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"Modulus of Rupture (f_r), is the engineering term use to quantify a member's flexural capacity"

Analyzing Unreinforced Concrete Elements

By Ronald E. Thornton, PE

We all know that concrete is strong in compression and weak in tension. Which is the reason we add reinforcing steel to our concrete structures. Although relatively weak, concrete does have a tensile capacity that can be used to analyze a slab or wall unit in terms of its resistance to flexural or bending stress. This value, known as the Modulus of Rupture (f_r), is the engineering term use to quantify a member's flexural capacity. This is an appropriate term given the brittle nature of concrete. Reinforcing steel, having a modulus of elasticity (E_c) of around 10 times that of concrete, is significantly more ductile than concrete. Therefore, steel will stretch and yield before it breaks. Whereas concrete will snap or rupture when failure occurs.

Modulus of Rupture can be expressed as a mathematical function of compressive strength (f_c) and typically runs in the range of 8 - 10 times the square root of f_c . ACI recommends using $f_r = 7.5 \times \sqrt{f_c}$ for analysis. There is a physical test under ASTM method C78 titled "Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)". This method can be used to determine the actual value of f_r specific to a given mix design and allow us to more accurately determine the point at which cracking will occur when subject to bending.

The most common application for analyzing unreinforced concrete is in the evaluation of handling stresses. A reinforced concrete member subject to bending will crack at the extreme tension fiber before engaging the reinforcing steel. Therefore, we try whenever possible to locate lifting devices in such a way that the unit will not crack during lifting and handling operations.

How is the analysis performed?

If you have ever broken a stick by holding it in your hands and pushing it with your knee, then you have experienced a flexural or bending

failure. The stick will bend until the stress at the outer surface exceeds its tensile capacity and begins to crack. The thicker and wider the stick, the harder it is to break. The cross sectional property of a stick or concrete member related to its resistance to bending is known as the section modulus (S). In a square or rectangular section, S is computed as (width x depth²)/6. The cracking moment or bending capacity of a concrete section is simply:

$$M_{cr} = f_r \times S$$

As an example let's look at a 6" slab of 4000psi concrete considering a 12" wide strip:

$$f_r = 7.5 \times \sqrt{4000} = 474 \text{ psi}$$

$$S = 12 \times 6^2 / 6 = 72 \text{ in}^3$$

$$M_{cr} = 474 \times 72 = 34,128 \text{ in-lbs or } 2.84 \text{ ft-kips}$$

DP_Vault Tips

I have a deep vault with four 5' middle risers and I want to be able to reduce the wall thickness and reinforcing on the top 2 risers. **DP_Vault** currently designs for the bottom most riser and conservatively uses the same design for all risers. To break it down further we need to make two runs. For the first run we put in the total inside height of the structure, design the base riser, first two middle risers and base slab. Print the summary and set aside. On the second run, set the inside height as measured to the top of the second riser. There will be no base slab or base riser. Design the top two risers and the cover slab. By combining the summaries from each of the two runs, we can easily estimate the amount of concrete and reinforcing for the entire structure.

Call or visit our website for additional information on **DP_Vault**.

Delta Enhances Corporate Image

Our new logo and newsletter format are just a couple of the recent changes we have made in order to keep our professional image consistent with our level of superior service and growth. Look for changes to our website at www.deltaengineers.com in the near future and be sure to visit us at the IOC in Greensboro, NC Oct 31 to Nov 2 or at the MCPX in Atlanta in February 2004.

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- Structural Design
- Shop Drawings
- Erection Plans
- Software Development/Sales
- Quality Control Plans
- Training Programs
- Management Consulting

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The Delta Advantage

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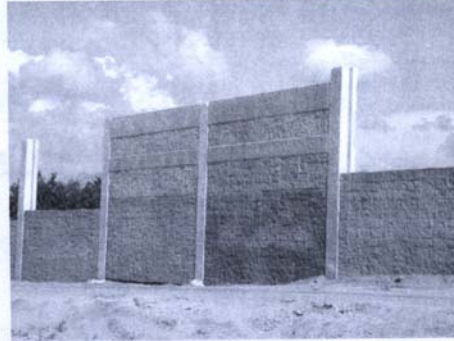
Featured Project

Noise Wall, Interstate 4 (SR400) Polk County, FL

Owner: Florida Department of Transportation

Produced by: Oldcastle Precast, Jacksonville, FL

Structural Design and Shop Drawings: Delta Engineers



Send us your project photos to be featured here

This project consisted of over 8800lf of precast noise wall with 443 posts on 20' centers. Each bay is 16' high with two 8' panels. Panels were cast using split faced block form liners with two bands of fractured fin finish. Posts were embedded in 3' diameter drilled caissons