Mechanics

Concrete Stress-Strain

The material properties of concrete are not constant as they are for a material like steel. They depend upon many factors including: the amount of cement; gravel; sand; and especially the amount of water added to the mix.

We must test a batch of concrete to determine its properties.

Concrete Cylinder Tests

- **Compression tests** on the concrete cylinders are run to obtain:
  - The **ultimate strength** of the concrete, **f'_C**
  - The stress-strain curve to obtain the **Modulus of Elasticity of concrete, E_C**

Since concrete properties vary so much from one batch to another, actual lab tests need to be run to truly determine the material properties. The cylinder compression test is the most commonly run test. In this test, the concrete cylinder is 12 inches long and 6 inches in diameter.

It is tested by applying a compressive load until failure, and measuring the stress and strain. The maximum stress that the cylinder can take prior to failure is the ultimate strength. The slope of the stress-strain diagram is the Modulus of Elasticity.

Concrete Stress

- The **data** collected included the **applied load** and the resulting **change in length** of the cylinder between the attached rings
- To get the **stress,** we divide the load by the area

$$\sigma_c = \frac{P}{A} = \frac{P}{\frac{\pi D^2}{4}} = \frac{P}{\frac{\pi 6^2}{4}}$$

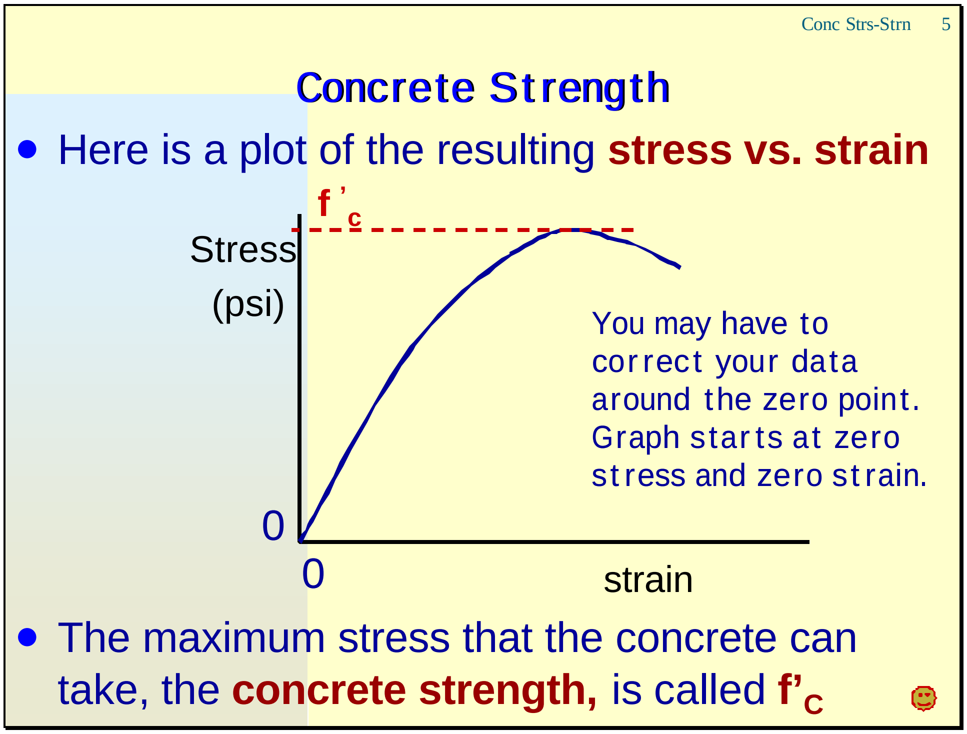
Here is the equation for stress for a 6 inch diameter cylinder.

Concrete Strain

- The **data** collected included the applied **load** and the resulting **change in length** of the cylinder between the attached rings.
- To get the **strain** we divide the change in length by the original length
  - The displacement value, Δ**, has been doubled** by the measurement apparatus
  - The distance between the rings was **6”**

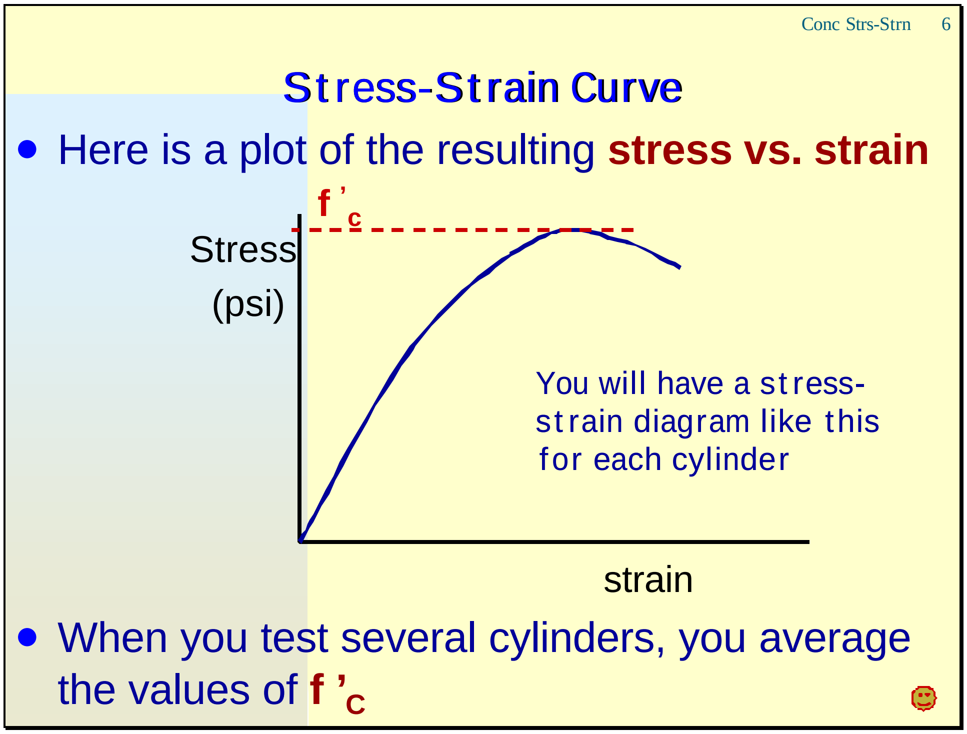
$$\varepsilon_c = \frac{\Delta L}{L} = \frac{\Delta/2}{6}$$

The particular strain measuring device we used in this test magnifies the displacement by a factor of two. This increases the reading and makes it somewhat more accurate. The rings that attached to the cylinders for measuring the displacement were 6 inches apart.

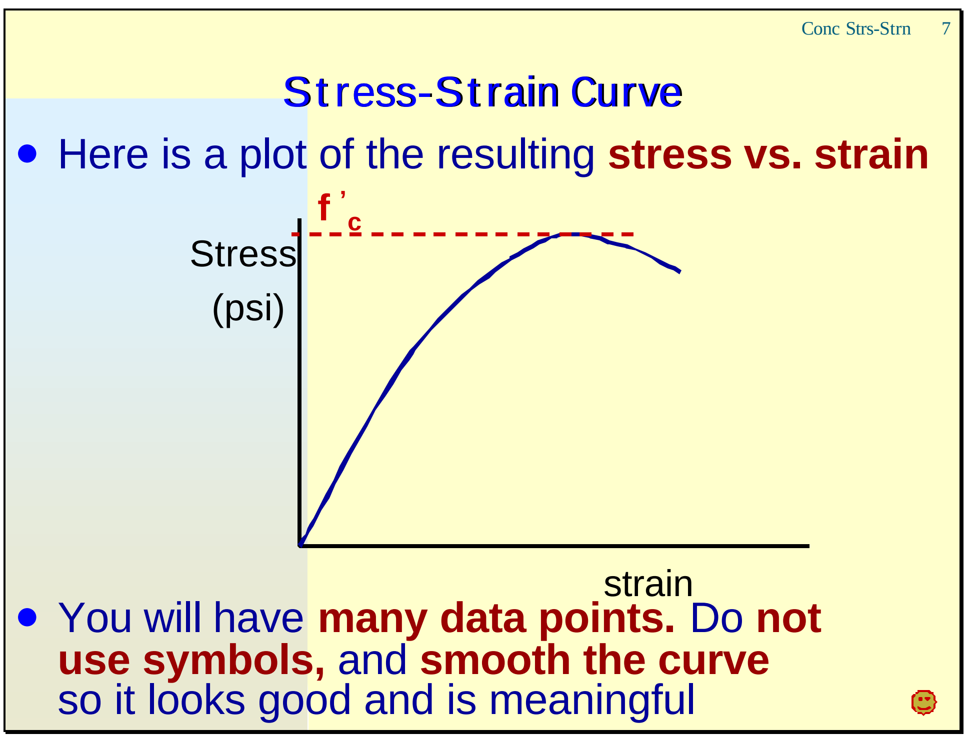


The strength is simply the maximum load divided by the area. Note that after the maximum load is reached, the strain continues to increase as the stress decreases. The f'_C is not the stress at the end of the test, it is the maximum stress applied to the cylinder, at the top of the curve.

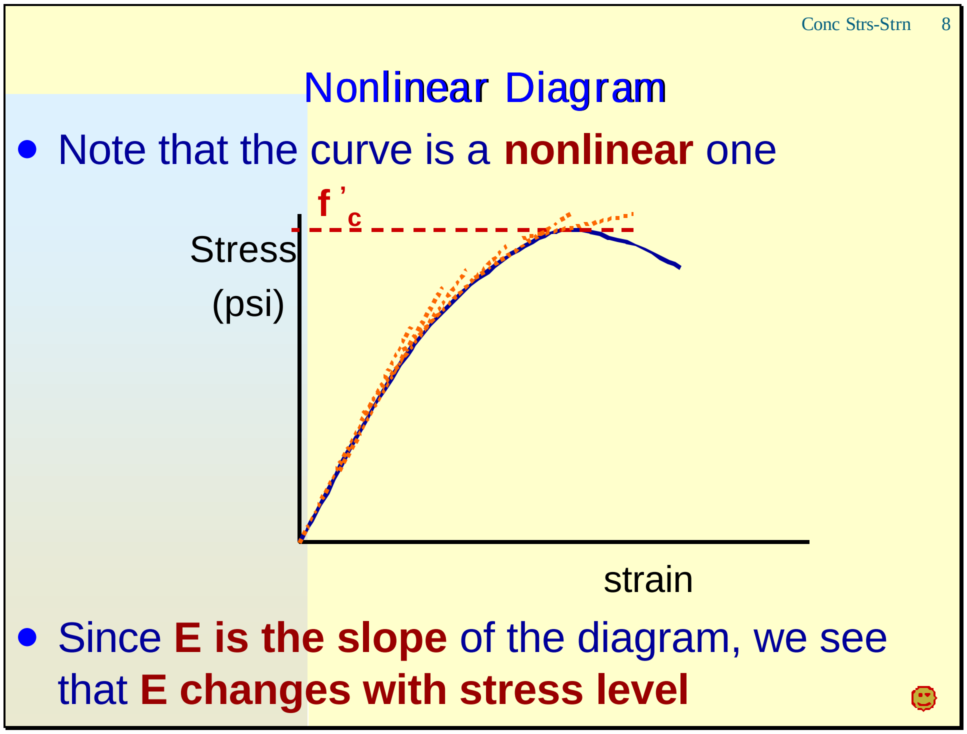
To get this plot you will have to correct the deflection data. There might be a lot of phony readings at the beginning. Discard all data that was recorded before the load started to increase. You also need to get rid of the data at the end of the test. You just want the data that defines the curve similar to the one shown. Also start the test with zero displacement by subtracting out the reading at the start of the test.



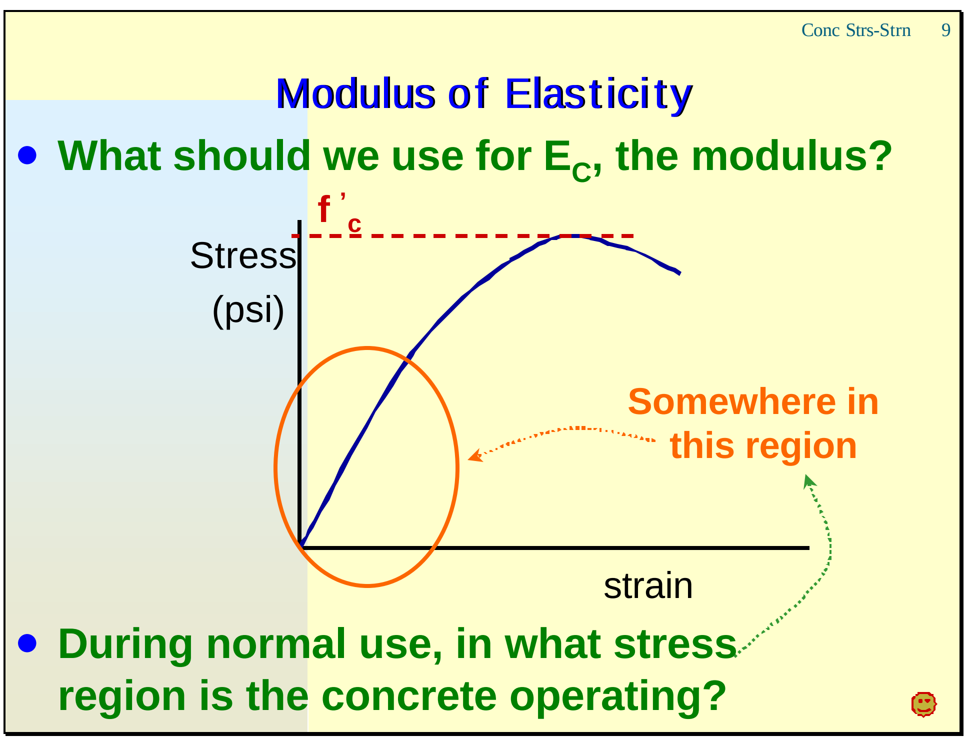
Again, f'_c is just the maximum load divided by the area. You will have a value for the ultimate strength even if you do not measure the strain.



Plot the data without symbols. If symbols are used, they will be so close together that they will merge together and look like a very wide line. Put a high order trendline through the data so that it matches the data well. You can check this trendline by plotting the data with symbols and viewing the trendline, drawn with a light colored line, on top of the symbols. When satisfied with the line, delete the symbols and color the line appropriately.



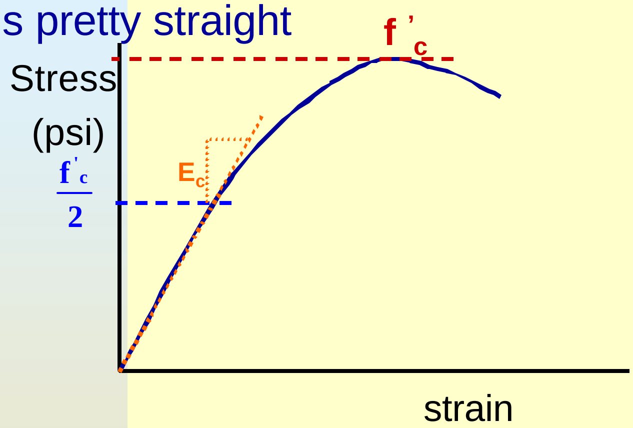
As you can see, concrete is a nonlinear material. As the stress level increases, the slope of the curve decreases, meaning that E_C, the modulus of elasticity of the concrete, decreases. The Stiffness of the concrete decreases at higher stress levels.



Since we always design structures with a factor of safety, generally the stresses during normal operation of a concrete structure will be in the region indicated on the diagram. We try to avoid stresses that approach the failure level.

E_C-Modulus of Elasticity

- For the **first half** of the test, the stress-strain curve is pretty straight

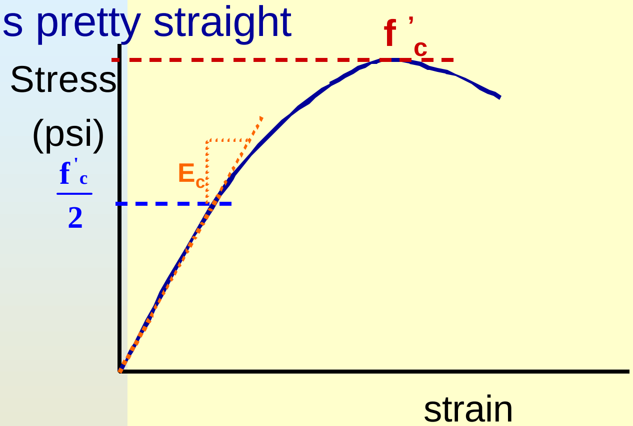


- The **slope of this line** is taken to be $\mathbf{E_C}$

In this region, the slope of the stress-strain curve is fairly constant.

E_C-Modulus of Elasticity

- For the **first half** of the test, the stress-strain curve is pretty straight



- Do a **regression** (trendline) through these data points(below $f'_C/2$). The **slope is called** $\mathbf{E_C}$

To get the slope of this line, we choose the data points up to about one half the ultimate strength and perform a linear regression to get the best straight line through the data. The slope of this regression line (trendline) is the value of E_C.

Approximate Modulus of Elasticity

- Based upon examining a series of concrete cylinder tests, an equation for **estimating the Modulus** of Elasticity of concrete was derived
- This is simply an easy equation to use

$$E_{Approx} = 57000\sqrt{f'_C}$$

  - **f '$_C$** in this equation must be in **psi**
- **Compare** the value from this equation to your measured values
  - It is frequently not very accurate

This equation is an empirical equation. It resulted from examining numerous stress-strain curves and finding an easy formula that would approximate E_C. Being an easy equation was more important than being extremely accurate.

Modular Ratio

- We tested at least two cylinders for stress and strain. Take **E$_C$** to be the **average of the slopes** of the two lines
- Once we have E_C, we can determine the **modular ratio, n**

$$n = \frac{E_s}{E_C} = \frac{29000ksi}{E_C}$$

Make sure that the units are in agreement. With this modular ratio it is now possible to examine the reinforced concrete beam to create the transformed section.