

## **Rotation-Free Beam and Shell Models for Geometric Nonlinear Analysis of Thin Shells**

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### **Summary**

In this paper, new rotation-free beam and shell models are presented. Unlike the finite element models, rotation-free models employ integration domains which are smaller than the domains of influence. Hence, they are sometimes known as overlapping elements. The present linear straight beam and plate models are the same as those of Phaal & Calladine in the sense that quadratic interpolation are employed to construct the transverse deflection. Nevertheless, Phaal & Calladine turned to a hinged-angle approach for the linear curved beam and shell models and did not present the geometric nonlinear models. In our formulation, the linear curved beam and shell still employs the interpolatory approach which is simple and physical yet their accuracy is competitive to the existing rotation-free models. Using the corotational framework and the small membrane strain assumption, the large displacement/rotation extensions of the linear beam and shell are formulated. When the beam/shell is initial straight/flat, the salient feature that the tangential bending stiffness matrix is constant can be derived. On the other hand, when the beam/shell is initially curved, the tangential bending stiffness matrix becomes complicated. However, the constant approximation, which becomes progressively less erroneous as the mesh is refined, only induce minimal adverse effect on the convergence. By combining the bending stiffness with the axial or inplane stiffness arising from the two-node truss or the three-node triangular membrane finite element, geometric nonlinear engineering beam/shell and fabric drape problems can be considered, see Figure 1 for instances. For the former problems, the predictions are favorable. For the latter problems, the draped patterns appear to be realistic and conform to our daily perception. Additional examples can be found in Reference.

