E04

Large displacement beam and its application to dynamic soil-structure interaction analysis

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1. Motivation and Objective

In January 12 of 2007, a crater suddenly took the place of what was Conselheiro Pereira Pinto street in Sao Paulo, Brazil. The accident happened during the rainy season, at the construction site of the Sao Paulo Metro. A numerical analysis to predict and avoid such a disaster would have to account for large displacements. The scope of this work is to formulate a beam element that accounts for large displacements and for the buckling one might expect to occur in such soil-structure interaction analysis.

2. Total Lagrangian formulation

Two of the possible finite element formulations were implemented, namely: a Total Lagrangian formulation for small rotations (TLsmall) and a Total Lagrangian formulation for finite rotations (TLfinite).

3. Buckling analysis

A series of situations that are conducive for the calculation of the critical buckling load were prepared, and analysis were run. The main indicator that buckling has occurred is the appearance of moment.

This buckling analysis seems to indicate that buckling behavior is accounted for by these formulations, and that soil-structure interaction can be adequately represented by them.

4. Assumption analysis

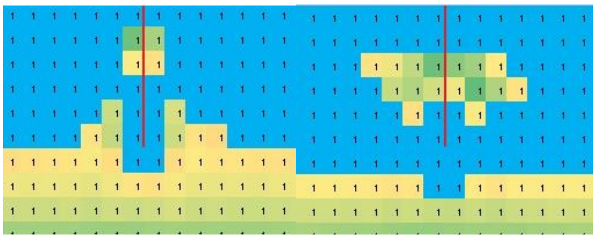
As an aside, this work presented the unexpected opportunity to evaluate one of the premises that is brought up during the formulation of geometrically linear beam elements: namely, that its cross-sections do not warp.

Several analyses were run with meshes composed of plane elements, for different loading conditions. These analyses showed that, for most purposes and uses, cross-sections remain straight. Furthermore, a new question is posed by this analysis: the question of the absence of a quantifiable measure of section warping.

5. Soil-structure interaction analysis

Two soil-structure interaction analyses - Sheetpile analyses - were run in order to verify the applicability of proposed formulations to a full-blown analysis. Also, comparisons were made between results of the same analysis, but with different formulations attached to the beam elements.

Results indicate that the use of large displacement formulation in beams can drastically alter the results obtained in the analyses, not only in the beam itself, but also in surrounding elements (see Fig. 1). A few unexpected insights were also obtained into the nature of the difference between large displacement formulations and infinitesimal formulations.



(a) (b)

Fig. 1 - Comparison of liquefaction of surrounding elements for infinitesimal and TLfinite fomulations of beam.