# Chapter 19
# SOIL–STRUCTURE INTERACTION FOR SEISMIC DESIGN

## 19.1 GENERAL

If the option to incorporate the effects of soil–structure interaction is exercised, the requirements of this section are permitted to be used in the determination of the design earthquake forces and the corresponding displacements of the structure if the model used for structural response analysis does not directly incorporate the effects of foundation flexibility (i.e., the model corresponds to a fixed-based condition with no foundation springs). The provisions in this section shall not be used if a flexible-base foundation is included in the structural response model.

The provisions for use with the equivalent lateral force procedure are given in Section 19.2, and those for use with the modal analysis procedure are given in Section 19.3.

## 19.2 EQUIVALENT LATERAL FORCE PROCEDURE

The following requirements are supplementary to those presented in Section 12.8.

### 19.2.1 Base Shear

To account for the effects of soil–structure interaction, the base shear ($V$) determined from Eq. 12.8-1 shall be reduced to

$$\tilde{V} = V - \Delta V \qquad (19.2\text{-}1)$$

The reduction ($\Delta V$) shall be computed as follows and shall not exceed $0.3V$:

$$\Delta V = \left[ C_s - \tilde{C}_s \left( \frac{0.05}{\tilde{\beta}} \right)^{0.4} \right] \bar{W} \le 0.3V \qquad (19.2\text{-}2)$$

where

$C_s$ = the seismic design coefficient computed from Eqs. 12.8-2, 12.8-3, and through 12.8-4 using the fundamental natural period of the fixed-base structure ($T$ or $T_a$) as specified in Section 12.8.2

$\tilde{C}$ = the value of $C_s$ computed from Eqs. 12.8-2, 12.8-3, and through 12.8-4 using the fundamental natural period of the flexibly supported structure ($\tilde{T}$) defined in Section 19.2.1.1

$\tilde{\beta}$ = the fraction of critical damping for the structure-foundation system determined in Section 19.2.1.2

$\bar{W}$ = the effective seismic weight of the structure, which shall be taken as $0.7W$, except for structures where the effective seismic weight is concentrated at a single level, it shall be taken as equal to $W$

#### *19.2.1.1 Effective Building Period*

The effective period ($\tilde{T}$) shall be determined as follows:

$$\tilde{T} = T \sqrt{1 + \frac{\bar{k}}{K_y} \left( 1 + \frac{K_y \bar{h}^2}{K_\theta} \right)} \qquad (19.2\text{-}3)$$

where

$T$ = the fundamental period of the structure as determined in Section 12.8.2

$\bar{k}$ = the stiffness of the structure where fixed at the base, defined by the following:

$$\bar{k} = 4\pi^2 \left( \frac{\bar{W}}{gT^2} \right) \qquad (19.2\text{-}4)$$

where

$\bar{h}$ = the effective height of the structure, which shall be taken as 0.7 times the structural height ($h_n$), except for structures where the gravity load is effectively concentrated at a single level, the effective height of the structure shall be taken as the height to that level

$K_y$ = the lateral stiffness of the foundation defined as the horizontal force at the level of the foundation necessary to produce a unit deflection at that level, the force and the deflection being measured in the direction in which the structure is analyzed

$K_\theta$ = the rocking stiffness of the foundation defined as the moment necessary to produce a unit average rotation of the foundation, the moment and rotation being measured in the direction in which the structure is analyzed

$g$ = the acceleration of gravity

The foundation stiffnesses ($K_y$ and $K_\theta$) shall be computed by established principles of foundation mechanics using soil properties that are compatible