Fast Nonlinear Analysis (FNA)

**Fast Nonlinear Analysis (FNA)** is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems. Because of its computationally efficient formulation, FNA is well-suited for time-history analysis, and often recommended over direct-integration applications. During dynamic-nonlinear FNA application, analytical models should:

- Be primarily linear-elastic.
- Have a limited number of predefined nonlinear members.
- Lump nonlinear behavior within link objects.

In addition to nonlinear material force-deformation relationships, these link objects may simulate concentrated damping devices, isolators, and other energy-dissipating technologies. If fuse mechanisms are not integral to the design intention, an initial elastic analysis may reveal locations where inelasticity is likely to occur. However, it is always best to predefined inelastic mechanisms such that their design may provide for sufficient ductility, while elastic systems are ensured sufficient strength. Capacity Design provides for a more reliable model and a better-performing structure.

The efficiency of FNA formulation is largely due to the separation of the nonlinear-object force vector $R_{NL}(t)$ from the elastic stiffness matrix and the damped equations of motion, as seen in the fundamental equilibrium equation of FNA, expressed as:

$$Mu(t) + Cu(t) + Ku(t) + R_{NL}(t) = R(t)$$

Stiffness- and mass-orthogonal Load-Dependent Ritz Vectors represent the equilibrium relationships within the elastic structural system. At each time increment, the uncoupled modal equations are solved exactly, while forces within the predefined nonlinear DOF, indexed within $R_{NL}(t)$, are resolved through an iterative process which converges to satisfy equilibrium. Following this procedure, FNA is an efficient and accurate dynamic-nonlinear application which satisfies equilibrium, force-deformation, and compatibility relationships.

**FNA application process**

Fast Nonlinear Analysis (FNA) may be implemented within SAP2000 using the process described in the FNA application process article.

**See Also**

- FNA application process article