Computers and Concrete, *Vol. 25, No. 5 (2020) 427-432*
DOI: https://doi.org/10.12989/cac.2020.25.5.427

Buckling analysis of sandwich beam reinforced by GPLs using various shear deformation theories

Sona Hanifehlou and Mehdi Mohammadimehr*

Department of Solid Mechanics, Faculty of Mechanical Engineering, University of Kashan, P.O Box 87317-53153, Kashan, Iran

(*Received February 8, 2020, Revised March 16, 2020, Accepted April 10, 2020*)

Abstract. In this research, the buckling analysis of sandwich beam with composite reinforced by graphene platelets (GPLs) in two face sheets is investigated. Three type various porosity patterns including uniform, symmetric and asymmetric are considered through the thickness direction of the core. Also, the top and bottom face sheets layers are considered composite reinforced by GPLs/CNTs based on Halpin-Tsai micromechanics model and extended mixture rule, respectively. Based on various shear deformation theories such as Euler-Bernoulli, Timoshenko and Reddy beam theories, the governing equations of equilibrium using minimum total potential energy are obtained. It is seen that the critical buckling load decreases with an increase in the porous coefficient, because the stiffness of sandwich beam reduces. Also, it is shown that the critical buckling load for asymmetric distribution is lower than the other cases. It can see that the effect of graphene platelets on the critical buckling load is higher than carbon nanotubes. Moreover, it is seen that the difference between carbon nanotubes and graphene platelets for Reddy and Euler-Bernoulli beam theories is most and least, respectively.

Keywords: buckling analysis; GPLs; sandwich beam; various distributions of Porous core; various shear deformation theories

1. Introduction

Sandwich structures are one of the composite materials that made of three layers including core layer and two facesheets layers. It is known that the material properties of core should be more flexible or tougher than that of the facesheets. These structures have an excellent features including high ratio of strength-to-weight, good energy and sound absorption capability, and good thermal insulation and employed in many engineering applications such as building constructions, auto- motive, aerospace and ship structures. Nanocomposites and nanosandwich reinforced by the graphene platelets, carbon nanotubes, and boron nitride nanotubes increase the stiffness of these composites. Many studies about the behavior of the sandwich structures are investigated.

Yang *et al*. (2017) considered the buckling and postbuckling behaviors of functionally graded (FG) multilayer nanocomposite beams reinforced with a low content of graphene platelets (GPLs) resting on elastic foundation. They assumed that GPLs are randomly oriented and uniformly dispersed in each individual GPL-reinforced composite (GPLRC) layer with its weight fraction varying layerwise along the thickness direction. Jalaei and Ghorbanpour Arani (2018) presented a size-dependent static and dynamic responses of embedded double-layered graphene sheets under longitudinal magnetic field with arbitrary boundary conditions. Mohammadimehr *et al*. (2018) obtained the mechanical properties of nanocomposite using an experimental tensile test and then analyzed the bending, buckling, and free vibration of carbon nanotube reinforced composite beams. Taherifar *et al.* (2019) presented buckling analyses of composite concrete plate reinforced by piezoelectric nanoparticles based on Halphin-Tsai model to obtain the effective material properties of nano composite concrete plate and third order shear deformation theory. Rajabi and Mohammadimehr (2019) considered bending analysis of a micro sandwich skew plate with isotropic core and piezoelectric composite face sheets reinforced by carbon nanotube on elastic foundations. They used Eshelby-Mori-Tanaka approach for the effective mechanical properties of the nanocomposite face sheets. The governing equations of equilibrium are derived using minimum principle of total potential energy and then solved by extended Kantorovich method (EKM). Mousavi *et al.* (2019) investigated the buckling of micro sandwich hollow circular plate with the porous core and piezoelectric layer reinforced by FG carbon nanotube. They employed the high-order shear deformation theory (HSDT) of plate and modified couple stress theory (MCST). Soleymani and Ghorbanpour Arani (2019) demonstrated an aero-elastic stability of a piezo-magneto-reological sandwich plate in supersonic airflow. Draiche *et al.* (2019) illustrated an analytical model to predict the static analysis of laminated reinforced composite plates subjected to sinusoidal and uniform loads by using a simple first-order shear deformation theory (SFSDT). Their most important aspect of their theory are that unlike the conventional FSDT, the proposed model contains only four unknown

*Corresponding author, Associate Professor
E-mail: mmohammadimehr@kashanu.ac.ir

ISSN: 1598-8198 (Print), 1598-818X (Online)

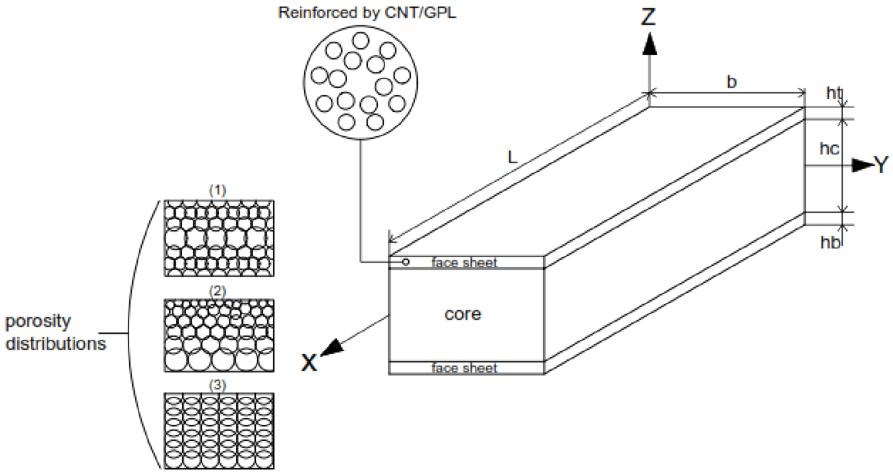

Fig. 1 A schematic view of sandwich beam with porous core and CNT/GPLs face sheets

variables. This is due to the fact that the inplane displacement field is selected according to an undetermined integral component in order to reduce the number of unknowns. Mao and Zhang (2019) analyzed the buckling and post-buckling behaviors for the multilayer functionally graded graphene platelets reinforced piezoelectric (FG-GRP) plates that the FG-GRP plates are subjected to the external electric potential and axial forces such as the uniaxial and biaxial loadings. Ghorbanpour Arani and Abdollahian (2019) considered transient response of FG higher-order nanobeams integrated with magnetostrictive layers using modified couple stress theory. Wang *et al*. (2019) studied buckling and postbuckling behaviors of graphene platelet (GPL) reinforced dielectric composite beams through theoretical formulation. They investigated the effective material properties of the GPL reinforced composite (GPLRC) for structural analysis. Yazdani and Mohammadimehr (2019) researched about wave propagation of double-bonded Cooper-Naghdi micro sandwich cylindrical shells with porous core and carbon nanotube reinforced composite (CNTRC) face sheets subjected to multi-physical loadings with temperature dependent material properties. Ebrahimi *et al*. (2019) studied analysis of propagation characteristics of elastic waves in heterogeneous nanobeams employing a new two-step porosity-dependent homogenization scheme. Luat *et al*. (2020) presented applications of the multivariate adaptive regression splines (MARS) method for predicting the ultimate loading carrying capacity (Nu) of rectangular concrete-filled steel tubular (CFST) columns subjected to eccentric loading. Alibeigloo (2020) studied thermo-elastic behavior of composite cylindrical panel reinforced with graphene platelets distributed along the radial direction uniformly (UD) or various functionally graded distributions. Babaeeian and Mohammadimehr (2020) investigated the time elapsed effect on residual stress measurement in a composite plate by digital image correlation (DIC) method that is a practical and effective tool for quantitative in-plane deformation measurement of a planar object surface and now widely accepted and commonly used in the field of experimental mechanics. It can be stated that their research may identify the optimal measurement time after the drilling and the holes with different diameters and the displacement and strain fields are measured at different times. So they discussed the residual stress measurement of a composite plate in the time elapsed. Also, the effects of hole's diameter and elapsed time after drilling in amount of released residual stresses are investigated by 2D DIC method. Anvari *et al*. (2020) studied free vibration analysis of a micro cylindrical sandwich panel reinforced by graphene platelet based on high-order shear deformation theory. Thai *et al*. (2020) presented a size-dependent model based on the NURBS basis functions integrated with quasi three-dimensional (quasi-3D) shear deformation theory. Also, based on modified couple stress theory (MCST), they investigated the free vibration and buckling analyses of multilayer functionally graded graphene platelet-reinforced composite (FG GPLRC) microplates. Sobhy (2020) considered the buckling and vibration analyses of a new model composed of a homogeneous ceramic curved nanobeam sandwiched between two reinforced composite layers in which the face sheets layers are made of an aluminum matrix reinforced with functionally graded (FG) graphene nanosheets. Javani *et al*. (2020) examined thermal buckling analysis of composite laminated annular sector plates reinforced with the graphene platelets. They assumed that the graphene platelets fillers are randomly oriented and uniformly distributed in each ply of the composite media. Dimitri *et al*. (2020) presented a new numerical formulation based on the generalized differential quadrature (GDQ) approach to determine the peeling and shear stresses along interfaces of arbitrary shape, made of laminated composite structures and subjected to mixed-mode conditions, as well as to examine the internal distribution of reactions.

By reviewing the literature it can be seen that up to date there are no researches about comparison various distributions of porous core, various shear deformation beam theories, graphene platelets and carbon nanotubes as reinforcements, simultaneously. Graphene platelets/carbon nanotubes as reinforcements for the mechanical properties of materials, are becoming popular today and increasing the flexural rigidity of structures. In this research, buckling analysis of sandwich beams with porous core and composite facesheets reinforced with graphene platelets/carbon nanotubes are discussed. The governing equations of equilibrium using minimum total potential energy are obtained. Therefore, the novelty of this research is simultaneously the investigation of various beam theories including Euler-Bernoulli, Timoshenko, Reddy beam theories and graphene platelets and carbon nanotubes reinforcements in facesheets layers and different distributions of porous core including symmetric, asymmetric and uniform distributions. The

2. Governing equations of motion for sandwich beam

Consider a sandwich beam with length L, width b, and height H. Also, in Fig. 1, h_c, h_t, and h_b are the thicknesses of core, top and bottom facesheets, respectively.

The displacement fields for various shear deformation theories are considered as follows

Euler-Bernoulli beam theory (Alimirzaei *et al*. 2019)

$$u(x,y,z)=u_0(x)-z\frac{\partial w_0(x)}{\partial x}\qquad v(x,y,z)=0\qquad w(x,y,z)=w_0(x)\tag{1}$$

Timoshenko beam theory (Bahaadini *et al*. 2019)

$$u(x,y,z)=u_0(x)-z\psi(x)\qquad v(x,y,z)=0\qquad w(x,y,z)=w_0(x)\tag{2}$$

Reddy beam theory (Mohammadimehr *et al*. 2016)

$$u(x,y,z,t)=u_0(x,t)-z\psi(x,t)-\frac{4z^3}{3h^2}\left(\psi(x,t)+\frac{\partial w_0(x,t)}{\partial x}\right)\qquad v(x,y,z,t)=0\qquad w(x,y,z,t)=w_0(x,t)\tag{3}$$

The kinematic equations for various beam theories is considered as follows

$$\varepsilon_{xx}=\frac{\partial u}{\partial x},\qquad \gamma_{xz}=\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\tag{4}$$

The constitutive equations for sandwich beam is written as the following form (Chen *et al.* 2017)

$$\begin{Bmatrix}\sigma_x\\ \tau_{xz}\end{Bmatrix}=\begin{pmatrix}Q_{11}&0\\0&Q_{55}\end{pmatrix}\begin{Bmatrix}\varepsilon_x\\ \gamma_{xz}\end{Bmatrix}\tag{5}$$

The stiffness matrix components for porous core is defined as follows

$$Q_{11c}=\frac{E_c}{1-\nu_c^2}\qquad Q_{55c}=\frac{E_c}{2\left(1+\nu_c\right)}\tag{6}$$

where the Young's modulus (E_c) of porous core for three types of different distributions is written as follows (Chen *et al*. 2017)

$$E_c=E_1\left(1-e_1\cos\left(\frac{\pi z}{2h_c}+\frac{\pi}{4}\right)\right)\qquad \text{Asymmetric type}\tag{7}$$

$$E_c=E_1\left(1-e_1\cos\left(\frac{\pi z}{h_c}\right)\right)\qquad \text{Symmetric type}\tag{8}$$

$$E_c=E_1\left(1-e_1\chi\right)\qquad \text{Uniform type}\tag{9}$$

where

$$e_1=1-\frac{G_1}{G_0}=1-\frac{E_1}{E_0}\qquad e_m=1-\frac{\rho_1}{\rho_0}=1-\sqrt{1-e_1}\qquad \chi=\frac{1}{e_1}-\frac{1}{e_1}\left(\frac{2}{\pi}\sqrt{1-e_1}-\frac{2}{\pi}+1\right)^2\tag{10}$$

Using the extended mixture rule, the Young's and shear modulus for top and bottom facesheets of sandwich beam reinforced by carbon nanotubes is considered as (Shahedi *et al*. 2020, Navi *et al*. 2019)

$$E_{11}=\eta_1E_{11CNT}V^*_{CNT}+V_mE_m,\qquad \frac{\eta_3}{G_{12}}=\frac{V^*_{CNT}}{G_{12CNT}}+\frac{V_m}{G^m},\qquad \nu_{12}=V^*_{CNT}\nu_{12}^{CNT}+V_m\nu^m\qquad V_{CNT}=V^*_{CNT}\tag{11}$$

Using the Halpin-Tsai micromechanical model, the Young's and shear moduli for top and bottom facesheets of sandwich beam reinforced by graphene platelets are written as (Bahaadini and Saidi 2018)

$$E_{11}=\frac{3}{8}\frac{1+\xi_L\eta_LV_{GPL}}{1-\eta_LV_{GPL}}E_m+\frac{5}{8}\frac{1+\xi_T\eta_TV_{GPL}}{1-\eta_TV_{GPL}}E_m\qquad \eta_L=\frac{(E_{GPL}/E_m)-1}{(E_{GPL}/E_m)+\xi_L}\qquad \eta_T=\frac{(E_{GPL}/E_m)-1}{(E_{GPL}/E_m)+\xi_T}$$
$$\xi_L=2\frac{a_{GPL}}{t_{GPL}}\qquad \xi_T=2\frac{b_{GPL}}{t_{GPL}}\qquad G_{12}=\frac{E_{11}}{2(1+\upsilon)}\qquad V_{GPL}=V^*_{GPL}\tag{12}$$

Using the rule of mixture, the Poisson's ratio for graphen platelets of sandwich beam are considered as follows (Bahaadini and Saidi 2018)

$$\upsilon=V_{GPL}\upsilon_{GPL}+V_m\upsilon_m\tag{13}$$

The elements of stiffness matrix for GPLs facesheets of sandwich beam is represented as the following form

$$Q_{11} = \frac{E_{11}}{1-\upsilon^2} \qquad Q_{55} = G_{12} \tag{14}$$

The variations of strain and kinetic energies are obtained as

$$\delta U = \int_0^l \int_A (\sigma_{xx}^i \delta\varepsilon_{xx}^i + \tau_{xz}^i \delta\gamma_{xz}^i) dA\, dx$$
$$\delta W_{ext} = \int_A -N_{x0} \frac{\partial^2 w_0}{\partial x^2} \delta w_0 dA \tag{15}$$

The governing equations of equilibrium for sandwich beam with porous core and graphene platelet facesheets/carbon nanotubes using various shear deformation theories such as Euler-Benoulli, Timoshenko, Reddy beam theories are obtained as follows

Euler-Bernoulli beam theory

$$\delta u_0 : \quad -Q_{11}^0 \frac{\partial^3 w_0}{\partial x^3} = 0$$
$$\delta w_0 : \quad Q_{11}^1 \frac{\partial^3 u_0}{\partial x^3} - Q_{11}^2 \frac{\partial^4 w_0(x,t)}{\partial x^4} + N_{x0} \frac{\partial^2 w_0(x,t)}{\partial x^2} = 0 \tag{16}$$

Timoshenko beam theory

$$\delta u_0 : \quad -Q_{11}^1 \frac{\partial^2 \psi}{\partial x^2} = 0$$
$$\delta w_0 : \quad -Q_{12}^0 \frac{\partial \psi}{\partial x} + Q_{12}^0 \frac{\partial^2 w_0}{\partial x^2} + N_{x0} \frac{\partial^2 w_0}{\partial x^2} = 0 \tag{17}$$
$$\delta \psi : \quad -Q_{11}^1 \frac{\partial^2 u_0}{\partial x^2} + Q_{11}^2 \frac{\partial^2 \psi}{\partial x^2} - Q_{12}^0 \psi = 0$$

Reddy beam theory

$$\delta u_0 : \quad -Q_{11}^1 \frac{\partial^2 \psi}{\partial x^2} - Q_{11}^3 \frac{4}{3h^2} \frac{\partial^2 \psi}{\partial x^2} - Q_{11}^3 \frac{4}{3h^2} \frac{\partial^3 w_0}{\partial x^3} = 0$$

$$\delta w_0 : \quad Q_{11}^3 \frac{4}{3h^2} \frac{\partial^3 u_0}{\partial x^3} - Q_{11}^4 \frac{4}{3h^2} \frac{\partial^3 \psi}{\partial x^3} - Q_{11}^6 \frac{16}{9h^4} \frac{\partial^3 \psi}{\partial x^3} - Q_{11}^6 \frac{16}{9h^4} \frac{\partial^4 w_0}{\partial x^4}$$
$$+ Q_{12}^2 \frac{4}{h^2} \frac{\partial \psi}{\partial x} + Q_{12}^4 \frac{16}{h^4} \frac{\partial \psi}{\partial x} + Q_{12}^4 \frac{16}{h^4} \frac{\partial^2 w_0}{\partial x^2} - Q_{12}^2 \frac{4}{h^2} \frac{\partial^2 w_0}{\partial x^2}$$
$$- Q_{12}^0 \frac{\partial \psi}{\partial x} - Q_{12}^2 \frac{4}{h^2} \frac{\partial \psi}{\partial x} - Q_{12}^2 \frac{4}{h^2} \frac{\partial^2 w_0}{\partial x^2} + Q_{12}^0 \frac{\partial^2 w_0}{\partial x^2} + N_{x0} \frac{\partial^2 w_0}{\partial x^2} = 0 \tag{18}$$

$$\delta \psi : \quad -Q_{11}^1 \frac{\partial^2 u_0}{\partial x^2} + Q_{11}^2 \frac{\partial^2 \psi}{\partial x^2} + Q_{11}^4 \frac{4}{3h^2} \frac{\partial^2 \psi}{\partial x^2} + Q_{11}^4 \frac{4}{3h^2} \frac{\partial^3 w_0}{\partial x^3}$$
$$- Q_{11}^3 \frac{4}{3h^2} \frac{\partial^2 u_0}{\partial x^2} + Q_{11}^4 \frac{4}{3h^2} \frac{\partial^2 \psi}{\partial x^2} + Q_{11}^6 \frac{16}{9h^4} \frac{\partial^2 \psi}{\partial x^2}$$
$$+ Q_{11}^6 \frac{16}{9h^4} \frac{\partial^3 w_0}{\partial x^3} - Q_{12}^0 \psi - Q_{12}^2 \frac{4}{h^2} \psi - Q_{12}^2 \frac{4}{h^2} \frac{\partial w_0}{\partial x}$$
$$+ Q_{12}^0 \frac{\partial w_0}{\partial x} - Q_{12}^2 \frac{4}{h^2} \psi - Q_{12}^4 \frac{16}{h^4} \psi - Q_{12}^4 \frac{16}{h^4} \frac{\partial w_0}{\partial x} + Q_{12}^2 \frac{4}{h^2} \frac{\partial w_0}{\partial x} = 0$$

Based on Navier's type solution, the displacements fields can be considered as follows

$$u_0(x) = \sum_{n=1}^{\infty} U_n \cos \frac{n\pi x}{L}$$
$$\psi(x) = \sum_{n=1}^{\infty} \psi_n \cos \frac{n\pi x}{L} \tag{19}$$
$$w_0(x) = \sum_{n=1}^{\infty} W_n \sin \frac{n\pi x}{L}$$

By substituting the Navier's type solution into the governing equations of equilibrium, the stiffness matrix can be obtained.

3. Numerical results and discussions

In this research, the buckling behavior of sandwich beam reinforced by graphene platelets/carbon nanotubes and porous core using various shear deformation theories such as Euler-Bernoulli, Timoshenko and Reddy beam theories is investigated.

The mechanical and geometrical parameters for sandwich beam with porous cores and graphene platelets/carbon nanotubes in facesheets layers are considered as follows

$$\begin{gathered} h_c = 0.08m,\ h_t = h_b = 0.01m, E_m = 2.5GPa, \\ \rho_m = 1190\ kg/m^3, \upsilon_m = 0.3 \\ E_{GPL} = 1.01TPa, \upsilon_{GPL} = 0.186, \\ a_{GPL} = 2.5\,\mu m, b_{GPL} = 1.5\,\mu m, t_{GPL} = 1.5\,nm, \\ V_{CNT}^* = 0.12,\ \eta_1 = 0.137,\ \eta_2 = 1.022, \\ \eta_3 = 0.715, \upsilon_{12}^{CNT} = 0.175, \\ E_{11CNT} = 5.6466TPa,\ E_{22CNT} = 7.08TPa, \\ G_{12CNT} = 1.9445TPa, \\ E_1 = 113.8GPa, \rho_1 = 4430\,kg/m^3, \upsilon_1 = 0.342, e_0 = 0.3, \end{gathered} \tag{20}$$

Fig. 2 shows the critical buckling load versus porous coefficient for various distributions of porous media such as Uniform, Symmetric and Asymmetric distributions and different beam theories including Euler-Bernoulli,

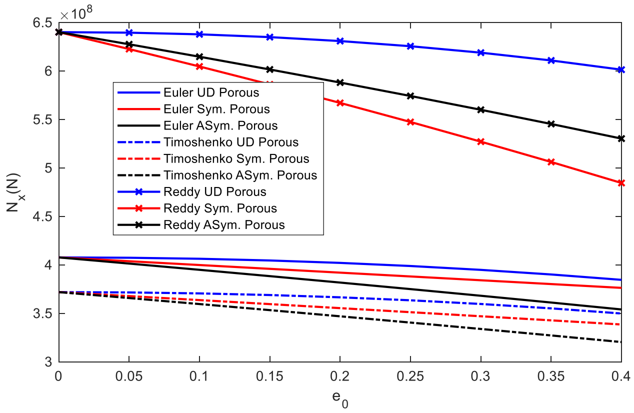

Fig. 2 The critical buckling load versus porous coefficient for various distributions of porous media and different beam theories

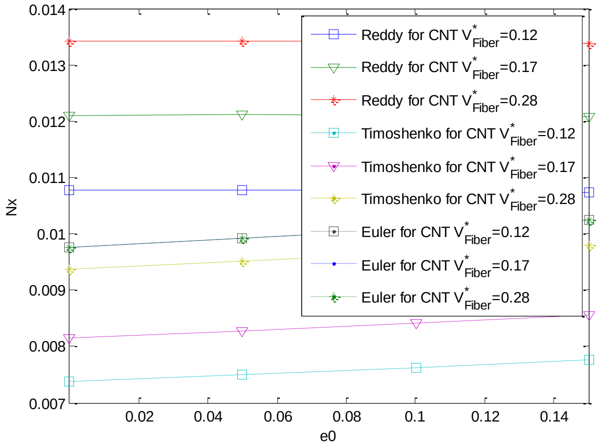

Fig. 3 The critical buckling load versus porous coefficient for different volume fraction of carbon nanotubes and various shear deformation beam theories

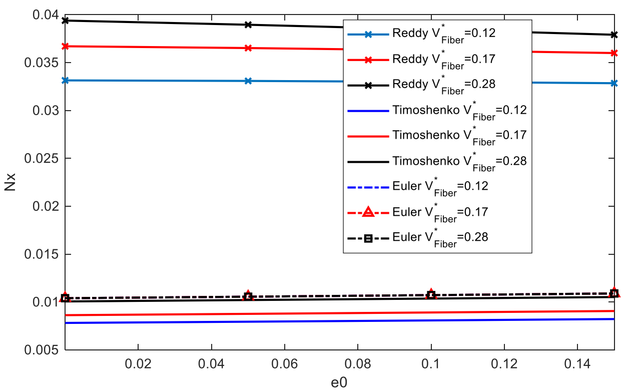

Fig. 4 The critical buckling load versus porous coefficient for different volume fraction of graphene platelets and various shear deformation beam theories

Timoshenko and Reddy beam theories. It is shown from this figure that the critical buckling load (Nx_0) with an increase in the porous coefficient (e_0) decreases, because the stiffness of sandwich beam reduces. Also, it is seen that the critical buckling load for asymmetric distribution is lower than the other cases for Euler-Bernoulli and Timoshenko beam theories; while for Reddy beam theory, the critical buckling load for symmetric distribution is lower than the other cases.

Figs. 3 and 4 depict the critical buckling load versus porous coefficient for different volume fraction of carbon nanotubes and graphene platelets, respectively. It can be seen that an increase of the volume fraction of carbon nanotubes/graphene platelets leads to enhance the stiffness of sandwich beam and then the critical buckling load increases; while the effect of graphene platelets on the critical buckling load is higher than carbon nanotubes.

Fig. 5 shows the comparison between carbon nanotubes and graphene platelets as reinforcements in composite facesheets for various beam theories including Euler-Bernoulli, Timoshenko and Reddy beam theories. It is seen that the difference between carbon nanotubes and graphene platelets for Reddy and Euler-Bernoulli beam theories is most and least, respectively.

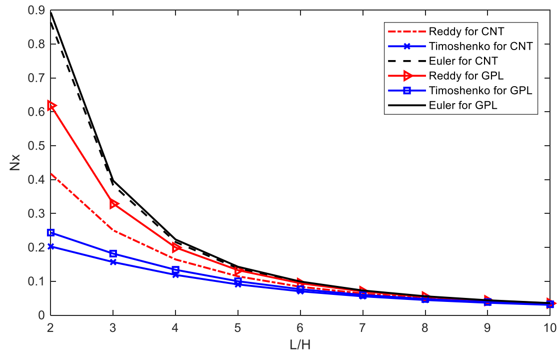

Fig. 5 The comparison between carbon nanotubes and graphene platelets as reinforcements in composite facesheets for various shear deformation beam theories

4. Conclusions

In this research, the buckling behavior of sandwich beam with composite reinforced by graphene platelets/carbon nanotubes (GPLs/CNTs) in face sheets layers using various shear deformation theories such as Euler-Bernoulli, Timoshenko and Reddy beam theories is investigated. Three type various porosity patterns including uniform, symmetric and asymmetric are investigated through the thickness direction of the core and composite face layers are reinforced with GPLs/CNTs based on Halpin-Tsai micromechanics model and extended mixture rule, respectively. The governing equations of equilibrium using minimum total potential energy are obtained. It can be seen from the figure that the critical buckling load with an increase in the porous coefficient decreases, because the stiffness of sandwich beam reduces. Also, it is shown that the critical buckling load for asymmetric distribution is lower than the other cases for Euler-Bernoulli and Timoshenko beam theories; while for Reddy beam theory, the critical buckling load for symmetric distribution is lower than the other cases. It can be seen that an increase of the volume fraction of carbon nanotubes/graphene platelets leads to enhance the stiffness of sandwich beam and then the critical buckling load increases; while the effect of graphene platelets on the critical buckling load is higher than carbon nanotubes. Moreover, it is seen that the difference between carbon nanotubes and graphene platelets for Reddy and Euler-Bernoulli beam theories is most and least, respectively.

Acknowledgment

The authors would like to thank the referees for their valuable comments. Also, they are thankful to the Iranian Nanotechnology Development Committee for their financial support and the University of Kashan for supporting this work by Grant No. 891238/21.

References

Alibeigloo, A. (2020), "Three-dimensional thermoelasticity

analysis of graphene platelets reinforced cylindrical panel", *Eur. J. Mech.-A/Solid.*, **81**, 103941. https://doi.org/10.1016/j.euromechsol.2019.103941.
Alimirzaei, S., Mohammadimehr, M. and Tounsi, A. (2019), "Nonlinear analysis of viscoelastic micro-composite beam with geometrical imperfection using FEM: MSGT electro-magneto-elastic bending, buckling and vibration solutions", *Struct. Eng. Mech.*, **71**(5), 485-502. https://doi.org/10.12989/sem.2019.71.5.485.
Anvari, M., Mohammadimehr, M. and Amiri, A. (2020), "Vibration behavior of a micro cylindrical sandwich panel reinforced by graphene platelet", *J. Vib. Control*, 1077546319892730. https://doi.org/10.1177/1077546319892730.
Babaeeian, M. and Mohammadimehr, M. (2020), "Investigation of the time elapsed effect on residual stress measurement in a composite plate by DIC method", *Opt. Laser. Eng.*, **128**, 106002. https://doi.org/10.1016/j.optlaseng.2020.106002.
Bahaadini, R. and Saidi, A.R. (2018), "Aeroelastic analysis of functionally graded rotating blades reinforced with graphene nanoplatelets in supersonic flow", *Aerosp. Sci. Technol.*, **80**, 381-391. https://doi.org/10.1016/j.ast.2018.06.035.
Bahaadini, R., Saidi, A.R. and Hosseini, M. (2019), "Flow-induced vibration and stability analysis of carbon nanotubes based on the nonlocal strain gradient Timoshenko beam theory", *J. Vib. Control*, **25**(1), 203-218. https://doi.org/10.1177/1077546318774242.
Chen, D., Kitipornchai, S. and Yang, J. (2017), "Free vibration and elastic buckling of functionally graded porous beams reinforced by graphene platelets", *Mater. Des.*, **116**, 656-665. https://doi.org/10.1016/j.matdes.2016.12.061.
Dimitri, R., Tornabene, F. and Reddy, JN. (2020), "Numerical study of the mixed-mode behavior of generally-shaped composite interfaces", *Compos. Struct.*, **237**, 111935. https://doi.org/10.1016/j.compstruct.2020.111935.
Draiche, K., Bousahla, A.A., Tounsi, A., Alwabli, A.S. and Mahmoud, S.R. (2019), "Static analysis of laminated reinforced composite plates using a simple first-order shear deformation theory", *Comput. Concrete*, **24**(4), 369-378. https://doi.org/10.12989/cac.2019.24.4.369.
Ebrahimi, F., Dabbagh, A., Rabczuk, T. and Tornabene, F. (2019), "Analysis of propagation characteristics of elastic waves in heterogeneous nanobeams employing a new two-step porosity-dependent homogenization scheme", *Adv. Nano Res.*, **7**(2), 135-143. https://doi.org/10.12989/anr.2019.7.2.135.
Ghorbanpour Arani, A.G. and Abdollahian, M. (2019), "Transient response of FG higher-order nanobeams integrated with magnetostrictive layers using modified couple stress theory", *Mech. Adv. Mater. Struct.*, **26**(4), 359-371. https://doi.org/10.1080/15376494.2017.1387326.
Jalaei, M.H. and Ghorbanpour Arani, A. (2018), "Size-dependent static and dynamic responses of embedded double-layered graphene sheets under longitudinal magnetic field with arbitrary boundary conditions", *Compos. Part B: Eng.*, **142**, 117-130. https://doi.org/10.1016/j.tws.2019.106589.
Javani, M., Kiani, Y. and Eslami, M.R. (2020), "Thermal buckling of FG graphene platelet reinforced composite annular sector plates", *Thin Wall. Struct.*, **148**, 106589. https://doi.org/10.1016/j.tws.2019.106589.
Luat, N.V., Lee, J., Lee, D.H. and Lee, K. (2020), "GS-MARS method for predicting the ultimate load-carrying capacity of rectangular CFST columns under eccentric loading", *Comput. Concrete*, **25**(1), 1-14. https://doi.org/10.12989/cac.2020.25.1.001.
Mao, J.J. and Zhang, W. (2019), "Buckling and post-buckling analyses of functionally graded graphene reinforced piezoelectric plate subjected to electric potential and axial forces", *Compos. Struct.*, 2**16**, 392-405. https://doi.org/10.1016/j.compstruct.2019.02.095.
Mohammadimehr, M., Mohammadi-Dehabadi, A.A., Akhavan Alavi, S.M., Alambeigi, K., Bamdad, M., Yazdani, R. and Hanifehlou, S. (2018), "Bending, buckling, and free vibration analyses of carbon nanotube reinforced composite beams and experimental tensile test to obtain the mechanical properties of nanocomposite", *Steel Compos. Struct.*, **29**(3), 405-422. https://doi.org/10.12989/scs.2018.29.3.405.
Mohammadimehr, M., Salemi, M. and Rousta Navi, B. (2016), "Bending, buckling, and free vibration analysis of MSGT microcomposite Reddy plate reinforced by FG-SWCNTs with temperature-dependent material properties under hydro-thermo-mechanical loadings using DQM", *Compos. Struct.*, **138**, 361-380. https://doi.org/10.1016/j.compstruct.2015.11.055.
Mousavi, M., Mohammadimehr, M. and Rostami, R. (2019), "Analytical solution for buckling analysis of micro sandwich hollow circular plate", *Comput. Concrete*, **24**(3), 185-192. https://doi.org/10.12989/cac.2019.24.3.185.
Navi, B.R., Mohammadimehr, M. and Arani, A.G. (2019), "Active control of three-phase CNT/resin/fiber piezoelectric polymeric nanocomposite porous sandwich microbeam based on sinusoidal shear deformation theory", *Steel Compos. Struct.*, **32**(6), 753-767. https://doi.org/10.12989/scs.2019.32.6.753.
Rajabi, J. and Mohammadimehr, M. (2019), "Bending analysis of a micro sandwich skew plate using extended Kantorovich method based on Eshelby-Mori-Tanaka approach", *Comput. Concrete*, **23**(5), 361-376. https://doi.org/10.12989/cac.2019.23.5.361.
Shahedi, S. and Mohammadimehr, M. (2020), "Nonlinear high-order dynamic stability of AL-foam flexible cored sandwich beam with variable mechanical properties and carbon nanotubes-reinforced composite face sheets in thermal environment", *J. Sandw. Struct. Mater.*, **22**(2), 248-302. https://doi.org/10.1177/1099636217738908.
Sobhy, M. (2020), "Buckling and vibration of FG graphene platelets/aluminum sandwich curved nanobeams considering the thickness stretching effect and exposed to a magnetic field", *Result. Phys.*, **16**, 102865. https://doi.org/10.1016/j.rinp.2019.102865.
Soleymani, T. and Arani, A.G. (2019), "On aeroelastic stability of a piezo-MRE sandwich plate in supersonic airflow", *Compos. Struct.*, **230**, 111532. https://doi.org/10.1016/j.compstruct.2019.111532.
Taherifar, R., Mahmoudi, M., Nasr Esfahani, M.H., Ashrafi Khuzani, N., Nasr Esfahani, S. and Chinaei, F. (2019), "Buckling analysis of concrete plates reinforced by piezoelectric nanoparticles", *Comput. Concrete*, **23**(4), 295-301. https://doi.org/10.12989/cac.2019.23.4.295.
Thai, C.H., Ferreira, A.J.M., Tran, T.D. and Phung-Van, P. (2020), "A size-dependent quasi-3D isogeometric model for functionally graded graphene platelet-reinforced composite microplates based on the modified couple stress theory", *Compos. Struct.*, **234**, 111695. https://doi.org/10.1016/j.compstruct.2019.111695.
Wang, Y., Feng, C., Santiuste, C., Zhao, Z. and Yang, J. (2019), "Buckling and postbuckling of dielectric composite beam reinforced with Graphene Platelets (GPLs)", *Aerosp. Sci. Technol.*, **91**, 208-218. https://doi.org/10.1016/j.ast.2019.05.008.
Yang, J., Wu, H. and Kitipornchai, S. (2017), "Buckling and postbuckling of functionally graded multilayer graphene platelet-reinforced composite beams", *Compos. Struct.*, **161**, 111-118. https://doi.org/10.1016/j.compstruct.2016.11.048.
Yazdani, R. and Mohammadimehr, M. (2019), "Double bonded Cooper-Naghdi micro sandwich cylindrical shells with porous core and CNTRC face sheets: Wave propagation solution", *Comput. Concrete*, **24**(6), 499-511. https://doi.org/10.12989/cac.2019.24.6.499.

CC