C2. Why performing non-linear calculations

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As in many areas of physics, it is only reasonable to undertake a non-linear calculation after having a good idea of the "end of the story". In other words, how the structure will evolve until it becomes unstable. Below are presented the good and more questionable reasons for undergoing non-linear calculations.

1. **Good reasons**

- To study the **effort redistribution**. When some parts of a structure enter the plastic phase, the stress level “freezes” to a determined value. The work of external forces can only be dissipated by increasing the stress level somewhere else or by making matter flow from other zones that are already in the plastic phase. The goal here is to verify in which order the structural elements “fail”, and to find the final failure mechanism.
- To determine **the evolution of support conditions of a structure**, either by a contact computation or by developing internal plastic joints.
- Before reaching a state where the efforts are redistributed, **to obtain an equilibrium state** where, in the plastic zones, the stresses are on average close to the yield stress of the material and the stresses are in the elastic domain elsewhere. For **geomaterials**, to obtain an equilibrium state where the stresses are purely compressive, except for some punctual zones (**eliminate tensile stresses**).

These procedures are reasonable, because:

- Generally, they can be conducted in a small deformation framework,
- They allow simplifying the model and the interpretation of the structure’s mechanics: since the plastic zones have no structural purpose anymore, a weakening analysis of the structure via a succession of elastic calculations can be proposed, which will “deactivate” the plastic zones at some stress levels. The analysis of the plastic zones can also suggest a static approach to the plasticization (strut and tie model).

2. **Questionable reasons**

- To determine the shape of the structure in response to large deformations (even while “exploding”), eventually using an automatic re-meshing algorithm provided by the software,
- To see if it is worth performing calculations with a behavior that seems very complete from a descriptive point of view, or if elastic calculations performed previously give better results.

Those motivations often end up leading to non-convergence or “zero-pivot” problems. When the calculation is interrupted at a given stage of the iterative process, the deformation of the structure (given by the deformation of the mesh, or the strain field) is misleading:

- The deformations are in general superior to 1%, so at this stage, the mechanical problem is no longer expressed with correct variables,
- The calculated deformation depends critically on the meshing. It means that for two different meshes initially close, one can obtain very different local deformation values,
- The calculation “follows”, by definition, one instability at a time; however, the large displacement problems are by its nature multi-branched. In other words, in a certain state, there are several possible equilibrium configurations for a given loading...

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