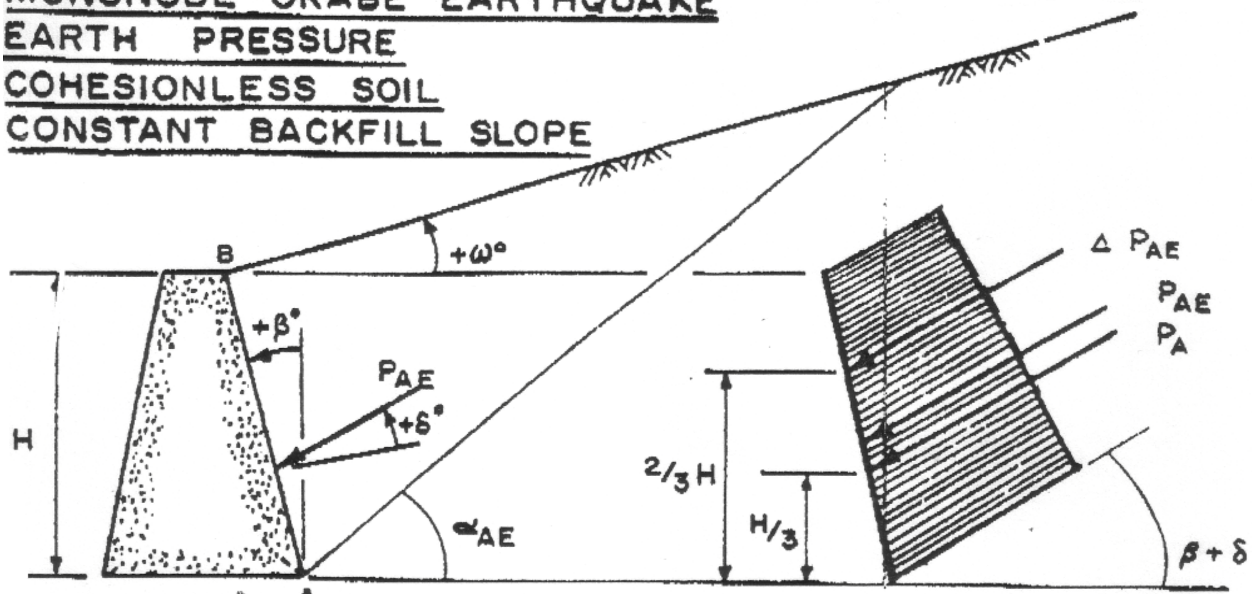
New Zealand. Ministry of Works and Development
Retaining Wall Design Notes (1973)

Quasi-static design

MONONOBE-OKABE EARTHQUAKE EARTH PRESSURE COHESIONLESS SOIL CONSTANT BACKFILL SLOPE



FAILURE PLANE FOR EARTHQUAKE LOADING

ACTIVE EARTHQUAKE PRESSURE ON A–B

ACTIVE PRESSURE

$$P_{AE} = \tfrac{1}{2} K_{AE} \gamma H^2$$

$$K_{AE} = \frac{\cos^2(\phi-\beta-\theta)}{\cos\theta \cos^2\beta \cos(\delta+\beta+\theta)\left[1 + \sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\omega-\theta)}{\cos(\delta+\beta+\theta)\cos(\beta-\omega)}}\right]^2}$$

$$\theta = \tan^{-1} CF$$

$$\cot(\alpha_{AE}-\omega) = -\tan(\phi+\delta+\beta-\omega) + \sec(\phi+\delta+\beta-\omega)\sqrt{\frac{\cos(\beta+\delta+\theta)\sin(\phi+\delta)}{\cos(\beta-\omega)\sin(\phi-\theta-\omega)}}$$

NOTES

1. The above equations are based on a resolution of the forces acting on a wedge of soil. The effect of an earthquake is represented by a static horizontal force equal to the design seismic coefficient times the weight of the wedge.
2. Where the earthquake earth pressure is calculated on a vertical plane through the rear of the heel, β is zero and δ is equal to ω.
3. For the determination of the point of application of P_{AE}, the total active earthquake pressure is divided into two components, P_A (from static loading) and the dynamic increment, $\Delta P_{AE} = P_{AE} - P_A$. P_A is applied at 1/3H up the wall and ΔP_{AE} at 2/3H up the wall. The point of application of P_{AE} is then calculated by taking moments, and the pressure diagram is determined accordingly.

FIGURE 19

Kramer, Steven L. (1996) Geotechnical Earthquake Engineering. Prentice Hall

Pseudo-dynamic Design

11.6.2 Nonyielding Walls

Some retaining structures, such as massive gravity walls founded on rock or basement walls braced at both top and bottom, do not move sufficiently to mobilize the shear strength of the backfill soil. As a result, the limiting conditions of minimum active or maximum passive earth pressures cannot be developed.

Wood (1973) analyzed the response of a homogeneous linear elastic soil trapped between two rigid walls connected to a rigid base (Figure 11.16). If the two walls are assumed to be spaced far apart, the pressures on one wall will not be strongly influenced by the presence of the other. Wood showed that dynamic amplification was negligible for low-frequency input motions [i.e., motions at less than half the fundamental frequency of the unrestrained backfill ($f_o = v_s/4H$)]. For this range of frequencies, in which many practical problems lie, wall pressures can be obtained from the elastic solution for the case of a uniform, constant, horizontal acceleration applied throughout the soil. For smooth rigid walls, Wood (1973) expressed the dynamic thrust and dynamic overturning moment (about the base of the wall) in the form

$$\Delta P_{eq} = \gamma H^2 \frac{a_h}{g} F_p \qquad (11.31)$$

$$\Delta M_{eq} = \gamma H^3 \frac{a_h}{g} F_m \qquad (11.32)$$

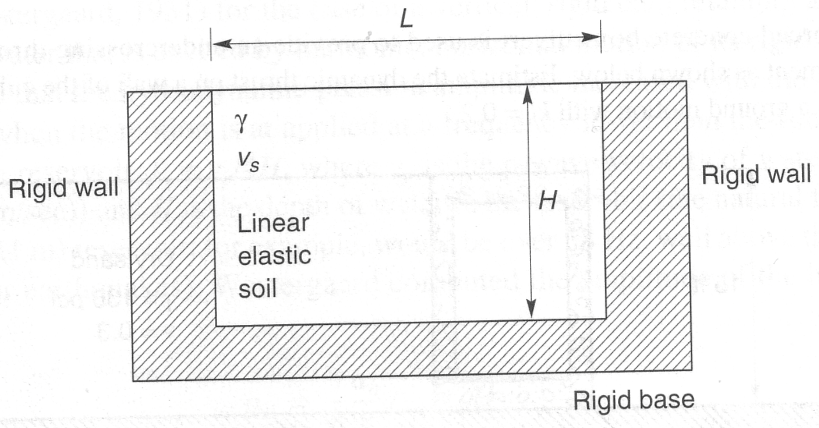


Figure 11.16 Wall geometry and notation for Wood (1973) analysis of pressures on nonyielding walls.

where a_h is the amplitude of the harmonic base acceleration and F_p and F_m are the dimensionless dynamic thrust and moment factors shown in Figures 11.17 and 11.18, respectively. The point of application of the dynamic thrust is at a height

$$h_{eq} = \frac{\Delta M_{eq}}{\Delta P_{eq}} \qquad (11.33)$$

above the base of the wall; typically, $h_{eq} \approx 0.63H$.

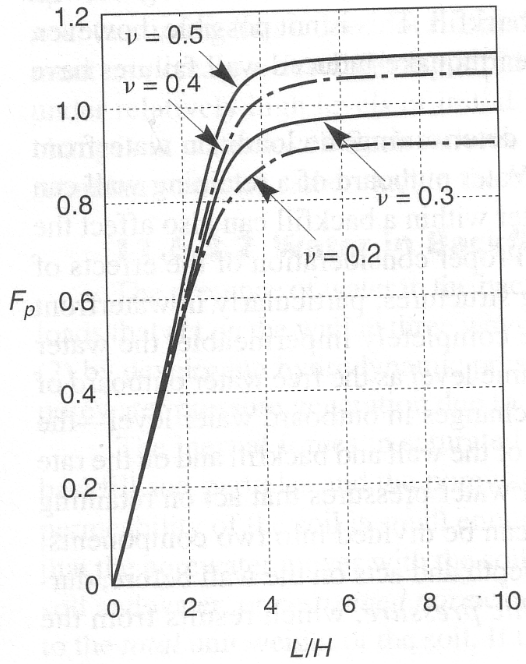


Figure 11.17 Dimensionless thrust factor for various geometries and soil Poisson's ratio values. After Wood (1973).

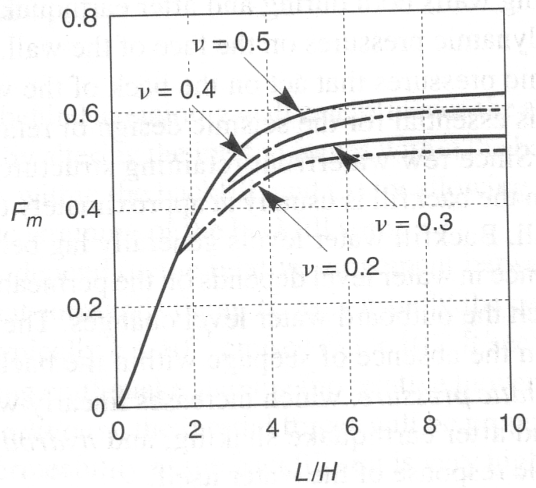


Figure 11.18 Dimensionless moment factor for various geometries and soil Poisson's ratio values. After Wood (1973).

Example 11.2

A reinforced concrete box culvert is used to provide an undercrossing through a railroad embankment as shown below. Estimate the dynamic thrust on a wall of the culvert when subjected to a ground motion with $k_h = 0.2$.

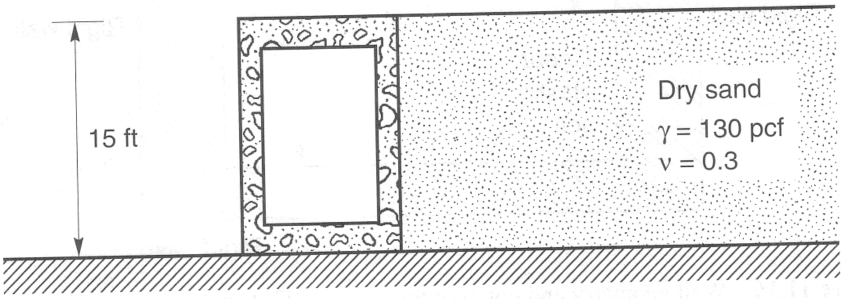


Figure E11.2

Solution Assuming they are properly reinforced and that the culvert cannot slide on its base, the culvert walls will not yield. Consequently, the dynamic thrust can be estimated using equation (11.31) and Figure 11.17

$$\Delta P_{\text{eq}} = \gamma H^2 \frac{a_h}{g} F_p = (130 \text{ pcf})(15 \text{ ft})^2 \frac{0.2 \text{ g}}{\text{g}}(1.0) = 5850 \text{ lb/ft}$$