High-temperature behavior of fire-resistant glass

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What is fire-resistant glass?

Many modern public buildings such as airports or offices use fire-resistant glass and special frames to create compartments and decrease the risk of fire spreading. Fire-resistant glass consists of layers of float glass with transparent silica gel between them. In fire conditions, due to high temperatures, the intumescent gel starts swelling creating an opaque, porous foam, shown in Fig. 1 and Fig. 2, that blocks the conductive and radiative heat transfer to other compartments. Fire-resistant glass can consist of two sheets of glass and one gel layer (EW30) or multiple sheets of glass and gel layers (up to EI120).

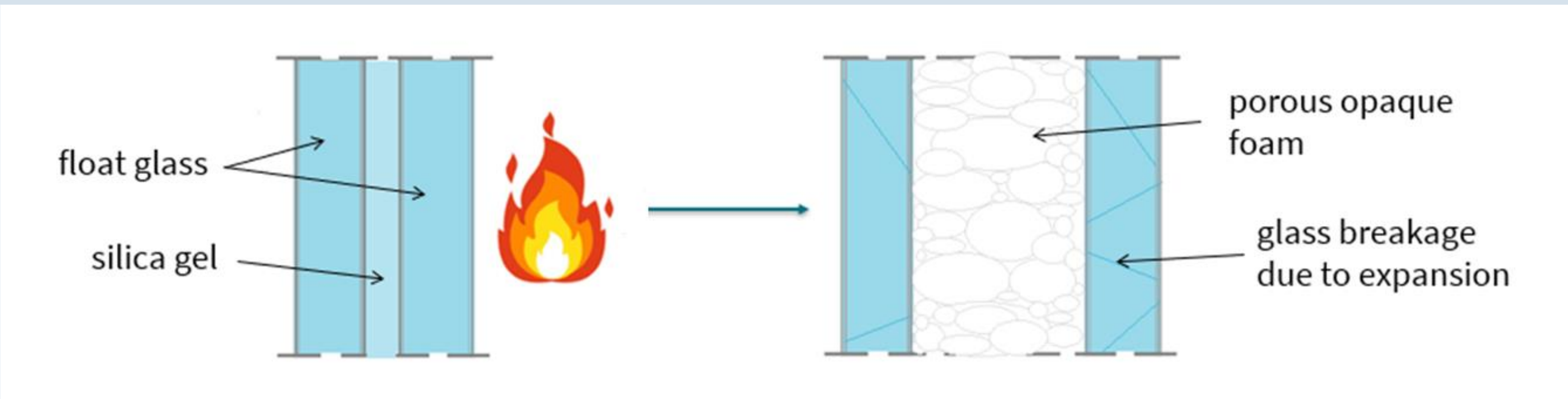

Fig. 1. Expansion of fire-resistant glass

Fig. 2. Expanded fire-resistant glass and the created foam

Little is published in the literature regarding science behind the fire-resistant glass behavior in a full-scale fire resistance test which is crucial for obtaining a product certification (i.e. EW and EI classes) [1, 2].

Reactions when exposed to fire

When subjected to fire, the fire-resistant glass undergoes a set of reactions that first include glass breakage due to thermal shock and free water vaporization in the silica gel (Fig. 3a) creating a visible white *fog effect*. Afterward, the bond water starts vaporizing creating bubbles inside the intumescent layer and causing its expansion (Fig. 3b-3e). In most cases, another glass breakage appears due to temperature gradient in the glass, mechanical restrain and/or pressure of gel reaction. When the foam is fully expanded, various chemical reactions happen depending on its chemical composition which differs from one producer to another.

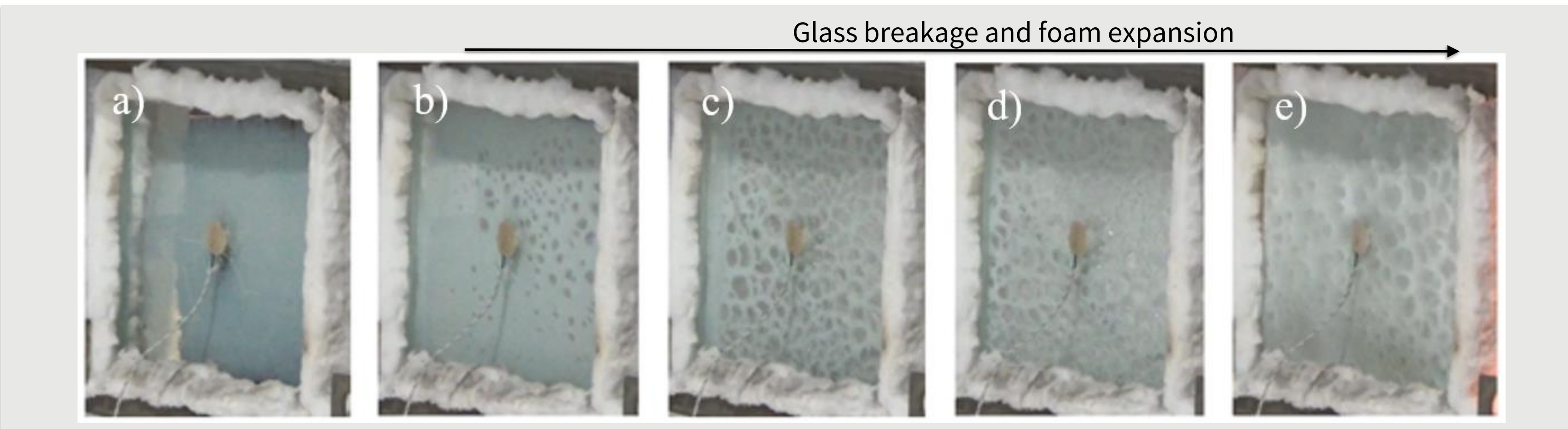

Fig. 3. Reaction of fire-resistant glass (bench-scale tests on specimens 20 x 20 cm^2)

Fig. 4. Softening of the exposed glass and foam layers

Additionally, after reaching a high temperature, usually above 700°C, the most exposed float glass and foam layer start softening and flowing down the furnace at the same time affecting the stability of the fire-resistant glass (Fig. 4).

Behavior in a full-scale fire test

Close observations of the fire-resistant glass' behavior in the bench-scale tests have shown how the bubbles are being created. These observations are rarely possible during a full-scale fire test due to safety concerns. In this case, observations are done after the test.

Two full-scale fire tests were performed on window frames filled with fire-resistant glass with EI30 rating. They were stopped after 40 and 55 minutes consecutively. The foam created in these tests was compared to the bench-scale tests. The pores created in the full-scale fire tests appeared to be significantly bigger than in the bench-scale tests: their diameters reached up to 4 cm in the fire tests compared to 2 cm in the bench-scale tests. As a results, the insulation properties were different in both cases.

Fig. 5. Foam in the fire-resistant glass created in the full-scale fire test: after 40 and 55 minutes

Further study on fire-resistant glass behavior in a full-scale fire test will include analysis of the glass stability and identification of factors which influence the size of pores in the foam.

References

[1] EN 1363-1:2020 Fire resistance tests - Part 1: General requirements, CEN (European Committee for Standardization), Brussels, Belgium

[2] EN 1634-1:2014 Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware - Part 1: Fire resistance test for door and shutter assemblies and openable windows, CEN (European Committee for Standardization), Brussels, Belgium