ABSTRACT

The objective of the present dissertation that has been written for partial fulfilment of the requirements of the post-graduate program on “Earthquake Resistant Design of Structures” is the investigation of simplified modelling and analysis procedures for including the effects of interaction between a structure and the supporting soil in order to apply nonlinear static analysis methods. A series of analyses are carried out for a five-storey moment frame as well as for a five-storey dual system. The parameters taken into account are (a) the type of the soil, b) the way of modelling the soil's flexibility (incl. the fixed base model), and c) the type of foundation (isolated footings, foundation beams).

The fixed base modelling assumption is inappropriate for many structures. A first step to a better approximation of reality partially addresses the flexible foundation effect through guidance on including the stiffness and strength of the geotechnical (soil) components of the foundation in the structural analysis model.

In the present investigation, the introduction of the flexibility of the soil-foundation system is accomplished by using two different methodologies. The first one is based on the well-known Winkler hypothesis, which assumes the soil to be made up of continuously distributed, non-interconnected discrete springs. The other and more realistic one consists in simulating the foundation-supporting soil by an appropriately fine finite element mesh. For comparison, the fixed base modelling approach is also carried out in addition to these two modelling cases.

Several parametric analyses are performed using simple 2D one-storey moment frames for three different categories of foundation soil (A, B and C according to the Greek Seismic Code EAK2000) and two types of foundation (isolated footings, foundation beam). The purpose of these analyses was to evaluate the various relations that can be found in the literature for the calculation of the coefficient of sub-grade reaction (or embedment factors), in order to select the most effective one for use in Winkler model analyses. The evaluation is carried out on the basis of best convergence between the results of these analyses (in terms of displacements and stresses) and the results obtained by simulating the foundation-supporting soil by a finite element mesh.

The design of the superstructure for the five-storey moment frame and the five-storey dual system resulted from analyses using the finite element program SAP2000 under the assumption of a fixed base. The foundation is designed on the basis of modern codes’ provisions and concerns only the determination of its dimensions in ground plan. In the present study, two types of shallow foundation were investigated, isolated footings and foundation beam.

The *nonlinear static analysis* is carried out using the finite element program SAP2000.The simulation of the inelastic behavior of the structural elements is estimated automatically by the program. The inelastic behavior of the shear wall is determined by analysing its cross-sections with the program XTRACT, complying with the appropriate nonlinear constitutive laws for concrete and steel. From the above procedure moment-curvatures (M-φ) diagrams are obtained for the cross-sections of the wall. These diagrams are then converted to moment-rotation (M-θ) diagrams, which are imported into the program SAP2000.

The comparisons between the buildings are carried out with regard to seismic behavior terms. For this purpose, pushover curves, plastic mechanisms and target displacements are calculated in accordance with Eurocode 8, using the design spectrum of the Greek seismic code. Moreover, comparisons between the results of all these analyses and those obtained in a

parallel dissertation on the same topic by postgraduate student Petrou Evangelia are implemented.

Finally, the main conclusions from the work accomplished in this dissertation are presented, which mainly involve the influence of soil-structure interaction in the seismic response of the structures. As it resulted from the analyses of the dual systems, structural systems that incorporate stiff vertical elements for lateral resistance can be particularly sensitive to even small base rotations and translations that are neglected with a fixed based assumption. Compared with the fixed-base modelling approach, the predicted period of the structure lengthens the distribution of forces among various elements changes and the sequence of inelasticity can change.

Furthermore, the fixed-base modelling assumption as well as the simulation of flexible foundation by the Winkler model are evaluated by comparison to the more precise solution achieved by using a finite element mesh for the foundation-supporting soil. The Winkler simulation constitutes a realistic evaluation of the probable structural behaviour and performance for relatively stiff soils, as types A and B of the Greek Seismic Code. On the contrary, in more flexible soils, as type C, the Winkler simulation should be applied with great concern, as it does not attribute realistically the seismic behaviour of the structure.