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# Experimental Investigation of Buckling Loads of Glass/Epoxy Composites Modified with Nanoparticles

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In this study, the effects of the carbon nanotubes and nanoclay particles on strength and load carrying capabilities of modified E-glass/epoxy composite plates are determined experimentally. The composite plates are modified with 0% (neat), 0.5% particle weight fractions based on the weight of composites, such as multi-walled carbon nanotubes and nanoclay. Aside from the effects of the nanoparticles, also the effects of fiber orientations such as (0°, 30°, 45°, 90°) on strength and load carrying capabilities of composite plates are determined experimentally. The addition of 0.5 wt% multi wall carbon nanotubes and nanoclay particles to composites increases the critical buckling load by almost 30% and 12%, respectively.

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PACS/topics: epoxy, e-glass, nano clay, multi-wall carbon nanotube (MWCNT), buckling load

## 1. Introduction

As a part of machine is produced from a composite material, rigid and lightweight properties will come to the fore for this part. During the service life, this part must fulfill all the duties without damage and the system must remain in stable equilibrium [1–4]. Composite plates are filled with unfilled, 5%, 10%, and 15% particle weight fractions, such as silicon carbide, which has two particle sizes, aluminum oxide, and boron carbide. The results indicate that the load carrying capability of composites are significantly influenced by particle weight fractions, different particle sizes and different ceramic particles [5]. Multiwall carbon nanotube (MWCNT) on the interfacial bond strength, flexural strength of glass-fiber reinforced epoxy (GFRE) composites showed improvement up to 30% compared to the control laminates [6].

In the present article, an experimental study has been carried out to investigate the buckling loads of glass-fiber/epoxy composite modified with 0.5wt% of MWCNT and nanoclay (NC) particles. Beside of the effects of nanoparticles, the effects of fiber orientations such as (0°, −30°, −45°, −90°) on strength and load carrying capabilities of composite plates are determined experimentally. As a comparison, the buckling loads of neat glass-fiber/epoxy composites are also evaluated under identical test conditions.

## 2. Materials and methods

The materials used were glass-reinforced composites based on epoxy resin. The epoxy resin was a standard diglycidyl ether of bisphenol A (DGEBA) and araldite LY 1564 supplied by Huntsman, Switzerland. The E-glass fibre fabric was a unidirectional fabric 0° pattern with an areal weight of 330 g/m$^2$ and 1200 TEX from Huntsman, Switzerland. The COOH functionalized MWCNTs had an outer diameter of 10–20 nm and length of 0.5–2 $\mu$m. Nanomer NCs Esan nono 1–140 was provided by Eczacibasi Inc, from Istanbul, Turkey. The nanoparticle modified E-glass/epoxy composite plates were fabricated with size of 300 mm × 500 mm as eleven layers at Fibermark Inc., Izmir, Turkey. A weighed amount of the particles was ratio of the weight of the particles to the total weight of the modified epoxy. After incorporating the particles and hardener into the resin, the mixtures were thoroughly mixed for 30 min using Hielscher UP400S sonicator, at 70% amplitude and 0.6 cycles. For preparation of modified composite laminates, eleven layers of E-glass fabrics were put on a table with smooth surface and impregnated by hand successive plies, with mixture resin. The neat E-glass/epoxy composite plate was also fabricated in the same manner. Finally, each composite plate was cured at 130 °C and 8 bar pressure in hot press for 2 h. The nominal thickness of the composite plates was measured as 2.4 mm. The tensile and buckling load test specimens were cut from the fabricated composites by water jet. The dimensions of the test specimens are 20 × 200 mm$^2$, as seen in Fig. 1.

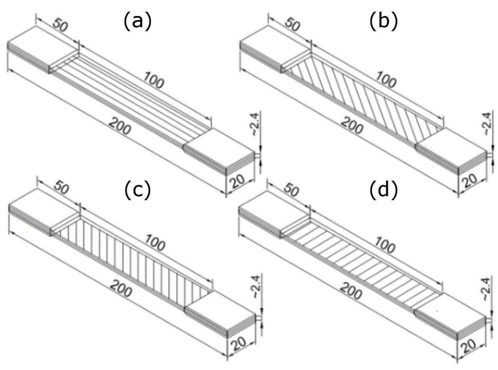


Fig. 1. The geometry of specimens: (a) 0° direction, (b) 30° direction, (c) 45° direction, (d) 90° direction. All dimensions are in mm.

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The tensile tests and critical buckling loads of neat and modified E-glass/epoxy composite plates were determined experimentally. Firstly, the tensile tests were performed according to the ASTM D3039 standards [7] with computer-controlled Instron 8801 Tensile Testing Machine. Composite specimens were prepared, as shown in Fig. 2. Test speed was preferred as 0.5 mm/min. The tensile tests results were presented in Table I.

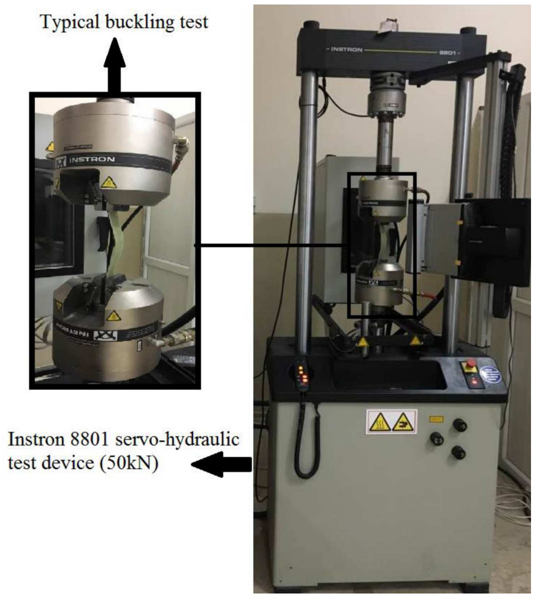


Fig. 2. Experimental setup of Instron 8801 for buckling test.

TABLE I

The tensile strength of composite laminates.

| Fiber orientation angles [°] | Neat [MPa] | E-glass/epoxy/ NC [MPa] | E-glass/epoxy/ MWCNT [MPa] |
|---|---|---|---|
| 0 | 650 | 779 | 795 |
| 30 | 139 | 142 | 145 |
| 45 | 107 | 108 | 112 |
| 90 | 84 | 87 | 95 |

The buckling test samples were tested by applying compression loads in fibers direction using Instron 8801 model Tensile-Compression Testing Machine of 50 kN load capacity.

For axial loading, test samples were placed between two stiff machine heads, of which the upper one was fixed during the test, whereas the lower head was moved upwards by servo hydraulic cylinder. The samples were clamped at 50 mm distance from the top and bottom edges by wedge grips (as seen in Fig. 1). That is why effective buckling length is 100 mm. All test samples were loaded until buckling at a constant compressive speed of 0.5 mm/min. For each neat and modified composites, three identical samples were tested and average results were reported. A buckling photo of a composite sample is shown in Fig. 2. The critical buckling load of each composite was determined. The comparative load value Fig. 3a and elasticity of modified and neat composites are shown in Fig. 3b.

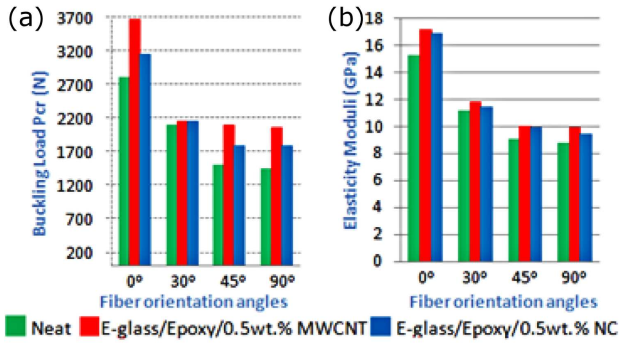


Fig. 3. The critical buckling loads (a), elastic properties (b) of neat and modified E-glass/epoxy composites.

## 3. Results and discussion

The elastic properties of the E-glass/epoxy composites modified with nanoparticles, having particle weight fractions of 0.5 wt%, are determined, and then the critical buckling loads of the modified composite plates are investigated experimentally. In the following, MWCNT and NC particles on the elastic properties and on the buckling loads of the composite are presented and discussed.

The E-glass/epoxy/0.5wt% MWCNT composite plate in the axial direction (0°) has the highest buckling load, as seen in Fig. 3. Compared to the buckling load, the difference between the neat and MWCNT, NC additive composites is 30% to 12% in the axial direction (0°) composite plates. It is a decrease in the critical buckling load by increasing the fiber orientation angle from 0° to 90° degrees. These reduction rates vary slightly with the addition of nanoparticles. In the study, the proportional changes in critical buckling loads of composite plates with different orientation angles (0°, 30°, 45°, 90°) are shown in Table II.

TABLE II

Proportional changes of critical buckling loads, $P_{cr}$, of composites with different orientation angles.

| | Buckling load $P_{cr}$ [N], (% proportional change, − decrease, + increase) | | | |
|---|---|---|---|---|
| Fiber orientation angles | 0° | 30° | 45° | 90° |
| E-glass/epoxy | 2812 | 2097, (−25) | 1510, (−46) | 1480, (−47) |
| E-glass/epoxy/NC | 3163, (+12)* | 2158, (−32), (+3)* | 1798, (−43), (+20)* | 2120, (−33), (+43)* |
| E-glass/epoxy/MWCNT | 3674, (+30)* | 2168, (-41), (+3.3)* | 2093, (-43), (+38)* | 2110, (-42), (+42)* |

*Proportional change in each orientation angle depending on the values of E-glass/epoxy composite.

## 4. Conclusion

It is concluded that the elasticity moduli and load carrying capability of composites are significantly influenced by MWCNT and NC particles. In general, the addition of MWCNT particles to composites increases the elasticity and load carrying capability of composites. Accordingly, all composites with 0.5 wt% MWCNT modifier have maximum elasticity values and the best ability to resist buckling load. It is concluded that MWCNT and NC particles creates a positive effect on the buckling load carrying capability of the composites. It is also concluded that the addition of 0.5 wt% MWCNT particles to composites increases the critical buckling load value of composite by almost 30% while the increase is almost 12% for NC, compared to value of neat composite.

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