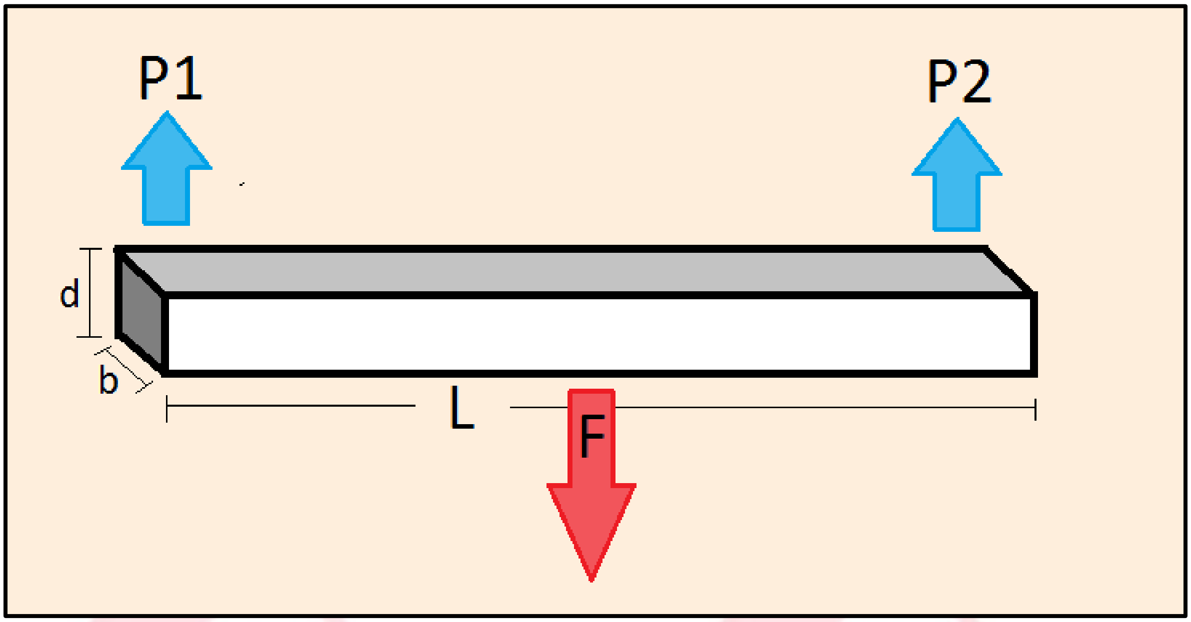
TSB GEN 0005

TECHNICAL SERVICE BULLETIN

MODULUS OF RUPTURE (MOR) TESTING

FORMULA DERIVATION



$L = beam\ length$

$F = force\ on\ beam$

$P1 = reaction\ force\ 1$

$P2 = reaction\ force\ 2$

$P1 = P2 = \frac{F}{2}$

$d = cross\ section\ thickness$

$b = cross\ section\ width$

$M = bending\ moment$

$c = distance\ from\ neutral\ axis\ to\ outer\ fiber$

$I = cross\ sction\ moment\ of\ inertia$

The **Modulus of Rupture formula** can be derived simply by using basic statics and strength of material equations.

Let's start with a **beam of length L** loaded at mid-span with a **force F** and is simply supported at the 2 ends of the beam. The **reaction forces** are **P1 and P2**. The **cross section** of the beam is rectangle and has a **width of b** (dimension into the paper), and a **depth** (height or thickness of the cross section) **of d**. This loading configuration represents a **simple 3 point bending test**.

The beam will **fail (rupture)** at the **point of maximum stress** where it exceeds the **ultimate strength** of the material. In the 3 point bending test, the beam will fail at the point of **maximum bending stress (maximum outer fiber stress)** that exceeds the ultimate material strength.

Maximum bending stress in the beam is determined by the famous formula of $\frac{M*c}{I}$**,** where **M is the bending moment**, **c is the distance from the neutral axis to the outer fiber**, and **I is the moment of inertia** of the beam cross section.

It should be clear that the **maximum bending moment** is located at the **midpoint** of the beam (for a beam loaded at midspan) which can be determined by $P1 * \frac{L}{2}$, where **L/2** is the **length from the support to the beam midspan**. **P1 = P2 = F/2** for a midspan loaded beam. For a **symmetric cross section** such as a rectangle, $= \frac{d}{2}$, where **d is the distance** from the **center** of the cross section to the **outermost fiber**). The **moment of inertia I** for a rectangle cross section is $\frac{bd^3}{12}$.

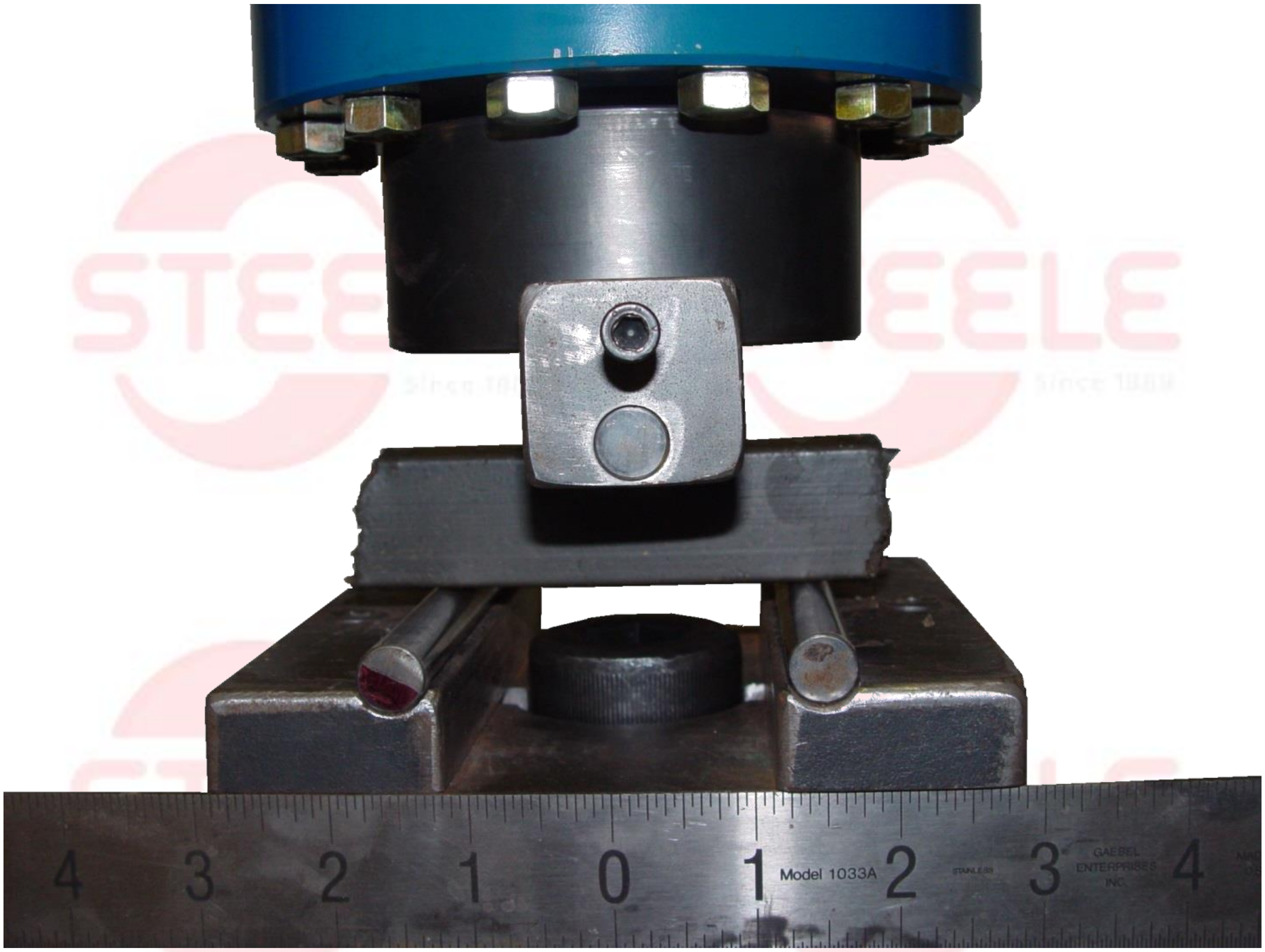
Therefore, putting everything together:

$$Maximum\ Bending\ Stress = \frac{M*c}{I} = \frac{\left(P1*\frac{L}{2}\right)*\left(\frac{d}{2}\right)}{\frac{bd^3}{12}} = \frac{\left(\frac{F}{2}*\frac{L}{2}\right)*\left(\frac{d}{2}\right)}{\frac{bd^3}{12}} = \boldsymbol{\frac{3FL}{2bd^2}}$$

For a **round pellet**, you substitute the **moment of inertia I** for a **circle** which is $\frac{\pi}{4} * r^4$, so:

$$Maximum\ Bending\ Stress = \frac{M*c}{I} = \frac{\left(\frac{F}{2}*\frac{L}{2}\right)*r}{\frac{\pi}{4}*r^4} = \boldsymbol{\frac{FL}{\pi r^3}}$$

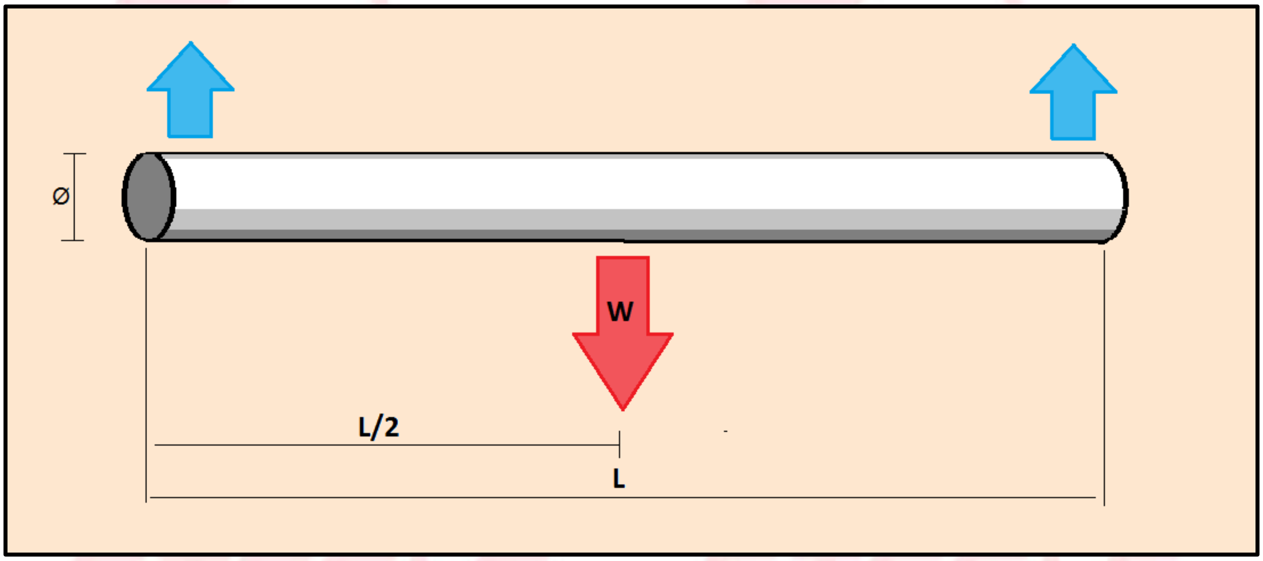
GREEN STRENGTH TESTING



To evaluate green strength of the extruded bars, a Modulus of Rupture test was performed.

Per ASTM C67, *Structural Testing Methods for Sampling and Testing Brick and Structural Clay Tile* Paragraph 5, *Modulus of Rupture (Flexure Test):*

$$MOR = \frac{WL}{\pi R^3}$$



$$MOR = Modulus\ of\ Rupture\ (\frac{lb}{in^2})$$

$$W = maximum\ load\ (lbf)$$

$$L = distance\ between\ supports$$

$$Ø = pellet\ diameter\ (in)$$

$$R = pellet\ radius\ (\frac{Ø}{2})$$

EXTRUSION PLASTICITY FACTOR (EPF)

In order to evaluate the plastic nature of the material during extrusion, penetrometer readings are divided by lab extruder motor amps to get some quantitative value for ease of extrusion. This value is called EPF (Extrusion Plasticity Factor) and the higher the value, the higher the column stiffness for a given level of extrusion amperage.