Engineering Structures 168 (2018) 23–34

Contents lists available at ScienceDirect

Engineering Structures

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

Buckling analysis and design proposal for 2-side supported double Insulated Glass Units (IGUs) in compression

Chiara Bedon*, Claudio Amadio

University of Trieste, Department of Engineering and Architecture, Piazzale Europa 1, 34127 Trieste, Italy

A R T I C L E I N F O

Keywords:
Structural glass
Insulated Glass Units (IGUs)
Load sharing effects
Buckling
Global imperfections
Temperature gradients
Standardized design curves
Analytical methods
Finite element numerical modelling

A B S T R A C T

Due to mainly thermal and energy potentials, Insulated Glass Units (IGUs) are largely used in modern buildings to realize curtain walls and enclosures. The typical IGU consists of two glass layers, either monolithic and/or laminated, joined together by enclosing an hermetically-sealed air (or gas) cavity between them. There, maximum stresses and deformations derive from external pressures (wind loads, etc.) or environmental/climatic loads (temperature variations, etc.). While the common IGU application involves 4-side continuous supports, novel restraint configurations are increasingly used in practice (i.e. 2-side supports, point-fixings, etc.), hence resulting in additional loading scenarios that could compromise the integrity of these systems. In this paper, following earlier research contributions, a standardized buckling approach in use for structural glass elements mainly compressed or under combined compression/bending is assessed, for the specific case of IGUs with 2-side continuous supports. Analytical and Finite Element (FE) numerical studies are reported, giving evidence of their actual performance and buckling resistance, including parametric analyses and comparisons towards simplified design formulations for both external and internal pressures.

1. Introduction

The use of glass components in constructions as an efficient load bearing solution is relatively recent, compared to consolidated structural applications of timber, steel, concrete or masonry in buildings. Major positive arguments of glass facades are related to the thermal, energy, light and aesthetic advantages. In terms of structural performances, however, the low tensile resistance, the high slenderness and flexibility of glass components represent the major issues in design, since stress peaks and large deformations should be prevented via appropriate *fail-safe* criteria (i.e. [1,2]). Special care should be spent especially to avoid possible buckling phenomena and premature losses of stability.

In this research study, extended investigations are focused on the buckling analysis of Insulated Glass Units (IGUs), being of large use in curtain walls and envelopes in buildings [3,4]. In the current design practice, the conventional IGU application includes 4-side supported glass panels, via metal frames acting as continuous bracing systems (see for example Fig. 1(a)). Novel solutions aimed to replace the metal framing members with thermo-mechanical efficient systems are under investigation [5–7]. For design purposes, special care should be spent especially for innovative boundary conditions (2-side supports, mechanical point-fixings, etc.), being increasingly used in buildings for IGUs spanning from floor-to-floor.

In this paper, double IGUs composed of two glass panels with a cavity gap interposed, restrained via linear top/bottom supports and under a combination of in-plane compressive loads and orthogonal pressures, are explored. There, linear top/bottom continuous supports can take the form of metal brackets preventing lateral displacements/rotations and gaskets/spacers able to avoid local damage and stress peaks in glass, see Fig. 1(c) and (d). Alternative solutions can involve aluminium or steel U-channel and "shoe" profiles, with equivalent effects and designed to withstand reaction forces transferred from the glass panels [2,8]. Non-structural sealant joints along the vertical edges ensure the visual continuity to glazing enclosures, but result in a rather vulnerable boundary condition to properly assess (see also [9,10]). Major outcomes are derived in this research study from advanced Finite Element (FE) numerical simulations [11] and past analytical models for the buckling performance assessment of single glass members under various loading/boundary conditions (see [12–15]).

Given the actual geometrical features, material properties and typical high slenderness ratios of glazing systems, the effects of design loads should be checked with respect to possible buckling phenomena. So far, research efforts have been spent for stability losses in compressed structural glass members [16–23]. This is not the case of IGUs, where the actual load bearing performance is strictly related to the

* Corresponding author.
E-mail address: chiara.bedon@dia.units.it (C. Bedon).

https://doi.org/10.1016/j.engstruct.2018.04.055
Received 28 December 2017; Received in revised form 13 April 2018; Accepted 16 April 2018

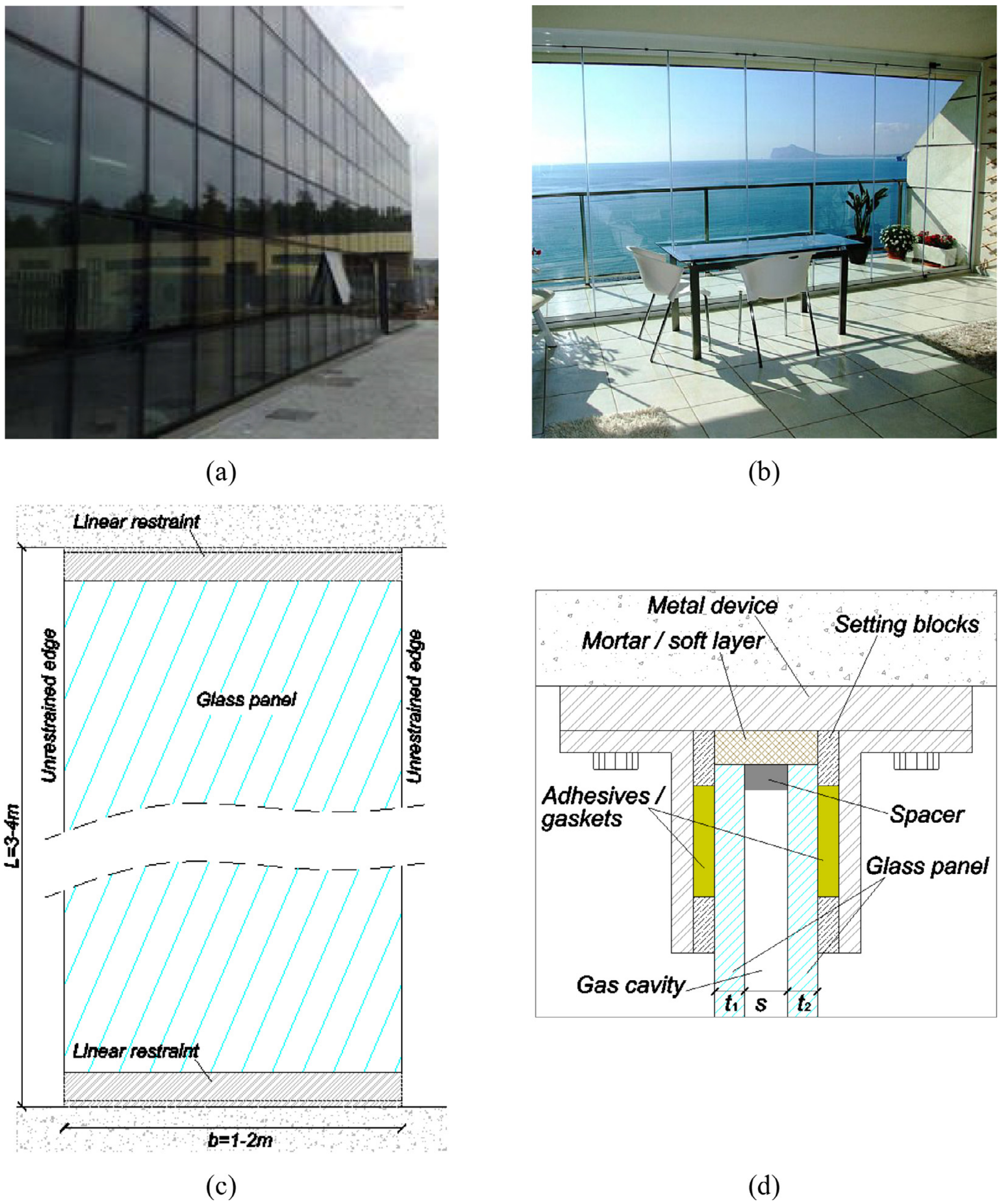

Fig. 1. IGUs in enclosures and curtain walls: examples of (a) 4-side or (b) 2-side supported panels, with (c) reference mechanical system and (d) typical restraint detail (cross-section).

additional effect of combined (shared) loads, both in presence of external (wind, crowd, maintenance, etc.) and internal (environmental loads inclusive of temperature, pressure and altitude variations) design actions.

Moreover, the structural role of linear spacers along the glass panels edges (see Fig. 2) represents a further aspect still requiring investigations. There, a flexible silicon joint and a mostly rigid bar (composed of metal or fiberglass thin profiles [3]) are in fact aimed only to keep fix the position of glass layers. When the glass panels are obtained from laminated glass (LG) sections, finally, the effects of flexible interlayer foils with mechanical properties depending on time loading/temperature conditions should be also taken into account (see for example [1,2,15]).

In this paper, aiming to provide useful design recommendations for 2-side supported, compressed IGUs according to Fig. 1(c), buckling design considerations are first briefly summarized (Section 2), giving evidence of standardized methods in use for (independent) single glass members. A refined FE modelling approach implemented in ABAQUS [11] is presented (Section 3), to explore the typical performance of IGUs under in-plane compressive loads. Several geometrical configurations are considered, by accounting for the gas cavity effects and giving evidence of the actual ‘coupled’ response of glass layers. Based on preliminary FE observations, simplified analytical expressions are also proposed in Section 3, highlighting the limited load bearing capacity of 2-side restrained IGUs. Section 4 focuses then on the combined compressive/bending response of the same IGUs, as it is in most of practical configurations. Simplified analytical formulations for a possible buckling design standardization are finally assessed and discussed towards FE predictions.

2. General buckling design considerations and existing analytical methods

While most of IGU studies have been focused on thermal, durability