
Question: What is the proper application of the 1997 UBC vertical earthquake term, E_v ?

Subject: Vertical Seismic

Code Reference: 97UBC, 1630.1.1

Answer:

For Strength Design, E_v has the effect of increasing compression and tension/uplift effects on vertical load carrying systems. E_v is not applicable for Allowable Stress Design.

The new term, E_v , was introduced in the 1997 UBC. UBC Section 1630.1 defines E_v as the load effect resulting from the vertical component of the earthquake ground motion. For Strength Design, E_v is defined as $0.5C_aID$. For Allowable Stress Design, E_v is defined as 0.

C_a = seismic coefficient from UBC Table 16-Q
 I = importance factor from UBC Table 16-K
 D = dead load

UBC Section 1630.1.1 defines the earthquake load, E , as the earthquake load on an element of the structure resulting from the combination of the horizontal component E_h and the vertical component E_v .

$$E = \rho E_h + E_v \quad (\text{UBC 30-1})$$

ρ = redundancy factor defined in UBC Section 1630.1.1
 E_h = earthquake load resulting from either the base shear, V , or the design lateral force, F_p

Substituting the definition of E_v into this equation results in:

$$E = \rho E_h + 0.5C_aID \quad (\text{Modified 30-1})$$

The 1997 UBC defines load combinations in Section 1612. Strength load combinations 12-5 and 12-6 include E .

$$1.2D + 1.0E + (f_1L + f_2S) \quad (\text{UBC 12-5})$$

$$0.9D \pm (1.0E \text{ or } 1.3W) \quad (\text{UBC 12-6})$$

Substituting modified equation 30-1 into these equations results in:

$$1.2D + 1.0\rho E_h + 0.5C_aID + (f_1L + f_2S) \quad (\text{Modified 12-5})$$

$$(0.9 + 0.5C_aI)D + \rho E_h \quad (\text{Modified 12-6a})$$

$$(0.9 - 0.5C_aI)D - \rho E_h \quad (\text{Modified 12-6b})$$

All terms with E_h are effects of horizontal earthquake components. These loads can be in any direction, for example, vertical loads on rigid frame columns, horizontal loads on columns, and diagonal loads on braced frames.

All terms with D , L , or S are effects of vertical loads or components. These loads can be in any direction, for example, vertical loads on beams, horizontal loads on rigid frame columns, and diagonal loads on braced frames.

For typical California values of $C_a = 0.40$ and $I = 1$, the modified equations become:

$$1.4D + 1.0\rho E_h + (f_1L + f_2S)$$

$$1.1D + \rho E_h$$

$$0.7D + \rho E_h$$

The impact of the vertical earthquake component on modified Strength Design equations 12-5 and 12-6a is to increase compression effects on columns and foundations. The impact of the vertical earthquake component on modified Strength Design equations 12-6b is to increase tension and uplift effects on columns, anchorage, and foundations.

There is no impact of the vertical earthquake component on Allowable Stress Design load combination equations.

Note that the 1999 SEAOC Blue Book differs from the 1997 UBC on this issue. Blue Book Section 105.1.1 defines the last Strength Design load combination as:

$$0.9D \pm (\rho E_h \text{ or } 1.3W) \quad (\text{Blue Book 101-6})$$

The impact of the Blue Book equation is that the vertical earthquake effects increase neither the axial compression or tension effects.

This recommendation by the SEAOC Seismology Committee, although not included in the 1997 UBC, may be useful in discussions with building officials and plan checkers.