**8th. World Congress on Computational Mechanics (WCCM8)**
**5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)**
**June 30 – July 5, 2008**
**Venice, Italy**

# Static Response of a Spindle-Shaped Tensairity Column under Compression: A Numerical – Experimental Study

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**Key Words:** *Inflatable Structures, Tensairity, Fabrics, Buckling, Full Scale Testing.*

## ABSTRACT

The reduction of structural weight, while considering the appropriate safety regulations, has always been a challenge in structural mechanics. Inflatable textile structures made up of plain-woven fabrics (polyester, glass, aramide or carbon fibers coated by PVC, rubber or Teflon) have been used in the past four decades in several applications, since they combine very low weight with low storage volume, ease to deploy and enhanced damping. In addition, the capability of tailoring their static and damped dynamic response via weave angle and internal air pressure indicate their promising potential towards adaptivity. However, the major shortcomings of airbeams lie on poor load bearing capacity. Minor bending rigidity and inability to carry compressive loads lead to instabilities, such as wrinkling. Thus, the application of a large air pressure is inevitable in order to maintain some bending stiffness.

Tensairity [1] is a lightweight structural concept consisting of struts and cables stabilized by a textile membrane, which is inflated by low pressurized air. Thus, it yields a drastically improved load bearing capacity compared to conventional airbeams. Since up to date applications of Tensairity include bridge and roof structures, the static response of such beams under bending loads has been numerically and experimentally studied [2].

In order to estimate the potential of Tensairity towards applications including axial compressive loads, full-scale compression experiments were conducted on a simply-supported spindle-shaped Tensairity column (Fig. 1). The column consisted of a pneumatic hull and three aluminium struts placed symmetrically along the circumference. Measured displacements and in-plane strains along the span, as well as, buckling loads and respective mode shapes for various internal pressure levels were compared to those predicted by a commercial finite element code. The finite element model developed (Fig. 2) included 4-noded membrane shell finite elements for the hull and 2-noded Timoshenko beam finite elements for the struts. Linear elastic orthotropic material properties for the inflated fabric were taken into account, whereas the solution was geometrically non-linear. Both measurements and numerical solution took place in two stages: 1) inflation of the column and 2) application of axial compressive loading.

Fig. 1: Experimental configuration.

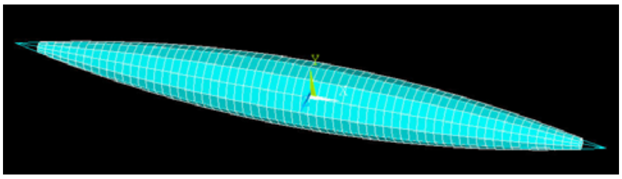


Fig. 2: Finite element model.

Fig. 3 illustrates measured radial displacements of the three struts near both edges of the column for variable internal air-pressure levels. The asymmetrical behaviour observed is enhanced in higher air-pressure levels and leads to higher deviations between measured and predicted load-displacement curves, as illustrated in Fig. 4, where the effect of internal pressure on the slope of the load-axial displacement curve at the column's tip is presented. Measurements and finite element results were also compared to predictions of an analytic model [3] describing the response of a circular arch on an elastic foundation subjected to axial compression, where k is the modulus of the foundation for the case studied.

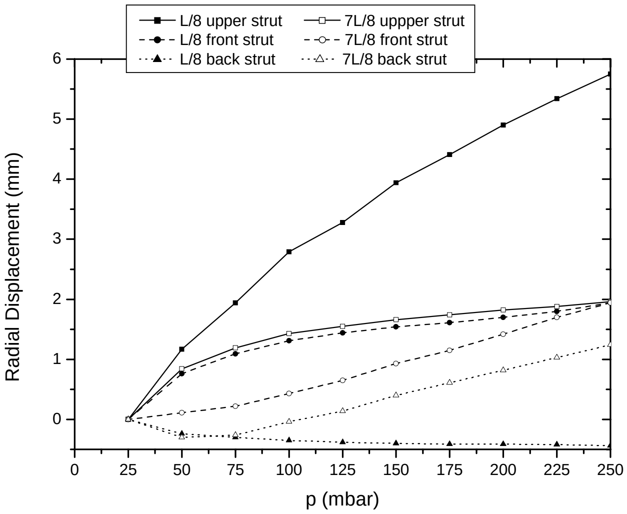


Fig. 3: Measured radial displacements near the edges during inflation.

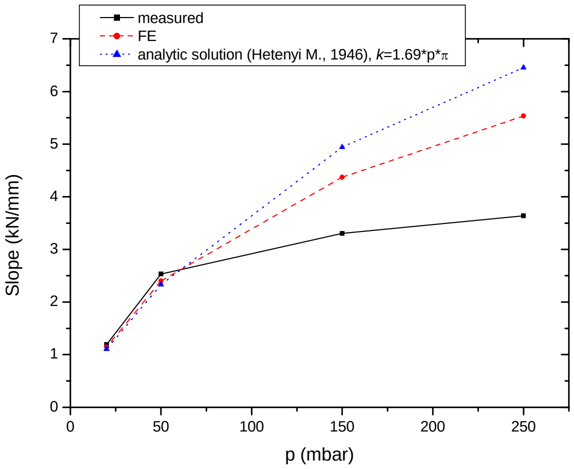


Fig. 4: Effect of internal pressure on slope of load-displacement curve at the tip.

Fig. 5 shows predicted and measured buckling loads for various pressure levels. Typical predicted and measured buckling mode shapes of the column are shown in Figs. 6a and b, respectively. It seems that the asymmetries occurring near the edges lead to local mode shapes and lower buckling loads than the ones predicted.

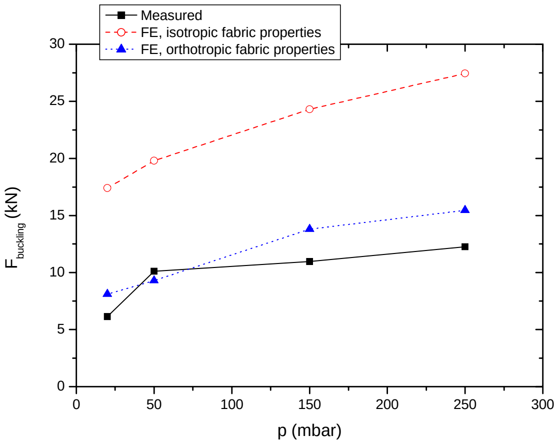
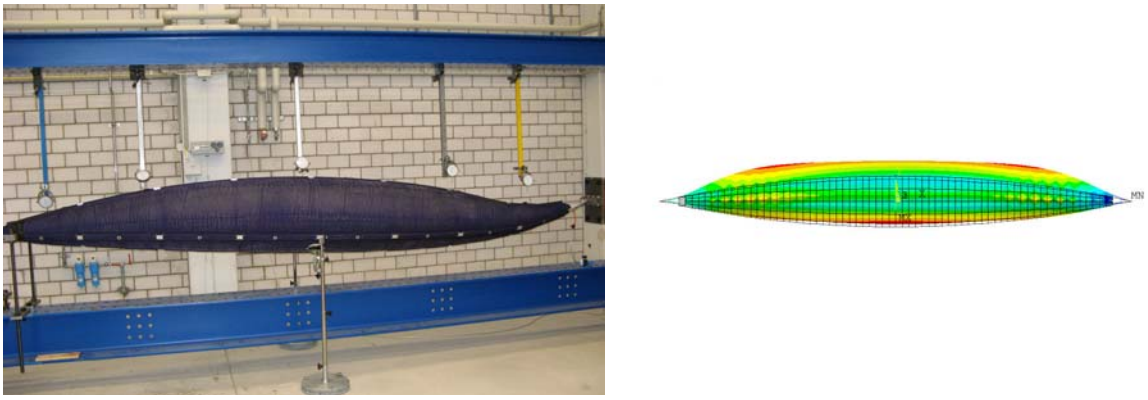


Fig. 5: Effect of internal pressure on buckling load.



a) b)

Fig. 6: Buckling mode shape by an air-pressure of 250mbar: a) Experimentally determined, b) Predicted.

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