Accepted Manuscript

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PII: S1359-8368(18)30020-9

DOI: 10.1016/j.compositesb.2018.05.032

Reference: JCOMB 5702

To appear in: *Composites Part B*

Received Date: 3 January 2018

Revised Date: 23 May 2018

Accepted Date: 24 May 2018

On modal analysis of laminated glass: Usability of simplified methods and Enhanced Effective Thickness

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Abstract

This paper focuses on the modal analysis of laminated glass beams. In these multilayer elements, the stiff glass plates are connected by compliant interlayers with frequency and temperature-dependent behavior. The aim of our study is (i) to assess whether approximate techniques can accurately predict the behavior of laminated glass structures and (ii) to propose a simple tool for modal analysis based on the Enhanced Effective Thickness concept.

For this purpose, we consider four approaches to the solution of the related nonlinear eigenvalue problem: a complex-eigenvalue solver based on the Newton method and three simplified approaches. In particular, we limit our attention to the modal strain energy method, the dynamic effective thickness method, and the Enhanced Effective Thickness method. A comparative study of free vibrating laminated glass beams is performed considering different geometries of cross-sections, boundary conditions, and material parameters for interlayers under two ambient temperatures. The viscoelastic response of polymer foils is represented by the generalized Maxwell model.

We show that the simplified approaches predict natural frequencies with an acceptable accuracy for most of the examples. However, there is considerable scatter in predicted loss factors. The Enhanced Effective Thickness approach adjusted to modal analysis results in lower errors in both quantities compared to the other two simplified procedures. It reduces the extreme error in loss factors by half compared to the modal strain energy method and to one quarter compared to the original dynamic effective thickness method.

Keywords: Free vibrations, Laminated glass, Complex dynamic modulus, Dynamic effective thickness, Enhanced effective thickness, Modal strain