A Study on Durability of Insulating Glass Units for Frameless Glazing Systems

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Keywords

1 = Insulating glass 2 = Durability 3 = Life estimation 4 = Frameless glazing systems

Abstract

Insulating glass (IG) units improve thermal insulation in glazed openings, and have been widely spreading to residential and office building uses today, from the viewpoint of energy conservation. On the other hand, the frameless glazing systems like Dot Point Glazing (DPG) system are in demand among a lot of designers in recent years for use in buildings, especially in the part of façades, because of its good design.

In order to investigate the durability of IG unit for use in frameless glazing systems, UV resistance of the edge seal and the resistance to daily cyclic wind loads, which might cause a plastic flow (or plastic deformation) of primary seal, were estimated experimentally.

The results of cyclic air pressure tests showed that the IG unit with a specially designed spacer had excellent durability compared with the general one.

This paper shows the relation between the deflection rate of the long side of the rectangular IG unit against daily cyclic wind loads and its durability. It was found that it is possible to design the IG unit for the frameless glazing system to have long-term durability by restricting its deflection rate to the predetermined value.

Introduction

IG units improve thermal insulation in glazed openings, and have been widely spreading to residential and office building uses today, from the viewpoint of energy conservation. On the other hand, the frameless glazing systems like DPG system are in demand among a lot of designers in recent years for use in buildings, especially in the part of façades, because of its good design. So it is important to know the performance of IG units for use in frameless glazing systems, especially the durability.

Classification of frameless glazing systems

In this study, frameless glazing systems were classified into the following three types.

A) Two sides simple support system
B) Dot point glazing system with holes on glasses (TPG system [1])
C) Dot point glazing system by clipping glasses without holes (MPG system [1])

Fig 1

Three types of frameless glazing systems concerned in this study

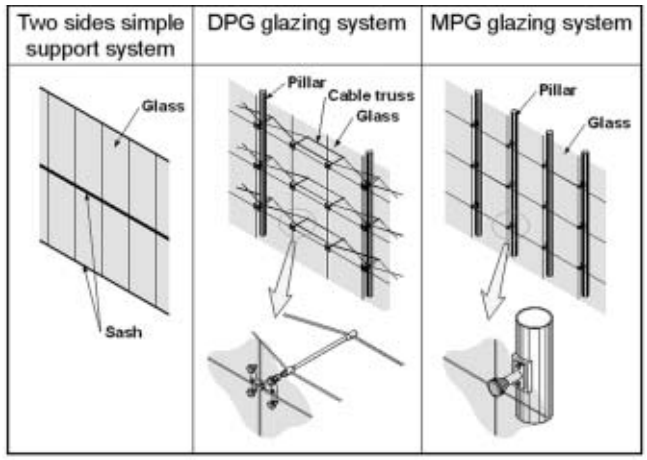


Fig 2

Construction example of TPG system

Fig 3

Construction example of MPG system

Standard specifications of each frameless glazing system were shown in Figure 1. And construction examples of DPG system and MPG system were shown in Figures 2 and 3.

Deterioration mechanism of IG unit in frameless glazing systems

It is considered that some factors make the life of IG unit decrease. Those

are ultraviolet ray, high temperature, high humidity (water), cyclic loads by temperature change and/or wind, etc. The deterioration of the primary seal and/or the secondary seal might happen year by year resulting from the influences of those factors.

In addition, it is necessary to take the following points into consideration in the case of frameless glazing systems.

a) Direct weathering, especially UV exposure at the glass edge
b) The surface distortion of tempered glass or heat-strengthened glass
c) Bigger shear deformation at the edge of the glass sheets by wind load because of the lack of supporting sash

Here, about direct weathering at the glass edge, outdoor exposure tests in OKINAWA and YOKOHAMA have been executed for many years. It is shown from the experimental results that no extreme damage could be found for a long time by using some silicone for the secondary seal. [2]

Tempered glass and heat-strengthened glass are used in many cases of DPG systems because high mechanical strength is needed for glass on structure. Since surface quality on those glasses is usually worse than that on float glass, it might cause the fault of IG unit. It is necessary to increase the thickness of primary seal in order to correspond to the surface quality of those glasses, but when the thickness is increased, the moisture permeates through the primary seal would be also increased.

Moreover, the shear deformation at the glass edge would occur when the glass receives wind loads, since two glass sheets of the IG unit bend similarly. Poly-isobutylene, which has a characteristic of low water permeability, is a very effective material for the primary seal from the viewpoint of preventing moisture penetration. But it might cause a plastic flow or plastic deformation, that is, its modification and move to the air space inside, by even daily cyclic wind loads for use in frameless glazing systems, since it is a viscous material. Thus the function of poly-isobutylene as a primary seal would be spoiled, as a result, moisture penetration would be accelerated, and that would cause the life of IG unit decrease.

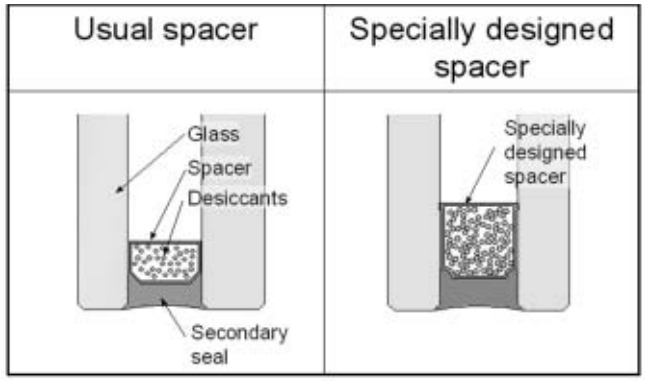
IG unit with a specially designed spacer

The special spacer was developed in order to solve these problems as shown in Figure 4.

Since the spacer height is large, the primary seal can remain at the proper gap between the spacer and the glass, and achieve its function continuously to prevent moisture penetration. Also since the amount of the primary seal can be increased in the height direction, even when its thickness has to be thick corresponding to the surface quality of the glass, durability performance of the IG unit could be maintained. Furthermore, the quantity of desiccants inserted in the spacer can be increased rather than usual one, and the IG unit with the special spacer could be expectable on durability improvement.

Fig 4

Comparison of the cross-sectional form between the special spacer and the usual one



Experimental procedure

Natural outdoor exposure examination is not enough to consider the influence of shear deformation at the glass edge by cyclic wind loads, because the size of IG unit for this examination is usually small.

In this study, the resistance to daily cyclic wind loads, which might cause a plastic flow or plastic deformation of primary seal, was estimated experimentally with relatively large-scale size specimens in order to investigate the durability of IG units for use in frameless glazing systems.

Modeling cyclic wind loads for the examination

Considering whether the mechanical strength of glass is enough or not for its use on structure, design wind speed, which represents a local hurricane or typhoon described to use such as 50 or 100 years recurrence period, is usually used.

But in this study, it was thought that not only the severe winds generating once or twice per 100 years but also daily cyclic winds could affect the durability of IG unit. Thus a model loading program for daily cyclic winds was determined by analytical procedure using statistical data of wind speeds at some representative cities in Japan.

The entire sequence of air pressure cycles of the model loading program was shown in Table 1. Where, P denotes the maximum air pressure differential, and was defined to be 392 Pa as the model wind loads in this study.

Specimens

Three types of IG units different in the glazing system were used as specimens. They were shown in Table 2. FL8 means 8 mm thick float glass, A12 means 12 mm thick air space, HS12 means 12 mm thick heat-strengthened glass, and PT10 means 10 mm thick tempered glass.

The amounts of desiccants enclosed into these specimens were decreased in order to aim at shortening of evaluation term, but all of the specimens had the same amounts of desiccants.

Table 1

Model loading program for daily cyclic winds

Loading Sequence	Loading Direction	Air Pressure Differential	Number of Air Pressure Cycles
1	Positive	P/3 to P	5000
2	Negative	P/6 to P/2	5000
3	Positive	P/3 to P	5000
4	Negative	P/6 to P/2	5000
5	Positive	P/3 to P	5000
6	Negative	P/6 to P/2	5000
7	Positive	P/3 to P	5000
8	Negative	P/6 to P/2	5000
9	Positive	P/3 to P	5000
10	Negative	P/6 to P/2	5000
11	Positive	P/3 to P	5000
12	Negative	P/6 to P/2	5000
13	Positive	P/3 to P	5000
14	Negative	P/6 to P/2	5000
15	Positive	P/3 to P	5000
16	Negative	P/6 to P/2	5000
17	Positive	P/3 to P	5000
18	Negative	P/6 to P/2	5000
19	Positive	P/3 to P	5000
20	Negative	P/6 to P/2	5000

* P in Table 1 denotes the maximum air pressure differential. It was defined to be 392 Pa as the model wind loads.

Table 2

Specimens with specific silicone for the secondary seal

Types of glazing systems	Composition of specimen	Size of specimen
Two sides simple support system	FL8+A12+FL8	1588 x 500 mm
TPG system	HS12+A12+HA6	1588 x 1588 mm
MPG system	PT10+A12+PT8	1588 x 1588 mm

Test methods

On the basis of the above-mentioned model loading program, the influence of shear deformation at the glass edge by cyclic wind loads on the durability of IG unit was estimated experimentally by the way to change the maximum air pressure differential value.

That is, some test loading programs to be applied to test specimens, that were the same in Table 1 except for P values, were introduced in this study. Each test loading program generates the different L. L denotes the maximum deflection rate of the long side of the rectangular IG unit, defined as "the maximum amount of deflection at the long side / the length of the long side".

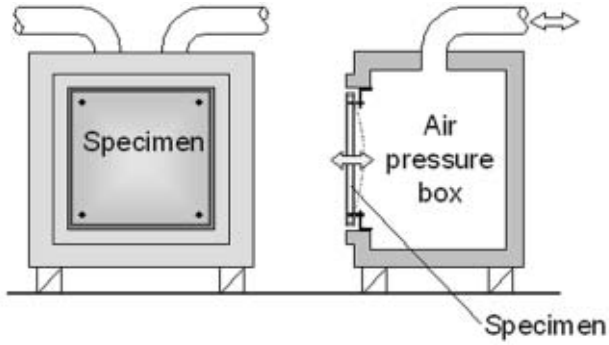
An air pressure cycling test chamber shown in Figure 5 was used in this study. The duration of each air pressure

cycle was controlled to be 1.5 or 2 seconds.

After those air pressure cycling tests, specimens were exposed under high temperature and humidity condition (60 degrees C and 95% relative humidity) to evaluate the resistance against moisture penetration. The life of specimen was defined as time when the dew point temperature became –60 degrees C or above.

Fig 5

Air pressure cycling test chamber



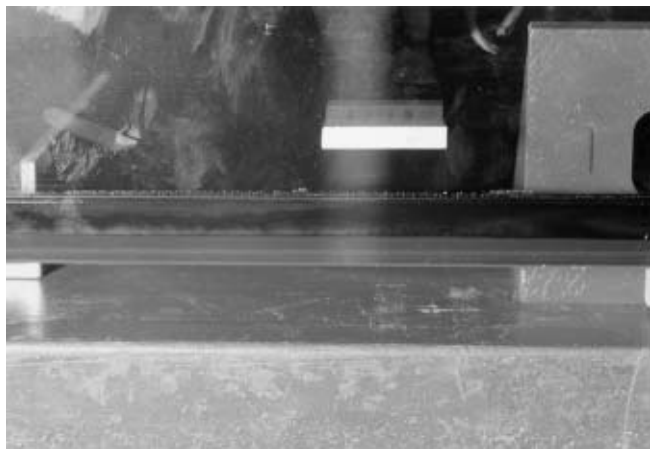
Results and Discussion

Air pressure cycling test

As shown in Figures 6 and 7, the phenomenon that the primary seal was deformed and moved to the air space inside of the IG unit, that is, "plastic flow and/or plastic deformation", was observed in every air pressure cycling test. Amounts of the flow/deformation after the test seemed to be bigger corresponding with L's value. It seemed obvious that any seal failure such as breakage or delamination of secondary seal was not generated, since the dew point temperature of the IG units did not change after these tests.

Fig 6

Plastic flow and/or plastic deformation after air pressure cycling test

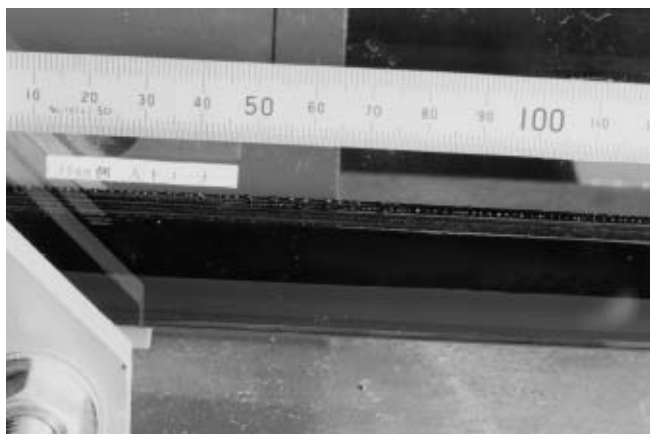


High temperature and humidity test

These IG units after the air pressure cycling tests were placed in the high temperature and humidity chamber, and their dew points were measured at certain interval. For example, the changes in dew point temperature about specimens of two sides simple support system after the high temperature and humidity test were shown in Figure 8. It was obvious that dew point temperature rose earlier when IG unit had been affected by air pressure cycling, and IG unit with the specially designed spacer had excellent durability compared with the general one.

Fig 7

Plastic flow and/or plastic deformation after air pressure cycling test



A design method of IG unit for long life use in frameless glazing systems

From these results, the relations between the maximum deflection rate of the long side, "L", against the air pressure cycling loads and its durability were obtained, shown in Figure 9. The durability of an IG unit for normal use, that is, for four sides of glass supporting system, was regarded as being positioned at 100% of the durability ratio in Figure 9.

As shown in Figure 9, there was the tendency that the durability of IG units under frameless glazing systems fell according to L's value, as being with non-supported sides. It was found that high durability could be maintainable even under the big deflection rate in the case of IG unit with the specially designed spacer.

Since the L's value when receiving the above-mentioned model wind loads can be easily calculated depending on its glass composition and/or size (see Figure 10), the glass composition and/or size of IG unit could be determined to satisfy

Fig 8

Change in dew point temperature

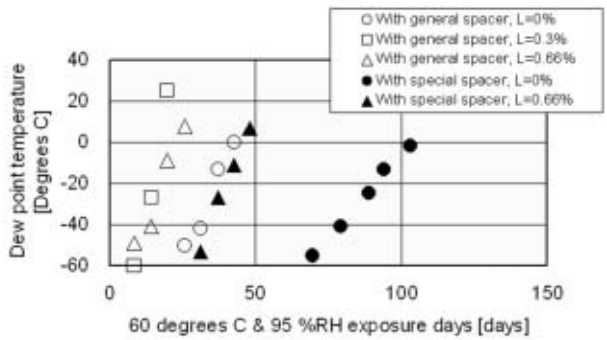
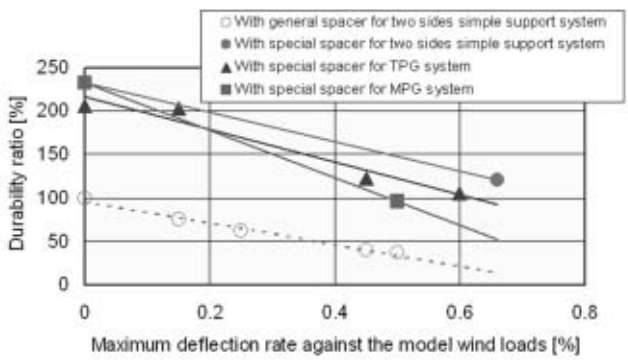


Fig 9

Relations between the maximum deflection rate and durability of IG units



its designed life for the use in frameless glazing systems from these results.

Higher durability of IG unit could be designed by making its calculated L's value smaller.

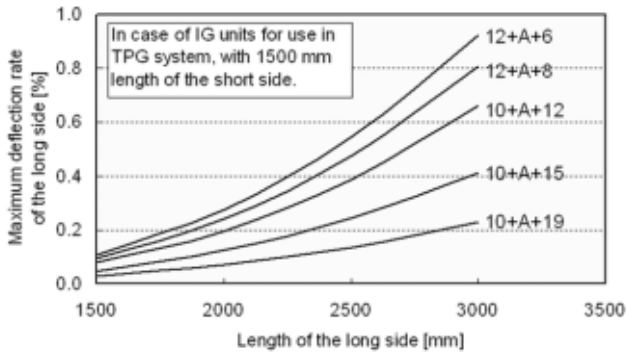
Summary

The resistance of IG unit to daily cyclic wind loads for use in frameless glazing systems was estimated experimentally. The phenomenon that the primary seal was deformed and moved to the air space inside of the IG unit, that is, "plastic flow and/or plastic deformation", was observed in the air pressure cycling test. There was the tendency that the durability of IG unit fell according to the deflection rate by the air pressure loads. It was found that the IG unit with the specially designed spacer was effective to obtain the sufficient durability even under the big deflection rate.

It was found that it is possible to design the IG unit for the frameless glazing system to have long-term durability by restricting its deflection rate to the pre-determined value.

Fig 10

Examples of calculated L's values of IG unit depending on its glass composition and size under the model wind loads



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References

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