Seismic Analysis of Retaining Wall- A Design Procedure Overview

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Abstract-*Retaining walls are the structures designed to restrain soil to unnatural slopes. They are used to bound soils between two different elevations in areas of terrain possessing undesirable slopes. They are also used in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. They are also used in bridge abutments and wing walls. The design of structures like retaining wall requires the knowledge of the earth pressure acting on the back of the wall because of the soil backfill in contact with it. Hence relation between the earth pressure on the retaining wall and strains within a backfill is a prerequisite.*

I. DESIGN PROCEDURE VERVIEW

The Four Primary Concerns for the Design of Retaining Wall:

1. That it has an acceptable Factor of Safety with respect to overturning.
2. That it has an acceptable Factor of Safety with respect to sliding.
3. That the allowable soil bearing pressures are not exceeded.
4. That the stresses within the components (stem and footing) are within code allowable limits to adequately resist imposed vertical and lateral loads. It is equally important that it is constructed according to the design

Basic Design Principals for Cantilevered Walls

Stability requires that a cantilevered retaining wall resists both overturning and sliding, and material stresses including the allowable soil bearing that must be within acceptable values. To resist forces tending to overturn the wall (primarily the lateral earth pressure against the back of the wall), the wall must have sufficient weight, including the soil above the footing, such that the resisting moments are greater than the overturning moments. The safety factor for overturning should be at least 1.5, some codes require more.

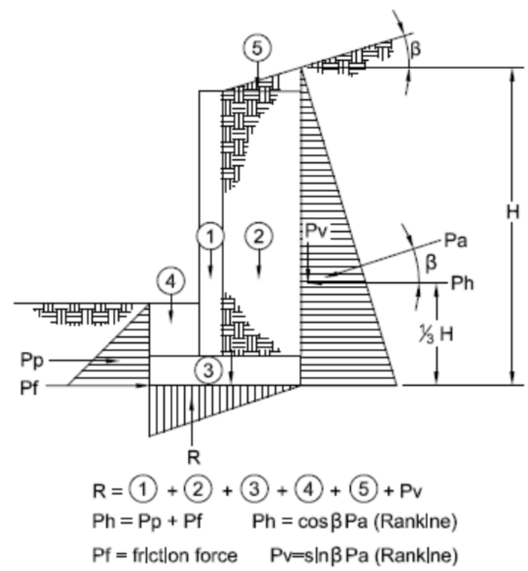

Figure .Free-body of cantilevered retaining wall

Step-by-Step Design of a Cantilevered Retaining Wall

The design usually follows this order:

1. Establish all design criteria based upon applicable building codes.
2. 2Compute all applied loads, soil pressures, seismic, wind, axial, surcharges, impact, or any others.
3. Design the stem. This is usually an iterative procedure. Start at the bottom of the stem where moments and shears are maximum. Then, for economy, check several feet up the stem (such as at the top of the development length of the dowels projecting from the footing) to determine if the bar size can be reduced or alternate bars dropped. Check dowel embedment depth into the footing assuming a 90° bend (hooked bar). The thickness of the stem may vary, top to bottom. The minimum top thickness for reinforced concrete walls is usually 150 mm to properly place the concrete, 200 mm at the bottom.
4. Compute overturning moments, calculated about the front (toe) bottom edge of the footing. For a trial, assume the footing width, to be about 1/2 to 2/3's the height of the wall, with 1/3 being at the toe.
5. Compute resisting moments based upon the assumed footing width, calculated about the front edge of the footing.

6. Check sliding. A factor of safety with respect to sliding of 1.5 or more is standard. A key or adjusting the footing depth may be required to achieve an accepted factor of safety with respect to sliding.
7. An overturning factor of safety of at least 1.5 is considered standard of practice.
8. Based upon an acceptable factor of safety against overturning, calculate the eccentricity of the total vertical load. Is it within or outside the middle-third of the footing width?
9. Calculate the soil pressure at the toe and heel. If the eccentricity, e, is > B/6 (B = width of footing) it will be outside the middle third of the footing width (not recommended!), and because there cannot be tension between the footing and soil, a triangular pressure distribution will be the result. Consult with the project geotechnical engineer if this condition cannot be avoided, as it will result in a substantially lowered allowable soil bearing pressure.
10. Design footing for moments and shears. Select reinforcing.
11. Check and review. Have all geotechnical report requirements been met?
12. Place a note on the structural sheets and on the structural calculations indicating that the backfill is to be placed and compacted in accordance with the geotechnical report.
13. Review the construction drawings and specifications for conformance with the design.

Seismic Design Background

Determining with some rationale how seismic forces act on retaining walls is complex and impeded by diverse opinions, differing theoretical assumptions, and in-situ tests that don't match theoretical approaches. Researchers acknowledge the complexity of this task as code-writers try to mandate minimum design guidelines for public safety.

This effort is difficult for two reasons. As stated earlier, unlike buildings where we can learn from failures, reports of damage to reasonably well designed retaining walls (that were not designed, considering seismic forces) are nearly non-existent (waterfront walls and liquefaction conditions excluded) therefore there is little to observe and analyze to suggest design remedies. And as opinioned above, many question the need for adding seismic forces to static-designed retaining walls, considering both performance history and factors of safety incorporated into the design of walls. Secondly, and compounding the dilemma, as stated above many of the theoretical approaches to determine seismic forces on retaining walls each relies upon differing assumptions that yield differing results, and to in-situ and laboratory tests that didn't perform as theory predicted.

In past years "pseudo-static" (that is, using a static force to simulate a dynamic force) analyses were conducted for which the inertial effects of ground shaking were represented by a lateral *force*, which then made the problem solvable using statics. That force was usually set equal to 0.15W, where 0.15 was assumed to be the effective horizontal ground acceleration and W the "rigid body mass" portion of the backfill. The line of action of the force was assumed to act through the center of gravity the rigid soil mass. Factors greater than 0.15 might have been used based upon a consideration of the "importance" of the wall (now codified as the *Importance Factor).*

The practice of assuming a static equivalent horizontal ground acceleration factor is now largely replaced with a "site acceleration" based upon site specific spectral analyses. The concept of spectral analysis, whereby the design acceleration is based upon the characteristics and period of a structure, was introduced in the 30's and codified in the 40's. Accelerations for retaining walls, which are generally considered "short period" structures (less than 0.2 seconds), use a design acceleration given for 2% damping with a 10% chance of being exceeded in 50 years. The pseudo-static approach is useful when analyzing a wall for stability – overturning, soil bearing, and sliding – but does not give the distribution of seismic lateral force incrementally on the stem.

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