Buckling of Laminated Glass Elements in Compression

C. Amadio, M.ASCE[1]; and C. Bedon[2]

Abstract: Monolithic and laminated glass beams or panes are frequently adopted as structural elements in modern and innovative architectural applications. Several aspects related to the load-carrying behavior of these new construction elements are very complex to evaluate. For example, the degradation of mechanical properties of the interlayer, the amplitude of the imperfections affecting the beams, or the presence of added external loads represent only some aspects that contribute to the complexity of evaluating the buckling response of these innovative structural components, characterized by high slenderness ratios and brittle behavior in tension. For these reasons, the buckling of laminated glass beams in compression is here investigated by using a simple analytical model developed on the basis of Newmark's theory of composite beams with deformable connection. Buckling curves are presented to illustrate how a combination of simultaneous weathering variations, initial imperfections, or particular load conditions can affect the response of compressed laminated glass beams and cause their failure. **DOI:** 10.1061/(ASCE)ST.1943-541X.0000328.

CE Database subject headings: Laminated materials; Glass; Columns; Buckling; Compression; Structural elements.

Author keywords: Laminated glass; Column buckling; Layered limit; Monolithic limit.

Introduction

In recent years, the structural use of monolithic or laminated glass elements has increase because of the architectural and esthetic aspects (glass transparency, sections slenderness) and the material's high compressive strength. Laminated glass, in particular, is generally preferred to monolithic glass because it is also advantageous in other aspects, such as thermal and sound insulation properties, damping qualities, impact resistance, and postbreaking behavior. However, the real capabilities of such innovative structural elements are currently not well known. Especially in regard to laminated glass beams, the real capabilities and the structural behavior of glass panes connected to polyvinylbutiral (PVB), ionomer (SG, for example), or ethylene-vinyl-acetate (EVA) interlayer materials are in fact very complex to estimate. In laminated glass units, it is commonly assumed that the interlayer behaves as a shear connection between the glass panes. At the same time, it is well known that each polymer mentioned is characterized by a distinct and specific viscous-elastic behavior, depending on temperature, time, and loading intensity. Several authors (Bennison et al. 2002, 2008; Meissner and Sackmann 2006; Kasper et al. 2007; Ensslen 2007; Belis et al. 2007; Haldimann et al. 2008) observed how strongly the temperature and an accelerated aging can influence the mechanical behavior and the stiffness of thermoplastic materials (PVB, SG, EVA). Moreover, these materials show a particular dependence on the loading duration and intensity. Applied as stiffeners in façade applications, as supports for glass floors and roofs, as columns, and generally as slender beams or panes, glass structural elements are usually subjected to failure mechanisms associated with buckling phenomena (Luible and Crisinel 2004, 2006). Consequently, an accurate investigation of load-carrying capacity of a laminated glass beam subjected to compressive loads, taking into account the degradation of the interlayer mechanical properties, could offer some interesting design rules and could constitute a simple analytical design method for glass panes. Although high temperatures and long-term loads have been assumed to lead to a decrement of the interlayer stiffness, the aim of this work is to describe with a simple analytical model the behavior of laminated glass beams subjected to compressive loads and to investigate how the mechanical properties of the interlayer, in conjunction with possible eccentricities or geometrical imperfections, can modify the value of the critical buckling load. The theory of composite beams with deformable connection proposed by Newmark et al. (1951) was originally developed to provide the analytical solution for simply supported composite beams with partial interaction under bending moment. As presented in this paper, if opportunely modified, it can lead to an accurate and simple analytical model for the evaluation of the critical buckling load of laminated glass columns and a valid alternative to sophisticated numerical models. The approach here presented in this paper differs from the analytical models generally proposed as design methods for laminated glass elements under compressive or flexural loads based on sandwich beam theory (Luible and Crisinel 2004, 2006) because it does not require the evaluation of an equivalent monolithic thickness to analyze the behavior of laminated units, allowing determination of their critical buckling load or evaluation of their maximum deflections on the basis of the real thicknesses of each layer. Another advantage of this approach is the possibility to individuate in a very simple way the limit behaviors of glass panes, associated with the presence of a rigid connection or the absence of any connection between the panes. As presented in this paper, this aspect makes it possible to understand the importance and the role of connection offered by the interlayer and to determine how the temperature variations could modify the response of these structural systems.

[1]Associate Professor, Dept. Of Civil and Environmental Engineering, Univ. of Trieste, Piazzale Europa 1, 34127 Italy. E-mail: amadio@univ.trieste.it

[2]Ph.D. Student, Dept. of Civil and Environmental Engineering, Univ. of Trieste, Piazzale Europa 1, 34127 Italy (corresponding author). E-mail: chiara.bedon@phd.units.it

Note. This manuscript was submitted on April 22, 2010; approved on October 6, 2010; published online on October 20, 2010. Discussion period open until January 1, 2011; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Structural Engineering***, Vol. 137, No. 8, August 1, 2011. ©ASCE, ISSN 0733-9445/2011/8-0–0/$25.00.