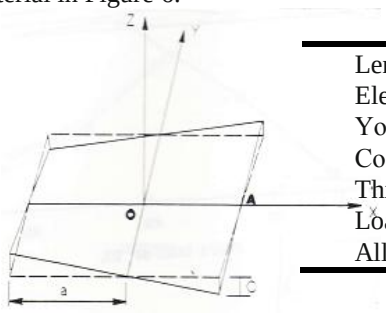
3.2. Hyperbolic paraboloid shell under uniform pressure.

We consider a section of semi-thin hyperbolic paraboloid shell (2a/h=52) with embedded (clamped) straight edges subjected to a uniform normal pressure. We show the geometrical data and mechanical properties of the material in Figure 6.



Length (2a)	12.92
Elevation (C)	1.304
Young's Modulus (E)	5.10^5
Coefficient of Poisson (υ)	0.39
Thickness (h)	0.25
Load (Normal Pressure q)	-1.0
All edges of shell are clamped	

Figure 6. *Clamped Hyperbolic paraboloid shell under uniform pressure*

The structure is not symmetrical. It is necessary to mesh the entire shell. The aims of the present example is to see the ability of our element to model double-curved structures. The present example is slightly dominant bending. We present the results of the study in the Figure 7. The figures characterize the deflection at the centre as a function of the total number of degrees of freedom for different meshes. We compare our results with the analytical solution given by Chetty and Tottenham [CHE 64] and with thus the numerical given by Guenfoud [GUE 90, 96] and by Bentaher [BEN 81]. We note a good non-monotonically convergence of the results of our element towards the analytical solution.

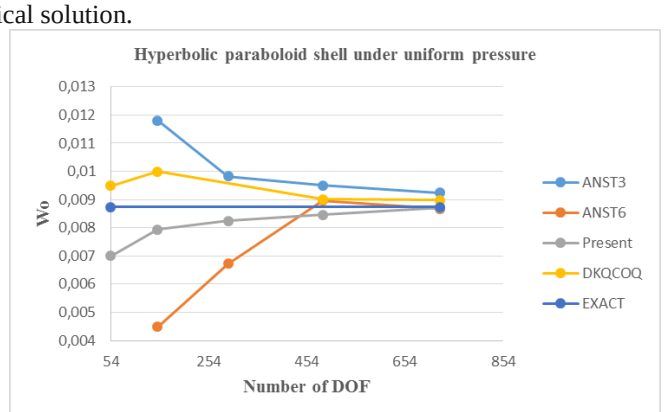


Figure 7. *Displacement at the center of the shell*

4. Conclusion.

The formulation of a flat triangular thin shell element with a true rotation based upon the strain approach has been successfully developed and presented in this communication. The three translational displacement (U, V, W) are each described in terms of cubic polynomial functions. The use of equal-order fields for all displacements has the effect of approximating further strictly the rigid body motion condition. The present formulation was demonstrated to be consistent in a very wide variety of linear analysis situations. A series of test problems were conducted to evaluate the efficiency of the element compared to other elements in the literature. The results obtained confirmed the fast convergence rate of the element. The proposed element has the advantage of being simple in form and uses the six degrees of freedom. Further, it can be used for the analysis of thin shell structures, even those with complex geometries

5. References

[HIM 15] Himeur, M., Zergua, A., & Guenfoud, M. (2015). A Finite Element Based on the Strain Approach Using Airy's Function. Arabian Journal for Science and Engineering, 40(3), 719-733.

[HIM 14] Himeur, M., Benmarce, A., & Guenfoud, M. (2014). A new finite element based on the strain approach with transverse shear effect. Structural Engineering and Mechanics, 49(6), 793-810.

[HIM 11] Himeur, M., & Guenfoud, M. (2011). Bending triangular finite element with a fictitious fourth node based on the strain approach. European Journal of Computational Mechanics/Revue Européenne de Mécanique Numérique, 20(7-8), 455-485.

[HIM 08] Himeur, M. (2008). Développement d'éléments membranaires nouveaux d'élasticité plane basés sur la formulation en déformation (Doctoral dissertation, Thèse de magistère, Université de Guelma (Algérie), Département de Génie Civil.