Using Section Modulus to Select and Compare Vinyl Sheet Piling

CRANE MATERIALS INTERNATIONAL

A Whitepaper by:

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The vinyl sheet piling market has come a long way since it was first conceived by the roots of Crane Materials International in the late 1980s. In the early days of vinyl sheet piling the only decision customers needed to make was weather to use the single vinyl sheet piling product available or one of the more traditional materials like steel, wood, or concrete. There have been considerable advancements over the years and there are now dozens of products available from several suppliers. Although the increase in performance and product selection for vinyl sheet piling has advanced the scope and notoriety of the industry, it has also brought several new challenges. Most notably, the process of comparing different vinyl sheet piling products on a true structural performance basis has become challenging. Different suppliers use different comparison numbers, like "Allowable Moment", that can often be confusing and misleading. It is essential that a customer have the ability to compare products on an equal basis in order to allow for effective bidding and budget evaluation of prospective projects. Furthermore, an unequal structural comparison can mislead a user of vinyl sheet piling into potentially using a product with inadequate safety for the application in question. This paper will outline the time tested method of structural comparison for sheet piling using an engineering property known as Section Modulus, and explain how Section Modulus can effectively be used to compare vinyl sheet piling products across the entire industry on a fair and equivalent basis.

There are two basic categories of engineering properties for all structural building products; shape properties and material properties. Shape properties are characteristics that describe the effectiveness of a given shape in supporting loads, and are completely independent of the material being used. Shape properties, which include Moment of Inertia, Cross-Sectional Area, and Section Modulus among others, are used to determine the effectiveness of the shape of a structural product. For example, shape properties would be used to determine the effect on structural performance of providing thicker flanges or structural ribs on a current product design. Material properties, on the other hand, are the engineering characteristics of a specific material and are completely independent of the shape of the product. Material properties, which include properties like tensile strength and modulus of elasticity, are used to describe the structural performance of a material. Material properties would be used to determine the performance change of a product of a given shape if the materials were to be changed. For example, material properties would be used to evaluate the difference between aluminum and vinyl sheet piling of the same shape. When shape properties and material properties are combined the overall performance of a structural product can be determined.

The most common factor used to describe structural performance is Bending Moment. Bending Moment combines the material property of Stress with the shape property of Section Modulus using the following equation:

$$M = \sigma \times Z$$

Where M is Bending Moment, σ is Stress, and Z is Section Modulus. This is by far the most common description of structural performance in engineering, particularly for sheet piling. When evaluating the ultimate performance, the maximum theoretically possible, the ultimate stress value is used in this equation. When evaluating the allowable capacity, the maximum within given safety parameters, the allowable stress (or Design Stress) of the material is used. The only number that changes based on the application requirement and desired safety of the designer is the stress.

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The Section Modulus is a constant and always remains so, regardless of the situation. The Section Modulus is the factor in the above noted equation that describes the performance of the shape of the product, and requires no judgment to accurately depict. The Section Modulus component of the equation can be simply calculated from a drawing of the cross section of the product at hand.

The challenge for designers evaluating vinyl sheet piling is that the allowable stress component of the Bending Moment equation can vary depending on the level of safety deemed necessary by the designer. For example, the following two calculations can be used for the exact same vinyl sheet piling product using two different Design Stress values.

Calculation A

Section Modulus of 15.3 in^3

Using a Design Stress of **3,700** psi

$$M = \sigma \times Z$$
$$M = 3{,}700\,psi \times 15.3in^3$$
$$M = 56{,}610in - lbs$$
$$M = 4{,}718\,ft - lbs$$

Calculation B

Section Modulus of 15.3 in^3

Using a Design Stress of **3,200** psi

$$M = \sigma \times Z$$
$$M = 3{,}200\,psi \times 15.3in^3$$
$$M = 48{,}960in - lbs$$
$$M = 4{,}080\,ft - lbs$$

Although the products, and therefore Section Moduli, of the products are exactly the same in calculation A and calculation B, it could be perceived that the product in calculation A is superior. In this specific case the product in calculation A is shown to be 16% stronger than in calculation B, when in fact the actual capacities are identical. This is due to the different factors of safety used to determine Design Stress. The different levels of safety are hidden in the moment calculation. The only common factor is the Section Modulus which is identical for both products. A more accurate comparison based on Section Modulus would show the products to be the same.

In an even more dramatic example let's compare two products of differing structural capacity.

Product C

Section Modulus of 15.3 in^3

Using a Design Stress of **3,700** psi

$$M = \sigma \times Z$$
$$M = 3{,}700\,psi \times 15.3in^3$$
$$M = 56{,}610in - lbs$$
$$M = 4{,}718\,ft - lbs$$

Product C

Section Modulus of 16.3 in^3

Using a Design Stress of **3,200** psi

$$M = \sigma \times Z$$
$$M = 3{,}200\,psi \times 16.3in^3$$
$$M = 52{,}160in - lbs$$
$$M = 4{,}347\,ft - lbs$$

If the designer was evaluating the two products described above based on Moment only, it could be assumed that product C is 9% stronger than product D. Contrary to what the moment comparison would imply, product C has an actual capacity that is 6% lower than product D. The difference is a lower level of safety was used to describe product C, and therefore the comparison is misleading and inaccurate.

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An accurate moment comparison of these two products would use the same design stress for both, as shown here:

Product C
Section Modulus of 15.3 in^3
Using a Design Stress of **3,200** psi

$$M = \sigma \times Z$$
$$M = 3{,}200\,psi \times 15.3in^3$$
$$M = 48{,}960in - lbs$$
$$M = 4{,}080\,ft - lbs$$

Product C
Section Modulus of 16.3 in^3
Using a Design Stress of **3,200** psi

$$M = \sigma \times Z$$
$$M = 3{,}200\,psi \times 16.3in^3$$
$$M = 52{,}160in - lbs$$
$$M = 4{,}347\,ft - lbs$$

This calculation accurately depicts product C to have a lower capacity than product D.

After several simple examples, it becomes relatively clear how comparing products based on Moment ratings can be extremely misleading. When Moment numbers are the sole means of comparison, the material supplier is able to conceal the level of safety used in determining product capacity, and can overstate product capability in an effort to gain a competitive advantage. In other words, moment based specifications can hide the true performance of a product by reducing the level of safety in order to give the product a stronger appearance than it actually has.

In order to minimize the confusion and possible error, the steel sheet piling industry has eliminated the use of Design Stress when comparing steel sheet piling products. For decades, steel sheet piling has been compared using Section Modulus only. When two products of the same material are being compared, the need to compare material properties is eliminated. In other words, if the materials for the two products being compared are the same, then they can be compared more accurately using shape properties only. The true structural performance can be compared accurately using Section Modulus - and Section Modulus alone. Knowing that the products C and D above are both made from vinyl, they could be more accurately compared using Sections Modulus. A simple comparison of Section Modulus would accurately show Product C to have a capacity 6% lower than product D.

In addition to being an accurate means for structural comparison, Section Modulus is a well-defined number that can be easily verified. Since Section Modulus is a shape property only, it can be verified by anyone at any time using a simple analysis of a published CAD drawing describing the cross-sectional shape of the sheet piling product in question.

In conclusion, Section Modulus has been used as the primary means of design and comparison for structural capacity of sheet piling products of like materials for decades by organizations such as The US Army Corps of Engineers. Section Modulus has been the comparison tool of choice because it is the only way to eliminate the possibility of misleading information through varying factors of safety, and can be easily verified, therefore giving the choice of level of safety for any given project to the designer rather than a material supplier. Moment based calculations can be biased by representing more subjective factors than true structural performance. The only way to provide a true performance based project specification is to specify vinyl sheet piling based on Section Modulus only.

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