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AN EQUIVALENT HOMOGENEOUS MODEL FOR FRP SANDWICH BRIDGE DECK PANELS WITH SINUSOIDAL CORES

Bibekananda MANDAL

Research Scholar
Indian Institute of Technology Roorkee
Roorkee, India

bibekanandabesu@gmail.com

Anupam CHAKRABARTI

Associate Professor
Indian Institute of Technology Roorkee
Roorkee, India

Anupam1965@yahoo.co.uk

Fibre reinforced plastic (FRP) sandwich panels with sinusoidal cores are an attractive solution both in new construction and rehabilitation of existing bridge decks. FRP sandwich panels, comprising of two face plates separated by a core of stiffeners offer better performance due to high stiffness-to-mass ratio along with numerous impressive properties like corrosion resistance, high impact strength etc. Analysis of sandwich panels using exact three dimensional (3D) modelling is very much complicated and also time consuming. To overcome this problem, the whole deck panel can be assumed as an equivalent orthotropic continuum for simplified analysis. This paper is focused on a numerical study to find equivalent elastic constants to replace FRP sandwich panel with a homogeneous orthotropic plate. The present numerical model is applicable for the sandwich panels with any type of core geometry which is periodic in nature. To determine flexibility of the present model, equivalent orthotropic properties have been generated for FRP sandwich panels with three types of core configurations: rib, circular and triangular. Static and dynamic analyses have also been performed using the proposed equivalent model and the results are compared with the results obtained from 3D finite element (FE) model.

1. Introduction

FRP pedestrian bridges gain a foothold in the marketplace, offering innovative designs and lightweight solutions. Landmark projects of FRP pedestrian bridges are like: North Bank pedestrian bridge, Fiber Line Bridge in Kolding and Composite Bascule Bridge in Bridgetown. North Bank pedestrian bridge (Fig.1) in Boston is a signature pedestrian bridge which connects two parks on the north bank of the Charles. The bridge deck was manufactured with FiberSPAN™ (Fig. 2) FRP sandwich panels which employs fiberglass top and bottom skins and closely-spaced internal webs that function like a series of I-beams.

Fig. 1.North Bank pedestrian bridge

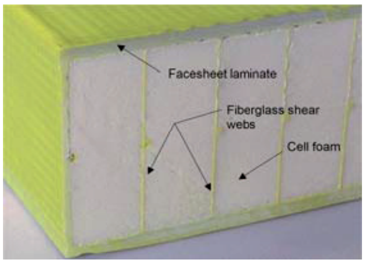

Fig. 2. FiberSPAN™ deck profile

Fiber Line Bridge (40m long) located in Kolding, Denmark is one of the world's largest FRP composite bridges and the first to cross a railway line. The busy railway line restricted installation work and required short installation time was illustrated the clear advantages of composites. The Composite Bascule Bridge (11.7m x 8.86m) in Bridgetown, Barbados won 2006 Award for Composites Excellence (ACE). FRP composite was selected to replace a dangerously obsolete steel structure. This bridge is an excellent example of how composites can be used to replace steel in vehicular superstructures, especially in corrosive saltwater environments.

2. Mathematical formulation

A FE based method to evaluate equivalent homogeneous orthotropic material property for FRP sandwich panels has been proposed using small deflection theory [1]. The deck has been modeled using 8 node shell element SHELL281 using ANSYS for this purpose. The behaviour of the sandwich panel has been compared with an equivalent homogeneous orthotropic thick plate continuum as illustrated in Fig. 3. To calculate curvature κ_x in the xz plane, moment M_x along *x*-axis at the two ends of the panel has been generated applying force couples. Similar strategy has been applied to calculate curvature κ_y in the yz plane. A sample calculation considered to find bending stiffness D_x and equivalent material properties is shown in the equation below:

$$D_x = -\frac{M_x}{\kappa_x}, \qquad E_x = \frac{12D_x}{h^3}, \quad \nu_{xy} = -\frac{\kappa_y}{\kappa_x} \tag{1}$$

3. Results and conclusions

The present method has been applied to FRP sandwich panels with three types of core configurations: triangular, circular and rib. For the rib type core, a bi-directional rib core sandwich panel problem has been chosen from Aref et al. [2], as shown in Fig. 4. Natural mode frequencies calculated from the 3D FE model and from the equivalent model have been presented in Table 1, which are in good agreement with each other.

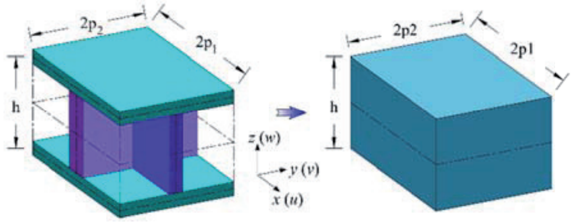

Fig. 3. Transformation of rib core sandwich element to equivalent homogeneous plate continuum

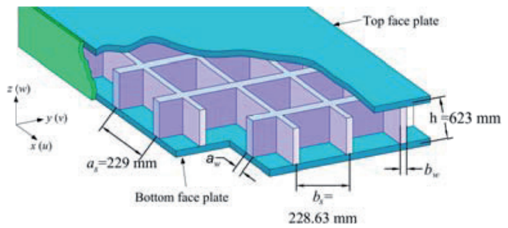

Fig. 4. The FRP rib core deck panel geometry

Mode	Frequency (Hz)		
	3D model	Equivalent model	%Error
1	50.38	50.78	0.79
2	78.92	79.70	0.99
3	98.13	99.39	1.28
4	118.44	120.22	1.50

Table 1. Modal frequencies of the rib core sandwich panel for all edges clamped boundary

When boundary condition of the panel is other than all edges clamped, some extra mode can generate in actual model. The present numerical model is very much efficient, versatile and easier than the previous methods and capable of transforming a FRP sandwich panel with any type of sinusoidal core configuration, into an equivalent homogeneous layer.

References

[1] LIBOVE C., and BATDORF S. B., “A General Small Deflection Theory for Flat Sandwich Plates”, Technical Note 1526, National Advisory Committee for Aeronautics (NACA), 1948.

[2] AREF A. J., ALAMPALLI S., and HEY Y., "Ritz-based Static Analysis Method for Fiber Reinforced Plastic Rib Core Skew Bridge Superstructure", Journal of Engineering Mechanics, Vol. 127, 2001, pp. 450-458.