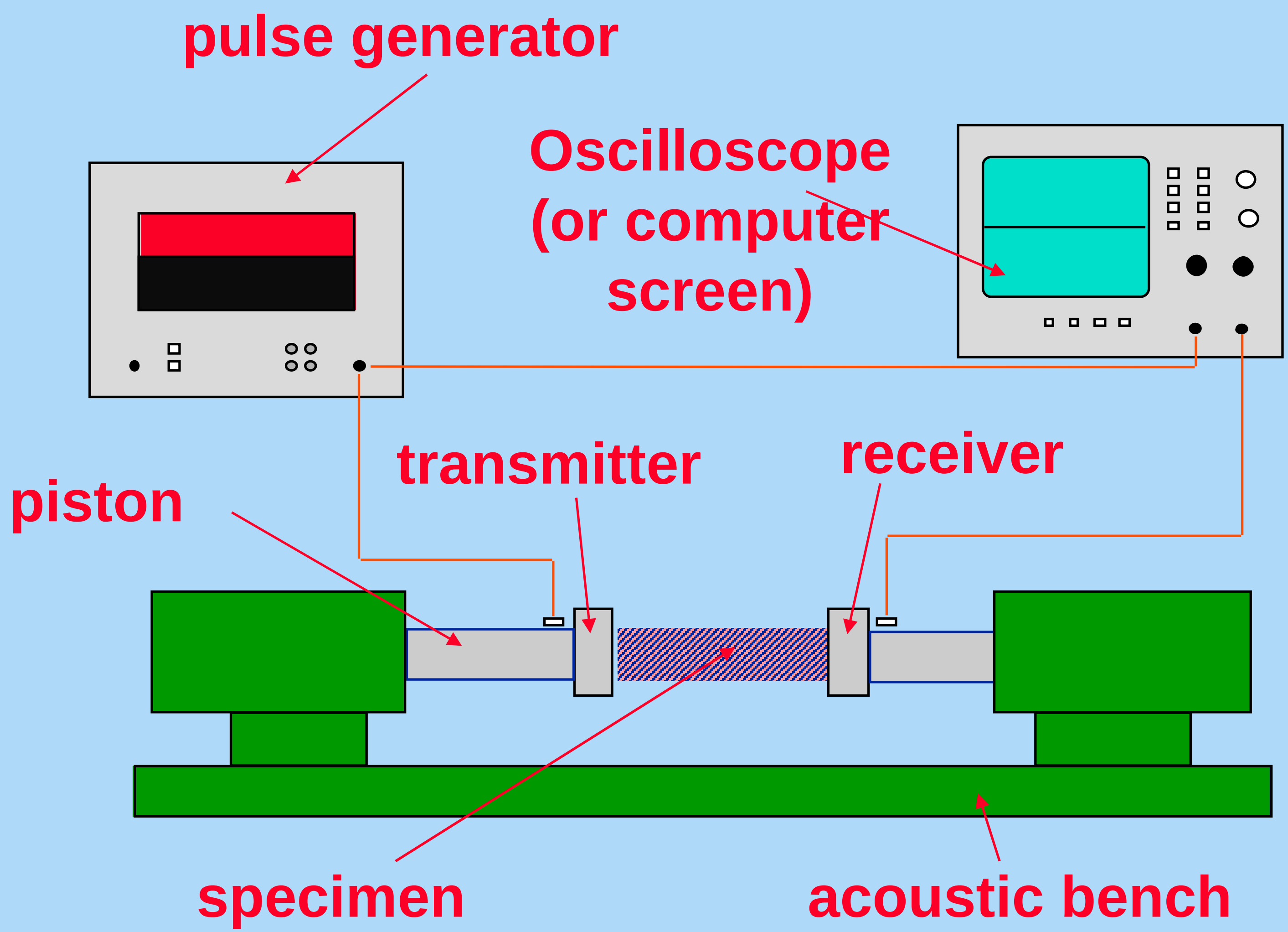
- Index properties
  - Longitudinal Velocity and Degree of Fissuring
  - Uniaxial Compression
  - Point Load Strength
  - Shore Hardness
  - Schmidt Hardness
  - Brazilian Test
  - 4-point Beam Test
  - Uniaxial Tension Test
  - Rock Quality Designation

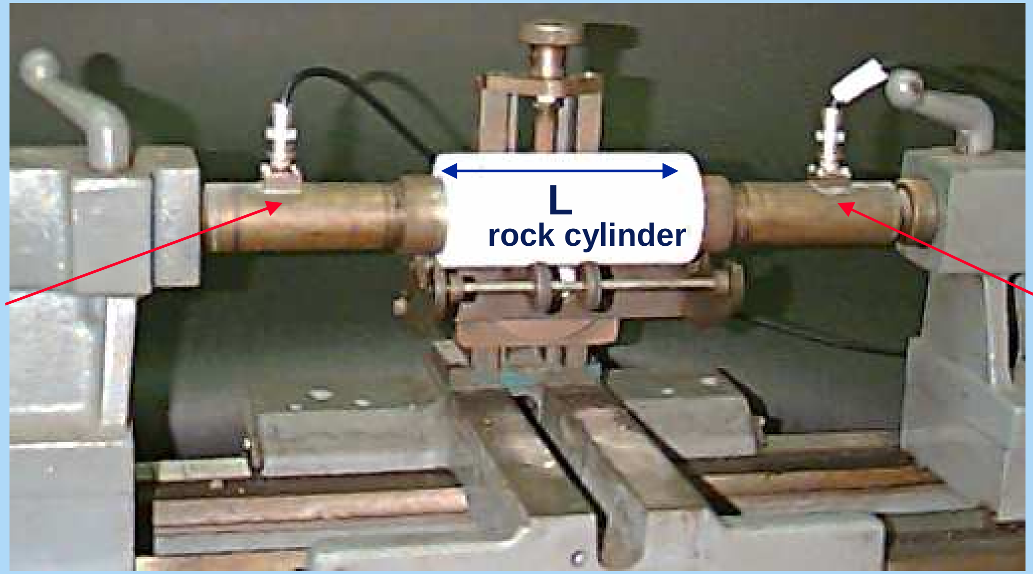
Measuring Longitudinal and Shear Velocities (V_l; V_s) in the Lab

Testing Setup



Measuring Longitudinal and Shear Velocities (V_l; V_s) in the Lab

T(ransmitter)

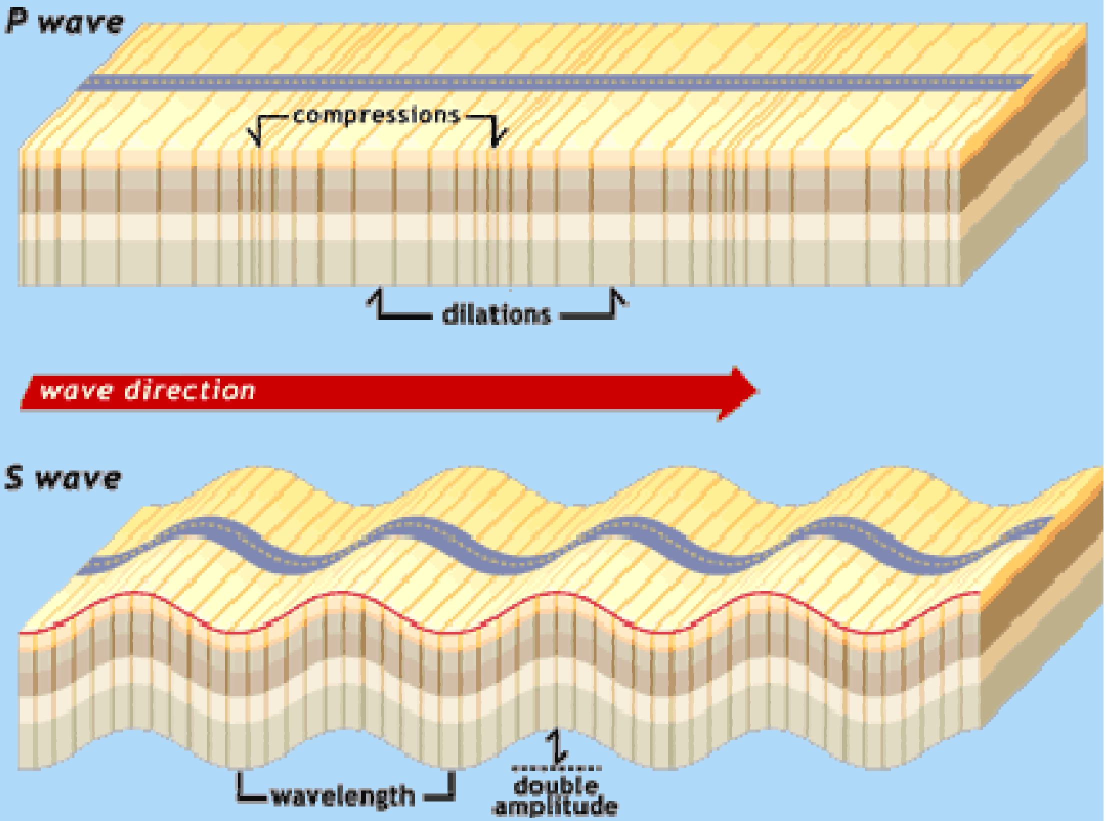


R(eceiver)

$$V_l = \frac{L}{t_R^l - t_T^l} \;;\quad V_s = \frac{L}{t_R^s - t_T^s}$$

Compressive and Shear waves

- Compressive waves
  - Particle motion is parallel to the wave direction
- Shear waves
  - Particle motion is perpendicular to the wave direction



•Testing Physical Properties (contd.)

Longitudinal velocity V_l

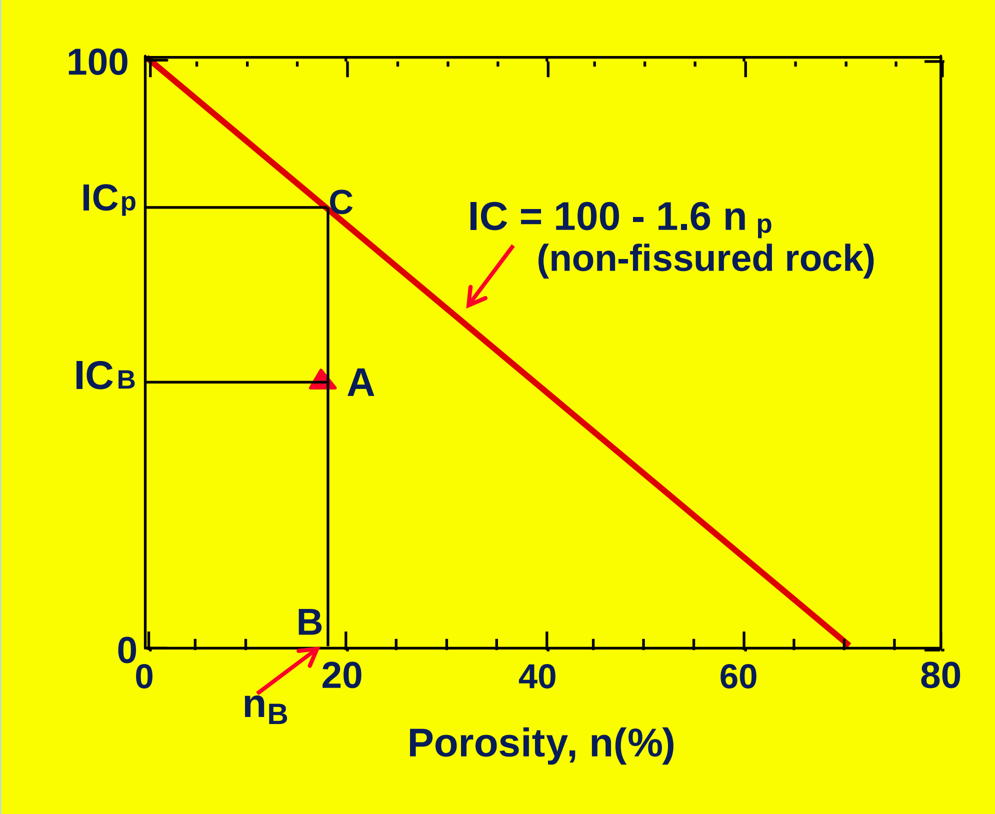
Degree of Fissuring D_f

The specific longitudinal velocity V^*_l of rocks with zero pores/fissures is given by:

$$\frac{1}{V_l^*} = \sum_i \frac{C_i}{V_{l,i}^*}$$

($V^*_{l,i}$ is longitudinal velocity of the i-th mineral constituent, whose volume proportion is C_i)

The **Degree of Fissuring** D_f is obtained from a plot of IC(%) versus n. If the IC_B of sample is given by A in Figure, than D_f is found from the following relationship, where IC_p (= C in plot) is for spherical pores only, and IC_B (=A) is for both pores and fissures:

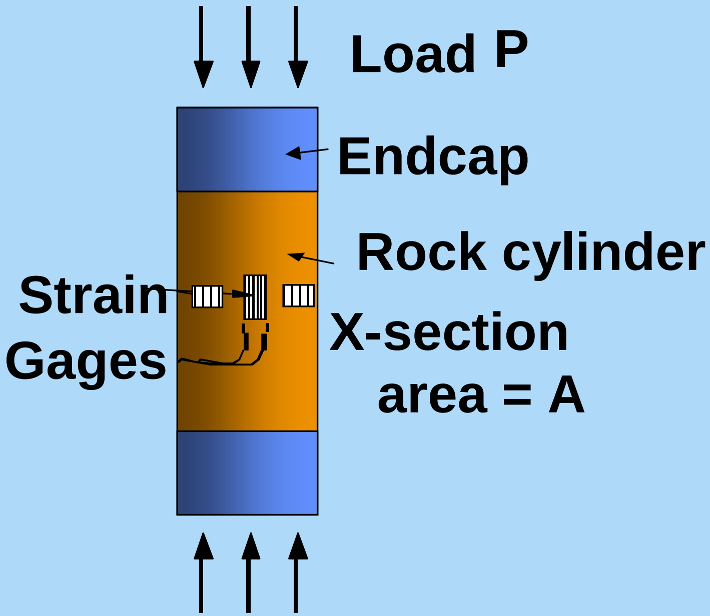


$$D_f(\%) = \frac{IC_p - IC_B}{IC_p} \times 100$$

Classification	Degree of Fissuring (%)
Non-fissured	0
Slightly fissured	0-10
Moderately fissured	10-25
Strongly fissured	25-50
Very strongly fissured	50-75

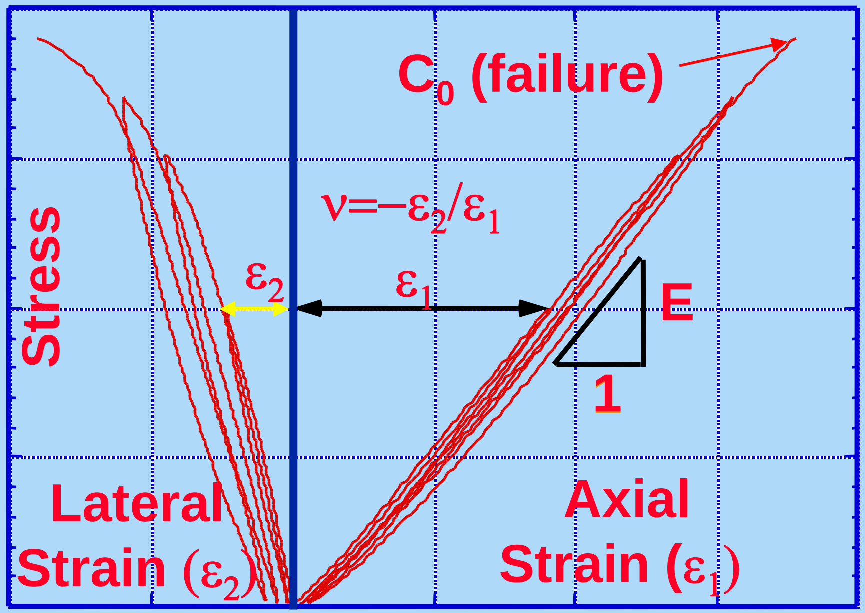
Testing Mechanical Properties

1 Uniaxial Compression Tests



Direct test

$$C_o = \frac{P_{peak}}{A}$$



C_0 : Uniaxial Compressive Strength

E: Modulus of Elasticity

ν : Poisson's Ratio

Testing Mechanical Properties

1. Uniaxial Compressive Strength Tests

Steel cones

Hydraulic ram

Indirect test (*Point Load* Test)

Measurement of the Point Load Strength I_s and of the indirect C_0

A rock core is loaded diametrically between the tips of two hardened steel cones, causing failure through the development of tensile cracks parallel to the loading direction.

The load at failure P_{peak} is recorded and the point load strength is calculated from:

$$I_s = \frac{P_{peak}}{D^2}$$

where D is the distance between the two cone tips.

Measurement of the point load strength I_s and of the indirect C_0

The uniaxial compressive strength C_0 is then indirectly obtained by using the empirical relationship:

$$C_o = 24 \times I_{s(50)}$$

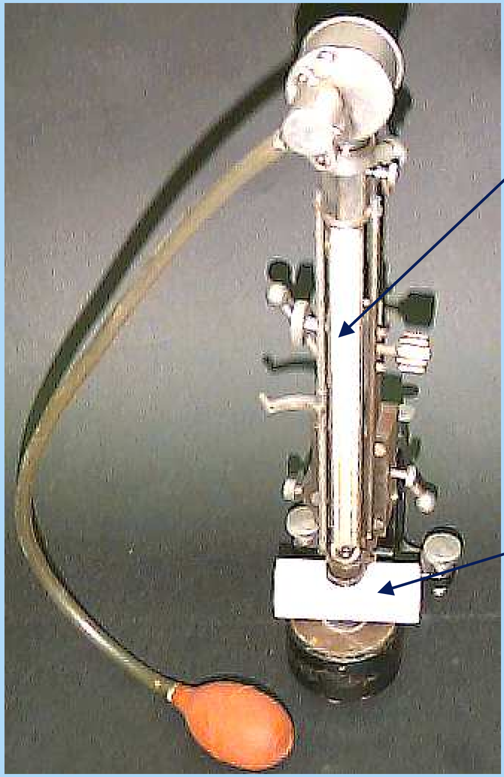
where $I_{s(50)}$ is the point load strength of 50 mm (2 in.) diameter cores

Testing Mechanical Properties (contd.)

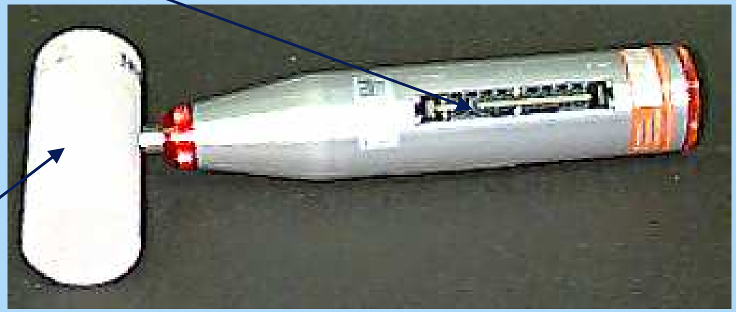
2. **Hardness** (also used as Indirect Uniaxial Compressive Strength Tests)

Graduated window showing the rebound of pellet or spring

Rock specimen



(a) Shore Scleroscope



(b) Schmidt Hammer

Measurement of the Shore hardness H_{Shore} and the Indirect Determination of C_0

Shore hardness (H_{Shore}) is measured as the extent of rebound of a steel bullet dropped from a specific height onto the surface of a rock specimen.

The harder the rock, the higher the bounce.

An empirical correlation between rock hardness and its uniaxial compressive strength has been obtained based on a large number of tests on different rocks, and is given by:

$$\log C_o(psi) = 0.000066 \times \gamma_{dry}(lb/ft^3) \times H_{Shore} + 3.62$$

Measurement of the Schmidt hardness H_{Smdt}, and the Indirect Determination of C_0

The Schmidt Hammer is a portable tool, similar in principle to the Shore Scleroscope. It is used exclusively for rock and rock-like materials and is easy of use in the field. It measures the rebound off the surface of rock of a spring-driven steel pellet.

An empirical correlation between the Schmidt rock hardness and uniaxial compressive strength has been obtained based on a large number of tests on different rocks:

$$\log C_0(psi) = 0.00014 \times \gamma_{dry}(lb/ft^3) \times H_{Smdt} + 3.16$$

Testing Mechanical Properties (contd.)

3. Tensile Strength Tests

Flat platens

Rock disk

(a) Brazilian (indirect) Test

(a) Measurement of the Brazilian tensile strength T_B

This is an indirect measurement of the tensile strength of rock.

A rock disk of uniform thickness is cut from a rock core, and is loaded diametrically between upper and lower flat (or rounded) platens in a compression testing machine. Thus, a compressive line-load is applied to the disk.

When the peak load P_{peak} is reached the disk will typically split along the loaded diameter.

Measurement of the Brazilian tensile strength T_B (contd.)

Theoretical analysis shows that uniform tensile stress develops along this diameter. The tensile strength T_B can be obtained from the elastic solution:

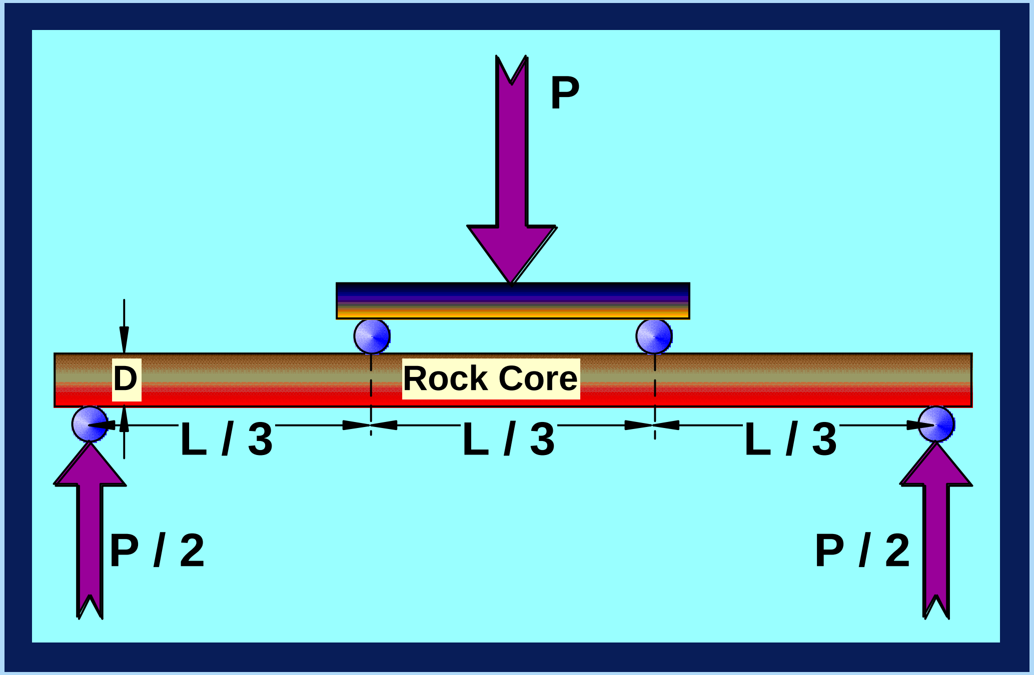
$$T_B = \frac{2P_{peak}}{\pi \times D \times t}$$

where P_{peak} is the load at failure, t and D are the thickness and diameter of the disk respectively. The ratio of t/D is 1/4 to 1/2.

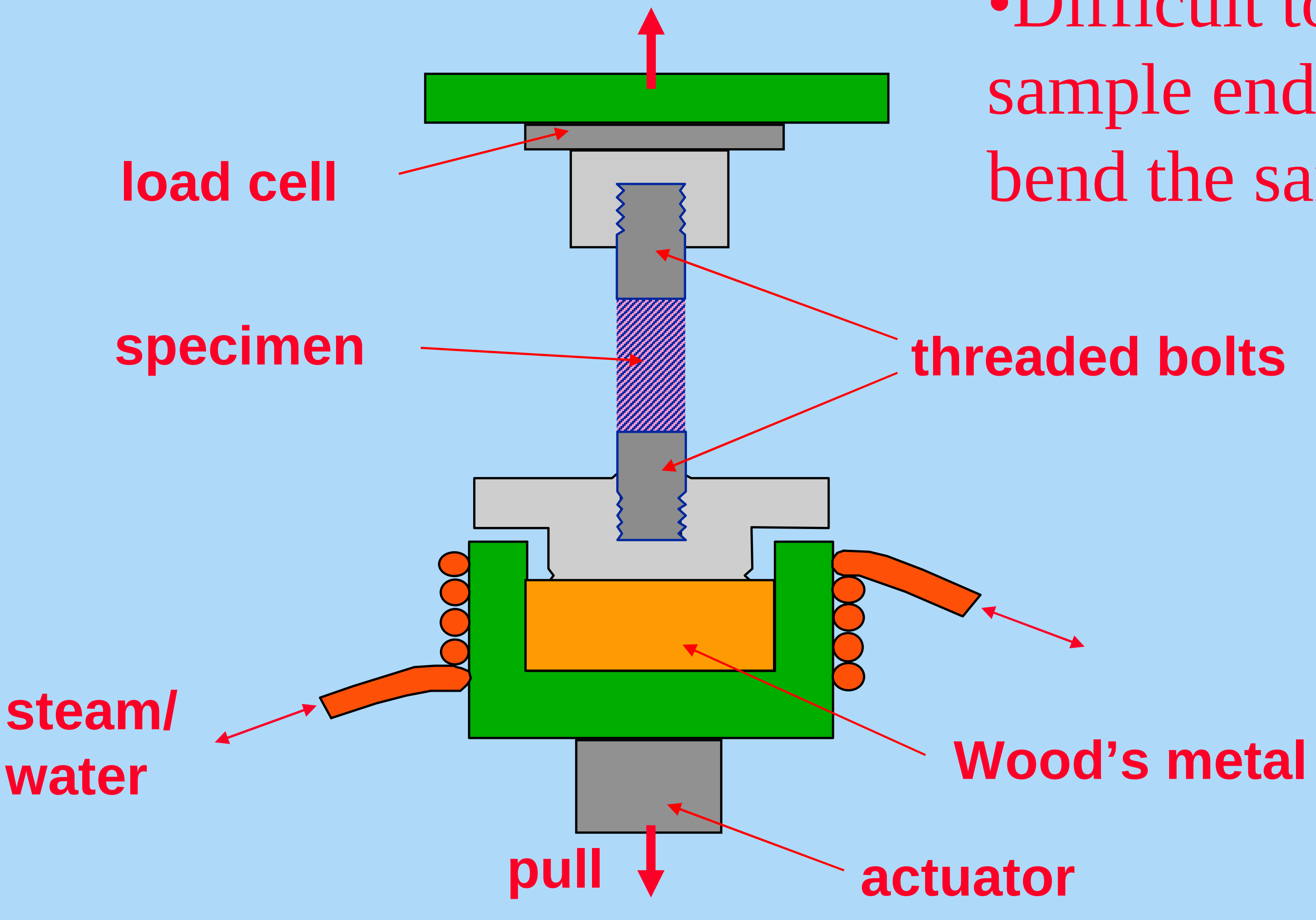
(b) Four-point-beam modulus of rupture (tensile strength) T_{MR}.

In this test a long rock core is flexured to failure. There are four contacting points dividing the core into three sections of equal length. The middle section is under pure bending. The maximum tensile stress occurs in the bottom layer of the middle section of the core, and this is where failure typically occurs as P reaches P_{peak}. This test determines the modulus of rupture (T_{MR}) (beam flexural tensile strength). From the theory of beams:

$$T_{MR} = \frac{16 \times P_{peak} \times L}{3 \times \pi \times D^3}$$



Direct Uniaxial Tension Test Setup

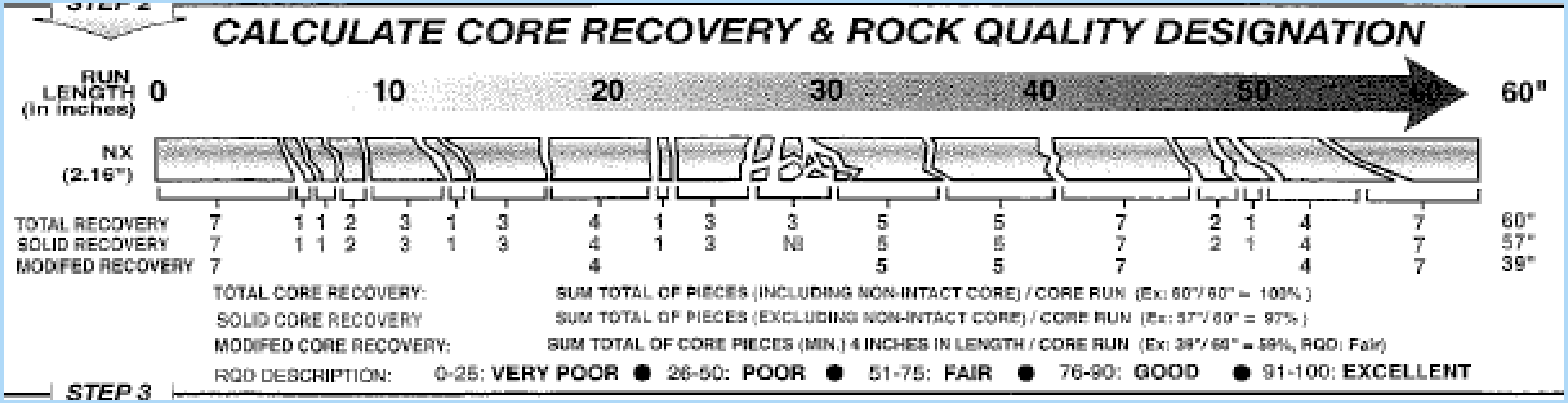


- Difficult to attach sample ends and not bend the sample

Rock Mass Classifications

- Rock Mass Rating
  - Strength of the rock
  - Drill core quality (RQD)
  - Groundwater conditions
  - Joint and fracture spacing
  - Joint characteristics

Rock Quality Designation



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Hi RQD – few fractures in core

Low RQD – many fractures in core

Table 2.11 Rock Mass Rating Increments for Drill Core Quality

RQD (%)	Rating
90–100	20
75–90	17
50–75	13
25–50	8
<25	3