Steel and Composite Structures, *Vol. 44, No. 4 (2022) 489-503*
https://doi.org/10.12989/scs.2022.44.4.489

Static buckling analysis of bi-directional functionally graded sandwich (BFGSW) beams with two different boundary conditions

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(Received February 6, 2022, Revised June 13, 2022, Accepted August 9, 2022)

Abstract. This paper presents the mechanical buckling of bi-directional functionally graded sandwich beams (BFGSW) with various boundary conditions employing a quasi-3D beam theory, including an integral term in the displacement field, which reduces the number of unknowns and governing equations. The beams are composed of three layers. The core is made from two constituents and varies across the thickness; however, the covering layers of the beams are made of bidirectional functionally graded material (BFGSW) and vary smoothly along the beam length and thickness directions. The power gradation model is considered to estimate the variation of material properties. The used formulation reflects the transverse shear effect and uses only three variables without including the correction factor used in the first shear deformation theory (FSDT) proposed by Timoshenko. The principle of virtual forces is used to obtain stability equations. Moreover, the impacts of the control of the power-law index, layer thickness ratio, length-to-depth ratio, and boundary conditions on buckling response are demonstrated. Our contribution in the present work is applying an analytical solution to investigate the stability behavior of bidirectional FG sandwich beams under various boundary conditions.

Keywords: deformation demand; earthquake resistant design philosophy; limit states; structural damage states; levels of earthquake shaking

1. Introduction

An innovative class of materials has emerged through scientific research and technological development. This new class of materials called functionally graded materials represents a new concept consisting of a gradual evolution of the properties from one surface to another by a continuous composition change. FGM is a sophisticated composite material that includes two or more phases with continuously varying properties from the lower to the upper surface.

The benefits of this type of material have led to the development of several FG sandwich structures with no interface problems compared to traditional laminate composites. Due to the functional change of the mechanical properties between the core and the two FG skins.

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Typically, there are two FG sandwich beams, homogeneous core-FG faces, and FG core-homogeneous faces. The beam's mechanical characteristics are considerably modified by the variation of the length or thickness of the part. The analysis of FGM structures has been widely performed over the past decades using analytical and numerical methods.

Finite element methods and analytical solutions have been utilized by (Murat and Ahmet 2013, Öner Erdal *et al*. 2015 and Murat 2016) to analyse the crack and the receding contact problem for elastic layer rests on two-quarter planes. In 2019, Yaylacı Murat *et al*. study the receding symmetric contact problem of two sheets based on half-elastic plane using the ANSYS and ABAQUS software. Recently, Yaylacı Murat *et al*. 2020, by means of analytical solutions and finite element method analyse the continuous and discontinuous contact problems of functionally graded (FG) layer resting on a rigid foundation. Uzun Yaylacı *et al*. 2020 examine the maximum contact pressures and contact areas using artificial neural network to predict the

http://www.techno-press.com/journals/scs&subpage=8 ISSN: 1229-9367 (Print), 1598-6233 (Online)