Design Stress for Vinyl Sheet Pile

A CMI Technical White Paper

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Vinyl has been a staple in the construction industry for over 50 years. Due to its strength, light weight, and corrosion resistance, Vinyl has long been a clear favorite for piping applications. It is now seeing increasing use in structural applications. But unlike steel, aluminum, and wood, no standard structural design codes currently exist. This lack of a governing design body has lead to inconsistent design methods, general confusion, and manipulation in the industry. Vinyl is not a mystical material. Vinyl sheet piling structures should be designed with the same methodology used for any construction component *(see How to Design with Vinyl Sheet Pile)*.

In the vinyl sheet piling industry, the topics of safety factor in product selection, and design stress in general, are often overlooked. Currently, many people are relying on manufacturers to give them a design stress value, or worse yet, simply the overall bending capacity of the sheet itself. While seeking advice from manufacturers is encouraged, some manufacturers take this opportunity to manipulate the design stress value to best suit their interests at the expense of the designer or end user who is unaware. Many times high design stress values are used, minimizing the factor of safety, to give the perception of increased strength with no physical change. Other times, different design stress values are used for the same material to give the appearance of a broader product range. When these things occur, the design stress values may be hidden or hard to find (see *Structural Comparison and Selection of Vinyl Sheet Piling)*. This paper will aid the designer in establishing the proper design stress. Once this value has been established, it should be used for all products being evaluated.

Factor of Safety and Design Stress

When designing any sheet pile wall, (see *Detailed Engineering Analysis of a Sheet Pile Structure*) two qualities, shape properties and material characteristics, are used to calculate an appropriate sheet for a project. A sheet's various shape properties are determined solely by the geometry of the profile and combined into one design value, Section Modulus. Material properties can be more challenging to quantify due to their inevitable inconsistencies. Unlike Section Modulus which is entirely objective, design stress is determined by taking the maximum stress a material can withstand before failure and applying a chosen level of safety.

Safety factors are always applied in the construction and

$$\frac{\textit{Max Stress Value}}{\textit{Factor of Safety}} = \textit{Design Stress}$$

Equation 1- design stress calculation

$$\frac{30{,}000\ psi}{2} = 15{,}000\ psi$$

Example 1- design stress calculation

engineering industry in this fashion to account for the unknown and to provide added safety in the design. It is the sole responsibility of the wall designer to choose an appropriate safety factor for the project.

Although no official governing codes exist, the US Army Corps of Engineers has long been the leader in sheet pile wall designs and installations. They designate a minimum safety factor of 2 for bending calculations of steel sheet piling (see USACE Publication EM 1110-2-2504, Design of Sheet Pile Walls, section 6-3, Design of sheet piling). At the very least, the same safety factor is recommended for all vinyl sheet pile products. But again, this decision should ultimately be made by the wall's designer.

Establishing a Design Stress for Vinyl Sheet Piling

The minimum tensile strength of Vinyl for use in a building product is designated by its ASTM cell classification (see Cell Class for Vinyl Sheet Pile Materials). This is the only stress value that should be used in the design of vinyl sheet piling.

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Design Stress for Vinyl Sheet Pile

Vinyl sheet piling materials are normally designated with the structural characteristics of cell classification 1-41443-33, meaning they will meet or exceed a minimum tensile strength of 6,500 psi. From Equation 1 above, use this value along with the recommended factor of safety to arrive at the design stress for vinyl sheet piling.

$$\frac{6{,}500\ psi}{2} \cong 3{,}200\ psi$$

Example 2-Vinyl design stress calculation

Although raw materials may vary slightly from manufacturer to manufacturer, vinyl's strength properties remain fairly constant regardless of the blend. If the ASTM cell classification is not known, the same design stress must be used across the board for product comparison. In fact, the US Army Corps of Engineers specifies 3,200 psi, as well, for the design stress of all vinyl sheet piling, regardless of the manufacturer.

Designing for long life

After establishing the proper design stress, long term effects should be considered to determine if this value will yield an acceptable design life. There are many factors that decrease a material's performance over time: fatigue, corrosion, and physical deterioration, for example. Another is creep, the tendency of a body to continually deform over time while held under constant load. While only a major concern at very high temperatures for most metals, creep can affect vinyl at room temperature. It is this phenomenon that is the driving factor in determining the long-term behavior of vinyl sheet piling. Strain is the measure of this deformation and is reported as a percentage change in length. Vinyl formulated to withstand impact like that used in the manufacture of vinyl sheet piling can withstand a maximum strain before failure of 5%. Again, using the methods applied in Equation 1, a safety factor should be applied to this maximum value to arrive at the maximum allowable strain.

$$\frac{5\ \%}{2} = 2.5\ \%$$

Example 3-maximum allowable strain

Fortunately, creep has been thoroughly studied and well documented. In 1962, William Findley began research on the long-term effects of creep on Vinyl. In 1987 Findley published "26-Year Creep and Recovery of Poly (Vinyl Chloride) and Polyethylene." Findley included in his publishing an equation to predict strain due to creep, for any given stress and time period, where ε is strain, t is time, and ε^{o}, ε^{+}, and n are constants.

$$\varepsilon = \varepsilon^{o} + \varepsilon^{+} t^{n}$$

Equation 2- prediction of strain due to creep

Findley's research is far and away the most comprehensive done in this area, and his model has proven to be extremely accurate. His findings are THE authority in the field of creep effects on plastics, and with 26 years of validation, his correlation should be used exclusively to predict long term creep effects on Vinyl.

Using an input stress of 3,200 psi and a maximum strain of 2.5%, a design life of just over 100 years is predicted for Vinyl, further validating the use of 3,200 psi. This relationship between stress and design life is exponential in nature, and a seemingly small increase in design stress will result in a significantly shorter expected life. For example, 3,200 psi results in a service life 30% longer than 3,300 psi (a difference of only 100 psi) and 250% longer than 3,700 psi.

Review

Vinyl is a standard construction material and should be designed with as such. In any structural application, engineers and designers should understand and endorse design methodology, factors of safety, and design values not only for the overall scope of the project, but for product

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selection as well. Retaining walls constructed with sheet pile, vinyl or otherwise, are no exception.

When all factors are taken into consideration 3,200 psi is the most responsible value to use for the design stress of vinyl sheet pile. CMI has been the leader in vinyl sheet pile since it's inception over 20 years ago and has produced millions of feet of installed sheet pile and over 90% of all vinyl sheet pile presently in the ground. These products and processes have been closely monitored over the years to ensure proper design, safety, and longevity. It is our hope that, with the information presented here, the designer or end user will be able to make a more informed and responsible decision regarding the selection and application of vinyl sheet piling.

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