CORRECTION FACTORS INCLUDING NONCLASSICAL NATURE OF SOIL- STRUCTURE INTERACTION SPECTRAL ANALYSIS

Farhad BEHNAMFAR
Department of Civil Engineering, Isfahan University of Technology, Esfahan, Iran
farhad@cc.iut.ac.ir

Hossein ALIBABAEI
M.Sc. Student, Department of Civil Engineering, Isfahan University of Technology, Esfahan, Iran
h.alibabaie@gmail.com

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The problem of non-classical dynamic analysis of structures resting on flexible bases is studied in this paper. Because of presence of the underlying soil in the dynamic model of structure that acts like an energy sink, the damping matrix is not proportional to structural mass and stiffness and theoretically a non-classical approach should be followed in modal analysis. This results in dealing with complex numbers that are not desirable for structural engineers. For the same reason, usually the nonclassical analysis is given up with the hope that it is not an unconservative approach. In this paper through a vast case study analysis, first the range of the acceleration spectrum where the nonclassical analysis makes a sensible difference with the classical spectral analysis of soil-structure systems is recognized. Then a correction factor is derived that easily modifies the results of a classical analysis to account for the nonclassical feature of the system.

For the purposes of this study, special steel moment frame structures being 1, 2, 4, 6, ..., 18 and 20 story building, two types of soils, and several suits of ground motions each containing 10 earthquake records especially selected for each building are included to make for generality of the results. The residential buildings are designed according to ASCE7-10 (ASCE 7-10, 2010). The seismicity of the region is considered to be very high with the effective peak acceleration at the ground surface to be 0.35g.

Three cases are considered: fixed-base buildings with classical analysis, flexible-base buildings with classical and with non-classical analysis. The equations of motion of structures resting on flexible soils are derived and decomposed into its nonclassical modal components with the use of substructure method. It is supposed that the supporting medium possesses a horizontal as well as a rotational DOF, and the input motion in the presence of structure is assumed to be identical to the free-field motion, disregarding as usual the kinematic interaction that is only important for very high frequency motions or structures being very long in plan. A multistory structure on flexible soil subjected to a horizontal ground motion is shown in Figure 1.

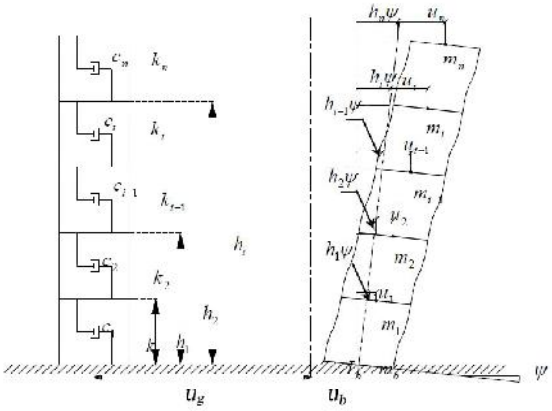

Figure 1. The multistory structure on flexible soil under a horizontal ground motion

The equations of motion of the system of Figure 1 can be written as follows:

$$[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = -[M]\{r\}\ddot{u}_g(t) \quad (1)$$

In the above equation, [M], [C] and [K] are matrices of mass, damping, and stiffness of the combined soil-structure system and $\{U\}$ and $\{r\}$ are the structural relative displacement vector and the influence vector of the ground acceleration $\ddot{u}_g(t)$. The soil flexibility is modeled using a spring and damper for each degree of freedom at the foundation. Stiffness and damping coefficients of the springs and dampers are calculated according to the recommendations of ASCE 41 regulations (ASCE/SEI, 41-13, 2013) and Gazetas (Gazetas, 1991).

The seismic responses, including base shear, roof displacement and maximum story drift, are calculated using time history and spectral analysis. It is shown that the code-based soil-structure interaction (SSI) analysis for the fundamental mode, according to ASCE 7, is not always safe. On each soil type, it is made clear that when the true non-classical nature of the SSI system must be accounted for and an equivalent classical modal analysis for such a non-classical system is presented deriving an equation for a correction factor.

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