3.18.2.2.4 The preceding values for effective ice strength are intended for use with piers of substantial mass and dimensions. The values shall be modified as necessary for variations in pier width or pile diameter, and design ice thickness by multiplying by the appropriate coefficient obtained from the following table:

b/t	Coefficient
0.5	1.8
1.0	1.3
1.5	1.1
2.0	1.0
3.0	0.9
4.0 or greater	0.8

where

b = width of pier or diameter of pile;
t = design ice thickness.

3.18.2.2.5 Piers should be placed with their longitudinal axis parallel to the principal direction of ice action. The force calculated by the formula shall then be taken to act along the direction of the longitudinal axis. A force transverse to the longitudinal axis and amounting to not less than 15 percent of the longitudinal force shall be considered to act simultaneously.

3.18.2.2.6 Where the longitudinal axis of a pier cannot be placed parallel to the principal direction of ice action, or where the direction of ice action may shift, the total force on the pier shall be computed by the formula and resolved into vector components. In such conditions, forces transverse to the longitudinal axis shall in no case be taken as less than 20 percent of the total force.

3.18.2.2.7 In the case of slender and flexible piers, consideration should be given to the vibrating nature of dynamic ice forces and to the possibility of high momentary pressures and structural resonance.

3.18.2.3 Static Ice Pressure

Ice pressure on piers frozen into ice sheets on large bodies of water shall receive special consideration where there is reason to believe that the ice sheets are subject to significant thermal movements relative to the piers.

3.19 BUOYANCY

Buoyancy shall be considered where it affects the design of either substructure, including piling, or the superstructure.

3.20 EARTH PRESSURE

3.20.1 Structures which retain fills shall be proportioned to withstand pressure as given by Rankine's formula; provided, however, that no structure shall be designed for less than an equivalent fluid weight (mass) of 30 pounds per cubic foot.

3.20.2 For rigid frames a maximum of one-half of the moment caused by earth pressure (lateral) may be used to reduce the positive moment in the beams, in the top slab, or in the top and bottom slab, as the case may be.

3.20.3 When highway traffic can come within a horizontal distance from the top of the structure equal to one-half its height, the pressure shall have added to it a live load surcharge pressure equal to not less than 2 feet of earth.

3.20.4 Where an adequately designed reinforced concrete approach slab supported at one end by the bridge is provided, no live load surcharge need be considered.

3.20.5 All designs shall provide for the thorough drainage of the back-filling material by means of weep holes and crushed rock, pipe drains or gravel drains, or by perforated drains.

3.21 EARTHQUAKES

In regions where earthquakes may be anticipated, structures shall be designed to resist earthquake motions by considering the relationship of the site to active faults, the seismic response of the soils at the site, and the dynamic response characteristics of the total structure in accordance with the following criteria or AASHTO *Guide Specifications for Seismic Design of Highway Bridges*.

3.21.1 Equivalent Static Force Method

For structures with supporting members of approximately equal stiffness, an equivalent horizontal force, EQ, may be applied to the structure. The distribution of the force shall consider the stiffness of the superstructure and supporting members, abutment restraint, and the deflected position of the structure.

3.21.1.1

$$EQ = C \cdot F \cdot W \qquad (3\text{-}6)$$

where

EQ = equivalent static horizontal force applied at the center of gravity of the structure;
F = framing factor;
F = 1.0 for structures where single columns or piers resist the horizontal forces;
F = 0.8 for structures where continuous frames resist horizontal forces applied along the frame;
W = total dead weight of the structure in pounds.

3.21.1.2

$$C = A \cdot R \cdot S / Z \qquad (3\text{-}7)$$

where

C = combined response coefficient (the calculated coefficient C shall not be less than 0.10 for structures with A greater than or equal to 0.3 g and 0.06 for structures with A less than 0.3g; values of coefficients for various depths of alluvium to rock-like material given in Figures 3.21.1A, B, C, and D may be used);
A = maximum expected acceleration of bedrock at the site (seismic risk map of the United States, shown in Figures 3.21.1 E, F, and G, with the following assignment of maximum expected rock acceleration, may be used; more exact peak rock acceleration values should be used in areas where "Maximum Expected Rock Acceleration" maps are available):

Zone I	A = 0.09 g
Zone II	A = 0.22 g
Zone III	A = 0.50 g

g = 32.2 ft./sec.^{2};
R = normalized rock response;
S = soil amplification spectral ratio;
Z = reduction for ductility and risk assessment.

3.21.1.3

$$T = 0.32 \sqrt{\frac{W}{P}} \qquad (3\text{-}8)$$

where

T = period of vibration of the structure in seconds;
P = total uniform force, pounds required to cause a 1-inch maximum horizontal deflection of the whole structure.

The period of vibration may also be computed using dynamic analysis techniques.

3.21.2 Response Spectrum Method

3.21.2.1 For complex structures, a response spectrum dynamic approach should be used for seismic analysis.

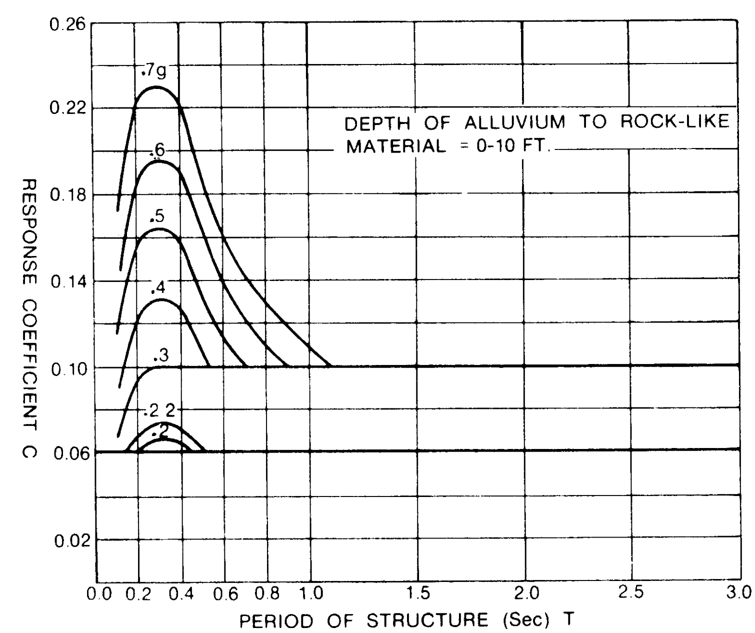

Figure 3.21.1A. Response Coefficient "C" for Various Values of Peak Rock Acceleration "A".

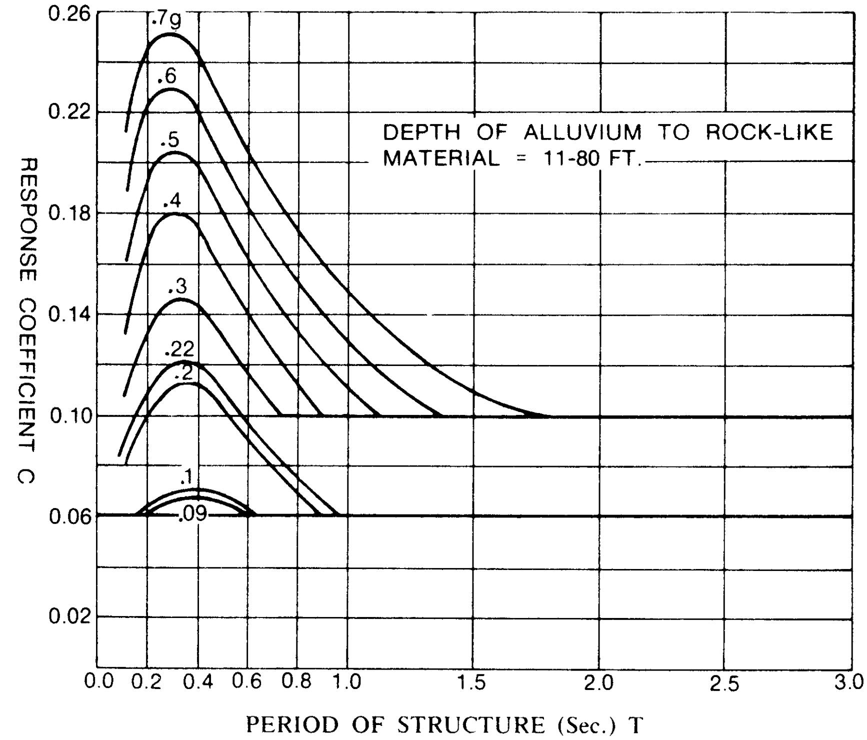

Figure 3.21.1B. Response Coefficient "C" for Various Values of Peak Rock Acceleration "A".

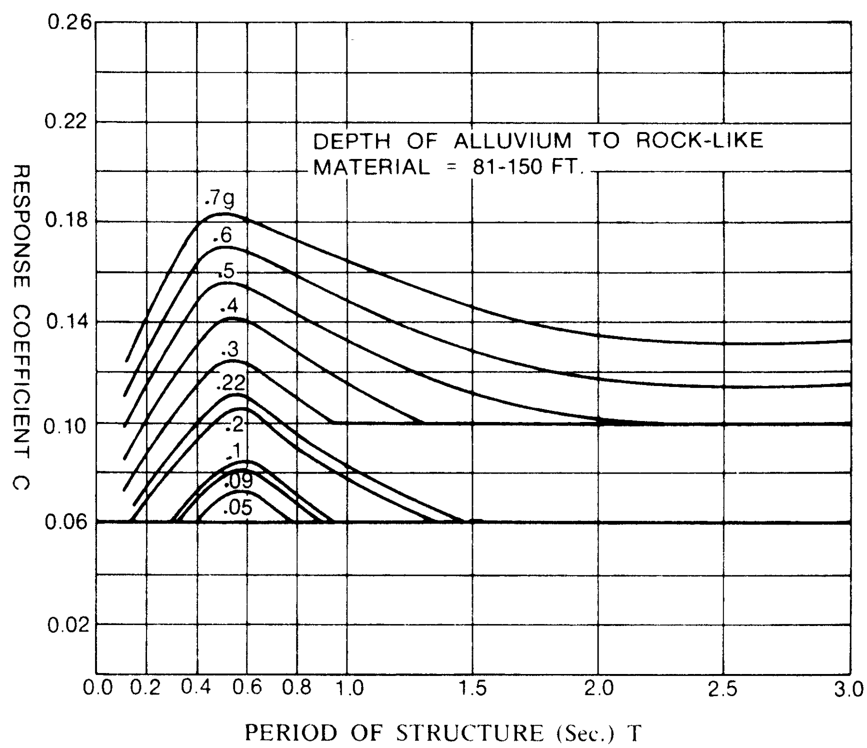

Figure 3.21.1C. Response Coefficient "C" for Various Values of Peak Rock Acceleration "A".

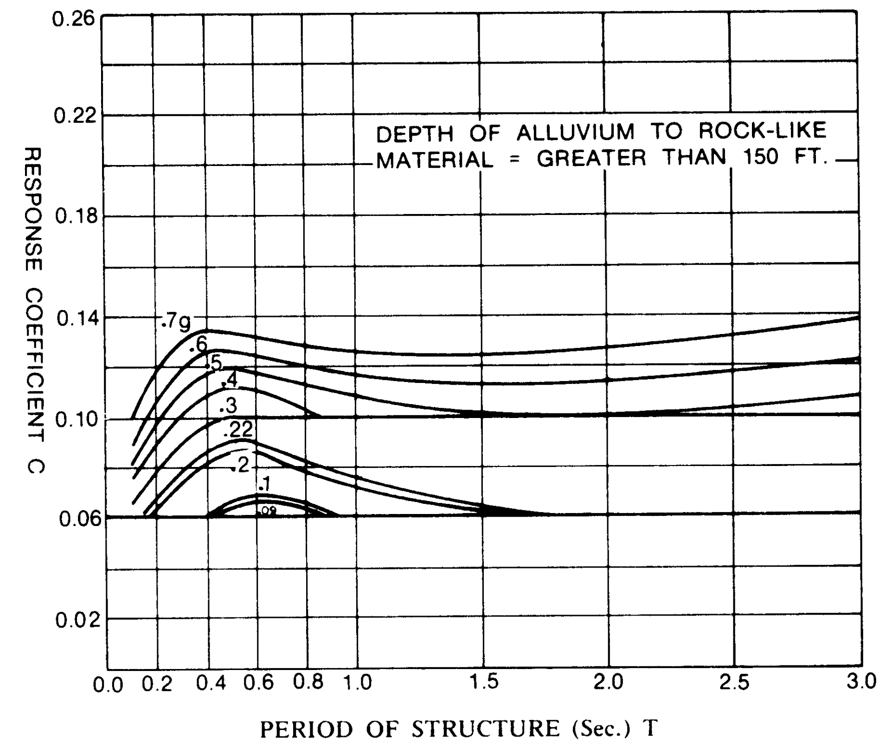

Figure 3.21.1D. Response Coefficient "C" for Various Values of Peak Rock Acceleration "A".

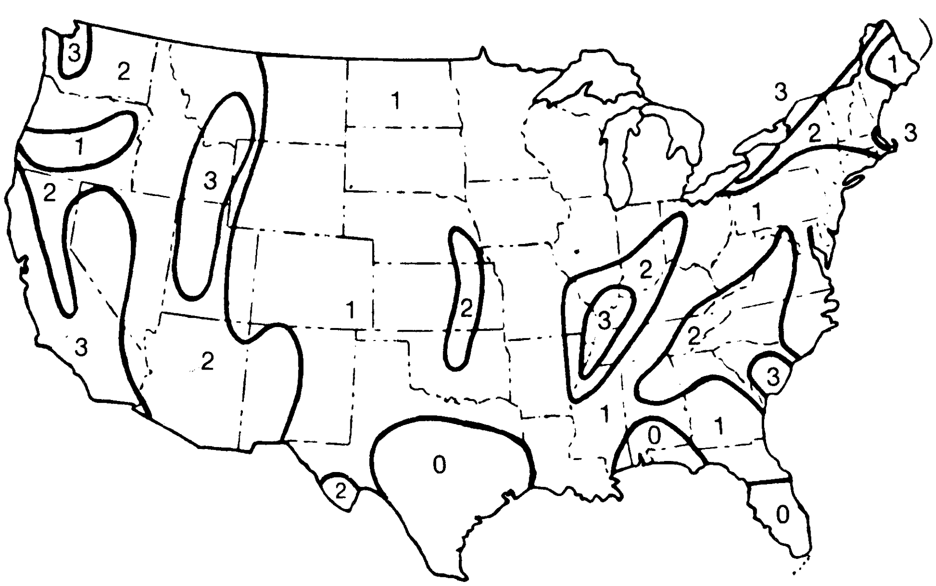

Figure 3.21.1E. Seismic risk map of the United States.

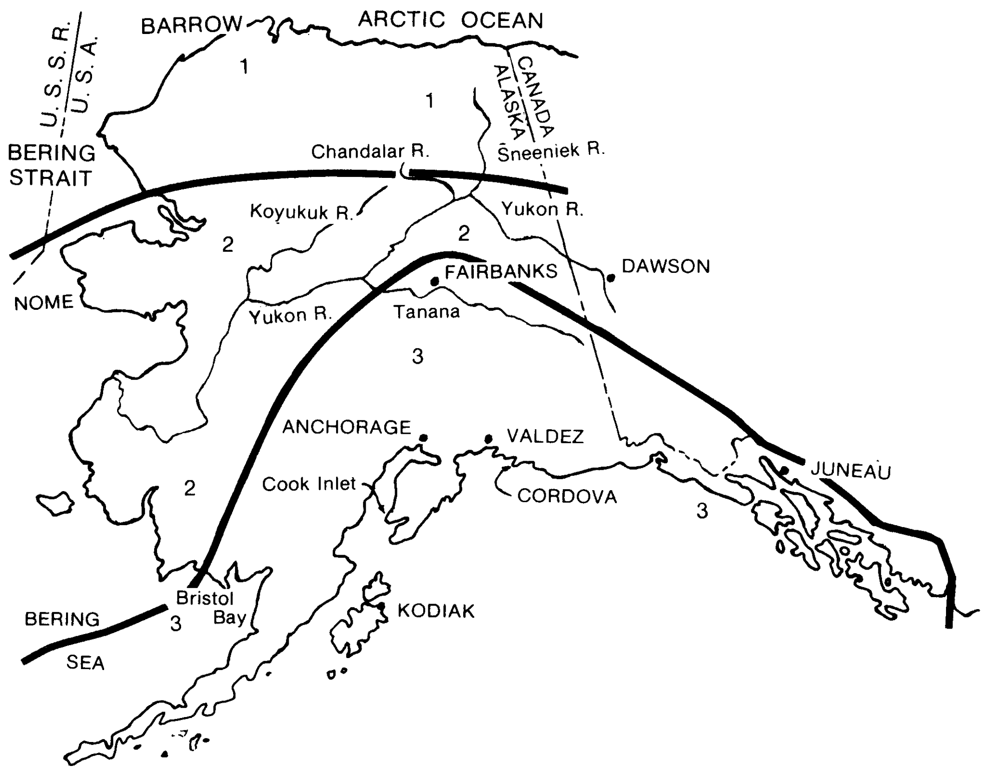

Figure 3.21.1F. Seismic zone map of Alaska.

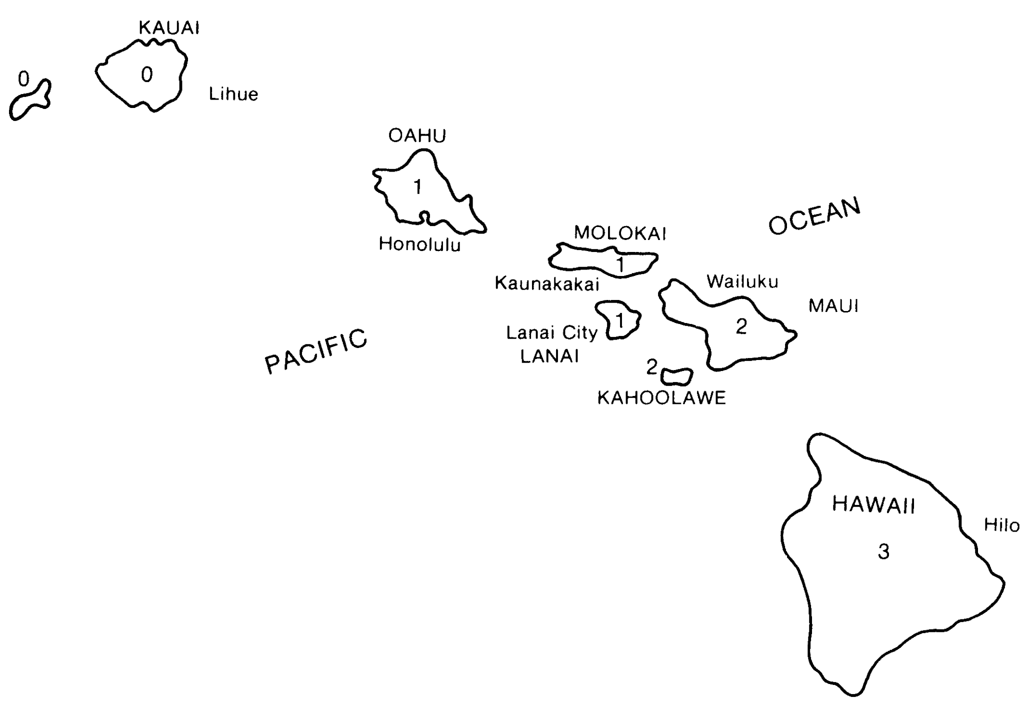

Figure 3.21.1G. Seismic zone map of Hawaii.

3.21.2.2 The combined response curves, C, given in Figures 3.21.1A, B, C, and D, or equivalent curves, modified by the framing factor, F, may be used as the design response spectrum.

3.21.3 Special Cases

Structures adjacent to active faults, sites with unusual geologic conditions, unusual structures, and structures having a fundamental period greater than 33.0 seconds will be considered special cases. These structures will be required to be designed using current seismicity, soil response, and dynamic analysis techniques.

3.21.4 DESIGN OF RESTRAINING FEATURES

3.21.4.1 Restraining features to limit the displacement of the superstructure,—i.e., hinge ties, shear blocks, etc.,—shall be designed for the following force:

$$EQ = 0.25 \times \text{contributing DL minus column shears due to EQ} \tag{3-9}$$

3.21.4.2 Contributing DL is determined by examining the entire frame. For example, a simple span fixed at one end and sliding at the other will have the entire superstructure as the contributing DL for longitudinal forces at the fixed abutment, while one-half of the superstructure DL will act at each abutment for transverse forces.

3.21.4.3 For a frame, such as a 2-span structure, the full length of the bridge should be used as the contribution length in the longitudinal direction. The resulting force can be reduced by deducting the shear in the column due to earthquake.

3.21.4.4 For hinge restrainers use 0.25 × DL of the smaller of the 2 frames and deduct the column shears due to EQ.

Part B
COMBINATIONS OF LOADS

3.22 COMBINATIONS OF LOADS

3.22.1 The following Groups represent various combinations of loads and forces to which a structure may be subjected. Each component of the structure, or the foundation on which it rests, shall be proportioned to withstand safely all group combinations of these forces that are applicable to the particular site or type. Group loading combinations for Service Load Design and Load Factor Design are given by:

$$\text{Group (N)} = \gamma[\beta_D \cdot D + \beta_L (L + I) + \beta_C CF + \beta_E E + \beta_B B + \beta_S SF + \beta_W W + \beta_{WL} WL + \beta_L \cdot LF + \beta_R (R + S + T) + \beta_{EQ} EQ + \beta_{ICE} ICE] \tag{3-10}$$

where

N = group number;
γ = load factor, see Table 3.22.1A;
β = coefficient, see Table 3.22.1A;
D = dead load;
L = live load;
I = live load impact;
E = earth pressure;
B = buoyancy;
W = wind load on structure;
WL = wind load on live load—100 pounds per linear foot;
LF = longitudinal force from live load;
CF = centrifugal force;
R = rib shortening;
S = shrinkage;
T = temperature;
EQ = earthquake;
SF = stream flow pressure;
ICE = ice pressure.

3.22.2 For service load design, the percentage of the basic unit stress for the various groups is given in Table 3.22.1A.

The loads and forces in each group shall be taken as appropriate from Articles 3.3 to 3.21. The maximum section required shall be used.

3.22.3 For load factor design, the gamma and beta factors given in Table 3.22.1A are only intended for designing structural members by the load factor concept. The actual loads should not be increased by the factors given in the table when designing foundations (soil pressure, pile loads, etc.). The load factors are also not intended to be used when checking the foundation stability (safety factors against overturning, sliding, etc.) of a structure.

3.22.4 When long span structures are being designed by load factor design, the gamma and beta factors