***Footing Bearing Pressure.*** To calculate the footing bearing pressure, the first step is to sum the vertical loads, such as the wall and footing weights. The vertical loads can be represented by a single resultant vertical force, per linear meter or foot of wall, that is offset by a distance (eccentricity) from the toe of the footing. This can then be converted to a pressure distribution by using Eq. (8.7). The largest bearing pressure is routinely at the toe of the footing, and it should not exceed the allowable bearing pressure (Sec. 8.2.5).

***Retaining Wall Analyses.*** Once the active earth pressure resultant force $P_A$ and the passive resultant force $P_p$ have been calculated, the design analysis is performed as indicated in Fig. 10.2*c*. The retaining wall analysis includes determining the resultant location of the forces (i.e., calculate *d*, which should be within the middle third of the footing), the factor of safety for overturning, and the factor of safety for sliding. The adhesion $c_a$ between the bottom of the footing and the underlying soil is often ignored for the sliding analysis.

### 10.1.2 Retaining Wall Analyses for Earthquake Conditions

The performance of retaining walls during earthquakes is very complex. As stated by Kramer (1996), laboratory tests and analyses of gravity walls subjected to seismic forces have indicated the following:

1. Walls can move by translation and/or rotation. The relative amounts of translation and rotation depend on the design of the wall; one or the other may predominate for some walls, and both may occur for others (Nadim and Whitman 1984, Siddharthan et al. 1992).
2. The magnitude and distribution of dynamic wall pressures are influenced by the mode of wall movement, e.g., translation, rotation about the base, or rotation about the top (Sherif et al. 1982, Sherif and Fang 1984a, b).
3. The maximum soil thrust acting on a wall generally occurs when the wall has translated or rotated toward the backfill (i.e., when the inertial force on the wall is directed toward the backfill). The minimum soil thrust occurs when the wall has translated or rotated away from the backfill.
4. The shape of the earthquake pressure distribution on the back of the wall changes as the wall moves. The point of application of the soil thrust therefore moves up and down along the back of the wall. The position of the soil thrust is highest when the wall has moved toward the soil and lowest when the wall moves outward.
5. Dynamic wall pressures are influenced by the dynamic response of the wall and backfill and can increase significantly near the natural frequency of the wall-backfill system (Steedman and Zeng 1990). Permanent wall displacements also increase at frequencies near the natural frequency of the wall-backfill system (Nadim 1982). Dynamic response effects can also cause deflections of different parts of the wall to be out of phase. This effect can be particularly significant for walls that penetrate into the foundation soils when the backfill soils move out of phase with the foundation soils.
6. Increased residual pressures may remain on the wall after an episode of strong shaking has ended (Whitman 1990).

Because of the complex soil-structure interaction during the earthquake, the most commonly used method for the design of retaining walls is the pseudostatic method, which is discussed in Sec. 10.2.

### 10.1.3 One-Third Increase in Soil Properties for Seismic Conditions

When the recommendations for the allowable soil pressures at a site are presented, it is common practice for the geotechnical engineer to recommend that the allowable bearing pressure and the allowable passive pressure be increased by a factor of one-third when performing seismic analyses. For example, in soil reports, it is commonly stated: "For the analysis of earthquake loading, the allowable bearing pressure and passive resistance may be increased by a factor of one-third." The rationale behind this recommendation is that the allowable bearing pressure and allowable passive pressure have an ample factor of safety, and thus for seismic analyses, a lower factor of safety would be acceptable.

Usually the above recommendation is appropriate if the retaining wall bearing material and the soil in front of the wall (i.e., passive wedge area) consist of the following:

- Massive crystalline bedrock and sedimentary rock that remains intact during the earthquake.
- Soils that tend to dilate during the seismic shaking or, e.g., dense to very dense granular soil and heavily overconsolidated cohesive soil such as very stiff to hard clays.
- Soils that have a stress-strain curve that does not exhibit a significant reduction in shear strength with strain.
- Clay that has a low sensitivity.
- Soils located above the groundwater table. These soils often have negative pore water pressure due to capillary action.

These materials do not lose shear strength during the seismic shaking, and therefore an increase in bearing pressure and passive resistance is appropriate.

A one-third increase in allowable bearing pressure and allowable passive pressure should not be recommended if the bearing material and/or the soil in front of the wall (i.e., passive wedge area) consists of the following:

- Foliated or friable rock that fractures apart during the earthquake, resulting in a reduction in shear strength of the rock.
- Loose soil located below the groundwater table and subjected to liquefaction or a substantial increase in pore water pressure.
- Sensitive clays that lose shear strength during the earthquake.
- Soft clays and organic soils that are overloaded and subjected to plastic flow.

These materials have a reduction in shear strength during the earthquake. Since the materials are weakened by the seismic shaking, the static values of allowable bearing pressures and allowable passive resistance should not be increased for the earthquake analyses. In fact, the allowable bearing pressure and the allowable passive pressure may actually have to be reduced to account for the weakening of the soil during the earthquake. Sections 10.3 and 10.4 discuss retaining wall analyses for the case where the soil is weakened during the earthquake.

## 10.2 PSEUDOSTATIC METHOD

### 10.2.1 Introduction

The most commonly used method of retaining wall analyses for earthquake conditions is the pseudostatic method. The pseudostatic method is also applicable for earthquake slope stability analyses (see Sec. 9.2). As previously mentioned, the advantages of this method are that it is easy to understand and apply.