

# Analysis of Staircase Emergency Evacuation of Pedestrian after Earthquake

Xuheng Chen<sup>1</sup>, Weiguo Song<sup>\*1</sup>, and Jun Zhang<sup>1</sup>

<sup>1</sup>State Key Laboratory of Fire Science/University of Science and Technology of China

**Abstract** In this paper we try to use the surveillance footage to capture the characteristic of staircase evacuation after a real earthquake. We got the time marks when entering and exiting stairs of 143 pedestrians and, based on this data, calculated evacuation time, average travel speed, average regional speed etc.

**Keywords** Pedestrian Evacuation Dynamics, Staircase, Earthquake, Emergency

## Introduction

Earthquakes, as sudden and devastating natural disasters, pose significant threats to urban safety. In densely populated cities where high-rise buildings are increasingly common, the safety of citizens during such events is paramount. According to Chinese fire regulations, elevators are prohibited for use during emergencies, necessitating the use of staircases for evacuation. This makes the study of high-rise building evacuations during earthquakes critically important.

For staircase evacuation, researchers organized various experiments aimed at quantitative analysis. Usually, volunteers were recruited to participate experiments in specific scenarios. Speeds of walking downstairs or upstairs, crowd density are direct parameters[1] as a result from videotape of experiments, helping quantifying evacuation characteristics. Hard to get around the fact that, differences of pedestrians' performance between control experiment, fire drill and true emergency are not clear. Thanks to permission from the relevant authorities, we obtained valuable raw footage of a building from which students and teachers evacuated following a distinctly perceptible 4.7-magnitude earthquake tremor. This real-world emergency scenario provided critical data for analyzing evacuation behaviors under genuine threat conditions.

## Method and Analysis

The spontaneous emergency evacuation happened in a 9-story building at a university in Hefei[2]. The building contained 2 identical staircases with 26 steps per floor (except between 1st floor and 2nd floor, 2nd floor and 3rd floor, which had 32 steps), located at both ends of the corridor. After the sudden shock of the ground, totally 143 students and teachers evacuated quickly through the 2 series of stairs, specifically 71 through the East one and 72 through the West one. To discover the evacuation characteristics when emergency from videotape, we conducted several analyses as evacuation time, average travel speed, average regional speed, and regional density.

**Evacuation time:** By analyzing timestamps embedded in videos recorded at the stairwell entrances and exits, the evacuation time of each pedestrian can be determined, as shown in Tab. 1.

**Average travel speed:** With the estimation of the spacial travel distance on stair, average travel speed can be calculated for every pedestrian. Following Tab. 1 shows maximum, minimum, mean and medium value of average travel speed.

**Average regional speed:** With the help of frame-level analysis software as the open-source video player 'VLC' and trajectory tracking software 'PeTrack', velocity diagram for the pedestrian passing through 3.652m before the exit can be provided and the histogram is shown below as Fig. 1.

**Spacial evacuation behavior:** All pedestrians followed the regulation of not using elevators. Under the influence of social relationships, some pedestrians delayed their evacuation to accompany friends.

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<sup>\*</sup>Email of the corresponding author: wgsong@ustc.edu.cn

## Result

Out of 143 pedestrians, 114(approximately 79.7%) evacuated at an average travel speed of less than 1.0 m/s. However, there were individuals who reached speeds up to 2.44 m/s, indicating that some pedestrian may accelerate under emergency conditions. Comparing the two figures in Fig. 1, the percentage of individuals with average regional speeds exceeding 1.0 m/s(56.3%) is significantly higher than those with average travel speeds(4.2%). As illustrated in Fig. 2, which compares the two types of pedestrian speeds, nearly all pedestrians exhibited a higher regional speed immediately before exiting compared to their average travel speed during the entire evacuation. This suggests that the merging of pedestrians from different floor occurred before reaching the exit, after which pedestrians accelerated, possibly due to a heightened sense of threat. There were up to 6 pedestrians in the 3.264 square meter stairwell because the people were walking side by side. Men were generally faster than women, but to less than 20%. In addition, the Voronoi diagram during evacuation is analyzed.

	Time use	Counts	Maximum v	Minimum v	Mean v	Medium v
West stair	144s	72 peds	2.44m/s	0.60m/s	1.09m/s	0.83m/s
East stair	187s	71 peds	1.13m/s	0.52m/s	0.66m/s	0.62m/s
Total	189s	143 peds	2.44m/s	0.52m/s	0.85m/s	0.91m/s

Table 1: Preview of Evacuation Time and Average Travel Speed

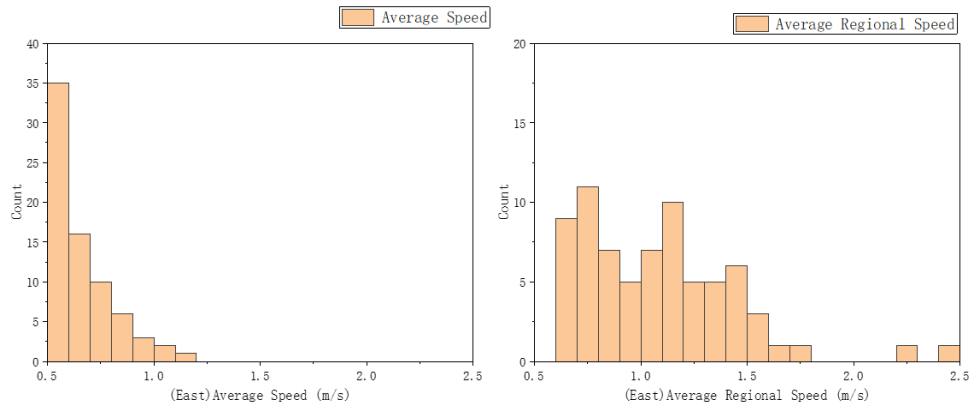


Figure 1: Average Travel Speed(left) and Average Regional Speed(right) on the East stair

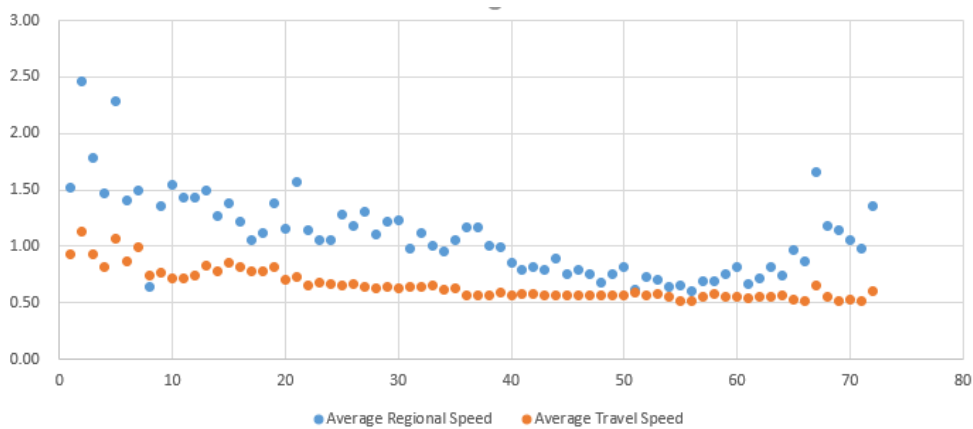


Figure 2: Comparison of Average Travel Speed and Average Regional Speed of Every Pedestrian

## Bibliography

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