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Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 132

Glass Thickness for Windows

Originally published December 1970

W.G. Brown

Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

By and large the choice of glass thickness for windows has always been one of conventional practice. During the past decade, however, considerable information has become available regarding glass strength and wind pressure characteristics. It is now possible to incorporate this information in an improved procedure for determining appropriate glass thicknesses for windows of different sizes subjected to different wind pressures. The design problem is essentially that of striking a balance between a low probability of failure and glass costs.

The strength of glass is highly variable. Tests on 30 identical window lights will show failure pressures differing by as much as 3 to 1. With this in mind it is necessary to treat design statistically and convention has generally settled on a breakage rate due to wind of about one failure per 100 windows at design pressure. Wind speeds and resulting pressures, however, are highly variable and in establishing a design pressure it becomes necessary to estimate the highest winds that will probably occur during the intended lifetime of the windows, viz, about 30 years.

The conventional failure rate of one per 100 windows, i.e. 1 per cent, is approximately the most economical glass thickness (assuming doubled costs for replacement). But where one failure in a small building with 100 windows might be quite tolerable, the failure of 100 windows in a skyscraper with 10,000 windows would be entirely unacceptable. Apart from considerations of public safety it is clear that buildings with large numbers of windows will require design for lower failure rates in order to avoid possible loss of public goodwill.

With this in mind it may be seen that glass thickness can be determined only after a failure rate acceptable for safety, goodwill and costs has been chosen. Thereafter, the problem involves the material strength of glass, and regional wind speed extremes and building aerodynamics.

Design Wind Pressure

Ideally, the design wind pressures for a given locale are based on measurements of wind speeds taken over many years. In most cases, however, available information consists of wind speed measurements taken at airports outside cities or towns. Furthermore, wind speeds vary with elevation above ground in ways that are characteristic of open ground or of built-up areas. In this circumstance it is necessary to convert data obtained at airports in a very empirical manner for use in nearby populated locations. In addition, the pressures experienced by windows are different on the different faces of a building and are conditioned by the air

tightness of the building. The windows become subjected to pressure differences about 50 per cent higher than the static wind pressure⁽¹⁾. Using already tabulated gust speeds for various locations⁽²⁾, these considerations lead to the following equation for design pressure load:

$$q_D = 2.7 \times 10^{-5} F_H V_G^2(\text{psi})^* (1)$$

where F_H is a height factor from Figure 1 and V_G is the design gust speed from Reference (2) in miles per hour. Representative gust speeds are given in Table I for several different locales.

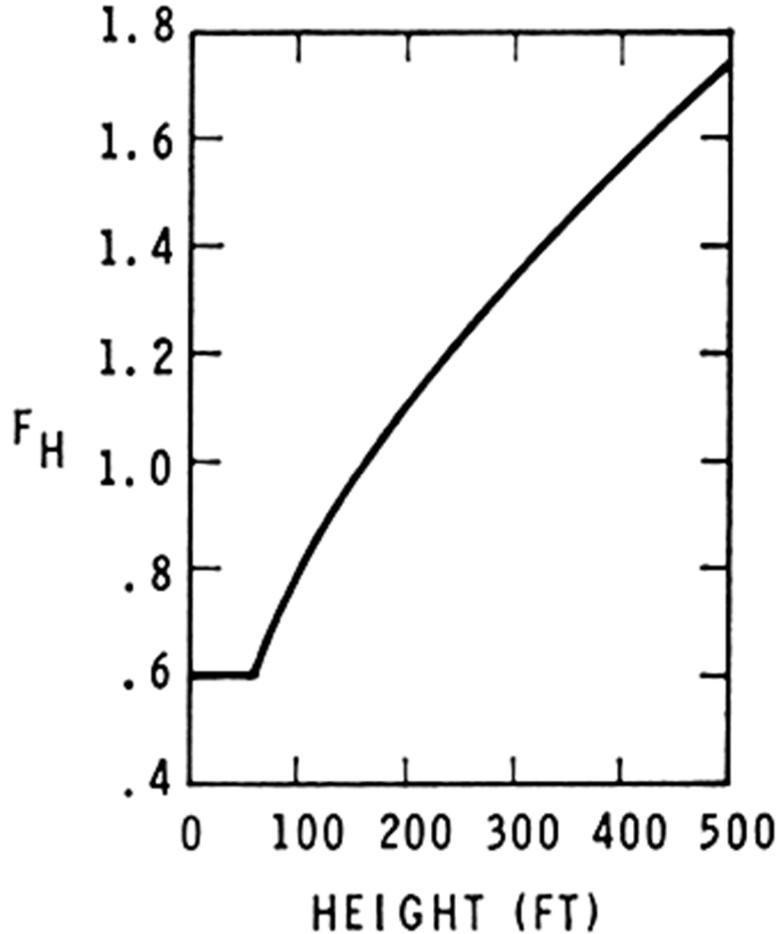


Figure 1. Height factor for wind pressures (suburban and town centres).

Table I. Design Wind Gust Speeds for Various Locales

Locale	Design Gust Speed V_G (mph)
Victoria	92
Vancouver	90
Saskatoon	81
Toronto	84
Ottawa	75
Montreal	75
Quebec	84
Halifax	88
St. John's	103

Example: Design pressures for the windows of buildings 100 feet high in Victoria, Ottawa and St. John's (from Figure 1 and Table I) would be

Victoria $q_D = 2.7 \times 10^{-5} \times 0.8 \times 92^2 = 0.18$ psi

Ottawa $q_D = 2.7 \times 10^{-5} \times 0.8 \times 75^2 = 0.12$ psi

St. John $q_D = 2.7 \times 10^{-5} \times 0.8 \times 103^2 = 0.23$ psi

Selection of Glass Thickness

Great variability in glass strength results from manufacturing and handling processes that leave minute, stress-raising scratches and flaws on the glass surface. The average test results from major manufacturers appear to be about the same, however, and are given in Figure 2 ⁽³⁾ for plate glass ** thickness determination for a failure rate of one per 1000 windows, viz. failure probability of 0.001.

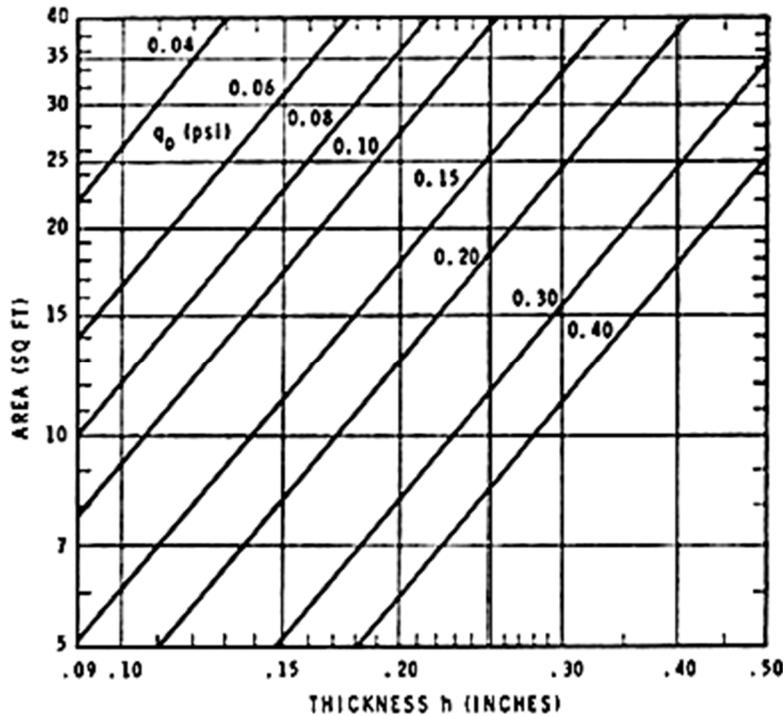


Figure 2. Glass thickness required for failure probability of 0.001.

To use Figure 2, enter on the vertical scale the proposed window area in square feet and proceed horizontally to meet the diagonal representing design pressure q_D already determined. The location of the intersection on the horizontal scale gives the glass thickness for this specific combination of window size, design pressure, and failure rate.

Example: For the previously determined design pressures and failure rates of one in 1000 the required glass thickness, h , for windows of 15 square feet would be (from Figure 2)

Plate Glass Sheet or Float Glass

Victoria $h = 0.20$ inch $h = 0.18$ inch

Ottawa $h = 0.15$ inch $h = 0.14$ inch

St. John's $h = 0.24$ inch $h = 0.22$ inch

To determine the glass thickness required for different failure rates, Figure 3 can be used to obtain multiplying factors for the results of Figure 2; for example, the thickness factor for a failure rate of 1 per 10,000 windows is 1.35.

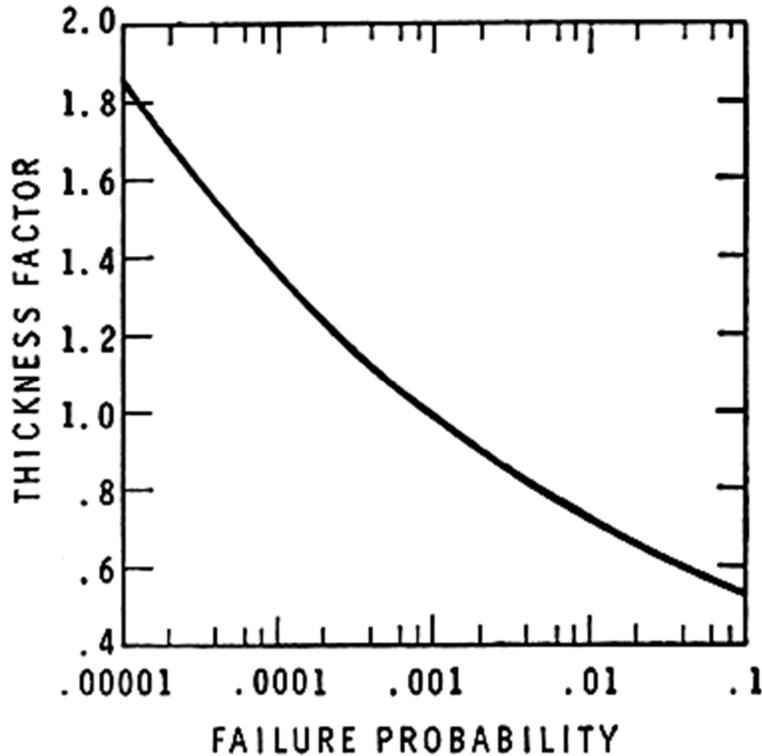


Figure 3. Thickness factors for different failure probabilities

For this failure rate, then, the following would be the required glass thickness:

Plate Glass Sheet or Float Glass

Victoria $h = 0.27$ inch $h = 0.24$ inch

Ottawa $h = 0.20$ inch $h = 0.19$ inch

St. John's $h = 0.32$ inch $h = 0.30$ inch

Safety, Anxiety and Goodwill

Provided that glass thickness is chosen to ensure a reasonably low failure rate, then virtually all breakage due to wind will occur only during high winds and personal anxiety will ordinarily assure refuge from any impending danger. High winds may also cause window fluttering, thereby furnishing a further danger signal. The consequence is that, on balance, wind breakage offers little real threat to public safety.

On the other hand, the inevitable public concern and loss of goodwill that would accompany even moderate numbers (albeit economical) of failures in large buildings dictates that breakage be kept to a reasonable level. In the absence of any present standards the window designer must consider this matter for himself, although the following might be in order:

No. of windows in Buildings	Suggested Design Failure Rate in 30 years	Probability of Failure
100	1 per 10 buildings	0.001
1,000	1 per 3 buildings	0.0003

10,000

1 per building

0.0001

Deflection and Flutter

The centre deflection of a square, lightly-glazed window can be estimated from the following equation:

$$q = 2.15 \times 10^8 \frac{wh^3}{a^4} \{1 + 0.165 (w/h)^2\} \quad (2)$$

where q is the pressure in psi, w is the centre deflection, h is glass thickness, and a is the length of a side (dimensions in inches).

Very little information is available on window flutter, during which glass may experience unusually high stresses. It is reported, however,⁽⁴⁾ that the possibility of flutter is remote if the natural frequency of a window is greater than 4 cycles per second. The natural window frequency is (approximately)

$$f = 10^5 \frac{h}{a^2} \text{ cycles/sec} \quad (3)$$

where a is the shorter dimension (dimensions in inches). All normal windows will have fairly high natural frequencies; for example, for $h = 0.10$ in. and $a = 36$ in., $f = 7.8$ cycles/sec. Large glass lights such as those in store fronts can be troublesome; for example for $h = 0.25$ in. and $a = 96$ in., $f = 2.7$ cycles/sec.

Costing of Window Glass

It is important to consider local market conditions for glass costs because price differentials for incremental glass thicknesses may be substantial for various reasons of supply and manufacture. A case in point is that of 1/4 -in. plate glass, which is often more expensive than sheet glass for small sizes but may be considerably cheaper for large sizes because of the need for special quality selection. Situations may also occur where thinner, tempered glass may be more economical than annealed glass.

Further Considerations

The procedure outlined in this Digest is sufficient for determining the thickness of single-glazed windows supported on all edges. Figure 2 applies for windows in which the ratio of length to width is less than about 4. Very long, narrow windows require special attention, as do multipaned windows and windows supported on only two edges. Sealed, double-glazed units will withstand pressure loads approximately 50 per cent greater than those that single windows will withstand, and can be designed on this basis by multiplying q_D equation (1) by 2/3 before using Figure 2. Wherever possible the glass for corner windows should be of the next higher thickness to that determined by design because somewhat higher wind suction pressures occur at building corners.

Most observed window breakage is the result not of wind but of impact or thermal stresses⁽⁵⁾ or the result of improper glazing. In addition, the strength of glass increases appreciably with decreasing temperature, increases slightly with decreasing relative humidity, and decreases somewhat with increased duration of loading. These and several other aspects of glass strength and window design lie outside the scope of this Digest. Future research is indicated for a number of areas including window flutter, actual rapid fluctuation wind pressures on buildings and wind speeds at various elevations in cities.

References

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* Note: this equation is valid only for use with figure 2.

** Limited data indicate that sheet and float glass will withstand somewhat greater pressure loads than plate glass. For these kinds of glass q_D should be multiplied by 0.85 before using Figure 2.