Engineering Structures 79 (2014) 322–340

Contents lists available at ScienceDirect

Engineering Structures

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

Numerical and analytical investigation on the dynamic buckling behavior of glass columns under blast

Chiara Bedon *, Claudio Amadio, Andrea Sinico

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

ARTICLE INFO

Article history:
Received 10 February 2014
Revised 13 August 2014
Accepted 14 August 2014

Keywords:
Laminated glass
Static and dynamic buckling
Equivalent lateral load (ELL)
SDOF system
Nonlinear geometry
Numerical dynamic simulations
Analytical method
Design approach

ABSTRACT

Current applications in buildings of structural glass elements often require design rules and formulations able to provide acceptable predictions for phenomena complex to describe, which generally depend on combination of several geometrical and mechanical aspects. The estimation of the buckling resistance of glass elements, for example, represents a topic of large interest for researchers, due to typical high slenderness ratios, limited tensile strength and brittle material behavior. In the paper, the buckling response of glass columns under impulsive orthogonal pressures (e.g. blast) and combined static compressive vertical loads (e.g. gravity loads or further service loads) is investigated. The dynamic buckling behavior of columns in out-of-plane bending is primarily analyzed. Advanced numerical nonlinear dynamic simulations are then performed on various laminated columns, by means of 3D numerical FE-models able to take into account the interaction of simultaneous loads and possible glass cracking. Analytical calculations are also carried-out by means of single-degree-of-freedom (SDOF) formulations derived from structural dynamics theories, in order to properly estimate blast and second-order effects on maximum deflections and corresponding tensile stresses. Finally, based on the rather good correlation generally found between numerical and analytical calculations, a design approach is proposed for practical estimation of buckling strength of glass elements in the analyzed loading and boundary conditions.

1. Introduction

Current innovative techniques and large use of glass in structural applications often require the development of analytical approaches and practical formulations able to provide acceptable predictions for structural phenomena – generally rather complex to describe – which usually depend on combination of multiple geometrical and mechanical aspects.

Glass, for example, is a typical brittle material, characterized by high compressive strength but limited tensile resistance. Typically used in conjunction with thermoplastic viscous polymers able to provide ductility and enhanced post-breakage behavior, thus in the form of multilayered cross-sections for laminated beams, columns and panels, glass elements are commonly associated to high slenderness ratios. As a result, if compared to load-carrying components composed of traditional construction materials, structural glass elements are strongly susceptible to buckling failure mechanisms.

Because of this reason, extended experimental, numerical and analytical studies have been performed in the last years, in order to provide useful information and possible design approaches (e.g. Eurocode-based design buckling curves) for the prediction of the typical buckling response and effective buckling strength of monolithic and laminated glass column, beams or panels under various boundary and loading conditions. In the case of laminated glass, specifically, the effective interaction between multiple layers, as well as possible stiffness degradation of the bonding interlayers – typically time-loading and temperature dependent – have been deeply analyzed. Recent examples can be found in [1–6]. Nevertheless, further knowledge is still required, especially in view of a full investigation of typical structural conditions that could be encountered in buildings and practical cases.

In this work, differing from earlier studies, specific attention is focused on the buckling response of compressed glass elements under impulsive orthogonal pressures, like for example blast loads. As known, dynamic loads – especially of impulsive nature – commonly involve behaviors in structural systems that strongly differ from their same response under quasi-static loads. In this context, the effects of blast pressures and explosive loads on several structural typologies – not necessarily composed of glass – recently encountered the interest of researchers and designers [7–10]. Carta and Stochino [11], for example, proposed a theoretical model, properly assessed to experimental predictions, for the

* Corresponding author. Tel.: +39 040 558 3842.
E-mail addresses: bedon@dicar.units.it, c.bedon@libero.it (C. Bedon).

http://dx.doi.org/10.1016/j.engstruct.2014.08.024
0141-0296/