

Design Stress for Vinyl Sheet Pile



A Whitepaper by:

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Physical properties are defined by ASTM testing standards, The Aluminum Association Design Manual, The Naval Facilities Design Manual DM 7.2, The US Army Corps of Engineers General Design Guide: PVC Sheet Pile and/or standard engineering practice. The values shown are nominal and may vary. The information found in this document is believed to be true and accurate. No warranties of any kind are made as to the suitability of any CMI product for particular applications or the results obtained there from. Crane Materials International is a Crane Building Products® company. ShoreGuard®, The ShoreGuard Seawall System™, C-Loc®, TimberGuard®, GeoGuard®, Dura Dock®, Shore-All®, GatorGates®, GatorDock Elite™, ArmorWare™, ArmorRod™, Box Profile™, UltraComposite™, Elite Wall™, Elite Panel™, Elite Fascia Panel™, Flat Panel™, XCR™, XCR Technology™, XCR Vinyl™, GatorBridge™, Gator Aluminum™, Gator Sheet Piling™, GatorDock™, I-Beam Lock™, Textured Slate™, Crane Materials International™ logo, CMI Sheet Piling Solutions™, Aqua Terra System™, Endurance™, Endurance CSP™, Polaris™, Eclipse™, GridSpine™, 21 Poly™, PileClaw™, SheerScape™, SheerScape Retaining Wall Systems™, Sheer Panel™ and CMI Waterfront Solutions™ are trademarks, service marks or trade names of Crane Materials International. United States and International Patent numbers 4,674,921; 4,690,588; 5,292,208; 5,145,287; 6,000,883; 6,033,155; 6,053,666; D420,154; 6,575,667; 7,059,807; 7,056,066; 7,025,539; 7,393,482; 5,503,503; 5,803,672; 6,231,271; 1,245,061CA and other patents pending. © 2011 Crane Materials International. All Rights Reserved.

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 led 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.

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. 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, 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.

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

Equation 1
Design Stress Calculation

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

Example 1
Design Stress Calculation

Safety factors are always applied in the construction and 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. This is the only stress value that should be used in the design of vinyl sheet piling. Vinyl sheet piling materials produced by CMI are designated with the structural characteristics of cell classification 1-42443-33, 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.

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

*Example 2
Vinyl Design Stress Calculation*

Although raw materials may vary slightly from manufacturer to manufacturer, vinyl’s strength properties remain 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 would 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. This phenomenon 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.

$$\epsilon = \epsilon^o + \epsilon^+ t^n$$

*Equation 2
Strain Due to Creep*

Findley’s research is by far 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 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 its 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.