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USING AXIAL FORCE ITERATIVE INTEGRATION IN PLASTIC ZONE INELASTIC ANALYSIS

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ABSTRACT

Nowadays the structural design practice requires more sophisticated and also complicated solutions, which need more assurance in defining the overall capacity of the structure or a more precise knowing of the structural behavior. However, plasticity consideration includes difficulties as the unavoidable simplifications in the formulations which can lead to unwanted path following divergence. The inelastic second-order analysis of steel structures [1] needs a predictor-corrector incremental-iterative strategy, and this requirement is very hard to apply when adopting plastic zone approach. Even in small structures, like plane frames, the memory requirement and the process time come to be very high.

In the *Advanced Analysis* concept, the engineer must consider the plasticity spread, the technology of materials, the unavoidable differences on the construction and erection, and so forth, in the models. The challenge design question is to capture the stability measure correctly. *Advanced Analysis* is considered the most precise way to capture the whole stability behavior of the structure [2]. Also, any kind of rational analysis must recognize that buckling phenomena occurs first than plasticity mechanism formation, as the laboratory tests and theory confirmed, and this is a code requirement [3], so the precise capture of the “inelastic” limit load is very important.

When plasticity appears in *Plastic Zones* (PZ) approaches, the finite element response can be sometimes inadequate for the Newton-Raphson process [4] because the equilibrium state can be broken at element level, and the numerical solution process is forced to capture and accommodate these discrepancies into a minimum displacement adjustment, which increase the number of iteration cycles to satisfy the convergence criterion.

This paper applies the elastic-plastic beam-column section equilibrium [5] to correct the changes in the internal forces when occurs unequal plasticity at FE level, at the element ends, which is the general case. This process tries to obtain the residual axial load defined by stress integration in an iterative way. Figure 1 shows that when some stress

at the section becomes higher then yield stress ($F_2 > F_y$, see Fig. 1b), at one incremental step, it must be reduced to F_y. Now, as shown in Fig. 1d, if some FE has a PZ at node A, while the section remain elastic in node B, the usual axial integration process gives $N_a \neq N_b$, leading to a correction force which applies dN/2 at nodes A and B. So the half difference, which was only originated at node A, is imposed also at node B generating an incorrect definition of stress and strain which will increase in each cycle.

The proposed axial force iterative integration process tries to re-equilibrate the FE forces. This is made including a new axial deformation ($d\varepsilon_a$) at the node A, represented in Fig. 1f, where the over yielded stress is reintroduced iteratively in the diagram to correct it in such way that dF becomes negligible (see Figs. 1b and 1c). This process has been used to solve several inelastic second order analysis benchmark problems [1] showing good agreement with those of the literature.

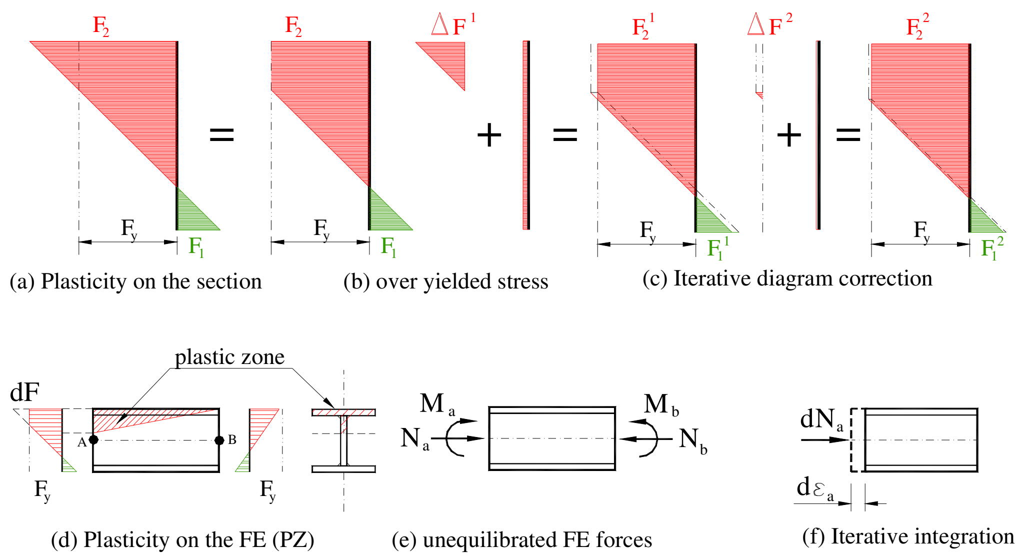

Figure 1 – Plastic zone axial force iterative integration process.

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