

Fire Safety Parameters of High-Rise Residential Building: A Literature Review of Performance-Based Analysis Method

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Abstract. The basic concept in occupant safety assessments in high-rise building residential against fire hazard is the determination of the time the occupants can be safe/escape before the fire danger conditions occur. This concept is also called performance-based appraisal. It is known by another name Available Safety Egress Time > Required Safety Egress Time (ASET > RSET). The concept of performance-based fire safety assessment has been widely used in the concept of fire safety. Discussions related to this literature study are focused on strength and weaknesses in ASET and RSET methodologies, which are related to the parameters. This paper provides a brief overview of the methodologies and parameters of ASET and RSET. The results of this literature study provide a clear picture that the simulation of fire hazards in high-rise residential buildings can be done accurately by considering the parameters of the ASET and RSET. However the lack of resources and experts in using this related software make this performance-based method is difficult to achieve.

1. Introduction

During this time, one of the ways to meet fire safety building criteria is to follow the requirements stated in the fire safety regulations. Each building element is designed according to the specifications defined by the rules, then checked for compliance to assess whether the required level of safety has been met. This procedure is known as a prescriptive based evaluation method. However, the approach used in fire safety regulations over the past decade has begun to shift from prescriptive to performance-based.

This change is triggered by dissatisfaction with prescriptive-based rules that cannot be used as a reference for assessing buildings with special functions and complex building designs. In addition, the safety levels set by prescriptive rules are overvalued so that to meet them are relatively expensive. A performance-based approach has been popular since decades ago. This approach provides an opportunity for building designers to produce innovative and cost-effective, equivalent or better designs of regulatory solutions [1].

The main difference between the two approaches lies in its substance. Performance-based approaches emphasis on goals and do not specify solutions, while prescriptive-based approaches focus on standard and regulations. Performance-based rules place greater emphasis on fire safety goals. That's why performance-based rules are considered more flexible, more functional, and easier to apply. Through performance-based regulation can also be obtained optimum design with better safety



and lower cost [2, 3]. Performance-based evaluation can be done by modeling and simulation. The simulation can be done by using computer analysis.

A modeling and simulation analysis is used to predict the behavior of occupants in the event of a fire. This analysis has evolved since the 1960s, with a model which is then applied to computer software where the risk of fire hazard can be predicted. One of the earliest known is Available Safe Egress Time (ASET) Model [4] that is one of the 2 part methods of ASET and RSET. The ASET model provides a good estimation of assessment time for this safe exit to introduce the fire safety concept by defining Available Safe Egress Time (ASET) as the time interval between detection time and hazard object. Meanwhile, to ensure that the building is considered safe for the occupants then there is a certain period of time used to know the movement of occupants to a safe place, that is known as Required Safety Egress Time (RSET). In RSET fire prevention concept should be less than ASET specified by space formation. RSET is only considered the time it takes to get to the exit. But in his theory, Cooper did not provide any guidance on the determination of RSET. Then some aspects of the RSET are enhanced by Sime [5] by adding the countermeasures phase, in early detection and exit. The coping phase may be more commonly referred to as a pre-movement time, to allow for various delays before starting to move towards the exit, following the moment of awareness of the fire cue.

2. ASET and RSET

The performance evaluation of buildings against fire hazard for buildings or other places of human occupancy, in the modern era has sought how to construct quantitative performance metrics [6]. Quantification is done by comparing two or more alternative strategies to be made. The ASET / RSET method is used to demonstrate occupant safety against fire hazard by taking time as an indicator.

The process of fire engineering analysis usually involves assessment of fire development, smoke distribution and evacuation of occupants. The concept of this method is that if a simple $ASET > RSET$ relationship is satisfied, it is assumed that the performance of the building against fire hazard is fully adequate, in terms of the evacuation safety of the occupants. RSET (Required Safe Egress Time) is the time to evacuate occupants. Potential sufficient time for occupants to get out of the place where fire appears is the most important factor in the security aspect of the occupants. ASET (Available Safe Egress Time), is the time for unsustainable conditions. The ASSET is determined from the moment the fire effect reaches the limit of tenability specified in the acceptance criteria. RSET is determined from the analysis of time taken by the occupants to escape from the fire effect to a safe place. Therefore, the assessment of acceptance criteria is ultimately made relatively that residents can safely escape the presence of fire hazards.

The ASET / RSET parameter relies on a number of key variables as shown in Figure 1 [7]. Safety is defined by the Assessment of a set of agreed criteria that are largely expressed in terms of potentially exposed fires. Simply put, if the occupants can be shown to escape from fire hazard with acceptable margins, the solution is deemed to have met the performance requirements. Hall [8] states while escaping with enough time, residents will not face a very thick smoke and will see the right way out. The children will need help from adults in any case to get out. But if enough time is available, there will be time for adults to gather and guard the children and lead them to a safe place.

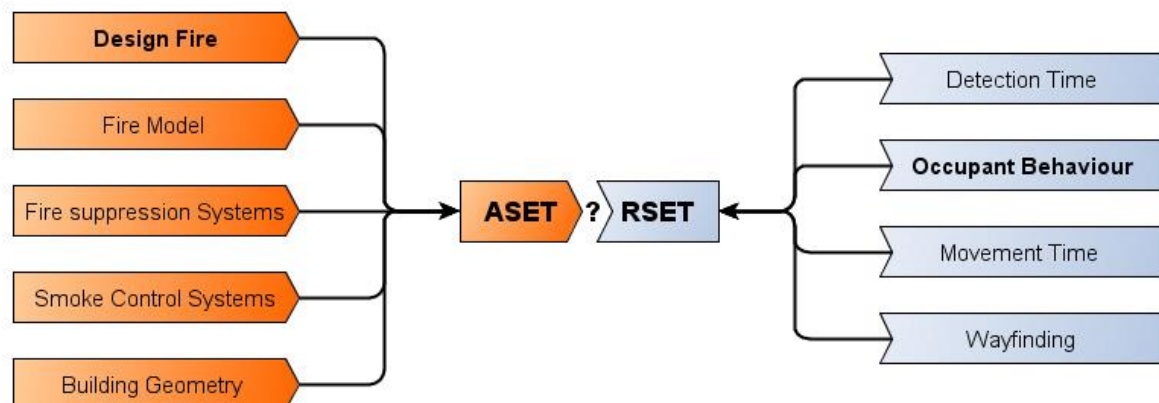


Figure 1. Dependent variables affecting ASET and RSET (most significant variable shown in bold)
[7]

3. Computer Simulation Model

New research in evacuation behavior has developed a more comprehensive method of analysis and is able to model complex behavior during evacuation. Fire safety codes called performance-based codes are used to validate the fire safety of buildings. Parameters that influence the efficiency of performance-based evacuation can be categorized into four main groups: the physical characteristics of the building, the behavioral characteristics of the occupants, the physiological characteristics of the occupants and the characteristics of environmental fire [9].

- Model of physical characteristics of buildings. Building physical characteristics such as corridors, stair widths, landing areas are modeled. As well as obstacles and physical disturbance of other architectures such as furniture and building layouts are also taken into account in the evacuation route.
- Modeling characteristics of occupant behavior. Differences in occupant behavior affect evacuation time in two different stages of pre-movement time and movement time. The diversion behavior of the occupants or persistence in finding the route when facing the smoke-filled area is another characteristic of the behavior that can be simulated.
- Modeling physiological characteristics of the occupants. The physical fitness of the occupant, sex, age, height and weight affects the speed of movement as well as his / her ability to tolerate gas and heat. The agility of the inhabitants to jump over small obstacles like furniture can also affect the evacuation time.
- Model of fire environment characteristics. The speed of the evacuation process is hampered by exposure from smoke. A variety of toxic gases can be generated during a fire depending on the burning object. However, there is sufficient information about the effects of these gases on the mobility parameters. The most commonly known effects are toxic gases (CO, CO₂, & HCN) and lack of oxygen can be seen in the evacuation analysis.

4. Discussion

From the parameter classification of ASET and RSET based on the software, related to the building function (Table 1) some parameters that affect the simulation performed can be seen. These parameters can affect ASET and RSET in the simulation process.

ASET is affected by the Type of Smoke and Fire parameters, Environment Condition, Ventilation, Wind Condition, Passive Protection, Active Protection, and Room Type.

- Type of Smoke and Fire relates to the height of smoke in the room, how poisonous the smoke, and how big of fire in the worst conditions.

- Environment Condition relates to temperature inside or outside room.
- Ventilation relates on length and width of doors and windows and their positions on the wall.
- Wind Condition associates with the wind speed in the room can affect the rapid or slow fire spread.
- Passive Protection includes some passive handling so the fire does not spread such as making a wall or ceiling with resistant for fire.
- Active Protection includes active handling which effectively and automatically can help reduce the fire spread, for example is sprinkler.
- Room Type is more emphasizes on the type of room and how large the room is. Room type can determine how long the fire can be spread to the next room.
- RSET is influenced by several parameters including Physical, Behavior Attributes, Person Mode, Type of Travel, and Number of Occupants.
- Physical relates to the physical factors of the occupants, Includes gender, height, weight and age.
- Behavior Attributes relates whether the occupants are well informed to handle fire.
- Person Mode relates to how the occupants react to the danger of fire, whether they are walking normally, walking fast, or half running.
- Type of Travel Time relates whether the occupants are moving horizontally or vertically.
- Number of Occupants covers how many occupants are in one building

Table 1 Parameter Grouping ASET(Available Safety Egress Time) and RSET (Required Safety Egress Time) based on software related building function.

No.	Building Function	Researcher	Software		Information
			ASET	RSET	
1	High-rise Student Apartment	Zhong-an, Jiang., et.al. [10]	-	EXODUS (Parameter: Physical, Behavior Attributes, Type of time travel, and Number of Occupants)	1. Use Experimental Method 2. Comparing experimental and simulation evacuation methods without considering ASET
2	High Rise Building Flats	Sujatmiko W., et. al. [11]	CFAST (Parameter: Ventilation, Wind condition, passive and active protection)	FDS-EAC (physical, behavior, attributes, person mode, and number of occupants)	
3	High Rise Residential Building	Zhixiang X and Yong T [12]	CFAST (Parameter: Type of smoke and fire, passive and active protection, room type)	EXODUS (physical, behavior, attributes, and number of occupants)	
4	6-Storey residential building	Li, Xiao [13], Zhixiang X and Yong T [12] and Hadjisophocleous, G.V. et. al [3]	CURisk (Parameter: Type of smoke and fire, passive and active protection, room type)	-	1. Evacuation on buildings is not simulated but using existing data
5	Multistory building	Sujatmiko W., et. al. [11]	CFD-FDS (Parameter: Type of smoke and fire, environment condition. Ventilation, wind condition, room type)	-	

5. Conclusion

In some software, not all have same parameters so that we must determine the right software to help analyze the data desired. Assessment of building performance against fire hazard can be done well using computer simulation by considering some parameters related to ASET and RSET. The disadvantage of performance appraisal using computer simulations is that there are software that can combine ASET and RSET simulations. It also requires precision in determining the parameters before starting the simulation. Not many experts can use software and perform computational analysis related to performance appraisal of buildings against fire hazard

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