Materials Testing

Synopsis:

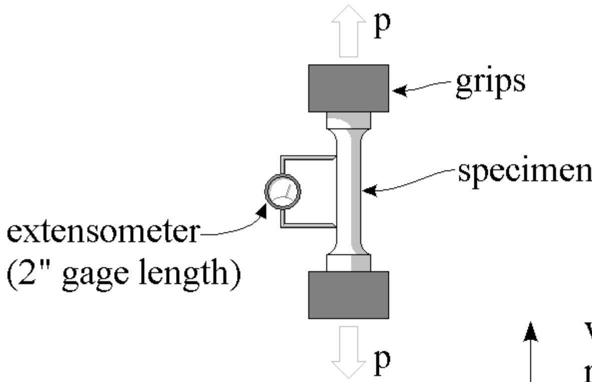
- Properties of Engineering Materials:
- Tension Tests: Steel, Wood, Concrete, Plastics
- Compression Tests: Steel, Concrete
- Shear: Concrete
- Bending: Concrete, Steel, Etc…
- Hardness: Various Materials
- Impact: Various Materials
- Non-Destructive: Various Materials

Properties of Engineering Materials

- Stress-strain relations
- Cracking, yield, ultimate strengths and deformations (inelastic behavior)
- Energy dissipation capacity
- Shear strength, bending strength, tensile strength, compressive strength, hardness, impact, toughness, splitting strength, shrinkage, creep etc.

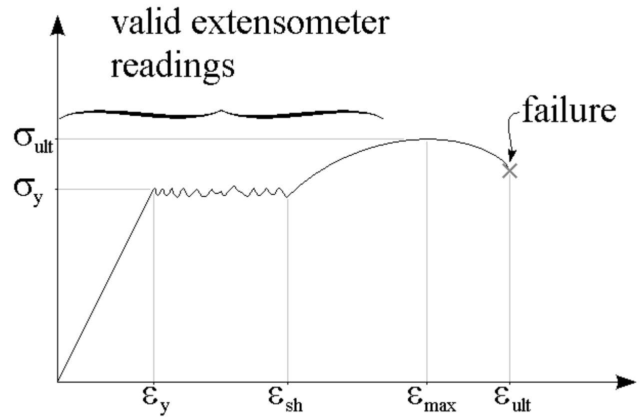
1. Tensile test

i.e. Steel, rebar, wood



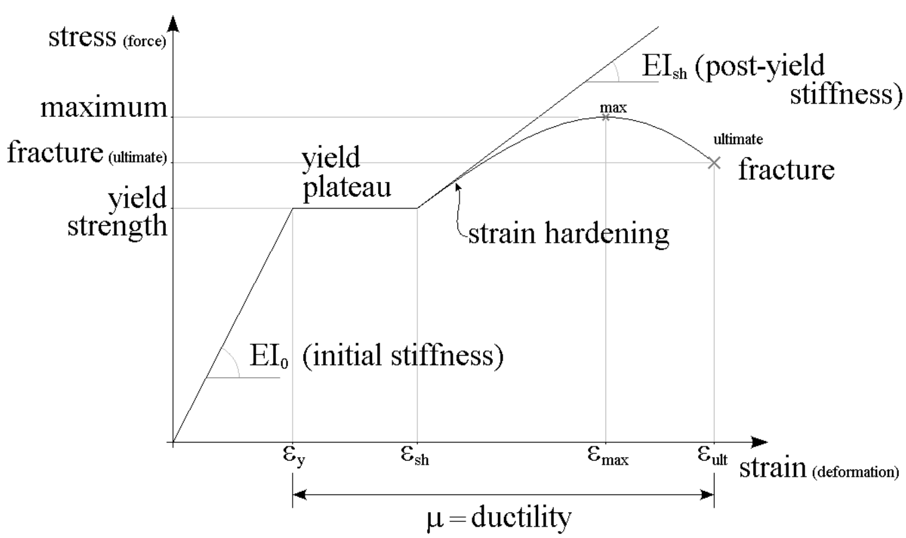
$$\sigma = P/A$$

$$\varepsilon = \text{ext. reading}/2"$$



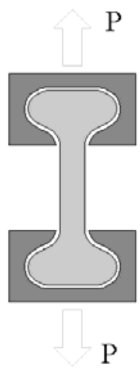
Important Response Quantities

Response Behavior for Steel:



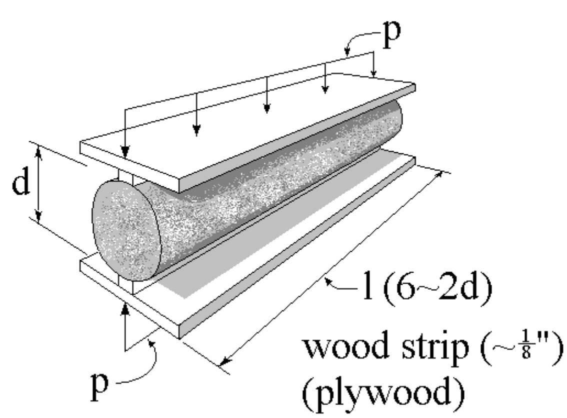
For wood and concrete special specimen geometries can be used,

i.e.:



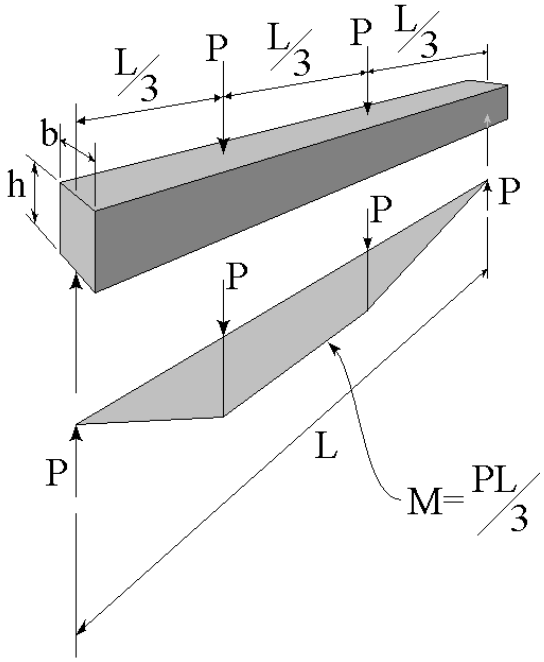
For concrete the tensile strength can be found using two methods:

The split test: (usually with a 6” diameter by 12” long specimen)



$$\sigma_{split} = \frac{p}{l}\left(\frac{2}{\pi d}\right)$$

The modulus of rupture:



$$\sigma_b = \frac{M_y}{I}$$

$$\therefore f_r = \frac{M\left(h/2\right)}{1/12\, bh^3} = \frac{6M}{bh^2} = \frac{6\left(p\, L/3\right)}{bh^2}$$

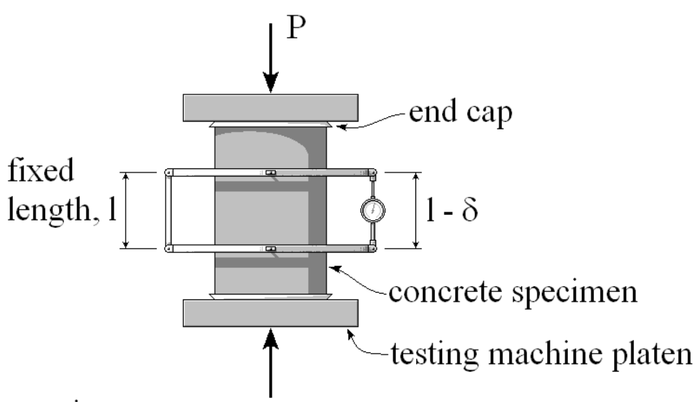
2. Static Compression Test

- Used to find f'_c in concrete.
- Normally tested at 3, 7, 14, 28 etc. days.
- Specimens are typically cylindrical (6" diameter, 12" long; 4" diameter, 8" long; 3" diameter, 6" long), though prisms may also be tested (4 cm by 4 cm by 8 cm; 8 cm by 8 cm by 16 cm).
- Test apparatus: universal testing machine or compression apparatus.
- Special requirements for concrete include end caps, usually of sulfur, hydrostone or rubber.
- Special measurements are σ vs ε

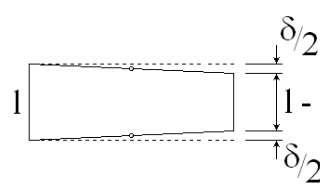
δ is taken from the extensometer reading

$$\varepsilon = \frac{\delta/2}{l} = \frac{\delta}{2l}$$

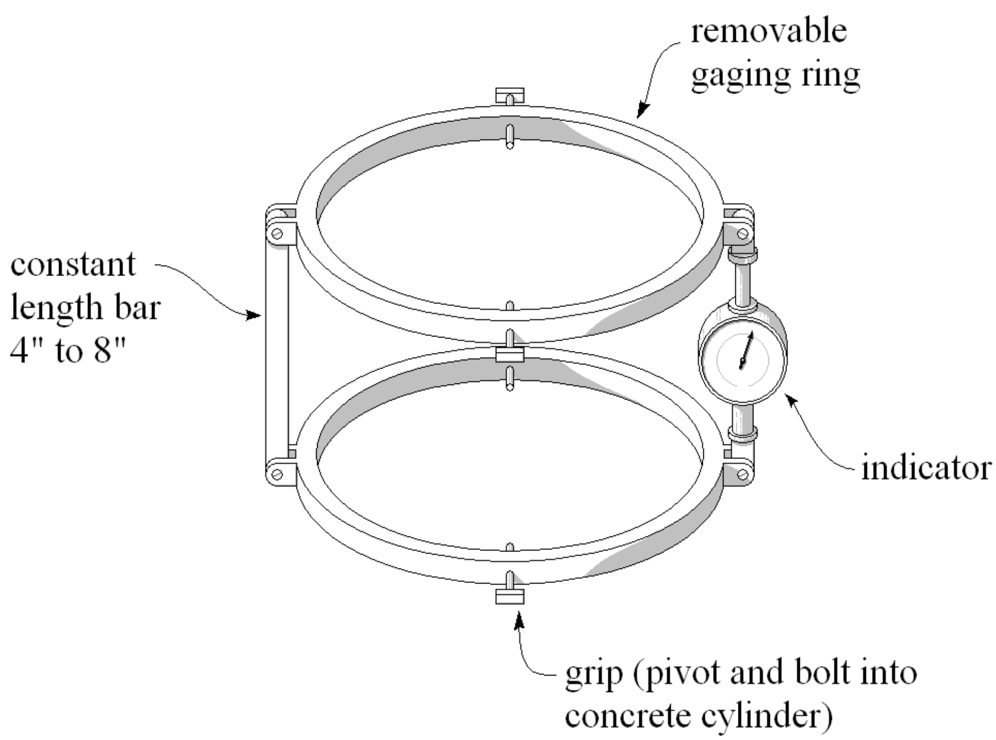
$$\sigma = P/A$$



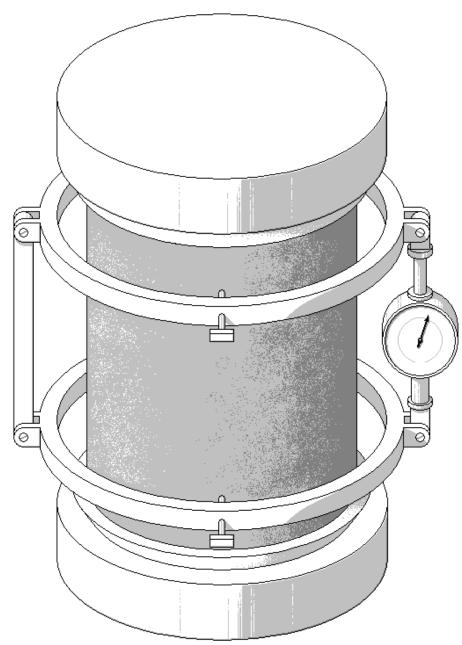
i.e.



Gauging ring setup

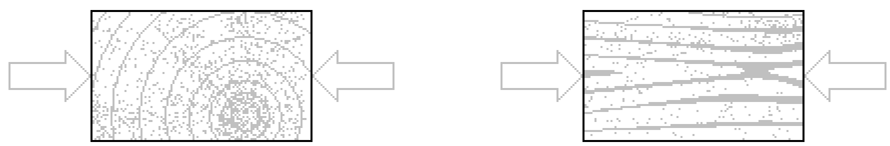


Static compression
test setup

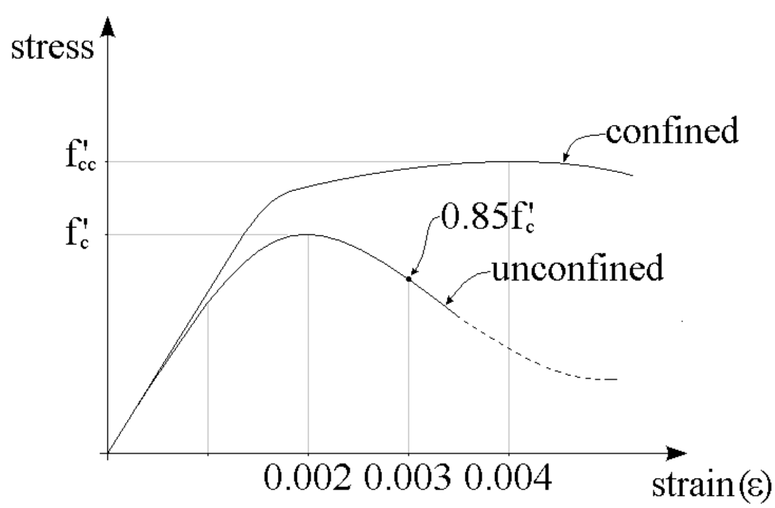


Wood has different properties in the various directions due to the grain of the wood.

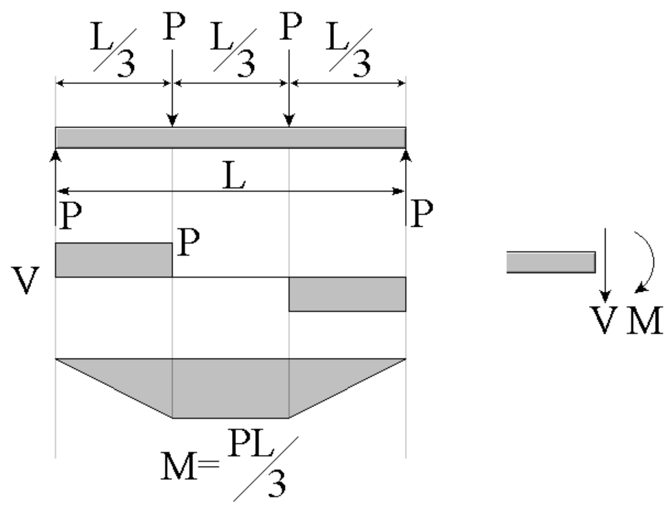
- Compressive strength parallel to grain must be tested, as should
- Compressive strength perpendicular to the grain.
- The parallel strength is approximately two to five times the perpendicular strength.



Response Behavior of Concrete (and Wood?):



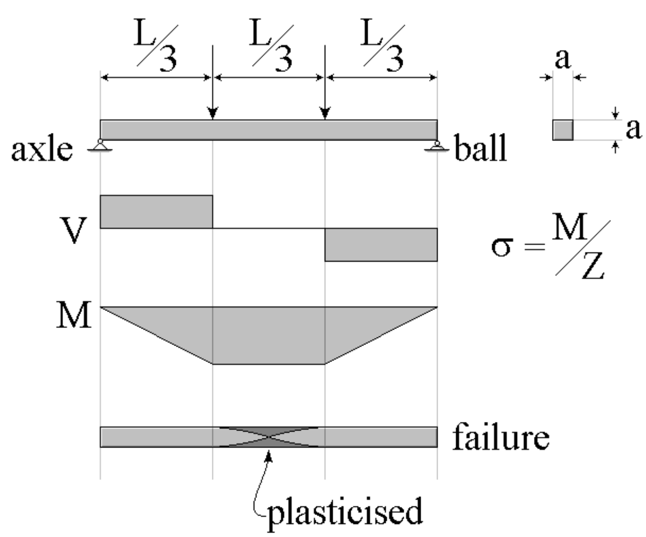
3. Bending Test



Bending is important in brittle materials, wood, and steel

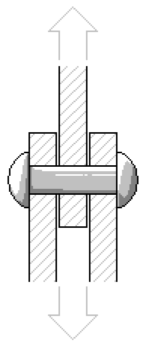
Determine modulus of rupture

Determine compressive / bending strength

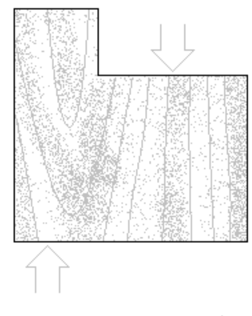


4. Shear Test

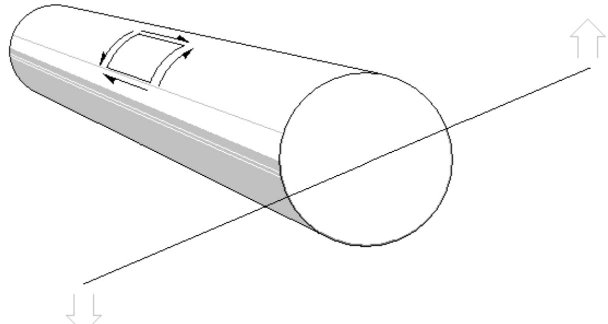
Test configurations:



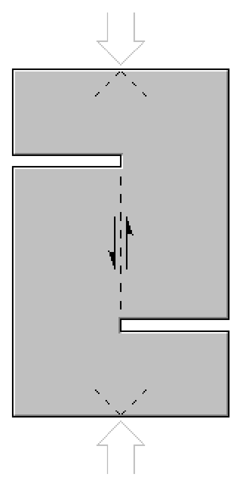
rivet test



wood (parallel)



torsion of cylinder

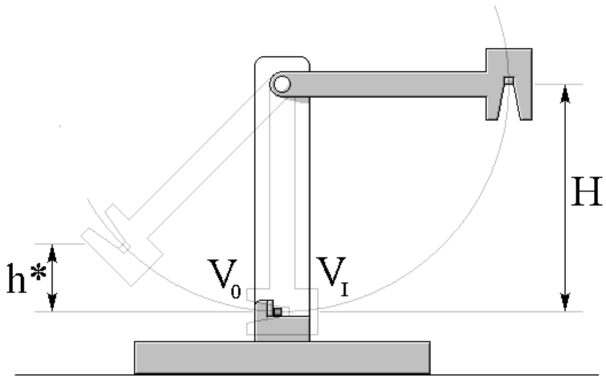


shear in compression

Shear stress is evaluated directly by: $\tau = \frac{P}{A}$

5. Impact test

Impact tests consider energy properties…



$$V_I = \sqrt{2gH}$$

$$V_0 = \sqrt{2gh^*}$$

The loss of momentum is due to absorbed energy.

6. Hardness test

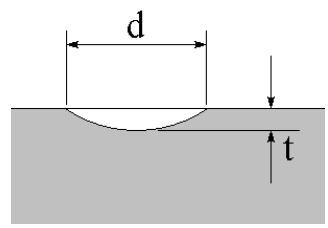
Refer to ASTM standards…

The usual tests include:

Brinell (1900)	-	Superficial indentation 10 mm ball, high loads
Rockwell (1920)	-	Superficial indentation 1/16”, small loads
Vickers (1925)	-	Superficial indentation Pyramidal diamond,
Schmidt hammer	-	Dynamic test (used for concrete and rock)

Brinell test:

$$\text{Brinell\#} = \frac{P}{\frac{\pi D}{2}\left(D-\sqrt{D^2-d^2}\right)}$$

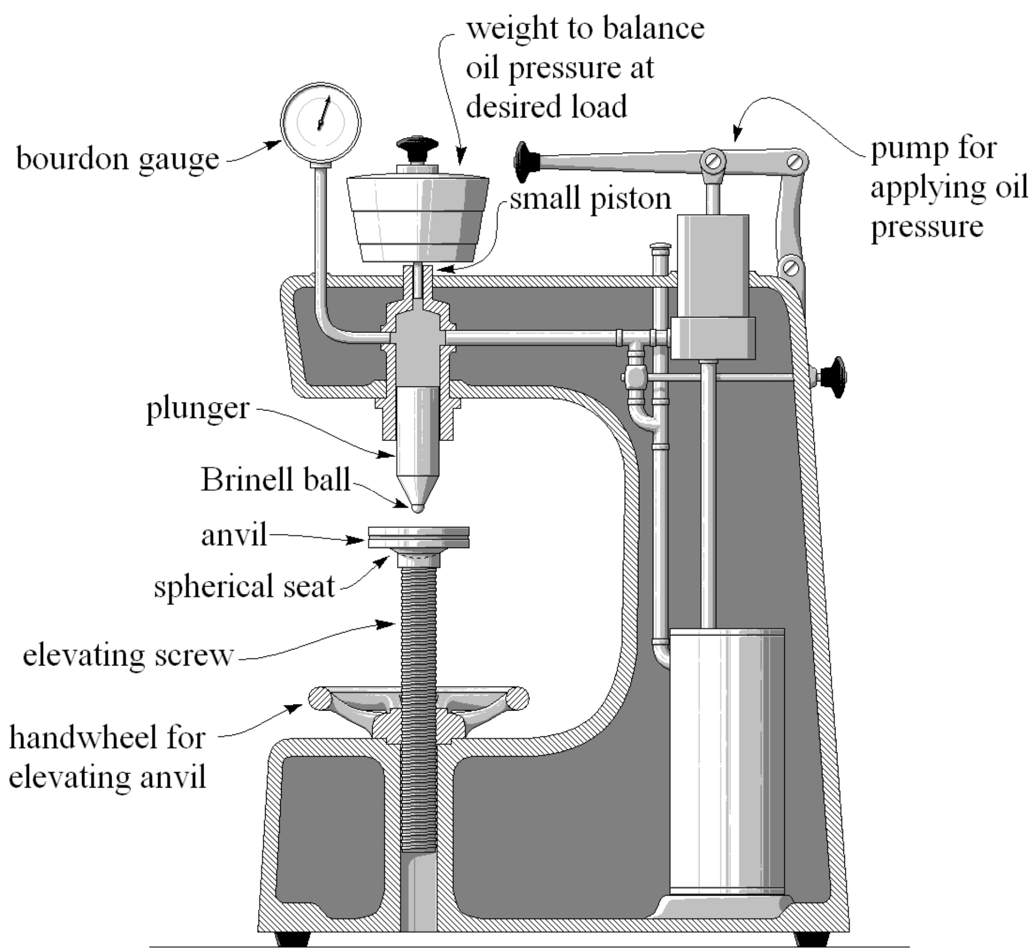


or

$$\text{Brinell\#} = \frac{P}{\pi D t}$$

where

D = diameter of ball

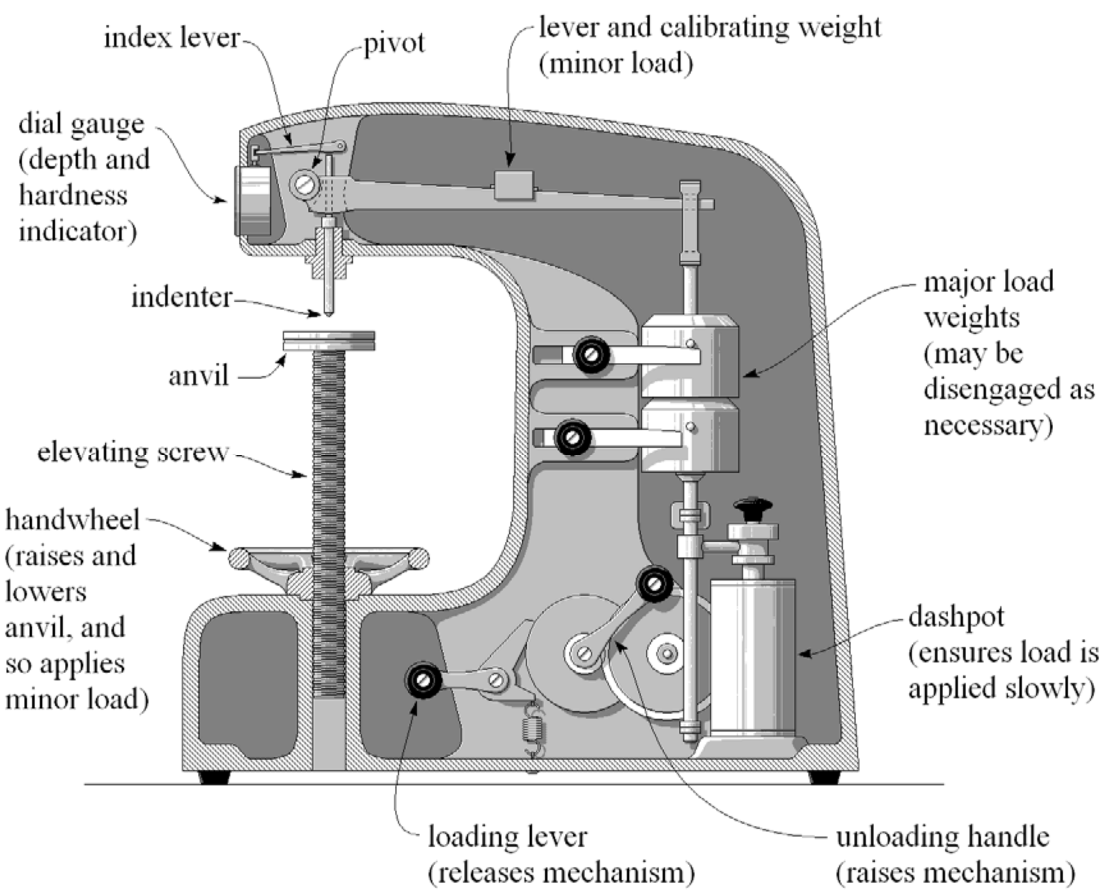


Rockwell test:

$$\text{Rockwell\#} = 130 - \frac{t(\mu m)}{2(\mu m)} \qquad (B)$$

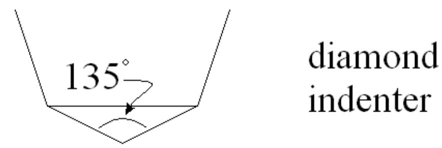
and

$$\text{Rockwell\#} = 100 - \frac{t(\mu m)}{2(\mu m)} \qquad (C)$$

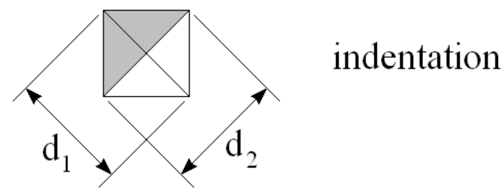


Vickers test:

The machine is similar to the Brinell test machine, but the indenter is a diamond cut as a pyramid with the faces at 136° to each other.



$$HV = \frac{C \cdot P}{d_1 \cdot d_2}$$



The Vickers hardness number is given in the format; 372HV10 where the 372 is the hardness value and the 10 is the test force in kilograms. For metals the Vickers hardness value is generally between 100 and 1000. The dimension d is read with a calibrated microscope.

Depending on the size and thickness of the material being tested, the test force can range from 10 grams to 100 kilograms.

Schmidt Hammer:

In this test a weight is thrown against a surface with a known force, and the rebound is measured. For hard materials the machine consists of a plunger with a contained weight and spring in a cylindrical housing, and for softer or thinner materials a pendulum type device is used. The rebound is directly recorded on a scale on the machine, and may be calibrated for different materials. The device is small and is held in the hand.

References:

Davis Troxell & Hauck " Testing of Engineering Materials" McGraw Hill, 1982

Gordon England ***http://www.gordonengland.co.uk/*** "Hardness Testing", 2004

Notes on Hardness