Fundamentals of Wall Design

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The engineering fundamentals used in the design of earth and water retention structures are well studied and documented. And while the basics are taught in most engineering curriculum, the specific performance objectives and the variables present in real world applications have the greatest impact on the success of your project. As with any other engineering design, designing a sheet piling structure can be done most effectively by following a logical problem solving procedure with a systematic approach. The typical steps are as follows:

- Define Design Goals
- Evaluate Project Site
- Establish Factors of Safety
- Engineering Analysis
- Specify Materials

Define Design Goals

The selection of the most economical components that meet the designer's criterion can only be accomplished after a proper definition of the site conditions and performance and longevity goals are defined. Therefore the first step to a successful design is to clearly establish and document the goals and end uses of the project and the wall structure itself.

The designer should answer a series of questions regarding the desired end result of the project. Some of the questions that can typically be found helpful in setting goals are:

- What is the main purpose of the structure?
  - Soil retention
  - Retaining wall
  - Seawall
  - Erosion Control
  - Ground water and/or chemical diversion
  - Ground water and/or chemical containment
  - Flood protection
  - Wave reduction
  - Water flow control
- What are the specific performance goals needed to successfully achieve the main purpose?
- What is the long term intended use of the structure?
- What is the desired service life of the structure?
- What is the scope of the project?
- What is the Budget for the project?
- What is the schedule for design and construction?
- What risk factors are associated with the project?
- Who will represent the owner during the design and construction phases?
- Who will be the project manager?
- Who will be the project designer?
- Who will construct the structure?

Evaluate Project Site

The conditions present at the jobsite dictate the forces and architectural constraints of the project. Engineers must have a working knowledge of local site conditions including the soil, water, surcharge loads and drivability in order to develop the design and choose the most economic sheet piling for the project.

Soil conditions on any project site can vary dramatically within relatively short distances. It is therefore essential to investigate the soil conditions at a sufficient number of well-distributed locations throughout the project site.

The most reliable and commonly used method to obtain detailed soil data is to perform soil borings at regular intervals at the location of the proposed structure. The process of collecting the borings will itself provide some indication as to the density and composition of the soil on the proposed project site; however lab testing of the samples collected is also required. The lab testing of the collected samples will yield a detailed description of the composition of the soil along with specific properties and descriptive variables that are essential in the understanding of the behavior of the soil on site and its interaction with the subsequent structure. The soil properties collected form the borings and lab testing will be used in the engineering analysis of the structure.

Along with a thorough understanding of the soils present on the project site, there needs to be an understanding of the site variables such as water levels, weather events and vegetation and their possible changes over time. The designer should study any historical documentation that may exist for the area and determine the frequency and magnitude of the site variables and how they affect the behavior of the soils and the function of the structure. The designer must also determine what frequency of major event the structure should be able to withstand and determine the level of performance required for that particular event. It is also of critical importance that the designer perform a detailed investigation into any possible environmental effects the structure may have, and ensure that the structure comply with all environmental regulations, codes or permits that may be associated with the project.

Establish Factors of Safety

With engineering design, one of the most critical factors is determining the appropriate safety factors to be used, and how to apply them. The process of assigning suitable safety factors normally involves investigation of relevant codes and standards, assessment of the magnitude of risk factors and consequences of failure, and sensitivity of the wall to changes in the variable inputs. The designer is left to use their own judgment as to how to apply safety factors to balance risk and cost.

With a geotechnical structure such as a sheet piling wall, small changes in soil and environmental conditions can create large changes is loading conditions. Significant changes in soil type and compaction, water levels, soil levels, and surcharge are not uncommon and need to be considered in the designer's analysis. The consistency, magnitude and reliability of the soil data obtained prior to design can also be an important factor in choosing appropriate safety factors.

The expected service life of the structure is also an important factor in determining the required safety factors. All aspects of loading, site conditions, product performance and possible changes over the expected service life should be incorporated into the design. In general, the longer the expected life of the structure the higher the safety factor should be.

In addition, the service life of all components used in the structure should be accounted for. The life of the structure will only be as long as the shortest lasting single component. In other words, the majority of the components of the wall may have a long service life; however, if one or more inferior components are used in the system, the usable life of the structure will only be that of the inferior components.

It is also of significant importance to consider the accuracy and reliability of product specifications and parameters when determining appropriate safety factors. If a component of the structure has been specified based solely on theoretical capacities or a combination of coupon tests and calculations, there is a greater risk with the use of the product and therefore a requirement for more safety in the design. If, on the other hand, the designer is incorporating products that have been full section tested and are coupled with an in-situ performance record, there can be added confidence on behalf of the designer and a commensurate lower factor of safety.

Geotechnical structures can be extremely difficult to design and the loading parameters difficult to predict. It is therefore common for designers to use relatively high safety factors in the design process of any geotechnical structure. The designer, in combination with other project stakeholders, must always balance project costs with the amount of potential risk and determine the level of insurance obtained through safety factors appropriate for that particular project.

Engineering Analysis

After all project goals, site data, and appropriate levels of risk have been determined, the next step is to perform the engineering analysis of the proposed structure to determine the associated loading and suitable wall parameters. Regardless of the type of sheet piling being used, the general engineering parameters and calculations use the same principles and methodology. The previously determined safety factors should be applied appropriately at each step of the engineering analysis.

The first step in the engineering analysis is to determine the pressure distribution associated with the soil conditions determined by site evaluation. The nature and specific characteristics of the soils, including whether the soils are granular or cohesive, will determine the specific calculations appropriate for the project at hand. There are several empirical and theoretical methods commonly used for the calculation of pressure distributions. The three most commonly used methods are:

- Coulomb's Method
- Rankin's Method
- Terzaghi's Method

Once the pressure distribution has been calculated, the designer can determine the required sheet length and possible wale placement by balancing the passive and active pressures and rotational forces. There are several methods commonly used for analyzing the rotational stability of the wall. The two most commonly used methods are:

- The Free Earth Support Method
- The Fixed Earth Support Method

It is often desirable to attempt several iterations of the rotational stability calculations with different sheet length and wale placement scenarios in an effort to find the optimal solution. The rotational stability analysis methods can then be used to determine suitable anchor placement behind the structure. Anchor placement and sheet length/penetration are the most commonly overlooked design parameters and need to be considered very carefully by the designer in order to ensure adequate global stability of the structure. The next step in the engineering analysis is to calculate the maximum bending moment induced in the sheet piling associated with the calculated loading conditions. The loading configurations for a sheet piling wall are often much more complex than those usually seen in standard engineering beam analyses, however the maximum moment can still be calculated by summing moments and forces in conjunction with the previously listed pressure distribution and rotational stability analysis methods.

Specify Materials

Your project specification is the most critical factor in ensuring the actual performance of the sheet piling you are choosing is appropriate for your particular application.

The best way to make sure that all products being bid or considered for your project are appropriate (and you are getting the most economical solution), is to write a performance-based specification. A performance-based specification lays out the specific performance requirements needed for your particular application, as opposed to a product specification which lays out the published specifications of a particular product. It is always wise to let your project parameters, goals, and design dictate the specification rather than what a particular supplier may tell you they think you need. Always pay particular attention to actual and overall product performance parameters that you need in the field and not small scale theoretical design values that may be pushed by a material supplier.

Your specification should be open to any product as long as it meets all of the parameters that are important to your project. This will allow you to get a product that meets all of your real project parameters and requirements at the best cost level possible.

The first step in your specification writing process is to determine which performance factors are critical to your project and to prioritize them. Some of the most common performance factors are:

- Sheet piling material selection (vinyl, composites, steel, etc.)
- Material quality (source of material, consistency, durability, weatherability, etc.)
- Material performance (mechanical properties, weatherability, chemical resistance, etc.)
- Product aesthetics (color consistency, overall appearance, etc.)
- Product structural performance (allowable moment, stiffness, ductility, etc.)
- Installation performance (drivability, impact strength, stiffness, etc.)
- Chemical resistance
- Transmissivity
- Product cost and budget
- Manufacturer performance (experience, ability to deliver on time, credibility, etc.)

Once your performance parameters are selected qualitatively, it is time to set specific and measurable levels for each requirement. For your own best interest, make sure that the numbers you select for performance requirements are determined based on what your project requires and not just one particular product. This will allow you to find the most competitively priced product that meets all of your site specific performance criteria.

The specification template given in the next section is intended to be used as a starting point and a guide to help you through the specification writing process. Take whatever performance criteria you have deemed required and set quantitative performance levels. Remove any sections that are not important for your project and add any other specifications or criteria that you may deem appropriate.