Conception of A New Notification of Building Glass Design in Japan

Masashi Kikuta*, Takahiro Murakami**, Shin'ichi Aratani***
* Nippon Sheet Glass Co. Ltd., Japan
** Asahi Glass Co. Ltd., Japan
***Central Glass Co. Ltd., Japan

Keywords
1 = Glass design 2 = Japan notification

Abstract

In June 2000, a new notification of glass design for use in buildings was published in Japan. The method of determining the equivalent wind load and a safety application of glass type in building are shown in the notification No.1458. Allowable load of window glass subjected to wind pressure is calculated by following simple equation.

$P=300k_1k_2(t+t^2/4)/A$

where, P : allowable wind load(N/m^2), k1 : glass strength factor, k_2 : glass type factor, t : nominal thickness of glass(mm), A : aspect area of glass(m^2).

Glass strength factors were determined by using a reliability design method, and they were defined as a unique value with respect to each monolithic glass panes having cumulative failure probability=1/1000. Even a float glass, we obtained the several glass strength factors depending on its thickness.

Glass type factors were defined as unique value for a monolithic glass, for a laminated glass and for an IG unit, respectively. For a laminated glass, glass type factor was determined by the results obtained from a lot of measurements and numerical analyses for stresses and displacements. Effective thickness of a laminated glass pane is also shown in this paper. For an IG unit, we considered the climatic effect, (ex. temperature, meteorological pressure, typhoon..), and an accurate load share factors. Then, Glass type factors were obtained as a function of each glass thickness composed IG units.

This paper provides a simple method for determining a glass type in safety use against a design wind load.

Introduction

An old design code of building glass higher than 31 meters titled Notification No. 109 had been established in 1971. It was presented by using numerous results obtained the wind pressure test of large sized glass, however, it became necessary to revise because of following four reasons;

1. Revision of glass manufacture process,
2. The strength data exceeding 19mm thickness glass were not defined,
3. Effect of aspect ratio against the wind load was not considered,
4. Allowable wind load of both laminated glass and IG unit had been estimated assuming as the layered glass.

A new notification No.1458 was published in June 2000 to revise the mentioned defects.

Conception of notification No. 1458 is shown in this paper. To determine the basis of mechanical glass strength, coaxial double ring test is carried out for annealed glass. The glass strength depending on its thickness is recognized through the test. Then, the allowable wind loads as the cumulative failure probability=1/1000 are determined by using the reliability design method and its own strength data for each monolithic glass thickness. The wind load resistance is evaluated in several aspect ratios of glass panes. The minimum wind load resistance is defined as the allowable wind load to simplify the calculation procedure in this notification. As the result, there is no term of aspect ratio in this equation to evaluate the wind load resistance.

Some new ideas evaluating the wind load resistance are introduced in new notification No. 1458. For laminated glass, the resistance is not evaluated as the layered glass, but calculated as an equivalent monolithic glass. For IG units, the resistance is estimated by using the accurate load share factor and climatic effect. The simple calculation method is shown in this new notification No. 1458.

Calculating equation

Allowable wind load with respect to glass thickness, glass strength and glass type can be expressed by

$$P = \frac{300 k_1 k_2}{A}\left(t + \frac{t^2}{4}\right) \quad (1)$$

Where, P is the allowable wind load (N/m^2), k1 and k_2 denote glass strength factor and glass type factor, respectively, A is aspect area of glass (m^2) and t is a nominal thickness of glass (mm). Allowable wind load is defined as the cumulative failure probability=1/1000 in a glass pane subjected 6 seconds constant wind load[1]. The outline of reliability design method is shown in Fig.1. In this method, it is important to determine the basis of glass strength and to estimate the cumulative failure probability of glass panes by using the statistical treatment and numerical analysis, respectively.

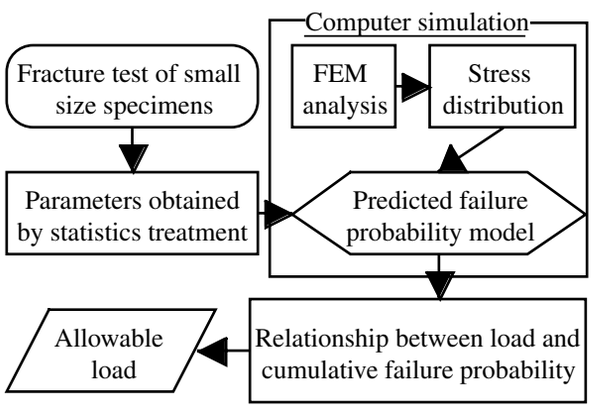

Figure 1 Reliability design method

Glass strength factor k_1

Coaxial double ring test was carried out with respect to some glass thickness. Logarithmic normal distribution was applied to treat as statistics of strength distribution, and the allowable mechanical strength is decided for each glass thickness. Fig.2 shows the testing apparatus.

(1) Annealed Glass

Table 1 shows the results obtained by coaxial ring test in case of commercial float glass. It is found that the strength of testing glass is depended on its thickness.

Table 1 Glass Strength

Thickness (mm)	Average Strength (MPa)	Allowable Strength (MPa)
6	95.1	42.2
8	93.3	40.9
10	91.5	39.7
12	89.7	38.4
15	87.0	36.5
19	83.4	34.0
22	80.7	32.2
25	78.0	30.3

The relationship between the thickness ratio and the strength ratio is shown in Fig.3, and it is approximated as equation (2).

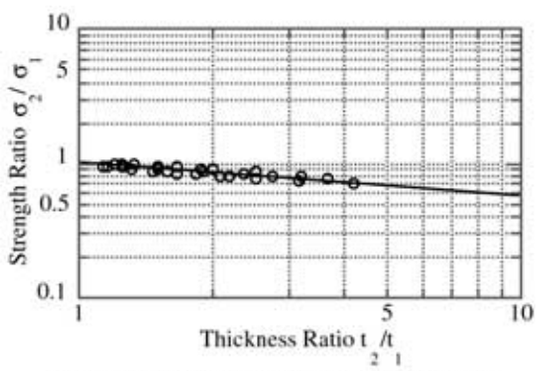

Figure 3 The Relationship between Thickness Ratio and Strength Ratio

$$\frac{\sigma_2}{\sigma_1} = \left(\frac{t_2}{t_1}\right)^{-\frac{1}{4}}$$

Using equation (2), the glass strength factors of commercial float glass are defined as Table 2.

Table 2 Strength Factor of Float Glass

Thickness	Strength Factor
Thickness =< 8 mm	1.0
9 mm =< Thickness =< 12 mm	0.9
13 mm =< Thickness =< 20 mm	0.8
21 mm =< Thickness	0.75

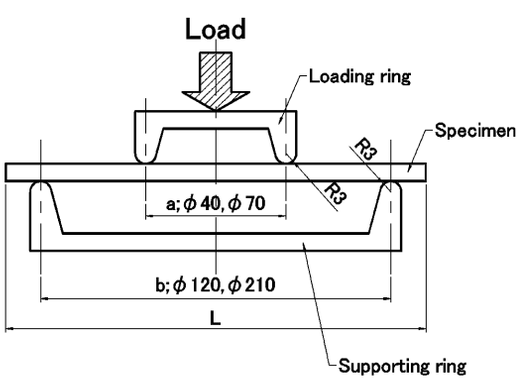

Figure 2 Schematic Diagram of Coaxial Double Ring Test Apparatus

(2) Heat strengthened (HS) and Fully tempered (FT) Glass

Strength of HS and FT glass for several thickness was also investigated as same way, however the changing of strength depended on its thickness was not found out because of the wide variance of residual stress. Table 3 shows the glass strength factor of HS and FT glass.

Table 3 Strength Factor of HS and FT Glass

Type of Glass	Strength Factor
Heat Strengthened Glass	2.0
Tempered Glass	3.5

(3) The other glass

The glass strength factors of the others are shown in Table 4.

Table 4 Strength Factor of the Other Glass

Type of Glass	Strength Factor
Sheet Glass	1.0
Polished Glass	0.8
Polished Wired Glass	0.8
Figured Glass	0.6
Figured Wired Glass	0.6

Glass type factor k_2

(1) Monolithic glass

Allowable wind load values for various aspect ratio of glass pane are obtained by using reliability design method. Some results are shown in Fig.4 and Fig.5. Minimum glass thickness defined in JIS R3202 is used in this calculation.

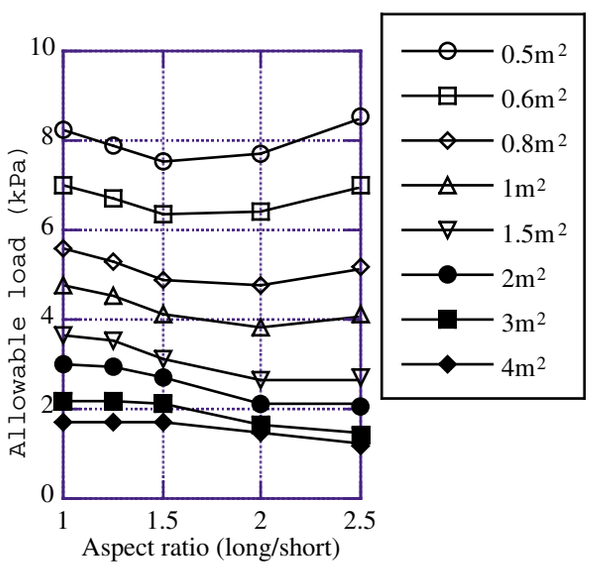

Figure 4 Allowable load (thickness 6mm)

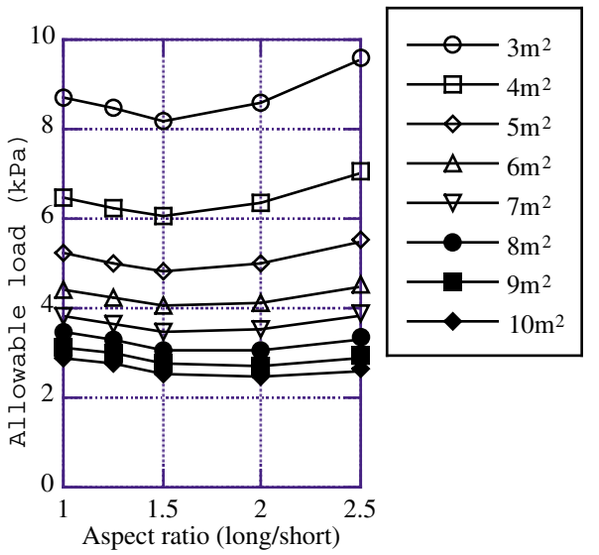

Figure 5 Allowable load (thickness 19mm)

Minimum wind load value is introduced as a allowable wind load for each glass thickness. Glass type factor of monolithic glass is defined 1.0 as basis of this design code.

(2) Laminated glass

Polyvinyl butyral (PVB) interlayer is assumed as the interlayer of laminated glass. The authors have investigated the allowable wind load of laminated glass composed two same thickness of glass pane for several loading speed and temperature of PVB interlayer[2,3]. It was found that the laminated glass is not similar to layered glass but similar to monolithic glass. For dynamic wind pressure, allowable wind load of laminated glass was 0.94~1.05 times and 0.80~1.04 times of monolithic glass having the total thickness of laminated glass except for interlayer thickness when the temperature of interlayer is 20°C and 50°C, respectively. In the case of laminated glass composed different glass thickness, the result was obtained that the above magnification of laminated glass becomes low which is approximately equal to 0.75.

So, laminated glass is assumed as monolithic glass having total glass thickness, and glass type factor of laminated glass is defined 0.75 as mentioned reasons. Effective thickness of laminated glass would be able to express as equation (3).

$$t = 0.866 \times T - 0.268$$

(3) IG units

In Fig. 6 and Fig. 7 are shown the calculated load share factor of IG units for several glass thickness ratio. This calculation was carried out by

using FEM, and also examined[4]. In calculation and examination, IG units was used as 1000mm x 2000mm x (10mm glass thickness + 6mm airspace + 10mm glass thickness). The results show that the load share factor cannot be assumed the layered glass. This phenomenon has been also reported by David Chou et al.[5].

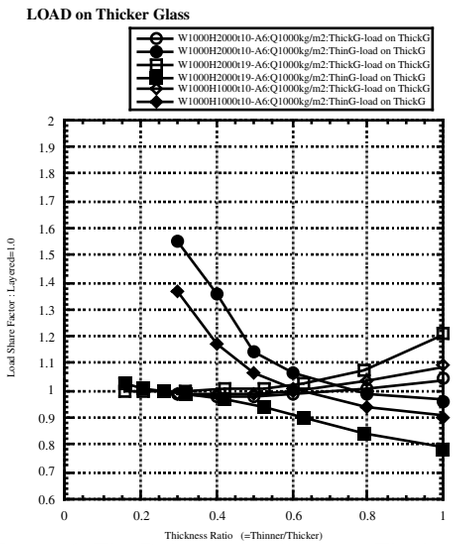

Figure 6 The Relationship between Thickness Ratio and Load Share Factor

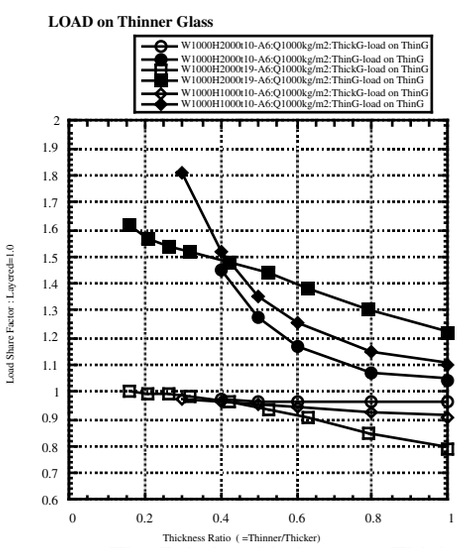

Figure 7 The Relationship between Thickness Ratio and Load Share Factor

Next, the climatic effect should be considered because it is easy to estimate that the meteorological pressure is very low (approximately, 940hPa) in Japan when typhoon attacked. If IG unit is produced in normal pressure 1013hPa, estimated load caused by inner pressure changing would be 15% of its allowable wind load.

Considering both load share factor and climatic effect, the glass type factor of IG units is defined as following equations.

$$k_{2,1} = 0.75 \times \left(1 + \left(\frac{t_2}{t_1}\right)^3\right)$$

$$k_{2,2} = 0.75 \times \left(1 + \left(\frac{t_1}{t_2}\right)^3\right)$$

Discussion and Conclusions

A simple method for determining a glass thickness and glass type in safety use against a design wind load is provided as the notification No. 1458 of Japan. This design code is prepared with numerous examinations and calculations, however some restrictions remain for application of design strength as follows,

(1) If the lateral deflection of the edges of the glass exceed 1/150 of their length, calculated allowable wind load cannot be confidence.

(2) For IG units, the accurate load share factor cannot be obtained when the glass thickness ratio (thicker glass/thinner glass) is greater than 2.5.

(3) For laminated glass, glass type factor should be required except for PVB interlayer.

References

[1] Takehiro Miura, Satoru Kasagi and Shunji Miyoshi, Report of the Research Laboratory,
Asahi Glass Co., Ltd., Vol.24, 1974
[2] Shin'ichi Aratani, Masashi Kikuta, Takahiro Murakami and Masahiko Ida, "Stress
measurement of laminated glass", 12th Fall Meeting of The Ceramic Society of Japan, 1999
[3] Takahiro Murakami, Yukihito Oketani and Yoshinobu Fujitani, Journal of architecture,
Architectural Institute of Japan, 2000
[4] Hidemi Kato,Taito Kinoshita and Masashi Kikuta, Summaries of technical paper of annual
meeting, Architectural Institute of Japan, 2000
[5] G. David Chou, Joseph E. Minor and C. V. Girija Vallabhan, The Structural-Mechanics
Behavior of Insulating Glass Units, 1986