Deflection and Design for Composite (FRP) Sheet Piling

A CMI Technical White Paper

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Deflection of FRP Sheet Piling

The most important factor when designing with any FRP composite product is to ensure that your supplier fully understands the materials and has a complete and broadly tested set of performance parameters. It is extremely important to ensure that the product you are incorporating in your design has been comprehensively evaluated by the manufacturer in both directional and localized stress analyses as well as full section testing. The capabilities of CMI's UltraComposite products have therefore been specified based on actual full section testing and include a design procedure that incorporates global deflections and insures real world performance will be accurately predicted.

All FRP composite designs are deflection based

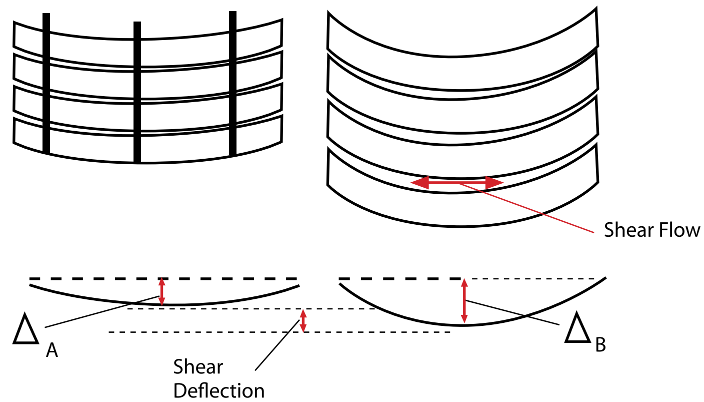
Deflections are a critical component when evaluating the performance of FRP composites. It is often possible for an FRP product to fail due to excessive deflections long before a simple moment capacity is reached even with the incorporation of significant factors of safety. As a result, the entire FRP composites industry has successfully incorporated deflection as a primary design constraint.

Because with FRP composites deflections are a design constraint rather than serviceability limit, accurate prediction becomes much more critical. The critical nature of the calculation combined with the complexity of the materials is significant enough for a more comprehensive evaluation of deflection calculations.

Shear deflection can significantly affect design accuracy

Although FRP composites are generally stiffer than other synthetic materials, an accurate prediction of product deflection requires a more extensive analysis. The deflection of FRP products are normally controlled primarily by simple beam formulas but are also significantly affected by the often overlooked shear component of the analysis.

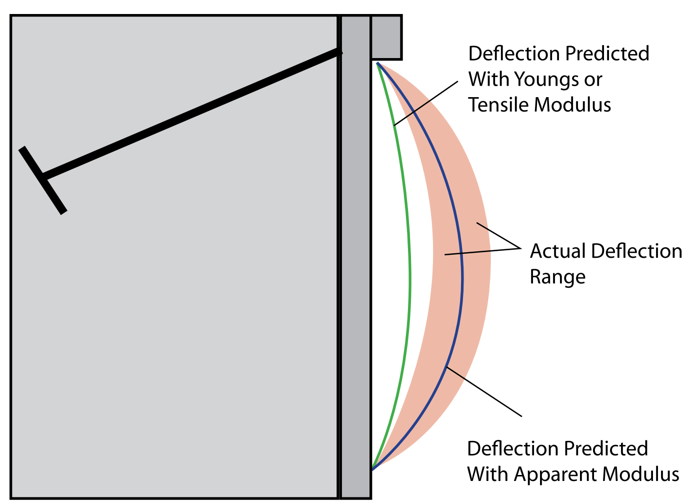
The deflection of a bending member can be effected by other stresses induced by beam loading. When dealing with composite materials in particular, deflections can be dramatically increased by shear deformation. Shear deformation or shear deflections are supplemental deflections occurring in a beam due to an induced shear flow. Shear flow is the horizontal stress within a beam cross section induced by beam loading.



For example, a stack of plywood will be significantly stiffer if the individual pieces are nailed or glued together rather than simply stacked with no bonding. The difference in stiffness is due to shear deflection.

Using Apparent Modulus to achieve accurate results

FRP composite materials are particularly susceptible to shear deflections due to a small amount of slippage of the different laminar layers with respect to one another within the composite. In fact, if shear deflections are not incorporated when designing with FRP composites, predicted deflections



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can be as much as 30% to 50% lower than those actually seen in the field.

Rather than relying on the designer to use a complicated shear term in deflection formulas, all CMI UltraComposite product specifications incorporate the shear deflection effect through the use of an Apparent Modulus of Elasticity. The Apparent Modulus of Elasticity is obtained not by coupon tests but rather by back calculation of modulus from standard full section bend testing and beam formulas. The net result is a modulus number that will allow calculations to predict true deflections rather than underestimate deflection by the use of coupon test derived modulus numbers.

Alternatives to Apparent Modulus

Unfortunately, obtaining an accurate Apparent Modulus requires the manufacturer have a thorough knowledge of FRP composites and undertake a substantial amount of full section full length testing rather than simple and inexpensive coupon testing. Because of the cost and complexity of determining an Apparent Modulus, certain competitors will not specify one. Designers must be wary, values obtained from coupon testing are not sufficient even when combined with a comprehensive Finite Element Analysis (FEA) design program. If only a Young's modulus, modulus of elasticity, or tensile modulus value, rather than an Apparent Modulus, is provided in a product specification it is essential that one of two possible procedures is used when calculating deflection for any FRP composite product:

- The first alternative is to incorporate a shear term in the deflection formula. This is relatively complex for standard bending equations and is extremely difficult when evaluating sheet piling loading scenarios. In fact, there is no computer model available today that will incorporate shear deflection in sheet piling design.

- The second alternative is to reduce the Young's modulus, modulus of elasticity, or tensile modulus by 50% in order to incorporate error, and then input into standard design formulas.

As an alternative to the preceding two options the designer can input an Apparent Modulus directly into all deflection calculations. If the product has been evaluated sufficiently, and comprehensively tested, then using an Apparent Modulus in standard deflection calculations is an effective an accurate method of predicting deflection and ensuring predictions will match real world performance.

Using deflection based design techniques

Once the designer has calculated a reliable deflection value based on the specific site conditions and project characteristics, and using an apparent modulus or reduced Young's Modulus, the value can be checked against the industry standard deflection limits specified for the sheet piling products being evaluated. The deflection based design procedure itself is relatively simple. However, the designer must beware, using improper calculation inputs like a standard modulus rather than apparent modulus can result in significantly flawed results.

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