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Application and Integrity Evaluation of Monolithic Fire-resistant Glass

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Abstract

This article introduced the classification and fire testing of monolithic fire-resistant glass in China. The integrity of monolithic fire-resistant glass is determined by both the ability to resist surface stress and the softening temperature. In the application of monolithic fire-resistant glass in China, there are some problems, include the wrong use of glass frame, the disordered production, the author gave some advices at last.

Keywords: Monolithic; Fire-resistant; Glass; Integrity

1. Introduction

Fire-resistant glass is a kind of special glass used in construction as building separate. In the normal status, fire-resistant glass is transparent and can be a windshield, but in the fire it can prevent the fire and high temperature gas and even heat transfer across the glass.

In these years, fire-resistant glass is widely used in construction field. In China, there are about 400000m^2 fire-resistant glass used in 2007, and the number changed to 500000 in 2008, the growth is more than 20 percent in a year. Even so, it is only 5 percent market share of the architectural glass and is far from widely used as in developed country. So there is a very huge market in the future[1].

According to the Chinese national standard GB 15763.1-2009 “Safety glazing materials in building—Part 1: Fire-resistant glass”, fire-resistant glass include monolithic fire-resistant glass and laminated fire-resistant glass. Laminated fire-resistant glass which is classified as FFB can be made of two or more layers of glasses, or be made of one layer of glass and one layer organic material. Monolithic fire-resistant glass is made of only one layer of glass and is classified as DFB[2]. Because of the good performance in fire resistance, thin, high strength, and durable, monolithic fire-resistant glasses is more and more used as fire partition and used as outside curtain wall in mega

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structures after the invention. So the monolithic fire-resistant glass is a very good substitute for laminated fire-resistant glass and will certainly dominate the market in the future.

This article will introduce the classification and fire test process of monolithic fire-resistant glass in China and will also introduce some application of this kind of glass.

2. Fire-resistant Grade of Monolithic Fire-resistant Glass[2]

According to Chinese standard GB 15763.1-2009, there are only two kinds of fire-resistant glass, heat-insulating fire-resistant glass (A type) and non-heat-insulating fire-resistant glass(C type). Monolithic fire-resistant glass is non-heat-insulating fire-resistant glass. The grade and fire resistance requirement of non-heat-insulating fire-resistant glass see table 1.

Table 1 Fire-resistant Grade and Requirement

Classification	Fire Resistance Grade	Requirement of Fire Resistance
Non-heat-insulating fire-resistant glass(C type)	3.00h	Integrity≥3.00h，no requirement in Insulation
	2.00h	Integrity≥2.00h，no requirement in Insulation
	1.50h	Integrity≥1.50h，no requirement in Insulation
	1.00h	Integrity≥1.00h，no requirement in Insulation
	0.50h	Integrity≥0.50h，no requirement in Insulation

Integrity is the ability of the glass when exposed to fire on one side to prevent the passage through of flames and hot gases or the occurrence of flames on the unexposed side. Insulation is the ability of the glass when exposed to fire on one side to restrict the temperature rise of the unexposed face.

Because there is no requirement in insulation of C type fire–resistant glass, so no unexposed thermocouple is needed during the fire test.

3. Testing and Classification of Monolithic Fire-resistant Glass

According to GB 15763.1-2009, the fire resistant test should comply with GB/T 12513-2006[3]. The average temperature of the furnace should be monitored and controlled with GB/T 9978.1-2008[4] such that it follows the relationship:

$$T=345 \lg (8t+1)+20 \quad (1)$$

Where, T is the average furnace temperature, in degrees Celsius;
t is the time, in minutes.

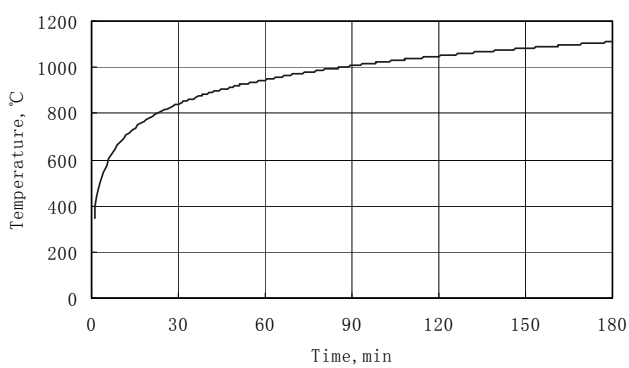

Fig. 1. Standard Time-furnace Temperature Curve

Fig. 1 shows the standard average furnace temperature in different time, there are tolerances in the real fire test. The tolerances are allowed in the test but it should be within the limits of the standard. Table 2 shows the typical time-temperature values.

Table 2 Time-Furnace Temperature Values

Time, min	0	5	10	20	30	40	60	120	180
Temperature, ℃	20	576	678	781	842	885	945	1049	1110

From the commencement of the test, the furnace temperature will follow the standard time-temperature curve as related above. The integrity is the elapsed time for the glass to maintain its separating function during the test without the following happens: (1) sustained flaming on the unexposed surface in excess of 10 seconds duration, (2) proves possible to enter a gap gauge into any opening[3].

From above we know that monolithic fire-resistant glass should resist the great temperature change of the exposed surface in the earlier test period, and should resist the high temperature in the later test period. The great temperature change of the glass exposed surface in the earlier test period could cause great temperature difference between the glass exposed surface and the unexposed surface, and this difference would lead to huge stress to break the glass. Because the softening temperature of glass is normally between 600℃ to 800℃, so increase the softening temperature of fire-resistant glass can ensure the glass keep hardness in the later period of fire resistant test especially when the temperature of the furnace is over 1000℃.

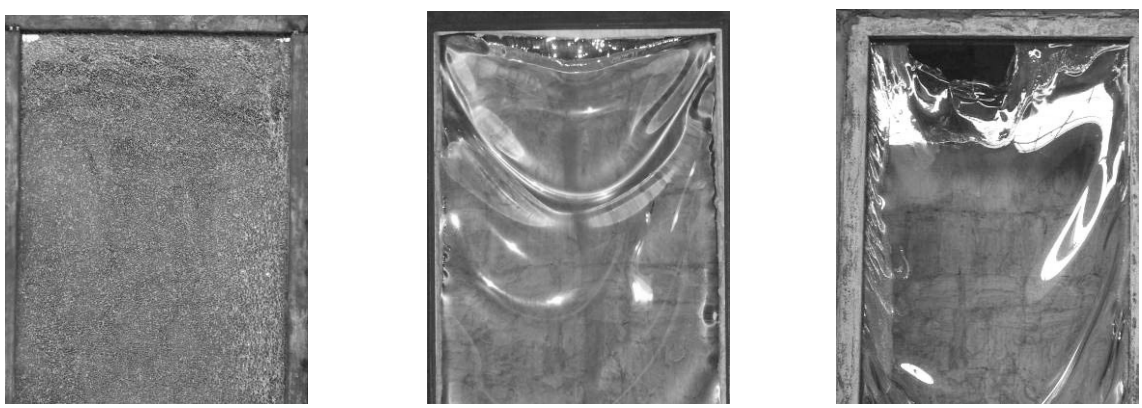

Fig.2.(a) Broken Glass Sample; (b) Softening Glass Sample; (c) Holes Appears Because of Softening

Fig.2.(a) shows the sample was broken under huge stress in the earlier test period. Although there isn't any hole or opening in the surface of the glass, but the glass can't bear any forces, even the slightest air pressure will lead to total break down of the glass.

Fig.2.(b) & Fig.2.(c) shows in the later test period, monolithic fire-resistant glass with lower softening temperature will turn soft and little by little there will be holes appears on the sample. Because the edges of the sample are protected by window frame, and glass is poor in thermal conductivity, so this part of the glass that directly exposed to fire will soften first and the sample edges will soften later. The softening part will be out of shape and drippy under the force of gravity. Under this condition the soften glass continue dripping down. The area between the softening upper part of the exposed surface and the solid upper sample edge become thinner and thinner and at last will become a hole, see Fig.2.(c), then the sample lose the integrity.

Because glass is a typical brittle material which compressive strength is much lower than tensile strength, the defect on the glass surface will become a stress concentrated area and cause the total break up of test glass. So improving the quality of glass edges and protecting the glass surface in transport and installation can obviously

improve the fire resistance of glass. And it is better to choose the glass which has fewer defects as a fire resistance test sample to get a good fire test result.

4. Problems of Monolithic Fire-resistant Glass Application in China

Although monolithic fire-resistant glass is a high performance product, but because it is a brand-new product and there are still so many people in China don't know it's performance and how it's work. And there are of course a lot of problems in the application of monolithic fire-resistant glass.

4.1. Problems in Frame Using

The frame of monolithic fire-resistant glass should have special design. According to GB 15763.1-2009, "The installation and design of the fire-resistant glass frame used in the fire test should be the same with in construction, and should record the frame and installation as drawings or other written description." Even so there are just fire-resistant glass manufacturer would comply with GB 15763.1-2009 to design and test, the glass manufacturer can do nothing about the frame in the construction engineering because they just provide fire-resistant glass, there are others provide glass frame. The construction designer or builder perhaps don't know that and often use other frames with good outlook but not the frame detailed in the glass fire test report. So that sometimes plastics frame or aluminous frame was used as fire-resistant glass frame in some construction. The melting point of aluminous is just about 650℃ and most plastic product can not resist fire. So if the plastics frame or aluminous frame is used as fire-resistant glass frame, it is waste for fire-resistant glass and also dangerous for the people living in the building because of the wrong use of the glass frame. Consequently, the related standard or construction code should better specify how to use fire-resistant glass and the frame to ensure the correct using and construction, so that the construction can have their designed fire-resistance [5].

4.2. Problems about Subcontract of Fire-resistant Glass Processing

Nowadays big constructions need a lot of subcontract to complete the total work and the same with fire-resistant glass processing in some construction of China. Because fire-resistant glass can't be cut into pieces in the building sit and the related process is complicated, so the quality of fire-resistant glass is very difficult to control. For example, when construction company A get the contract of the window and door project of a construction, company A will subcontract fire-resistant glass related project to glass cutting plant B. Glass cutting plant B will buy original glass board from company C and cut into different sizes. After that glass cutting plant B will send some of the glasses to company D to complete fire-resistant treating and get the monolithic fire-resistant glass. And later company B will give all the processed glasses back to company A to complete the window and door project. There are 4 companies involved in the fire-resistant glass construction and it is very difficult to control the control, beside that the glasses need to be transported from one company to another and the transportation will increase the defects on the glass board surface. Both of the management and the transportation will influence the fire resistance of glasses. So the management is very important to ensure the fire-resistant of the glasses.

5. Conclusion

Monolithic fire-resistant glass as a brand-new product is widely used in construction, at the same time there are a lot of problems appeared in the application. Standards and codes related should be perfect to ensure the correct use of monolithic fire-resistant glass.

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