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Nonlinear Behavior of Laminated Glass Plates with Hinged-Free Boundary Conditions

Deniz Can Elci[1], Ebru Dural[2] and Mehmet Zülfü Asik[3]

[1] Department of Aerospace Engineering, Middle East Technical University, 06530, Ankara, Turkey, deniz.elci@metu.edu.tr

[2] Department of Civil Engineering, Adnan Menderes University, 09100 Aydın, Turkey
Department of Technical Programs Kyrgyz-Turkish Manas University, 720044, Bishkek, Kyrgyz Republic ebrudural@gmail.com

[3] Department of Aerospace Engineering, Middle East Technical University, 06800, Ankara, Turkey azulfu@metu.edu.tr

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Abstract

Laminated glass is made by "sandwiching" two glass sheets and a polyvinyl butyral (PVB) interlayer in between them. When it is broken, the interlayer in between the glass layers can stick them together. Since the laminated unit is broken into many small pieces of glass without sharp edges during natural and man-made disasters, the hazard of sharp missiles reduces. They can be widely applied in building, architecture, automotive, transport industries.

Laminated glass can easily undergo large displacements even under their own weight. In order to explain their true behavior, they should be analyzed by using large deflection theory to represent nonlinear behavior. In this study, a nonlinear mathematical model is developed for the analysis of laminated glass plate which is free in two directions and restrained in the other directions. The assumptions of model will be verified by using the results of developed finite element model.

Five nonlinear partial differential equations which govern the behavior of laminated glass unit are derived by employing variational principles and minimum potential energy concept. Finite difference method is employed to solve the coupled differential equations and they are converted into a system of matrix equations. The matrix systems are solved by applying iterative procedure. Problems occurred in getting convergent sequence generated by the employed procedure are overcome by employing variable underrelaxation factor. The procedure developed to solve the differential equations provides not only less storage but also less calculation time, which is a substantial advantage in computational mechanics problems.

REFERENCES

[1] Vallabhan, C.V.G., Das, Y.C., Magdi, M. Aşık, M.Z.,Bailey, J.R. (1993) Analysis of laminated glass units, Journal of Structural Engineering, 119(5), 1572-1585.

[2] Asik, M.Z. (2003) Laminated Glass Plates: Revealing of Nonlinear Behavior, Computers & Structures, 81 (28-29), 2659-2671.

[3] Dural, E., Aşık. M. Z.,(2014) Experimental Investigations of Laminated Glass Cylindrical Shells.ACE 2014. 21-25 October 2014 Istanbul, Turkey.

[4] Asik, M.Z., Dural, E., Yetmez, M. and Uzhan, T. (2014) A Mathematical Model For The Behavior of Laminated Uniformly Curved Glass Beams, *Composites Part B: Engineering* 58, 593–604.

[5] Asik, M.Z., Tezcan, S. A Mathematical Model for the Behavior of Laminated Glass Beams, *Computers & Structures* 83, 1742-17