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Sensitivity analysis of influencing factors on glass façade breakage in fire

Yu Wang [b], Qimiao Xie [a,*], Yi Zhang [c], Qingsong Wang [d], Jinhua Sun [d]

[a] College of Ocean Science and Engineering, Shanghai Maritime University, Shanghai, 201306, China
[b] School of Engineering, BRE Centre for Fire Safety Engineering, University of Edinburgh, Edinburgh, EH9 3JL, United Kingdom
[c] China Agri-Industries Holdings Limited, COFCO Corporation, Beijing, 100020, China
[d] State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, 230026, China

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ABSTRACT

Glass façade is the weakest part of a building. When subject to a fire, its breakage and fallout may create a new vent, allowing the fresh air entrainment and fire spread, which may significantly accelerate the compartment fire development. Previous studies established that a large number of factors can influence the fire performance of glass façades. However, very little is known about the relationship and importance of these factors. In the present work, three different importance analysis methods, including the correlation coefficient, rank correlation coefficient and normalized coefficient of variation, were employed to systematically investigate the primary 16 influencing factors based on experimental and numerical results. The linear relationship, monotony and variation between glass breakage time and these factors are quantitatively analyzed. Through comparison of three methods, glass type, fire location and installation form are found to be the three most important factors, while glass thickness, glass dimension and shading width may be ignored during the fire safety design of glass façades. Through the survey from experienced researchers, the thermal shock need more attention as well. The results are intended to provide a reference for fire performance-based design of buildings with glass façades.

1. Introduction

In recent years, glass façades are increasingly employed in modern high-rise buildings due to their better artistic, durable and environment-friendly characteristics [1]. However, different from concrete and steel, glass is a kind of brittle material that may break and fall out very easily when subject to a big fire. The fallout of glass will create a new vent for fresh air entrance and fire spread outside, facilitating the occurrence of flashover or backdraft. Compartment fire dynamics may thus be considerably changed, causing more serious disasters [2]. In particular, the glass fire resistance plays a very important role in the fire spreading from the interior space to exterior cladding.

This issue was first highlighted by Emmons as “one structural problem of importance to fire growth” [3]. Subsequently, a large amount of work has been conducted [4–11]. It was established that the thermal gradient is the primary cause of glass breakage in the fire, and a large number of factors may influence the fire response of glass [12]. For example, Skelly et al. [7] conducted fire tests within a two-layer fire environment and demonstrated that the edge protection from the frame could significantly shorten the glass breakage time. Manzello et al. [13] and Debuyser et al. [1] determined the performance differences between single-pane and double-pane glazing in a real compartment fire and indicated the importance of glass type selection. By changing the distance between glass and radiation panel, Harada et al. [11] found that the fallout area mainly depends on imposed heat flux. In addition, the smoke movement [4], glass orientation [14], edge condition [8] and fire location [15] were all found to be of great importance to the occurrence of glass breakage.

However, some other parameters do not have as much influence on glass thermal performance as above factors. McArthur et al. [16] compared the performances of timber- and aluminium-framed windows in the fire, but the performances were almost identical under simulated bushfire conditions. Similarly, no significant difference was found between glass frames with or without accessories, such asvinyl film sun screens, bright aluminum or black fiberglass insect screens attached to the exposed side of the window frame [17]. Moreover, experimental results suggested that the restraint of glass almost has no effect on its cracking [11], and the effect of burner-glazing distance change in a certain range can be ignored [18].

A large number of factors whose significances differ markedly will inevitably cause difficulty for the fire safety assessment of glass façades. It is almost impossible to evaluate the glass façades by considering all the

* Corresponding author.
E-mail addresses: ywang232@foxmail.com (Y. Wang), qmxie@shmtu.edu.cn (Q. Xie).

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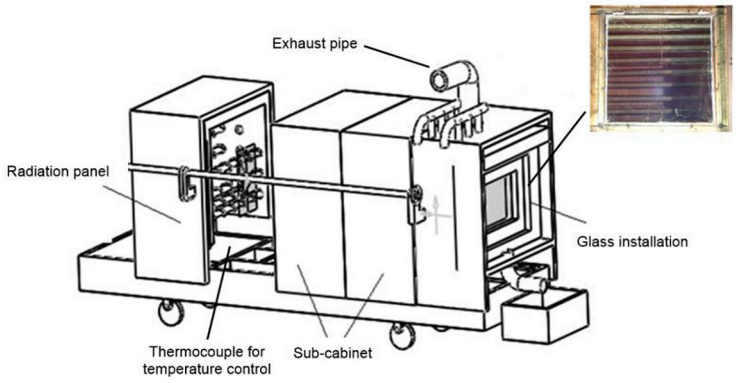
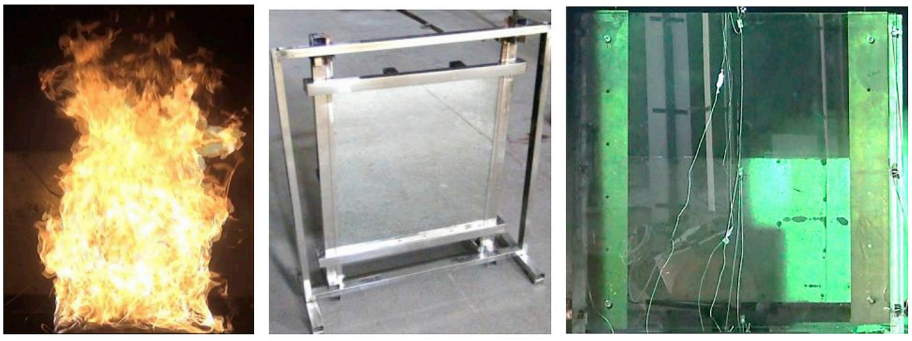
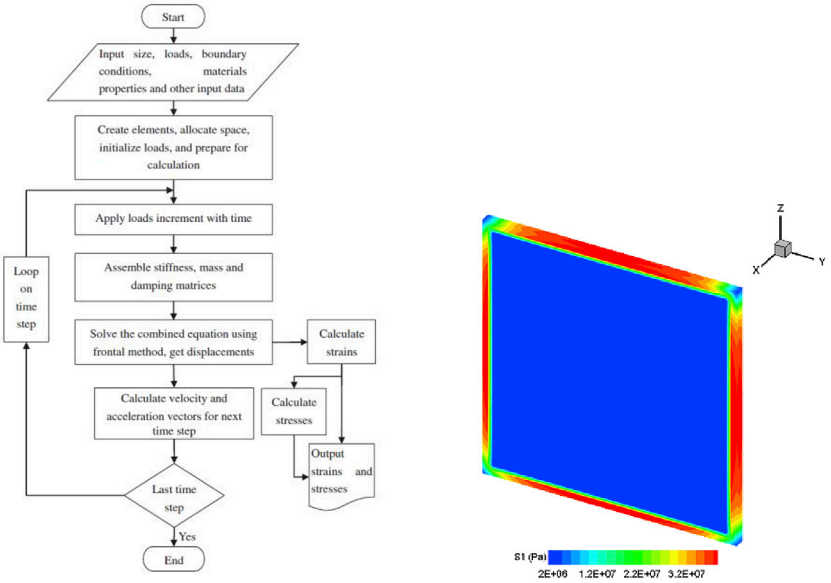
factors due to time and expenditure consumption in engineering. In addition, the conflicting data derived from various studies may render the situation more confusing. Previous studies employed Weibull distribution [19,20], Gaussian distribution [21] or exponential distribution [22] to predict the glass breakage in a statistical method, but primarily focused on the probabilistic characteristic of breakage occurrence and no breakage influence factors were considered. What is more, the previous study objective was limited to the ordinary edge-covered window glass which is anticipated different from glass façades with more diverse characteristics [23]. To the authors' knowledge, no work has been



(a) The setup for uniform radiation panel



(b) Pool fire, frame and point supported glass panels



(c) FEM simulation flow chart and results

Fig. 1. Experimental and numerical conditions in our previous work. (a) The setup for uniform radiation panel; (b) Pool fire, frame and point supported glass panels; (c) FEM simulation flow chart and results.