Research on the Impact of Crowd Flow on Crowd Risk in Large gathering spots

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***Abstract*——In order to assess crowd risk involved with mass of people gathering in large gathering spots, four common crowd flows including two-way flow, heterogeneous crowd flow, circular flow and arching phenomenon were specifically analyzed on the basis of investigation of crowd's route selection. The formation mechanism of crowd risk consists of four stages namely free movement, retention, congestion and stampede, and by using the method of event tree, the important impact of crowd flow on crowd risk was found out. Combined with crowd risk model, the thinking of computer simulation on crowd risk was proposed to provide a reference for crowd security management in large gathering spots.**

Keywords-crowd risk; crowd flow; computer simulation

Ⅰ. INTRODUCTION

Population density is large and crowd flow is messy in large gathering spots (such as stadiums, city squares, exhibition centers and so on), especially in entrances or intersections. When the crowd has opposed flow or heterogeneous pedestrians, there will be crowd phenomenon bearing the risk of stampede, which is likely to result in serious injury or death consequences. Therefore, crowd safety issues in large gathering spots have drawn great attention of the scholars and management.

Many scholars have studied the crowd risk from different aspects recent years. Lee R C and Hughes R.L. introduced a continuous pedestrian flow model to analyze congestion accident and stampede accident quantitatively [1]. Ma, J. et al analyzed and suggested that the simulation platform on GIS can serve as a useful tool to evaluate pedestrian movement in transportation facilities. Some scholars also studied the computer simulation on crowd and evacuation [2]. Helbing D et al established a social force model to analyze the crowd mechanism, and this model took into account pedestrian intentions, desired speed and the interaction between individuals [3]. Chen Feng et al introduced a new method to the original social force model based on a smart agent model using object-oriented programming, to study both one-directional and bidirectional interchange walkway simulations[4]. Wang Sixuan and Gabriel Wainer established a method based on a distributed architecture with simulation in the cloud, and composition using workflows, to support the analysis of the behavior of crowds [5].

The situation on some researches is relatively simple, and this paper will consider the impact of the crowd flow on crowd risk on the daily state to make risk analysis and simulation results more accurate and truthful.

Ⅱ. CROWD MOVEMENT FETURES IN LARGE GATHERING SPOTS

Through direct observation and photography tracking in large gathering spots, this paper measured crowd flow velocity and density, and summarized the main types of crowd flows, such as the one-way flow, two-way flow, heterogeneous crowd flow, circular flow and arching phenomenon.

A. Two-way flow

The opposite movement of pedestrians is often seen on the streets and sidewalks. Pedestrians with different movement directions will form their own walking path. As shown in Figure 1. In order to avoid the opposite pedestrians, people need to constantly change their directions and speed of movement, the formation of the walking path can make the mutual influence between pedestrians a minimum.

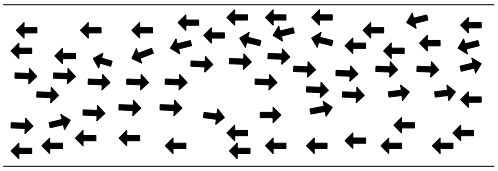

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Figure 1. Two-way flow

B. Heterogeneous crowd flow

The difference of physique and movement behavior between pedestrians is large, so the walking speed will be quite different, for example, the walking speed of the elderly, children and frail people is relatively slow. If the population density is low, other people will bypass the pedestrian who walks slowly, there will be a vortex around this pedestrian, as shown in Figure 2. If the population density is high, or the pressure of the crowd is high, it is prone to fall or stumble phenomenon.

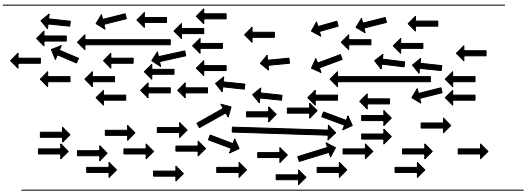

Figure 2. Heterogeneous phenomenon

C. Circular flow

There will be a temporary unstable circulation phenomenon when pedestrians walk in intersections, and the direction of circular flow is alternately changed. The formation of this phenomenon can reduce the frequency of deceleration and avoid behavior. As shown in Figure 3.

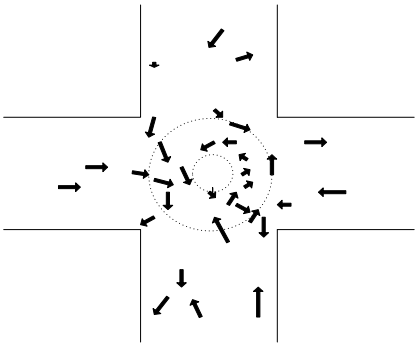

Figure 3. Circular flow

D. Arching phenomenon

When the crowd gathers at the entrance, apart from the positive side, there are many people crowd into the entrance from other sides, hindering the flow from positive side, so that the population density rapidly increases and the arched crowd is formed. When the density reaches a certain level, the pressure of large crowd makes some people off balance, and lead to the occurrence of falls and trampling accident. As shown in Figure 4.

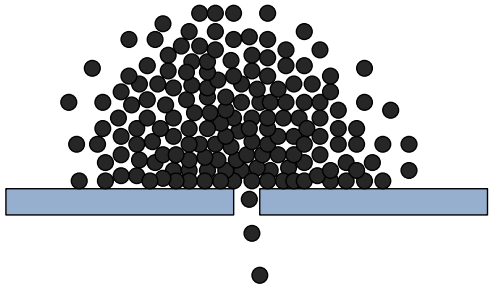

Figure 4. Arching phenomenon

III. DEFINITI AND FORMATION MECHANISM OF CROWD RISK

A. Definition of crowd risk

Crowd risk refers to the possibility and severity of death or injury in stampede accidents caused by external disaster factors or internal population factors when a large number of people walk at the large gathering spots.

B. Analysis of formation mechanism

The formation of crowd risk is a process in which energy gathered over time and suddenly released after the quantitative change turns into qualitative change. Based on characteristics of crowd movement, the process needs to go through four stages namely free movement, retention, congestion and stampede [6]. As shown in Figure 5.

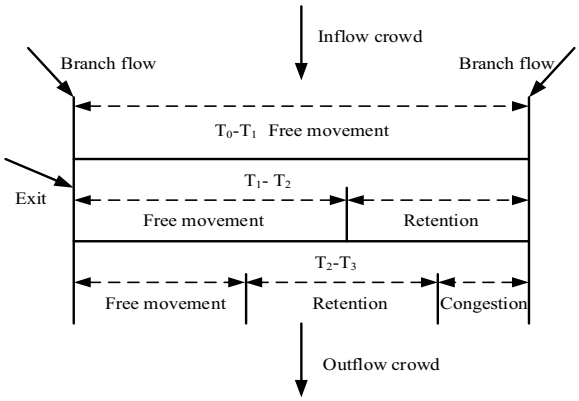

Figure 5. The graph of formation mechanism

In the time T_0-T_1, population density is relatively small, all people are free to move. In the T1-T_2 time, the number of pedestrians near the exit is more than the pedestrians through the exit, and with the increase in population density, the pedestrians move more slowly, there is a retention. In the time T_2–T_3, when the population density reaches the maximum, flow coefficient becomes zero, then

the crowd congests.

Ⅳ. MODELLING AND SIMULATION OF CROWD RISK

A. Theoretical model of crowd risk

1) The expression of risk

According to classical risk theory, risk is a comprehensive measure of the likelihood and severity of the hazard accident [6]. The risk rate R measures the level of the risk, which is equal to the product of the accidents probability P and loss severity S.

$$R=P \cdot S \quad (1)$$

Since the probability value is difficult to obtain, it is often represented by frequency probability; and loss severity can be expressed as the number of deaths, the number of accidents or economic loss.

2) Theoretical model

The construction of the theoretical model is based on event tree of crowd risk, as shown in Figure 6. This model has the following characteristics: First, the stampede accident caused by crowd risk is made up of several fortuities; Second, accidents are caused by multi-stage evolution of the initial incident, including move, retention, congestion and stampede; Third, all fortuities constitute a complete chain, each stage has its probability of occurrence [7].

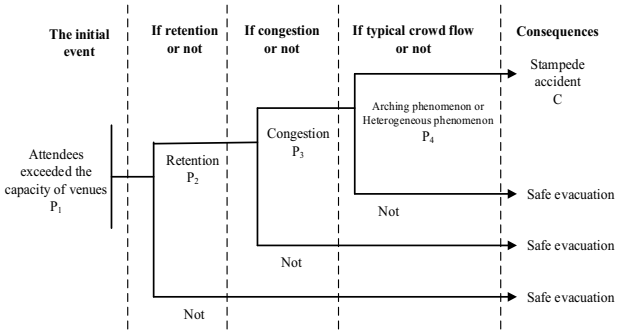

Figure 6. Event tree of crowd risk

Based on analysis of event tree, the general expression of crowd risk is equation (2):

$$R = P * C = (P_1 * P_2 * P_3 * P_4) * C \quad (2)$$

R is the crowd risk; P is the frequency of stampede accident; C is the accident consequences; P_1 stands for the frequency of the number of pedestrians exceeded place capacity; P_2 represents the frequency of retention status; P_3 represents the frequency of congestion status; P_4 is the frequency of typical crowd flow.

B. The general thinking of computer simulation

Combined with crowded risk model, a computer simulation of crowd risk can be developed on a multi-agent simulation platform. Thinking of computer simulation system is divided into three steps:

The first step is to select a multi-agent simulation platform.

NetLogo is a programmable modeling environment that can be used to simulate a variety of natural and social phenomena, especially for time-based complex systems [8]. Simulator can send commands to thousands of independent Agent. It is a tool to explore the individuals' behavior and the interaction between individuals.

The second step is to construct a simulation model and to determine individual behavior rules.

The basic principle of MAS-based crowd risk simulation system is to track the trajectory of each individual in each simulation time step, and to assess its position and orientation, and then calculate the interaction between it and the environment and other individuals, which will affect the position and status of an individual [9]. Mechanism of simulation system as shown in Figure 7.

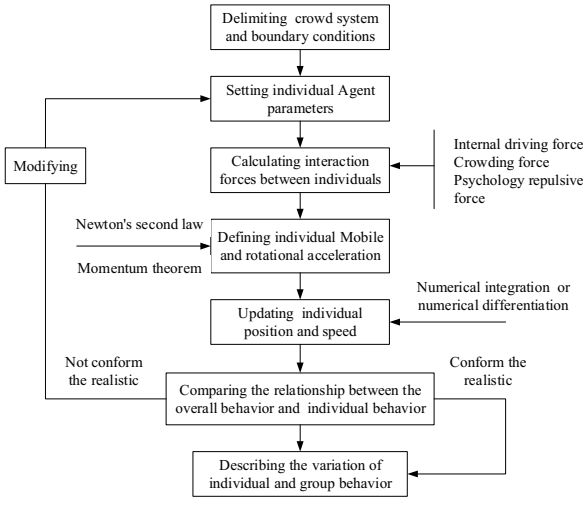

Figure 7. Mind map of computer simulation

The third step is to achieve simulation by using programming methods and languages.

Ⅴ. PREVENTIVE RULES OF CROWD RISK IN LARGE GATHERING SPOTS

The prevention and control of risk crowd should take

appropriate action from three aspects: engineering, education and enforcement ("3E" rule).

A. Engineering strategy

Based on engineering and technical means, it is to solve the problem of monitoring in large meeting place, to control the number and density of crowd in the safe range and to prevent accidents and reduce injuries and losses. Monitoring method commonly used is artificial observation method, GPS collection method, infrared collection method and video collection method.

B. Education strategy

Through safety education, the public will consciously analyze the crowd risk in large gathering spots, and have psychological and operational readiness of how to deal with the risk; they can calmly deal with the emergency situation, take corrective measures to help themselves and to help each other. Through training, managers will develop the sense of responsibility for security, standardize safety management of large-scale activities to improve ability to response and handle emergency situations.

C. Enforcement strategy

Good information management is not only beneficial to the crowd shunting and grooming, but also help suppress psychological mutation in an emergency situation to prevent the accident. Emergency management should focus on the preparation and exercises of emergency response plan. A set of scientific and reasonable emergency rescue plan and a trained emergency response team, is the important means of preventing and reducing crowd risk in large meeting place.

Ⅵ. CONCLUSION

Through observation and analysis, this paper summarizes the four typical crowd flows, and through the event tree analysis and modeling, found that crowd flow has a significant impact on the crowd risk, corresponding measures should be taken from three major aspects engineering, education and enforcement to reduce crowd risk and finally to reduce the occurrence of stampede accidents.

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