APPLICATION OF A NONLINEAR CABLE FINITE ELEMENT IN LARGE DISPLACEMENT ANALYSIS

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This paper utilises a newly proposed nonlinear cable finite element and describes its application on various load cases with large displacements. This element was developed to capture large displacements in Cable Structures (CS). The load – deflection response of these types of structures usually shows stress – stiffening effect. Since displacements are very large we cannot use small deflection theories and superposition to analyze CS. Even though large displacements are considered, deriving the closed form solution of a field variable (displacement, strain... etc) for an arbitrary loading would be possible in a few cases only.

It is clear that we have to go for a high accuracy numerical technique, such as Finite Element Method, to solve for field variables in CS. Already existing small displacement finite element such as frame elements cannot handle problems with almost zeroed bending stiffness. We selected full nonlinear axial strain to define the mathematical model of the proposed cable finite element. This strain model can capture large displacements in CS even without introducing bending stiffness.

Total Lagrangian approach was used in the theoretical formulation of this nonlinear continuum mechanics problem. Full nonlinear axial strain, nodal displacement vector and shape function matrix were used to formulate the total potential energy of the system. Minimizing this potential functional using calculus of variations leads to the closed form solution of element secant stiffness.

In the solution procedure, resulting system of nonlinear equations are solved by using second order Newton's method considering Kuhn – Tucker necessary condition. This optimization procedure successfully works for root finding technique with secant as well as tangent stiffness and Hessian. This proposed nonlinear cable finite element was tested on four different load cases and results are compared with SAP2000 frame elements with P-delta effect solution. The percentile errors, with the finite element and exact solutions show that the newly proposed element gives better approximation than SAP2000 element.