Important Aspects for Designing & Using Anchored Wall Systems

By Frederick Slack

An anchored wall is one type of earth retention system that uses vertical structural elements (soldier piles) to define the perimeter of the excavation. The soldier piles can be driven or drilled into the earth. As the excavation takes place in front of the soldier piles, wood lagging is installed to retain the earth between the soldier piles. Depending on the final height, the wall may need horizontal support for stability. This support is provided by installing one or more levels of bracing as the excavation proceeds to the final grade. The bracing can be walers and struts (internal bracing) or soil or rock anchors (external bracing). This article will deal with the externally braced excavations, typically called anchored soldier pile and lagging walls. *Figure 1* shows the basic wall elements.

Over the years that we have been designing and installing this type of wall, several issues arise repeatedly. These issues usually fall into one of two categories — they cost additional money for a minimum benefit, or they are easily overlooked items that can have a large impact on the design and configuration of the earth retention system.

Testing Anchors to 150% of Design Load

One of the unseen benefits of an anchored earth retention wall is that 100% of the supporting elements are tested to verify that they are capable of providing and maintaining the required supporting load. Think about a pile supported building. One pile load test is used to verify the capacity of all the piles beneath the structure. No wonder the pile load test is taken to 200% of the design capacity of the piles.

Some specifications require that the anchors be load tested to 150% of the design load. The industry standard specification for anchor tendon material indicates that the maximum design load can not exceed 60% GUTS (Guaranteed Ultimate Tensile Strength) and the maximum test load should not be greater than 80% GUTS. Dividing the two limits indicates that a 133% test load would satisfy both requirements (.80/.60 = 1.33). Specifying a test load higher than 133% requires a larger anchor tendon just to satisfy the test load. Since all the anchors are tested, is it really worth the extra cost just to test to 150% of the design load rather than 133%?

Use of 125% of Allowable Stresses for Temporary Systems

It is quite common throughout the industry to use higher than specified allowable stress when designing temporary structures. This practice is mentioned in the literature. *Reference 1* (p. 403, 406 & 407) discusses the reasoning and acceptability of this approach. Engineers reviewing earth retention submittals should be aware of this widely used practice.

Use of Reduced Moments for Soldier Piles and Walers

It is also a practice of some designers to use only 2/3 of the moments developed in the soldier piles and walers from the apparent earth pressure diagrams (*Reference 2*, p. 463). The engineering principles for this recommendation are beyond the purpose of this article, but they have to do with the system flexibility and the redistribution of the loads.

Composite Action and Soldier Piles

A beam, its web and flanges confined by concrete, will develop some composite action between the steel and concrete. Recall that the soldier piles can be installed by either drilling or driving. If the steel soldier pile is placed in a drilled hole, the hole could be backfilled with concrete. The resulting composite action can then be used to optimize the size of the steel soldier pile. *Reference 3* (p. 5-56 & 5-57) indicates that a bending stress of $0.76F_y$ can be used to size the soldier pile in this situation.

Designing for Extra Lateral Earth Pressure Does Not Necessarily Limit Wall Movement

The use of a more conservative lateral load when designing the anchored wall will not guarantee that the wall will move or deflect less. Additional wall load is typically accomplished by requiring that the at-rest earth pressure coefficient, K_o, be used in lieu of the active earth pressure coefficient, K_a to determine the lateral pressure on the retaining system.

Wall movements during the construction of an anchored wall are hard to determine precisely. The wall will deflect towards the excavation as it cantilevers until the first row of anchors is installed and tensioned. At that point, the wall will be drawn back into the soil bank. Sometimes the wall will go "past zero" and end up further away from the excavation than when it was first installed. Sometimes the pile will not go all the way "back to zero". As the excavation proceeds, this process of inward and outward movement is repeated with each level of anchors.

Many papers have been presented and research done regarding wall movements. At best, the only prediction of wall movement at the end of construction will be a range related to the wall height. For example, the final movement may be described as "between 0.3% to 0.5% of the wall height". It has been our experience that the largest factors in limiting wall movement are the speed at which the wall is built and the care and attention to details used in performing the work. Projects that have good cooperation between the excavation and retention contractors proceed smoothly and expeditiously. On these projects, the wall never sits open without the lagging

being placed in a timely manner; loss of ground behind the wall is addressed as it occurs; surface water is addressed and maintained. The list is longer, but a cooperative effort and good workmanship will win the day. It is not surprising that a project constructed in this manner produces a wall that performs well and does not move excessively.

There is no question that there are instances when movement must be minimized. There are models and computer programs that can be used to design a wall for minimum movement. It is important to remember, however, these are models and the results are predictions. When movement is critical, monitor the wall and respond accordingly to the data you receive.

Top of Wall Details

It is very easy to get so involved in the wall, and the excavation in front of it, that the details at the top of the wall may be overlooked. Items such as handrail, fencing or guard rail can add load and dictate details that need to be addressed from the start. Also, final grading and water control must be considered at the top of the wall. It is not that unusual that the grade at installation is different than the final grade required. This condition will have an impact on the design and the process of how the wall is built. The project team can be so goal oriented to "get to the bottom" as fast as possible, that details at the top of the wall can be missed. A little time spent upfront can save many headaches at the end.

Bottom of Excavation

The most logical place to find the bottom of excavation is on the structural drawings. The bottom of footer is the bottom of excavation, right? A savvy earth retention contractor and a smart reviewer will also check the utility, plumbing and/or electrical drawings. Many times a utility pipe or electrical conduit must be installed at an elevation lower than the bottom of the structure. An earth retention system can be severely compromised if this is not taken into account.

Be cautious also of mass excavation bid packages that are let before the structural drawings are issued. An earth retention system designed only to the mass excavation grade most probably will not address the balance of the excavation required to install the actual foundation elements.

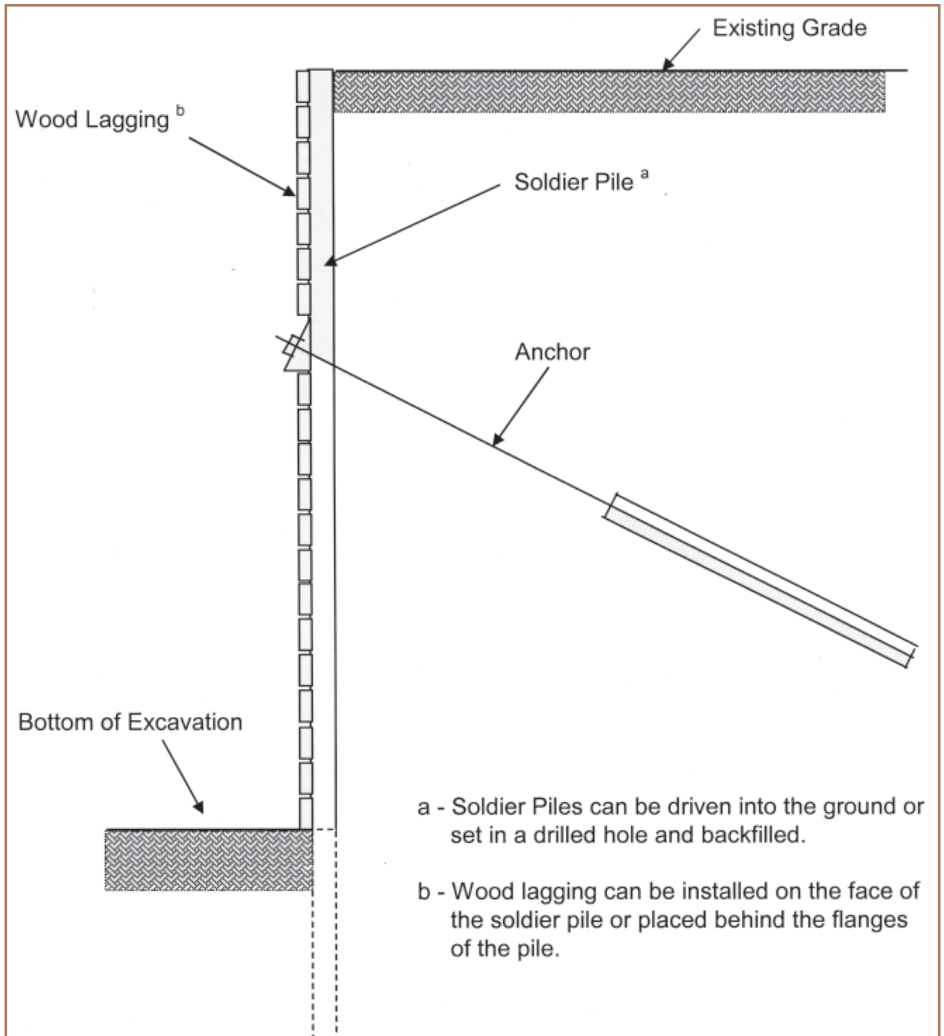
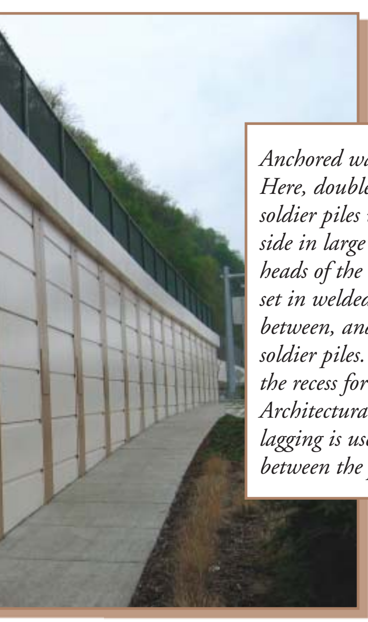


Figure 1



Anchored walls can be attractive. Here, double w-shaped steel soldier piles were placed side by side in large drilled holes. The heads of the tieback anchors are set in welded brackets recessed between, and welded to the two soldier piles. Steel plates cover the recess for the anchor head. Architectural precast concrete lagging is used to retain the soil between the pairs of soldier piles.

Lumber Left in Place

This is a very popular question. In *Reference 4* (p. 63), the authors address this question. The concern is that when the wood decays a void will be left and settlement and/or loss of ground will occur. Some specifications call for removal of the lagging or the use of a more durable material than wood. The authors state, "In the opinion of the authors, this requirement results in needless expense. In their whole experience, no single instance of settlement of structure or even loss of ground has ever been brought to their attention in which decay of wood sheeting might have been the cause. On the contrary, there are many cases where later excavations have exposed wooden sheeting that had been in the damp ground for many years. While it is true that this sheeting was often rotten, enough substance always remained to prevent any perceptible movement of the ground into the space originally occupied by sound wood". We couldn't have said it better.

Detailed Information on Adjacent Existing Structures and Utilities

The main support elements of an anchored retaining wall extend behind the wall and outside of the excavation. This is the beauty of an anchored system — no internal bracing within the excavation. However, those anchors will extend off the property, into the public right-of-way or under an adjacent building. It is imperative that all existing conditions behind the proposed wall be known. This is important to determine if the earth retention system components will clear the existing utilities behind the wall; if any surcharges should be included in the design; to verify that the system elements will clear the existing features and to determine the appropriate installation methods for the retention system.

First, the location of the existing utilities behind the retention system is critical information. Anchors can be moved, inclined, skewed or adjusted in some manner to avoid utilities *if* their location is known. The expense and mess of fixing a sewer damaged by a tieback anchor is considerable, impacts the construction schedule and is a great inconvenience to the utility user. Every effort should be made to include the required utility information in the contract documents or aide the earth retention contractor in finding this critical information.

Second, the size and load on existing footers and their location relative to the anchored retaining wall are necessary to examine what, if any, influence they may have on the proposed retaining wall. The dimensions of all footers and their bottom elevation are necessary to evaluate the interaction between the retention system and the existing structure. If drawings of the existing structure are not available, the contract documents should allow for the earth retention contractor to perform exploratory excavations or gain access to adjacent structures.

Tiebacks for anchored temporary wall being installed as excavation progresses

Third, existing structure information is necessary to verify that the proposed retaining system components will physically fit into the space available. If not, alternate sizes or methods may be required. If the depth of the soldier pile and lagging is 16 inches and only 12 inches is available, there obviously is a problem. If this information is discovered after the bidding process, it gets even more troublesome.

Lastly, the physical location of the retaining structure and the existing features may have an impact on the installation techniques used. For example, a hospital setting may necessitate that the soldier piles be drilled to avoid the noise and vibration of driven piles. The soil types encountered will also dictate the type of equipment used to install the retention system components.

Summary

Hopefully, this brief list of topics has helped you, as structural engineers, understand some of the aspects that go into the design and construction of an anchored earth retention system and will aid in the successful execution of that design. It should be noted that many of these topics will also relate to other types of earth retaining structures, such as soil nail walls, cantilevered walls, etc.

Just as it is with any project, a small investment of time up front to think through details or find existing information will pay off with an efficient and economical earth retention system.▪

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References

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