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Influences of intelligent evacuation guidance system on crowd evacuation in building fire

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ABSTRACT

The intelligent evacuation guidance system (IEGS) is a new concept and product in China, using an intelligent inducing algorithm to get dynamic evacuation routes and improving evacuation efficiency. This paper analyzes IEGS's influences on crowd evacuation by simulating a fire scene on the experimental platform of the "black house", and some important conclusions are obtained. These conclusions including layout of exit position, settings of evacuation channel number and width, determining of installation distance and installation position mode of the intelligent acousto-optic evacuation indicator (IAEI), and choice of sound and visual inducing, can be a guidance in practical engineering and provide a reference for national standard 'fire emergency evacuation lighting indication system (EELIS)' modification.

1. Introduction

Safe crowd evacuation in fires, a complex system involving three factors (architectural structure characteristics, fire development process and human behavior) which interact with each other, is one of the hot researches of architectural science and fire safety science. In recent years, the development and utilization of large-scale, multi-functional buildings and underground space raise higher requirements for safe evacuation. Most of these buildings have as features, large areas, large room capacities, functional diversity, many combustible materials, large electricity power load, etc., and these features would lead to the result that the evacuation path is too long or complex, and causes evacuation time delay. Fire smoke movement in large space areas spreads quickly, especially in atrium and vertical opening spaces, which increases the fire hazard and personnel evacuation difficulty. Therefore, many scholars make studies on safety evacuation in fire. Galea ER [1] and Thompson PA [2] study the personnel behavior changes in fire from different perspectives. Song Weiguo [3,4] researches the evacuation model and carries out the simulation of the people evacuation in fire. Zhang Shuping [5] launches a questionnaire survey and analysis of crowd behavior factor effects in fire. Zhang Weili [6] has conducted the research on crowd evacuation simulation in a school dormitory fire. Cui Xihong [7] researches the crowd evacuation model in large public places. These results provide the scientific and theoretical basis for how building structure parameters, fire process structure parameters and population features make effects on safety evacuation. Zheng Xiaoping [8] analyzes the crowd jam in public buildings based on cusp-catastrophe theory. Especially, Zheng Fatai [9] puts forward the idea of intelligent acousto-optic evacuation indicator (IAEI) which could be applied in engineering for safety evacuation (IAEI is a product conforming to GB17945-2000 [10,11]). Jianyong Shi [12] proposes an agent-based evacuation model which is developed to simulate and analyze the egress progress in large public buildings. M. liu [13] uses the support vector machine (SVM) approach to study pre-evacuation human behavior in super high-rise buildings fire. Nowadays, Chinese scholars propose a new concept — intelligent evacuation guidance system (IEGS) as a guide for people to evacuate from fire, and some companies produced this kind of commercial system (including IAEI) and applied it in building engineering. However, there are no clear instructions and standards for IEGS installing. Therefore, we design the experiments to analyze the IEGS influences, and then settle on the installation distance, position and mode of IAEI which provides references for national standard 'fire emergency lighting and evacuate indicating system' modification.

2. The working principle of intelligent evacuation guidance system

Traditional evacuation system (here we take emergency evacuation lighting indication system (EELIS) as an example) consists of identification devices showing the fixed direction and safety exit sign devices. The devices are installed according to "code for fire protection design of buildings" [14] and "fire emergency lighting system" [15], as shown in Fig. 1. The safety signs are high exit signs, low dispersal indicators and ground continuous oriented indicators, and all the signs could be sound-inducing, visual-inducing, or dual-inducing (such as sound and light alarm device).

The IEGS shown in Fig. 2, is composed of a computer, the smoke detecting device, crowd evacuation speed detectors, evacuation route identification (using luminous type indicator, sound and light alarm

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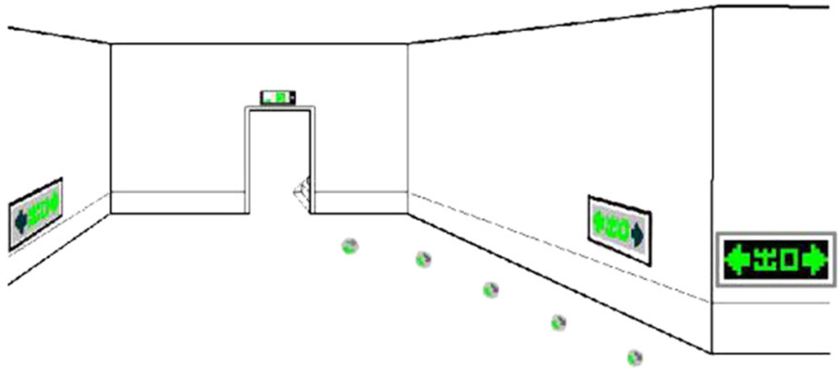

Fig. 1. Safety sign installation diagram.

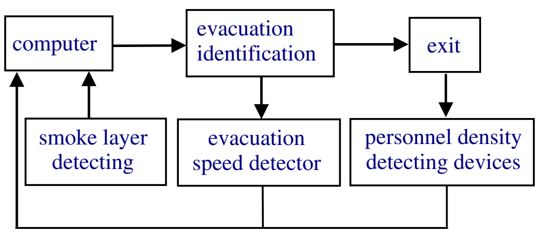

Fig. 2. The intelligent evacuation guidance system.

devices or IAEI to indicate the route) and exit signs. IEGS system uses an intelligent inducing algorithm based on multi-parameters to get dynamic evacuation routes. The smoke state parameters, human behavior parameters and construction parameters (the three kinds of parameters would influence crowd evacuation model), are input variables in the system. Control signals for safety signs are the output variables. Luminous type indicators, sound and light alarm devices or IAEI, and exit signs are all safety signs in IEGS. When the fire occurs, the system constantly optimizes the evacuation routes according to the personnel density or speed, smoke layer information, building facilities and structure, building environmental parameters, and then outputs the optimal real time dynamic evacuation routes. The dynamic evacuation routes adopt a three-point orientation principle, as shown in Fig. 3. There are three IAEIs in the same line. If the sounding order is ① → ② → ③, the evacuees are guided to the right. If the sounding order is ③ → ② → ①, the evacuees are guided to the left. The flash arrow has four kinds of shapes: ↑, ↓, ←, and →, corresponding with sounding directions, keeping on flashing while inducing sound (the flashing frequency is consistent with sound inducing cycle), which increases the visual effect.

3. Construction of experimental platform

It is the ground floor (31 × 16 × 5.5 m) of a building with three exits, A, B and C. The A, and B exits are both 2 m wide, and C is 4 m wide. The walls, top surface and ground are painted gray. A number of movable shelves are displayed in the ground floor. The width and number of channels can be adjusted by moving shelves.

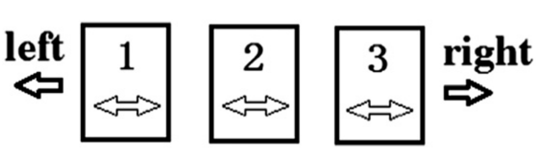

Fig. 3. Three-point orientation principle.

Fire smoke is generated by an outdoor smoke generating device through a pipeline. The smoke production is obtained by the following steps: ① Setting the fire scene: combustible wooden shelves (shelf height is 4.3 m), leather seats, sofas and other common items are as fire loads, and with these loads we can use equation $Q = 0.1876t^2$ (kw) [16,17] to design the fire scene. The ignition point is set in the middle of the black house shown in Fig. 4.② Obtaining the danger time T according to fire danger conditions by the CFAST model (danger time means the time from fire starts to the fire causes harm to people). There are three kinds of fire danger conditions which would cause harm: (a) The smoke layer height is higher than that of human eyes, and the gas temperature is 80 °C ~ 200 °C. In this situation the thermal radiation produced by smoke gas would cause unrecoverable skin burns for people. In this paper the gas temperature is set as 190 °C; (b) The smoke layer height is lower than that of human eyes, and the gas temperature is 110 °C ~ 120 °C. In this situation thermal radiation produced by smoke gas would harm the human body, here taking 115 °C as gas temperature; (c) The volume fraction of CO reaches 2.5×10^{-3}, and the toxic gas would cause harm to humans. In this paper, the human eye characteristic height is taken as 1.5 m, and the environmental temperature is 20 °C [18]. The results from the CFAST model shows that: when the fire time reaches 248 s, the thickness of the smoke layer is 4 m, and the temperature is 55 °C, which is not harmful to the people; when the fire time reaches 410 s, the smoke layer temperature is 115 °C, which can cause direct burn on human body, and at the same time the volume fraction of CO is far less than 2.5×10^{-3}, no harm to human body. Therefore, the fire danger time is set as 410 s according to the fire danger condition (b); ③ The smoke production per unit time would be obtained via the volume (31 × 16 × 5.5 m) divided by the T (410 s). Based on smoke production per unit time, smoke generating device is selected to simulate fire smoke environment.

The smoke gas concentration sensors, crowd evacuation speed detectors and camera equipments are arranged on the specified location. The cameras are installed as in Fig. 4. Smoke gas concentration sensors are distributed according to GB50016-2006 in the “Black house”.

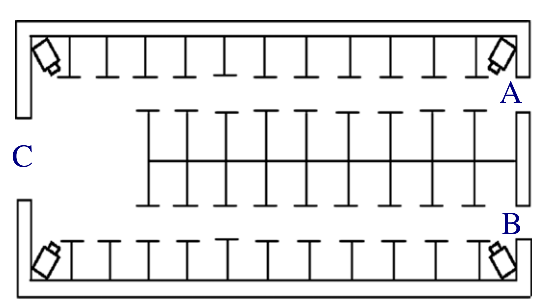

Fig. 4. Diagram of black house distribution.