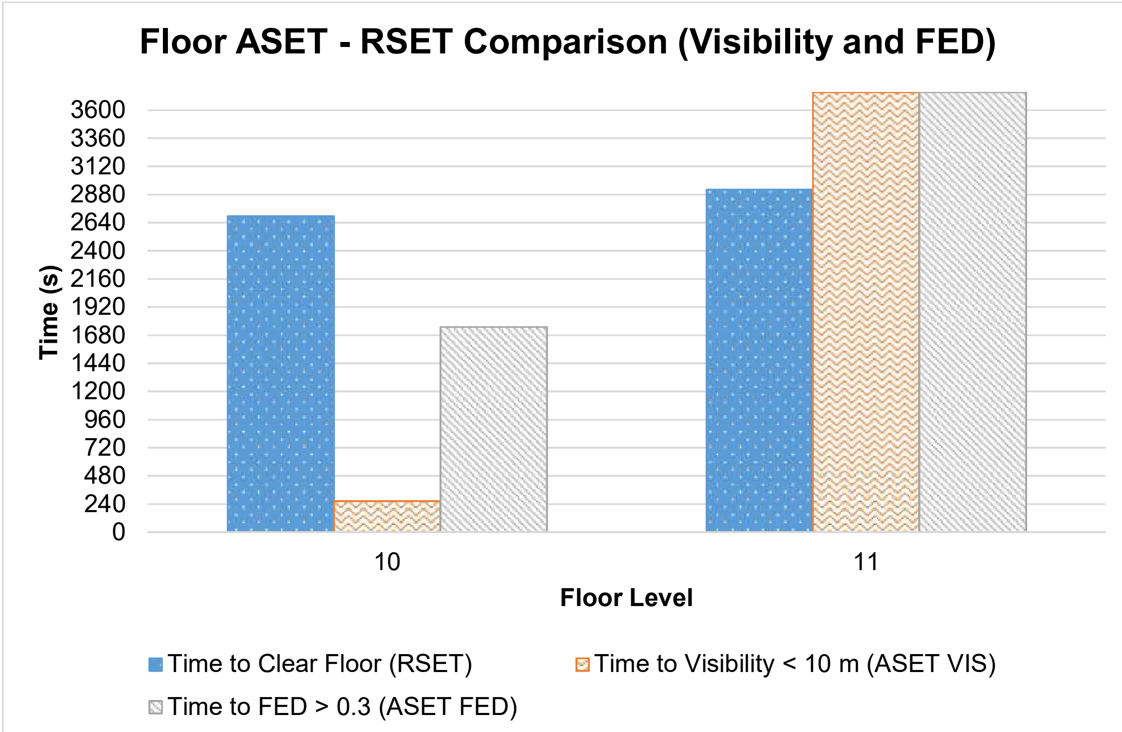
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

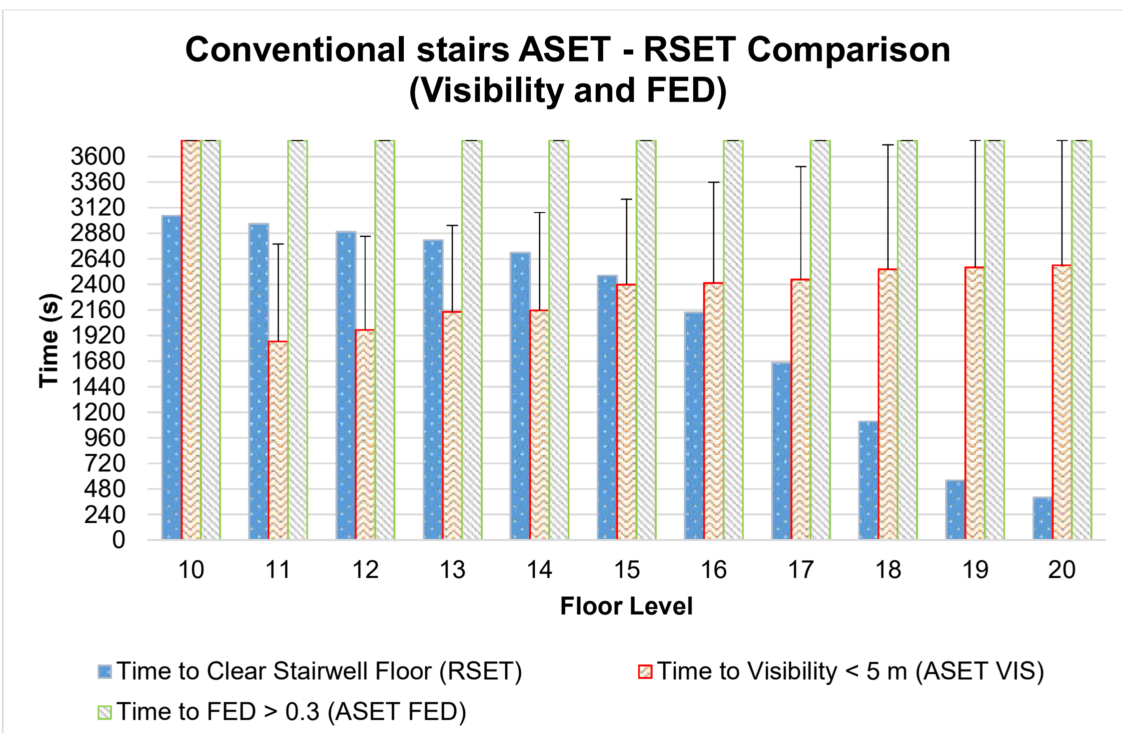
| Tenability conditions during evacuation period<br>Total Evacuation Time: 1546 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 448 s |
| Visibility < 10 m | Yes (195/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1241 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1102 occupants)** | |
| Visibility < 5 m | Yes (5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 360 s/80 s<br>6th – NEVER/0 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (1103 occupants)** | |
| Visibility < 5 m | Yes (5th to 9th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 270 s/210 s<br>6th – 380 s/135 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |

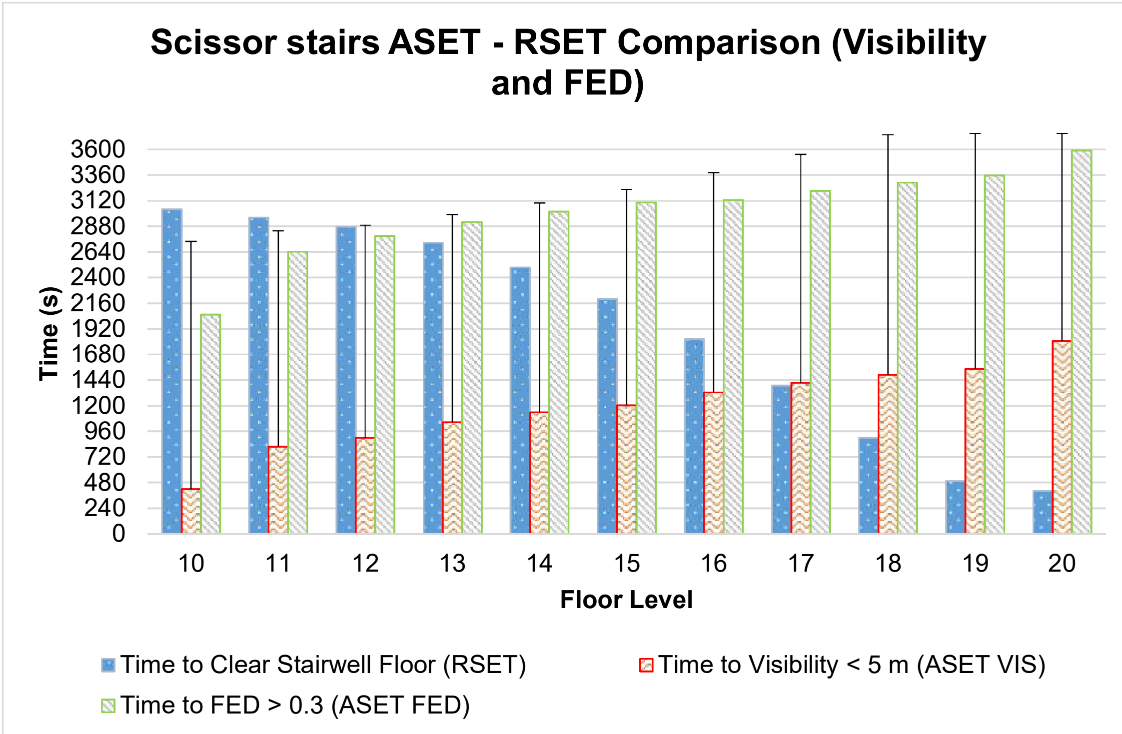
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F11 L_20_T7_T_2.7**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
Time (s)
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 3752 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 2697 s |
| Visibility < 10 m | Yes (268/-)* |
| FED > 0.3 | Yes (1752)** |
| Maximum temperature | 65°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2923 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (11th to 15th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 11th – 1866 s/913 s<br>12th – 1974 s/877 s<br>20th – 2580 s/>1172 s*** |
| FED > 0.3 | No |
| Maximum temperature | 27°C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (10th to 16th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 419 s/2321 s<br>11th – 820 s/2017 s<br>20th – 1806 s/>1946 s*** |
| FED > 0.3 | Yes (10th to 12th floor) |
| Maximum temperature | 50°C (Fire Floor) |

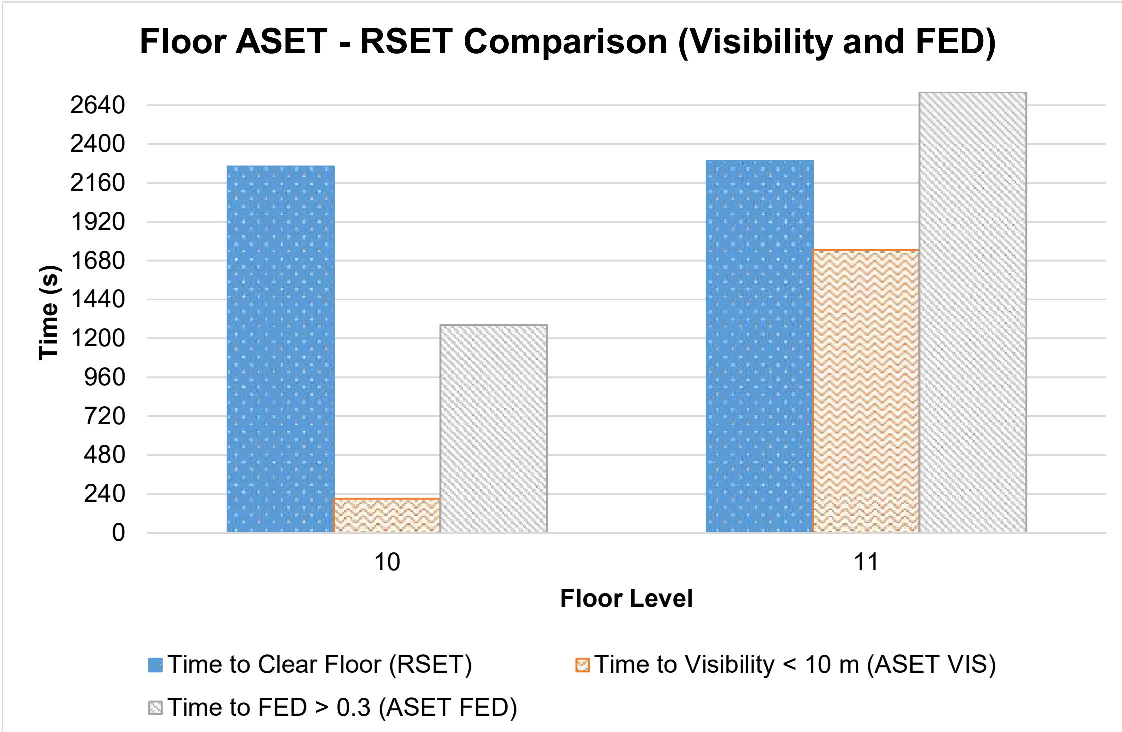
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

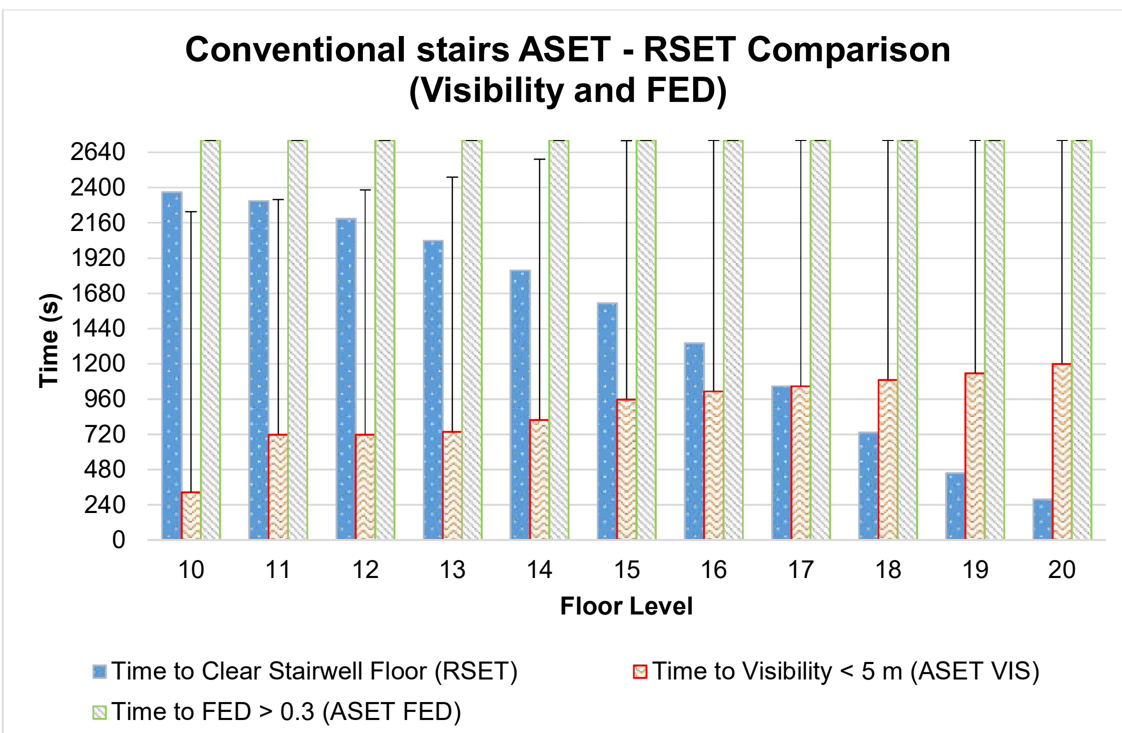
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

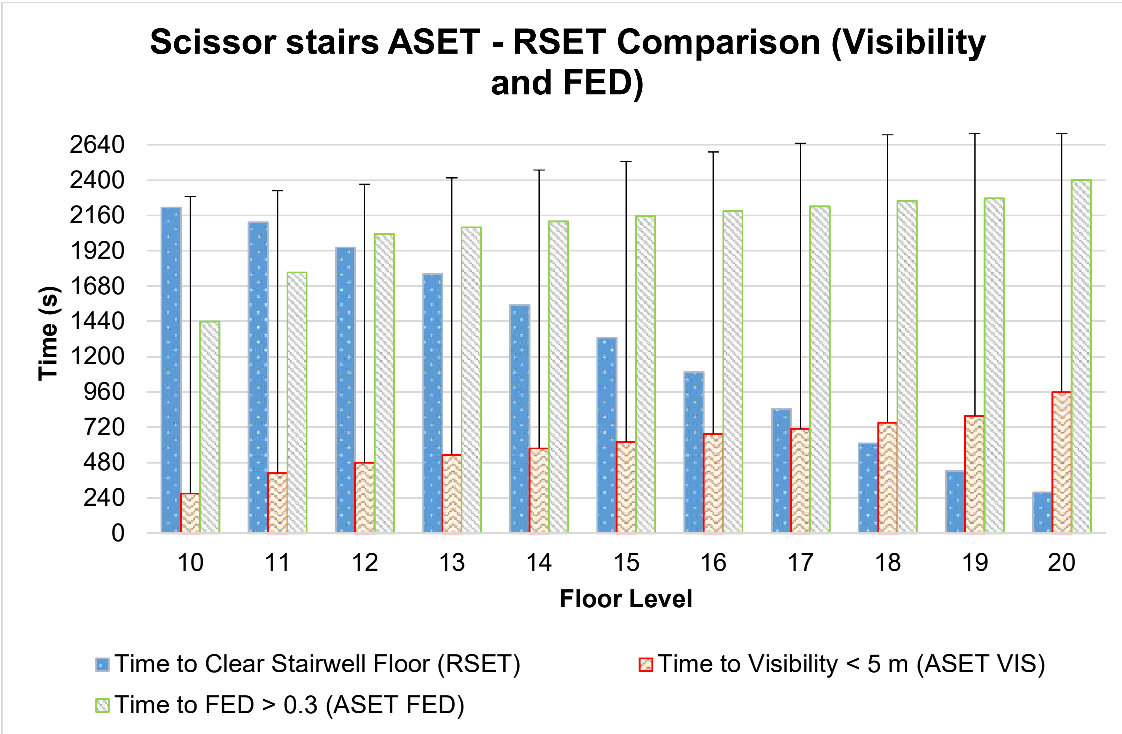
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F12 M_20_T7_T_2.7**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| Tenability conditions during evacuation period<br>Total Evacuation Time: 2721 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 2263 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | Yes (1282)** |
| Maximum temperature | 87°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2299 s |
| Visibility < 10 m | Yes (1747/2554)* |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes (10th to 16th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 326 s/1910 s<br>11th – 720 s/1599 s<br>20th – 1200 s/>1521 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 270 s/2018 s<br>11th – 410 s/1917 s<br>20th – 960 s/>1761 s*** |
| FED > 0.3 | Yes (10th to 11th) |
| Maximum temperature | 70°C (Fire Floor) |

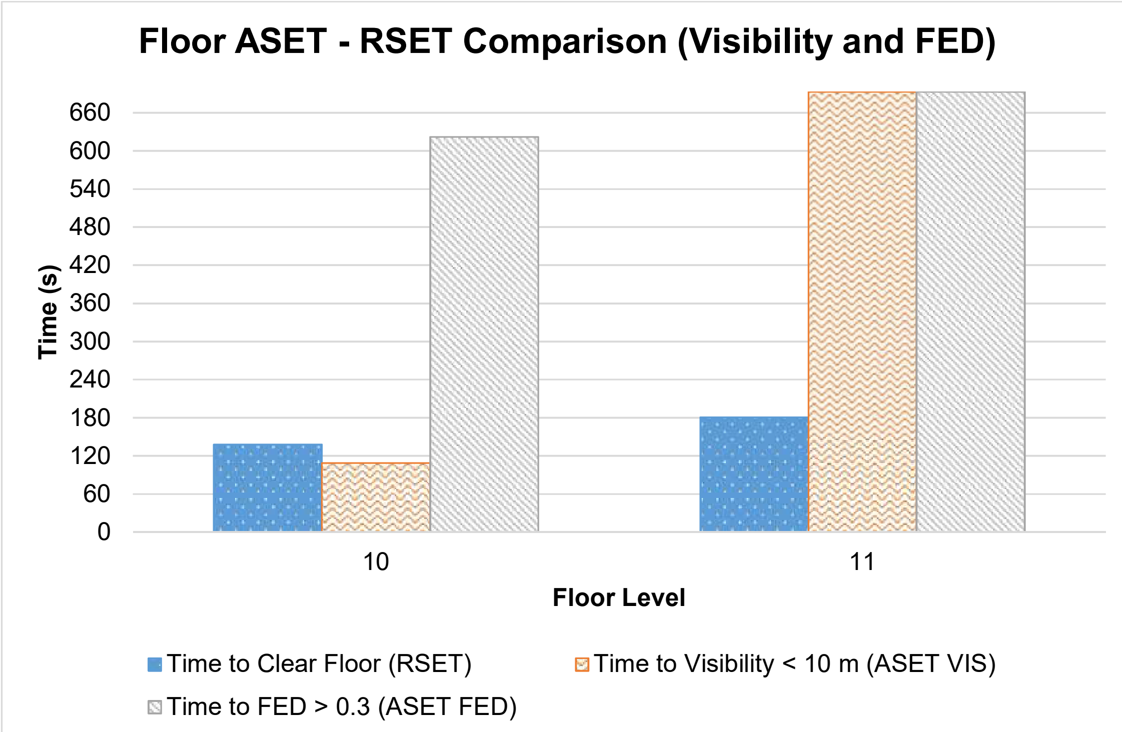
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

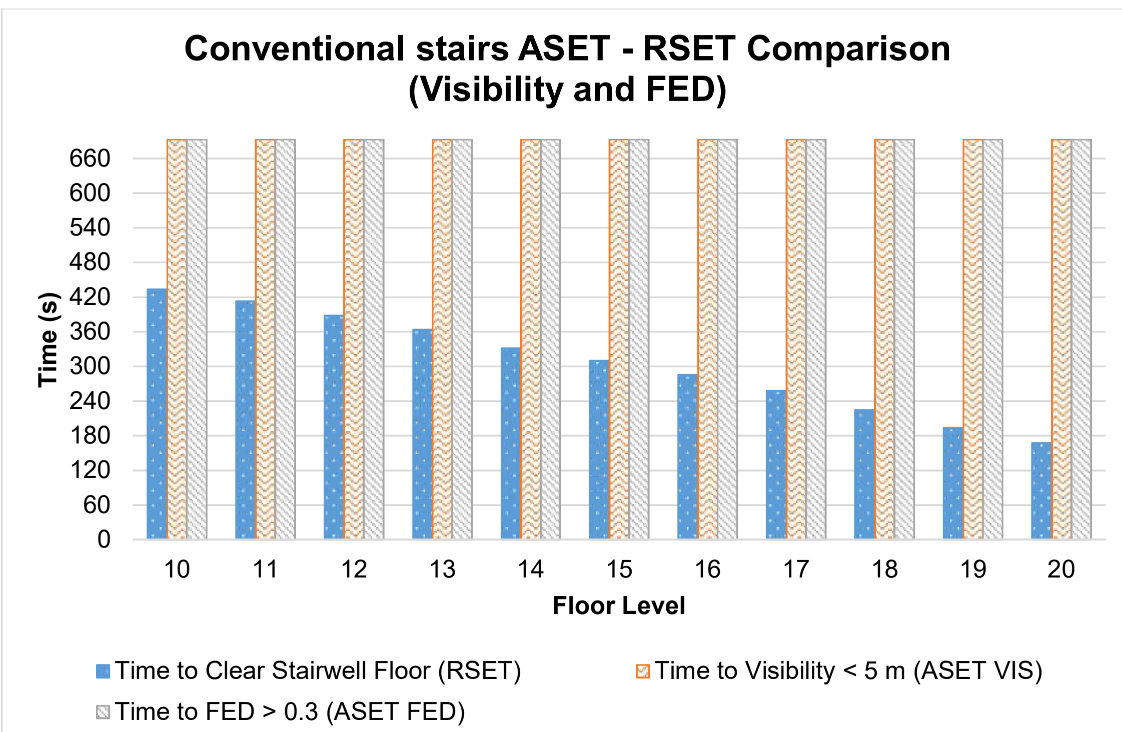
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

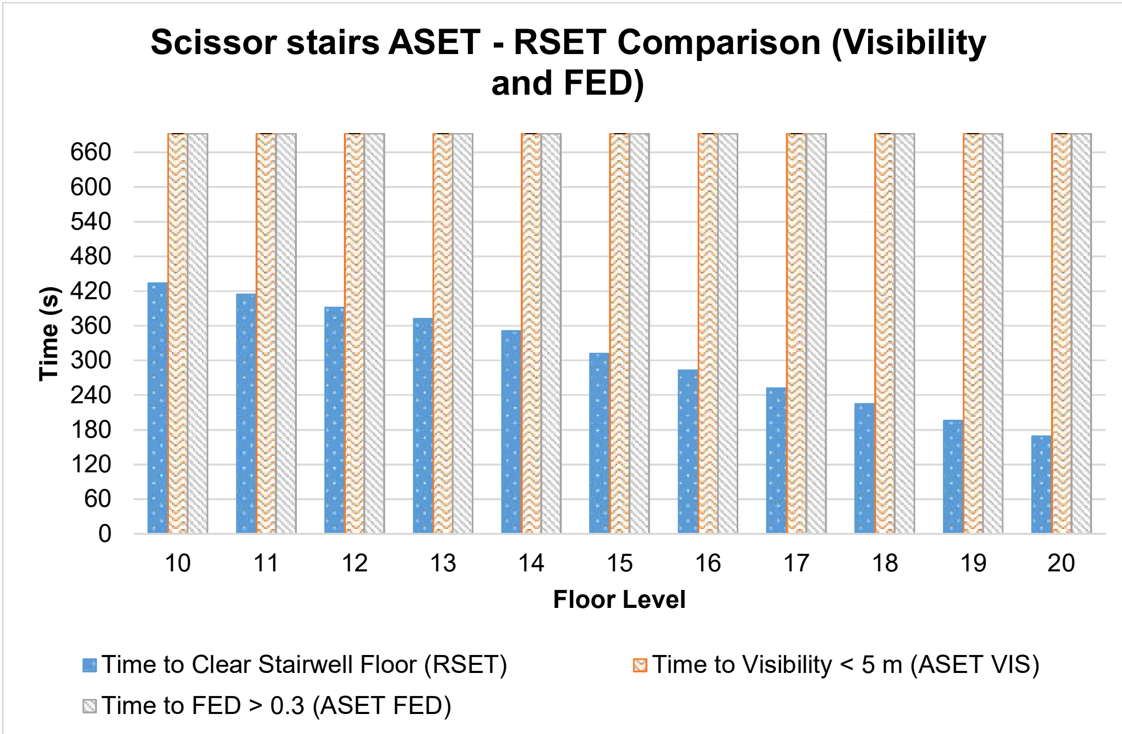
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F13 S_20_T7_T_2.7**



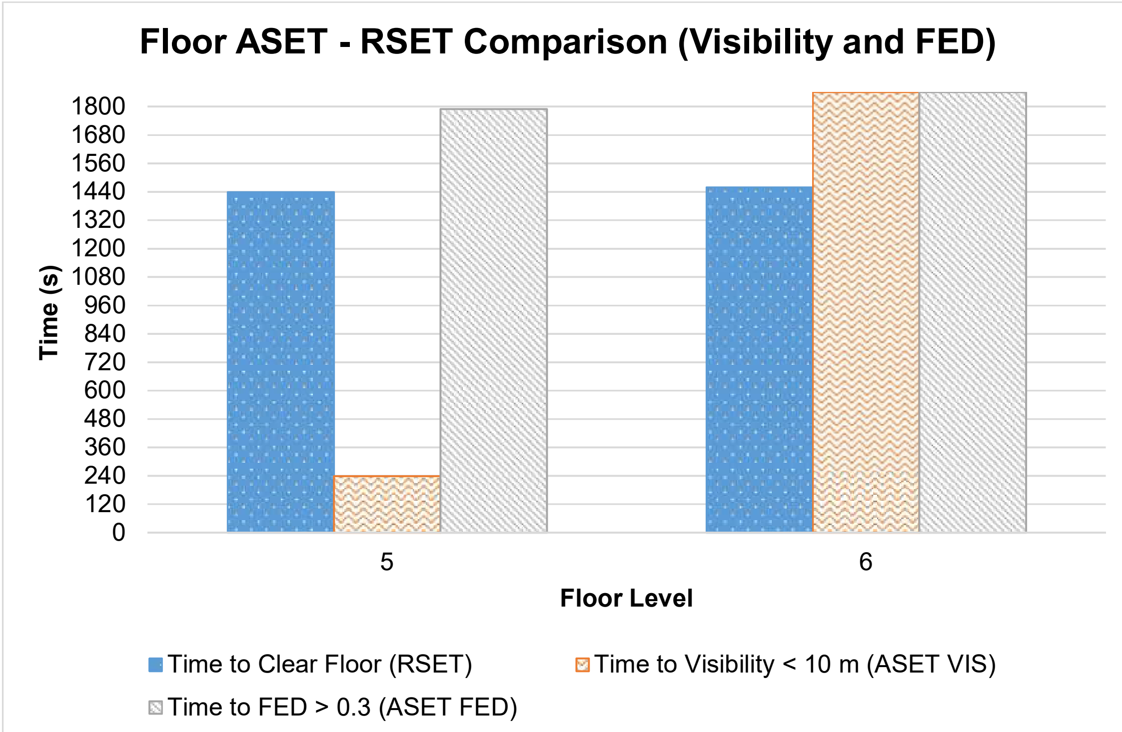

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
0
60
120
180
240
300
360
420
480
540
600
660
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

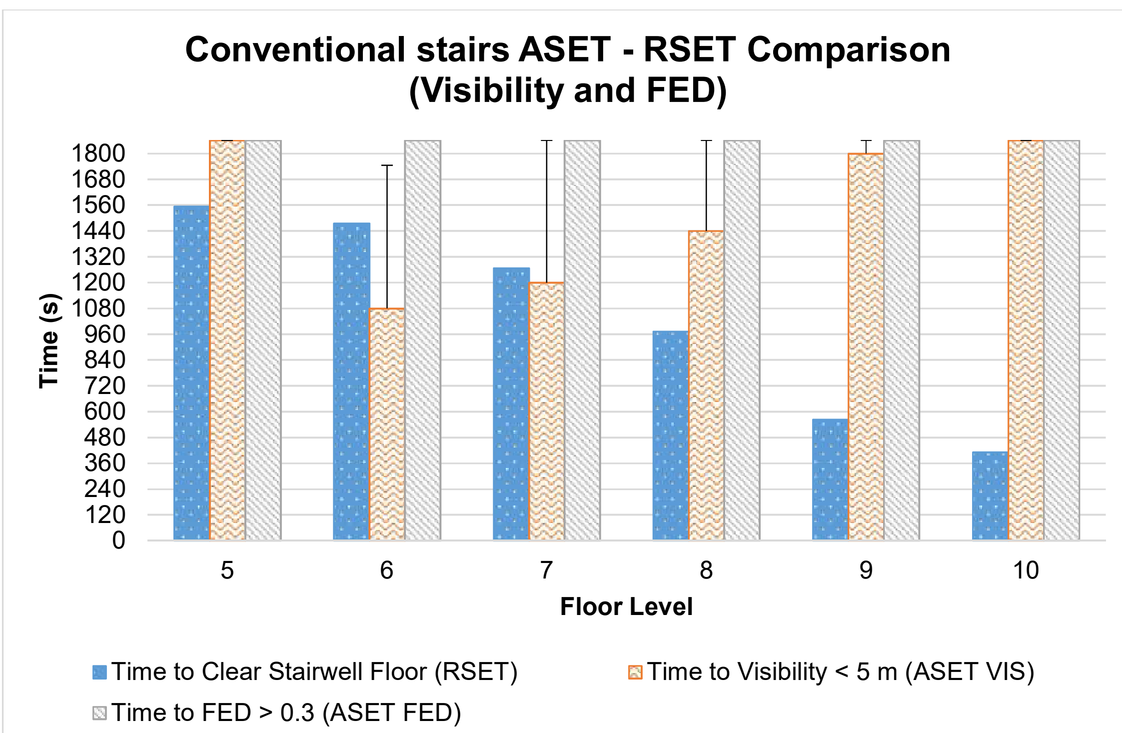
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 693 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 138 s |
| Visibility < 10 m | Yes (109/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 181 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (475 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (494 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |

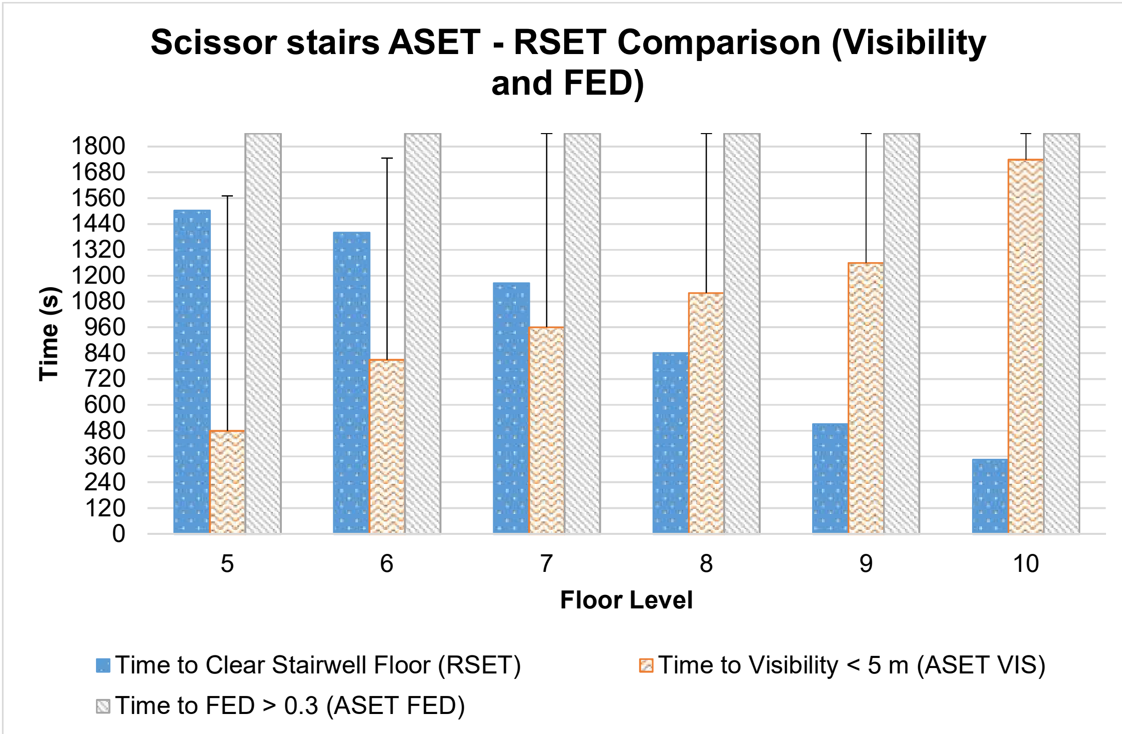
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F14 L_10_T7_T_2.7**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

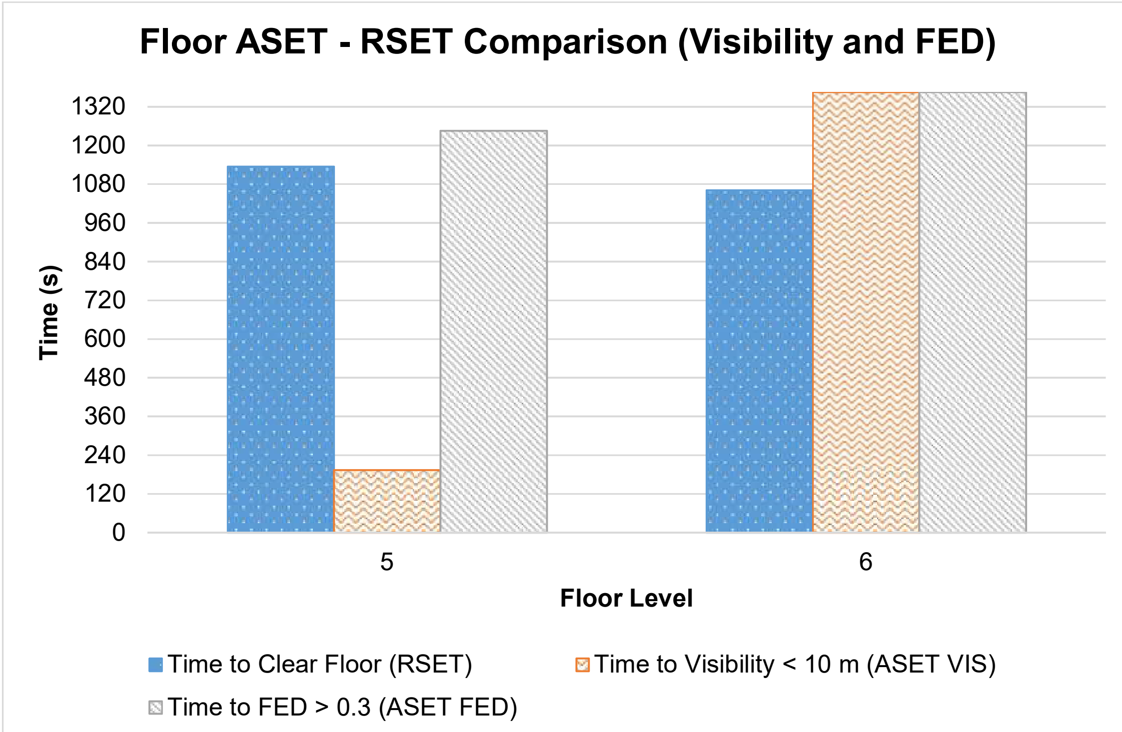
| Tenability conditions during evacuation period<br>Total Evacuation Time: 1861 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 1440 s |
| Visibility < 10 m | Yes (240/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1460 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (6th and 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – NEVER/0 s<br>6th – 1080 s/665 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (5th to 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 480 s/1090 s<br>6th – 810 s/937 s<br>10th – 1740 s/>121 s*** |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |

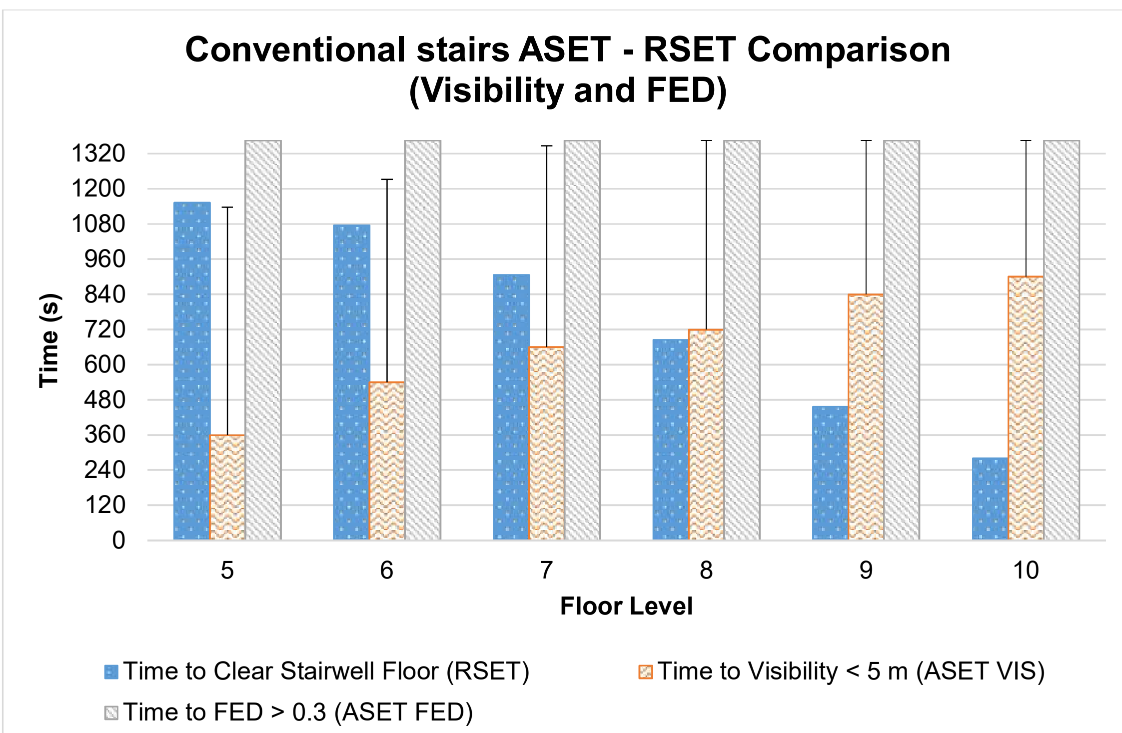
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

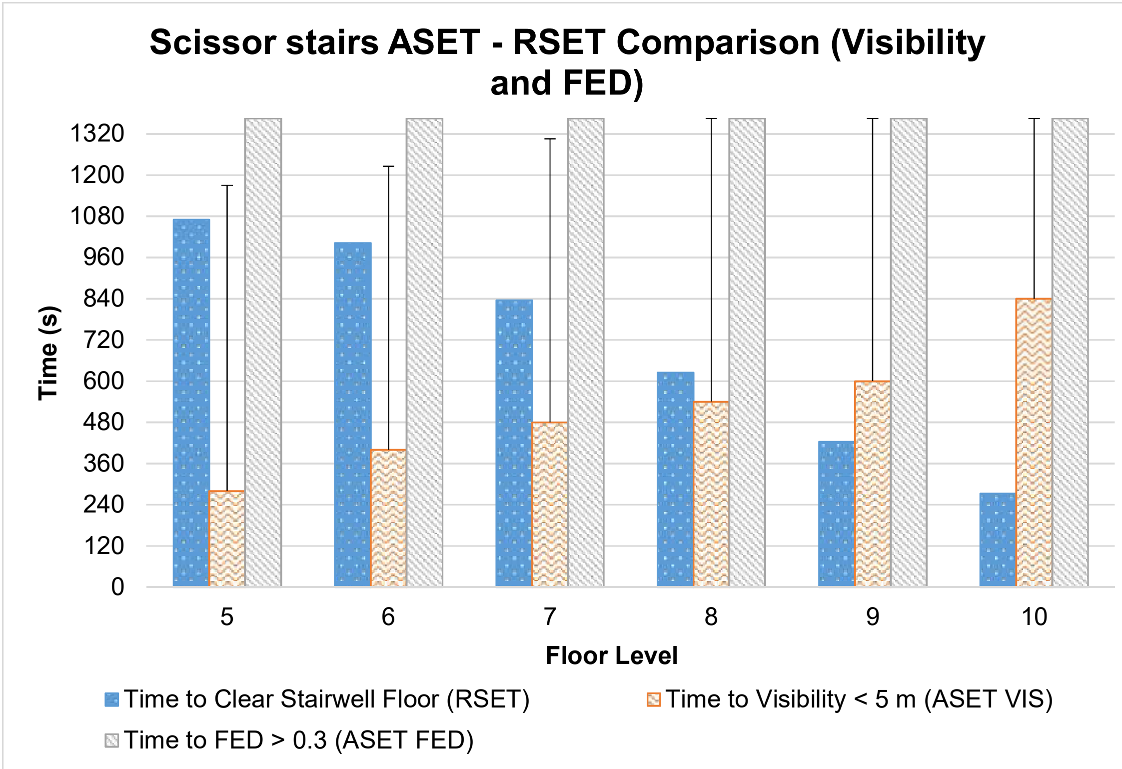
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F15 M_10_T7_T_2.7**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

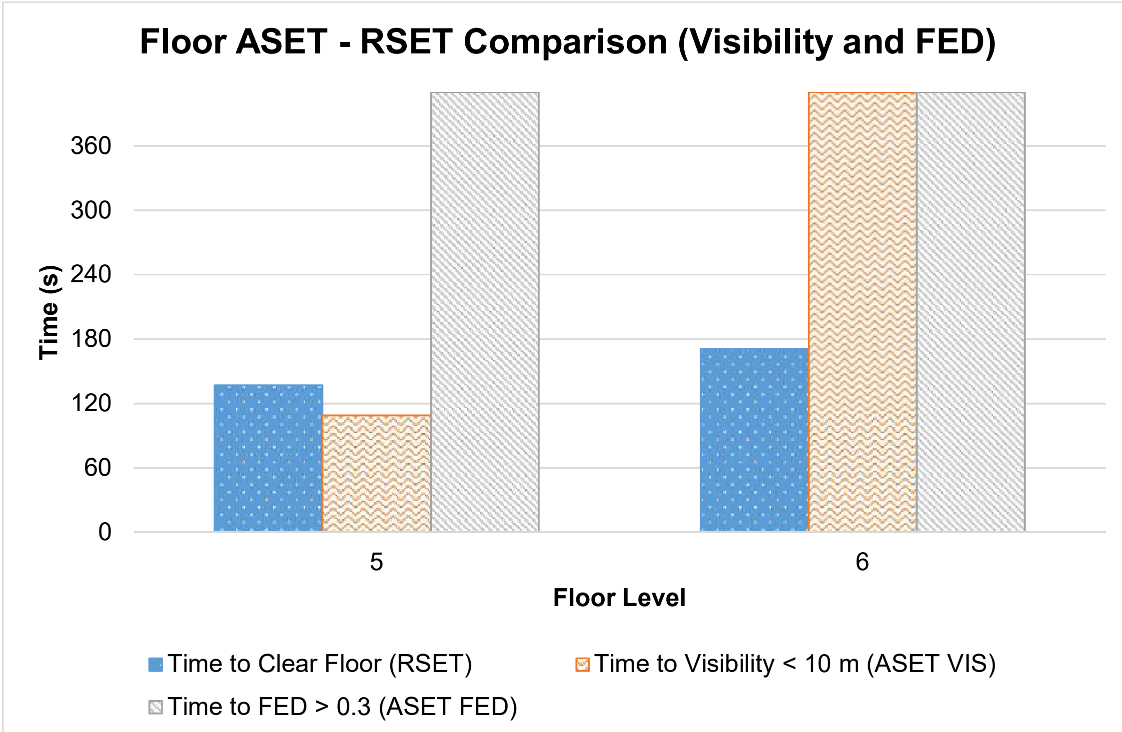
| Tenability conditions during evacuation period<br>Total Evacuation Time: 1365 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 1135 s |
| Visibility < 10 m | Yes (194/-)* |
| FED > 0.3 | No |
| Maximum temperature | 70°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1062 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1098 occupants)** | |
| Visibility < 5 m | Yes (5th and 7th floor) |
| ***Duration where visibility < 5 m | 5th – 360 s/777 s<br>6th – 540 s/692 s<br>10th – 900 s/>465 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (1107 occupants)** | |
| Visibility < 5 m | Yes (5th to 8th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 280 s/890 s<br>6th – 400 s/825 s<br>10th – 840 s/>525 s*** |
| FED > 0.3 | No |
| Maximum temperature | 60°C (Fire Floor) |

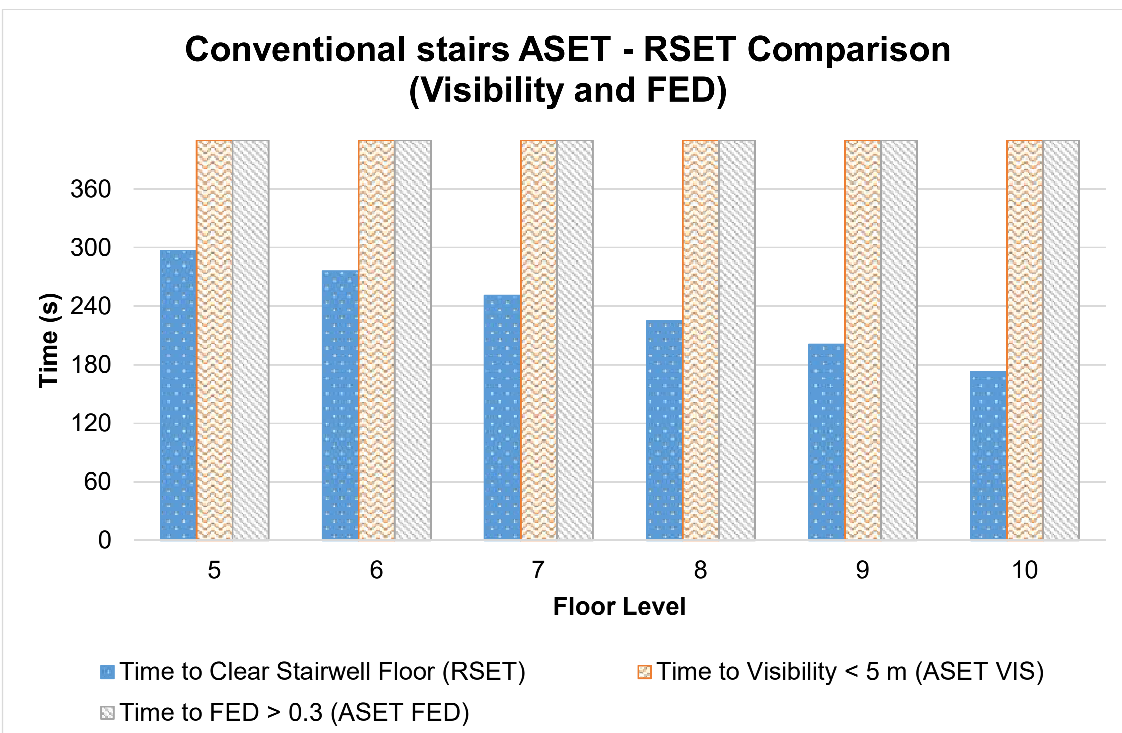
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

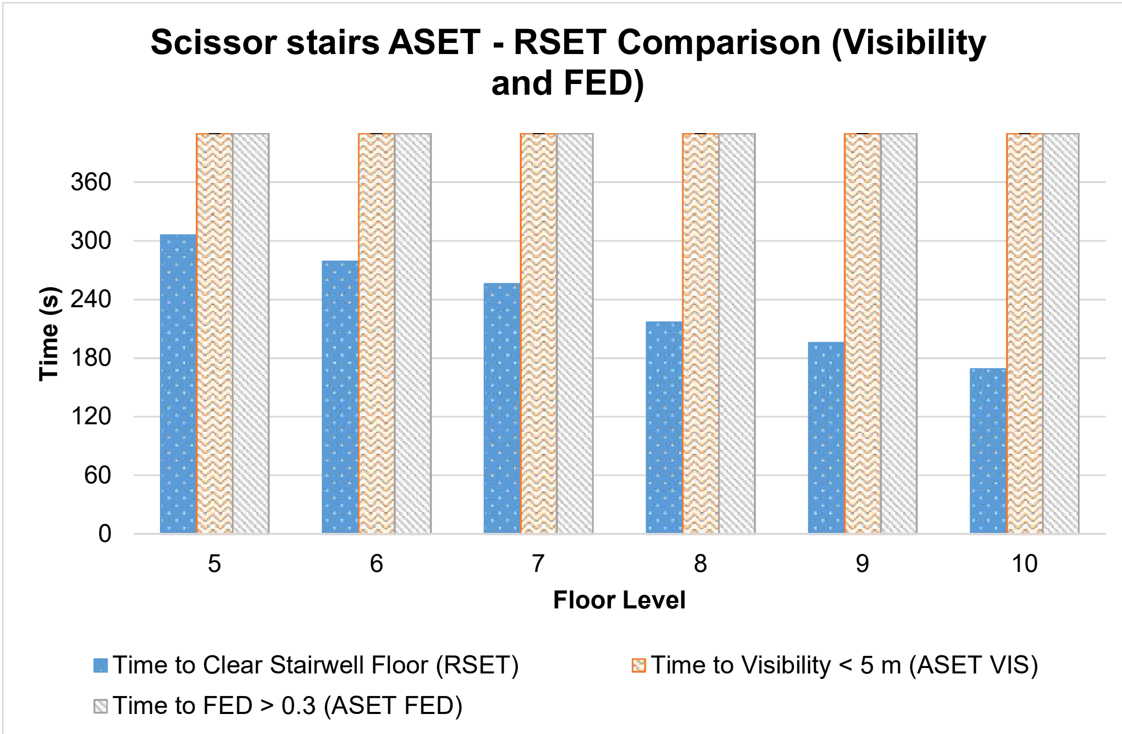
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F16 S_10_T7_T_2.7**



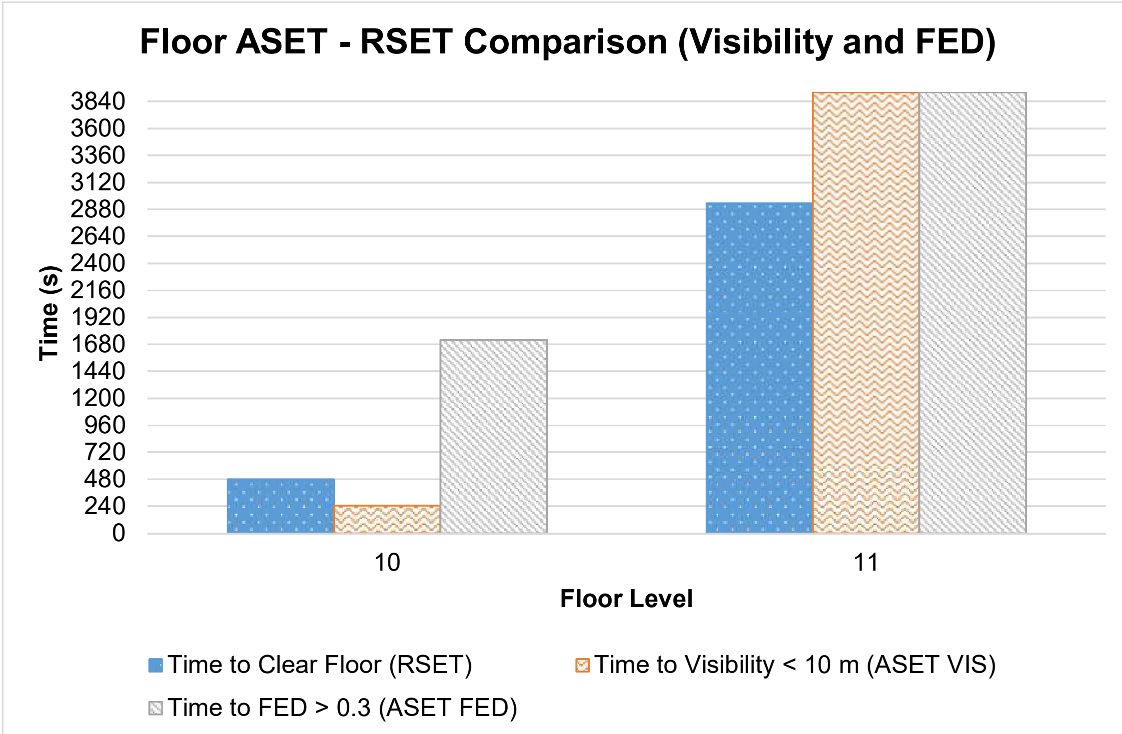

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
0
60
120
180
240
300
360
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

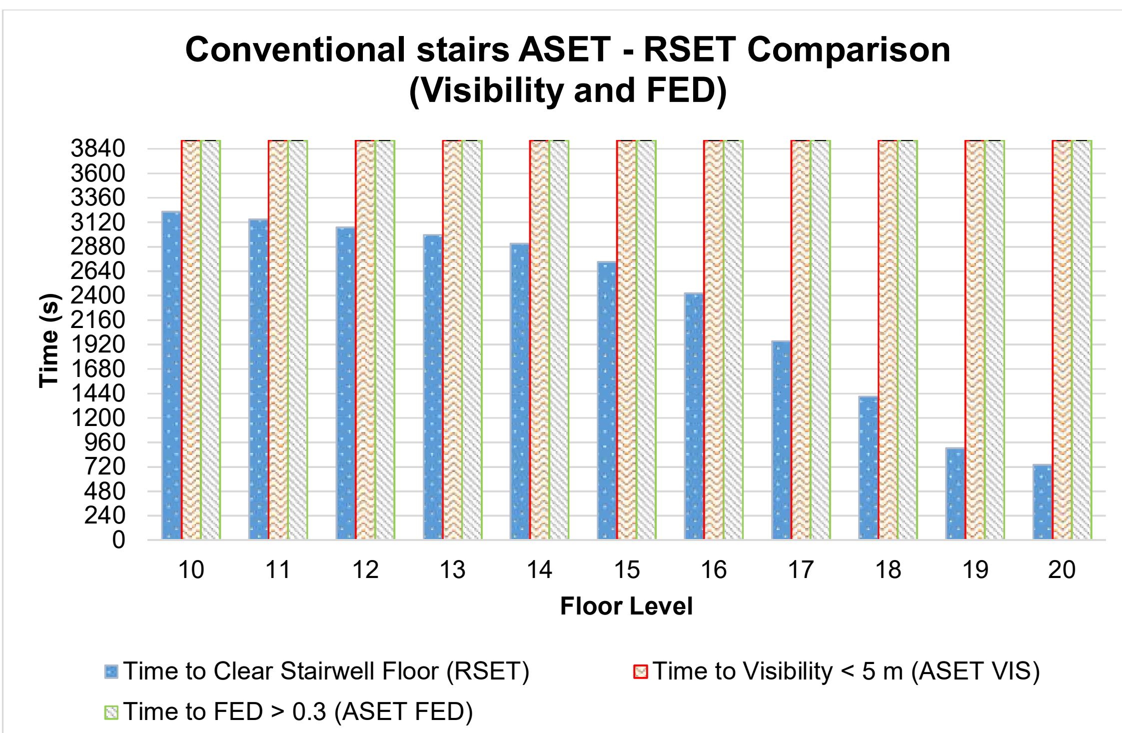
| Tenability conditions during evacuation period<br>Total Evacuation Time: 410 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 137 s |
| Visibility < 10 m | Yes (109/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 171 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 20°C |
| **Conventional stairs (225 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C (Fire Floor) |
| **Scissor stairs (234 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |

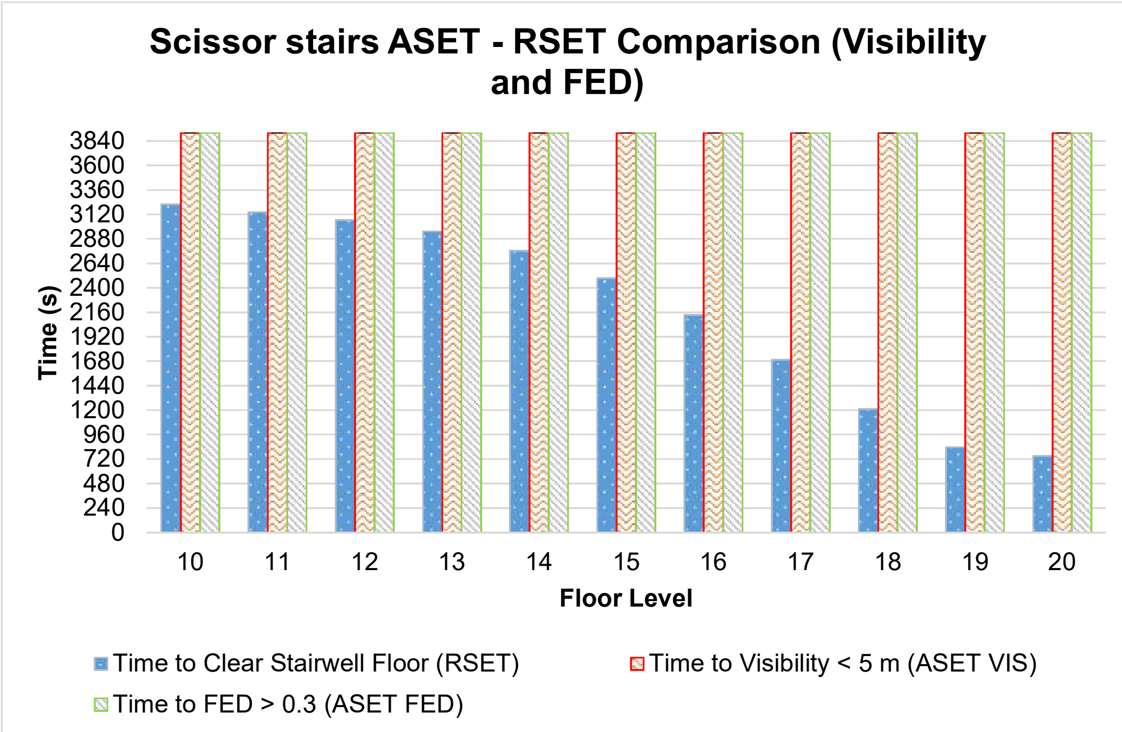
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F17 L_20_T7_P_2.7**





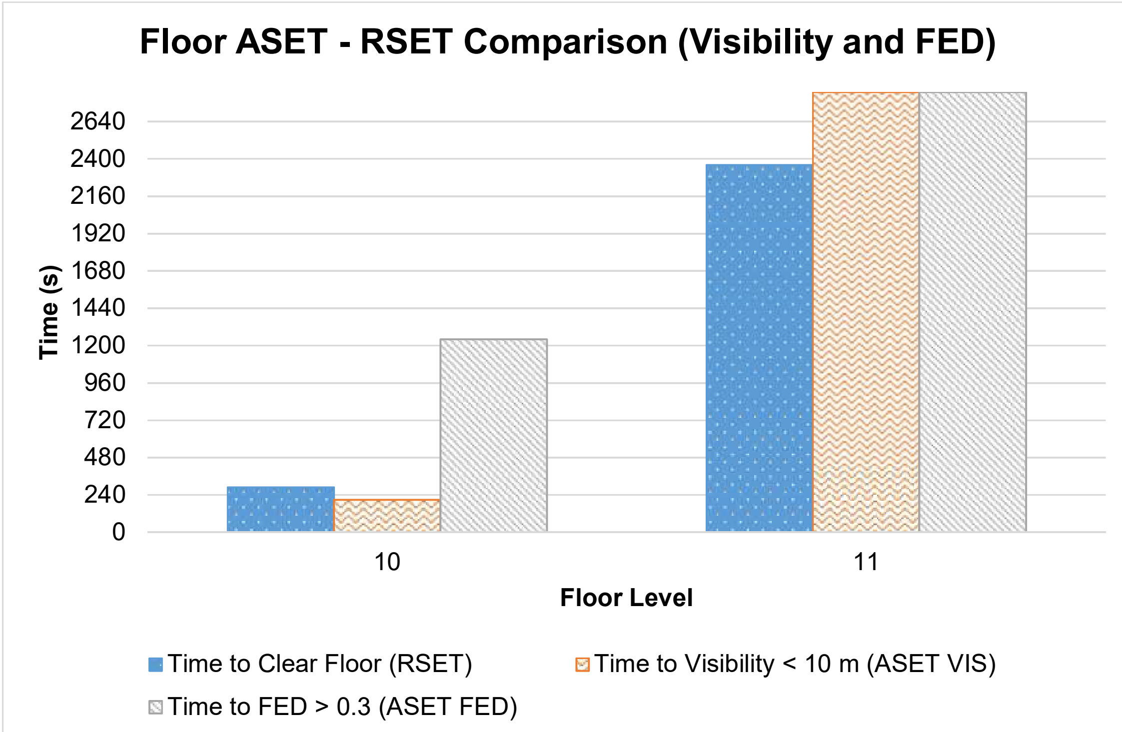
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

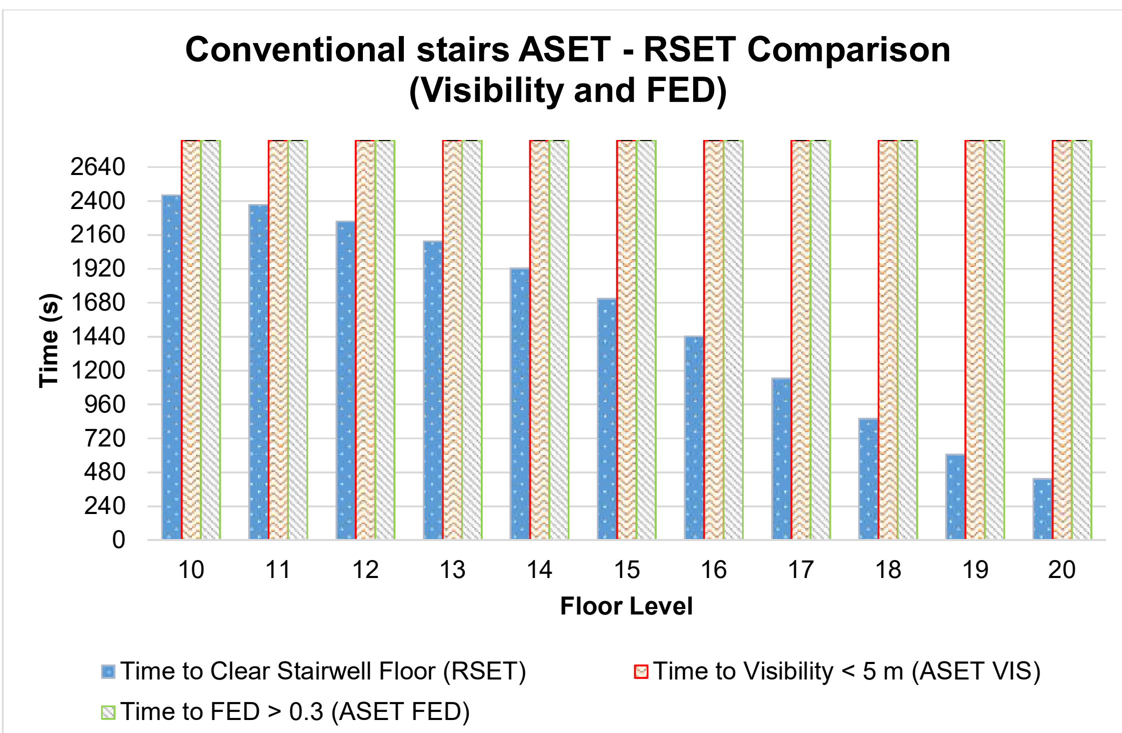
| Tenability conditions during evacuation period<br>Total Evacuation Time: 3923 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 481 s |
| Visibility < 10 m | Yes (247/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45$^{o}$C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2935 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30$^{o}$C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25$^{o}$C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35$^{o}$C (Fire Floor) |

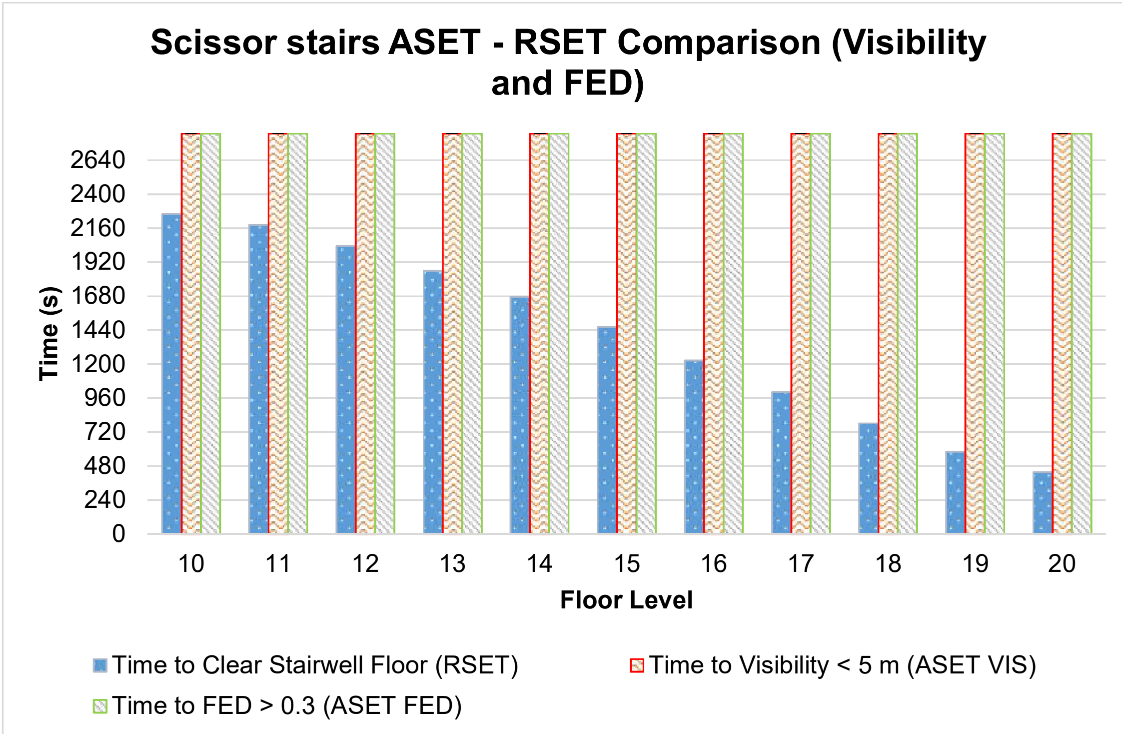
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F18 M_20_T7_P_2.7**



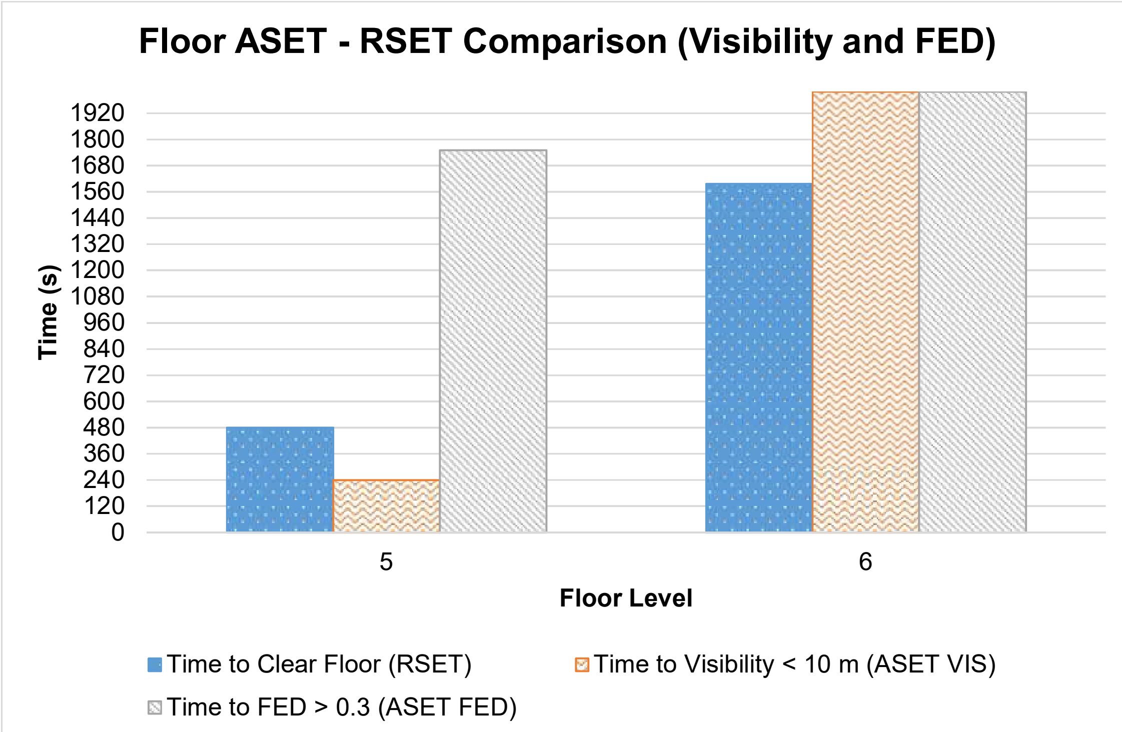

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

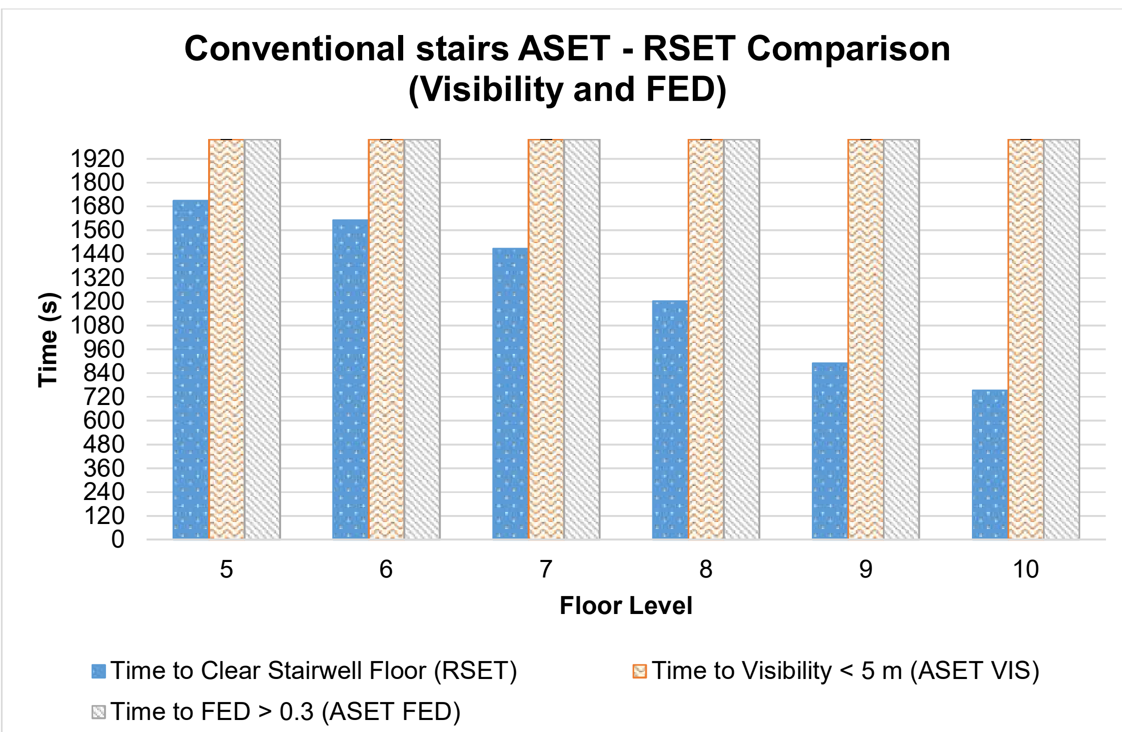
| Tenability conditions during evacuation period<br>Total Evacuation Time: 2829 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 291 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2363 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |

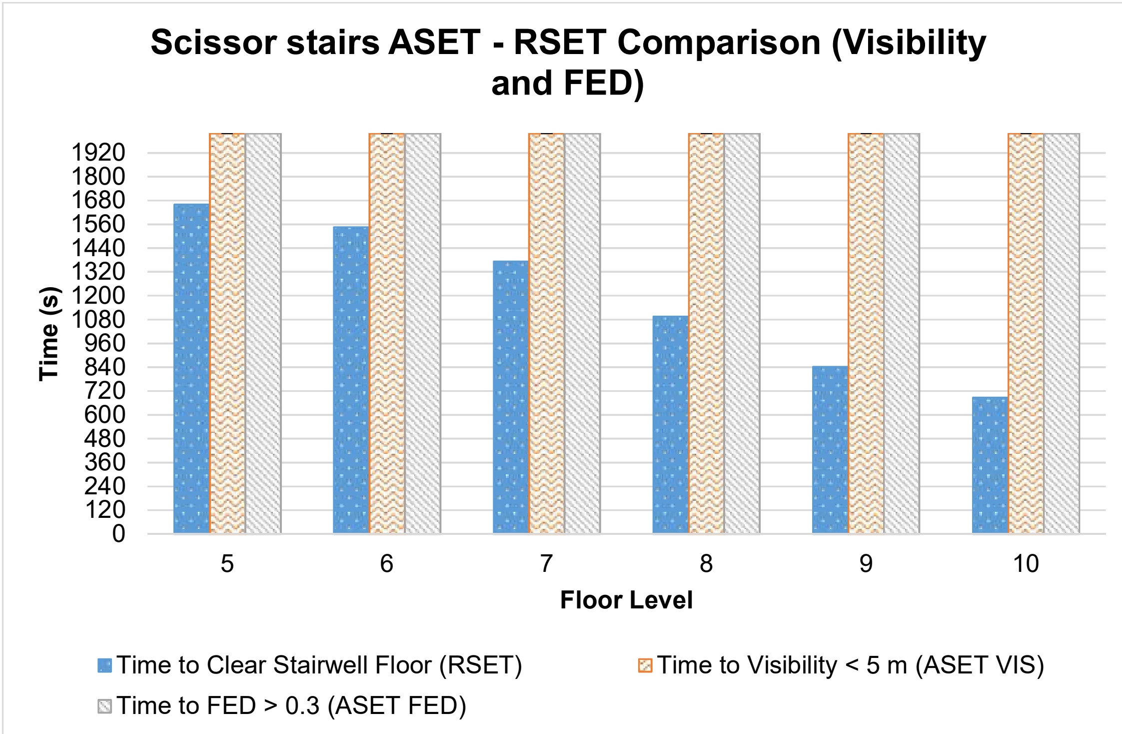
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F19 L_10_T7_P_2.7**



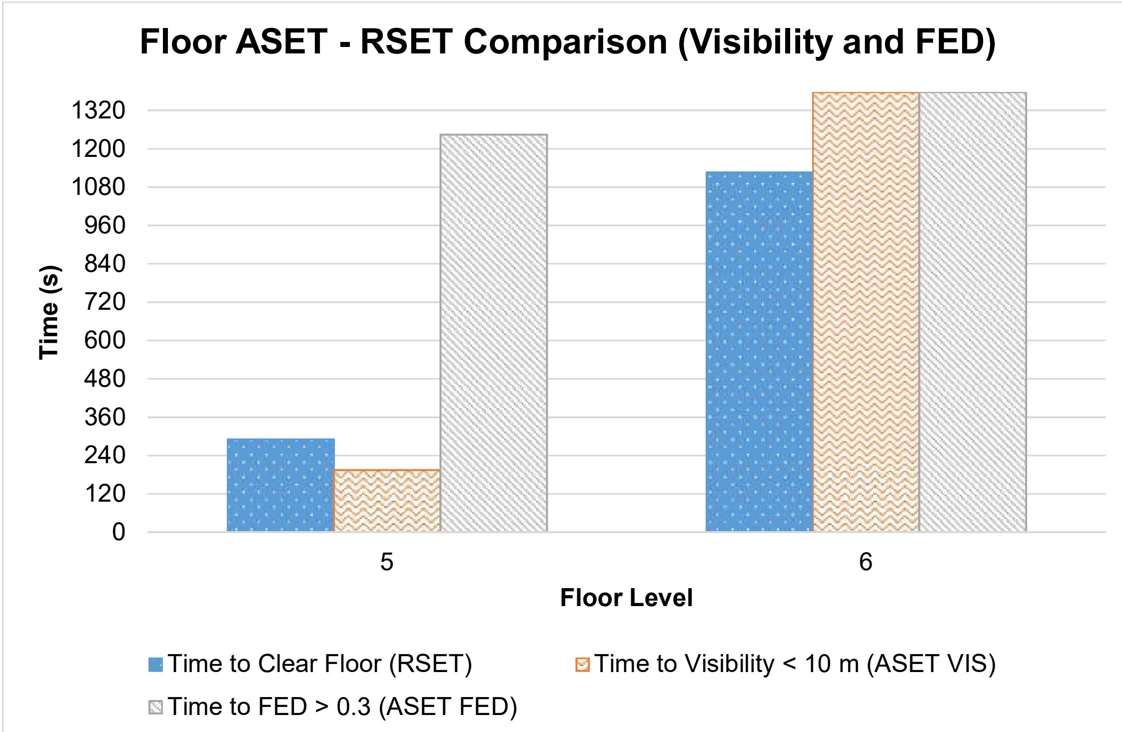

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

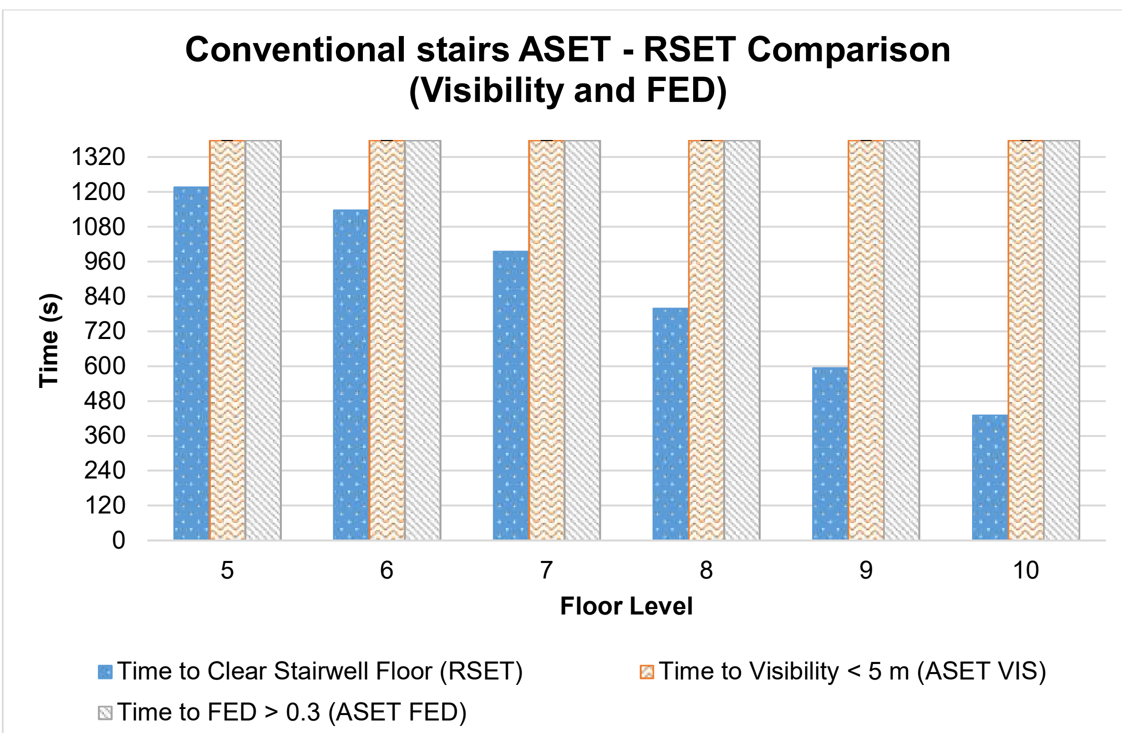
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 2018 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 481 s |
| Visibility < 10 m | Yes (240/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1597 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2250 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C (Fire Floor) |
| **Scissor stairs (2250 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C (Fire Floor) |

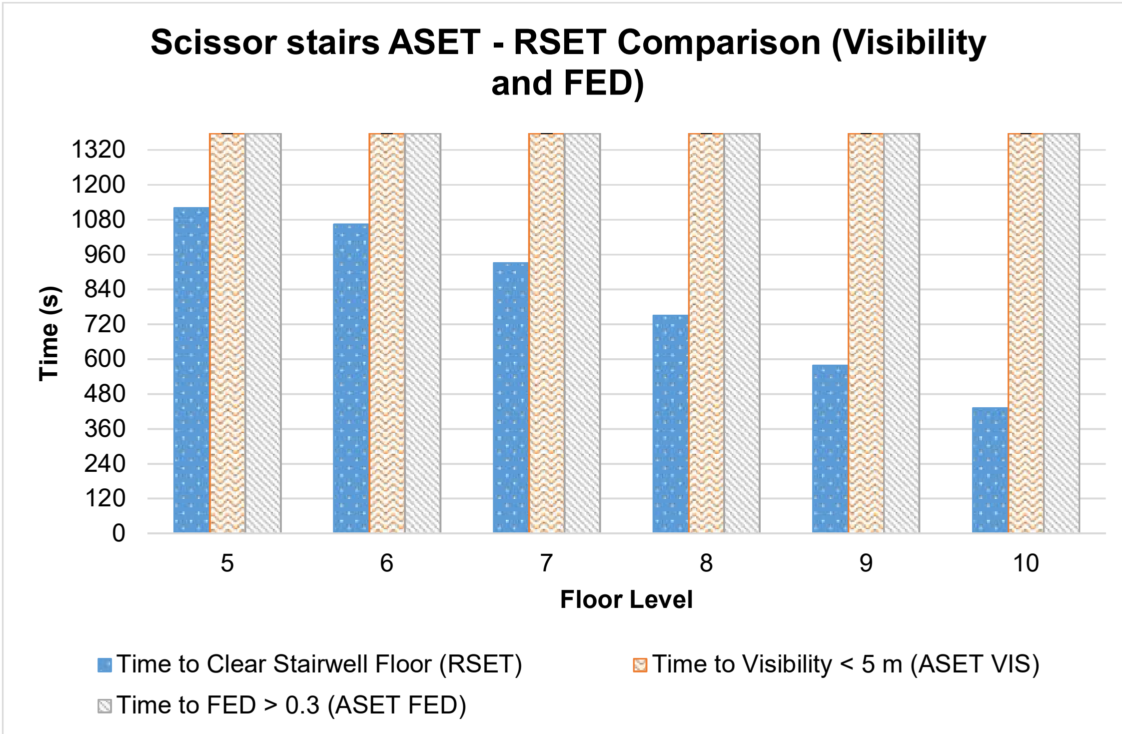
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F20 M_10_T7_P_2.7**



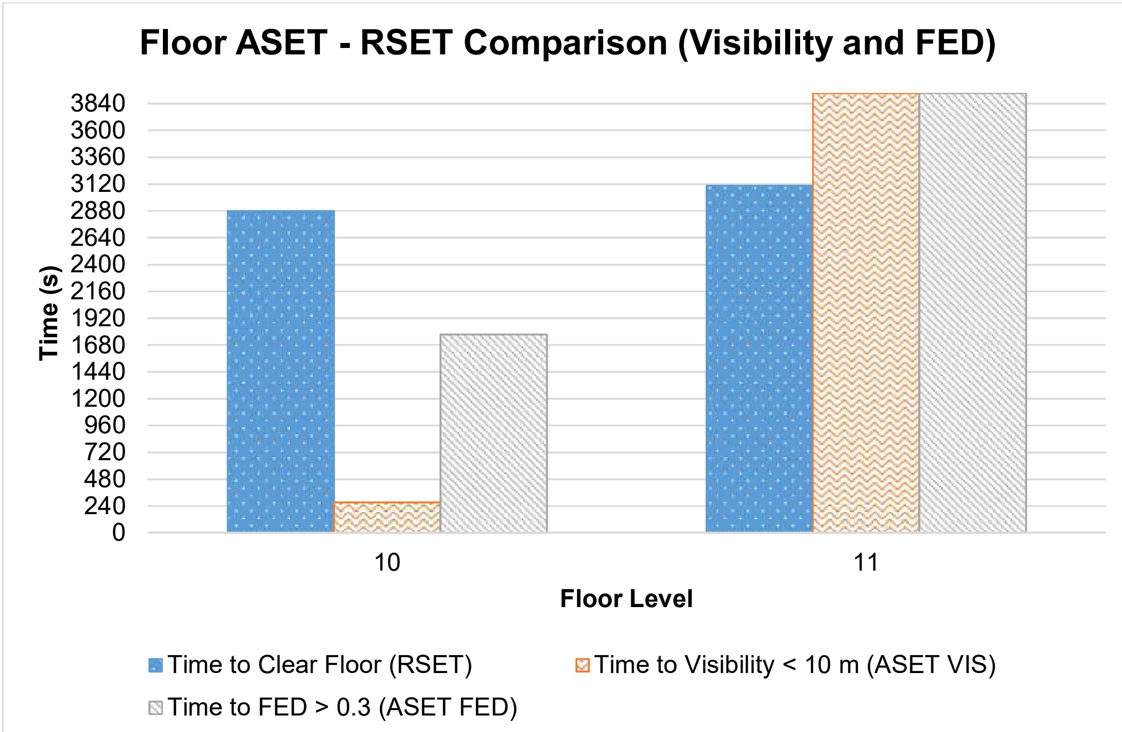

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

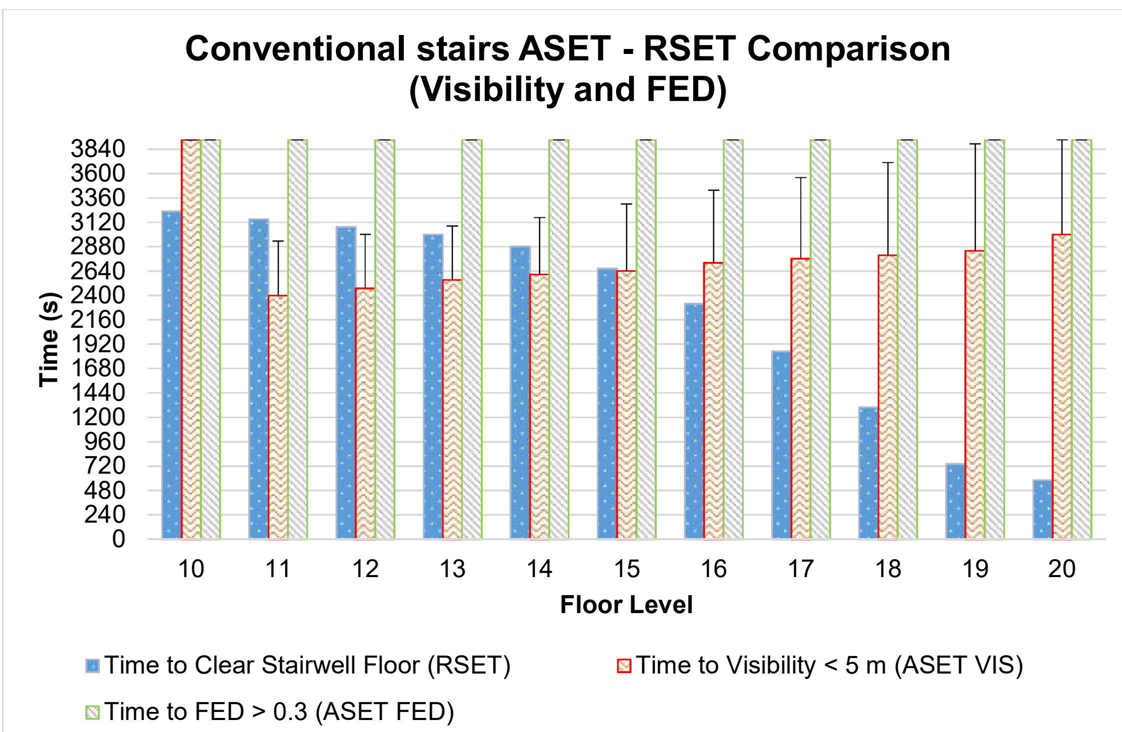
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 1377 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 291 s |
| Visibility < 10 m | Yes (195/-)* |
| FED > 0.3 | No |
| Maximum temperature | 50°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1127 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1098 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |
| **Scissor stairs (1107 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |

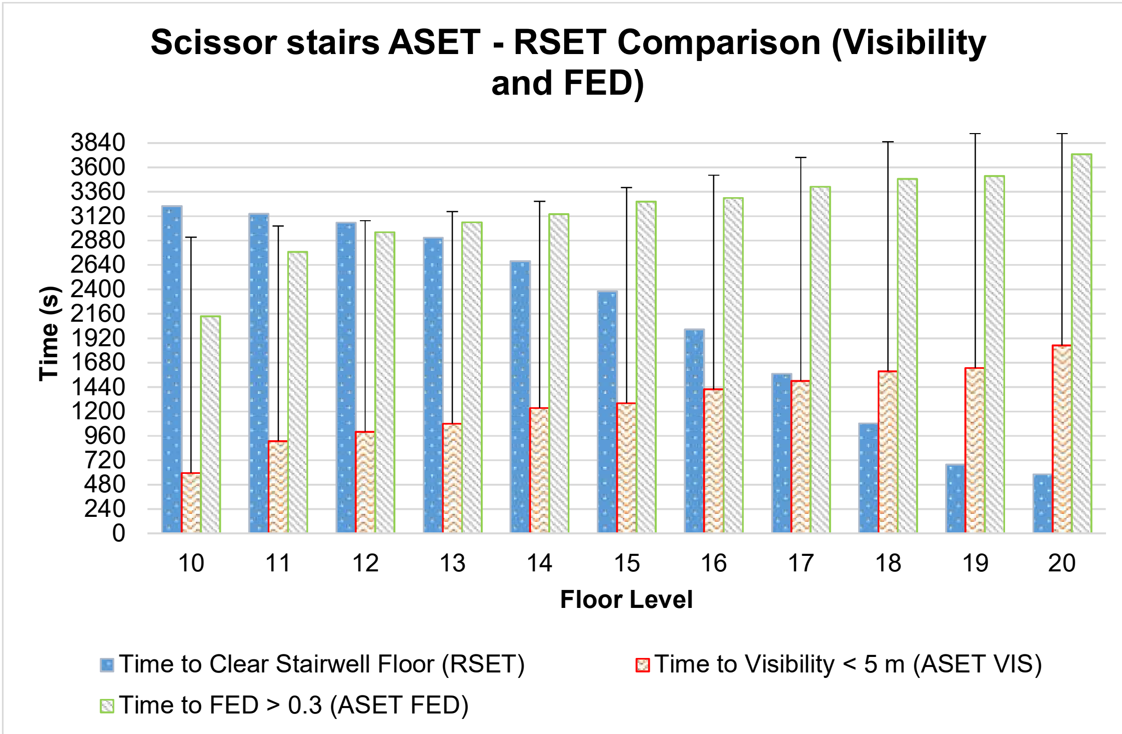
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F21 L_20_T6_T_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 3934 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor ($10^{th}$ floor)** | |
| Time to Clear | 2879 s |
| Visibility < 10 m | Yes (275/-)* |
| FED > 0.3 | Yes (1776)** |
| Maximum temperature | $66^{o}$C |
| **Floor Above ($11^{th}$ floor)** | |
| Time to Clear | 3105 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | $30^{o}$C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | Yes ($11^{th}$ to $15^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $11^{th}$ – 2400 s/535 s<br>$12^{th}$ – 2471 s/530 s<br>$20^{th}$ – 3000 s/>934 s*** |
| FED > 0.3 | No |
| Maximum temperature | $30^{o}$C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes ($10^{th}$ to $17^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $10^{th}$ – 597 s/2317 s<br>$11^{th}$ – 908 s/2113 s<br>$20^{th}$ – 1851 s/>2083 s*** |
| FED > 0.3 | Yes ($10^{th}$ to $12^{th}$ floor) |
| Maximum temperature | $55^{o}$C (Fire Floor) |

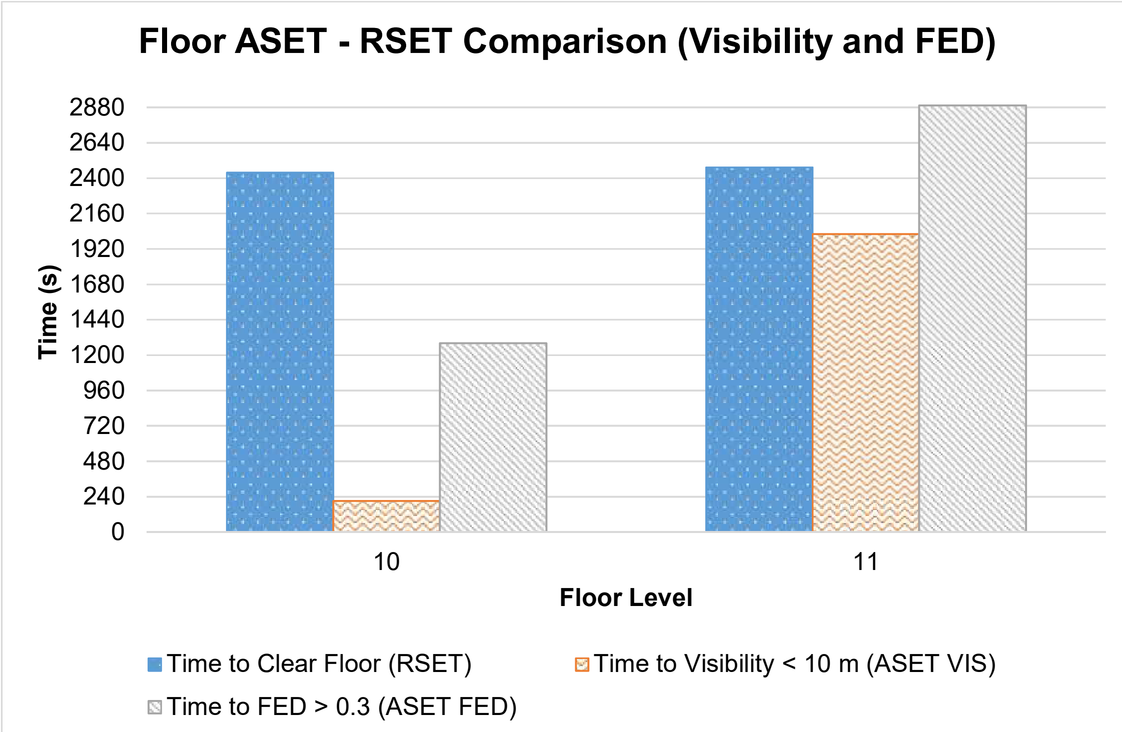
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

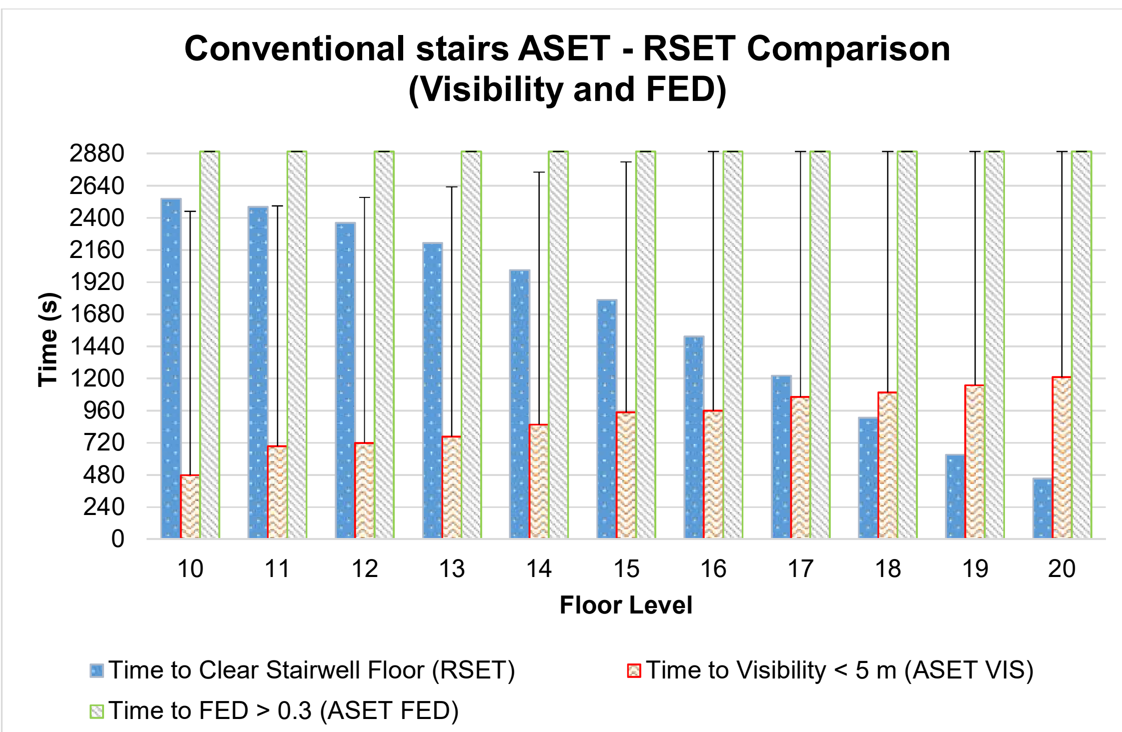
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

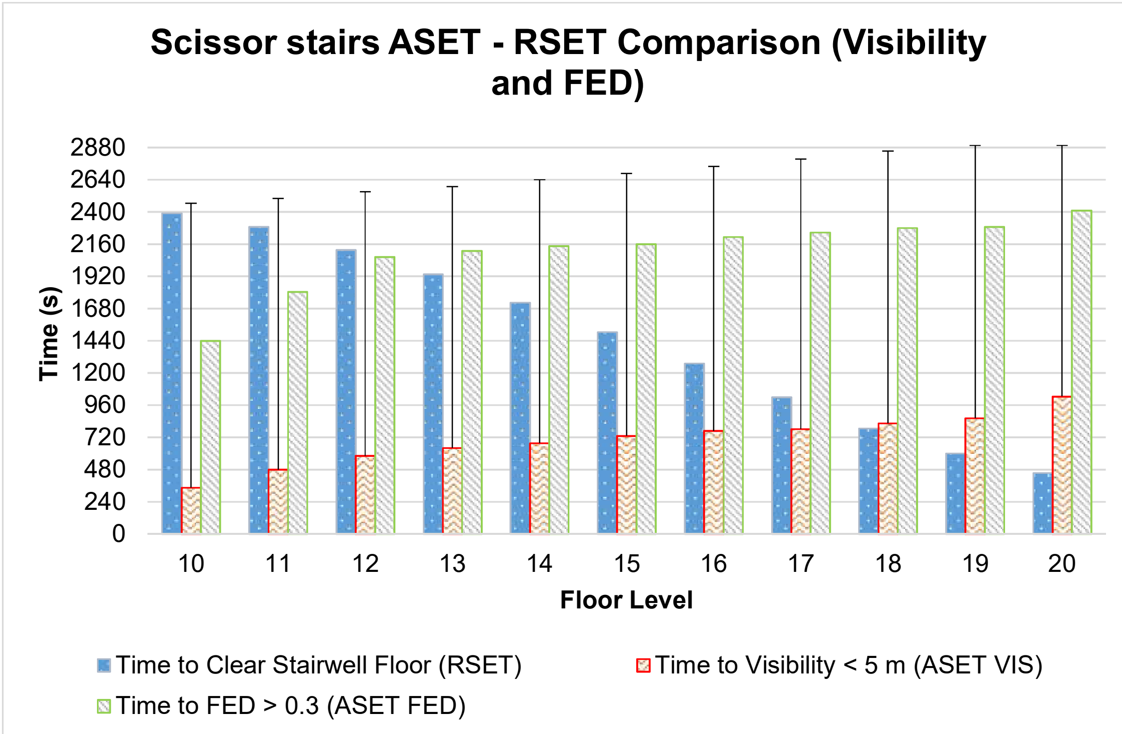
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F22 M_20_T6_T_3.3**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| | |
|---|---|
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 2721 s<br>Decoupled Simulation | |
| **Fire Floor ($10^{th}$ floor)** | |
| Time to Clear Floor | 2438 s |
| Visibility < 10 m | Yes (213/-)* |
| FED > 0.3 | Yes (1281)** |
| Maximum temperature | $95^{o}C$ |
| **Floor Above ($11^{th}$ floor)** | |
| Time to Clear Floor | 2474 s |
| Visibility < 10 m | Yes (2022/2698)* |
| FED > 0.3 | No |
| Maximum temperature | $30^{o}C$ |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes ($10^{th}$ to $17^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $10^{th}$ – 480 s/1970 s<br>$11^{th}$ – 696 s/1795 s<br>$20^{th}$ – 1212 s/>1684 s*** |
| FED > 0.3 | No |
| Maximum temperature | $50^{o}C$ (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | Yes ($10^{th}$ to $17^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $10^{th}$ – 345 s/2121 s<br>$11^{th}$ – 480 s/2021 s<br>$20^{th}$ – 1025 s/>1871 s*** |
| FED > 0.3 | Yes ($10^{th}$ to $12^{th}$) |
| Maximum temperature | $70^{o}C$ (Fire Floor) |

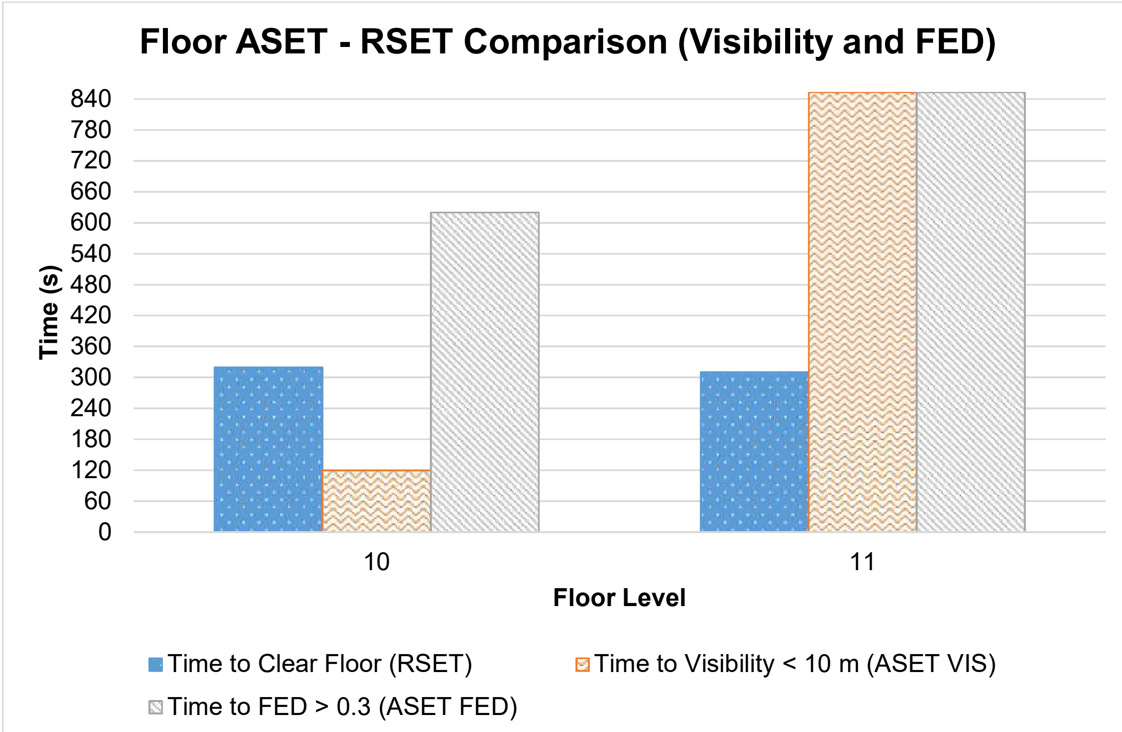
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

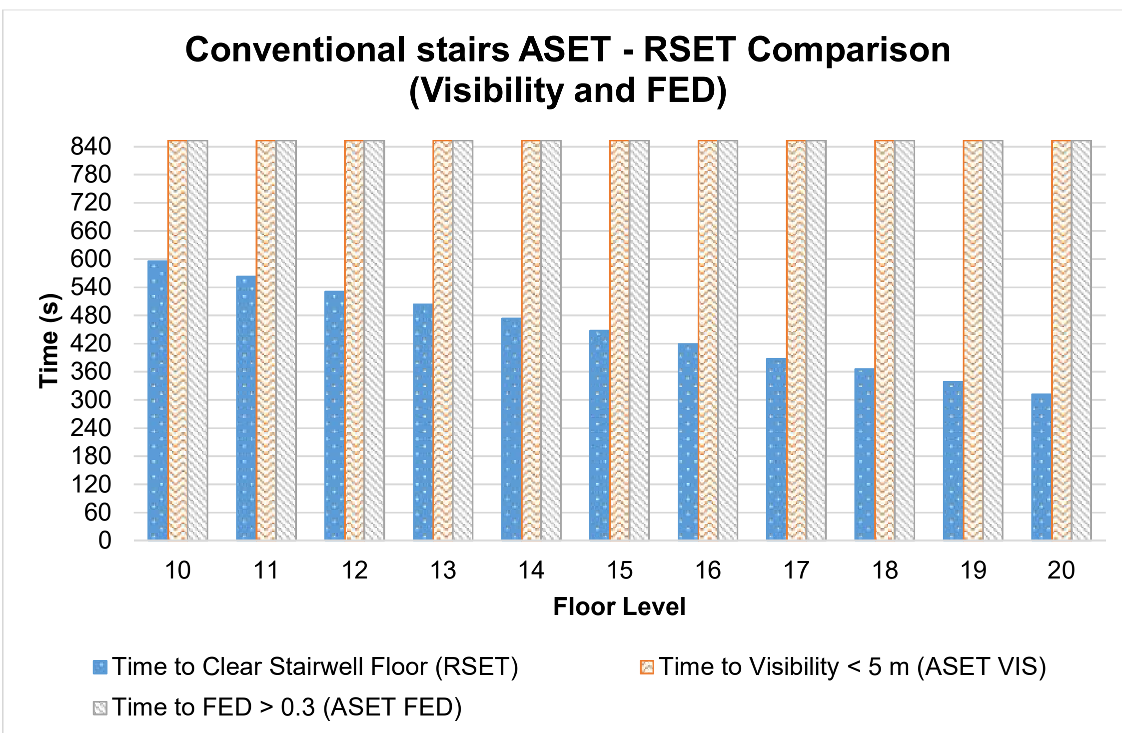
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

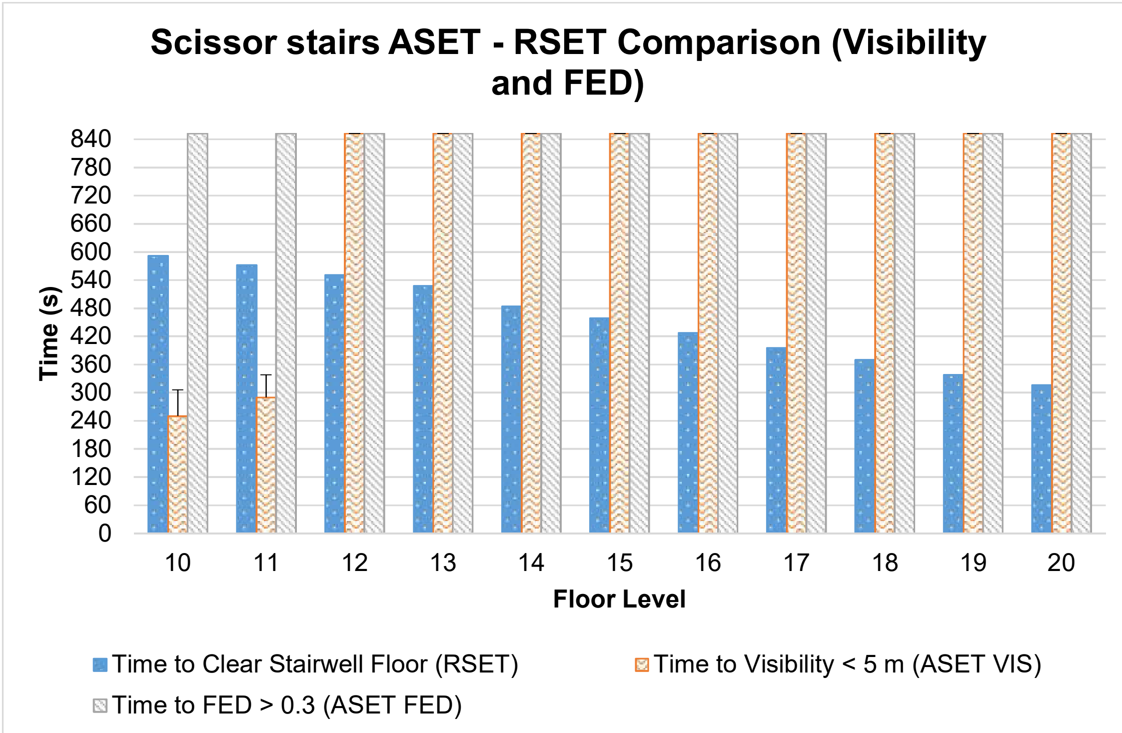
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F23 S_20_T6_T_3.3**





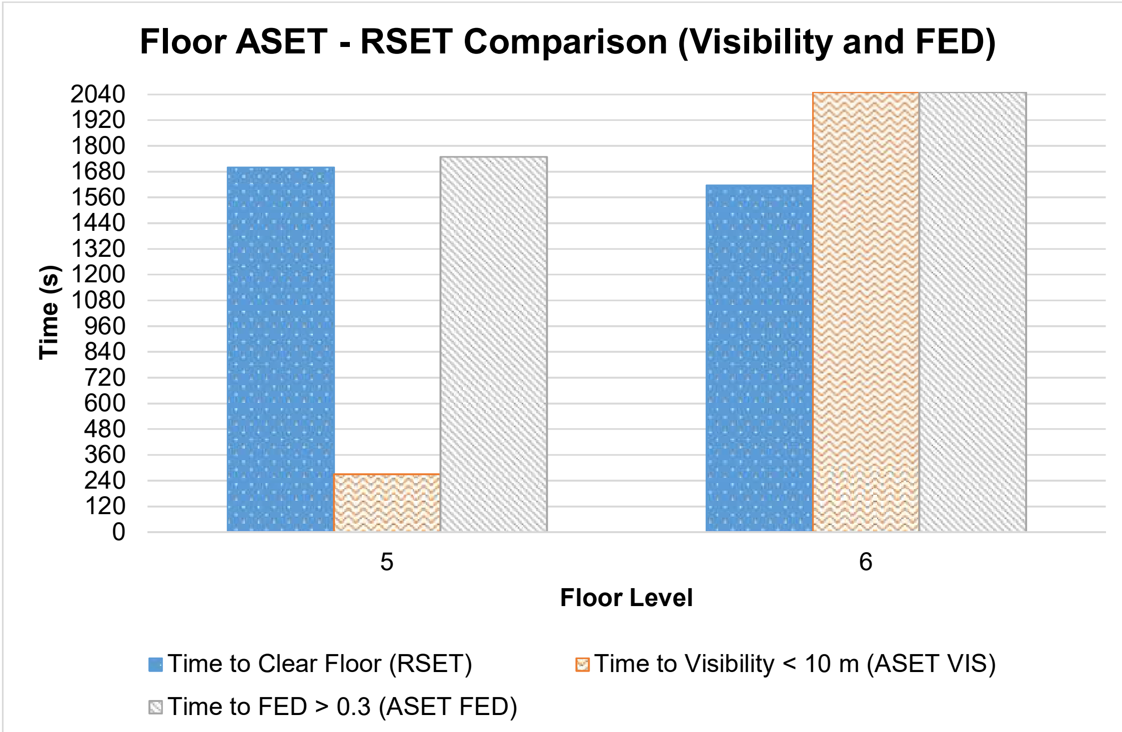
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
840
780
720
660
600
540
480
420
360
300
240
180
120
60
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

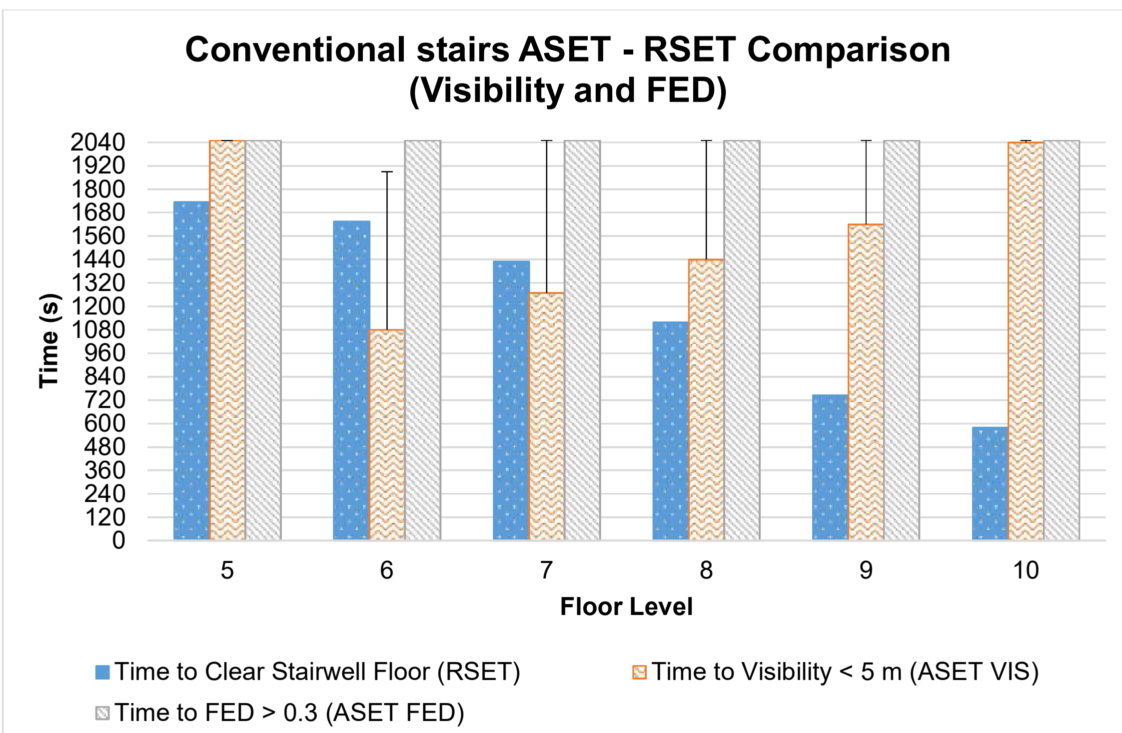
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 853 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 320 s |
| Visibility < 10 m | Yes (120/-)* |
| FED > 0.3 | No |
| Maximum temperature | 110°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 311 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (501 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (468 occupants)** | |
| Visibility < 5 m | Yes (10th to 11th) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 250 s/56 s<br>11th – 290 s/48 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 60°C (Fire Floor) |

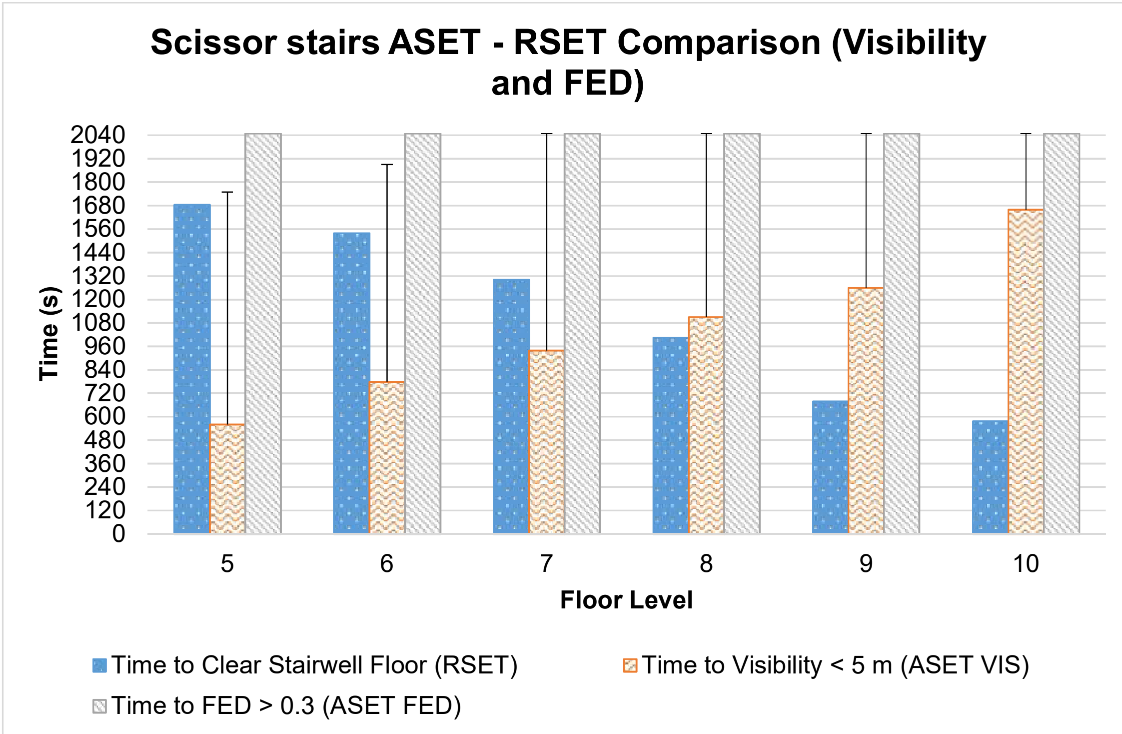
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F24 L_10_T6_T_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

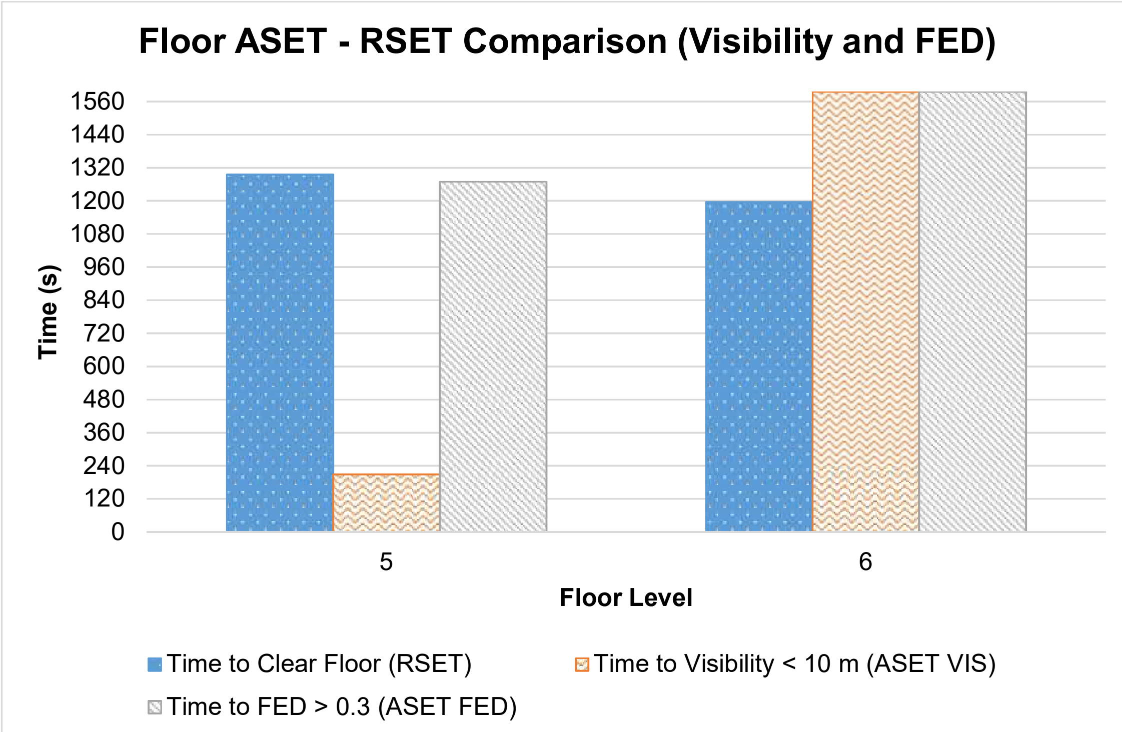
| Tenability conditions during evacuation period<br>Total Evacuation Time: 2050 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 1701 s |
| Visibility < 10 m | Yes (270/-)* |
| FED > 0.3 | No |
| Maximum temperature | 55oC |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1617 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25oC |
| **Conventional stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (6th and 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – NEVER/0 s<br>6th – 1080 s/810 s<br>10th – 2040 s/>10 s*** |
| FED > 0.3 | No |
| Maximum temperature | 30oC (Fire Floor) |
| **Scissor stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (5th to 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 560 s/1189 s<br>6th – 780 s/1112 s<br>10th – 1660 s/>390 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50oC (Fire Floor) |

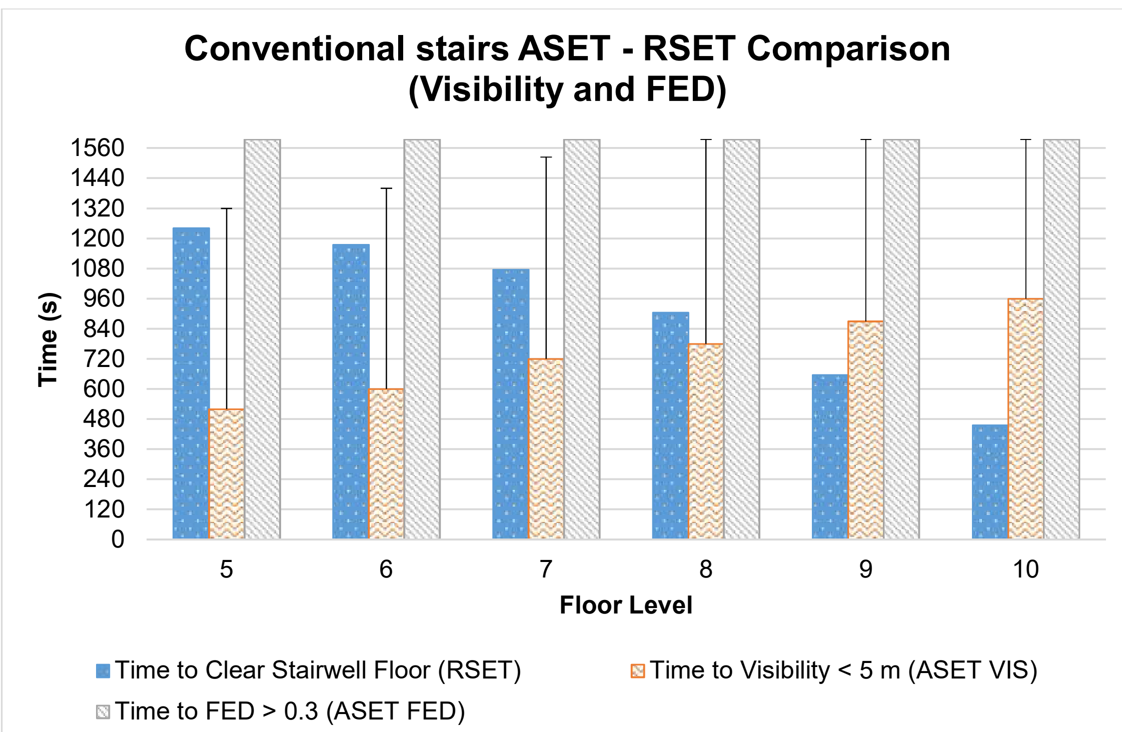
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

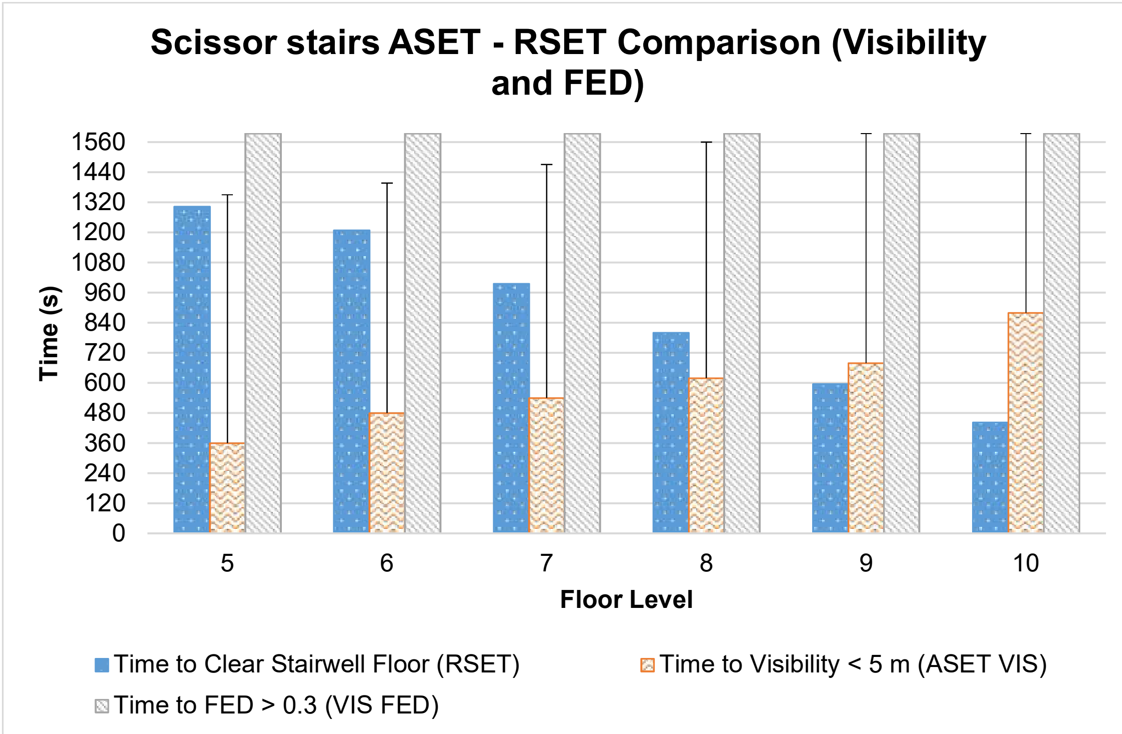
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F25 M_10_T6_T_3.3**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (VIS FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 1595 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor ($5^{th}$ floor)** | |
| Time to Clear Floor | 1296 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | Yes (1270)** |
| Maximum temperature | $80^{o}$C |
| **Floor Above ($6^{th}$ floor)** | |
| Time to Clear Floor | 1197 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | $25^{o}$C |
| **Conventional stairs (1058 occupants)** | |
| Visibility < 5 m | Yes ($5^{th}$ and $8^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $5^{th}$ – 520 s/800 s<br>$6^{th}$ – 600 s/800 s<br>$10^{th}$ – 960 s/>635 s*** |
| FED > 0.3 | No |
| Maximum temperature | $50^{o}$C (Fire Floor) |
| **Scissor stairs (1147 occupants)** | |
| Visibility < 5 m | Yes ($5^{th}$ to $8^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | $5^{th}$ – 360 s/990 s<br>$6^{th}$ – 480 s/917 s<br>$10^{th}$ – 880 s/>715 s*** |
| FED > 0.3 | No |
| Maximum temperature | $65^{o}$C (Fire Floor) |

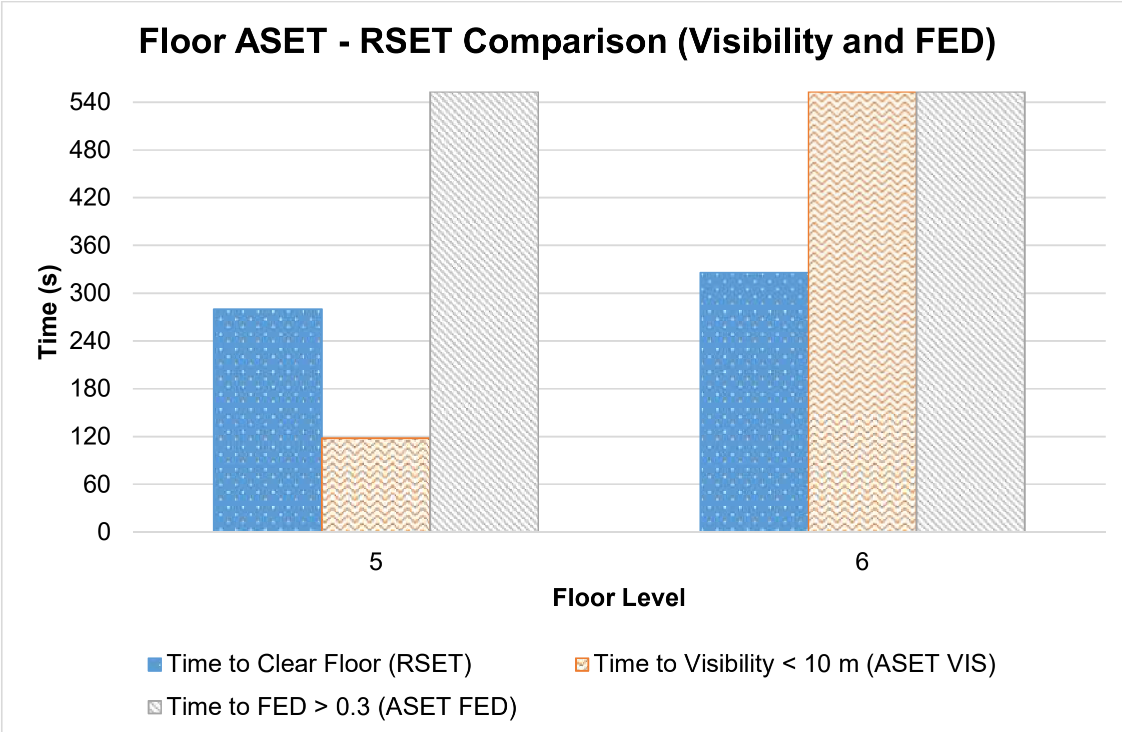
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

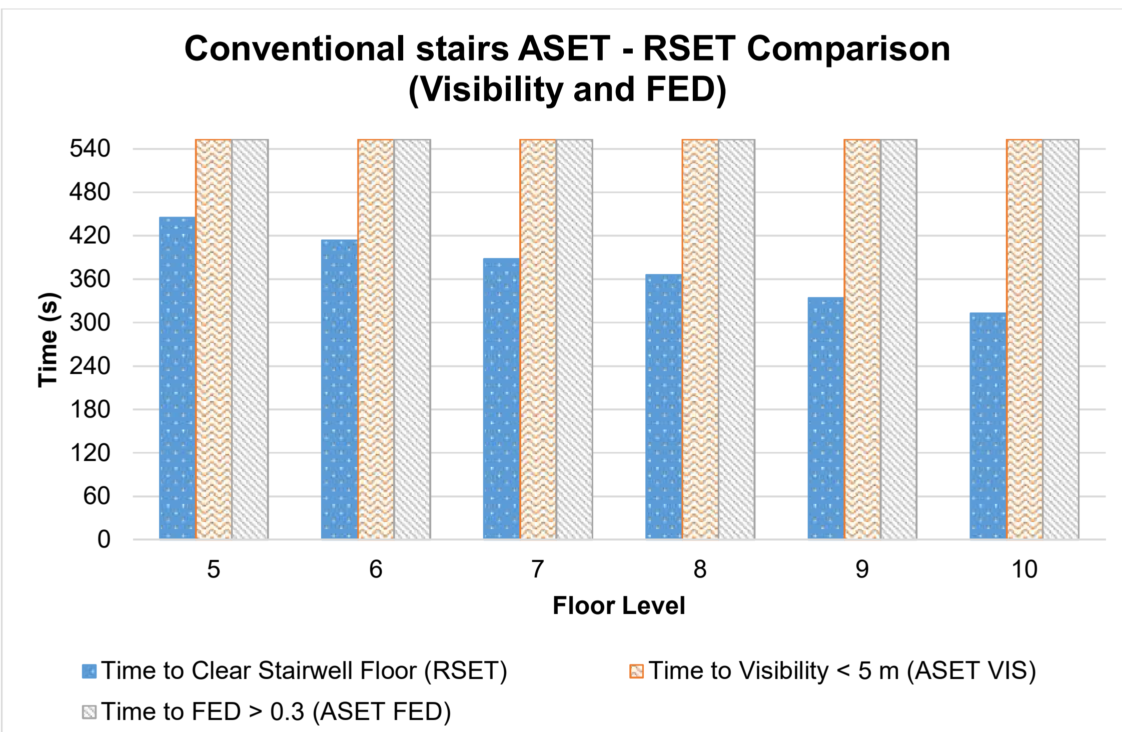
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

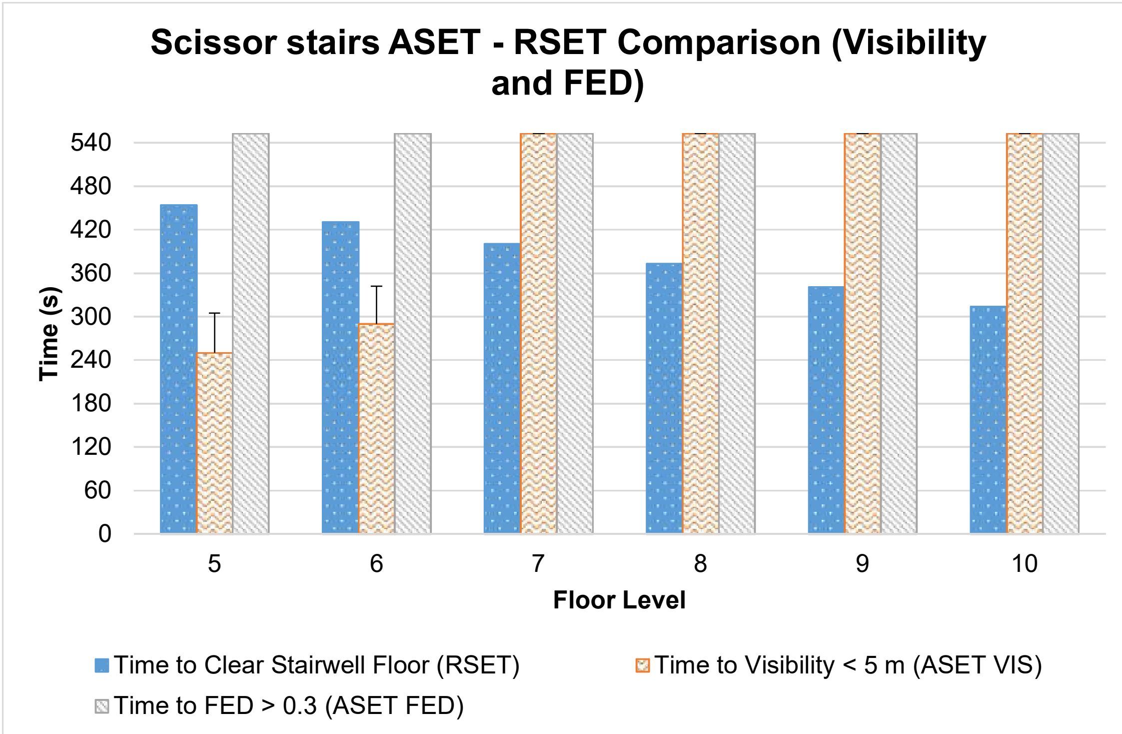
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F26 S_10_T6_T_3.3**





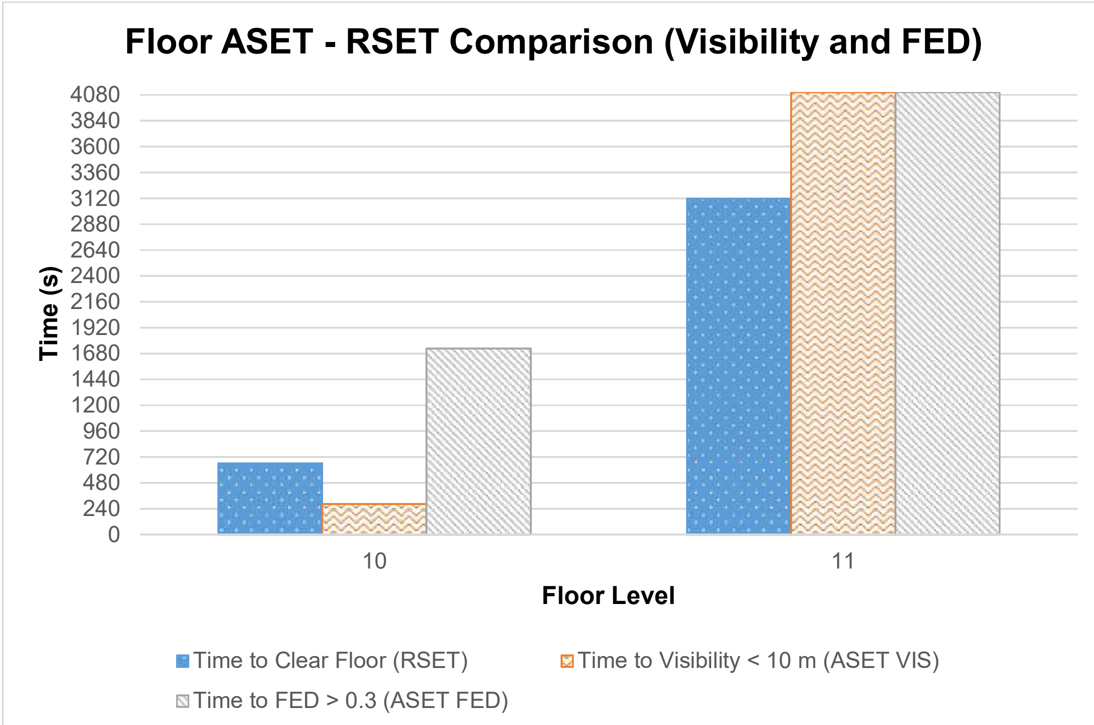
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
540
480
420
360
300
240
180
120
60
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

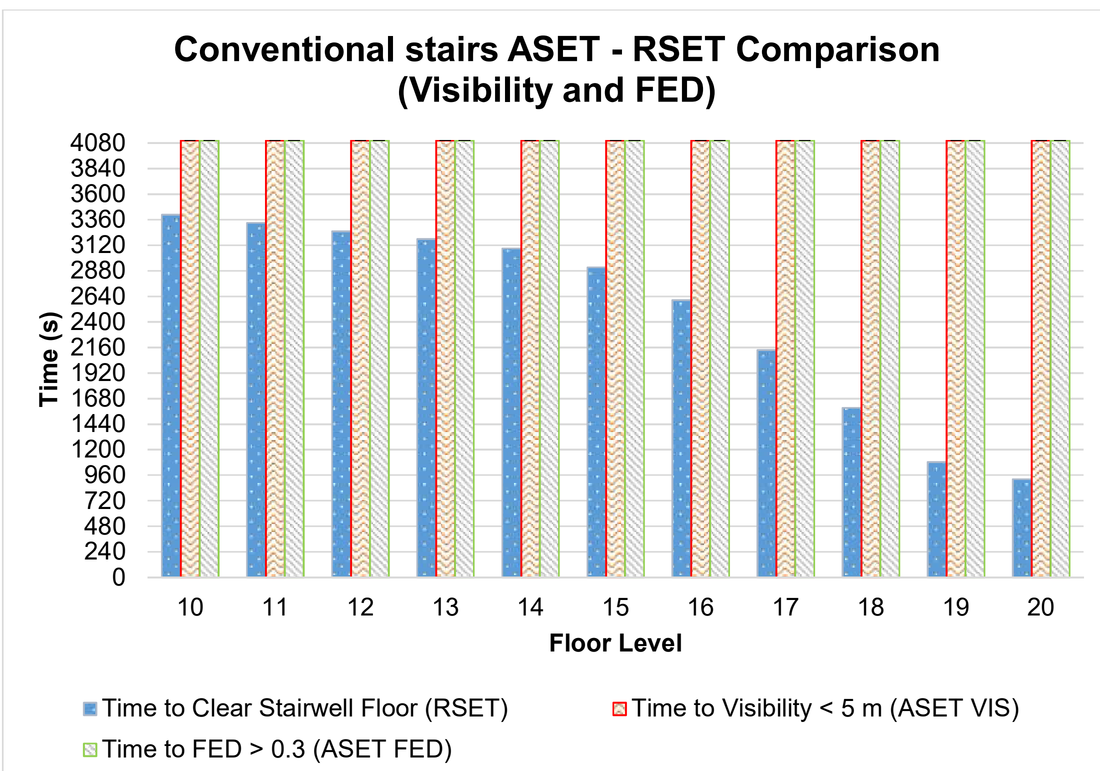
| Tenability conditions during evacuation period<br>Total Evacuation Time: 533 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 280 s |
| Visibility < 10 m | Yes (118/-)* |
| FED > 0.3 | No |
| Maximum temperature | 100°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 326 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 20°C |
| **Conventional stairs (225 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 40°C (Fire Floor) |
| **Scissor stairs (234 occupants)** | |
| Visibility < 5 m | Yes (5th to 6th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 250 s/55 s<br>6th – 290 s/52 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 80°C (Fire Floor) |

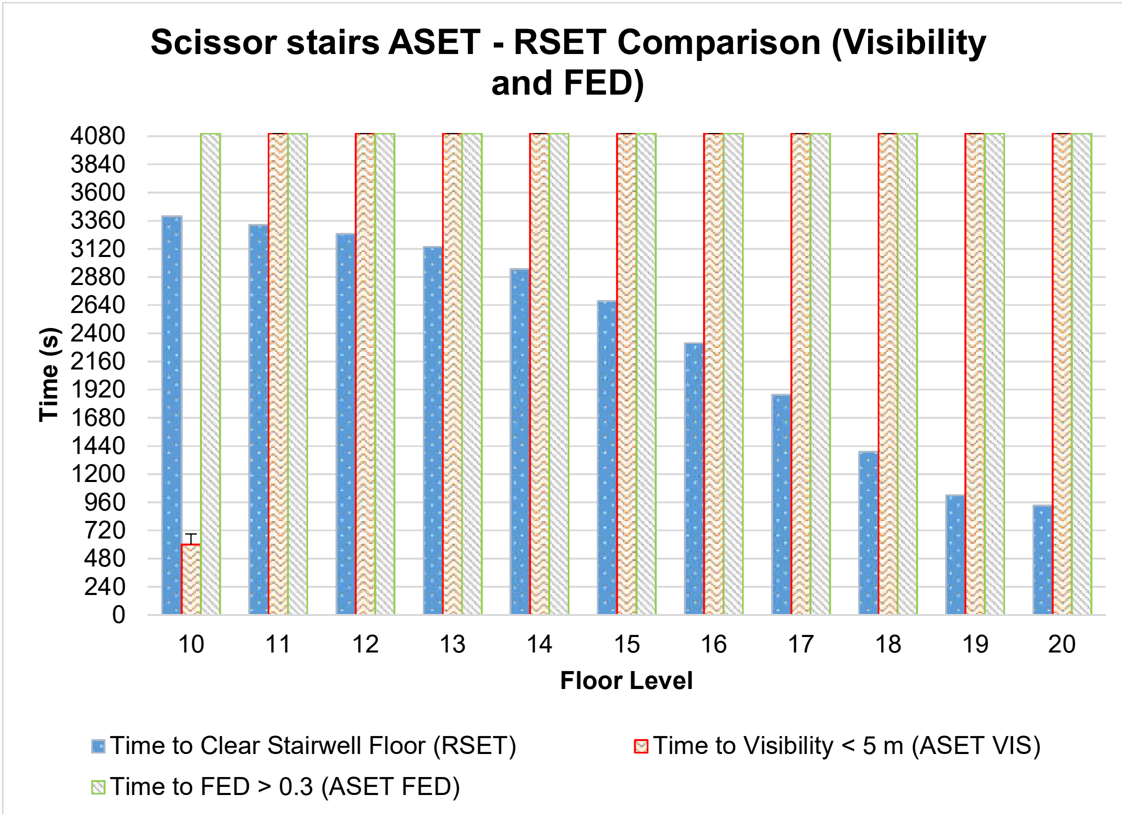
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F27 L_20_T6_P_3.3**



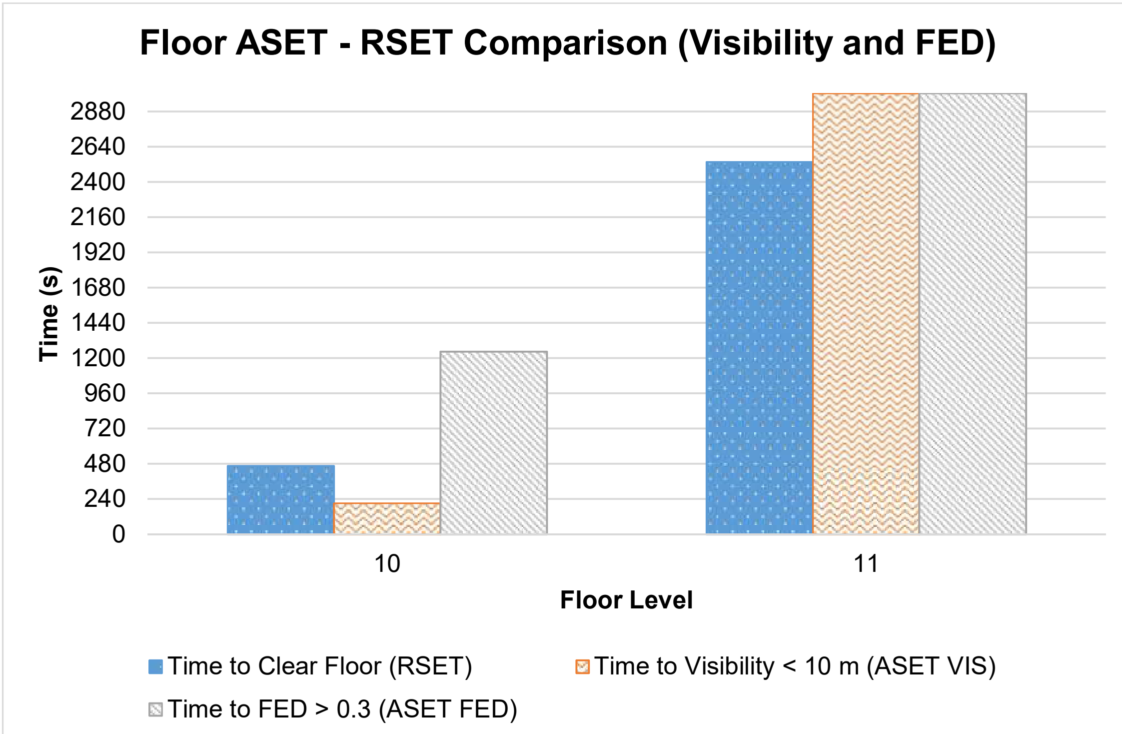

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
4080
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

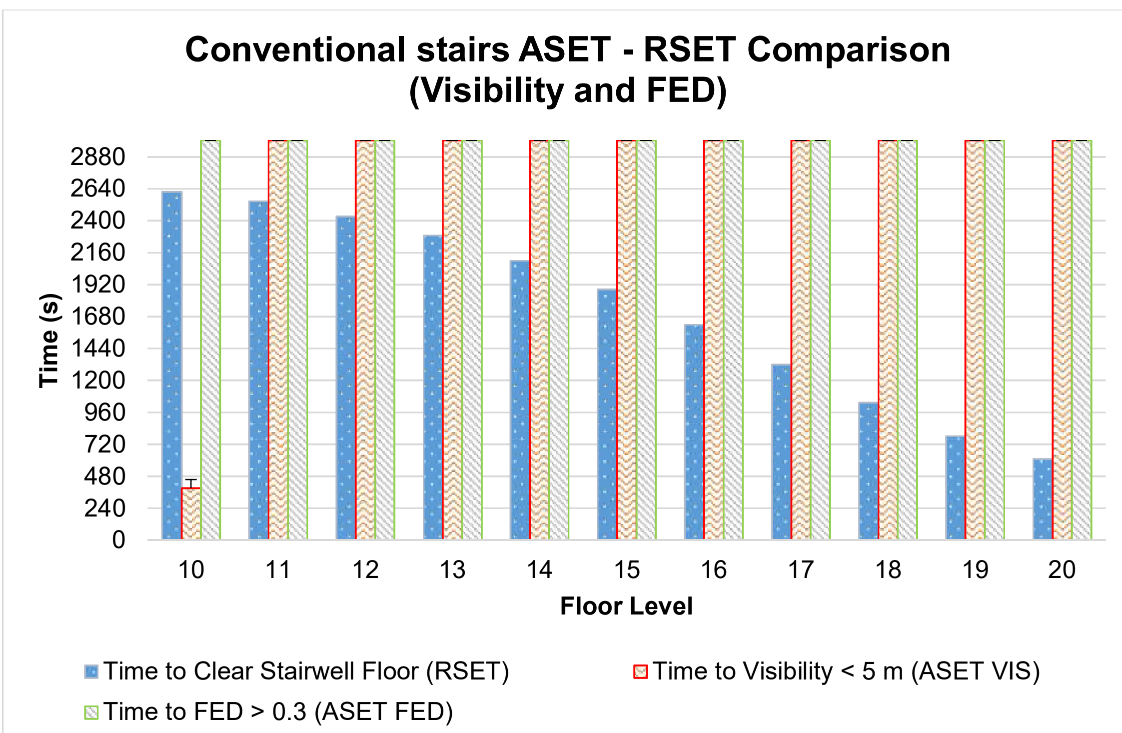
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 4105 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10$^{th}$ floor)** | |
| Time to Clear | 663 s |
| Visibility < 10 m | Yes (284/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45$^{o}$C |
| **Floor Above (11$^{th}$ floor)** | |
| Time to Clear | 3117 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30$^{o}$C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30$^{o}$C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (10$^{th}$ floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10$^{th}$ – 600 s/90 s<br>11$^{th}$ – NEVER/0 s<br>20$^{th}$ – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 35$^{o}$C (Fire Floor) |

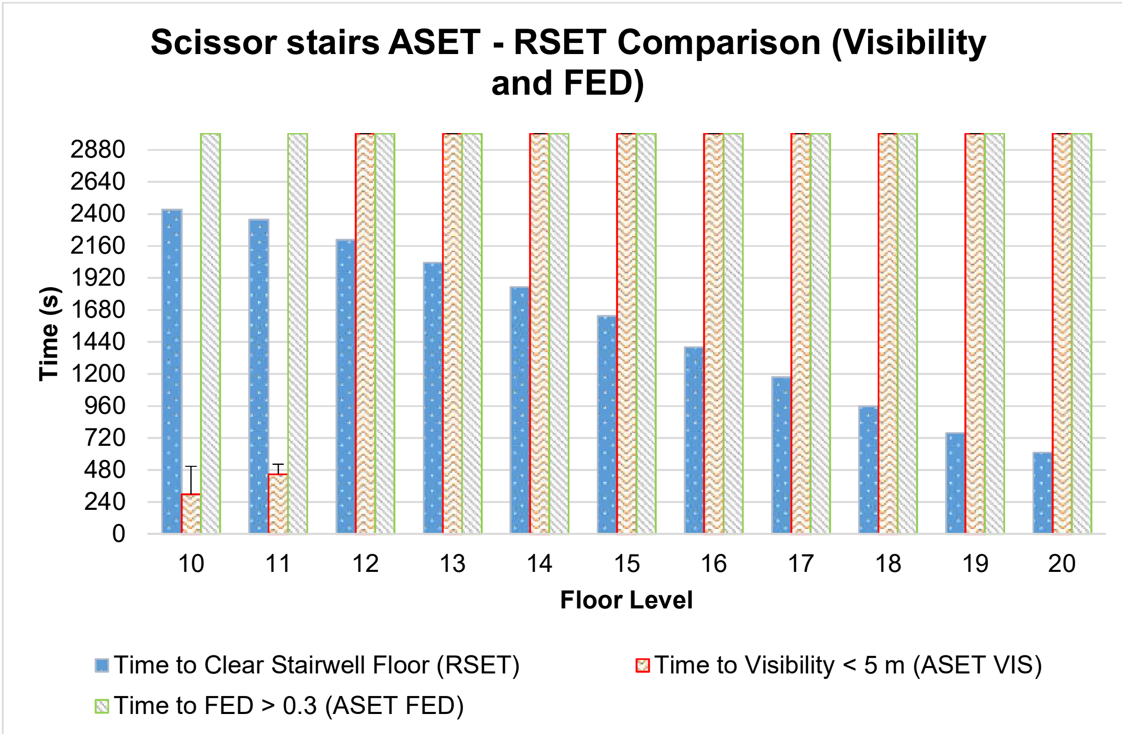
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F28 M_20_T6_P_3.3**



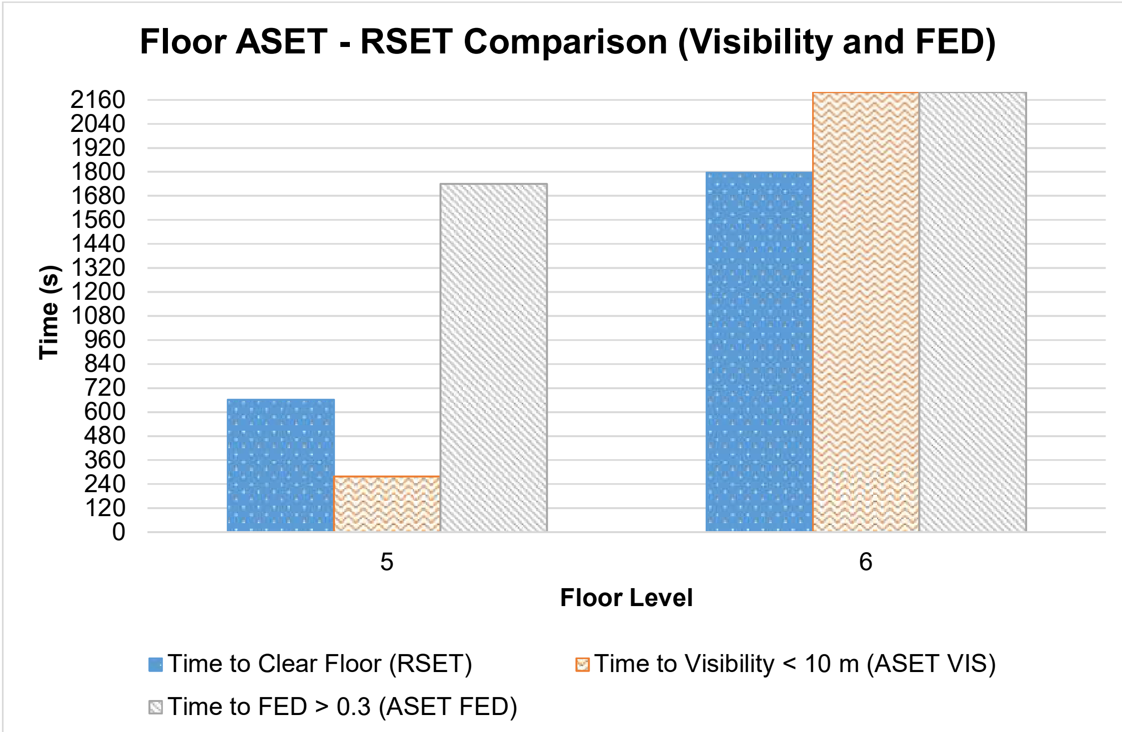

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

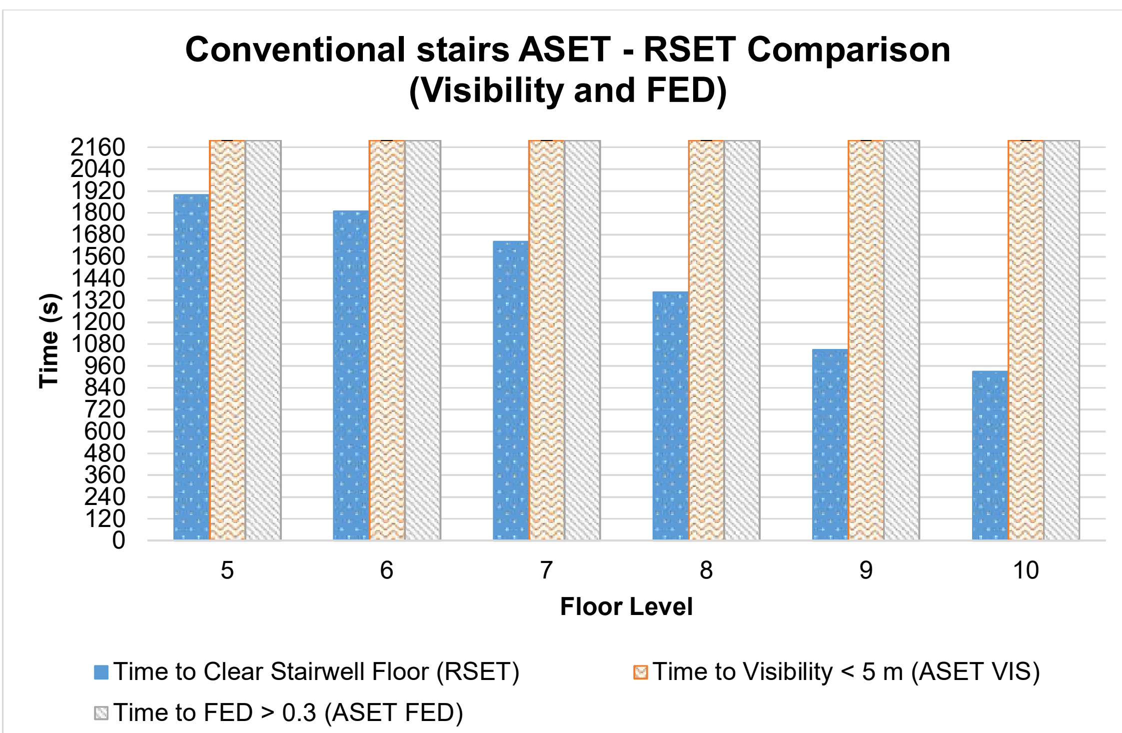
| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 3004 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 466 s |
| Visibility < 10 m | Yes (213/-)* |
| FED > 0.3 | No |
| Maximum temperature | 57°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2538 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes (10th) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 391 s/65 s<br>11th – NEVER/0 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | Yes (10th to 11th) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 298 s/210 s<br>11th – 448 s/76 s<br>20th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 45°C (Fire Floor) |

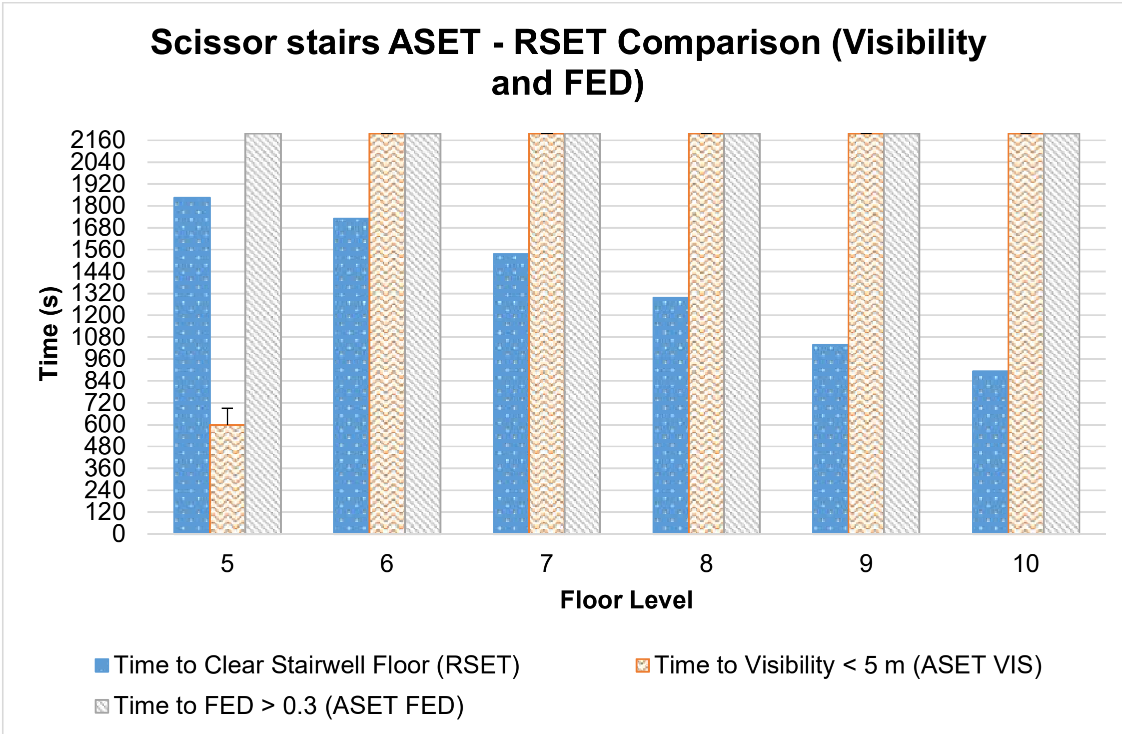
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F29 L_10_T6_P_3.3**





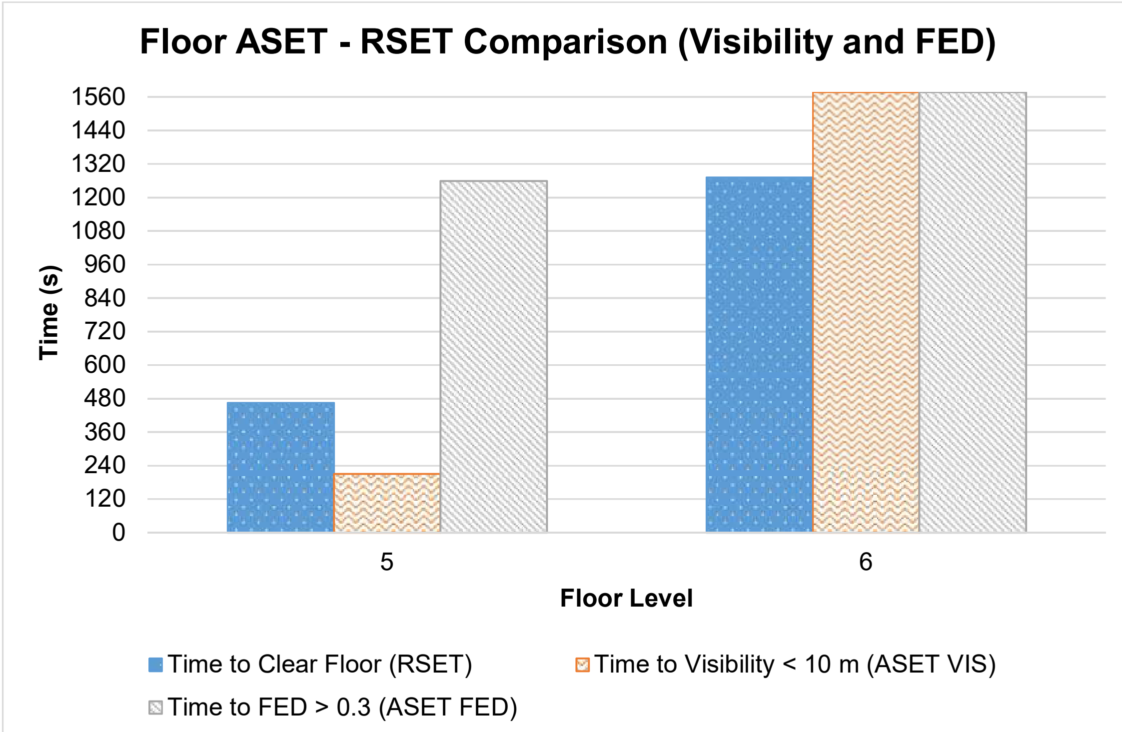
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2160
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

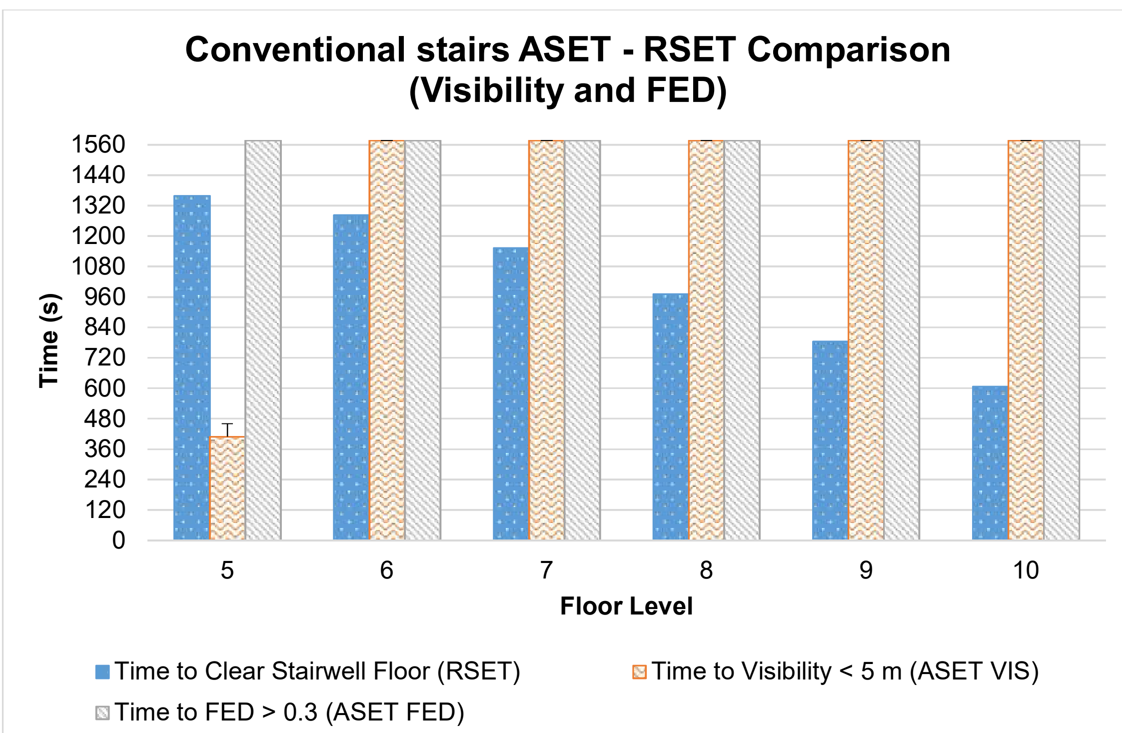
| Tenability conditions during evacuation period<br>Total Evacuation Time: 2198 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 663 s |
| Visibility < 10 m | Yes (280/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45$^{o}$C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1797 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25$^{o}$C |
| **Conventional stairs (2252 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25$^{o}$C (Fire Floor) |
| **Scissor stairs (2248 occupants)** | |
| Visibility < 5 m | Yes (5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 600 s/90 s<br>6th – NEVER/0 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 35$^{o}$C (Fire Floor) |

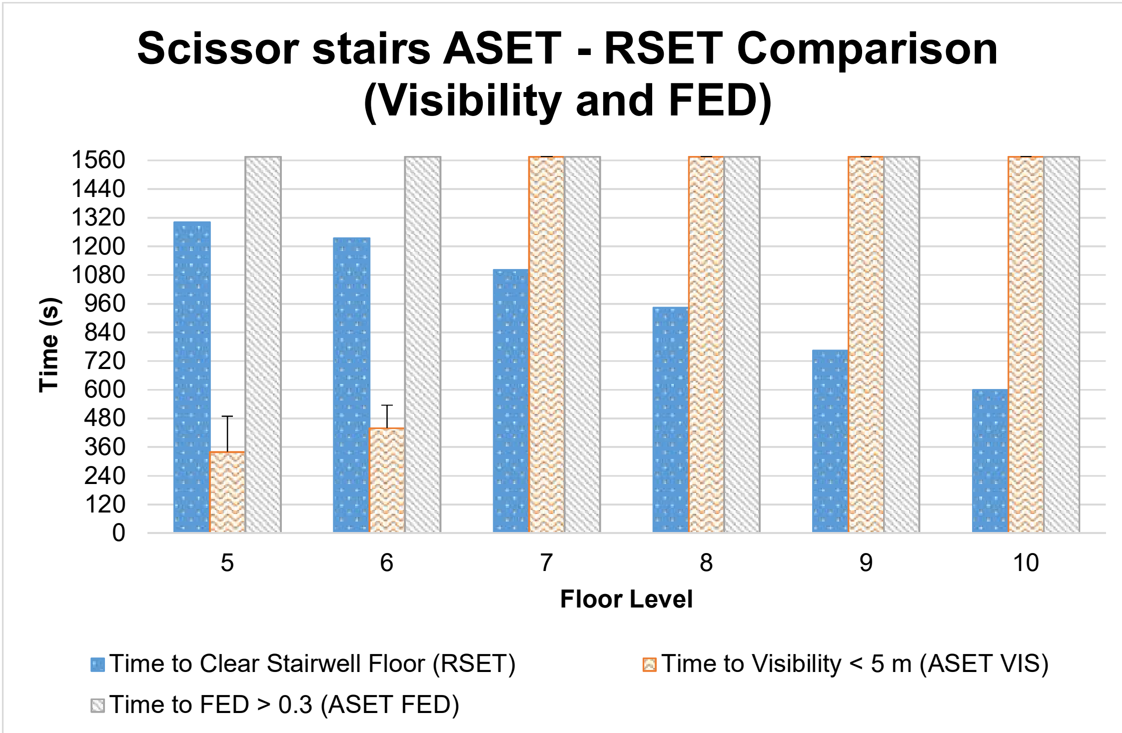
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F30 M_10_T6_P_3.3**





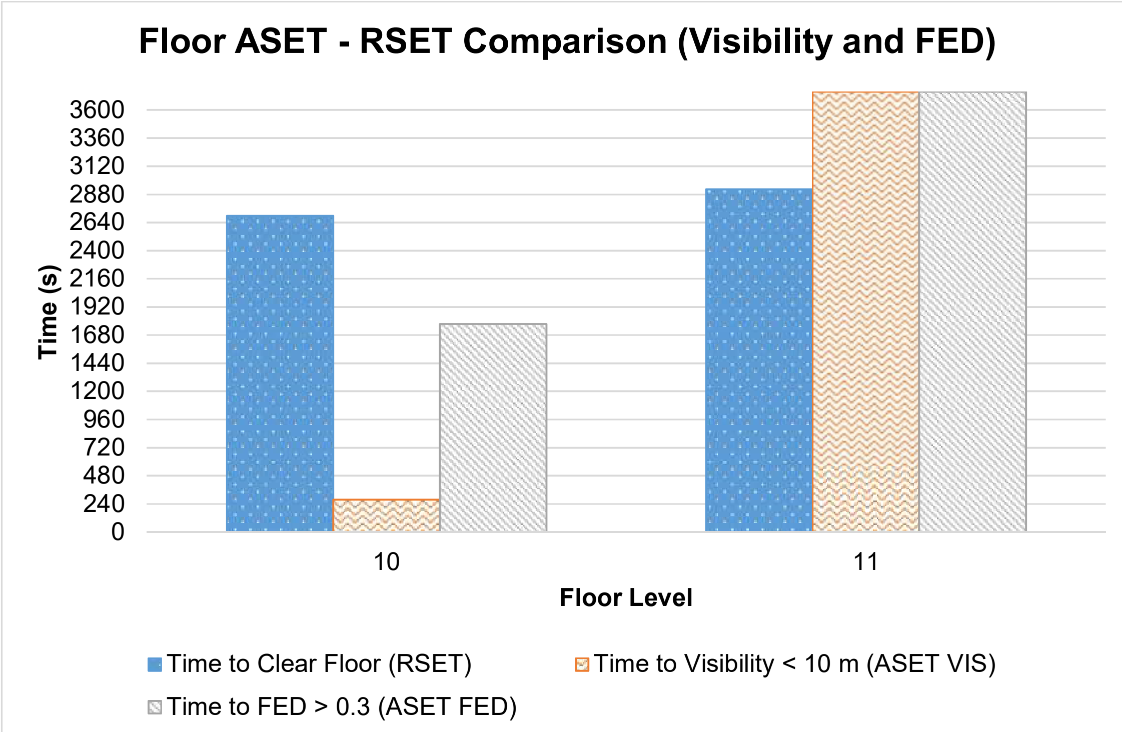
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

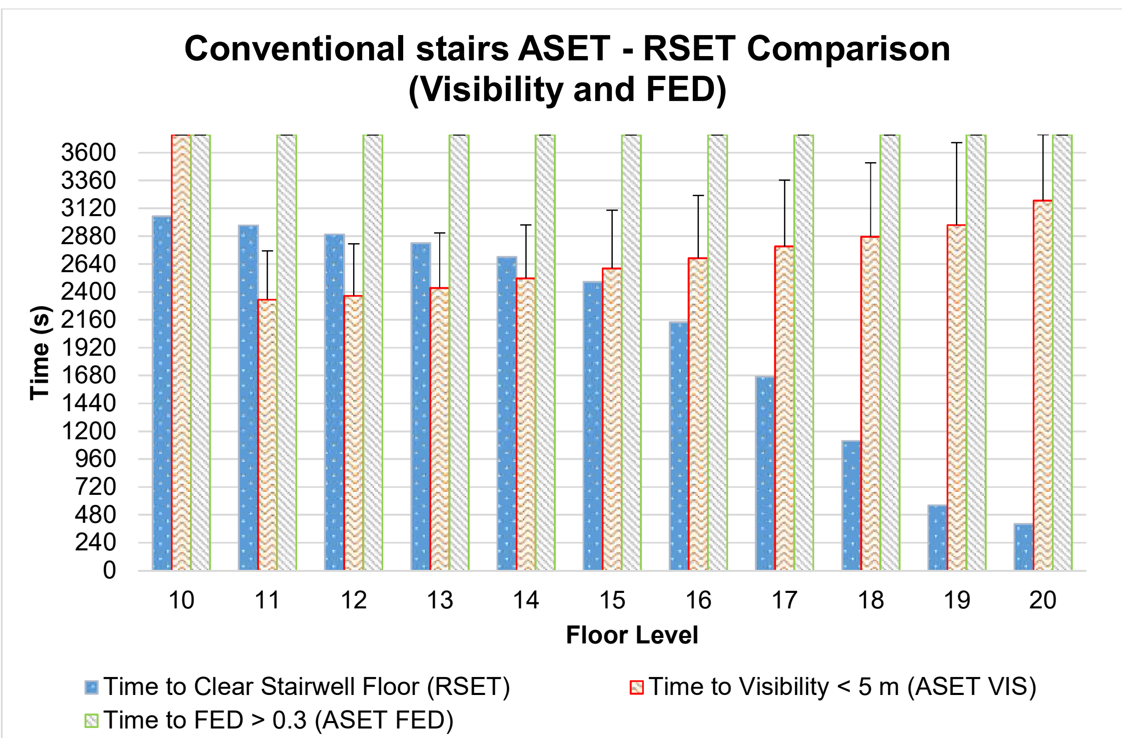
| Tenability conditions during evacuation period<br>Total Evacuation Time: 1577 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 466 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | No |
| Maximum temperature | 55°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1273 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1101 occupants)** | |
| Visibility < 5 m | Yes (5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 410 s/50 s<br>6th – NEVER/0 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (1104 occupants)** | |
| Visibility < 5 m | Yes (5th to 6th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 340 s/149 s<br>6th – 440 s/95 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |

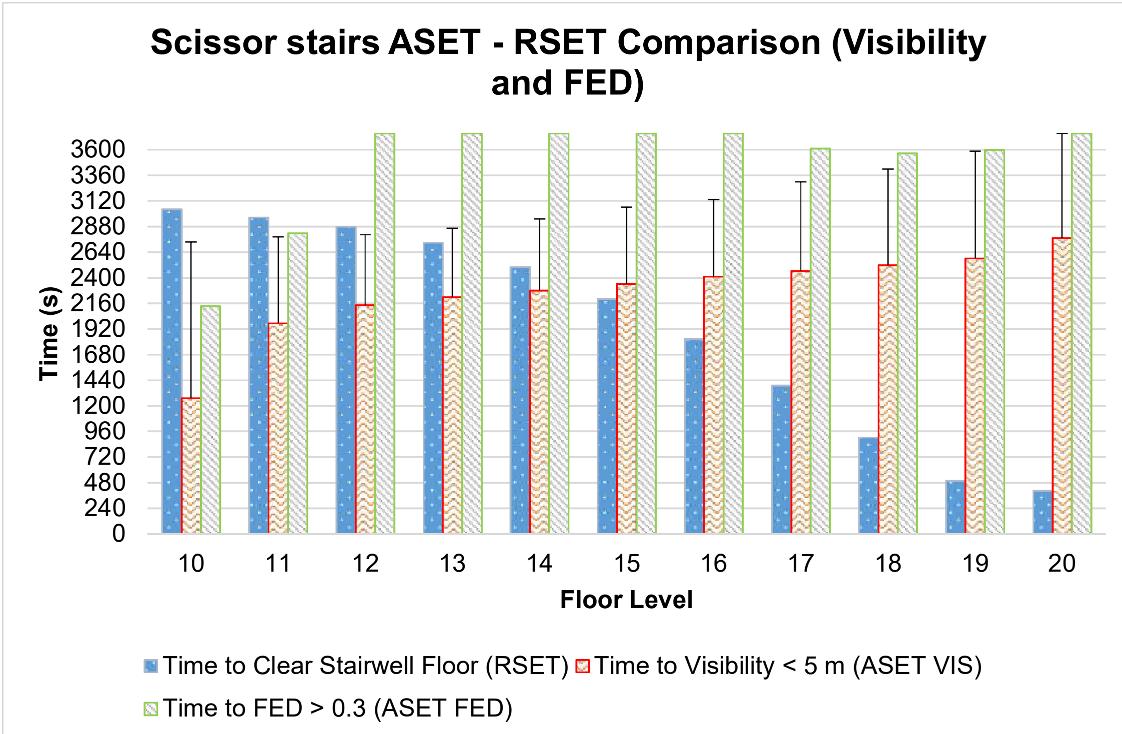
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F31 L_20_T7_T_3.3**





Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| Tenability conditions during evacuation period<br>Total Evacuation Time: 3755 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 2700 s |
| Visibility < 10 m | Yes (278/-)* |
| FED > 0.3 | Yes (1776)** |
| Maximum temperature | 68°C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2926 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (11th to 14th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 11th – 2334 s/420 s<br>12th – 2368 s/445 s<br>20th – 3186 s/>569 s*** |
| FED > 0.3 | No |
| Maximum temperature | 25°C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | Yes (10th to 14th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 1272 s/1464 s<br>11th – 1974 s/809 s<br>20th – 2776 s/>979 s*** |
| FED > 0.3 | Yes (10th to 12th floor) |
| Maximum temperature | 55°C (Fire Floor) |

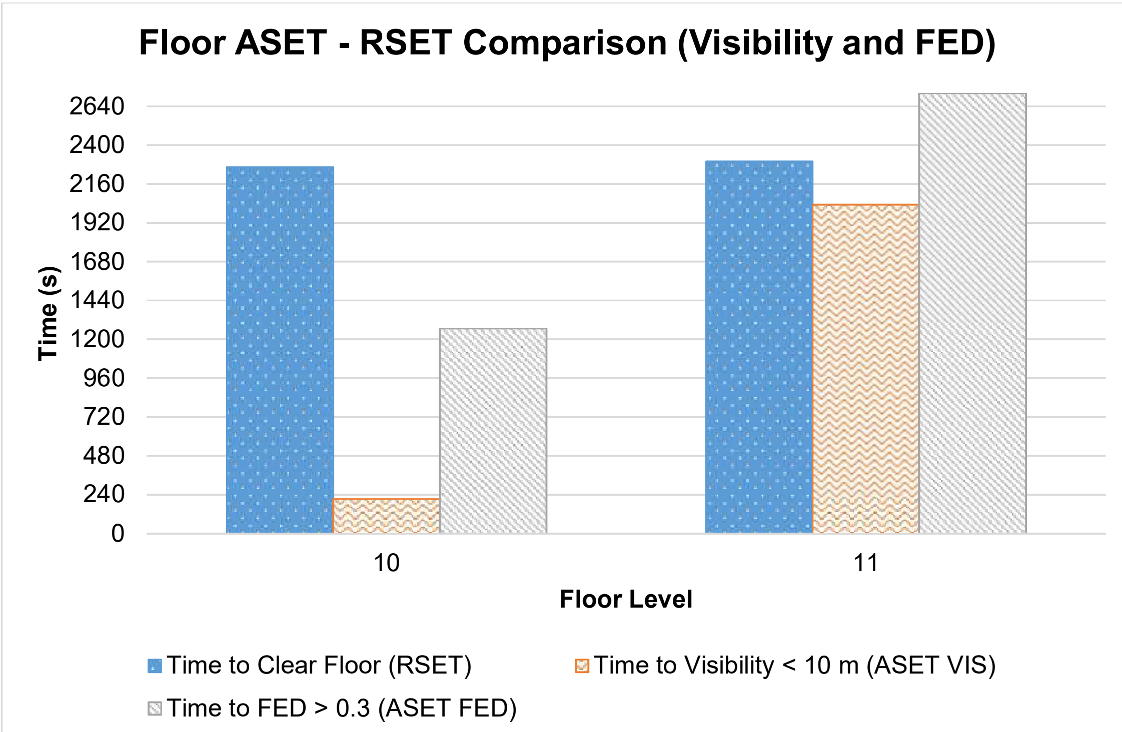
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

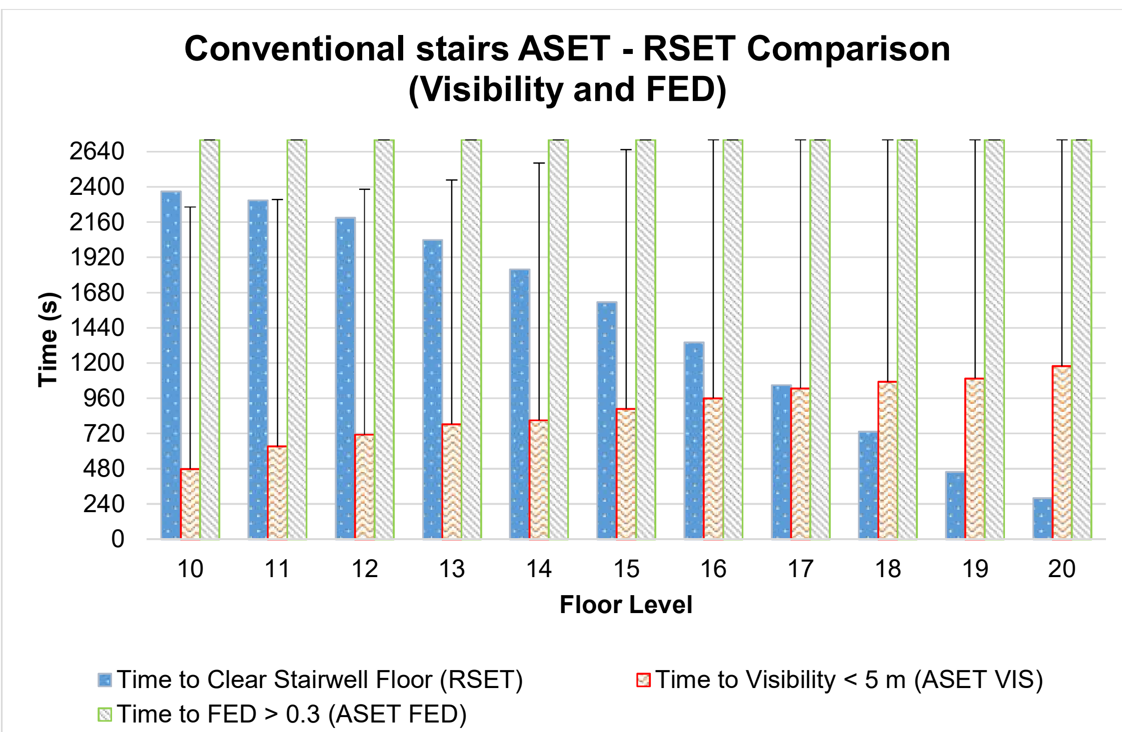
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

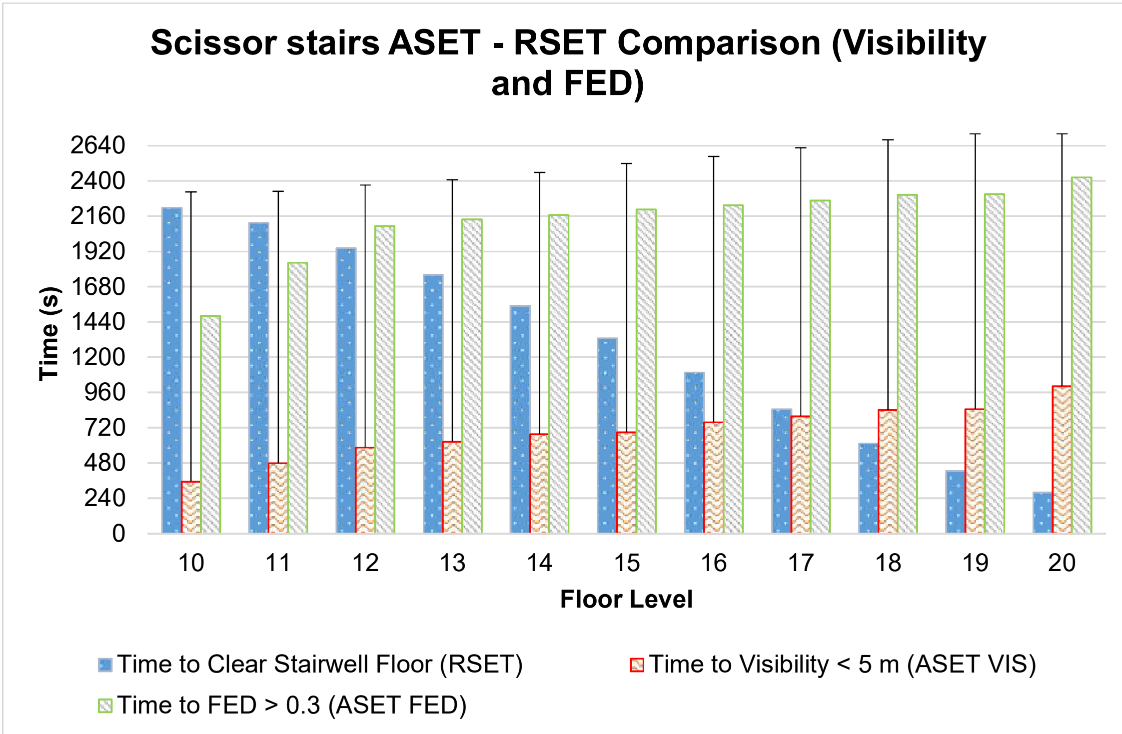
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F32 M_20_T7_T_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during evacuation period**<br>Total Evacuation Time: 2722 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 2264 s |
| Visibility < 10 m | Yes (213/-)* |
| FED > 0.3 | Yes (1267)** |
| Maximum temperature | 95°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2300 s |
| Visibility < 10 m | Yes (2033/2425)* |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 480 s/1782 s<br>11th – 632 s/1682 s<br>20th – 1180 s/>1542 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | Yes (10th to 17th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 10th – 355 s/1970 s<br>11th – 480 s/1848 s<br>20th – 1004 s/>1718 s*** |
| FED > 0.3 | Yes (10th to 11th) |
| Maximum temperature | 70°C (Fire Floor) |

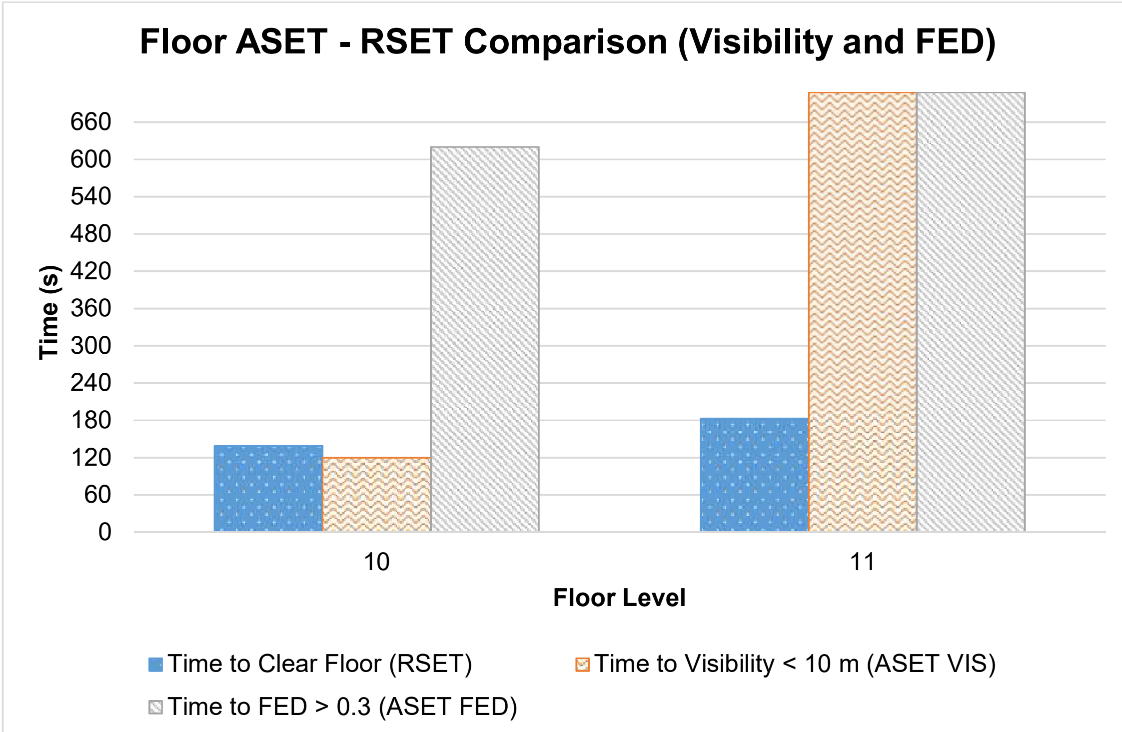
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

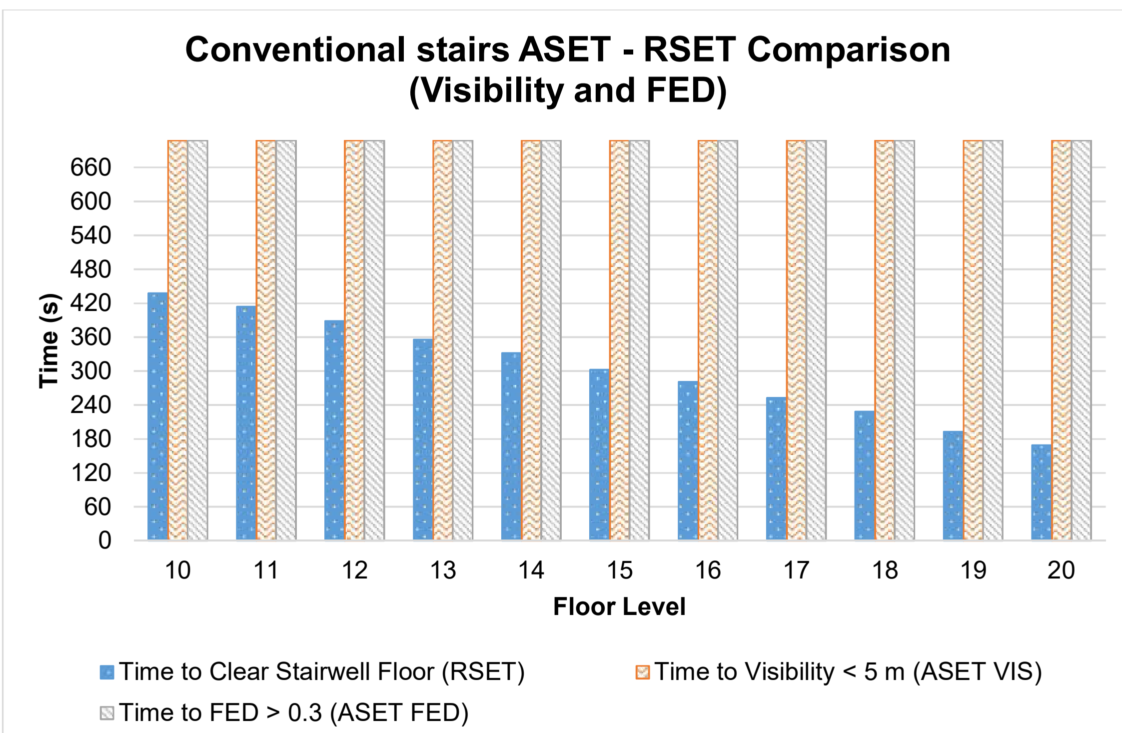
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

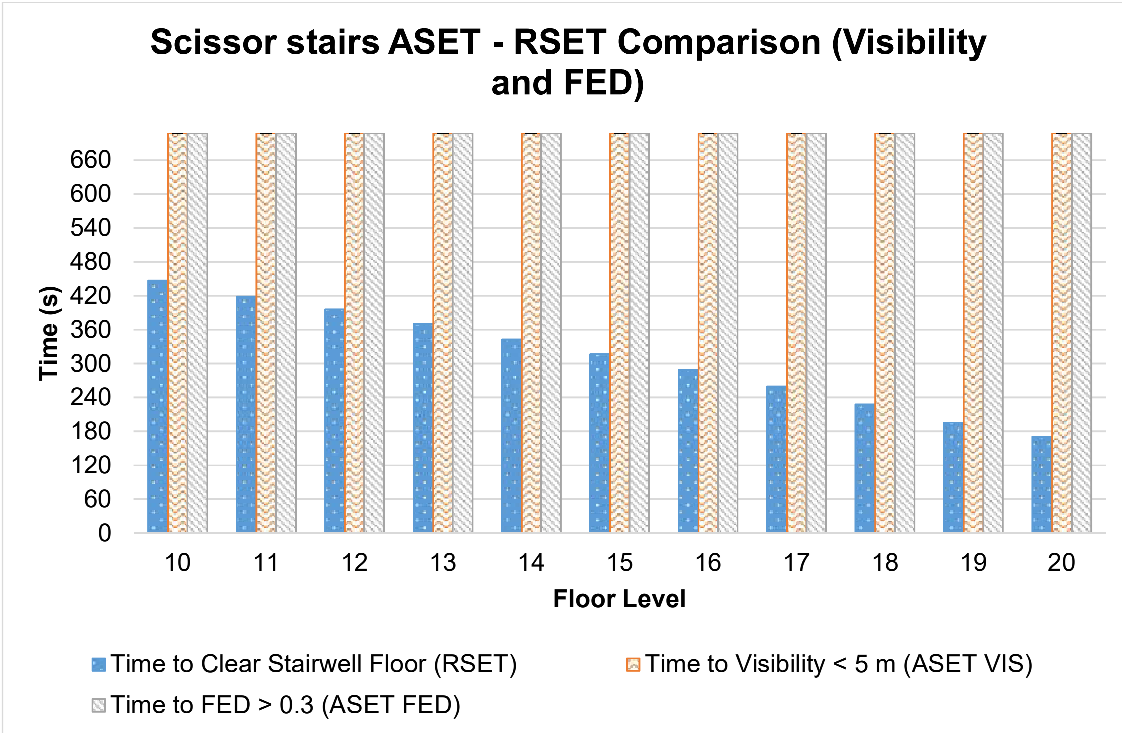
** (###) refers to (time [in seconds] it takes for the first FED device to register a value of 0.3

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F33 S_20_T7_T_3.3**





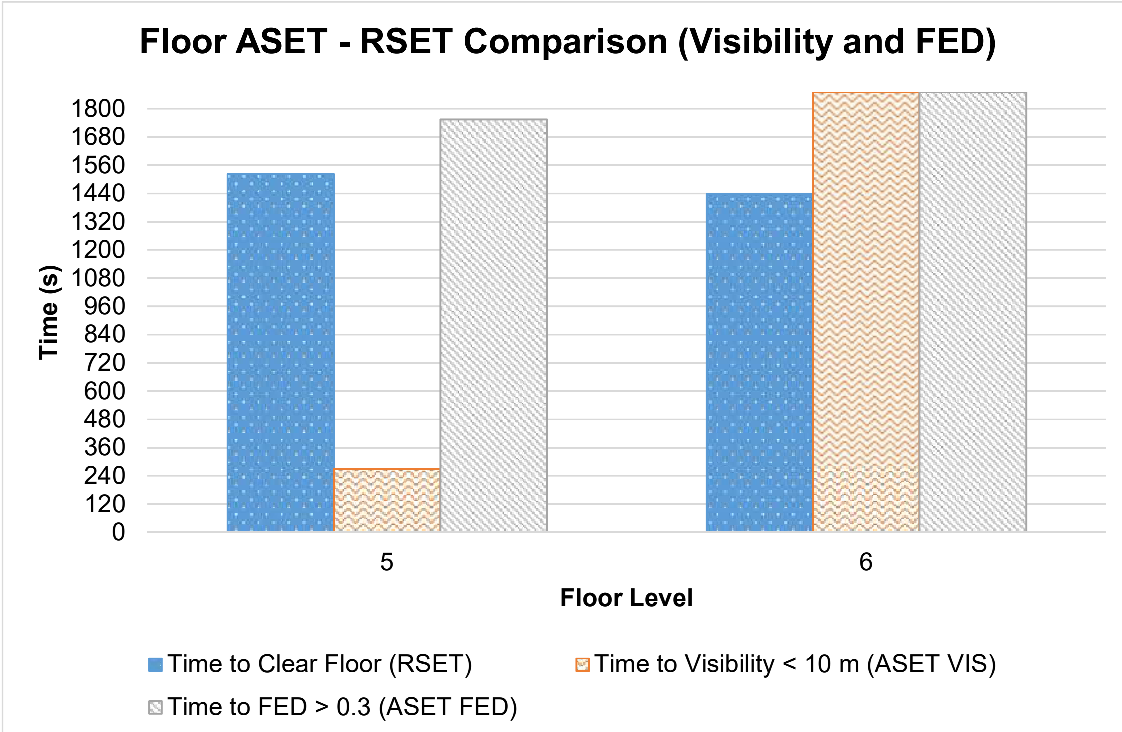
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
660
600
540
480
420
360
300
240
180
120
60
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

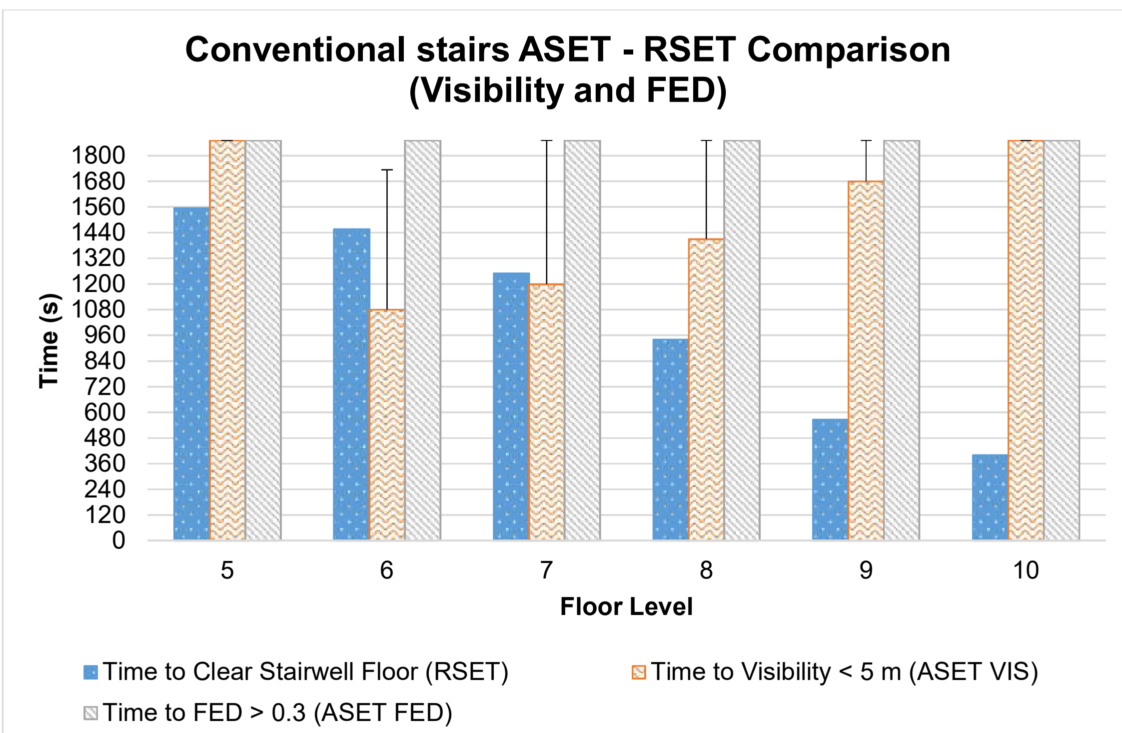
| Tenability conditions during evacuation period<br>Total Evacuation Time: 708 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 139 s |
| Visibility < 10 m | Yes (120/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 183 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 20°C |
| **Conventional stairs (475 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (494 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |

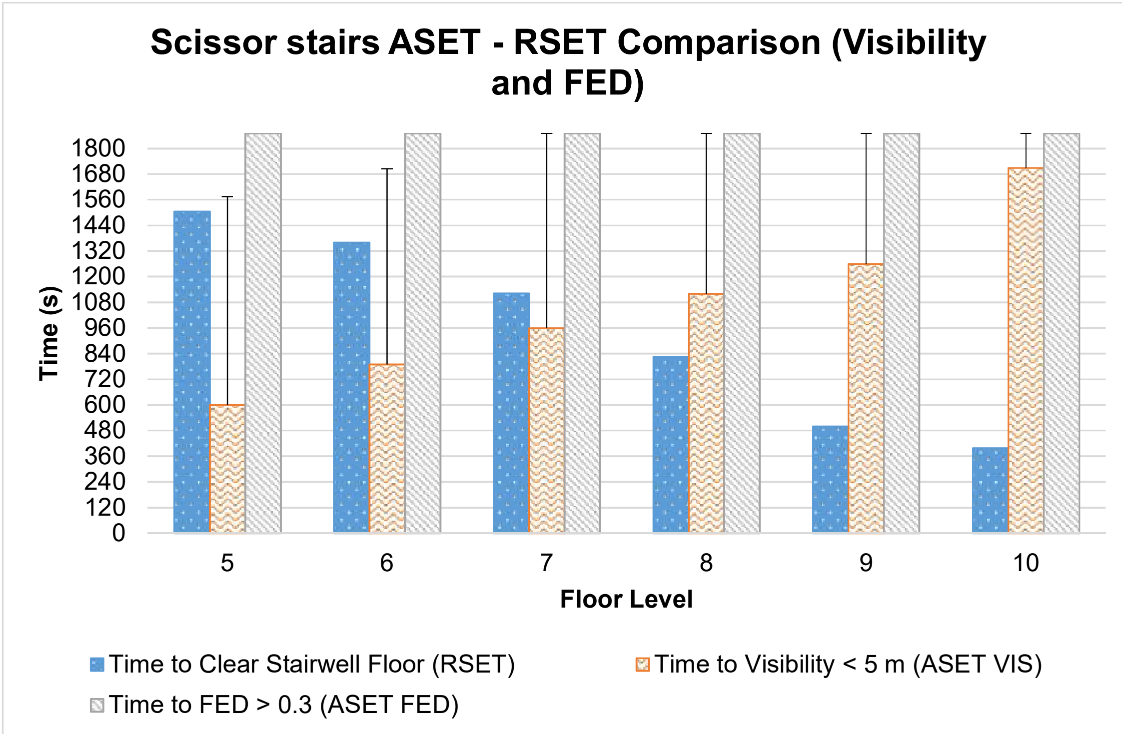
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F34 L_10_T7_T_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

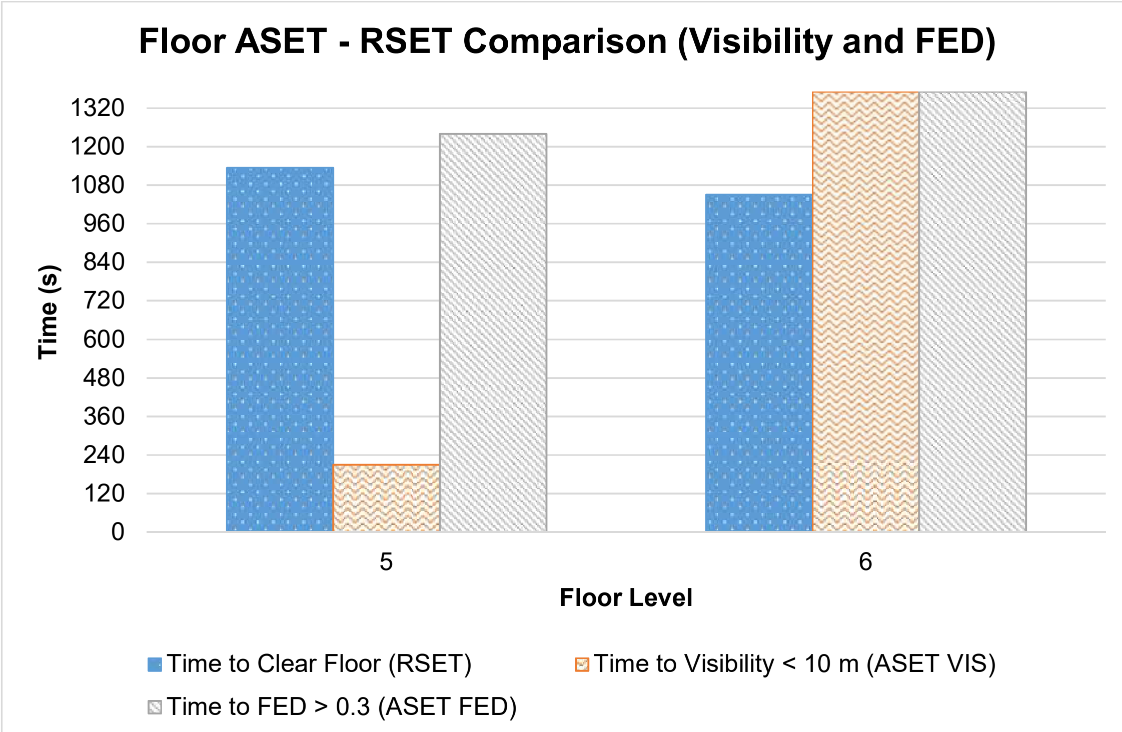
| Tenability conditions during evacuation period<br>Total Evacuation Time: 1871 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 1522 s |
| Visibility < 10 m | Yes (270/-)* |
| FED > 0.3 | No |
| Maximum temperature | 55°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1438 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (6th to 7th) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – NEVER/0 s<br>6th – 1080 s/653 s<br>10th – NEVER/0 s |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |
| **Scissor stairs (2250 occupants)** | |
| Visibility < 5 m | Yes (5th to 7th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 600 s/975 s<br>6th – 790 s/915 s<br>10th – 1710 s/>161 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |

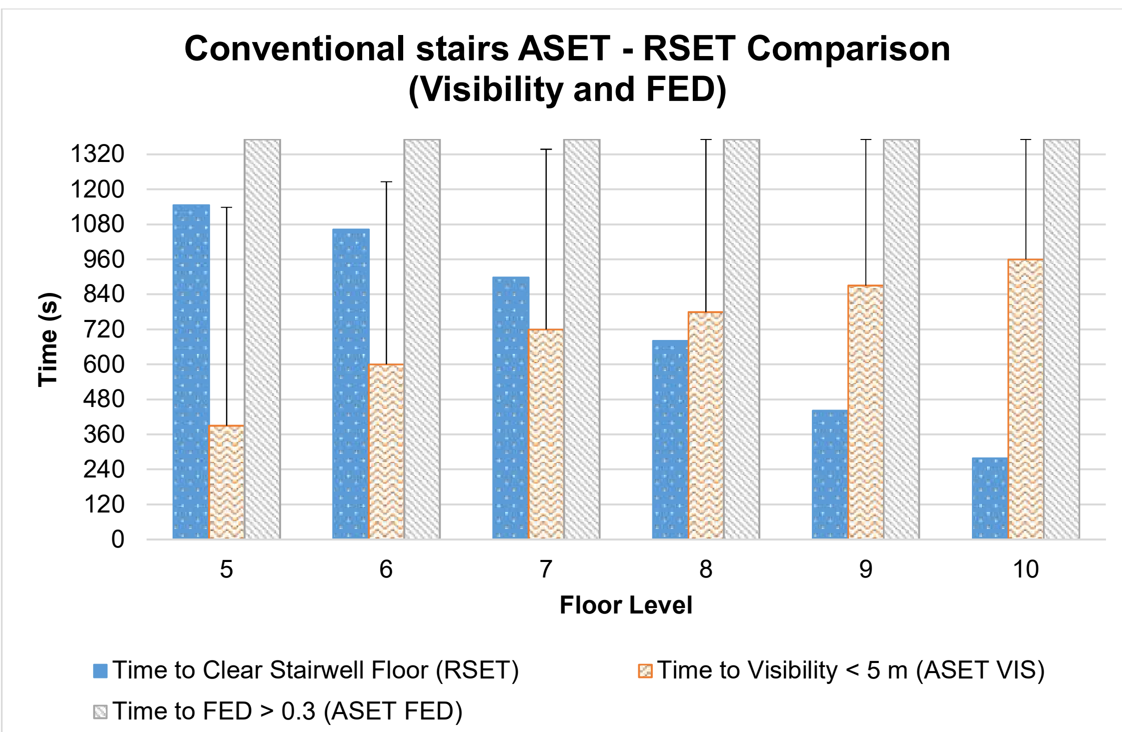
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

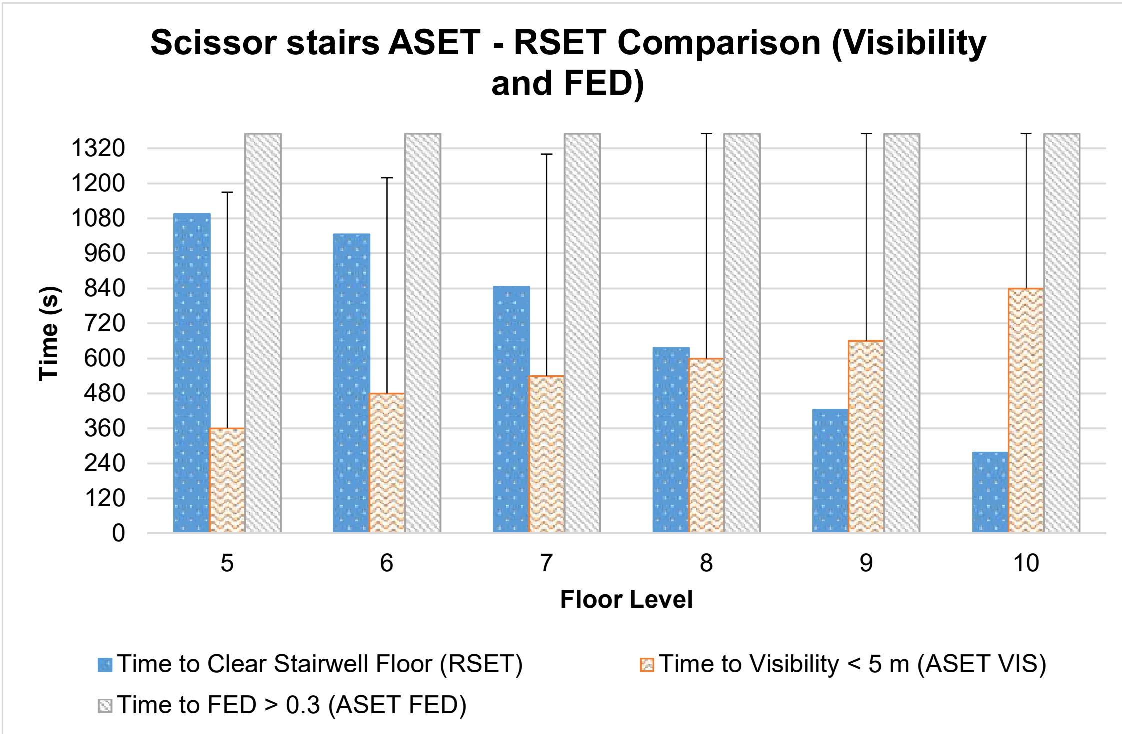
“ – “ indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with “>” sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F35 M_10_T7_T_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

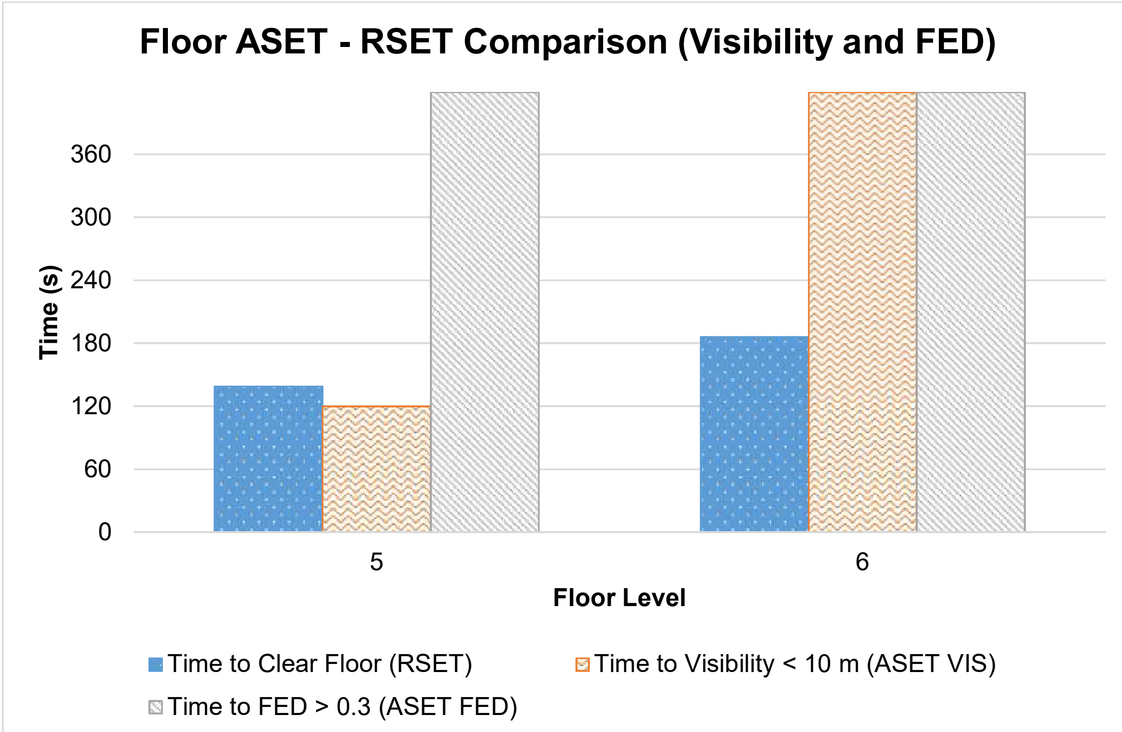
| Tenability conditions during occupied period<br>Total Evacuation Time: 1371 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 1134 s |
| Visibility < 10 m | Yes (210/-)* |
| FED > 0.3 | No |
| Maximum temperature | 75°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1051 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1098 occupants)** | |
| Visibility < 5 m | Yes (7th and 5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 390 s/748 s<br>6th – 600 s/626 s<br>10th – 960 s/>411 s*** |
| FED > 0.3 | No |
| Maximum temperature | 50°C (Fire Floor) |
| **Scissor stairs (1107 occupants)** | |
| Visibility < 5 m | Yes (8th to 5th floor) |
| (Time for visibility first drop to below 5 m/duration of visibility less than 5 m) for fire floor, floor above and top floor | 5th – 360 s/810 s<br>6th – 480 s/739 s<br>10th – 840 s/>531 s*** |
| FED > 0.3 | No |
| Maximum temperature | 60°C (Fire Floor) |

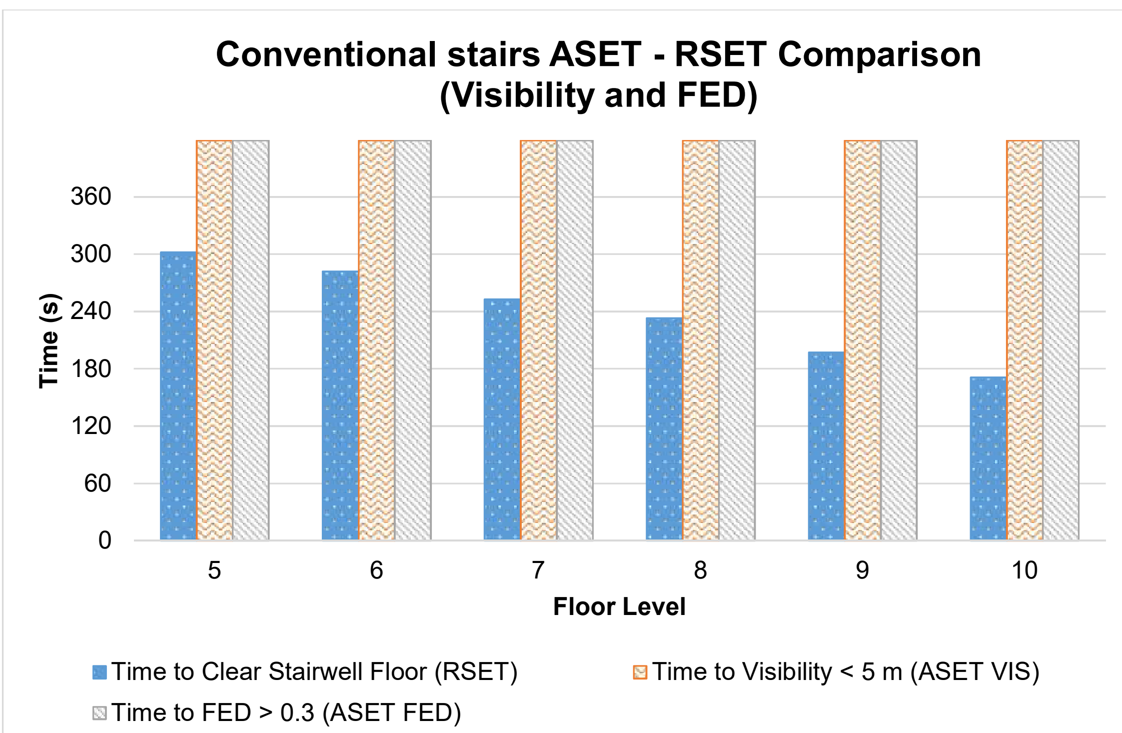
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

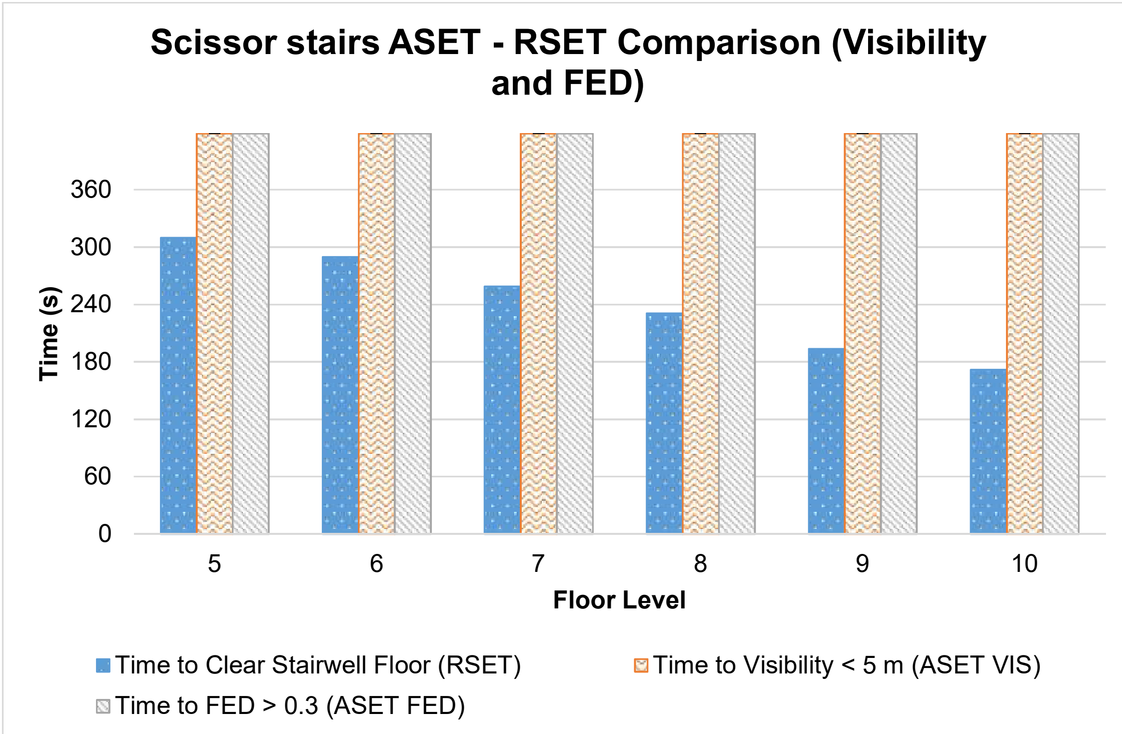
" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

*** Duration with ">" sign indicates that the duration in which visibility dropped to below 5 m is expected to be longer than the specified value. The exact duration is not known because visibility never recovers to above 5 m up to the total evacuation time.

**F36 S_10_T7_T_3.3**



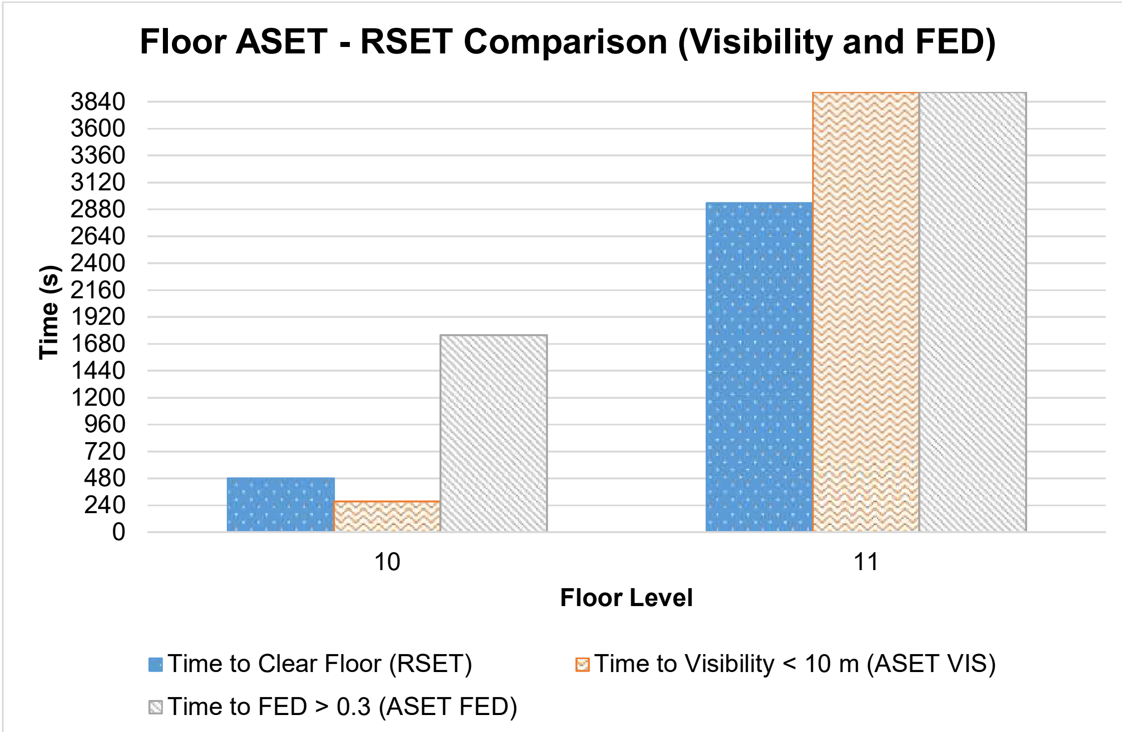

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
360
300
240
180
120
60
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

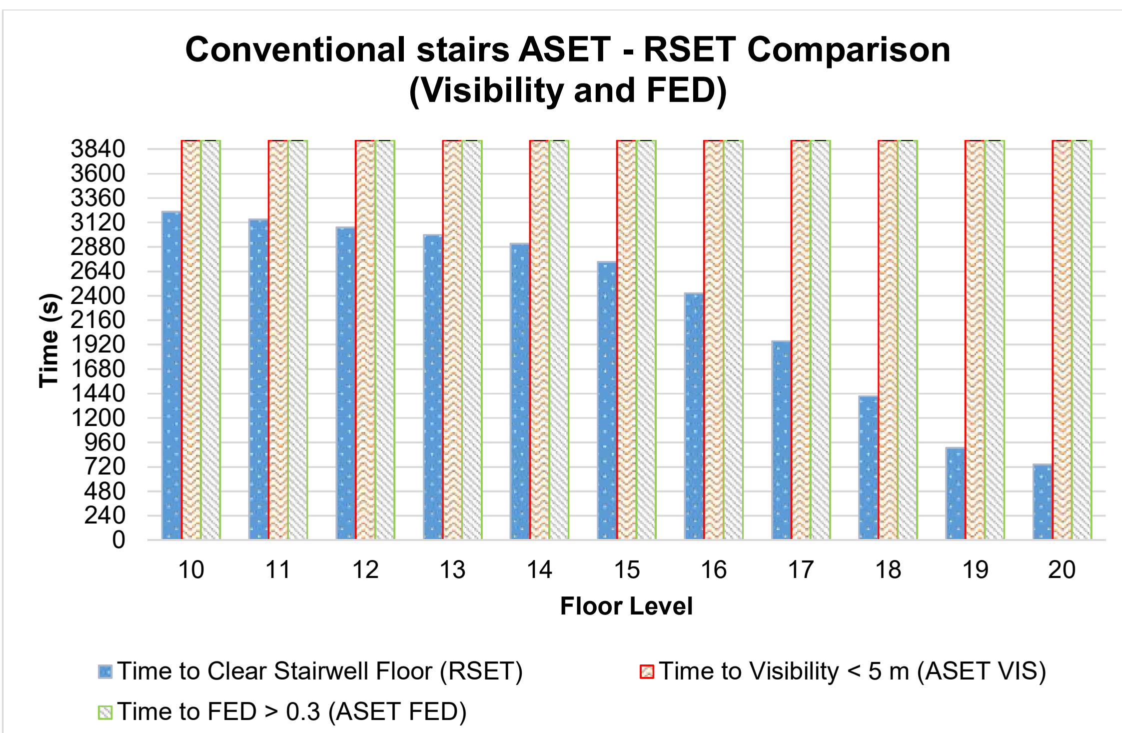
| Tenability conditions during occupied period<br>Total Evacuation Time: 419 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 139 s |
| Visibility < 10 m | Yes (120/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 186 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 20°C |
| **Conventional stairs (225 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C (Fire Floor) |
| **Scissor stairs (234 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |

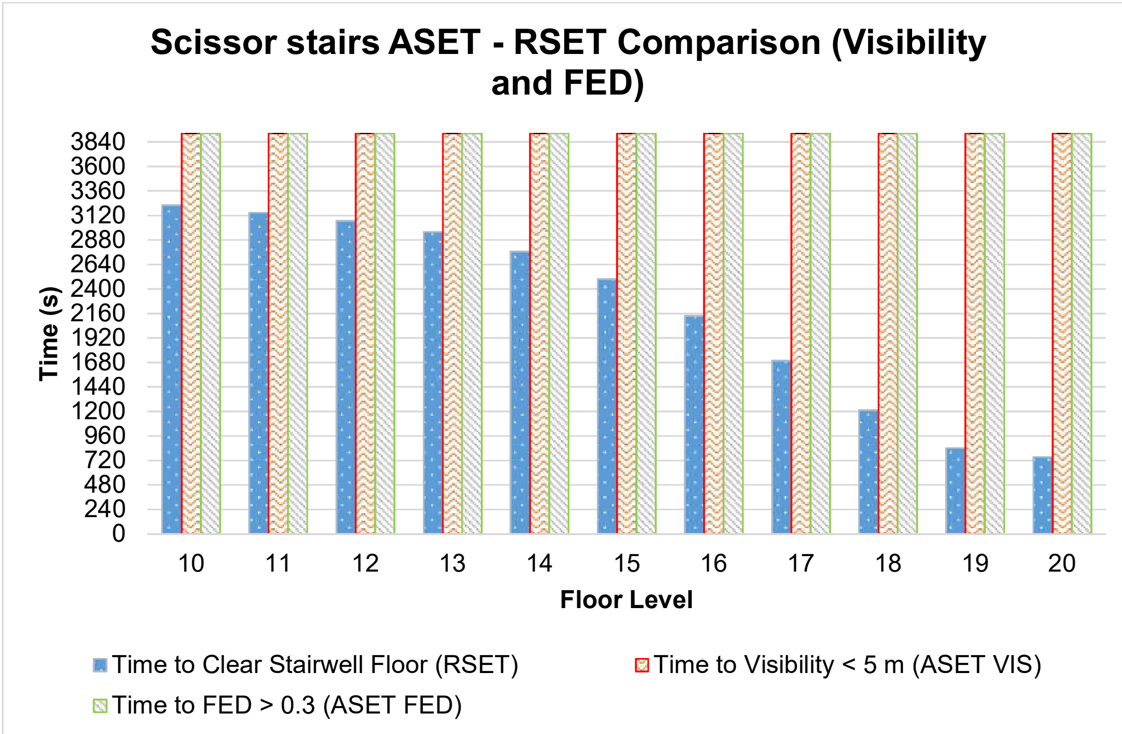
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F37 L_20_T7_P_3.3**





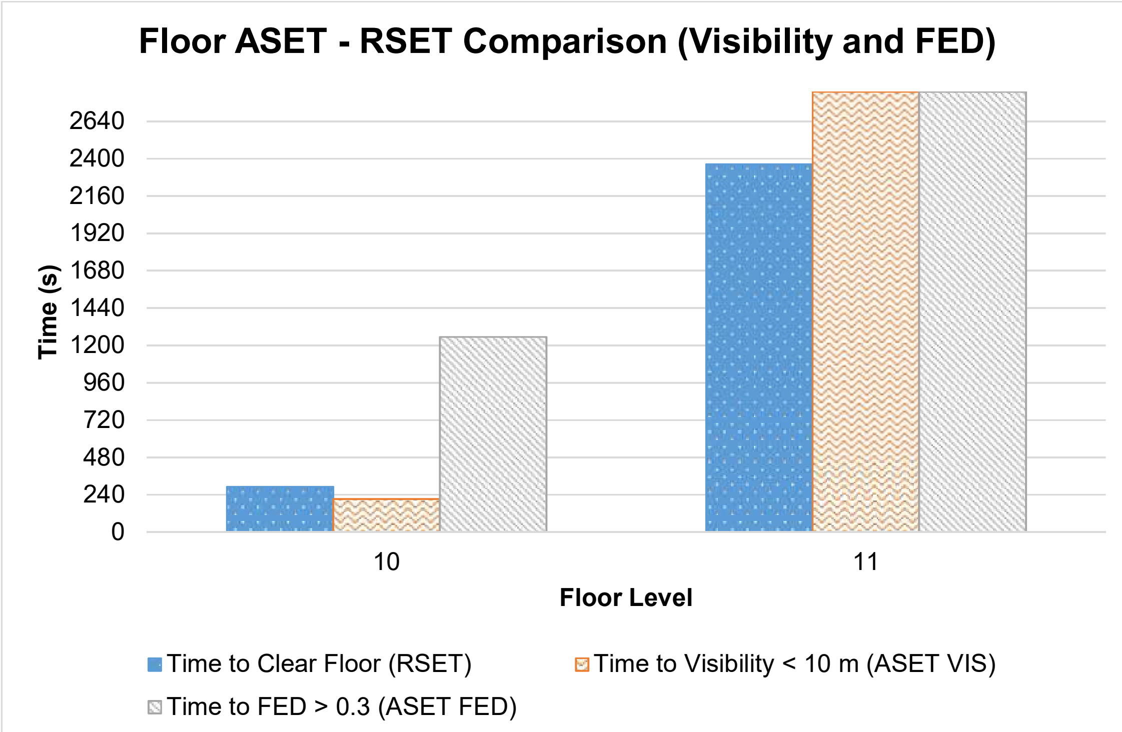
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
3840
3600
3360
3120
2880
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

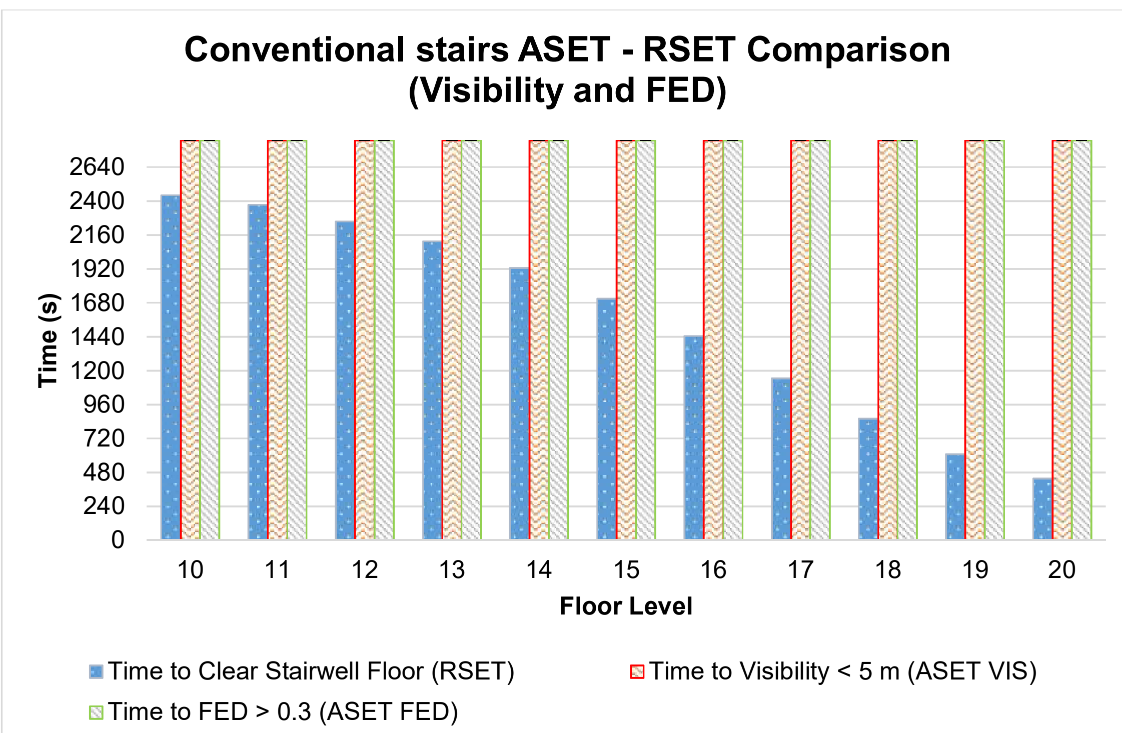
| **Tenability conditions during occupied period**<br>Total Evacuation Time: 3926 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear | 484 s |
| Visibility < 10 m | Yes (277/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40$^{o}$C |
| **Floor Above (11th floor)** | |
| Time to Clear | 2938 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30$^{o}$C |
| **Conventional stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25$^{o}$C (Fire Floor) |
| **Scissor stairs (4750 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30$^{o}$C (Fire Floor) |

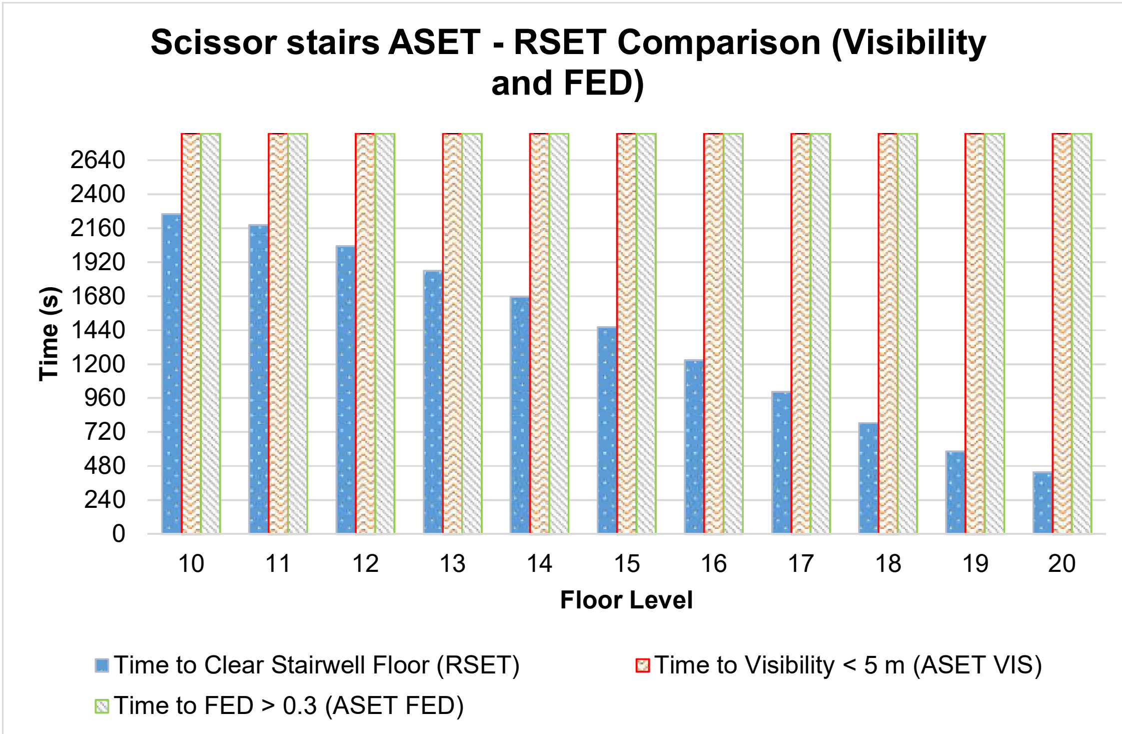
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F38 M_20_T7_P_3.3**





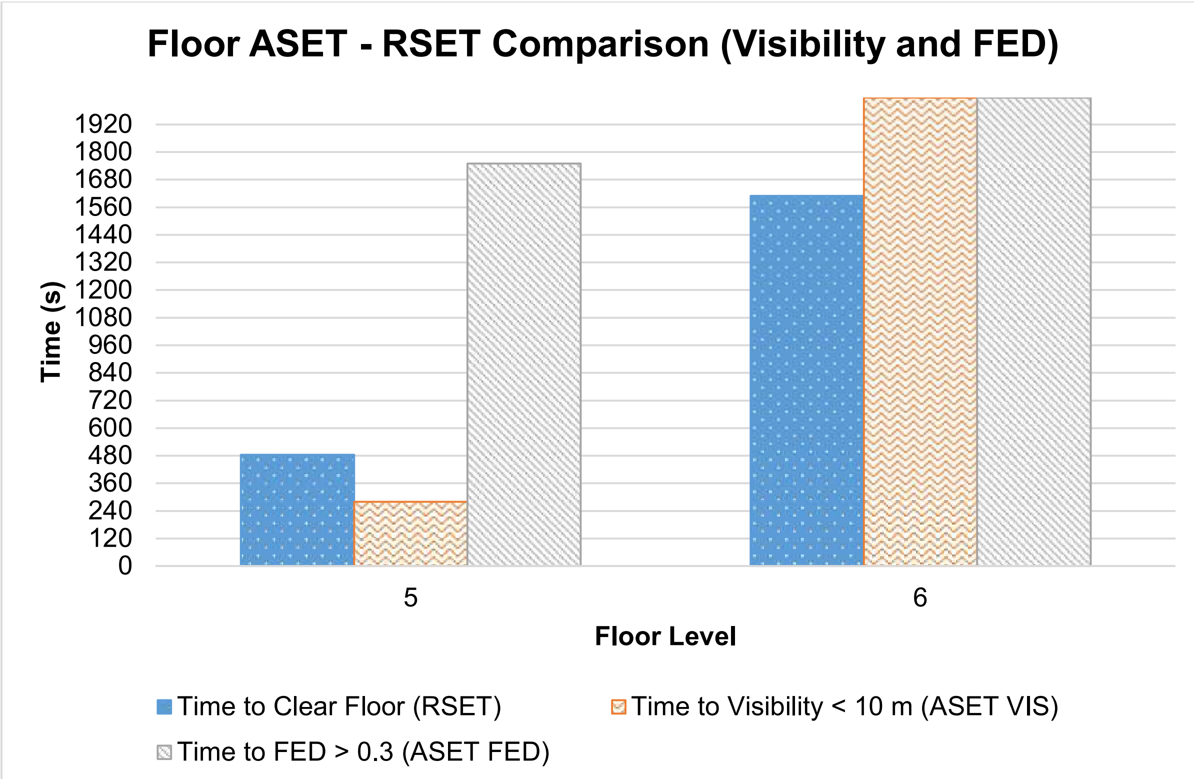
Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
2640
2400
2160
1920
1680
1440
1200
960
720
480
240
0
10
11
12
13
14
15
16
17
18
19
20
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

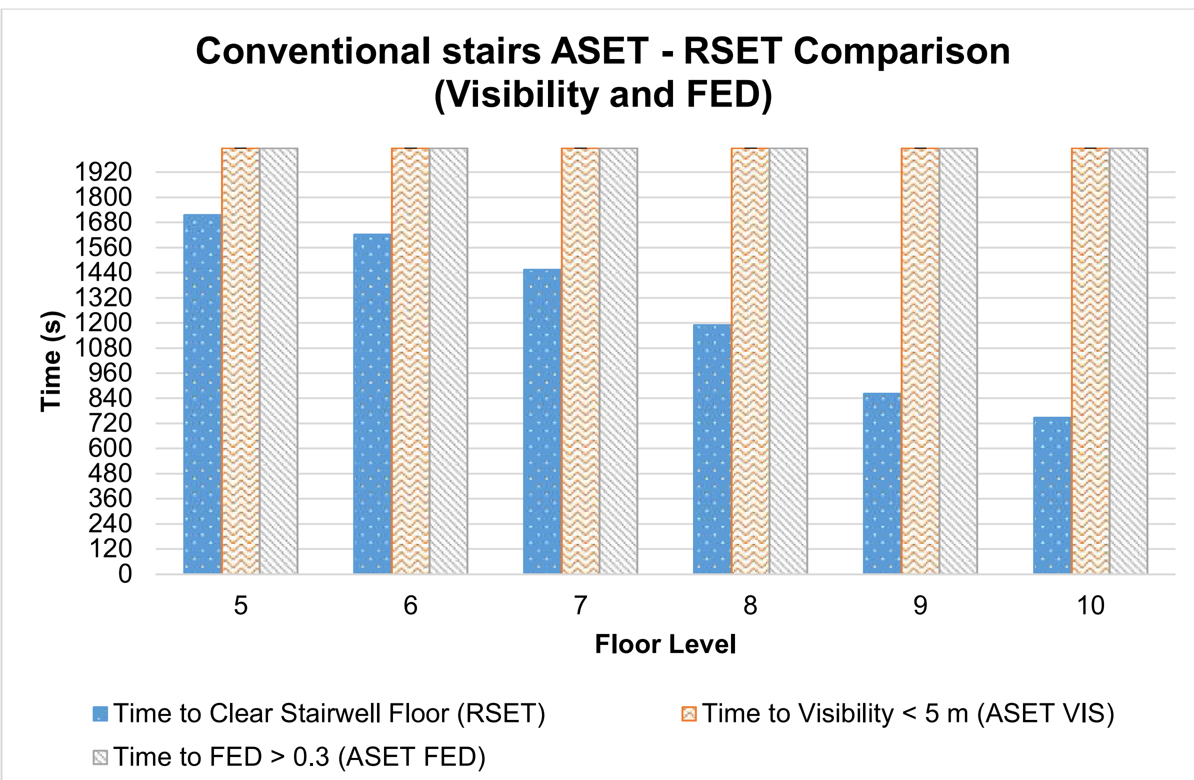
| Tenability conditions during occupied period<br>Total Evacuation Time: 2830 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (10th floor)** | |
| Time to Clear Floor | 292 s |
| Visibility < 10 m | Yes (213/-)* |
| FED > 0.3 | No |
| Maximum temperature | 45°C |
| **Floor Above (11th floor)** | |
| Time to Clear Floor | 2364 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C |
| **Conventional stairs (2318 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C (Fire Floor) |
| **Scissor stairs (2337 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C (Fire Floor) |

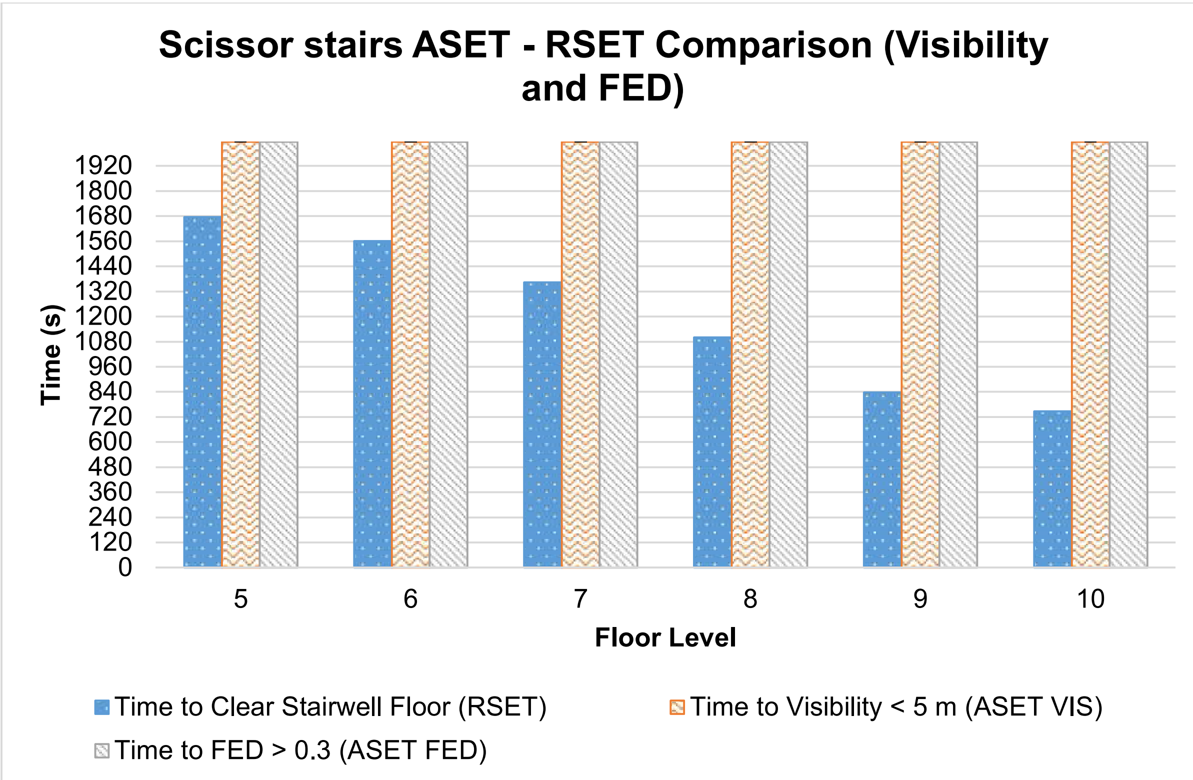
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F39 L_10_T7_P_3.3**



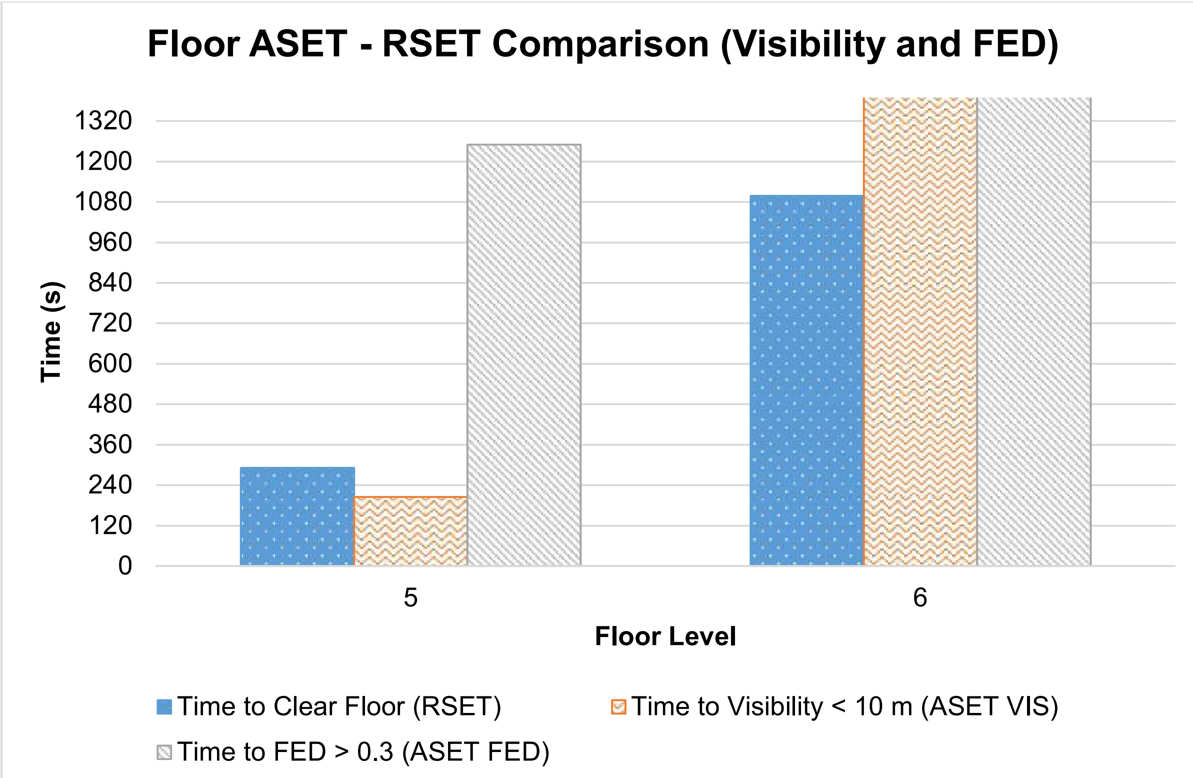

Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

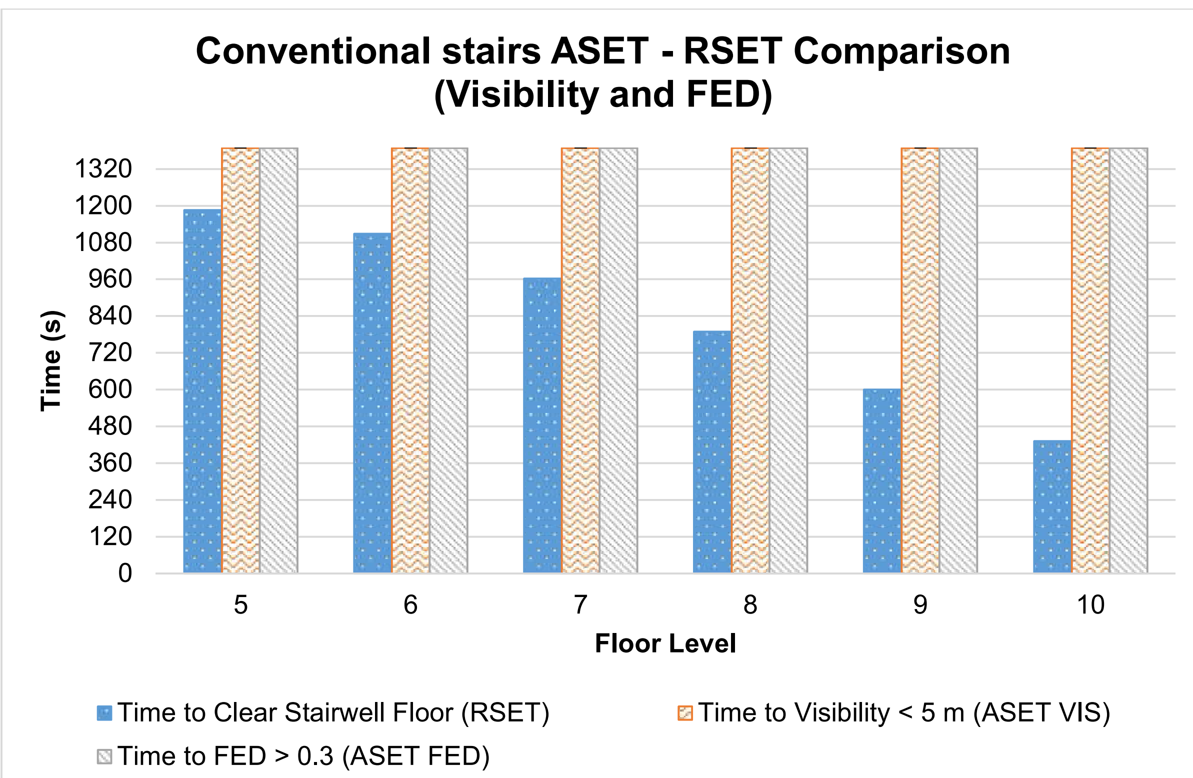
| **Tenability conditions during occupied period**<br>Total Evacuation Time: 2036 s<br>Decoupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 484 s |
| Visibility < 10 m | Yes (280/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1610 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (2250 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C (Fire Floor) |
| **Scissor stairs (2250 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 30°C (Fire Floor) |

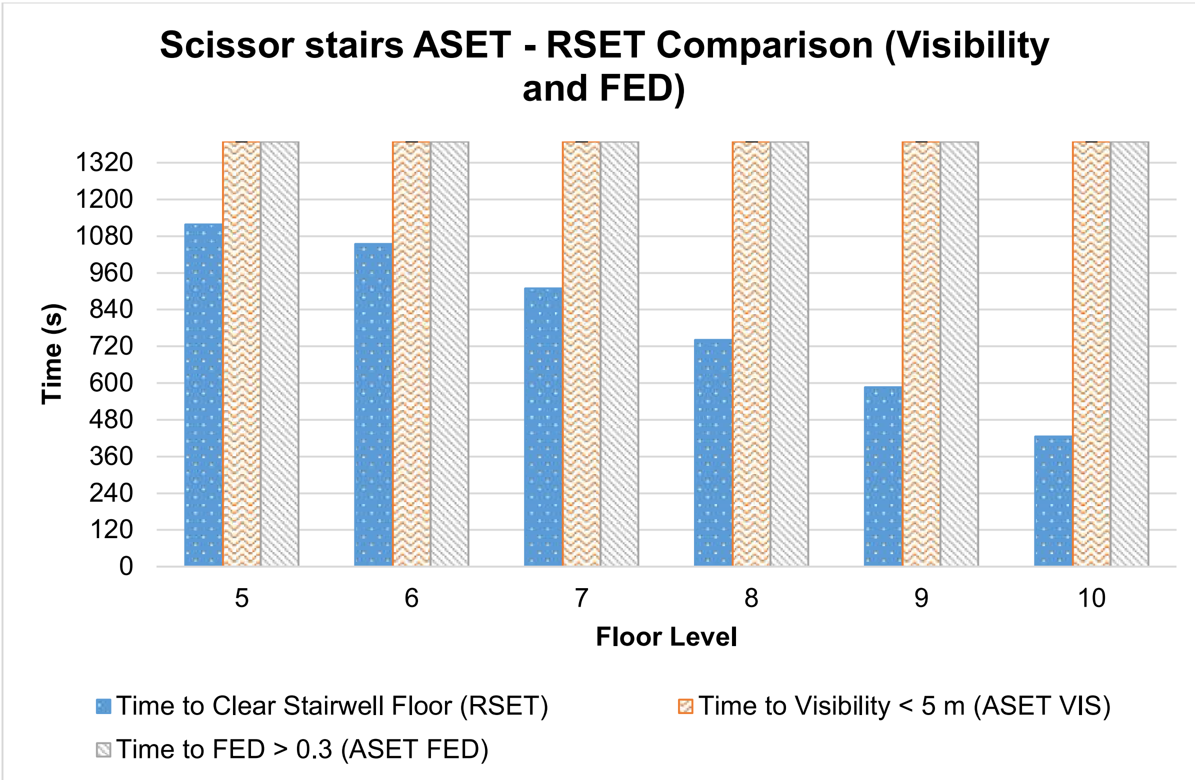
* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor

**F40 M_10_T7_P_3.3**




Scissor stairs ASET - RSET Comparison (Visibility and FED)
Time (s)
1320
1200
1080
960
840
720
600
480
360
240
120
0
5
6
7
8
9
10
Floor Level
Time to Clear Stairwell Floor (RSET)
Time to Visibility < 5 m (ASET VIS)
Time to FED > 0.3 (ASET FED)

| **Tenability conditions during occupied period**<br>Total Evacuation Time: 1389 s<br>Coupled Simulation | |
|---|---|
| **Fire Floor (5th floor)** | |
| Time to Clear Floor | 292 s |
| Visibility < 10 m | Yes (205/-)* |
| FED > 0.3 | No |
| Maximum temperature | 40°C |
| **Floor Above (6th floor)** | |
| Time to Clear Floor | 1098 s |
| Visibility < 10 m | No |
| FED > 0.3 | No |
| Maximum temperature | 25°C |
| **Conventional stairs (1098 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C (Fire Floor) |
| **Scissor stairs (1107 occupants)** | |
| Visibility < 5 m | No |
| FED > 0.3 | No |
| Maximum temperature | 35°C (Fire Floor) |

* (###/###) refers to (time [in seconds] to visibility first drop below 10 m/time [in seconds] for visibility to recover above 10 m)

" – " indicates visibility never recover to above 10 m once dropped below 10 m throughout the occupied period of the floor