by elements of the structure, at or just below the effective yield displacement of the seismic force-resisting system

β_{Vm} = component of effective damping of the m^{th} mode of vibration of the structure in the direction of interest due to viscous dissipation of energy by the damping system, at or just below the effective yield displacement of the seismic force-resisting system

μ_D = effective ductility demand on the seismic force-resisting system in the direction of interest due to the design earthquake ground motions

μ_M = effective ductility demand on the seismic force-resisting system in the direction of interest due to the maximum considered earthquake ground motions

Unless analysis or test data supports other values, the effective ductility demand of higher modes of vibration in the direction of interest shall be taken as 1.0.

18.6.2.1 Inherent Damping

Inherent damping, β_I, shall be based on the material type, configuration, and behavior of the structure and nonstructural components responding dynamically at or just below yield of the seismic force-resisting system. Unless analysis or test data supports other values, inherent damping shall be taken as not greater than 5 percent of critical for all modes of vibration.

18.6.2.2 Hysteretic Damping

Hysteretic damping of the seismic force-resisting system and elements of the damping system shall be based either on test or analysis or shall be calculated using Eqs. 18.6-3 and 18.6-4:

$$\beta_{HD} = q_H (0.64 - \beta_I)\left(1 - \frac{1}{\mu_D}\right) \qquad (18.6\text{-}3)$$

$$\beta_{HM} = q_H (0.64 - \beta_I)\left(1 - \frac{1}{\mu_M}\right) \qquad (18.6\text{-}4)$$

where

q_H = hysteresis loop adjustment factor, as defined in Section 18.6.2.2.1

μ_D = effective ductility demand on the seismic force-resisting system in the direction of interest due to the design earthquake ground motions

μ_M = effective ductility demand on the seismic force-resisting system in the direction of interest due to the maximum considered earthquake ground motions

Unless analysis or test data supports other values, the hysteretic damping of higher modes of vibration in the direction of interest shall be taken as zero.

18.6.2.2.1 Hysteresis Loop Adjustment Factor The calculation of hysteretic damping of the seismic force-resisting system and elements of the damping system shall consider pinching and other effects that reduce the area of the hysteresis loop during repeated cycles of earthquake demand. Unless analysis or test data support other values, the fraction of full hysteretic loop area of the seismic force-resisting system used for design shall be taken as equal to the factor, q_H, calculated using Eq. 18.6-5:

$$q_H = 0.67 \frac{T_S}{T_1} \qquad (18.6\text{-}5)$$

where

T_S = period defined by the ratio, S_{D1}/S_{DS}

T_1 = period of the fundamental mode of vibration of the structure in the direction of the interest

The value of q_H shall not be taken as greater than 1.0 and need not be taken as less than 0.5.

18.6.2.3 Viscous Damping

Viscous damping of the m^{th} mode of vibration of the structure, β_{Vm}, shall be calculated using Eqs. 18.6-6 and 18.6-7:

$$\beta_{Vm} = \frac{\sum_j W_{mj}}{4\pi W_m} \qquad (18.6\text{-}6)$$

$$W_m = \frac{1}{2}\sum_j F_{im}\delta_{im} \qquad (18.6\text{-}7)$$

where

W_{mj} = work done by j^{th} damping device in one complete cycle of dynamic response corresponding to the m^{th} mode of vibration of the structure in the direction of interest at modal displacements, δ_{im}

W_m = maximum strain energy in the m^{th} mode of vibration of the structure in the direction of interest at modal displacements, δ_{im}

F_{im} = m^{th} mode inertial force at Level i

δ_{im} = deflection of Level i in the m^{th} mode of vibration at the center of rigidity of the structure in the direction under consideration

Viscous modal damping of displacement-dependent damping devices shall be based on a