Calculation Procedure

Consider the following procedure as a guide for calculations required to predict the failure load of the bridge based on the failure mechanisms discussed in CIV102.

1. Calculate internal **forces**, Shear Force, $V(x)$, and Bending Moment, $M(x)$, from a 400 N train
   a. Under train loading, consideration must be made to account for the train being at multiple locations (I.e., moving) along the bridge

$$[V(x), M(x)] = \textit{Solving equations of equilibrium}$$

2. Define bridge **geometry (Design Parameters)**:
   a. Define bridge cross-section shape, and parameterize dimensions: widths (b), height (h), thickness (t), …
   b. Define changes (if any) to cross-sectional dimensions along the length of the bridge

$$\textit{Choose geometry} \quad \{b(x), h(x), t(x), \ldots\}$$

3. Calculate cross-sectional **geometric properties**

$$[\bar{y}(x), Q(x), I(x)] = f\,(\textit{geometry})$$

4. Calculate applied **stresses**

$$[\sigma_{top}(x), \sigma_{bot}(x), \tau_{cent}(x), \tau_{glue}(x)] = f\,(V(x), M(x), \bar{y}(x), Q(x), I(x))$$

5. Calculate material/thin plate buckling **capacities**

$$[\sigma_{tens}(x), \sigma_{comp}(x), \sigma_{buck}(x)\ \tau_{max}(x), \tau_{glue}(x), \tau_{buck}(x)] = f\,(\textit{geometry}, \textit{material properties})$$

6. Compare applied stresses vs capacities to determine **Factors of Safety *(FOS)*** against each failure mechanism

$$FOS_{tension}(x) = \sigma_{tens}(x) / \sigma_{bot}(x)$$

$$FOS_{compression}(x) = \sigma_{comp}(x) / \sigma_{top}(x)$$

$$FOS_{flex.buck1,2,3}(x) = \sigma_{buck1,2,3}(x) / \sigma_{top}(x)$$

$$FOS_{shear}(x) = \tau_{max}(x) / \tau_{cent}(x)$$

$$FOS_{glue}(x) = \tau_{glue}(x) / \tau_{glue}(x)$$

$$FOS_{shear.buck}(x) = \tau_{buck}(x) / \tau_{cent}(x)$$

7. Find **minimum FOS**. This value represents "how many" trains would fail the current design
   a. If minimum FOS < 1, the current design will not support the given train
   b. If minimum FOS > 1, the current design will be able to carry a heavier train. Calculate maximum train weight the current design can hold.

8. For visualization, find the Shear Force Capacities, $V_{fail}(x)$, and Bending Moment Capacities, $M_{fail}(x)$

$$M_{fail\_tens}(x) = FOS_{tension}(x) \cdot M(x)$$

$$M_{fail\_comp}(x) = FOS_{compression}(x) \cdot M(x)$$

$$M_{fail\_buck1,2,3}(x) = FOS_{flex.buck1,2,3}(x) \cdot M(x)$$

$$V_{fail\_shear}(x) = FOS_{shear}(x) \cdot V(x)$$

$$V_{fail\_glue}(x) = FOS_{glue}(x) \cdot V(x)$$

$$V_{fail\_buck}(x) = FOS_{shear.buck}(x) \cdot V(x)$$

9. **Repeat from step 2**, choose new geometry, to increase the minimum FOS and the maximum train weight (i.e., failure load)