MODULE-3

- **Elastic and time dependent (Creep) behavior of rock and their determination**
- **Rock Deformability**

* Creep Behaviour of Rock

Time dependent deformation-stress behaviour

(i) **Creep strain**

Change in strain with time without change of stress.

(ii) **Creep strength**

Maximum stress sustend by rock at which no failure will occur no matter how long stress is applied.

* CREEP LAW (After elastic limit)

1. **GRIGG's LAW**

$$\varepsilon = A + B\log t + Cp$$

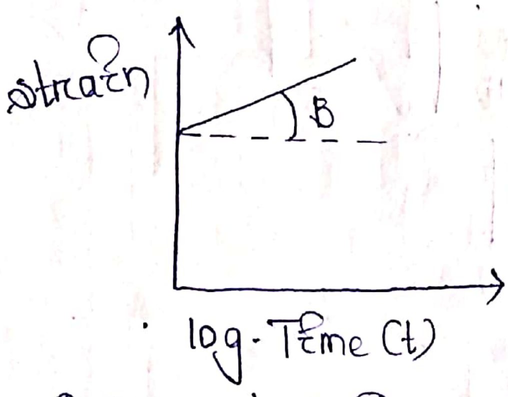
Where,

ε = Total strain at time (t)

A = Elastic strain

Blog = Primary strain

Cp = Secondary strain



2. **OBEST's LAW**

$$\varepsilon_t = K\sigma^{\alpha}\left(\frac{t}{t_1}\right)^{\lambda}$$

Where,

ε_t = Total strain at time (t)

σ = stress difference $(\sigma_1 - \sigma_3)$

α = power function, depends on stress-strain relationship.

n = power function, depends on strain time relationship

K = Constant at t_1

t_1 = Variable depends upon stress-strain relationship.

* Rock experiences high Creep = Carbonate rocks (chalk, Marble, Limestone, sandstone, Coal, shale.)

Factor influencing Creep Behaviour

1. Nature of stress

Creep Rate is less in tension and bending than Compressive Load.

2. Level of stress

Creep rate and total strain depends on Level of stress w.r.t yield stress (stress before breaking of rock)

3. $\varepsilon_p = \frac{1}{t}\left(\frac{\sigma_1-\sigma_3}{2G}\right)^n$

Where, ε_p - primary Creep strain

n = 1 to 5 (at Room temperature) (20°C)

3. Type of Rock

4. Confining Pressure on Rock

Creep Rate is higher at high confining pressure.

5. Rock temperature

Creep Rate increases with temperature

$$\varepsilon_s = A\left(\frac{\sigma_1-\sigma_3}{G}\right)^n \exp\left(\frac{-Q}{Kt}\right)$$

Where ε_s : secondary Creep strain

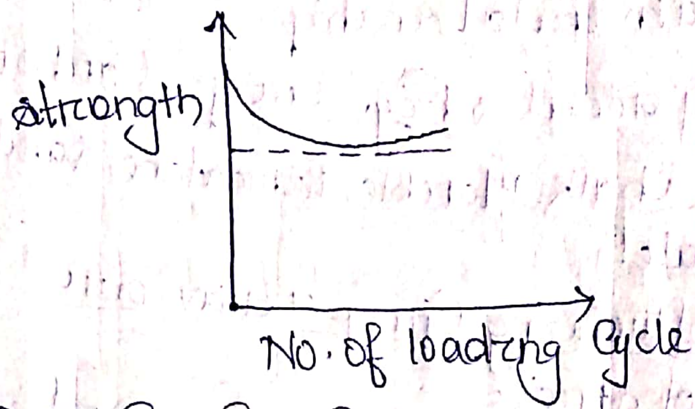
Q = Activation energy

K = Universal Gas Constant

t - Absolute temperature (270K)
A and n = Constants depend on rock type

6. Cyclic Loading

Creep rate increases with more loading.



7 Grain size in Rock.

Fine grains are more resistance to creep at low temperature but at high temp. it is reversed.

8 Moisture content in Rock

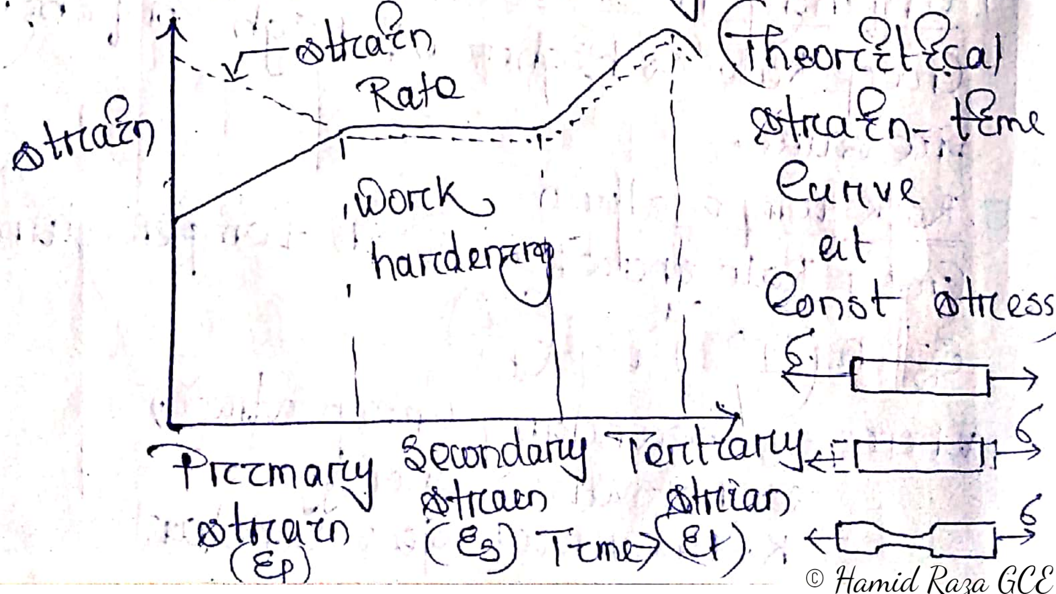
Creep rate increases with Moisture content

9. Porosity

Creep rate increases with porosity.

10 Geological discontinuity

Creep rate increase $\left(\frac{d\varepsilon}{dt}\right)$ with geological discontinuity.

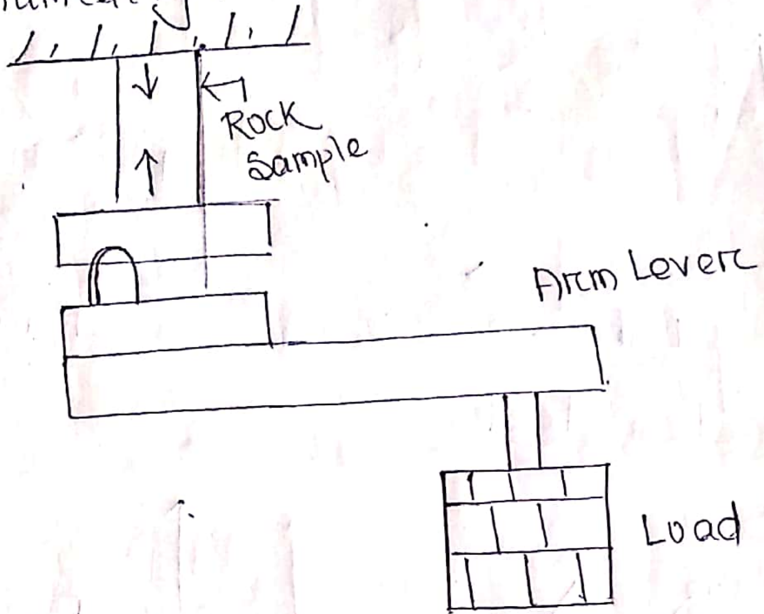


Determination of Creep strain of Rock

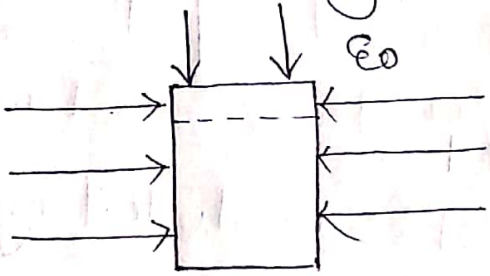
There are two methods to determine the Creep strain of Rock
1. Laboratory Method
2. Insitu Method

*. Creep test apparatus is selected based on the following consideration.

a) Capability to produce const. load for long period
b) Arrangments for Controlling temperature and humidity.



(Fig- Constant loading set up in compression)

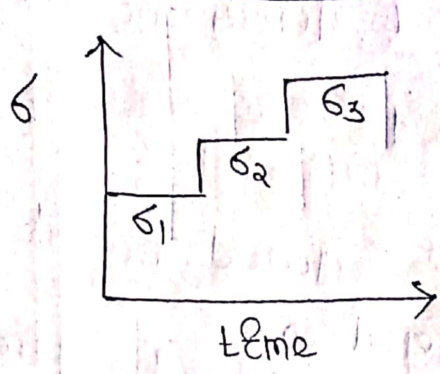


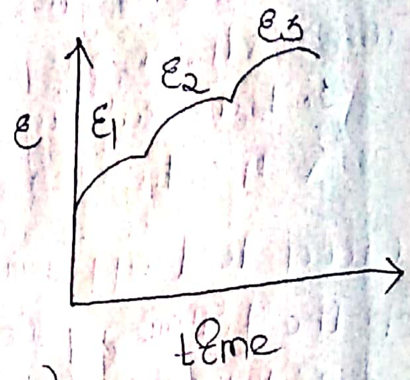
Laboratory test Triaxial test

Laboratory test is Conducted by three tes

1. Constant stress test
2. Constant strain rate test
3. Relaxation test

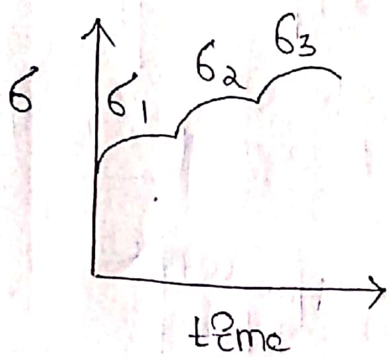
1. Constant stress Test

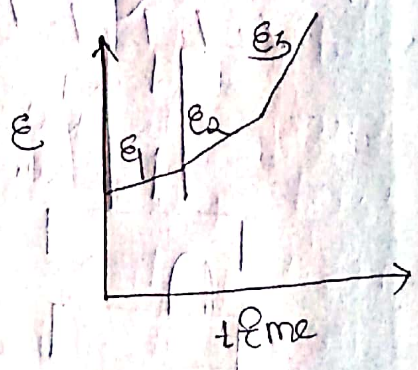




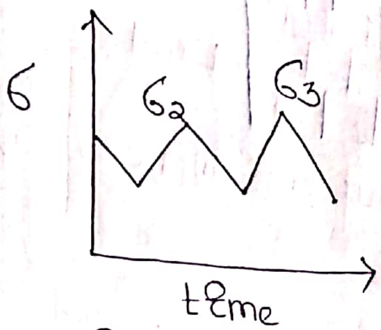
Here $\sigma_1, \sigma_2, \sigma_3 < UCS (\sigma_{ci})$

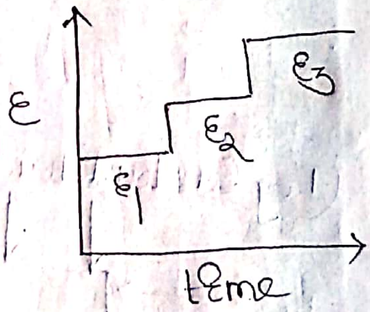
2. Constant strain rate $\left(\frac{d\varepsilon}{dt}\right)$ test





3. Relaxation test



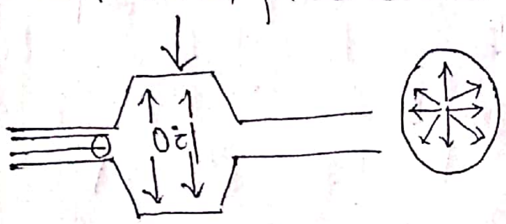


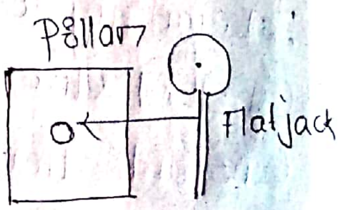
2. Insitu Creep Test

Insitu Creep Test is conducted by flat jack apparatus.

(i) Compressive load with flat jack

(ii) Internal pressure





Rock Deformability

(i) Modulous of rock deformability is different from that the Modulous of intact elasticity which is the property of rock Mass.

(ii) Modulous of deformability of rock mass is different from the modulous of elasticity which is the property of intact rock.

(iii) Hence it is better that the Modulous of deformation of or deformability of rock mass is evaluated by insitu test

Deformability Test

Static Test

(i) Large static load are applied on the rock surface and the subsequent deformation is observed.

a) plate load test
b) Bore hole test
c) Pressure tunnel test

Dynamic Test

(i) The Velocity of propagation of elastic wave is measured and deformation is evaluated.

a). PLATE LOAD TEST

(i) This method consists of applying a normal load to an exposed ~~sure~~ flat surface of rock by means of a hydraulic jack and mesuring the resulting displacement of rock surface.

Deformation Modulous $= \delta = \frac{mp(1-\mu)}{E\sqrt{A}}$

δ = Avg. surface displacement of rock surface
m = Displacement coefficient
p = Total normal surface load
μ = Poisson's Ratio
E = Modulous of deformation of subgrain
A = Area of loading plate

$$I_m = \frac{K \times p \times \pi \times a (1-\mu^2)}{v}$$

Where K = 0.5 (For a Perfect rigid plate)
0.54 (For a Perfect flexible)

p = Applied pressure

a = Radius of plate

μ = poisson's Ratio

v = Avg. displacement of plane surface

Case: r = Em (If rock and sample are elastic)

2. Pressure Tunnel Test

(i) It is also known as pressure chamber test.

(ii) In this test, a part of the circular tunnel is shield by concrete wall known as bulk head.

(iii) Then the shield portion is radially loaded by hydrostatic pressure / Fluid pressure.

(iv) The diametrical deformation of the rock tunnel is observed which helps in determination of modulous of elasticity of rock material.

$$\Delta d = \frac{d \times p \times (1-\mu)}{E}$$

Where, d = dia of tunnel

p = Intensity of uniform radial hydrostatic pressure

μ = poisson's Ratio

E = Modulous of elasticity

Advantages

(v) Rock deformation can be known in any dir^n

(vi) The hydrostatic pressure on rock in a tunnel can be sustended for a long period of time to observe long term effect

Disadvantages

(i) It is very expensive.

(ii) It brings about tensile stress in rock and if exceeded by compressive strength of rock than radical crack can be occure

3. Bore hole test (It is economical)

(i) The instrument used is known as dilatometer or deformeter.

(ii) It consists of a shell which can be inserted in the borehole at any depth.

(iii) The shell is filled with oil and pressure is applied to the oil.

(iv) The shell expands laterally and pushes the wall of the borehole thus imparting pressure with the help of transducer.

(v) The deformation of rock mass is measured by

$$E_m = 0.8 \times Q_h \times \left(\frac{D}{\Delta D}\right) T\phi$$

Where Q_h = Increase in hydraulic Pressure

D = Dia of hole

ΔD = Increase in dia

$T\phi$ = A coefficient depends on poisson's Ratio.

μ	0.1	0.2	0.25	0.3
$T\phi$	1.519	1.474	1.438	1.397

Finite Element Method (FEM)

(i) FEM is a numerical technique to perform finite ana element analysis of any given physical phenomena.

(ii) It is necessary to use mathematics for comprehensively understand and rectify any physical phenomena such as structure, flow behaviour, thermal transport and wave propagation etc.

(iii) For the vast majority of geometry and problems are generally expressed in terms of partial diff eqn which can't be solved by analytical Method.

(iv) Therefore these "descretization method" approximate "partial diff. eqn" (pde) with "numerical models" which can be solved using numerical method.

(v) The soln of numerical model eqn are approximation of the real eqn.

Types of Failure

a). Rupture
b) Brittle fracture
c) shear fracture

Rupture

(i) Rupture occurs when ductile material fails in tension,
(ii) It is preceded by a plastic deformation causing necking,
(iii) It is also known as cup and cone fracture.

Brittle ~~failure~~ Fracture

(i) It occurs in brittle material when subject to tension and causing tensile or cleavage fracture in a plane perpendicular to the dirn of tensn

shear fracture

(i) shear fracture occurs in brittle material when subjected to compression.
(ii) The failure plane occurs along the dirn of maxm shear stress.