Safety Science 78 (2015) 35–40

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Firefighters ascending and evacuation speeds during counter flow on staircase

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ARTICLE INFO

Article history:
Received 9 July 2013
Received in revised form 8 January 2014
Accepted 1 April 2015

Keywords:
Modelling
Experiments
Egress
Counter-flow

ABSTRACT

The counter flow condition on the escape stairs is a situation that may occur during the evacuation from buildings when the downward flow of evacuating occupants passes the upward flow of firefighters heading to the fire floor.

The aim of this work is to provide data of firefighter movement speeds for numerical modelling and calculations. A series of experiments was conducted on a staircase with and without a simultaneous counter flow of ascending firemen.

1. Introduction

Bidirectional flow involving a fire brigade ascending stairs with evacuating occupants of a building may be observed in evacuations from tall buildings or sport facilities, where a large number of people may be simultaneously present, and a fire-fighting and rescue operation starts before the building evacuation is completed. The occurrence of this condition is influenced by a firefighting and adopted evacuation strategy. The basic strategies may either consist in simultaneous evacuation of the entire building, increasing population density on the vertical and horizontal evacuation routes, or they can adopt a sequential method of informing people who are located on particular floors. Therefore when applying sequential method of alarming – reducing density may delay the arrival of people at a place of safety even though it improves conditions during the evacuation movement. Hence, both basic evacuation strategies may result in occurring the counter flow of rescue teams with evacuees. A significant issue affecting this condition is the technical conditions of buildings and the sizing of stairs. According to code requirements in many countries, the minimum width of stairs school be at least 1.2 m. This width should allow an evacuation of two people side by side or it can allow a bidirectional flow on stairs. At this same time the stair width is usually adjusted to account for the maximum number of people only on one floor. In buildings having more than few floors, described width allows a populations of hundreds or thousands of people. When applying any evacuation strategy in those buildings, the bidirectional flow involving fire brigade is likely to occur because of the length of evacuation time.

Apart from issues mentioned above, the discussed condition may occur in buildings, which do not have an elevator for rescue teams. Another problem, which has not been examined in this article, though, refers to the evacuation of people with disabilities and its influence on this type of condition.

The purpose of this study and the experiment was to examine the speed of rescue teams ascending stairs and the speed of evacuating people with the influence of particular flows of people on each other and without this influence. The elaborated results allow for applying them in modelling of evacuation and estimating the time needed to launch a rescue operation.

The study where the actual experiment was conducted with pedestrian counter flow was presented by Isobe et al. (2004). In that paper the authors clarified the characteristic properties of pedestrian channel flow and they have shown the simulation model representing counter flow. However in that paper the study was conducted in a flat tunnel and both opposite flows were composed of typical walking people. After that time no experiments were conducted involving counter flow – especially concerning vertical movement and with influence of ascending firefighters.

2. Experiments

2.1. Main assumptions and initial conditions

For the experiment 10-storey office building was selected. The experiment was carried out after working hours of the building

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http://dx.doi.org/10.1016/j.ssci.2015.04.002
0925-7535/

Fig. 1. Building and the staircase.

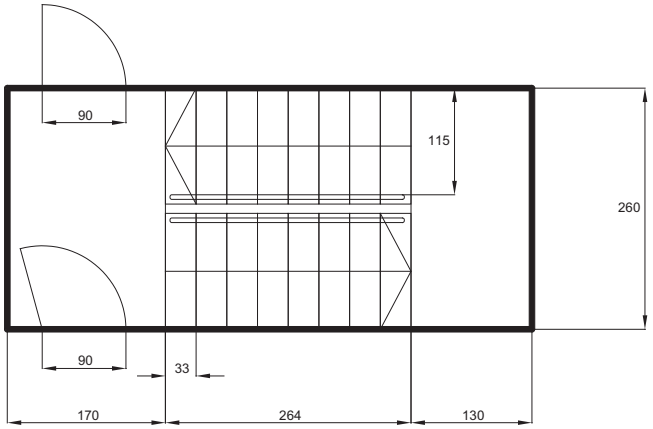

Fig. 2. Staircase dimensions.

in one out of two staircases. Figs. 1 and 2 given photos present a general view of the building, the stairs and its dimensions.

2.2. Experiment description

78 people took part in the experiment, with the group composed of 73 evacuees and 5 firefighters. These were students from the Main School of Fire Service in Warsaw. The individuals who participated were mostly male (67 male, 6 female participants) and they were between 20 and 25 years old. The students who played the role of evacuees were not prepared and had not participated in similar evacuations before. The firefighters (all male) were fully equipped, just like in the case of actual hazard to the office building. Apart from wearing a full uniform composed of special clothing, a belt and helmet, they were equipped with breathing apparatuses, demolition tools, torches, hoses, nozzles and a rescue rope. Additionally, one person was also carrying a video camera in order to record the people descending the staircase. The firefighters were climbing the stairs at a standard pace keeping to the external side of the staircase. There were eight evacuation trials carried out during the experiment depending on the adopted scenario with a variable initial density of people on the stairs. This article presents six analyses of such attempts. The remaining two, carried out for variable initial density of 3 pers./m^2, were deemed as not representative due to some measurement errors. The scenarios adopted for the analyses are presented in Table 1.

Table 1
Plan of experiments.

Run no.	Initial floor density (p/m^2)	Firefighters
1	4	No
2	4	Yes
3	2	No
4	2	Yes
5	1	No
6	1	Yes

The same number of evacuees took part in each scenario. The change in density of people distribution was represented by the change in surface of occupied stairs and landings. Tables 2 and 3 are illustrating the people's location at each segment of stairs before commencing next experiments. Commencement of each experiment was signalled by loud acoustic sound audible for all the people on the staircase. The evacuees were beginning their movement concurrently keeping as much as possible steady density until meeting with the rescue team (Tofilo et al., 2012).

The firefighters participating in the experiment and their fittings are presented in Fig. 3.

2.3. Data collection

For data collection a measuring installation was prepared. It was composed of two IR directional sensors (one for every exit door) connected with the counting unit to the computer with

Fig. 3. Firefighting team.