Nuclear Reactor Foundation Shakedown Analysis

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Abstract

A two-dimensional finite element shakedown analysis of the foundation of a nuclear reactor containment structure is presented. The containment shell and base mat are modelled by equivalent plane strain elastic elements. The soil is represented by a two-phase medium; Biot's formulation for the mechanics of deformation of fluid-saturated porous solids is used. Darcy's law for fluid flow and the Drucker-Prager yield condition for the solid skeleton are assumed. The effects of energy dissipation into the porous soil medium are taken into account by incorporating the standard viscous boundary.

For foundations subjected to nonproportionally time-dependent loads varying within prescribed limits, classical limit theorems can give unsafe estimates of the collapse loads, as failure can occur at loads well below the static collapse values. Shakedown theorems, which are generalisations of the limit theorems, provide appropriate bounds for complex loadings. The approach, which is a combination of dynamic finite element analysis and linear programming, determines whether the system shakes down to a purely elastic behaviour or undergoes incremental or repeated plastic yielding leading to failure.

The nonlinear formulation for the foundation is adapted to linear programming by piecewise linearisation of the yield surfaces. The solution is based on the elastic dynamic response of the medium for prescribed initial conditions and the derived static characteristics of the system, which define the plastic strain - self equilibrated stress relationship (influence matrix). The problem is treated as a parametric linear complementary one and solved to obtain a shakedown load factor. A specially developed computer code is used to determine the sensitivity of this factor to parametric variation of the soil properties.