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Effect of varying two key parameters in simulating evacuation for a dormitory in China

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ABSTRACT

Student dormitories are both living and resting areas for students in their spare time. There are many small rooms in the dormitories. And the students are distributed densely in the dormitories. High occupant density is the main characteristic of student dormitories. Once there is an accident, such as fire or earthquake, the losses will be cruel. Computer evacuation models developed overseas are commonly applied in working out safety management schemes. The average minimum widths of corridor and exit are the two key parameters affecting the evacuation for the dormitory. The effect of varying these two parameters will be studied in this paper by taking a dormitory in our university as an example. Evacuation performance is predicted with the software FDS + Evac. The default values in the software are used and adjusted through a field survey. The effect of varying either of the two parameters is discussed. It is found that the simulated results agree well with the experimental results. From our study it seems that the evacuation time is not in proportion to the evacuation distance. And we also named a phenomenon of "the closer is not the faster". For the building researched in this article, a corridor width of 3 m is the most appropriate. And the suitable exit width of the dormitory for evacuation is about 2.5 to 3 m. The number of people has great influence on the walking speed of people. The purpose of this study is to optimize the building, and to make the building in favor of personnel evacuation. Then the damage could be minimized.

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1. Introduction

Student dormitories are both living and resting areas for students in their spare time. There are many small rooms in the dormitories. And the students are distributed densely in the dormitories. High occupant density is the main characteristic of student dormitories.

During the last decade, many observed self-organization phenomena in traffic flows [1–5] and pedestrian streams [6–10] have been successfully reproduced with physical methods. This has not only stimulated research in granular, biological, and colloid physics [11–13], but also encouraged physicists to study evacuation processes [14–16], since it has been shown that many aspects of crowd stampedes can be understood by driven many particle models [17,18]. The empirical observations have many common features with driven granular media.

Evacuation processes have been studied by the use of various simulation models. The typical models of pedestrian motion are based on molecular dynamics methods [6,17,18], lattice gas models [7,19–25], cellular automata model [9,15,16,26,27], the social force model [17] and the mean-field model [28]. Pedestrian flow is a kind of many-body system of strongly interacting persons. The pedestrian flow dynamics is closely connected with the driven many particle systems. To know

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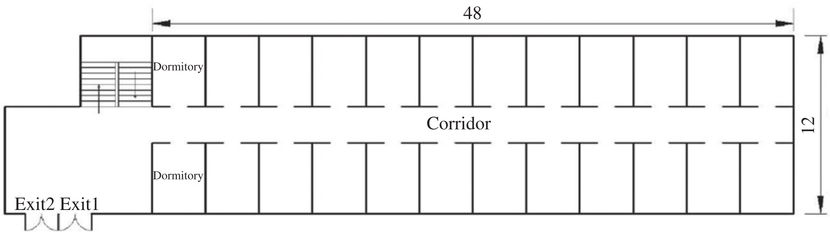

Fig. 1. The configuration and dimension of the dormitory.

the properties of pedestrian flow is important in our life. It is necessary to know the flow rate of pedestrians for rush hour and panic escape. It is also important to avoid the jammed state of pedestrians in the exit of the dormitory.

Henderson has conjectured that pedestrian crowds behave similarly to gases or fluids [29]. Helbing has shown that human trail formation is interpreted as a self-organization effect due to nonlinear interactions among persons [6]. Helbing et al. [17,30] have studied the dynamical features of escape panic using the social force model that performs features of escape panic such as arching, "faster-is-slow effect", mass behavior and clogging of pedestrians at the exit [17]. Helbing et al. have also studied the evacuation process from a classroom by means of experiments and simulations using the lattice gas model of a raw grid [30]. Isobe et al. [28,31] have conducted the experiment of pedestrian counter flow and shown that the arrival time obtained from the experiment agreed well with that from simulation [28]. The escape panic [15,17,18,30], counter channel flow [7], and bottleneck flow [14,21,23] have been studied numerically. Zhang et al. had conducted experimental and multi-grid modeling of evacuation from a classroom. The results show that the evacuation times exhibit a (truncated) normal distribution and vary within a region of about 30% of the mean value. And the evacuation time of the egress experiment is close to the minimum value calculated with the model [32].Yusuke Tajima and Takashi Nagatani have investigated scaling behavior of crowd flow outside a hall. And they have shown that the crowd flow rate and the transition time have relationships to the size of the door [14].

In this paper, the simulation of students evacuating from a dormitory is conducted. Based on the experimental results, a computer evacuation model is developed to investigate the characteristics of the evacuation. The effect of varying these two parameters will be studied in this paper by taking a dormitory in our university as an example. The relationship between evacuation distance and time is also investigated. We simulate the evacuation process in four different scenarios. The purpose of this study is to optimize the building, and to make the building in favor of personnel evacuation. Then the damage could be minimized. And the results obtained from our study are also suitable to all those buildings in which both living and resting areas occupy the majority of the space, such as dormitory, residential building, hotel (restaurant) and so on.

2. Experiment

The experiment was conducted in a dormitory as schematically illustrated in Fig. 1. And the main body of this evacuation mainly consists of sophomore girls. Those sophomore girls were mainly distributed on the right side of the first floor of the dormitory. The exact size of the right side of the first floor is about 55 m $\times$ 12 m. The exit is divided into two parts. The width of each part is 2.0 m.

The video camera was located in front of the exit. And the camera was used to record the students' outflow from the exit. The snapshot of the evacuation experiment is shown in Fig. 2. The evacuation process could be observed by the camera in the experiment. There were 240 sophomore girls in the right side of the first floor at the beginning of the experiment. At time $t = 0$ all of the students stayed in the dormitories at random.

Because there were so many students, in order to know the room a student stayed in, the students were required to bring the room number with them. At the end of the evacuation, the room numbers would be collected for evacuation simulation. For the purpose of making a distinction between the students who participated in the evacuation and who did not, all the students participating in the evacuation were asked to wear camouflage clothes. The evacuation started as soon as an emergency alarm was given out. The students at the left (right) side of the aisle moved to the right (left) to enter the aisle and then moved forward to the exit. Once the students arrived at the exit, they went through the exit and left the dormitory. The whole evacuation process was recorded by the camera.

3. Model and simulation

3.1. Introduction to FDS + Evac

In this paper, FDS + Evac is used to simulate pedestrian evacuation. This software is a combined agent-based egress calculation model and a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow, where the fire and egress parts are interacting. It can also be used to calculate the egress problem without any fire-driven fluid flow calculation, e.g.; it can be used to simulate fire drills.

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