Fire Resistance of Glass

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Abstract

One of the problems in using glass is the poor fire resistance. On heating the glass usually fails by the strains introduced by heating too quickly on one side. For this purpose several types of fire resistant glass have been introduced. Using two types of experimental tests a standard commercial and a comparable laboratory produced fire resistant glass has been investigated. Different approaches to the problem of testing are discussed.

Introduction

Fire resistance is one of the more difficult to define parameters. Building codes demand certain levels of fire resistance which are determined according to certain codes. Basically the test method is illustrated in figure 1.

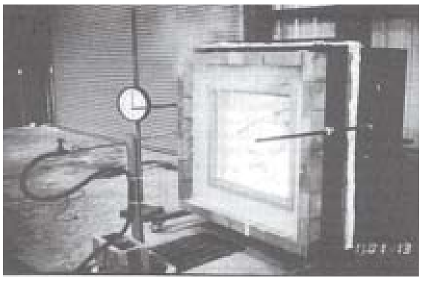

Fig 1
Oven for fire resistance testing of glass [1]

This is according to the American ASTM E163 testing method. Essentially all other testing methods are similar, placing the assembly in front of an oven and heating at a certain rate until the glass fails or the required time period has elapsed.

Nolte gives a good overview of the types of glasses and assemblies that are considered fire resistant according to this testing method in [2]. Considering this testing method the following variables that influence the result exist:
– edge finish of the glass
– size of glass panel under test
– contamination of the glass surface
– Can the glass expand freely in its fixtures or is the expansion partly or completely hindered
– heating rate
– maximum temperature

The last two are controlled in the codes governing the tests, the first three are usually not controlled while there is some flexibility about the fourth variable.

From a physical point of view the test is failed when the glass fails under the thermal and mechanical strain that develops during heating before the expected time.

This strain is dependent on the first four variables. This limits the scientific value of the testing methods and also allows manipulation of the results by the user. Certainly the possibility is introduced that standard production fire resistant glass is on average (significantly) less capable than the samples which are tested to achieve the requested fire resistance rating. Anecdotal evidence from the glass industry exists that 30 minutes fire resistant glass can obtain a 60 minute fire resistant rating by testing it in smaller panels. As in smaller panels the thermo-mechanical strain development in the glass would be less, this is not surprising but also demonstrates the futility of this testing method for scientific purposes. Other anecdotal evidence exists that some commercially available types of fire resistant glass were certified on pieces that were the survivors of an earlier, private, testing series.

To study the concept of fire resistance two testing methods are introduced which are more suitable for scientific purposes and which also do not require as extensive facilities.

Theoretical concepts for valid testing methods

The whole purpose of fire resistance testing is to determine the thermo-mechanical strain that the assembly can absorb without all glass layers failing. The nature of glass is that it can fail in only two ways :
- from the edges
- from the surface

This implies that two testing methods are necessary, one that induces failure from the edges and one that induces failure from the surface. This should also give an upper and lower boundary for the fire resistance, related in part to how the glass is fixed in the window frame.

In reference [3] a testing method is described that was developed for inducing failure from the thermo-mechanical strain development from the edges. A beam specimen that is under a static four point bending load is exposed on one side to a burner providing a constant heat flow. When the last glass layer fails the specimen break. The provision of a pre-stress gives a more constant failure point. The method is illustrated in figure 2.

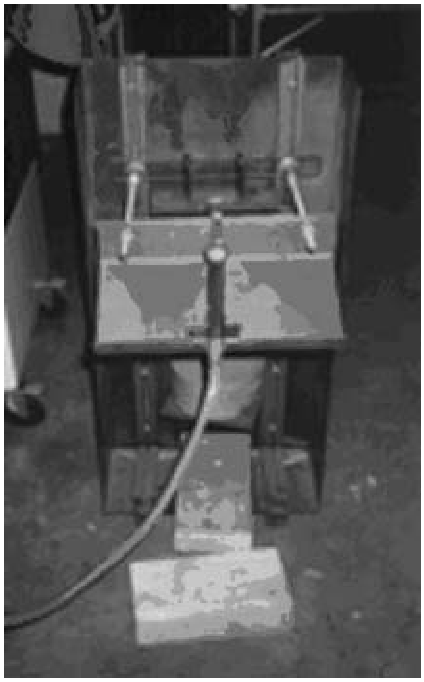

Fig 2
Testing method for beams

Plates can be tested in a similar way. Placing the plate horizontally with two edges on continuous metal supports allows a point load to be placed in the centre and the plate to be heated by an array of burners from underneath. A wire mesh is placed 4 cm under the plate to distribute the heat evenly and avoid localisation of the heat input.

The testing method is shown in figure 3.

These methods are still under development and finite element calculations to verify the second technique are not finished. It is intended to finish developing this method and publish the results completely in one year.

Experiments on beams

Tests were conducted on 400 mm long beams, with a height of 40 mm, thickness is dependent on the layers

Fig 3
test rig for testing plates

Table 1
overview of beam experiments

Material	Layers of glass	Pre-load (N)	Average time to failure (s)
Pyroguard 730	2	200	120
Pyroguard 730	2	500	100
Pyroguard 1060	3	200	206
Pyroguard 1060	3	500	129
Laboratory made specimen with two glass layers, epoxy thickness 0.5 mm	2	200	362
Laboratory made specimen with three glass layers, epoxy thickness 0.5 mm	3	200	1245

of glass in the sample. Commercially available pyroguard was compared with a laboratory made alternative of 3 mm glass bonded with a cheap, clear, epoxy resin. The pyroguard and the glass for the laboratory made specimens had comparable glass edges to ensure a fair comparison. During the test the temperature is measured with a thermocouple on the back face of the specimen and recorded.

The tests are summarised in table 1:

The results suggest that the commercially available product tested does not perform well under these testing conditions. Both the pyroguard and the laboratory made glass showed charring of the interlayer after several seconds, as is shown in figure 4.

Fig 4
Charring during test

Both interlayers are epoxies, but the one used for the laboratory made specimens started to char at a higher temperature and had a more ablative effect, gas could be seen coming from the specimen which burned up with a blue colour suggesting it was carbon monoxide gas.

Clearly the chemical nature of the interlayer influences the result. A 0.5 mm layer of the epoxy used in the lab. made glass giving better results than the 1 mm epoxy in the pyroguard. Presumably the epoxy in the pyroguard was selected more for castability than fire resistance.

Experiments on plates

The preliminary results for testing the plates show a similar pattern as with the beam. As failure now started from the bottom surface of the specimen the times to failure are greater than with the edge stressed tests. This testing method is still being refined, but it is hoped to develop this into a method of testing that can give a proper comparison of different types of glass.

Discussion and conclusion

A study of the standard methods of fire resistance testing has shown several problems with the approach used. Two different techniques have been proposed which should give upper and lower boundary values for the fire resistance. The second test method need further development and both need validation against a wider range of commercial fire resistant glass products.

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