Evacuation Times of High-Rise Buildings in Thailand

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ABSTRACT

In Thailand, the trends of new constructing high-rise buildings higher than 200–300 meters are increasing rapidly. The present design for evacuation follows the prescriptive code that is the same for all buildings higher than 23 meters. This code is concerned about the building types and the number and density of building occupants. This paper studies the evacuation time of a high-rise building in Thailand. A case study of high-rise residential building is employed using simulation techniques. The findings from this paper can be applied in both existing and new buildings. The simulation techniques used in this paper are applicable to Thailand and elsewhere.

1. Introduction

Nowadays, many high-rise buildings can be found around the world. A number of the world's tallest buildings that have a height of more than 200 meters are more than 1,200 buildings. Fifteen of them are located in Thailand. In addition, the buildings that have a height of more than 300 meters are more than 100 buildings and two of them are in Thailand, and another nine buildings are under construction [1]. The driving force behind this progression is not only financial, political, and environmental, but is also related to modern technological development, such as structural technology and new construction materials. They have enabled development of high-rise buildings [2].

When constructing a new building, architects and engineers should take into consideration not only general use but also safety, especially in the case of fire. The most important objectives during a fire are to evacuate safely and quickly. Regarding the evacuation design for high-rise buildings in Thailand, the requirements for buildings higher than 23 meters are the same code. However, the code has been used for more than 25 years. At present, the trends of high-rise buildings higher than 200-300 meters are on the rise.

Safety in evacuation is about the time. In the past, the evacuation time was for all occupants to be outside a building. But in the near future it is also to reach a safe zone, which means a place of refuge, inside or outside the building [2]. In Thailand, there are important parts for the fire safety and evacuation code, such as:

- There are at least two staircases and the distance between them must be less than 60 meters.
- The evacuation time for leaving the building must be less than one hour.
- Each riser must be less than 20 cm and the width of each tread must be more than 22 cm.
- The width of the stair door must be greater than 90 cm and the height of the door must be greater than 90 cm.

The code or regulation was considered adequate in the past. However, the outdated code or design method does not work effectively with new high-

rise buildings in Thailand. Moreover, Building management pays very little attention to fire safety. Designers only follow the code, but are not concerned about what happens in practice in terms of different building types, and the number and density of building occupants. This paper studies the evacuation time of High-rise buildings in Thailand. It is an important issue because it must be considered whether the existing code is appropriate or not. The findings from this paper can be applied in existing and new buildings, regardless of building type.

2. Literature Review

Fire evacuation can be divided into many components in terms of timeline concept in evacuation for example, pre-movement time, recognition time, response time, travel time, walking time, and flow time [3]. Different components play unique roles before and during the evacuation, but all of them are important to complete the whole process. Building designs in each country are differences. Some countries use prescriptive codes, but others use performance based designs for evacuation [2,4,7-11].

The prescriptive code method forms the bounds that are implied by rules. If a designer follows these rules, the safety of the design will be implicit. Nevertheless, it takes too long time to improve the codes. On the other hand, the performance based design allows a designer to apply rational engineering for improving specific goals, functional objectives, and performance requirements [2].

For evacuation time, it has been found that the rate of evacuation depends on both the building environment and human behavior [5,12]. There are some studies on average walking speed, but in reality fatigue during evacuation reduces significantly the effectiveness of evacuation and increases the time of moving people out of the building [13]. Moreover, many case studies have shown the failure rates for stair, pressurization system, and life risks [2,11].

According to previous studies, it was found that high-rise buildings in Thailand require further study to ensure that the existing code is still appropriate. As per the current code, Occupants have to be able to be outside the building within an hour. There are several methods to study evacuation time. One of the most efficient ways is a simulation technique [6,13,14].

3. Methodology

The methods applied to study evacuation time in the literature include calculation, experimental study, and simulation models. The experimental study can be divided into five categories: (i) field observation, (ii) evacuation drill, (iii) controlled experiment, (iv) experiment based on animals, and (v) data-collection in real emergency [15]. The simulation model [16,17] can be used for supporting both user interface and animated 3D results. The software can transform hand calculations to software simulation for egress analysis and can be analyzed to provide realistic results. Nowadays,

due to the complexity of input data and accuracy of results, simulation models have been widely used in the AEC (Architecture, Engineering and Construction) industry. Details, simulation assumptions, and parameters used in this paper are described in the following section together with a case study.

4. A Case Study: The River Condominium

4.1 Background of Building

The River Condominium South Tower (Figures 1 and 2) is a case study building in this paper. It was completed in 2011. It is currently the third tallest building in Thailand (as of July 2017). It consists of 70 floors of residential condominium, with a height of 258 meters. The height from the evacuation floor is 221 meters

Figure 1. The River Condominium South Tower (from permission drawing).

Figure 2. Fire stair for the River Condominium South Tower (from permission drawing).

4.1.2 Evacuation Simulation Model

Pathfinder is an emergency egress simulator that includes an integrated user interface and animated 3D results. The software can transform hand calculations to software simulation for egress analysis.

The software can simulate performance-based pedestrian movement, evacuation, and congestion studies. Moreover, other nearby facilities and objects, such as stadiums, hospitals, skyscrapers, and aircraft, can be analyzed to provide realistic visual results. The Pathfinder model established for the simulation object for this project is shown in Figure 3. The assumptions for simulation of the case study are as follows [3]:

- The number of people is based on the number of beds.
- All areas are for residential purposes, no parking and common areas.
- People start to evacuate as soon as they hear the fire alarm.
- People do not stop, and there is no confusion.
- The personal stepping speed is automatically adjustable according to the personal density.
- People can choose their own route at random.
- Evacuating people have the same body conditions and they are able to evacuate themselves.
- Both staircases are smoke-preventing type and can be accessed immediately.
- All signs to explain the steps in evacuation are clear and easy to understand.
- All the systems involved are in good condition.
- There is no obstruction.
- The premovement time is 9 minutes before general alarm.

Figure 3. Simulation model for The River Condominium South Tower: Floor plan with building occupants

4.2 Simulation Results

After running the simulations according to the assumptions, the model is shown in Figure 4. This model is defined as the number of successful evacuees, and is compared with the total occupants in the building in each time left. It is also capable of tracing the evacuees in every compartment of the building at every time step.

Figure 4. Simulation model for The River Condominium South Tower: Amount of time and number of evacuees leaving the building.

The evacuation time from simulation is divided into pre-movement time (nine minutes) and travel time (40 minutes). The total evacuation time for 2,448 occupants is 49 minutes, slightly less than an hour. However, the simulation time does not consider other factors that will make the time longer, such as the reluctance of evacuees to leave after they hear the fire alarm, and obstruction along the evacuation route.

5. Conclusion and Future Research

In Thailand, every building with a height of more than 23 meters applies the fire safety issue from the same prescriptive code. This code was considered adequate in the past but may be not for the case of high-rise buildings (200–300 meters). In the future, Thailand will have more high-rise buildings, both in terms of number and height. Therefore, the study on evacuation will be crucial to ensure that the design is able to handle evacuation effectively during a fire. The simulation results show that the evacuation time from the case study, which is a 220 meter high-rise building is nearly 60 minutes in an ideal situation (every system is in good condition, no fatigue, and no chaos).

In case of the design method in Thailand, the code should be categorized for buildings with a height of 23-100 meters, 100-200 meters, and more than 200 meters. There are other issues that should be considered as well, such as complexity, risk, type of building. However, if the code cannot be categorized, it should consider the requirement to leave the building within one hour, which may not be enough for some high-rise buildings.

In the future, a study on evacuation time can be done by the simulation model method with different assumptions, such as the number of people in the building, human behavior influence, condition of building systems, obstruction, and alarm stage. The research can study by experiment,

such as field observation and evacuation drill. On the other hand, evacuation from code, design method and the high-rise buildings abroad can be applied to new design methods or new codes, including area of refuge, fire compartment, and evacuation elevator.

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