Composite Structures 107 (2014) 512–521

Contents lists available at ScienceDirect

Composite Structures

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

Buckling of three-layered composite beams with viscoelastic interaction

Laura Galuppi, Gianni Royer-Carfagni *

Department of Industrial Engineering, University of Parma, Parco Area delle Scienze 181/A, I 43100 Parma, Italy

ARTICLE INFO

Article history:
Available online 27 August 2013

Keywords:
Sandwich structure
Viscoelasticity
Creep buckling
Quasi-elastic approach
Viscoelastic memory
Laminated glass

ABSTRACT

A three-layered structure is composed by two external elastic beams that sandwich a viscoelastic core providing their shear coupling. The time-dependent bending of a simply-supported composite-beam of this type, axially-compressed and with an initial sag, are studied assuming a Maxwell–Wierchert constitutive model of viscoelasticity accounting for the memory effect. The phenomena of *glassy*-, *rubber*- and *creep*-buckling are examined for various values of the load. Comparisons are made with a quasi-elastic approximation that assumes a relaxed elastic shear modulus for the interlayer, parametrically dependent on time. The limits of this simplified approach are discussed.

1. Introduction

In recent years, sandwich structures have become increasingly used in many applications, especially for buildings and transportation vehicles. Generally they are composed by two external sheets and an inner core, which usually has negligible bending stiffness but provides the shear coupling of the external layers. Optimal designs can be obtained by choosing different materials and geometric configurations of the face sheets and core. Here, the case is considered in which the inner core is formed by a viscoelastic material. The applications for this type of composites may range from structural insulating panels to laminated glass.

Structural Insulating Panels (SIPs) consist of an insulating layer of rigid polymeric foam sandwiched between two layers of structural board (usually sheet metal, plywood or cement). Thanks to their strength and stability, as well as to their good capability to reduce noise and vibrations due to the presence of the viscoelastic core [6,5], they can be used as exterior walls, roofs, floors and foundation systems [29]. In general, they have application also in the aerospace, aeronautical, automobile and naval industries [24]. Sandwich plates with viscoelastic core are very effective for lightweight and flexible structures because the soft core, strongly deformed in shear, provides passive damping [35,4,3].

Laminated Glass (LG) is composed by two (or more) glass plies bonded together by a polymeric viscoelastic interlayer. LG is widely used in architecture thanks to its transparency, strength and other advantageous aspects, such as sound-insulation capability and non-catastrophic post-glass-breakage response. The degree of connection offered by the polymer affects the design of glass structures in the serviceability limit state, and this is why a great number of studies have considered the response of the composite laminated package [10,13,19]. As discussed in several articles [40,15,8,18], the temperature-dependent viscoelastic properties of the polymer govern the gross performance of LG.

Other borderline cases of structural elements that can be assimilated to three-layered composite beams, but with interlayers of negligible thickness, are wood-based composite building materials, made of layers glued together with moisture-resistant adhesives. Their mechanical behavior, accounting for the interlayer slip, as well as for the creep effect due to the viscoelasticity of the glue connection [36,26], has been studied since the sixties [22,25]. Further examples are composite steel–concrete structures, formed by a concrete slab connected to a steel beam through shear connecting studs. Their performance depends primarily on the shear transfer mechanism provided by shear coupling: varying the strength, stiffness, and spacing of connectors, full or partial composite action can be achieved. Also in recent years, several studies have investigated the non-linear behavior of such a composite [20,38,7], where the relative slip between the constituents is usually time-dependent.

The first analytical model for a composite beam with partial shear interaction is commonly attributed to Newmark et al. [30], who was interested in the response of composite steel–concrete beams. Since then several studies, also in very recent years [21,14,33], have investigated the effects of non-linearity and interlayer slip. In general, the performance is somehow intermediate between the two borderline cases of (i) *monolithic* limit, with perfect bonding between the external layers (shear-rigid interlayer) and of (ii) *layered* limit, with frictionless sliding layers.

As suggested for the first time by Schapery [34] and later discussed in [2], in the common design practice viscoelasticity is

* Corresponding author. Tel.: +39 0521 905896; fax: +39 0521 905705.
E-mail address: gianni.royer@unipr.it (G. Royer-Carfagni).

0263-8223/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compstruct.2013.08.006