

**Factor of safety** is used to provide an allowance over the theoretical material capacity in order to accommodate uncertainties in the design process. It is defined as the ratio of the stress that will cause failure ( $S_{fail}$ ) to the allowable stress ( $S_{all}$ ).

Because steel behaves as a ductile material in a structural tie rod configuration, sizing must be governed strictly by ensuring that the normal tensile stress operating under the design load does not violate the safe operational stress boundary dictated by the factor of safety.

### **Step 1: Determination of the Allowable Working Stress ( $S_{all}$ )**

The ultimate tensile strength ( $S_u = 65,000$  psi) represents the absolute maximum theoretical stress this specific grade of steel can endure before experiencing catastrophic rupture. To ensure absolute safety under real-world bridge conditions, engineers de-rate this maximum limit by dividing it by an empirical structural modifier known as the Factor of Safety (FS). This yields the safe allowable working stress ( $S_{all}$ ), which serves as our strict engineering design ceiling.

Using the foundational relationship from your reference material:

$$FS = \frac{S_{fail}}{S_{all}} \quad \Rightarrow \quad S_{all} = \frac{S_{fail}}{FS}$$

Substituting the given values ( $S_u = 65,000$  psi and  $FS = 3.5$ ):

$$S_{all} = \frac{65,000 \frac{lb}{in^2}}{3.5} = 18,571.43 \text{ psi}$$

*This indicates that to preserve structural integrity with a 3.5-fold buffer, the internal stress within the rod must never exceed 18,571.43 psi of material.*

### **Step 2: Formulation of the Tensile Stress and Cross-Sectional Area**

Normal tensile stress ( $S_T$ ) develops when an external load ( $F$ ) acts perpendicular to the cross-sectional plane of a member. This internal resistance is assumed to be distributed uniformly across the active area.

$$S_{all} = \frac{F}{A}$$

Assuming the bridge tie rod utilizes a solid, standard circular cross-section, its cross-sectional area ( $A$ ) is geometrically defined by its diameter ( $d$ ):

$$S_{all} = \frac{F}{\frac{\pi}{4} d^2}$$

Substituting this area expression back into our core stress formula links the allowable design stress directly with the structural diameter:

$$18,571.43 \frac{lb}{in^2} = \frac{6,500 lb}{\frac{\pi}{4} d^2}$$

$$\mathbf{d = 0.67 \text{ in}}$$

In practical industrial procurement, an engineer will rarely machine a rod to exactly 0.66755 inches. Instead, they will consult standard steel mill catalogs and round up to the next available fractional commercial standard size, which in this case would be a **11/16-inch** (0.6875 in) or a **3/4-inch** (0.750 in) solid steel bar. This practical choice adds an extra layer of safety while keeping production costs low.