7 Biggest MSE Retaining Wall Mistakes and How to Avoid Them

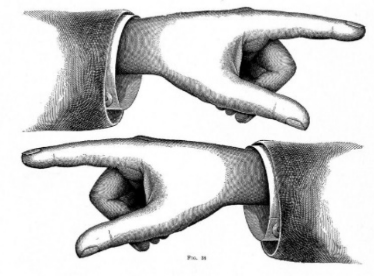
By Chad Clark, P.E.
September 2021

Introduction

There are few counties and municipalities in the US that require the complete design of required Earth Retention Structures such as Cast-In-Place Retaining Walls, Mechanically Stabilized Earth Walls (MSE), Steep Reinforced Slope, Sheet Pile Retaining Walls, Soldier Pile Retaining Walls, Soil Nail Walls, etc. to be submitted along with the Civil Engineer's grading and utility plans to allow a developer or owner to obtain a Land Disturbance Permit (LDP). However, the overwhelming majority do not require this design to be completed prior to the LDP. Therefore, most Earth Retention Structures are bid on a design build basis and the final design is not completed until AFTER the project budgets have been established and/or after the LDP has been obtained. This approach has resulted and will continue to result in increased risk and expense to the project owner or developer.

This paper will discuss the 7 biggest mistakes of the most common type of Earth Retention Structures which are Mechanically Stabilized Earth (MSE) Retaining Walls with the goal to convince the reader that the potential risk of not designing these structures early in the project planning stage far outweighs costs of incurring these fees earlier in the project.

Background on the MSE Bid Process



It is typical for a project owner or developer to contract with a Geotechnical Engineer to perform a basic Geotechnical investigation on a property they are planning to develop and produce a report outlining the results from the investigation. Often the purpose of this basic investigation is to satisfy a lender requirement, look for unsuitable soil or rock that might require blasting. These reports are predominately comprised from boiler plate paragraphs that give generic recommendations for things like bearing capacity, soil shear strength, etc. The soil testing is typically limited to Standard Penetration Tests performed through several borings generally located within the proposed building footprint and expected mass excavation locations.

Almost never do these basic investigations include actual laboratory testing of the onsite soils, instead the soils are assigned soil classifications based on visual inspection of the jar samples taken from the borings. In addition, if earth retention structures like retaining walls are required, many of these basic reports might contain a boiler plate paragraph about site retaining walls, listing an equivalent fluid pressure, unit weight, etc. with additional language that states that if a Mechanically Stabilized Earth (MSE) structure is to be used on the site, the recommendations in the report do not apply. Considering that MSE structures are used on most projects where earth retention structures are required, the information contained in most basic Geotechnical investigation reports is not sufficient to help solve the majority of the 7 Biggest MSE Retaining Wall Mistakes listed in this paper.

This risk is unknowingly transferred to the owner or developer that is ultimately responsible for the long-term performance of the MSE structures.

Following the completion of the basic Geotechnical report and the proposed grading plans showing wall locations, this information is then sent out for bidding using a "design build" approach. Typically, the low bidder for the design build MSE system is the company or team that assumes the most risk by making the most aggressive design assumptions. This risk is unknowingly transferred to the owner or developer that is ultimately responsible for the long-term performance of the MSE structures.

Much of this risk could be mitigated by expanding the scope of the Geotechnical investigation to include actual borings along the alignment of proposed MSE structures and performing actual laboratory testing to determine the properties of the soils that are to be used as backfill and within the influence of these structures. The cost of this additional testing is extremely low relative to the reduced risk to the owner, change orders during construction, unsatisfactory performance and/or failure of the structures, or overpaying for an MSE structure that is significantly over-designed.

This paper will list 7 of the biggest mistakes in MSE design and construction and the consequences of not addressing the items appropriately and proactively.

1. Unsuitable or Unknown Soils

Figure 1 Wall Failure Due to Unsuitable Soil

An owner or developer hires a project Civil Engineer to design the proposed layout of the site improvements, infrastructure, utilities, and final elevations of the site. Along with determining the site final elevations, the project Civil Engineer is often required to specify locations of earth retention structures on portions of the site to achieve the required elevations. There is typically little communication with the project team on the type of the required earth retaining structures or the technical requirements to investigate the appropriate design parameters needed to produce a site-specific design.

As discussed, an MSE structure is usually the most cost-effective system and these systems are made up of three main components; the facing, the reinforcement, such as geogrid, that will reinforce the soil and the soil that is being reinforced. While the facing and reinforcement are man-made components whose properties are well defined, the properties of the soil that is to be reinforced is largely unknown. The project Civil Engineer usually assumes that all the soil on the site can be used within the MSE structure and has balanced the cuts and fill on the site under this assumption.

Since the Geotechnical Report is often very basic in nature and does not address the suitability of the site soils to be used as MSE wall backfill, the project is put out to bid with the project team assuming that all soils can be used as backfill for the MSE structure. The problem is that certain types of soil like clays and plastic silts, do not promote proper performance of a flexible MSE structure. The same fill that may be suitable to support the proposed building, is not acceptable for use as backfill within the reinforcement zone of an MSE structure. Typically, clays and highly plastic silts are not acceptable for MSE fill because they are not able to quickly dissipate pore pressure and tend to creep over time. These types of soils could be acceptable for a rigid structure like a cast-in-place concrete wall but do not perform well with flexible structures.

It is often not until the project is under construction that the proper testing is performed on the proposed fill and the fill is rejected by the wall designer. The owner or developer is usually shocked to be told that their onsite soil cannot be used since they have assembled a project team that they expect would have communicated this early in the project planning phase. At this point, the owner or developer is forced to pay the cost to blend the soil or import select fill which generates an excess off-site soil that must be hauled off the site. A worse scenario is that all the notes requiring a specific soil type on the earth retention shop drawings are ignored, the unsuitable site soil is used, and the structure fails.

The project Civil Engineer usually assumes that all the soil on the site can be used within the MSE structure and has balanced the cuts and fill on the site under this assumption.

The issues of unsuitable or unknown fill types can be solved by better coordination and discussion between the project team early in the project planning phase. The scope of the Geotechnical report must be expanded to address the appropriate type of earth retention structures to be used on the project and the suitability of the onsite soils to be used as backfill if MSE structures are proposed.

2. Global Stability Analysis Not Performed

Figure 2 Global Stability Wall Failure

The analysis of global stability investigates the overall stability of earth retaining structures in relation to slopes above and below the structure as well as tiered wall configurations. This analysis for MSE structures is usually the driving factor in determining the required length of soil reinforcements. While an internal only design might only require reinforcements to be 60 percent of the structure height, a global stability analysis might require reinforcements to be increased to 100 percent of the MSE structure height or more. An effective global stability analysis can only be performed with adequate soil and groundwater information. The presence of partially weathered rock, rock or soft soils can have a dramatic impact on the analysis.

Often the wall design/build team will exclude an analysis of global stability, assuming that the project geotechnical engineer is responsible for this analysis. However, most Geotechnical engineers do not include this within their scope of work nor perform the analysis on a routine basis. Since the design/team that excludes this analysis is usually the low bidder, the analysis is many times not performed.

In many cases it isn't until the project team realizes that the city or county requires the wall designer to certify to a global stability factor of safety that the issue is confronted. There are cases where large retaining walls have had to be torn down and re-built due to not being designed for global stability. In areas where the city or county does not require certification for a global stability factor of safety, MSE structures are often constructed and do not meet the required factors of safety. In these cases, the best-case scenario is that the owner or developer did not get what they paid for and in worse case scenarios, the structure fails.

Without a project specific global stability analysis, the geogrid limits cannot be determined.

Furthermore, since global stability analysis is not performed early in the project planning stage, the Civil Engineer does not have adequate information to determine how far MSE structures should be placed from property lines or limits of disturbance. Many projects are put out to bid with MSE structures located too close to these limits and can therefore not be built. Also, there are many municipalities that will not allow geogrid reinforcements to be located within sanitary sewer easements or beneath buildings. Without a project specific global stability analysis, these limits cannot be determined.

3. Unsuitable Foundation Soils

Figure 3 Wall Settlement Due to Unsuitable Foundation Soils

As discussed earlier, because borings are not typically done along proposed MSE structure alignments, little is known about the actual foundation conditions that the structures will be supported by. A basic geotechnical report might recommend a generic 3,000 pounds per square foot (psf) be used to design the building foundations while on another part of the site, there is 40 ft tall earth retention structure that will apply much more than 3,000 psf on the foundation soil.

Typically, the foundation soils are only somewhat investigated until the foundation of the earth retention structure is excavated. This investigation usually consists of shallow probing or shallow DCP testing which does not adequately reveal the real maximum allowable bearing pressure. It also does not adequately predict the potential settlement that might occur from the load of the new structure.

In fact, most recommended bearing pressures in a basic geotechnical report are recommendations for buildings that can tolerate a very limited amount of total or differential settlement. These recommendations are not adequate for flexible earth retention structures that have a relatively wide base and can tolerate large amounts of settlement.

Typically, the foundation soils are only somewhat investigated until the earth retention structure is excavated.

Designing a 40 ft tall structure to an allowable maximum bearing pressure of 3,000 psf, would require the earth retention designer to assume a significant undercut below the structure and therefore would not be awarded the project. Once again, a geotechnical report that includes borings and settlement analysis along the structure's alignments, prior to design, would reveal potential issues far in advance.

4. No plan for Backfill Consolidation or MSE Wall Movement

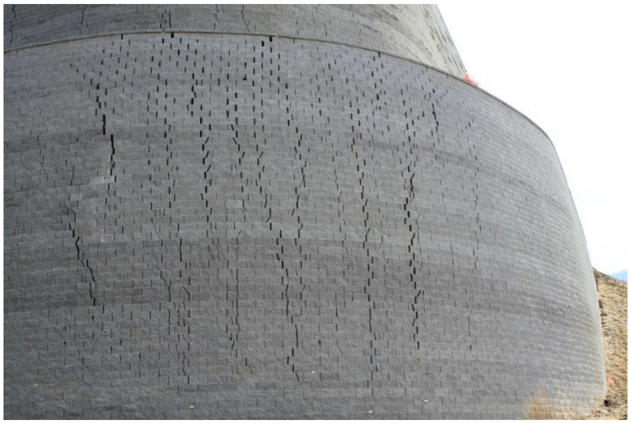


Figure 4 Wall Movement due to Backfill Consolidation

Consolidation of large amounts of fill placed to reach proposed grades on a project is inevitable, especially when the fill thicknesses are more than 30 feet. This consolidation could occur at lower fill heights if the foundation soils are not adequate. While it is very common to discuss the effect of fill consolidation beneath buildings, it is almost always ignored as it relates to fill placed beneath and behind earth retention structures.

The consolidation of fill below and behind earth retention structures can not only have significant impact on the performance of the earth retention structure but also the surrounding utilities, curb, building, asphalt, etc. A consolidation analysis requires the collection of project specific soil samples and laboratory testing and is typically performed by the project geotechnical report. This type of analysis is rarely included in a typical project geotechnical report.

A consolidation analysis is rarely included in a typical project geotechnical report.

Often it isn't even discussed until the earth retention designer submits plans to the project which is usually a few weeks before construction of the earth retention structures is to begin. There have been many cases where a project owner is told, at the last minute, that due to the fill heights, a consolidation period is required, and this additional time has not been factored into the project schedule. Much better coordination should be done between the project geotechnical engineer and the earth retention designer early in the project planning stage.

5. Lack of Coordination from Civil Plans to MSE Wall Plans

Figure 5 Bottom of Retaining Wall at Wrong Elevation for Standard Curb

Since the earth retention plans are almost never a condition for a project to obtain a Land Disturbance Permit from the city or county, as stated throughout this discussion, the earth retention plans are usually an afterthought and are not properly coordinated with the approved civil plans. Since the civil designer does not choose the actual type and details of the earth retention structure, it is often the case that the actual dimensions and batter of the earth retention structure do not fit within the site layout as defined by the civil engineer. This is particularly the case if toe and top slope are present, and the civil designer has assumed that the earth retention structure will be perfectly vertical with no batter.

This is further complicated by the fact that the surveyor performing the layout on the project site during construction typically only has the electronic plans from the civil engineer loaded into their electronic surveying equipment. Since the civil plans and earth retention plans have usually not been coordinated, the stakes placed in the field by the project surveyor are often not in the correct location because they do not account for the actual batter that will be used to construct the earth retention structure. In addition, due to the batter and the presence of toe and/or top slopes, the earth retention structure's height shown on the civil plans is inaccurate. This inaccuracy in height is also further complicated by the fact that the project civil plans does not account for the actual required burial of the earth retention structure.

Since the civil plans and earth retention plans have usually not been coordinated, the stakes placed in the field by the project surveyor are often not in the correct location.

Along with problems with elevations, it is common for the required length of reinforcement behind the earth retention structure to be unknown. This is particularly problematic in cut situations where an earth retention structure is placed adjacent to the property line. Since it is rare for a soil investigation to be done at these cut locations, often the project civil engineer places the earth retention structure based on "rule of thumb" offsets from the property line. Planning for an additional offset for the cut to be made at a safe inclination per OSHA requirements is rarely done. This issue is typically not discovered until after the site layout has been completed. At that point, it becomes very expensive to address and correct this mistake or change to a different type of earth retention structure.

6. Inadequate Quality Control During Construction

Figure 6 Wall Failure Due to Improper Quality Control

Once the construction of an earth retention structure begins, the inspection and testing is usually contracted to the project geotechnical firm that is also performing construction testing for all the other aspects of the sitework and building construction. Typically, there is little knowledge of earth retention construction techniques and practices.

It is common for the owner to be paying for a geotechnical testing firm to be onsite full time or part time during construction and the firm's onsite personnel has little knowledge of what to inspect. The notes on plans regarding checking of reinforcement length, moisture content, gradation, bearing capacity and shear strength are often ignored. Much better coordination should be done between the designer and testing firm on exactly what data will be required to be provided to the designer for them to sign off on the final certification for the structure.

There have been many instances where an owner could not obtain a final certificate of occupancy for a building because the designer of the earth retention structure could not produce the final certification due to lack of testing and inspections during construction.

There have been many instances where an owner could not obtain a final certificate of occupancy due to lake of quality control documentation during earth retention construction

7. Poor Surface Water Management

Figure 7 Bottom of Wall Erosion Due to Poor Surface Water Management

Temporary and permanent surface water management is critical to the short term and long-term performance of earth retention structures. This is especially true for structures that are designed and constructed with geogrid reinforcement. Infiltration of water into the geogrid zone or erosion around and below these structures can cause a catastrophic failure.

Because the design and detailing of required earth retention structures is rarely completed as the project civil plans are being developed, the discussion and review between the civil engineer and earth retention designer is not coordinated. Temporary erosion control measures to protect earth retention structures during the different stages of construction are rarely discussed. This is especially problematic when the detention ponds that will collect the majority of the site's runoff are constructed with earth retention structures around their perimeter.

During the stages of construction of these structures, if the surface water is not directed to an alternate location, there is a high probability that a significant rainfall event will cause severe erosion and possible failure of the earth retention structures. It is also common for storm sewers lines, manholes, catch basins and drop inlets to be placed within the geogrid zone of earth retention structures. Without watertight joints, excessive settlement of these features can cause surface water to infiltrate the soil behind and below the earth retention structure. Over time, this infiltration can cause poor performance and likely failure of the structure.

If the surface water is not directed to an alternate location, there is a high probability that a significant rainfall event will cause severe erosion and possible failure of the earth retention structures.

It is imperative that the civil engineer and earth retention designer coordinate the design of the site surface water management early in the conceptual stages of the project design.

Conclusion

The development of many project sites requires the use of earth retention structures which are predominately Mechanically Stabilized Earth (MSE) structures. These structures are overwhelming sent out for bids on a design build delivery method with inadequate information. Therefore, the design build teams are forced to make assumptions to generate a bid proposal. Often, the team that makes the most aggressive assumptions is the one that is awarded the contract. It isn't until the project is under construction that the discovery is made that the assumptions made at the time of the bid proposal are incorrect. Often this results in increased costs or risks to the owner. More often than the industry cares to admit, these inaccurate assumptions result in poor performance, structural failures and/or lawsuits.

Many of these issues could be resolved at the planning stage if a qualified earth retention engineer was a part of the design team early in the project. This type of change will require the owners or developers to understand the risks and see the value in making an earth retention engineer part of the design team from the beginning.   This approach will solve the mistakes numbered 1 through 5 above.

Prior to beginning construction of MSE structures, a preconstruction meeting should be held with entire project team members to discuss everyone's anticipated scope of work as it relates the structures. In this meeting, the required quality control procedures and erosion control procedures should be discussed. The approach will solve the mistakes number 6 and 7 above.

Earth Retention specializes in helping owners, developers, civil engineers, and contractors avoid these errors and mistakes. If you have a project that requires engineering expertise in earth retention, OR if you just need to consult with our team, contact us at contact@ersdb.com.

Earth Retention
Design + Supply + Support

www.earthretention.com