The Most Common Mistake Made By Retaining Wall Designers

What You Should Be Including In Your Construction Drawings
Where Do Retaining Wall Problems Start?

It has been said that there are three things that can cause a retaining wall to fail—water, water and water!

Although this may be a bit of an exaggeration, water is often one of the primary factors that can influence a wall’s performance and stability. Therefore, it is very important to understand the impact that water has on a retaining wall and how you can incorporate proper water management into your wall design.

Determining Lateral Earth Pressure

Before discussing water’s effect on a retaining wall and proper water management, it is important to understand how lateral forces are determined under normal conditions. Lateral earth pressure, the primary driving force acting on a retaining wall, is calculated using soil properties and information regarding site and wall geometry. Internal friction angle and soil unit weight are critical in this calculation process and both can be influenced by the presence of water.

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P_a = \frac{1}{2} \cdot K_a \cdot \gamma_m \cdot H^2
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The first variable that appears in the Lateral Earth Pressure equation is \( K_a \) which is the active earth pressure coefficient. This coefficient is a function of internal friction angle and values associated with site and wall geometry.

So, what is the internal friction angle of a soil? In simple terms, it represents how much internal strength the soil has or how much the soil particles interlock. The greater the angle, the more the particles interlock and the stronger the internal strength. The opposite holds true for lower internal friction angles. Since \( K_a \) and internal friction angle are inversely proportional, higher friction angles result in lower \( K_a \) values and thus, less pressure acting on the wall. In most cases, \( K_a \) will vary between 0.25 and 0.50 depending on the friction angle unless the wall has a backslope, in which case \( K_a \) can approach or exceed 1.0.

The next variable in the equation is \( \gamma_m \), which is the moist unit weight of the retained soil material. Moist unit weight, a combination of soil, water and air, will generally range from 110 to 130 pounds per cubic foot depending on the soil type. From the equation we can see, as unit weight increases, so does lateral earth pressure.

The final variable in the equation, \( H \), is the total height of the retaining wall. Once the three variables of the equation are known, a lateral earth pressure (primary driving force) can be calculated. This driving force is counteracted by resisting forces that are derived from the mass of the retention structure.

All retaining walls are analyzed according to three external stability requirements: sliding, overturning and bearing. Additionally, walls will be analyzed for overall global stability, and for internal stability if they utilize geogrid soil reinforcement. The results of the external, global and internal stability analysis are then reported as a ratio of resisting force divided by the driving force. This ratio is referred to as a Factor of Safety.

Introducing Water into Soil

Now that we have the basics for determining lateral earth pressure and how it relates to retaining wall analysis, let’s introduce water to examine the affect that it has. For the purposes of this discussion, we are referring to incidental water and not retaining wall analysis in water applications. Incidental water may result from surface runoff, a perched water table or unanticipated high ground water.

The most immediate effect of water on the soil behind a retaining wall, is the soil unit weight. As previously mentioned, the moist unit weight of the soil is used in determining lateral earth pressure. As water begins to fill the void spaces between the soil...
particles, the soil becomes heavier. If enough water is introduced, all of the voids will be filled and the soil is considered saturated. During this process, the weight of the soil increases from the moist unit weight to the saturated unit weight. The saturated unit weight of a soil will vary, depending on soil type and the amount of void spaces, but can weigh about 10 to 20 percent more than moist soils. This increase has a direct effect on the resulting lateral earth pressure, most likely exceeding what was accounted for in the original design.

Water can also influence the internal strength of soils. This condition is harder to quantify since it is highly dependent upon soil type. In general, the overall shear strength of a soil depends on the internal friction angle, the moisture content and the level of compaction. For many soils, as the moisture content increases, the shear strength, or its ability to support load, will decrease. Since the amount of force transferred to the retaining wall is dependent upon the soil’s shear strength, if the strength decreases, then additional force is transferred to the wall. In many cases, these additional forces may exceed what the retaining wall was originally designed for. This same concept holds true for the foundation soils supporting the wall. As the moisture content of the soil increases, its ability to support the load of the wall will decrease. The ultimate bearing capacity, or amount of load that foundation soils can support, can decrease by as much as 50 percent as the soils become saturated.

The first two conditions discussed identify how water can affect the soil behind and beneath the retaining wall. A third condition can develop when the retention system actually begins to retain water. This occurs when water attempts to move from a more permeable material towards a less permeable material. This may occur between two different soil zones or at the interface with the retaining wall. In either case, the accumulation of water will exert a lateral hydrostatic pressure. The resultant horizontal force, of soil and water, can be two to three times that of the soil alone. Since modular block wall systems are not water tight, it is uncommon for this condition to occur at the back of the block. However, it can occur between the reinforced and retained soil zones in a geogrid reinforced wall.

When all of these conditions combine, it is understandable why water can be so detrimental to retaining wall performance. This leaves the question, how can we design a retaining wall to manage incidental water? The answer starts with understanding where the water is coming from.

### Managing Above-Grade Water

It is important for a wall designer to determine the possible sources of above grade water. These may include building downspouts, parking lot runoff, water inlet structures located behind the wall, irrigation systems or simply accumulated rainfall. Where possible, site topography should slope away from the top of wall, but in many cases this is not always feasible. Therefore, Figures 1 and 2 below give options for completing final grade if the slope will be directed towards the top of wall. The primary difference between these two is the incorporation of the swale. Swales, as shown in Figure 1, should be used in situations where the top of wall grade can be pitched side-to-side or end-to-end to promote water drainage. For walls with a consistent elevation along the top, a swale should not be used. This condition is shown in Figure 2. In this case, water should be allowed to drain over the top of the wall and down the face. Additional wall toe protection (scour protection) may be required depending on the amount of anticipated water. The intention of both options is to manage and divert water so that it does not permeate into the below-grade soils.

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**Moist Unit Weight of Soil**: 110 to 130 lbs

**Saturated Unit Weight of Soil**: 125 to 150 lbs

Saturated soils can weigh as much as 10 to 20 percent more than moist soils.

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**Figure 1**

![Swale Diagram](image)
Managing Below-Grade Water

Even if above-grade water is properly managed, it is possible to have incidental water below grade migrate into the retained and foundation soils. Once again, it is important to understand where the water is coming from so that it can be properly collected and transported away from the effected soils. Drainage columns, or chimneys, can be placed in front and/or in back of soil zones to move water away and prevent infiltration. Draintile, or drainage pipes, can be used to move larger amounts of water, that may collect within the chimneys, and discharge them to appropriate locations. Finally, a blanket drain or aggregate base, prevents high ground water from reaching and affecting the retained soils. Figure 3 below shows the location of these various water management features.

Putting It All Together

It is clear that water can have a significant impact on retaining wall performance. Properly managing incidental water starts with a good understanding of the proposed wall site and incorporating appropriate details into the construction drawings. It is then critical that contractors are made aware of these details and requirements so that they can be implemented during the installation of the wall. Also, as a designer it is important to understand who is responsible for what during construction. For instance, wall installation contractors rarely complete final grade and landscaping on a site. Therefore, who’s responsibility will it be to install the low-permeable cap soil at the top of the wall? Making these items prominent within the construction drawings and discussing them with all involved parties will help ensure that they get completed.

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