

## RETAINING WALL DESIGN

This information bulletin provides general criteria for design of retaining walls. In particular, guidelines include:

- Minimum static design earth pressures retaining level and sloping ground;
- Vertical surcharge loads on walls;
- Seismic lateral earth pressure on retaining walls; and,
- Acceptable engineering criteria for retaining wall design.

Alternative design procedures justified in a geotechnical report may also be approved.

Design of retaining walls as presented in this Bulletin are in accordance with Sections 1610.1 and 1807.2 of the City of Los Angeles Building Code (LABC).

### I. SOIL LATERAL LOADS

**LABC 1610.1 General.** *Foundation walls and retaining walls shall be designed to resist lateral soil loads. Soil loads specified in Table 1610.1 shall be used as the minimum design lateral soil loads unless determined otherwise by a geotechnical investigation in accordance with Section 1803. Foundation walls and other walls in which horizontal movement is restricted at the top shall be designed for at-rest pressure. Retaining walls free to move and rotate at the top shall be permitted to be designed for active pressure. Design lateral pressure from surcharge loads shall be added to the lateral earth pressure load. Design lateral pressure shall be increased if soils at the site are expansive. Foundation walls shall be designed to support the weight of the full hydrostatic pressure of un-drained backfill unless a drainage system is installed in accordance with Sections 1805.4.2 and 1805.4.3.*

**Exception:** *Foundation walls extending not more than 8 feet (2438 mm) below grade and laterally supported at the top by flexible diaphragms shall be permitted to be designed for active pressure.*

Maximum values presented in Table 1610.1 shall be used for design, unless a geotechnical investigation determines the type of material retained or justifies lower values or both.

Table 1610.1 does not provide design lateral soil loads for retaining sloping ground. Therefore, a geotechnical investigation report shall be provided when walls will retain sloping ground.

**II. RETAINING WALL DESIGN**

**LABC 1807.2.2 Design lateral soil loads.** Retaining walls shall be designed for the lateral soil loads set forth in Section 1610.

**LABC 1807.2.3 Safety factor.** Retaining walls shall be designed to resist the lateral action of soil to produce sliding and overturning with minimum safety factor of 1.5 in each case. The load combinations of Section 1605 shall not apply to this requirement. Instead, design shall be based on 0.7 times nominal earthquake loads, 1.0 times other nominal loads, and investigation with one or more of the variable loads set to zero. The safety factor against lateral sliding shall be taken as the available soil resistance at the base of the retaining wall foundation divided by the net lateral force applied to the retaining wall.

**Exception:** Where earthquake loads are included, the minimum safety factor for retaining wall sliding and overturning shall be 1.1.

**III. MINIMUM DESIGN STATIC ACTIVE LATERAL EARTH PRESSURES FOR RETAINING WALLS SUPPORTING LEVEL AND SLOPING GROUND WHEN A GEOTHECNICAL INVESTIGATION REPORT IS PROVIDED**

The design static active equivalent fluid pressure (EFP) for walls that retain drained earth<sup>1</sup> when a geotechnical investigation report is provided shall not be less than the values shown in Table 1. The horizontal resultant force is determined as illustrated in Figure 1. A vertical component equal to one third of the horizontal force so obtained may be assumed at the plane of contact between the retained soil and wall surface when considering the total resisting moment taken at the toe of the wall. Such a vertical component is not permitted when filter fabric is used behind retaining walls.

The depth of the retained earth shall be the vertical distance below the ground surface measured at the wall face of stem design or measured at the heel of the footing for overturning and sliding.

**TABLE 1 Minimum Static Equivalent Fluid Pressures**

Surface Slope of Retained Material* Horizontal (H) to Vertical (V)	Equivalent Fluid Pressure $\gamma_{EFP}$ (pounds per cubic foot, pcf)
LEVEL (0° angle)	30
5 to 1	32
4 to 1	35

<sup>1</sup> Drainage system shall be installed in accordance with LABC Section 1805.4.2 and 1805.4.3.

3 to 1	38
2 to 1	43
1.5 to 1	55
1 to 1 (45° angle)	80

\* Where the surface slope of the retained earth varies, the design slope shall be obtained by connecting a line from the top of the wall to the highest point on the slope whose limits are within the horizontal distance from the stem equal to the stem height of the wall.

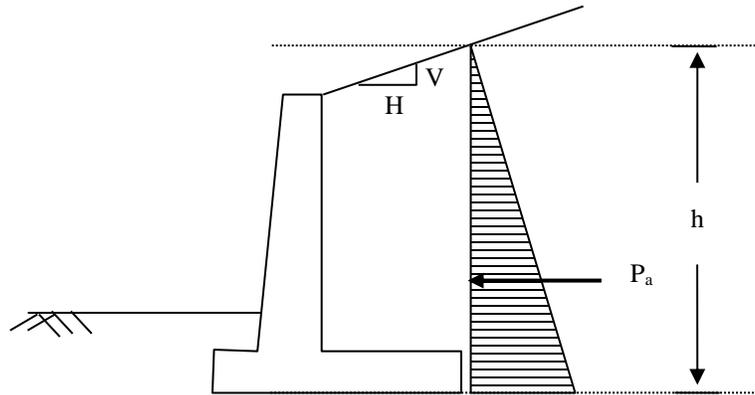


Figure 1 – Horizontal Resultant Force

$$P_a = 0.5 * \gamma_{EFP} * h^2 \text{ (in pounds);} \quad \text{Equation 1}$$

applied at  $\frac{1}{3} h$  measured from bottom of wall footings

#### IV. METHODS OF DETERMINING VERTICAL SURCHARGE LOADS ON WALLS

Any superimposed vertical loading, except retained earth, shall be considered as surcharge and provided for in the design. Uniformly distributed loads may be considered as equivalent added depth of retained earth. Surcharge loading due to continuous or isolated footings can be determined by Equations 2 and 3, and as illustrated in Figure 2, or by an equivalent method approved by the Superintendent of Building. Equation 2 is limited to retaining walls that are permitted to be designed for active pressure<sup>2</sup>. This method shall also be limited to the design of retaining walls only under vertical surcharge. Retaining walls under lateral surcharge shall be designed by licensed civil/structural engineer with approval from the Department. The Superintendent of Building may require a site-specific geotechnical investigation prior to approving a permit for such a wall.

<sup>2</sup> Per LABC section 1610.1: Retaining walls free to move and rotate at the top shall be permitted to be designed for active pressure.

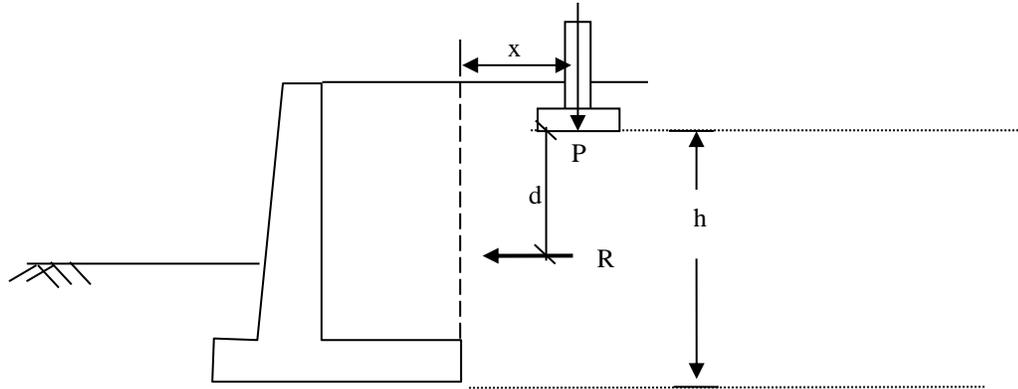


Figure 2 - Vertical Surcharge Loads

Resultant lateral force:

$$R = \frac{0.3 P h^2}{x^2 + h^2}; \quad \text{Equation 2}$$

Location lateral resultant:

$$d = x \left[ \left( \frac{x^2}{h^2} + 1 \right) \left( \tan^{-1} \frac{h}{x} \right) - \left( \frac{x}{h} \right) \right]; \quad \text{Equation 3}$$

Where:	R	is the resultant lateral force measured in pounds per foot of wall width.
	P	is the resultant surcharge loads of continuous or isolated footings measured in pounds per foot of length parallel to the wall.
	x	is the distance of resultant load from back face of wall footings measured in feet.
	h	is the depth below point of application of surcharge loading to bottom of wall footing measured in feet.
	d	is the depth of lateral resultant below point of application of surcharge loading measured in feet.
	$\tan^{-1} h/x$	is the angle in radians whose tangent is equal to h/x.

Loads applied within a horizontal distance equal to the wall height (i.e.  $x \leq h$ ), measured from the back face of the wall footings, shall be considered as surcharge.

For isolated footings that have a width parallel to the wall less than 3 feet, “R” may be reduced to one-sixth the calculated value.

The resultant lateral force “R” shall be assumed to be uniform for the length of footing parallel to the wall and to diminish uniformly to zero at the distance “x” beyond the ends of the footing, as shown in Figure 3.

Vertical pressure due to surcharge applied to the top of the wall footing may be considered to spread uniformly within the limits of the stem and planes making an angle of 45 degrees with the vertical, as shown in Figure 3.

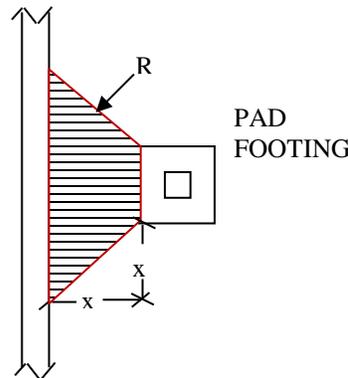


Figure 3 - Vertical Surcharge Loads, Plan View

Guidelines for determining live loads surcharge from sidewalk pedestrian traffic and street traffic are provided in the Information Bulletin P/BC 2023-141.

**V. METHOD FOR DETERMINING SEISMIC LATERAL EARTH PRESSURE ON RETAINING WALLS**

Section **1803.5.12** of the LABC specifies that for Seismic Design Categories D through F, retaining walls supporting more than 6 feet of backfill shall be designed for seismic lateral earth pressures due to design earthquake ground motions.

The seismic lateral earth pressure for walls retaining level ground can be calculated using the Equation 4, based on Seed and Whitman (1970)<sup>3</sup>:

$$\gamma_{EFP (seismic)} = \frac{3}{4} k_h \gamma_{soil}; \quad \text{Equation 4}$$

Where:

<sup>3</sup> Seed, H.B. and Whitman, R.V., 1970, Design of Earth Retaining Structures for Dynamic Loads, *ASCE Specialty Conference, Lateral Stresses in the Ground and Design of Earth Retaining Structures*, pp 103-147.

- $\gamma_{EFP (seismic)}$  is the seismic increment expressed as equivalent fluid pressure (pcf);
- $k_h$  is the seismic lateral earth pressure coefficient equivalent to one-half of two-thirds of  $PG_{AM}$ ;
- $\gamma_{soil}$  is the unit weight of the retained soils, may be taken as 120 pcf without a soils report.

The seismic lateral earth pressure shall be applied in addition to the static lateral earth pressure, and can be applied assuming an inverted triangular distribution, with the resultant applied at a height of  $2/3 h$  measured from the bottom of wall footings.

*Example:* For a site located at 201 N. Figueroa St, for Site Class C, the  $PG_{AM}$  is 0.94g. The seismic lateral earth pressure can be calculated as the following:

$$\gamma_{EFP (seismic)} = \frac{3}{4} k_h \gamma_{soil} = \frac{3}{4} \times \frac{1}{2} \times \frac{2}{3} \times 0.94 \times 120 pcf = 28.2 pcf;$$

## VI. ACCEPTABLE ENGINEERING CRITERIA FOR RETAINING WALL DESIGN

**LABC 1807.2.1** Retaining walls shall be designed to ensure stability against overturning, sliding, excessive foundation pressure and water uplift.

### a. Bearing Pressure and Overturning

Minimum values presented in LABC Table 1806.2<sup>4</sup> shall be used for design, unless a geotechnical investigation determines the type of material for foundation support or justifies higher load-bearing values or both. The resultant of vertical loads and lateral pressures shall pass through the middle one third of the base.

### b. Lateral Pressures

Retaining walls shall be restrained against sliding by lateral sliding resistance of the base against the earth, by lateral bearing pressure against the soil, or by a combination of the two<sup>5</sup>. Minimum values presented in LABC Table 1806.2 shall be used for design, unless a geotechnical investigation determines the type of material for lateral bearing and lateral sliding resistance or justifies higher allowable lateral bearing and lateral sliding resistance values or both.

When used, keys shall be assumed to lower the plane of lateral sliding resistance and the depth of lateral bearing to the level of the bottom of the key. Lateral bearing pressures shall be assumed to act on a vertical plane located at the toe of the footing.

<sup>4</sup> Per LABC 1806.2: Mud, organic silt, organic clay, peat or **unprepared fill** shall not be assumed to have a presumptive load-bearing capacity.

<sup>5</sup> Reference code section LABC 1806.3.1.

## **VII. SPECIAL CONDITION**

The Superintendent of Building may require a site-specific soil investigation before approving any permit for a retaining wall whenever, the following exist: the adequacy of the foundation material to support a wall is questionable; an unusual surcharge condition exists such as seepage pressure; or when the retained earth is so stratified or of such a character as to invalidate normal design assumptions..

Additionally, the footings for all retaining walls shall extend a minimum of 24 inches below the natural and finish grades in accordance with the requirements contained in Information Bulletin P/BC 2023-116 for expansive soils conditions unless a soil report indicates expansive soils do not exist at the site.