Construction and Building Materials 61 (2014) 349–359

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effects of shape of transverse cross-section on the load carrying capacity of laminated glass columns

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HIGHLIGHTS

- Compressive tests on glass columns with rectangular, T and X cross-sections.
- Stability analyses including elastic torsional and local buckling.
- Buckling strength of single panels depends very much on the slenderness.
- Local and torsional buckling effects reduce the bearing capacity of T and X columns.

ARTICLE INFO

Article history:
Received 29 October 2013
Received in revised form 12 February 2014
Accepted 17 February 2014
Available online 13 April 2014

Keywords:
Laminated glass
Glass columns
Compression
Buckling
Flexure
Torsion

ABSTRACT

In this paper simplified expressions for the calculus of the load carrying capacity of glass columns having rectangular, tee (T) and cruciform (X) transverse cross-sections are proposed and verified against available experimental data. Members with T and X cross-sections are obtained by gluing single multilayered glass panels.

The expressions derived take into account of the: shape of the transverse cross-section (rectangular, T, and, X sections); buckling phenomenon (flexural and torsional); failure in the glued sections; long time effects. Case of full connections and absence of connections are considered to determine the range of variation of expressions adopted. The comparison between the analytical and the experimental results highlights that in the case of columns or beam-like elements having rectangular cross-sections the flexural buckling resistance governs the load carrying capacity of columns, while in the case of glass columns with X and T cross-sections failure due to torsional buckling effects strongly limits the load carrying capacity of members, also penalized by the glued connection failure.

1. Introduction

The interest in the use of laminated multilayered glass (LG) columns or beam-like elements to form glass columns is increasing today in the architecture. On this field it is widely accepted that buckling phenomenon and time depending effects are the main causes limiting the load carrying capacity of glass columns or beam-like elements (due to their b/L ratio).

Several studies were addressed to analyze the effects of the shape and of the dimension of the transverse cross-section of columns often constituted by LG columns assembled together by two component glue based on epoxy resin. Fig. 1 shows some examples of cross-section shapes analyzed in [1] and tested in compression. Similarly, real applications refer to the use of open section for glass columns [1].

In the case of the transverse cross-section shown in Fig. 1 glass columns had length 1000 mm and they were formed by gluing single monolithic glass columns of thickness 8 mm with two-component glue based on epoxy resin.

In some other cases [2,3] tee (T) and cruciform (X) cross-sections were utilized to form glass columns to be tested in compression. Cross-sections were formed assembling single LG columns with two-component glue based on epoxy resin. Single glass columns had thickness 4 mm put together though a thin interlayer of PVB with thickness t_{int} = 1.00 mm (Fig. 2).

In these cases some of the most important aspects to take into account are the following: viscoelastic and temperature depending effects governing mainly the behavior of PVB and glue; buckling phenomenon of glass columns and of single LG columns activating

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http://dx.doi.org/10.1016/j.conbuildmat.2014.02.053
0950-0618/

Nomenclature

A	area of transverse cross-section of glass columns or beam-like elements (due to their b/L ratio)
b	height of the cross-section
E	Young modulus of glass
G	shear modulus of glass
G_{int}	shear modulus of PVB interlayer
I	moment of inertia
I_w	warping section constant
I_x, I_y	principal axis moment of inertia
J	torsion section constant
L	height of panel
M^{II}	second order moment
N_{ol}	elastic local buckling load
N_{oz}	elastic torsional buckling resistance
N_u	ultimate axial force
r_0^2	polar radius of gyration
t	thickness of monolithic glass
$t_{eq,w}$	equivalent thickness deflection-effective thickness
$t_{eq,\sigma}$	equivalent thickness stress-effective thickness
$w(z)$	lateral displacement of the beam
w_o	initial geometrical imperfections
β	buckling coefficient reducing
Γ	shear transfer coefficient
ν	Poisson's ratio
τ	shear stress
ϕ_m	twist rotation
ϕ_{0m}	maximum initial twist rotation

as flexural buckling (Fig. 3a) and/or torsional buckling phenomenon (Fig. 3b). In both cases imperfections (indicates as w_o, ψ_0 in Fig. 3) and tolerances play a fundamental role on the reduction in the load carrying capacity of glass columns and they have to be considered in the models [4].

Torsional buckling is an instability phenomenon for a vertical structural element. If the torsional rigidity of a cross-section under compressive forces is lower than its bending stiffness, torsional buckling could be the failure mode of a column. The resistance of the section to torsion depends strictly on its shape and it is well known, especially for steel members, that closed sections are better that open ones. A cross-section with maximum torsional rigidity is a circle. Moreover, close cross-sections tend to be stiffer to torsion compared to open sections. Also, if the number of the sides of a cross-section increases it will be more resistant to torsion. The center of twist normally coincides with the centroid. In symmetric sections the center of twist lies at the intersection between the axes of symmetry. A cruciform section, which shape is sensitive to torsion, could fail by torsional buckling due to compressive forces.

In the case of glass columns a close section cannot be utilized because it does not allows one to clean glass member compromising its transparency (aspect of fundamental importance in the architecture). In these cases (see Fig. 1) the better cross-section shapes to adopt are T, H and X; while square and double wed cross-sections have to be excluded. Single rectangular glass columns have also to be excluded because of their slenderness that limits the load carrying capacity. Of interest could be also the angular cross-sections but no applications are available at the moment in the literature.

For the theoretical design of glass columns against buckling three different approaches are generally followed: the use of buckling curves based on a slenderness ratio for glass which must be based on the maximum tensile strength [4–7]; analytical models

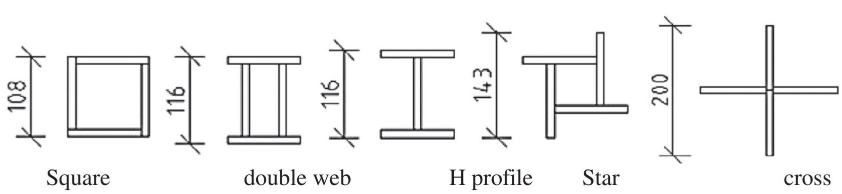

Fig. 1. Typical transverse cross-section in glass columns with thickness 8 mm [1] (dimensions in mm).

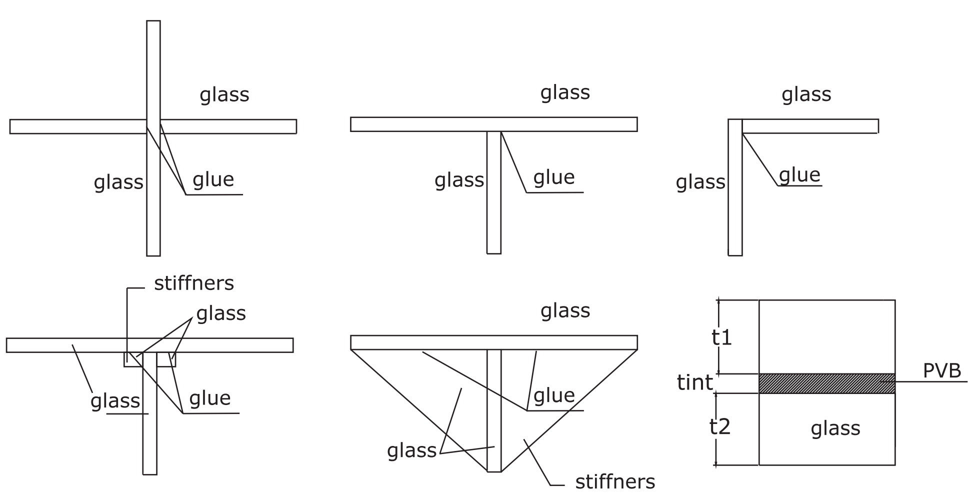

Fig. 2. Multilayered glass panel and glued connection in different cross-sections.