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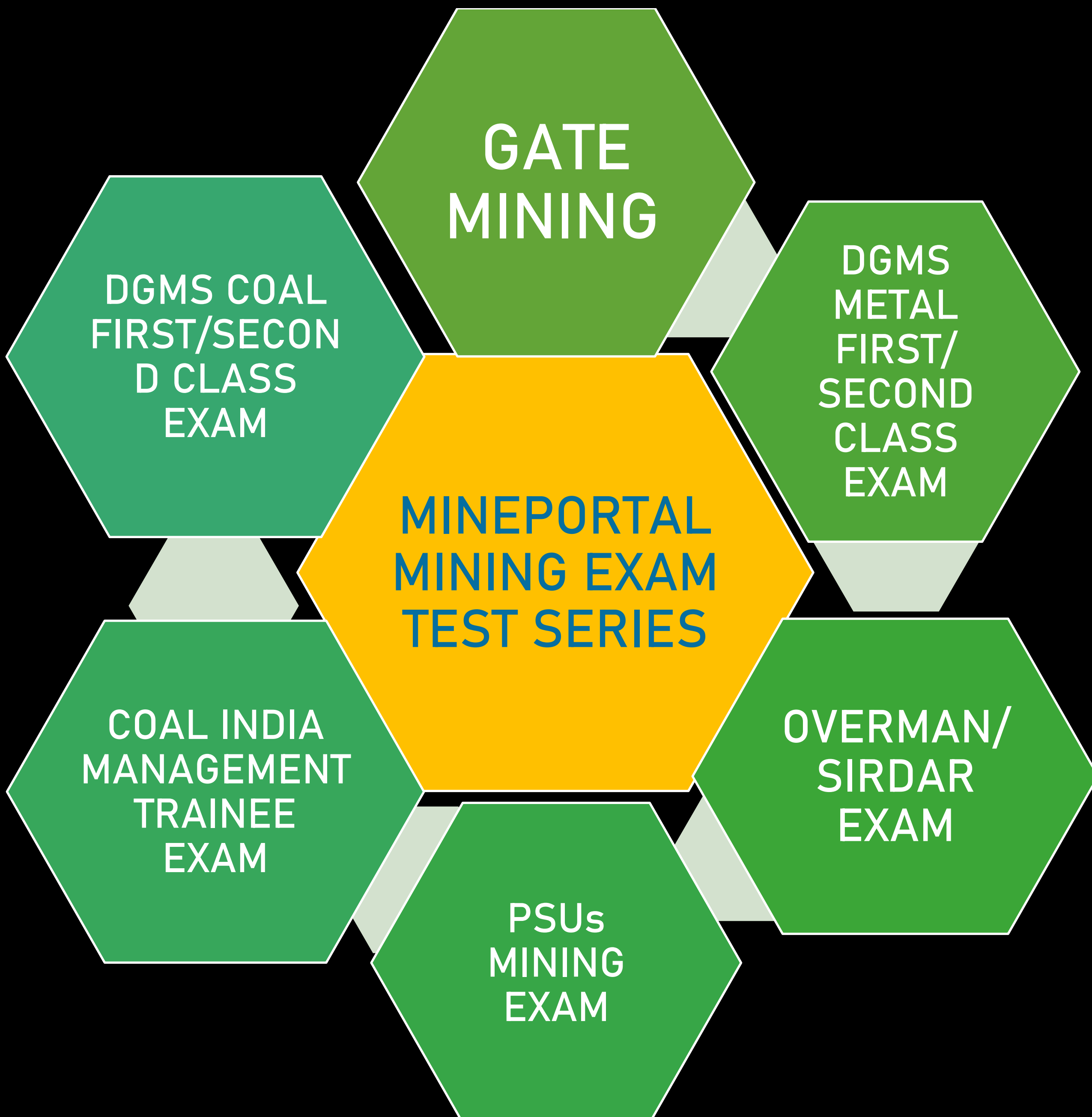

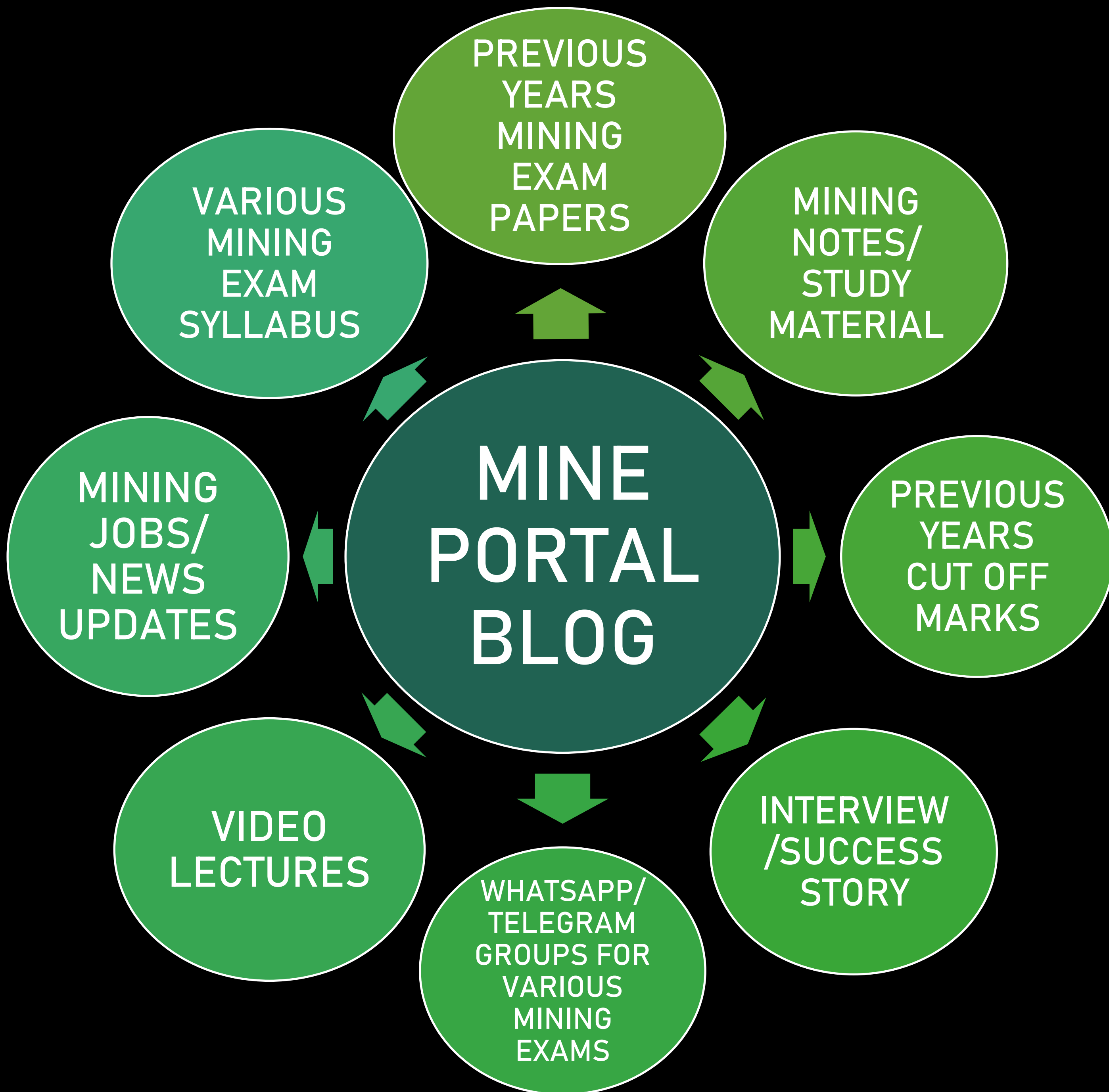
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NOTES ON ROCK MECHANICS

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Duploma V

Subject Rock Mechanics

Lecture 1

What is Rock Mechanics

Rock mechanics is a theoretical and applied science of the mechanical behavior of rock. The nature of the Rock is affected by the forces and the surrounding atmosphere. It is concerned with the mechanical responses of all geological materials, including soils. It is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment. In soil mechanics, we mostly talk about strengths, where as in rock mechanics, it is all about weaknesses

Rock is an aggregate of the minerals which are naturally occurring substances having fixed chemical composition. Some minerals are very strong and do not deteriorate easily. Some other minerals are softer and produce weaker Rocks. The strength of rock reduces with increase discontinuities/ fractures/ joints which plays a decisive role. Moreover, the behavior of rock is seriously affected by confinement. Rock mass found in the field is generally found intact.

- By increasing Depth Pressure of Over Burden Increases hence changes

- By increasing Depth Presuure of Over Burden Increases hence changes the nature of the Rock Properties

- With Increase of Depth the Temperature also increases, Hence There is Change of nature of Rock

For the study of Rock following things are to be known.

1. Study of weathering, joints, shears, faults and other rock deformation.

2. Determination of the rock quality designation (**RQD**)
3. Rock mass rating (**RMR**) from drill core.
4. The measurements include laboratory testing of the strength of various rocks likely to encounter during mining.
5. Rock Mechanics and Support System.

100% Find

Rock Mass used as a structural material in three ways

1. As a construction material

    a) Reservoir dam
    b) Building
    c) Structures made above the Rock
    d) Etc etc

2. Used as foundation so that heavy constructions are made on the top of the rock

    a) Tall Building
    b) Fly Over's
    c) Bridges
    d) Etc

3. Design of structures made inside the Rocks

    a) Bore Hole
    b) Mine Shafts
    c) Underground Mines
    d) Tunnels

Though the modern rock mechanics may be 50-60 years of old, but in the history there are number of examples of structures made out of rocks

Examples

1. Famous Taj Mahal at Agra constructed is made with marvels.

2. Delhi's Red fort is constructed with red sandstone.

3. The famous Brihadishwara is one of the largest temples in India. The entire BIG temple structure is made out of granite.

4. Ajanta Caves made of Natural Rock by Excavation

A detail study of Rock Mass is done during Mining. Then only any Excavation of minerals are carried out either on surface or in

Lecture 2

Scope of Rock Mechanics

The study of deformation resulting from the strain of rocks in response to stresses is called rock mechanics. There is a change in nature of Rock due to pressure which is called stress. Change in shape of Rock due to stress is called strain. Sometimes deformation in geologic structures in the crust of the Earth is large. As such geotechnical study is required.

There is a lot of scope for Rock Mechanics in following fields.

1. Civil Engineering
2. Mining Engineering
3. Petroleum Engineering
4. Geology Engineering
5. Geophysics Engineering

Civil Engineering

For any construction of any nature of civil work its necessary to have detail knowledge about two things.

1. Selection and layout of constructions sites.
2. Selection of materials to be used in any construction

Selection and layout of constructions sites-

If we have to construct a tall building, then its foundation must rest over a rock. For that we have to go deeper in the ground for stability of the building. To have good foundation support, capacity of the Rock shall be within permissible limit. To make the building stable the foundation is to be anchored in deep strong and stable Rock. For this operation knowledge of Rock Mechanics is essential. While constructing a Bridge over any river, Pillars are to be constructed in river itself, there also study of nature of Rock and Soil is required.

Example ; Tall Building, Fly over, Bridges, Water Dams, etc

Selection of materials to be used in any construction

For any construction proper material has to be selected. For example in construction of Dam, the nature of Rock n material must be strong. They not be permeable in nature, so that there is no chance of seepage of water from Dam

Mining Engineering

Whenever any excavation is made into the Rock Mass, there is a relief of stress immediately from the surrounding mass which develops a tensile stress. Due to which cracks form in the surrounding rocks. Ultimately that opening is filled by the Rock pieces. In this situation the opening has to be designed in such a way that cracks are not formed excessively. There should not be any fall. For this following parameters are to be considered in Underground and Open cast Mines.

1. Design of Opening

2. Method of Excavation

3. Design of blasting operations

4. Design of support systems

5. Studies of rock deformation at high temperatures.

6. Studies of rock deformation at high pressures.

Petroleum Engineering

In case of any oil exploration holes are drilled at very great depth. These holes are drilled in surface and in sea also. A place is selected in such a way that the place should be free from followings.

1. Free of cracks

2. Free of Faults

3. Free of Fissures

4. Free of Joints

5. There should not be any major Geological Disturbances

4. Geology Engineering

Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. It includes the study of organisms that have inhabited our planet. An important part of geology is the study of how Earth's materials. Geologists studies help to locate rocks that contain important metals, plan the mines that produce them and the methods used to remove the metals from the rocks. Study helps to locate and **produce oil, natural gas, and groundwater.**

5. Geophysics Engineering

The rapid population growth and the pressure from human activities have strongly influenced their extension and occurrence so that they have become disasters causing vast direct and indirect socioeconomic consequences. Artificial fills are usually composed of excavated, transported and placed soil or rock, but they can also contain demolition debris, ash, slag

5. Geophysics Engineering

The rapid population growth and the pressure from human activities have strongly influenced their extension and occurrence so that they have become disasters causing vast direct and indirect socioeconomic consequences. Artificial fills are usually composed of excavated, transported, and placed soil or rock, but they can also contain demolition debris, ash, slag.

There may be natural hazards

1. Landslides,
2. Rock falls,
3. Avalanches
4. Rock glaciers,
5. floods,
6. Sinkholes and Subsidence,
8. Earthquakes and volcano

Rock Mechanics

Lecture 4

Application of Rock Mechanics In Mining Field

One of the most important decisions facing a mine planner is the selection of a suitable mining method. The choice of an underground mining method must be based on the ground conditions. So that any mining operation is to be make successful. The method of work is selected on nature of the rock and surrounding condition. All mining method may be different in different types of Mines.

1. Surface/ Open Cast Mines

2. Under Ground Coal Mines

3. Under Ground Metal Mines.

Surface / Open Cast Mines

In any open cast mines the method is selected after proper study of Rock Mass. This helps in selection of method, Equipments to be used. For any type of open cast mines following things are to be studied.

1. Drilling
2. Blasting
3. Ground Vibration Study
4. Slope Stability Investigation.

Drilling

The selection of drill method depends upon the nature of Rock. For that following parameters are to be selected

1. Depth of Hole

2. Diameter of Hole

3. Spacing between Holes

4. Burden of the holes

2. Blasting

Rock Blasting is very important part which effects the productivity of mines. Well-fragmented ROM are required for the processing plants. The production of well-fragmented rock helps in loading, transportation, handling and crushing. Proper blasting techniques are adopted & applied so as to control rock fragmentation and to minimize damage. Proper control of factors, such as, type, weight and distribution of explosives, blast hole diameter, effective burden, effective spacing, blast hole inclination, stemming delay between successive sequence hole or row firing

GROUND VIBRATION STUDY

The ground vibration studies are helpful in designing blasting parameters, in order to reduce the distance of fly rocks and improved fragmentation. Blast induced vibrations are measured with the help of blasting seismograph so as to avoid possible damage to important surface structures, such as, railway lines, crushers, buildings, archeological sites, temples and village localities.

4. Slope Stability Investigation

Nowadays, the number of opencast mines is increasing as compared to underground mines. Slope stability analysis is being carried out at the start-up of the project in order to avoid any further unexpected consequences.

1. Design of ultimate pit slope angles,

2. Working bench height,

3. Bench slope angles,

Rock Mechanics

Lecture 5

Application of Rock Mechanics In Mining Field (Continued)

Under Ground Coal Mines

For underground mine first thing to select design for opening of the mine. Then a sample of rocks are tested in laboratory for any mechanical defects, such as, joints, fractures, and faults. For this a detail study of Rock Mechanics is required for starting any under ground Coal Mine.

A Method Of Work

1. Bord and Pillar
2. Long wall
3. Any other Method

B Following Measures are to be taken

1. Control of blasting for stable roof and sides
2. Control, and to ensure long-term stability.
3. Drivage of cross-cuts and inclined shafts.
4. Shaft pillar design.
5. Design and Support for main excavations such as
   a) Pump chambers
   b) Water dams

c) Shaft bottom lay out

d) Design of pillars to act as water barriers.

6. Support elements and abutment

7. During Depillaring Behavior of Roof Strata

6. Control of the incidence of Rock Bursts/ Coal Burst

Under Ground Metal Mines.

It is a must that strata conditions must be of proper standards before starting any Mining Operation. In Metal Mines of Under ground nature a lot of advance planning is required. The method of work completely depends upon the nature of deposition of Ore. Following method of works are adopted after study of Rock Mechanics in detail.

1. **BLOCK CAVING**
2. **BLASTHOLE STOPING**
3. **SHRINKAGE STOPING**
4. **CUT AND FILL STOPING**
5. **OPEN STOPING**
6. **Sublevel Caving**
7. **Room and Pillar Stoping**

Over all in both the cases of Underground Mines either in Coal or Metal many observations are common.

1. The theoretical and experimental knowledge of stress distribution around the rock structure may be useful for interpreting the early failure of rock.

2. Rock mechanics instruments commonly used for the purpose of evaluating the stability of working places, monitoring the ground movement, stress vibration etc.

3. Monitoring of stress meter, extensometer, strain and stress gauges;
4.Determination of in situ stresses by using over coring technique,

5. Measurement of deformation using borehole deformation gauges

6. Micro seismic network, are used for prediction of ground stability and seismic activity in mines that are very deep.

7. In order to analyze the stability of existing pillar so as to get a warning of possible failures and to achieve safer design of future stope and pillars, there is need to measure the in situ rock stresses at different levels

8. Signal advance warning system to be monitored so that safety of men and machinery could be ensured

Rock Mechanics

Unit II

Lecture1

Various forces acting on block

Rock at depth is subjected to stresses resulting from the weight of the overlying strata and from locked in stresses of tectonic origin. There is Vertical stress as well as Horizontal stress also from all sides.

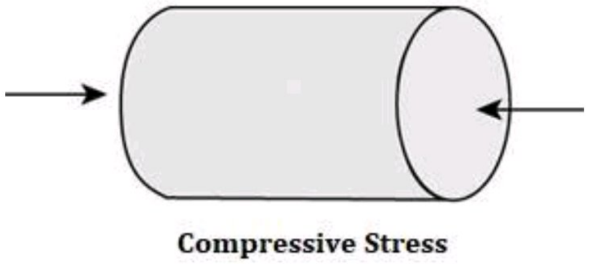
Consider an element of rock at a depth of 1,000 m below the surface. The weight of the vertical column of rock resting on this element is the product of the depth and the unit weight of the overlying rock mass. The horizontal stresses acting on an element of rock at a depth z below the surface are much more difficult to estimate than the vertical stresses

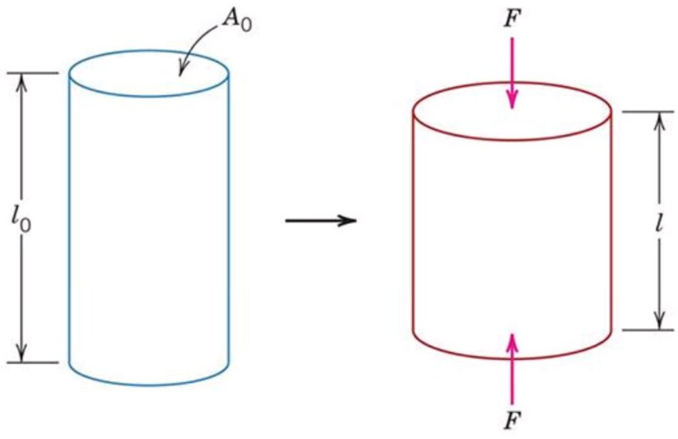
The Earth has three layers, the crust, the mantle and the core. The Earth's crust is like the shell of an egg; it is the thinnest of the Earth's layers. The crust is broken into several parts, known as the continental plates. When the plates are pulled or pushed together, stress occurs. Four types of stresses affect the Earth's crust:

1. Compression stress
2. Tension Stress
3. Shear Stress
4. Confining stress

Compression Stress

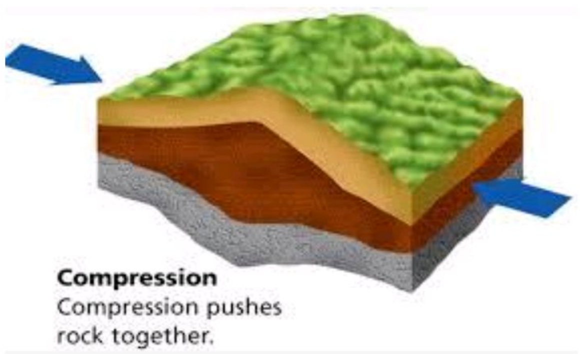
When a force is applied on any object from opposite direction moving towards each other then there is a change in the shape of object. Force is called Compressive stress

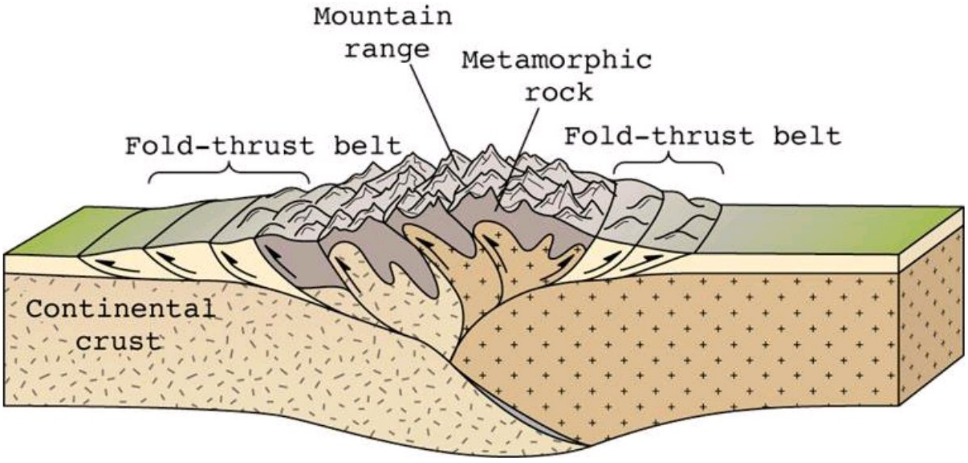




Compression is a type of stress that causes the rocks to push or squeeze against one another. It targets the center of the rock and can cause either horizontal or vertical orientation. In horizontal compression stress, the crust can thicken or shorten. In vertical compression stress, the crust can thin out or break off. The force of compression can push rocks together or cause the edges of each plate colliding to rise. Mountains are a result of high-impact compression stress caused when two plates collided.

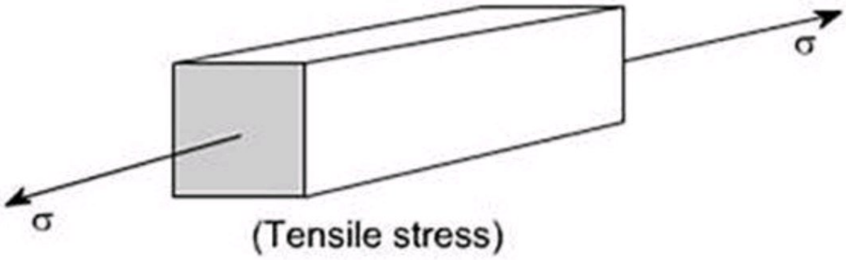
1. Compressive stress results in the shortening of the solid
2. Compressive stress is due to the application of external compressive force



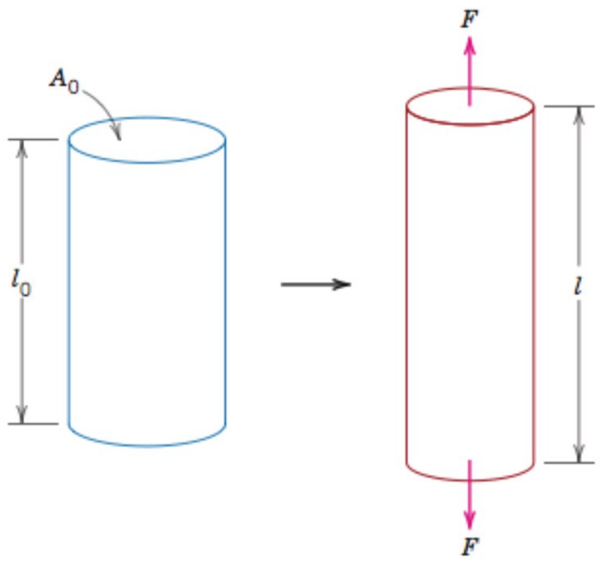


Tension Stress

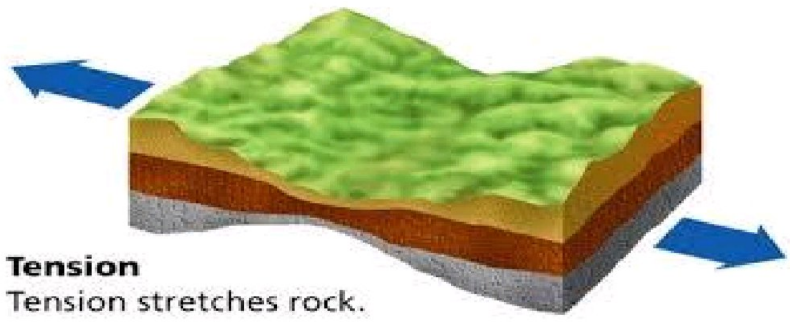
When a force is applied on any object from opposite direction moving away with each other then there is a change in the shape of object. Force is called tensile stress



(Tensile stress)

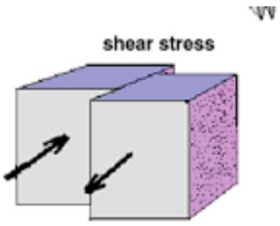


Tension is the opposite of compression. While compression forces the rocks and crust to collide and move together, tension forces the rocks to pull apart. Tension can happen in two ways. Two separate plates can move farther away from each other, or the ends of one plate can move in different directions. Some scientists think tension stress caused the ancient, massive continent Pangaea to break off into the seven continents we have today.

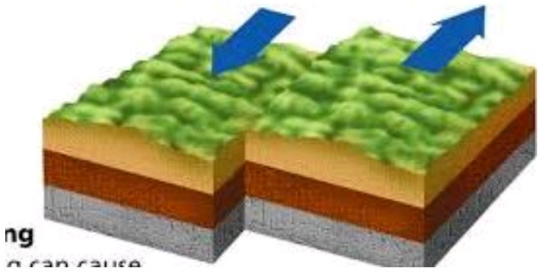


Shear Stress

When a force is applied on any object from opposite direction moving towards each other and they are parallel to each other then there is a change in the shape of object and finally its shears (Breaks)

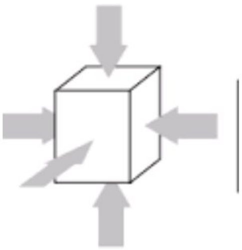


When shear stress occurs, the force of the stress pushes some of the crust in different directions. When this happens, a large part of the crust can break off, which makes the plate size smaller. Shear stress usually happens when two plates rub against each other as they move in opposite directions. The friction of a shear stress at the edges of the plate can cause earthquakes.



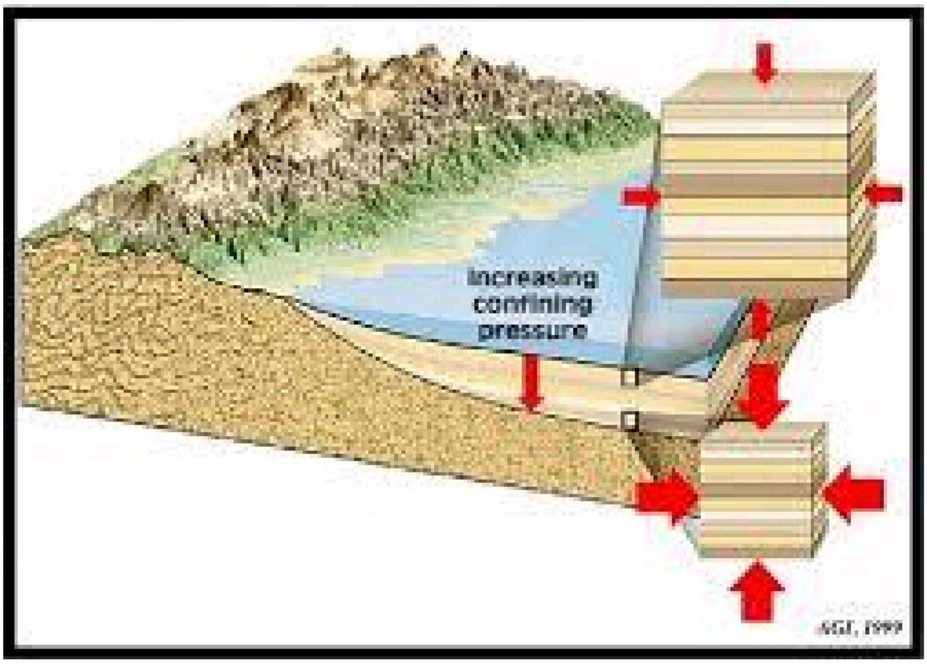
Confining Stress

A deeply buried **rock** is pushed down by the weight of all the material above it. Since the **rock** cannot move, it cannot deform. This is called **confining stress**.Due to confine ment from all sides there is Compression which further squeezes **rocks** together. As result there is fold or fracture in the Rock. This is most common **stress** at plate boundaries. When stress is applied to all sides of the crust, confining stress occurs.. This causes the crust weight to decrease but the crust shape remains the same. Confining stress can cause sinkholes in the Earth.



Uniform
(= Confining pressure)

Confining Pressure



Rock Mechanics

Unit II

Relation between Stress and Strain

Rocks deformation

Earth can change dramatically over time. Stress changes physical conditions in the earth. As a result, there is fold or fault in the rocks. Changes take place due to stress. Due to continuous stress there is strain (deformations) in the structures.

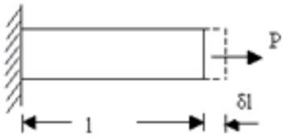
- **Stress** is force acting on a rock per unit area. It has the same units as pressure, but also has a direction . There are three types of stress: ***compression, tension, and shear***. There is no change if it is sufficient to overcome the strength of the object that is under stress. But as the stress (Pressure) increases, strain is developed and change in shape of the Rock.
- **Strain** is a change in shape or size resulting from applied forces (deformation). Rocks only strain when placed under stress. Any rock can be strained. Strain can be elastic, brittle, or ductile. Ductile deformation is also called plastic deformation.
- **Structures** in geology are deformation features that result from permanent (brittle or ductile) strain. Examples include folds and faults. These features are used to identify the type of stress in the Rocks.
- **Stress is the same as pressure.**
- **Stress can happen without strain,**
- **But strain cannot happen without stress.**
- **Strains**
- Whenever a force is applied to any object, there may be change in shape and dimension. Strain is defined as the ratio of change in dimension to original dimension of a body when it is deformed. It is a dimensionless quantity as it is a ratio between two quantities of same dimension.
- **Types of strain**
- **Linear Strain**

Linear strain of any Block is defined as the ratio of the change in length of the body due to the deformation to its original length in the direction of the force. If **l** is the original length and **dl** the change in length occurred due to the deformation, the linear strain is given by **e=dl/l.**

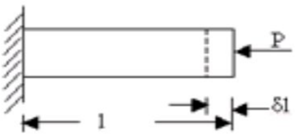
<u>**Concept of strain :**</u> if a bar is subjected to a direct load, and hence a stress the bar will change in length. If the bar has an original length L and changes by an amount Δl, the strain produce is defined as follows:

$$\text{Linear Strain} = \frac{\text{Change in length}}{\text{Initial Length}}$$

1. **When Tensile Force is applied Linear strain =** $\frac{\Delta l}{L}$ **(+)**



2. **When compressive Force is applied Linear Strain =** $\frac{\Delta l}{L}$ **(-)**



Lateral Strain

In mechanics, lateral strain, also known as transverse strain, is defined as the ratio of the change in diameter of a circular bar of a material to its diameter due to deformation in the longitudinal direction. It is a dimensionless quantity, as it is a ratio between two quantities of the same dimension.

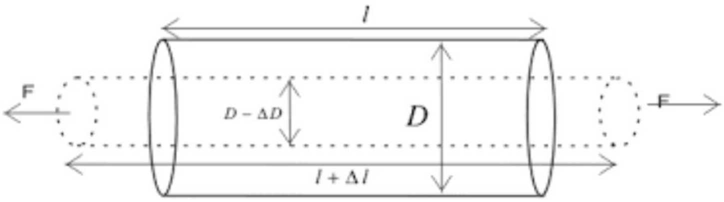
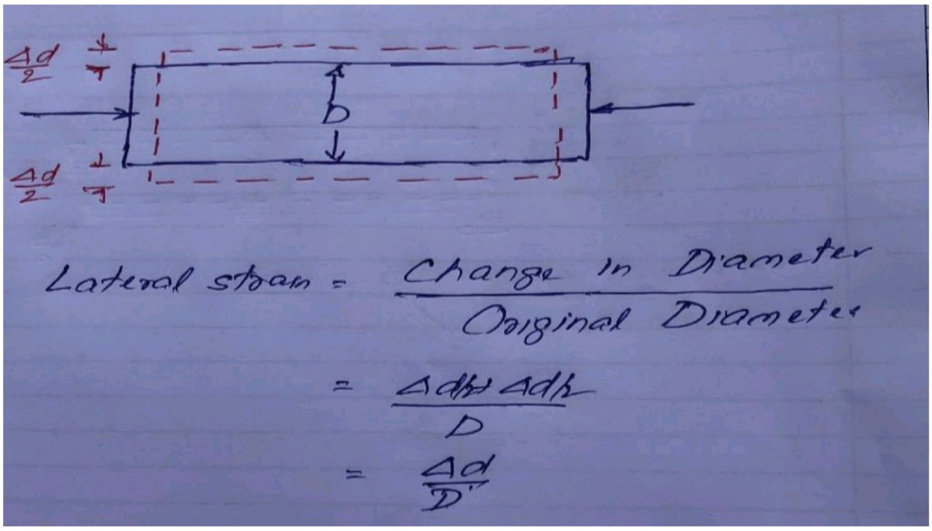
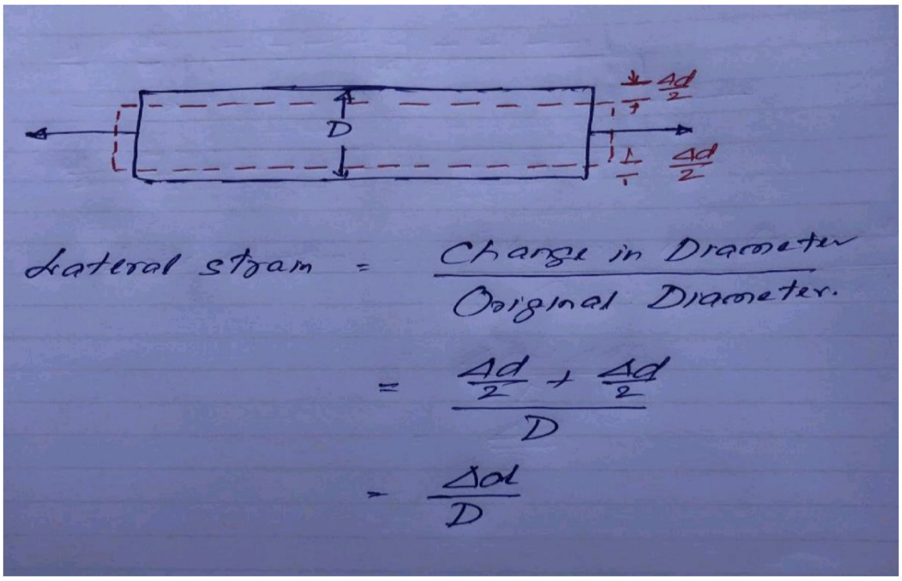


Figure 4.



Here the forces are applied in both directionon cylindrical shape block. As it is compressed, there is increase in diameter, but decrease in length.



Here the forces are applied in both directions on cylindrical shape block. As it is tensile in nature, there is decrease in diameter, but increase in length.

Numerical 1

After applying a load on 2.0-m-long wire it stretches by 1.0 mm . What is the tensile strain in the wire?

Solution

Original length 2.0meter = 2000 mm

Change in Length = 1.0mm

Strain = Change in Length/ Original length

= 1.0/2000

=0.0005

= 0.05 %

Numerical 2

A strip of rubber 2.0 m long is compressed. After compression the length reduced to 198 cm. Calculate linear strain in rubber strip.

Solution Original Length 2.0 meter = 200 cm

New length after compression = 198 cm

Change in Length = 2cm

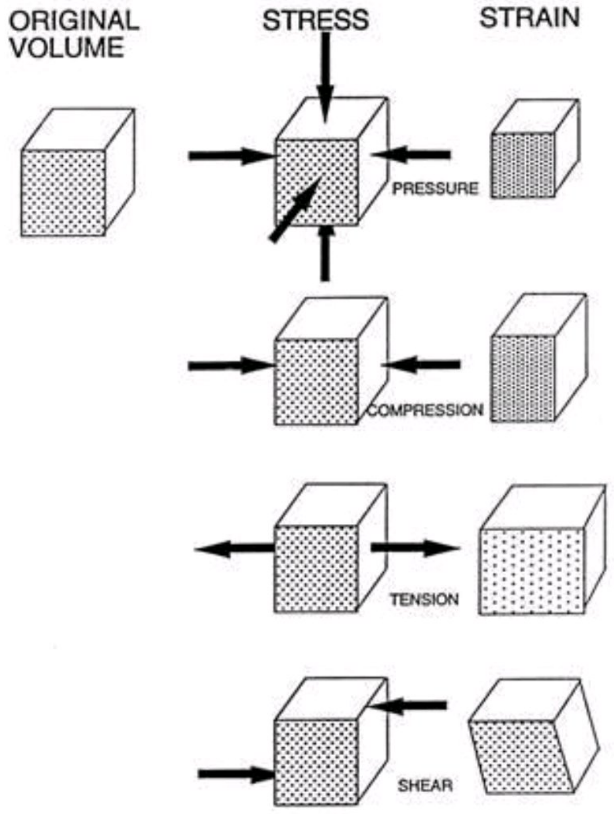
Strain =2.0/ 200

=0.01 or 1.0%

Relation Between Stress and Strain

There are four general types of stress. One type of stress is uniform, which means the force applies equally on all sides of a body of rock. The other three types of stress, tension, compression and shear, are non-uniform, or directed, stresses. All rocks in the earth experience a uniform stress at all times

- **Elastic strain** is reversible. Rock that has undergone only elastic strain will go back to its original shape if the stress is released.
- **Ductile strain** is irreversible. A rock that has undergone ductile strain will remain deformed even if the stress stops. Another term for ductile strain is plastic deformation.
- **Fracture** is also called rupture. A rock that has ruptured has abruptly broken into distinct pieces. If the pieces are offset—shifted in opposite directions from each other—the fracture is a fault.



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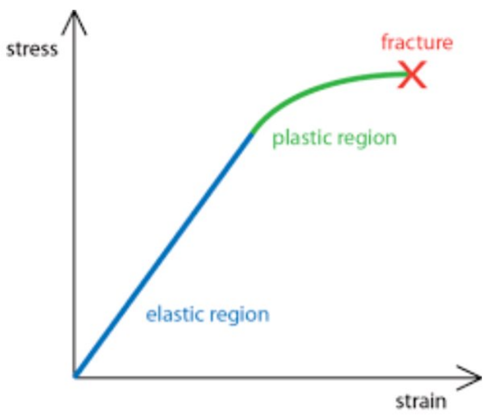


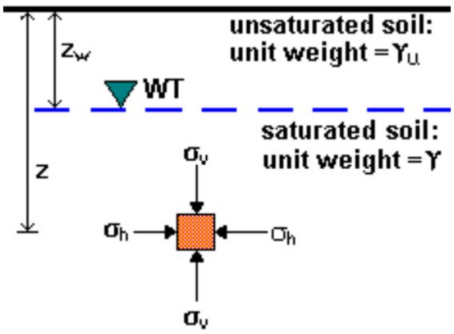
Unit 2

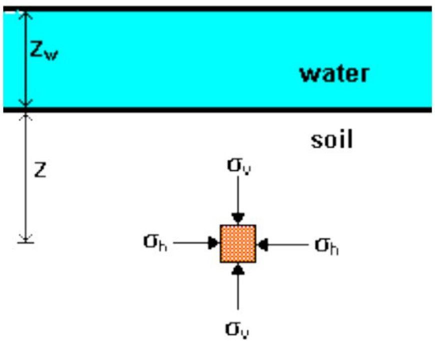
Lecture 3

Vertical Stress and Lateral stress

Vertical stress

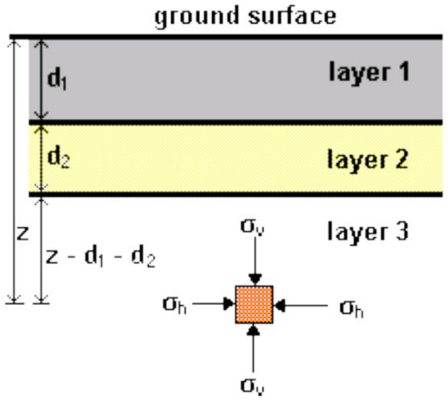
It is one of the principle **stresses** due to confined underground formations. The other **stresses** are minimum and maximum as horizontal **stresses** and Vertical Stress. The magnitude and direction of these **stresses** depend on tectonic conditions and failure of the Rocks





When a load is applied to soil, it is carried by the water in the pores as well as the solid grains. The increase in pressure within the pore water causes **drainage** (flow out of the soil), and the load is transferred to the solid grains. The rate of drainage depends on the permeability of the soil. The strength and compressibility of the soil depend on the stresses within the solid granular fabric. These are called effective stresses.

The **total** vertical stress acting at a point below the ground surface is due to the weight of **everything** lying above **soil, water, and surface loading**. Total stresses are calculated from the unit weight of the soil.



Unit weight ranges are

Dry soil ??$_d$ 14 - 20 kN/m³ (average 17kN/m³)

Saturated soil ??$_g$ 18 - 23 kN/m³ (average 20kN/m³)

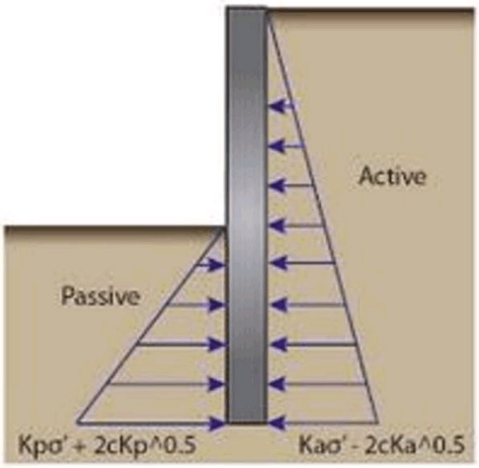
Water ??$_w$ 9.81 kN/m³ (10 kN/m³)

Total stress increases with depth and with unit weight:
Vertical total stress at depth z,

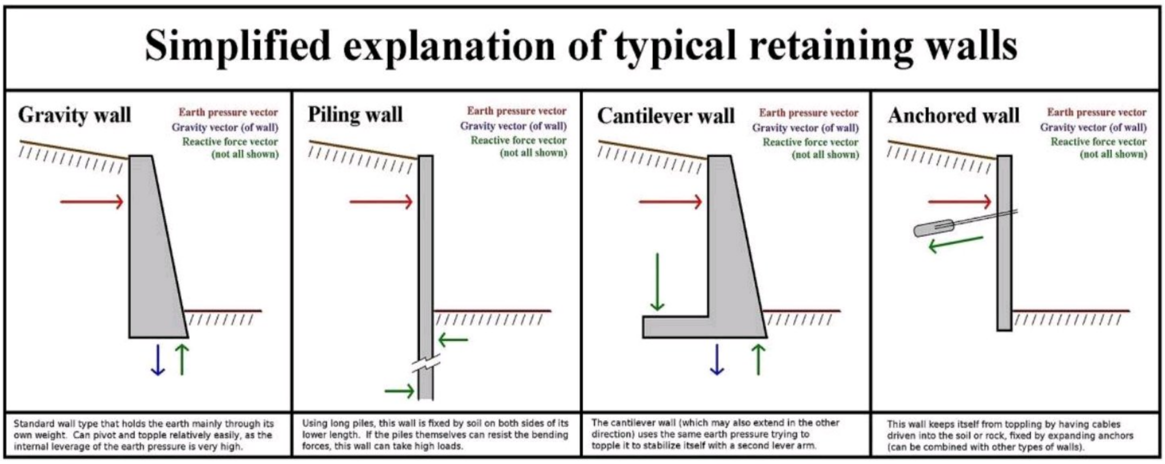
stress below a river or lake $\sigma_v = \gamma.z$

Lateral Stress

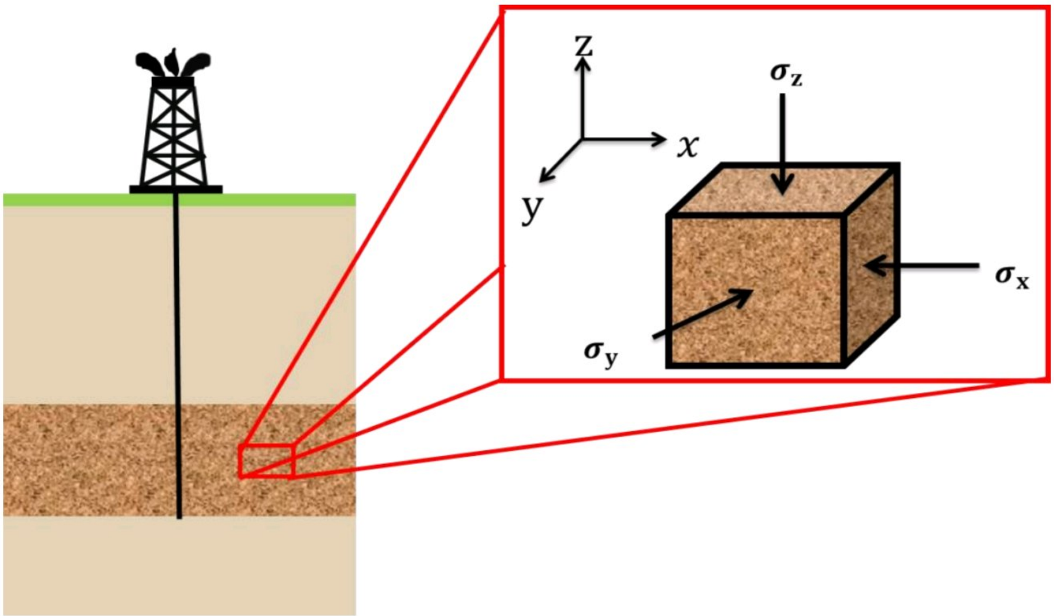
There are the three types of later earth pressure and how to calculate them. Introduction So far, we have only been calculating the vertical stress in soils. This is the stress caused by the weight of soil above. But this vertical stress also causes a horizontal stress in the soil. we will assume that the water table is deep and total stresses equal effective stresses. Vertical stress in Soil Mechanics is caused by the weight of soil and , etc. above. We calculate the vertical total stress σv in a soil simply by multiplying the bulk weight density of the soil γbulk (kN/m3) by the height of soil above. If you apply a vertical stress to a solid element it compresses vertically but also expands horizontally. But if you also apply enough horizontal stress, you can stop the solid element from expanding horizontally and it only compresses vertically .



Effect of vertical and horizontal stresses on a solid element shows what happens to soil in the ground. The soil cannot expand horizontally because the other soil surrounding it applies a horizontal stress.



The higher the vertical stress the higher the horizontal stress must be to stop horizontal expansion. The relationship between vertical and horizontal effective stresses in a soil is described with earth pressure coefficients.



An earth pressure coefficient is given the symbol K and is equal to the ratio of horizontal and vertical effective stresses the in-situ earth pressure coefficient is K0. K0 is difficult to measure in a site investigation so it is often estimated from the equation. For most soils this would give a K0 value of between 0.25 and 0.65, which means that the in-situ horizontal effective stress σ'h (or earth pressure) is generally about 0.25 to 0.65 times the in-situ vertical effective stress σ'v. The distribution of in-situ horizontal effective stress σ'h with depth would look something like the example. The insitu horizontal effective stress σ'h still increases with depth.

K = Horizontal Stress /Vertical Stress

Where K is Coefficient its value varies depending on nature of Rocks

Numerical 1.

A nylon string has a diameter of 2 mm, pulled by a force of 100 N. Determine the stress

Known :
Force (F) = 100 N
Diameter (d) = 2 mm = 0.002 m
Radius (r) = 1 mm = 0.001 m
Wanted : The stress

Solution :
Area :
A = π r2
A = (3.14)(0.001 m)2 = 0.00000314 m2
A = 3.14 x 10-6 m2
Unit of stress is Newton per square meter or Pascal. It is same as pressure

Stress = F/A

$$Stress = \frac{Force(F)}{Area(A)}$$

$$Stress = \frac{100\,N}{3.14\,x\,10^{-6}\,m^2}$$

$$Stress = 31.5\,x\,10^6\,N/m^2$$

Stress = 31.5 Mega pascal

Numerical 2

A string 4 mm in diameter has original length 2 m. The string is pulled by a force of 200 N. If the final length of the spring is 2.02 m, determine : (a) stress (b) strain

Known :

Force (F) = 200 N
Diameter (d) = 4 mm = 0.004 m
Radius (r) = 2 mm = 0.002 m

Solution
Area (A) = π r2 = (3.14)*(0.002 m)2

Area (A) = 0.00001256 m2 = 12.56 x 10-6 m2
Force (F) = 200 N
Original length of spring (l_0) = 2 m
The change in length (Δl) = 2.02 – 2 = 0.02 m

STRESS

$$Stress = \frac{Force\,(F)}{Area\,(A)}$$
$$Stress = \frac{200\,N}{12.56\,x\,10^{-6}\,m^2}$$
$$Stress = 15.92\,x\,10^{6}\,N/m^2$$

STRAIN

$$Strain = \frac{The\,change\,in\,length\,(\Delta l)}{Original\,length\,(l_0)}$$
$$Strain = \frac{0.02\,m}{2m}$$
$$Strain = 0.01$$

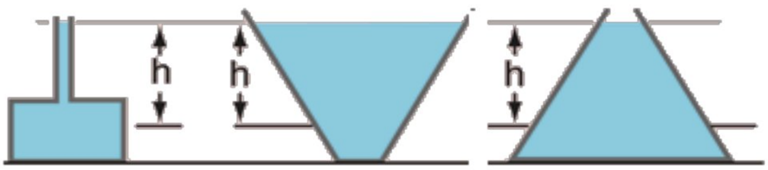
Lecture4

Hydrostatic & litho static Pressure

Hydrostatic Pressure

The air around us at sea level presses down on us at 14.5 pounds per square inch (1 bar). We do not feel this pressure since the fluids in our body are pushing outward with the same force. But if you swim down into the ocean just a few feet and you will start to notice a change. The deeper you go under the sea, the greater the pressure pushing on you will be. For every 33 feet (10.06 meters) you go down, the pressure increases by 14.5 psi (1 bar).

Hydrostatic pressure is the pressure that is exerted by a fluid at equilibrium at a given point within the fluid, due to the force of [gravity.](gravity) Hydrostatic pressure increases in proportion to depth measured from the surface. As the depth increases weight of fluid also increase downward due to [force of gravity.](force of gravity)



The static fluid fluid pressure at a given depth does not depend upon the total mass, surface area, or the geometry of the container.

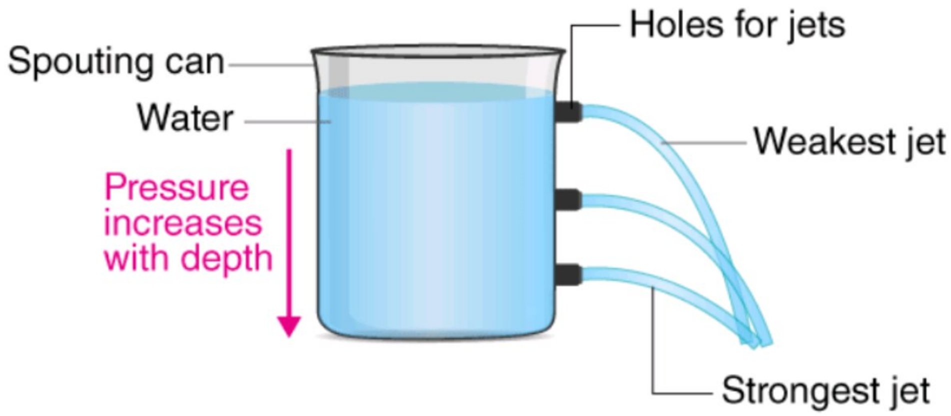
$$P = \rho * g * h$$

Pressure = (density of liquid) x (acceleration gravity) x (height)

If a fluid is within a container then the depth of an object placed in that fluid can be measured. The deeper the object is placed in the fluid, the more pressure it experiences. This is because the weight of the fluid is above it. The denser the fluid above it, the more pressure is exerted on the object that is submerged, due to the weight of the fluid.

Depth of water		**Pressure**	
ft	**m**	**Pa**	**bar**

1	0.30	2990	0.03
5	1.52	14949.99	0.15
10	3.05	29899.98	0.30
15	4.57	44849.97	0.45



Let us derive the formula for Pressure on a object submerged in a fluid:

From, what is pressure: Pressure = Force/Area

From, what is Force: Force = mass x acceleration

= m x g (acceleration in gravity)

So: Pressure = F/A = mg/A

From What is Density:

Density = Mass/Volume ;

Mass= Density x Volume

We now have Pressure = (density x volume x acceleration)/area.

Pressure = (Density * Area * Height * Acceleration)/ Area

Pressure = density x height x acceleration

$$P = \rho * g * h$$

r - (rho) density of the fluid,
g- acceleration of gravity
h - height of the fluid above the object

The pressure due to the liquid alone (i.e. the gauge pressure) at a given depth depends only upon the density of the liquid, the acceleration of gravity and the distance below the surface of the liquid.

Numerical

Find the pressure on a Rock which is 100 meters below the surface of the ocean. Assume standard atmospheric conditions. Use the density of sea water = 1.03×10^3 kg/m^3.

Solution:

P fluid = r g h

= (1.03 x10 3 kg/m3) (9.8 m/s^2) (100 m)

= 1.09×10^5 N/m^2.

= 10.9×10^5 Pa (Pascals)

=1.09 * 10 power 6 pascal

= 1.09 Mega pascal

Numerical

Solution

What is the pressure acting on the bottom of Bore Hole made for exploration of oil at a depth of 1km at 4°C, Where drilled Hole is full of water.

Ans: The depth of Oil column = 1km

= 1000 m

The density of water at 4°C = $1000 kg/m^3$

The formula used is: $p = \rho g h$

$= (1000 kg/m^3)(9.81 m.s^{-2})(1000 m)$

= 9810000 Pascal

= 9.8 * 10 -6 pascal

= 9.8 Mega pascal

A Bar is 50cm long and when force of 50KN is applied on it the lenth is increased by 5mm. Diameter of Bar is 10mm. Calculate Strain and Stress.

Stress = Force /Area

Force = 50 KN

= 50* 1000 N

= 50000 N

Area = πr^2

= 3.14 * 5*5

Stress = 50000/ (3.14*25)

= 636.9 Mega Pascal

Strain = 5/500

=0.01

Unit II

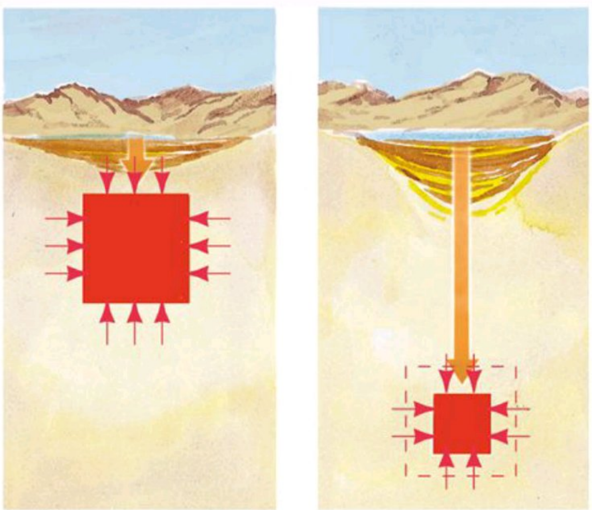
Lecture 5

Lithostatic Pressure

Lithostatic Pressure

Litho Static pressure, or overburden pressure, is the pressure exerted on a layer of soil or rock under the surface of the earth. The litho static **pressure** is caused by the density of the rocks and is transmitted through the grain-to-grain contacts of successive layers of rocks. its like an Overburden pressure which is the vertical pressure applied on a layer of rock from the rock and soil above it. Overburden pressure is sometimes called overburden stress. This overburden **pressure**, also called **lithostatic pressure**, or vertical **stress**. It is the **pressure** or **stress** imposed on a layer of soil or rock by the weight of overlying material.

Metamorphism and Metamorphic Rocks



Before compression After compression

(a) Confining pressure

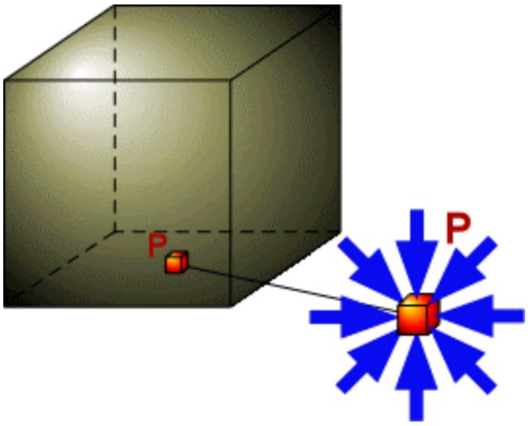
I. Factors controlling metamorphism

B. Pressure

1. Confining pressure (lithostatic pressure)

- Deep in the Earth
- Equal pressure from all directions
- Rock will be compressed into a smaller volume (no change in rock shape)
- Ions migrate within minerals from high pressure to low pressure

The total **overburden pressure** at a given depth is obtained from summing the product of the total unit weight times the layer thickness versus depth. The effective **overburden pressure** at a given depth is the total **pressure** minus the pore water **pressure**.



a) Lithostatic Pressure increases with the depth of the object
b) Lithostatic Pressure depends upon the nature of the overlying rocks
c) This also increases if the density of the Rock is more.

Lithostatic Pressure $\quad$ $P = \rho \times g \times h$

ρ- (rho) density of the Rocks,
g- acceleration due to gravity
h - Depth of the Rock

Numerical1

Find the Lithostatic Presuure at the depth of 10 km on a Ultramafic Rock. The overlying Rock is of sedimentary in nature of density 3300 kg/m3

Solution

Given Depth = 10 km
=10 × 1000 meter
Density = 3300 kg/m3
g =9.8 m/sec2

Lithostatic Pressure $\quad$ $P = \rho \times g \times h$

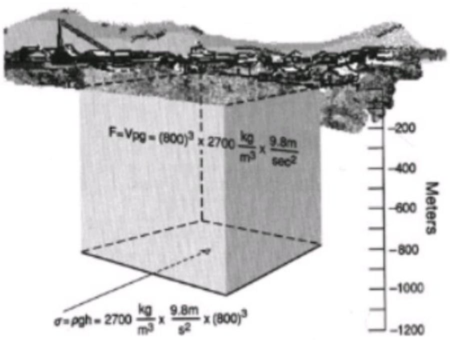
$P = 3300 \times 9.8 \times 10000$

= 323,400,000 pascals

=323.4 ×10(6) pascals (it is 10 to power 6)
= 323.4 Mega pascals

Numerical 2

There is a Block of granite dimension Length 1000 meter, width 1000 meter, and height of 1000meter.Density of the Granite Block is 2700 kg/m3. . Find the Lithostatic stress at the base of granite**.**



Solution.

Given Height/ Depth =1000 meter
Density of Granite = 2700 kg/m3x^2
g = 9.8 m/s2

Lithostatic Pressure **P = ρ× g × h**

P = 2700×9.8×1000

= 26,460,000 pascals

= 26.46 ×10 power 6 pascals

=26.46 Mega Pascals

Numerical 3

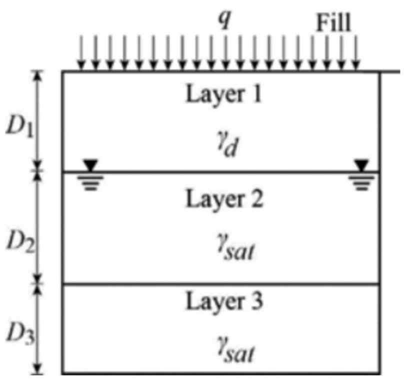
A coal seam is lying at depth of 3.5 km. Three different types of Rocks lying above it as mentioned below.

a) 1.0 km thick layer of shale having density 2100 kg/m3

b) 2.0 km thick layer of lime stone having density 2400 kg/m3

c) 0.5 km thick layer of sandstone having density 2600 kg/m3

Find Lithostatic Pressure on coal seam



Solution

Lithostatic Pressure = **ρ× g × h**

a) At 1km depth = 2100×9.8×1000
= 20580000 pascals
=20.58 mega pascals

b) Lithostatic Pressure = **ρ× g × h**
At 2km depth = 2400×9.8×2000
=47040000 pascals
=47.04 mega pascals

c) Lithostatic Pressure = **ρ× g × h**
At 0.5km depth = 2600×9.8×500
=12740000 pascalas
=12.74 Mega pascals

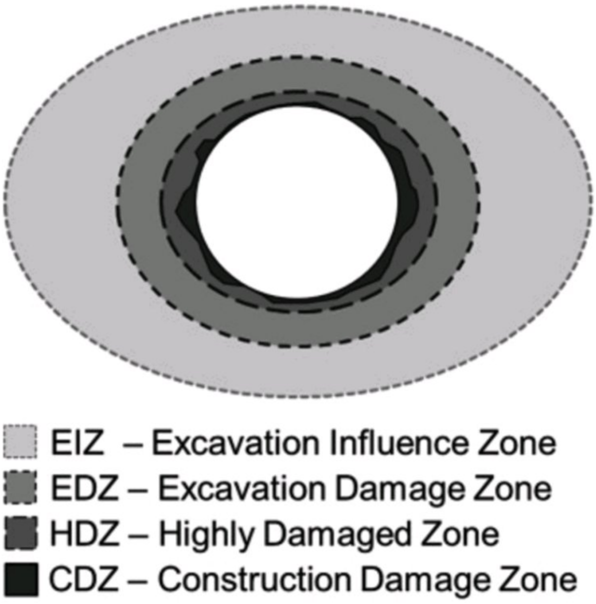
Total Lithostatic Pressure =20.58+47.04+12.74
=80.36 Mega Pascals

Unit II

Lecture 6

Induced Stress due to Mining

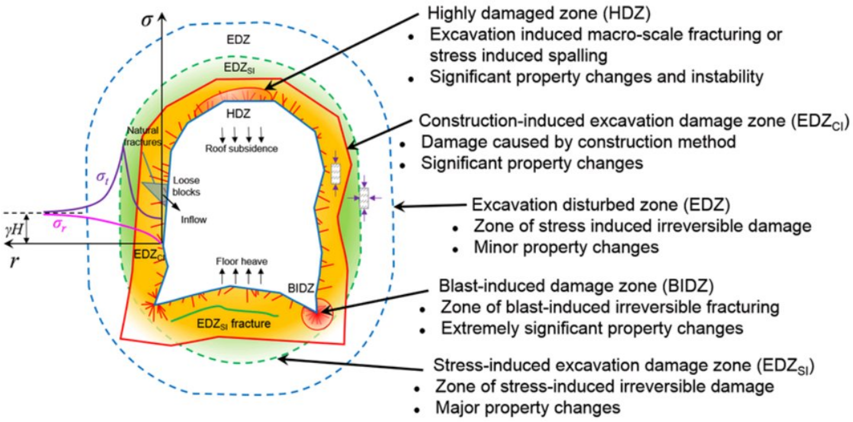
Rock at depth is subjected to stresses resulting from the weight of the overlying strata and from locked in stresses of tectonic origin. When an opening is excavated in this rock, the stress field is locally disrupted and a new set of stresses are induced in the rock surrounding the opening. Knowledge of the magnitudes and directions of these in situ and induced stresses is an essential component of underground excavation design since, in many cases, the strength of the rock is exceeded and the resulting instability can have serious consequences on the behaviour of the excavations



In situ stresses

Consider an element of rock at a depth of 1,000 m below the surface. The weight of the vertical column of rock resting on this element is the product of the depth and the unit weight of the overlying rock mass (typically about 2.7 tonnes/m3 or 0.027 MN/m3). Hence the vertical stress on the element is 2,700 tonnes/m2 or 27 MPa. This stress is estimated from the simple relationship: z v σ = γ (10.1) where σv is the vertical stress γ is the unit weight of the overlying rock and z is the depth below surface.

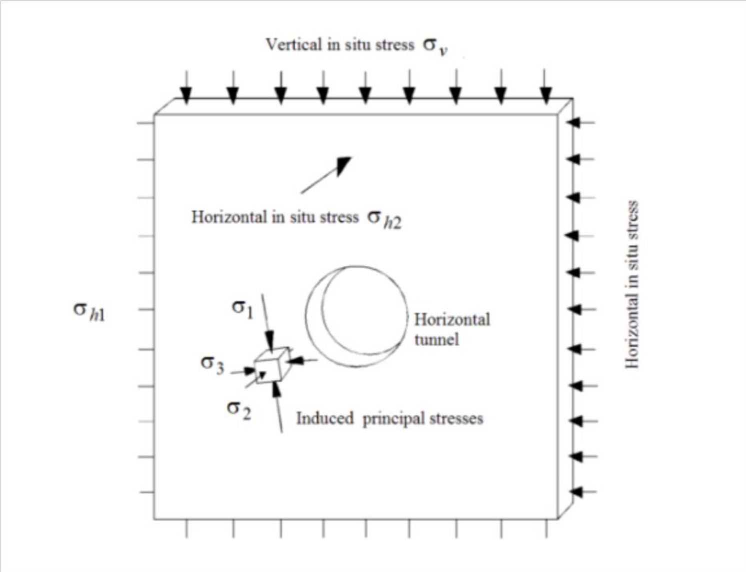
For stability assessments as well as for support design, it is important to understand the factors leading to detrimental stress changes. Stress changes not only influence the demand on the rock support, they also change the support capacity of frictional support components such as plain cable bolts. This study presents a practical example illustrating the usefulness of stress change measurements in providing an accurate picture of the **mining-induced stress** changes and their value for numerical model calibration.



Because of the large original stress in deep mining, compared with shallow mining, it is more likely to cause the occurrence of dynamic disasters such as **rock burst, coal and gas outburst** by the mining-induced stress concentration. Therefore, it is of great significance to master **mining-induced stress** distribution in deep mining.

Analysis of induced stress

When an underground opening is excavated into a stressed rock mass, the stresses in the vicinity of the new opening are re-distributed. Consider the example of the stresses induced in the rock surrounding a horizontal circular tunnel as illustrated in Figure, showing a vertical slice normal to the tunnel axis. Before the tunnel is excavated, there is in situ stresses, and are uniformly distributed in the slice of rock under consideration. After removal of the rock from within the tunnel, the stresses in the immediate vicinity of the tunnel are changed and new stresses are induced. Three principal stresses are acting on a typical element of rock are shown in Figure.



Tunnel shape

Most Mining Engineer like a simple horseshoe shape for tunnels since this gives a wide flat floor for the equipment used during construction. For relatively shallow tunnels in good quality rock this is an appropriate tunnel shape and there are many hundreds of kilometers of horseshoe shaped tunnels all over the world.

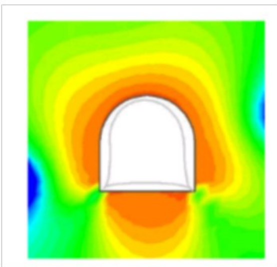
In poor quality rock masses or in tunnels at great depth, the simple horseshoe shape is not a good choice because of the high stress concentrations at the corners where the sidewalls meet the floor or invert. In some cases failures initiating at these corners can lead to severe floor heave and even to failure of the entire tunnel perimeter as shown in Figure

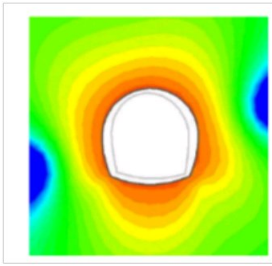
In situ and induced stresses

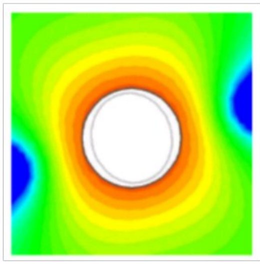
Figure 8: Failure of the lining in a horseshoe shaped tunnel in a highly stressed poor quality rock mass. This failure initiated at the corners where the invert meets the sidewalls.

Comparison of three tunnel excavation as shown below

The deformed boundary profile (exaggerated) is shown inside each excavation. It is clear that the flat floor of the horseshoe tunnel (top figure) allows upward displacement or heaving of the floor. The sharp corners at the junction between the floor and the tunnel sidewalls create high stress concentrations and also generate large bending moments in any lining installed in the tunnel. Failure of the floor generally initiates at these corners as illustrated in Figure .In few cases these modifications to the horseshoe shape may be sufficient to prevent or at least minimize the type of damage as shown in Figure.







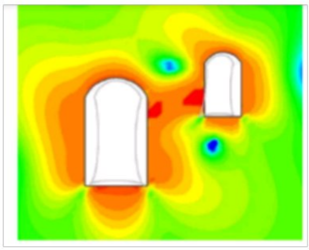
1. Generally tunnels are driven in the shape (figure 1) as given in above. This the most appropriate shape of tunneling as the excavation is done as per requirement. This is very convenient for movement of any transport system. We find that due to induced stress the damaged Zone is higher in this shape.

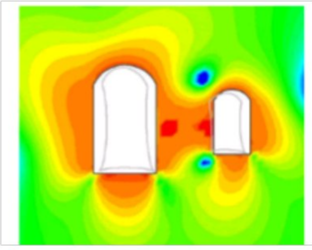
2. This shape (figure2) is almost elliptical, curved on both sides and at the top. Here also damaged due to induced stress slightly less in comparison to Figure 1. Floor heave is reduced significantly by the concave curvature of the floor of the modified horseshoe shape.

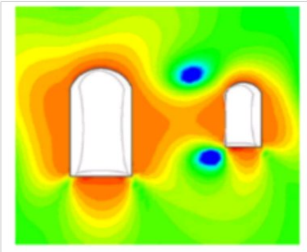
3. This the best shape (figure 3) as damage due to induced stress is concerned. But the utilization of place not adequate. However, in severe cases, a circular tunnel profile is invariably the best choice, as shown by the smooth Strength Factor contours and the deformed tunnel boundary shape in the bottom.

Two Tunnels at a time

Comparison of three different underground gallery layouts. The deformed boundary profile (exaggerated) is shown inside each excavation







A closer examination of the deformations induced in the rock mass by the excavation of the underground gallery, shows that the smaller of the two excavations is drawn towards the larger opening and its profile is distorted in this process. This distortion can be reduced by relocating the smaller gallery and by increasing the spacing between the galleries as has been done in last Figure .

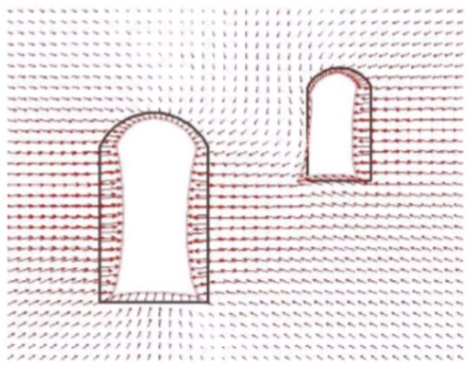
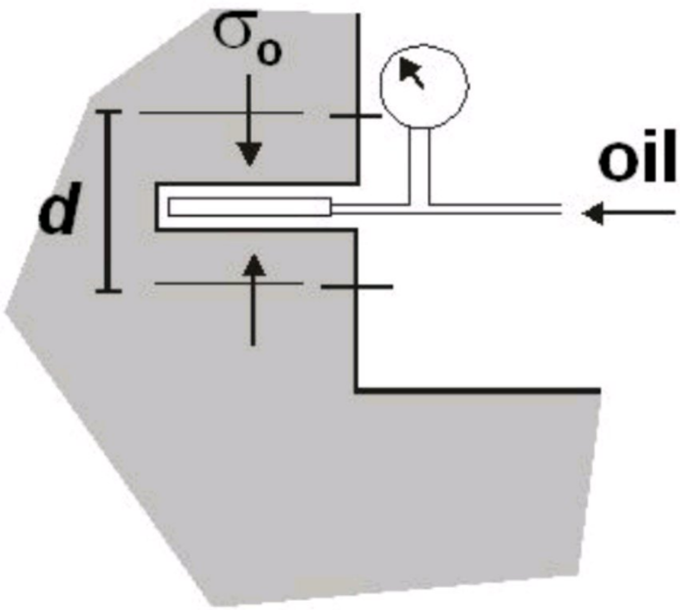


Figure 13: Displacement vectors and deformed excavation shapes for the underground powerhouse and transformer gallery.

Where the combination of rock mass strength and in situ stresses is likely to cause overstressing around the opening in the pillar. **A good rule of thumb is that the distance between the two openings should be approximately equal to the height of the larger opening**.

Measurment of Insitu Stress

A slot of 400x200 mm with a thickness of around 6mm was made on the mortar joint using the cutting machine as shown in Figure.Two pins at different places are fixed on either side of the hole, that has been cut. The distance between pins are measured. Cutting the slot causes partial stress relief in masonry above and below of the hole aslo. After drilling holes due to insitu stress in the rock, this stress is relieved. As result Distances between the pins also decreases. Again The displacement between the pins are recorded.



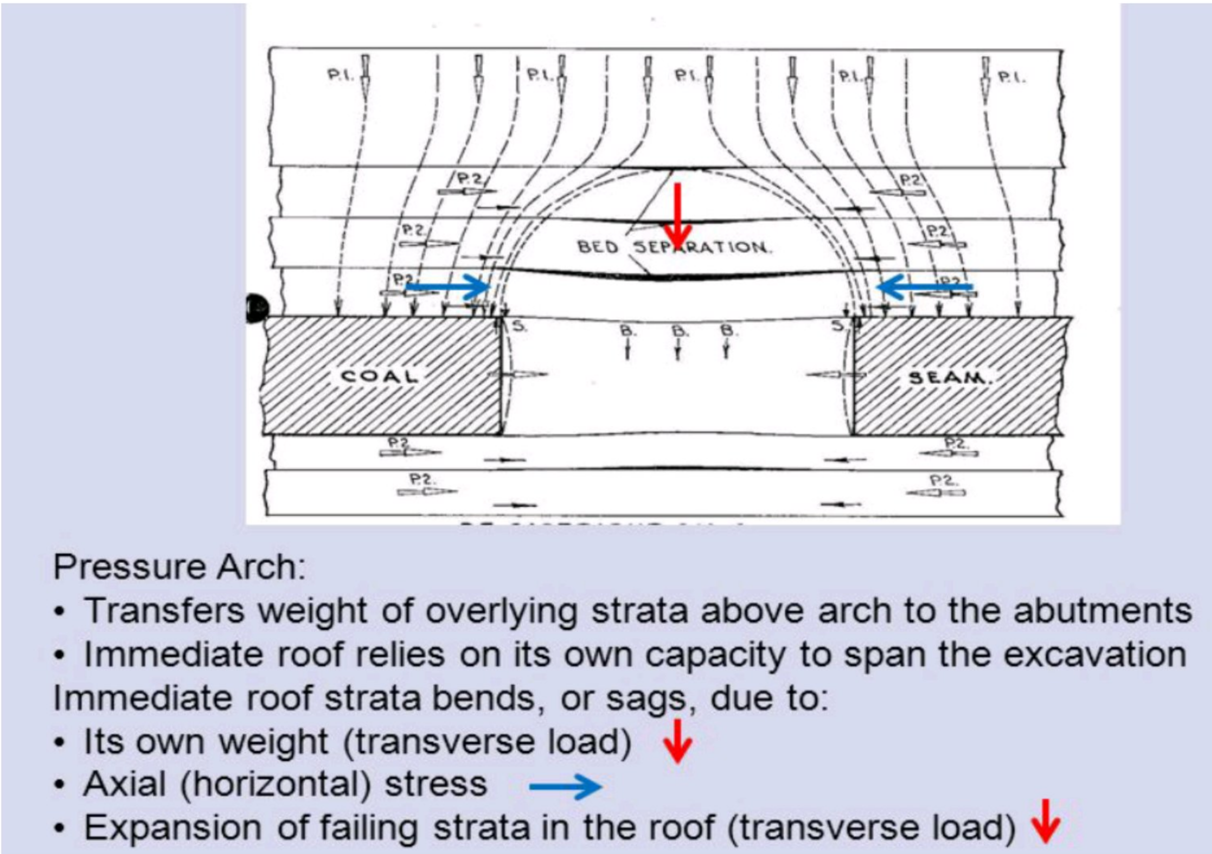
The flat-jack of size 400x200 mm was inserted into the slot and the gap between flat-jack and surrounding masonry was filled with shims as shown in Figure. With the aid of this flat jack, pressure (compressive stress) is applied to the masonry. The pressure is applied with the help of Hydraulic Pressure pump. This is continue till the two pins reaches at their original position. The pressure is note, which is insitu stress. Although this is very old method.

Narrow Opening

As soon as any excavation is made in the strata, all the forces are redistributed. The latent energy which is always exists in the strata is gradually released. Hence the pressure is redistributed. When any roadway is driven in the strata.

1. Roof tries to bend down
2. Floor tries to lift
3. Side tries to bulge

When any narrow opening is made in the strata, all stresses largely sheer and tensile are induced in the opening. The Rocks above the opening is in the form of layers. Hence the moment opening is made the immediate first layer tries to bend down due to vertical pressure and weight due to gravity. After bending the pressure is neutralized. The bending of roof beds is continued. Gradually all immediate layers tries to come down, bends downwards so that pressure is neutralized.The first layer sags more next layer sags slightly less. This keeps on decreasing as we move away from the opening. Due to tension most of the pressure moved on the side of the pillars. The distressed layers form an arch as shown.



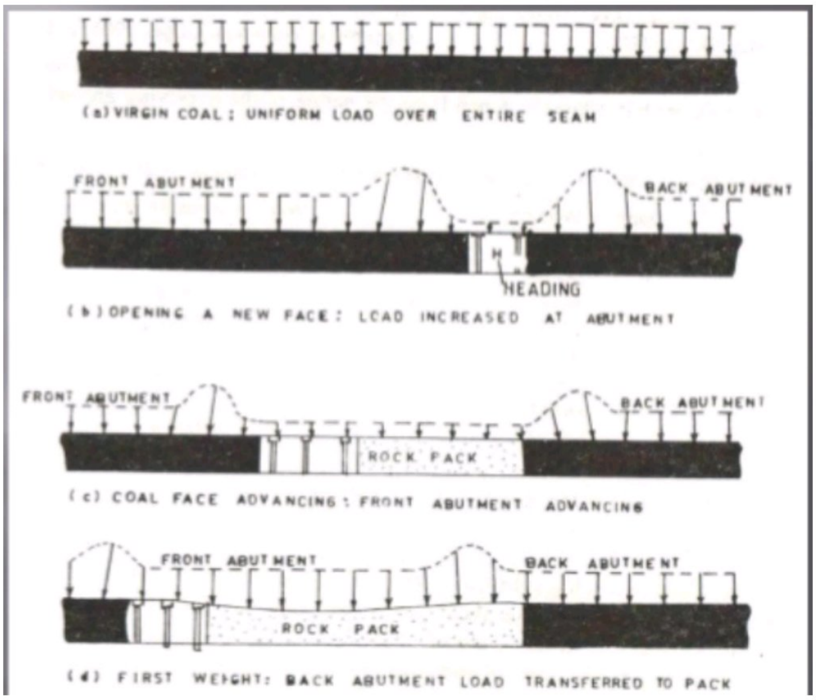
The vertical force P will be deflected side ways and it will contact each bed at different points.

The line of increased pressure is known as Pressure arch. There is similar type of vertical pressure at centre will more and will go on decreasing while moving away the openings. Because other pressures are near to solid coal pillars. Shearing force S will also develop, which separate immediate roof to shear away. Forces also develop in the floor due to roof and side wall pressure. As a result Floor tries to heave. The rocks above the opening are in layer form or bed forms. The immediate roof bends due to vertical stress. The reason is to neutralize the pressure of vertical stress. This bending of roof will cause the bed to sag downwards. Hence each bed will separate with other roof bed. The distressed strata will form an arch as shown in figure. The exact shape of arch depends upon

1. **Nature of Rock**
2. **Amount of vertical stress**
3. **Amount of bending.**
4. **Thickness of each bed**
5. **Strength of each bed**

Wider Opening

Although nothing is mentioned as definition of wide gallery for coal in mines rules**. In general gallery less than 8 meter width comes under narrow gallery**. All depillaring operation and Longwall working comes under wider Excavations. When an opening is created in coal, the pressure which was just above the opening is shifted to side solid pillars is called abutment pressure. The areas where is the remaining coal, all pressure will be shifted to those remaining pillars. Hence pressure in remaining pillars is more. It is called abutment pressure.



As the face advances the roof beds bend .All the layers bends with different amount. The roofs above in layers have different in nature so their separation may be different due to different elasticity.

1. In first figure when there is no working, entire throughout the seam Pressure is uniform throughout.

2. When an opening is made as H, The vertical pressure is reduced just above the heading and both sides of side pillar Pressure is increased. This pressure is called Abutment Pressure. There are

a) Front Abutment Pressure

b) Back Abutment Pressure

3. As we go on increasing the excavation, this abutment pressure continued to increase. To overcome the Abutment pressure we install face supports. At this stage local roof fall takes place. Back abutment pressure is reduced.

4. As the excavation is increased further roof fall takes place. This is also called main fall. Now goaf is completely settled. Back abutment pressure is neutralized.

There are many theories about maximum abutment Pressure.

A Maximum abutment pressure is at distance of 15m from the face

B Another theory it is maximum at 30m from the face

Although it varies due to

a) Width of Longwall face
b) Depth of Working
c) Nature of overlying strata.

Unit II 17-12-2020

Lecture 8

Instruments for stress

Need Of Instrumentation

- Today instrumentation is a basic need for prediction of rock strata behavior
- Many instruments: FOR STRESS & DEFORMATION MEASUREMENT, used for ground control measures and monitoring of strata movement.
- Geotechnical Problems in underground coal mines and tunnels as the overlying rock above the immediate: After excavation process, overlying bedded rocks get associated with strata movement if proper support system has not been provided.
- In underground mines and tunnels roof fall is the major reason of casualties. By instrumentation it gets much easier to monitor the rock movement, which enables management to reinforce their support system, if analysis of instrumentation-data so suggest, or else reduce the support or increase the width of excavation.
- Continuous monitoring of strata helps to envisage the likely excessive rock movement and stress, which may create big problem during excavation.

Objective Of Instrumentation

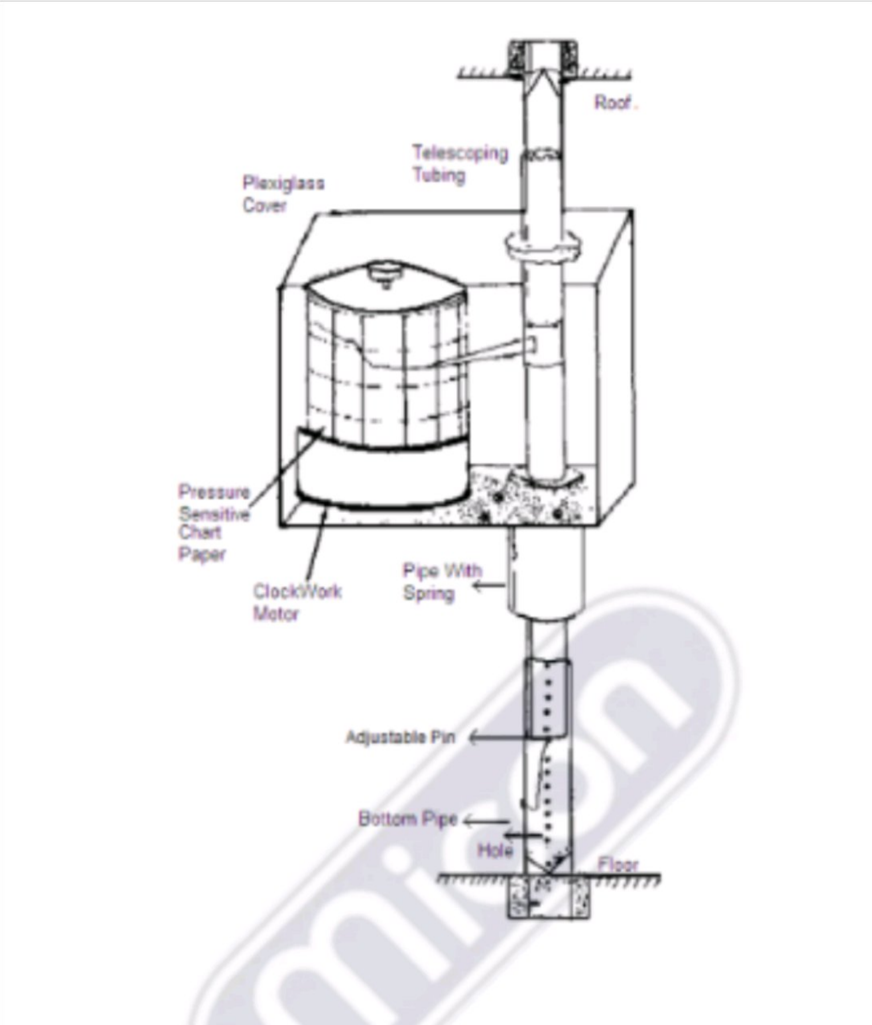
Monitoring rock behavior

- Movement of strata in immediate roof
- To evaluate ground stability at working areas in experimental panel.
- To assess the efficacy of the proposed support system, subsequently to modify the support design, as and when required; and finally,
- To establish a support design norm-using roof bolts in similar geomining environment.

3. Instruments used for stress measurement

1 Bore Hole Extensometer
2 Load Cell
3. Stress Meter
4. Auto-warning Tale tale
5. Remote Convergence Indicator
6. Convergence Rod
7. Telescopic Convergence Indicator
8. Indicator props

Remote Convergence Indicator



It consists of two tubes, one of greater diameter. The inner tube is fixed, upper tube fixed with spring which moves over inner tube. In the beginning the indicator is fixed. One lower end firmly fixed on the floor. The upper end also firmly tightened against the roof. A drum is attached with the outer tube. A paper is rolled on this drum. An indicator is attached to the inner tube. Now when there is stress, the roof will sag down. As a result the inner tube moves down, with the help of the indicator, it is marked on paper. The convergence is recorded on the paper, which is rotated around a drum by some mechanically device

Unit II 15-10-2020

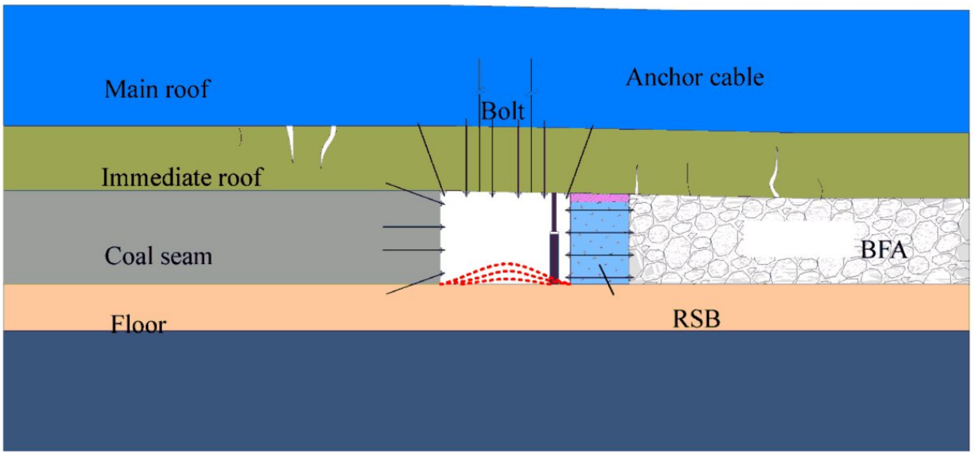
Lecture 9

Stress Distribution around Roadways.

Stability of roadways has been a primary concern in underground coal mining. Roadways excavated through a coal seam are a common situation, which can affect the stability of the roadway. If the coal seam is subjected to high in-situ stresses, the roadway will collapse or

Heave

The floor in a coal mine acts as a foundation to support coal pillars and artificial supports, thereby providing support to the mine roof. The overburden load, transferred through pillars and other supports, applies tremendous stress to the floor. Based on foundation theory, vertical load on pillars causes high shear stress zones in the floor.

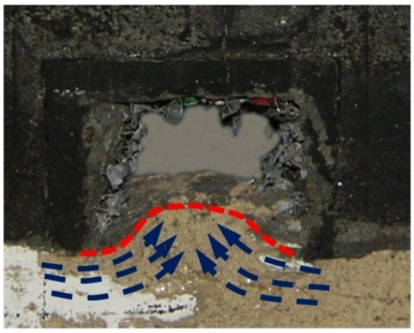


(a)

If the floor is relatively weak, it may fail and dislocate upward into the mine opening. Strong roof strata that do not readily fail transmit most of the overburden load through pillars to the floor. In many instances, the floor heaves at a slow rate without causing health and safety related problems; only additional roadway maintenance and coal handling equipment are required. However, when rapid, massive heaving occurs, the safety of mine personnel becomes unsafe. Based on foundation theory, vertical load on pillars causes high shear stress zones in the floor. If the floor is relatively weak, it may fail and dislocate upward into the mine opening.

The following parameters were included in the analysis
1. Principal horizontal stress in the immediate floor member,
2. Upward force on the immediate floor member caused by deformation of a soft lower member,
3. Unit weight of the immediate floor member

(b)



(c)

Main Reasons for Heave and Creep

The seam depth and thickness of this coal seam varies in the ranges of400–800 m and 10–20 m, respectively. The overlying strata largely comprise hard roofs, and a high mining pressure is observed in the process of mining. Although the working face is supported adequately. The problems generally occurs when
1. Depth of coal seam is more
2. Gradient of seam
3. Nature of Coal

4. Geological condition
5. Nature of overlying strata
6. Method of working
7. Thickness of Coal Seam
8. Influences of the Breakage Position of the Main Roof

Creep

The deformation of rocks is time-dependent. Some rocks, such as granite show little time-dependent strain whereas in other rocks such as salt, potash, coal, time-dependent strain greatly exceeds the instantaneous elastic deformation. In underground mines, particularly salt and potash mines studies have indicated that deformation of pillars does not occur instantaneously but increases with time. Pillars which appear stable after mining may deteriorate with time and subsequently fail due to the development of limiting vertical deformation.

The affect of creep on rock-bursts is two-fold. Firstly, the time-dependent deformation may cause a gradual release of abutment stress and hence decrease the danger of rock -bursts. There is frequent occurrence of out-bursts in anthracite mines. If coal creeps, the stresses are easily accommodated as workings advance and the strength of coal is not exceeded; but if coal does not creep, as is the case with anthracite, its strength is exceeded and this results in violent outbursts.

If the Roof is relatively weak, it may fail and come downward into the mine opening. Strong roof strata that do not fail easily and transfer most of the overburden load through pillars to the floor. In many cases the roof bends at a slow rate without causing danger to workers and mine. Only additional supports in roadway are required. Support should be installed immediately before separation of beds take place. However, when rapid, massive sagging takes place the safety of workers becomes danger. Based on foundation theory, vertical load on pillars causes high shear stress zones in the floor. If the roof is relatively weak, it may fail and comes downward into the mine opening

The seepage action of underground water accelerates the deformation of roadway surrounding rock in deep mines. Therefore, the study of creep characteristics of surrounding rock under seepage action is the basis for the stability control of roadway surrounding rock in deep water-rich areas. The study results showed that the maximum creep deformation of sandstone under natural and saturation state decreased

Main Reasons for Creep

The seam depth and thickness of this coal seam varies in the ranges of400–800 m and 10–20 m, respectively. The overlying strata largely comprise hard roofs, and a high mining pressure is observed in the process of mining. Although the working face is supported adequately. The problems generally occurs when

1. Depth of coal seam is more
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6. Method of working
7. Thickness of Coal Seam
8. Influences of the Breakage Position of the Main Roof

Unit III 29-10-2020

Lecture 1

Physical and Mechanical Properties of Rocks

Physical properties

We rely on a number of basic properties of rocks which reflects variations of structure, types and components. Properties which are relatively easy to measure and valuable in this regard are called index properties of rock as described below.

1. Density/Sp. Gravity
2. Porosity
3. Permeability
4. Hardness: Strength of Rocks
5. Abrasivity: It is resistance to abrasion.
6. Durability:
7. Defects in Rock Mass
8. Weathering Agents Of Rocks

   a) Mechanical Fragmentation

   b) Chemical Decomposition

   c) Oxidation, Leaching and Reduction

   d) Hydrothermal Alteration

   Deep Below surface temp more then 500 ℃, changes nature of Rock

Mechanical Properties of Rocks

This shows the strength of Rocks. For finding Strength of Rocks there are various tests which are done in the laboratory.

1. Compressive Strength of Rocks
2. Tensile Strength
3. Shear Strength
4. Point Load Strength
5. Young's Modulus

These above tests help in deciding

1. Method of work
2. Equipment to be used in mine
3. Type and capacity of support to be used in underground

Unit III 05-12-2020

Lecture 2

Compressive Strength of Rocks

When a specimen of material is loaded in such a way that after applying the load from two sides the material compresses and shortens it is said to be in *compression*. When we keep on increasing the pressure at one stage material breaks. **Compressive strength** or **compression strength** is the capacity of a material or structure to withstand loads tending to reduce size and finally it fails. In other words, compressive strength resists being pushed together.

Compressive strength is often measured on a universal testing machine. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

Compressive Strength Formula:

$$\text{Compressive Strength of the Concrete Cube Specimen} = \frac{\text{Maximum Load Applied to the Cube Specimen}}{\text{Cross Sectional Area of the Cube Specimen}}$$

F= P/A

Where,

F= **Compressive strength** of the specimen (in MPa).

P= Maximum load applied to the specimen (in N).

A = Cross sectional area, where the force is applied

In very simple words, compressive strength is calculated by dividing the failure load with the area of application of load, usually after 28 days of curing. The strength of concrete is controlled by the proportioning of cement, coarse and fine aggregates, water, and various admixtures. The ratio of the water to cement is the chief factor for determining concrete strength. The lower the water-cement ratio, the higher is the compressive strength.

There are following type compressive Strength Tests

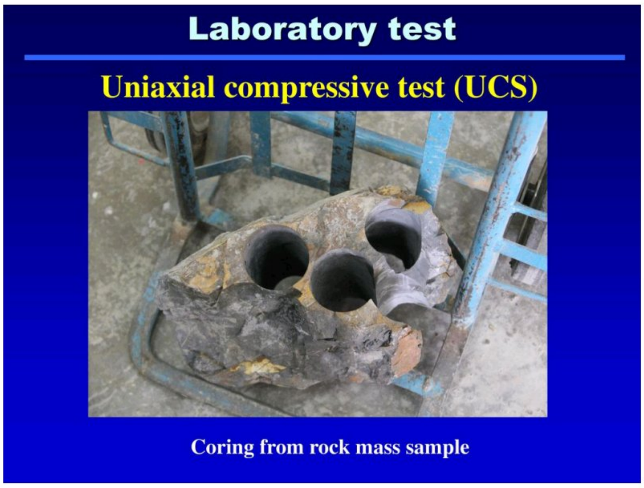
1. **Uniaxial compressive strength**
2. **Triaxial compressive strength**
3. **Point Load Strength**

Unit III 05-12-2020

Lecture 3

Uniaxial compressive strength of Rocks

(UCS) is the maximum axial compressive stress that a right-cylindrical sample of material can withstand before failing. Samples are prepared by drill cores and are selected cautiously in order of the original rock formation. The minimum diameter of a specimen must be at least 47 millimeters and 10 times larger than the size of the largest mineral grain



The samples' length to diameter ratio (L/D) must be between 2.0 and 2.5, according to ASTM (American Society for Testing and Materials) and 2.5-3.0 according to ISRM (International Society for Rock Mechanics). The cylindrical surfaces are prepared in order to be flat and smooth.

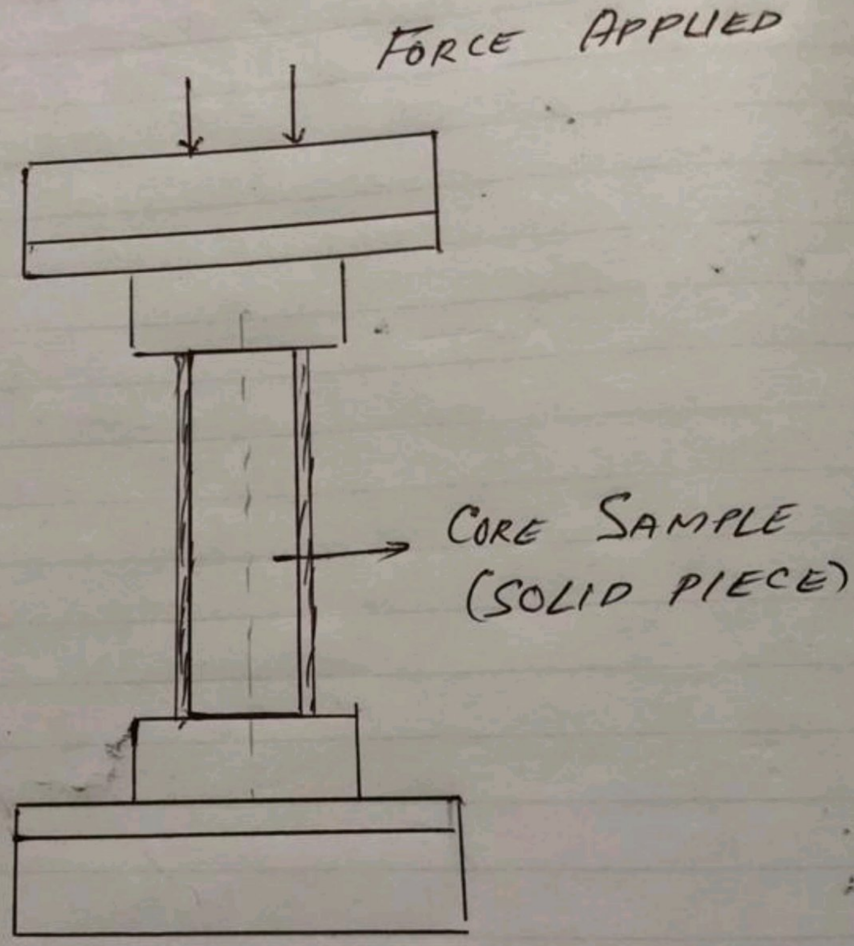
Apparatus

Loading Device: The loading device must be designed to consistently apply load at the required rate until the end of the test. The test may be stress- or strain-controlled. It is pointed out that only strain-controlled devices can capture the post-failure behavior of a material.

Platens: The axial stress applied by the loading device is transferred to the specimen by two steel platens that are made with a minimum Rockwell Hardness of 58. Their diameter must be at least equal to the sample's diameter.

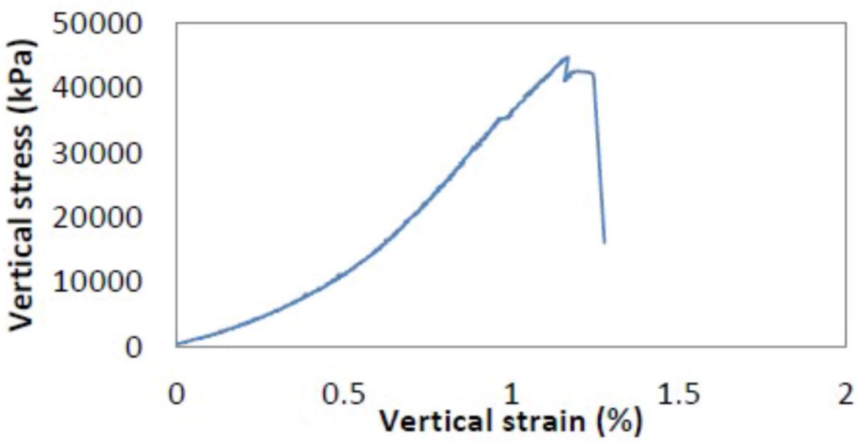
Strain measurement devices: The axial and lateral deformations are measured by various devices (e.g. Linear Variable Differential Transformers (LVDTs), Compressometers, Electrical Resistance Strain Gag

Testing Procedure



UNVERSAL COMPESSIVE STRENGHT TEST OF ROCK.

The two plates shall be carefully cleaned before the specimen is placed in the testing chamber. The load should be continuously applied at a rate of 0.5 MPa/s to 1.0 MPa/s (in case of a stress-controlled load device) and failure must occur in approximately 10 minutes. Stress and deformation data can be recorded through an electronic system that has the appropriate accuracy specifications. The maximum load is recorded in Newtons within a 1% accuracy



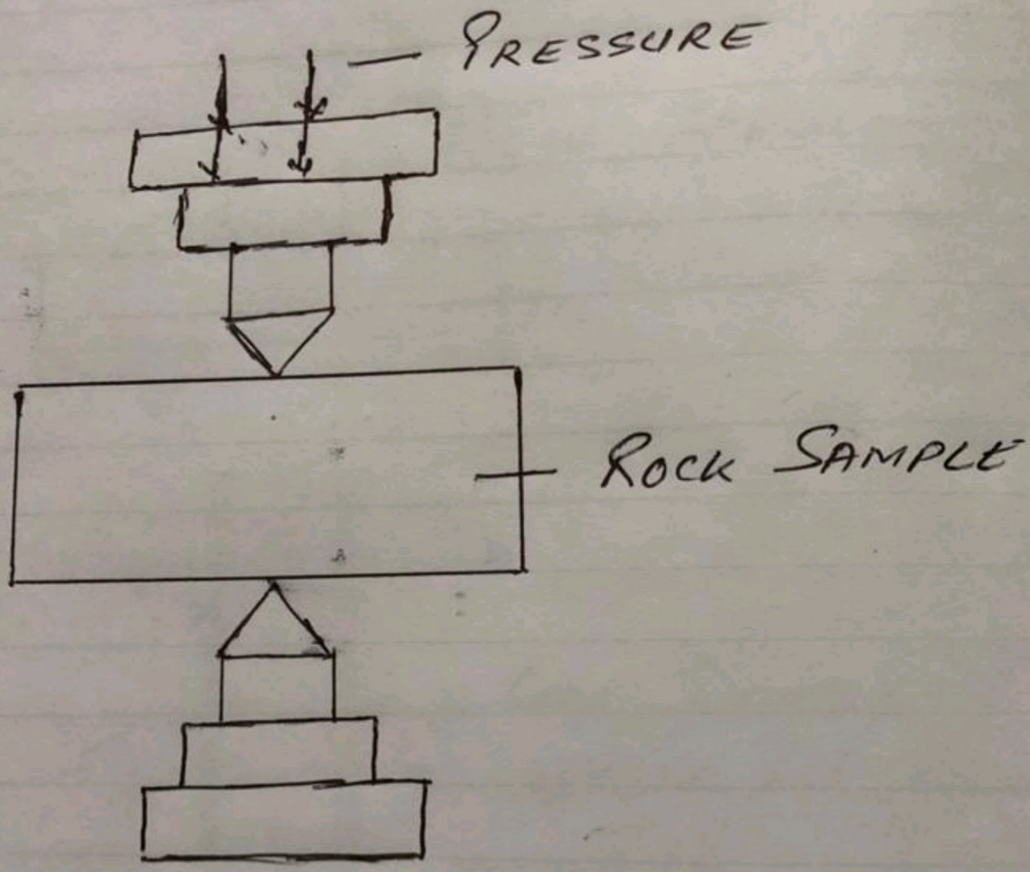
A typical stress-strain diagram deriving from a Uniaxial Compression Test of an undisturbed specimen of basalt is presented in **Figure** . The UCS is the peak value of the diagram and is equal to 44.7 MPa. Photos of the specimen before and after the test are presented **.** During the failure process, cracks propagated from the bottom to the top of the specimen, shearing off a large piece of the sample.

Unit III 20-11-2020

Lecture 4

Point Load Strength Index of Rocks

The **Point load test** is an index test by which the rock is classified according to the strength. The test can be used to estimate other characteristics of intact rocks with which it correlates, such as uniaxial compressive and tensile strength.



POINT LOAD STRENGH TEST

Scope

1 This test method covers the guidelines, requirements, and procedures for determining the point load strength index of rock. This is an index test and is intended to be used to classify rock strength.

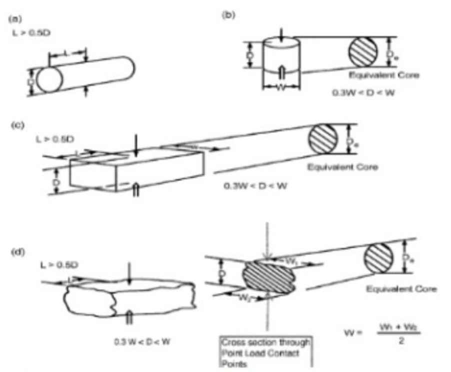
2 Specimens in the form of rock cores, blocks, or irregular lumps with a test diameter from 30 to 85 mm can be tested by this test method.

3 This test method can be performed in either the field or laboratory. The test is typically used in the field because the testing machine is portable, little or minimal specimen preparation is required, and specimens can be tested within a short time frame of being collected.

4 This test method applies to medium strength rock .

5 This test method does not cover which type of specimen should be tested. The specifics of the point load test program need to be developed prior to testing and possibly even before sampling.

FIG. 2 Truncated, Conical Platen Dimensions for Point Load Apparatus



NOTE 1—Legend: L = distance between contact points and nearest free face, and D_e = equivalent core diameter (see 10.1).

FIG. 3 Load Configurations and Specimen Shape Requirement for (a) the Diametral Test, (b) the Axial Test, (c) the Block Test, and (d) the Irregular Lump Test[3]

Apparatus

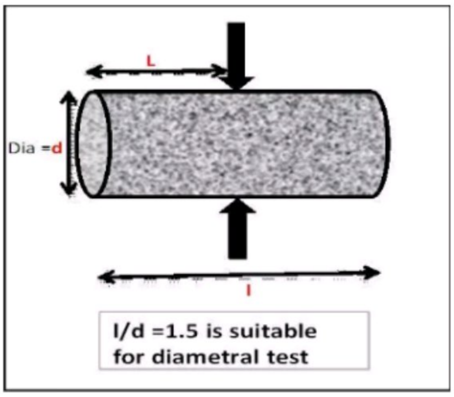
EQUIPMENTS

- Point load strength test machine
- A 100 mm scale attached with the loading frame
- Pressure gauge (Capacity 25 kN or 50 kN)

Depending upon the size and shape of test specimen, the point load strength index can be conducted by four different methods. These are

1. Diametral Test
2. Axial Test
3. Block Test
4. Irregular lump Test

. DIAMETRAL TEST



PROCEDURE

1. The diametral test is conducted on rock core sample. Minimum of 10 test specimens are required to find out the average value of point load strength index.
2. This test can be conducted on the core specimens which are completely dry or after soaking it for 7 days.
3. Measure the total length (**l**) and diameter (**d**) of the core specimen. Specimen of **l/d=1.5**, are considered to be suitable for this test.
4. Place the specimen horizontally between two platens in such a way that the distance between the contact point and the nearest free end (**L**) is at least 0.75times the diameter of the core (**d**).
5. Measure the distance between two platen contact points (**D**) with the help of the scale attached with the loading frame.
6. Apply load to the core specimen such that failure occur within 10-60 sec. Record the failure load '**P**'.

CALCULATION

Point load strength index (I_s) = $\mathbf{(P*1000)/D^2}$ Mpa

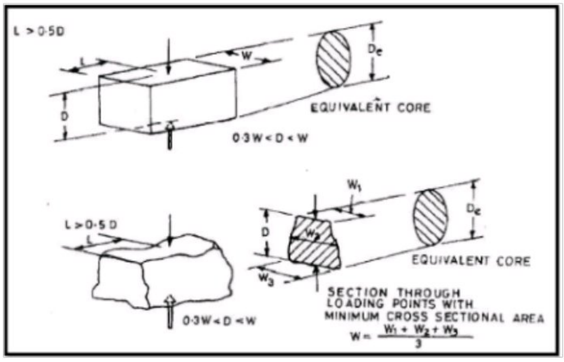
Where **P** is breaking load in kN

D is the distance between platens in mm

REPORT

The corrected mean value of the point load strength index I_{s50} is reported in Mpa.

BLOCK OR IRREGULAR LUMP TEST



PROCEDURE

1. This method of test is conducted on rock block or irregular samples. Minimum of 10 test specimens are required to find out the average value of point load strength index.
2. This test can be conducted on the core specimens which are completely dry or after soaking it for 7 days.
3. Place the specimen horizontally between two platens.
4. Measure the distance between two platen contact points (**D**) with the help of the scale attached with the loading frame. Measure the smallest specimen width (**W**) perpendicular to the load direction. If the sides are not parallel , then '**W**' is obtained from $\mathbf{W_1}$, $\mathbf{W_2}$ and $\mathbf{W_3}$ as show in the figure and calculated as $\mathbf{W= (W_1+W_2+W_3)/3}$. Measure the distance between platen contact point and nearest free end (i.e. **L**). The distance **L** should be at least **0.5D**.
5. Apply load to the core specimen such that failure occur within 10-60 sec. record the failure load '**P**'.

CALCULATION

Uncorrected Point load strength index (I_l) = **$(P*1000)/D_e^2$** Mpa

Where **D_e**= Equivalent core diameter

$D_e^2 = (4A)/\pi$

And **A** is calculated using following equation

A=W*D

Where **W** is the specimen width in mm

D is the distance between platens in mm

P is the breaking load in kN

REPORT

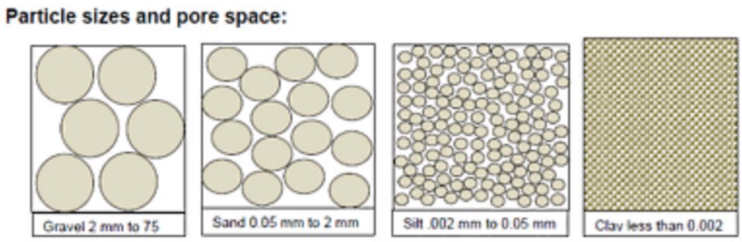
The corrected mean value of the point load strength index **I_{s50}** is reported in Mpa

Unit III 26-11-2020

Lecture 6

Porosity

Soils are made of particles of different types and sizes. The space between particles is called **pore space**. Pore space determines the amount of water that a given volume of soil can hold. **Porosity** refers to how many **pores**, or holes, a soil has. The porosity of a soil is expressed as a percentage of the total volume of the soil material



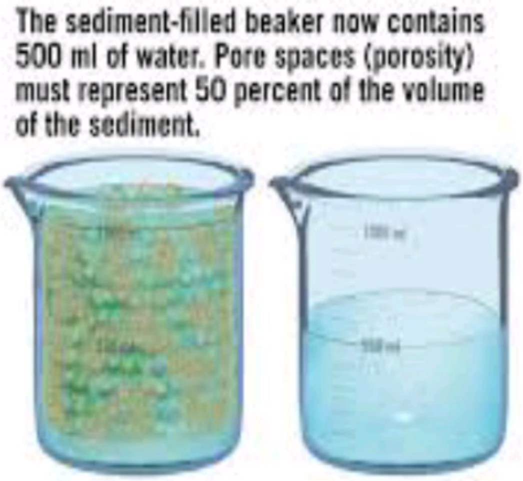
Porosity or void fraction is a measure of the void (i.e. "empty") spaces in a material, and is a fraction of the volume of voids over the total volume, between 0 and 1, or as a percentage between 0% and 100%. More specifically, **porosity** of a rock is a measure of its ability to hold a fluid. Mathematically, it is the open space in a rock divided by the total rock volume (solid and space). The porosity can be expressed either as a fraction or as a percentage. Two out of the three terms are required to calculate porosity.

How to Measure Porosity

Material

- Water
- Permanent marker
- Soil samples

Calculating Porosity Experimentally by Saturation



1) Take a sample of the soil of which porosity has to be found.
2) Transfer the soil sample to a graduated beaker to measure the volume of the soil. Record this volume exactly. This measurement is the Volume of the Sample Vs

3) Fill a graduated cylinder to 1000 ml with water Measure an amount of water into a graduated cylinder.

4) Slowly and carefully pour the water into the first beaker until the water just reaches the top of the sand. Pour slowly so no water spills out of the measuring cup.

5) Saturate the soil sample with the water. Get the water as close as you can to the exact top of the soil in the beaker but don't go over the top

6) Subtract the volume of water that you used up from the starting volume in the graduated cylinder. That shows you how much water it took to saturate the soil.

7) Record exactly how much water was used

8) The volume of the water used is equal to the Pore Volume Vp

Use the formula below to calculate the percent porosity for the sand

Porosity = (Amount of water added to sample ÷ Total sample volume) x 100

Porosity = Pore Volume/Total Volume ×100%

Unit III 28-11-2020

Lecture 7

Permeability

Permeability is the ability of fluids to flow through rock. It depends on the connectivity of the pore space. **Permeability** in fluid mechanics (commonly symbolized as *k*) is a measure of the ability of a porous material, often a rock or an unconsolidated material to allow fluids to pass through it. Permeability is the property of rocks that is an indication of the ability for fluids to flow through rocks.

High permeability will allow fluids to move faster. Permeability refers to how connected pore spaces are to one another. If the material has high permeability than pore spaces are connected to one another allowing water to flow from one to another. In case of low permeability then the pore spaces are isolated and water is trapped within them. For example, in gravel all of the pores well connected one another allowing water to flow through it, however, in Clay most of the pore spaces are blocked, meaning water cannot flow through it easily. Permeability is affected by the pressure in a rock.

Application

The concept of permeability is of importance

1. In determining the flow characteristics of hydrocarbons

2. In oil and gas reservoirs [l]

3. Groundwater in aquifers

4. Applications outside of geology

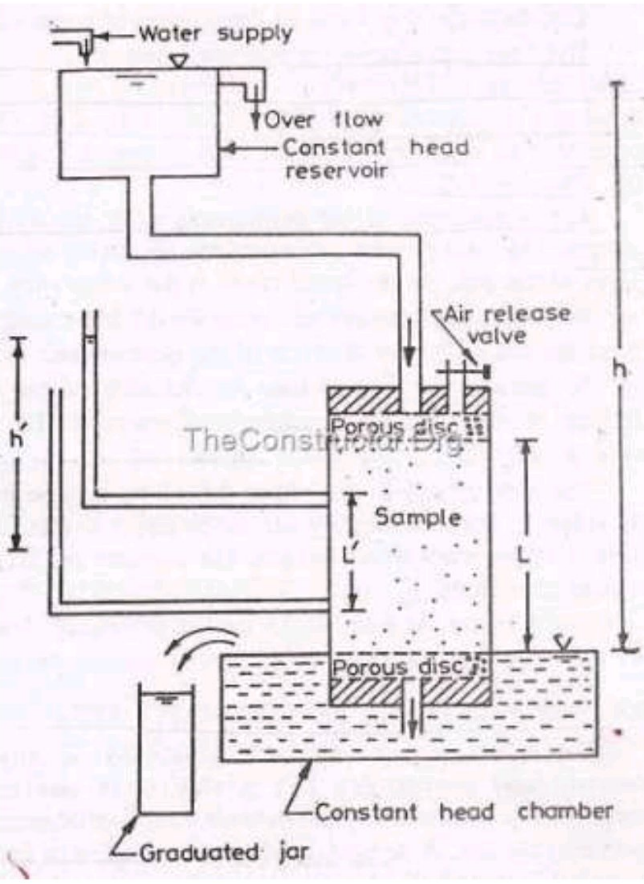
5. In chemical engineering (e.g., filtration)

6. In Civil Engineering, determining ground conditions of site suitable for construction.

7. Construction of Dam

Determination of permeability in the laboratory

Permeability is measured on cores in the laboratory by flowing a fluid of known viscosity through a core sample of known dimensions at a set rate, and measuring the pressure drop across the core, or by setting the fluid to flow at a set pressure difference, and measuring the flow rate produced.



1. A sample cylindrical in shape is taken.

2. Sample is covered by plastic from sides' all-around.

3. Not it is put into the instrument.

4. From Top of the sample water is applied at one end.

5. After seepage water is collected at the bottom of the sample.

6. Quantity of water is measured

7. Area of the sample is measured.

8. Time is also measured

From given formula Permeability is calculated.

K = QL/Aht

K – Coefficient of Permeability cm/sec

Q - Discarge of Quantity cm qube

L – Length of Sample cm

A -Area of Cross section of sample cm square

h – Difference in level of water cm

T – Time in Sec

Unit III 03-12-2020

Lecture 7

Rock Burst and Bumps

Rock Burst

Rock bursts, in which rocks are ejected suddenly in deep pits or tunnels, are caused by increase of stress in the surrounding rocks. A **rock burst** is a spontaneous, violent failure of rock that can occur in high-stress mines. Although mines may experience many mining-related seismic events, only the tremors associated with damage to accessible mine workings are classified as rock bursts. The opening of mine workings relieves neighboring rocks of tremendous pressure, which can literally cause the rock to explode, or trigger abrupt movement on nearby geological structures. Rock bursts are a serious hazard.

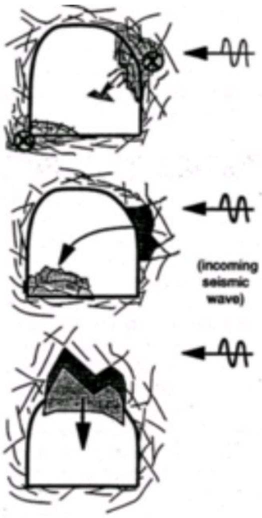
Rock bursts result from brittle fracturing of rock, causing it to collapse rapidly with violent spalling of rock that is approximately 100 to 200 tones, or more. This release of energy reduces the potential energy of the rock around the excavation. Another explanation is that the changes brought about by the mine's redistribution of stress trigger latent seismic events, deriving from the strain energy produced by its geological aspects

Definition of rock bump

The sudden release of the weight of the rocks over a coal seam or of enormous lateral stresses due to structural or tectonic folds and thrusts and sometimes both. A rock bump may take the form of a pressure bump or a shock bump.

Reasons for rock bursts

1. Increases as the depth of the mine increases.
2. Rock bursts are also affected by the size of the excavation (the larger the more risky), becoming more likely if the excavation size is around 180 m and above.
3. Induced seismicity such as faulty methods of mining can trigger rock bursts.
4. Other causes of rock bursts are the presence of faults, dykes, or joints



Types of Rock bursts

Rock bursts are generally divided into three classifications:

• **Strain bursts:** These are caused by high-stress concentrations at the edge of mine openings that exceed the strength of the rock. Events can range from small slivers of rock being ejected from the walls to the collapse of a complete wall as it tries to achieve a more stable shape.

• **Pillar bursts**: Severe rock bursts, involving thousands of tons, have been caused by the complete collapse of support pillars. These tend to occur in extensively mined-out areas, and the resulting damage can be severe.

• **Fault slip bursts**: Recognized in the 1980s, this type of rock burst occurs when slippage suddenly occurs along a geological weakness plane. This is the same mechanism as for an earthquake.

Damage may occur as rock bulking by fracturing, ejection of rock due to seismic energy, or rockfalls by seismic quaking. Each mechanism may result in different levels of damage to an excavation and its support system. The damage severity depends on many factors, including:

• Failure potential near the opening;

• Support effectiveness;

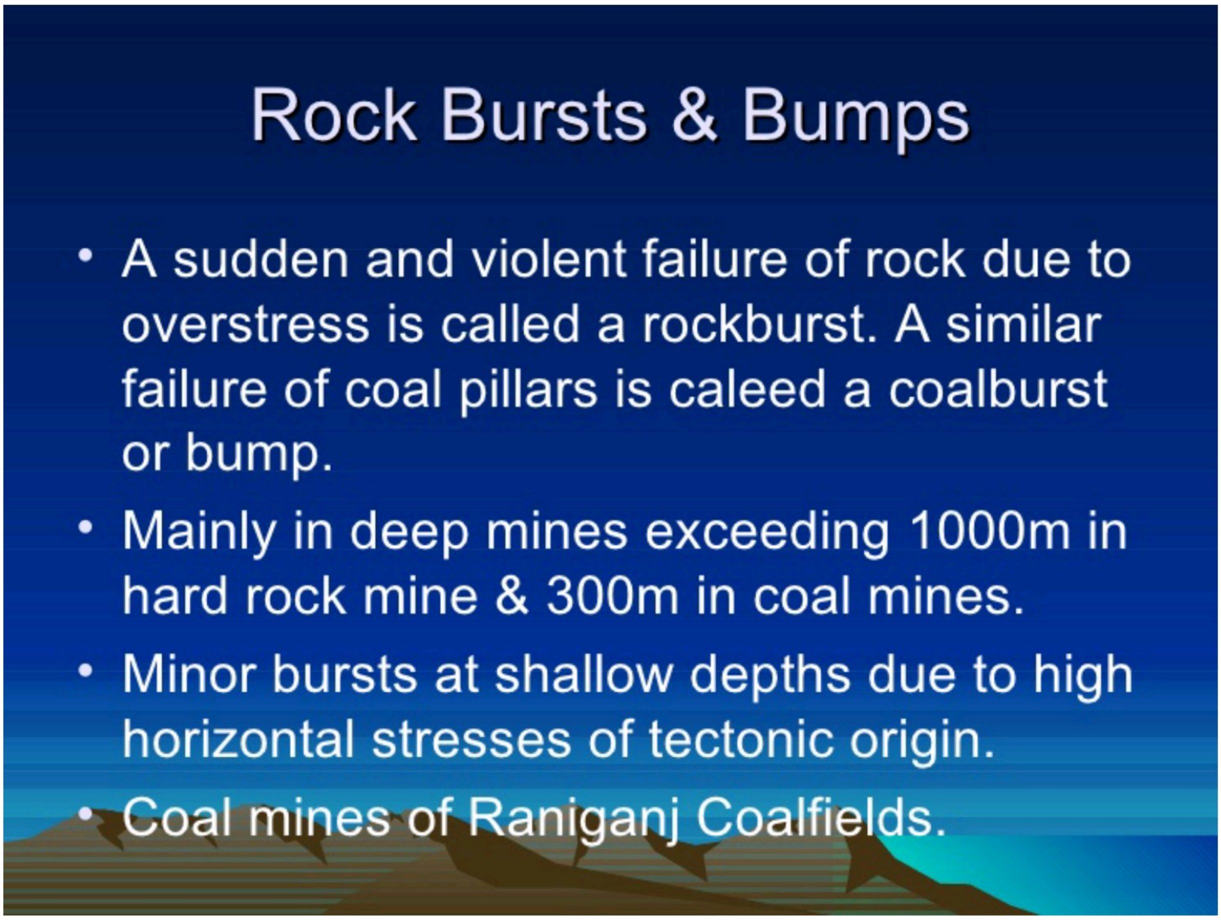
• Local rock stiffness;

• Magnitude of seismically induced stress, rock accelerations, or velocities;

• Opening geometry, size, and orientation;

• Geological structure.

Three levels of rock burst damage severity are defined as follows



Unit III 04/05-12-2020

Lecture 9

Prevention Of Rock Burst

Rock burst is a kind of artificial earthquake induced by human activities, such as mining excavations.

Prevention

For prevention and control of rock burst, the most essential steps are considered and listed as follows:

1. Using suitable support systems that absorb energy and deform without breaking
2. Using destress blasting can reduce rock burst hazards, particularly highly stressed brittle rock. Destress holes can be efficiently integrated into conventional rounds. Destress blasting of large volumes, however, can be more problematic.
3. Slowing the rate of extraction will often reduce the amount of seismicity in relation to tonnage mined and may actually prevent bursting under some conditions.
4. Using proper mining methods. Optimizing mining layout and excavation sequence,
5. Avoiding large stress concentration in rock mass.

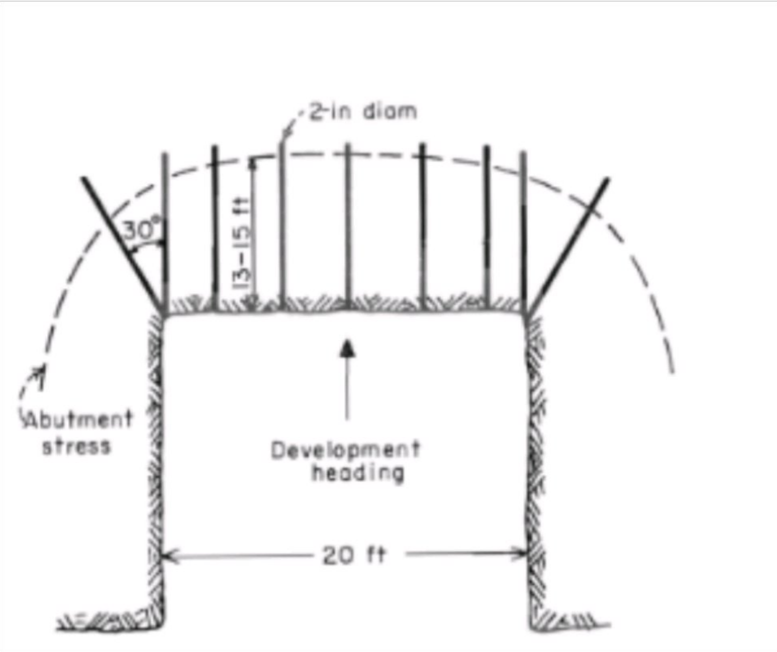
Following the above-mentioned steps, accumulation of disturbance energy in rock mass induced by mining excavation can be effectively controlled.

Control of Bump or Coal Burst In Coal Mines

High stress is the common denominator in the bump problem. Causes of high stress can be traced to a number of factors, such as pillar size and shape, roof and floor confinement, coal material properties, mining method, rate of advance, cutting depth, orientation of panel with respect to in situ stress fields. The basic concept of destressing or transferring high stress concentrations from one portion of a mine structure to another is not new. Fracturing or softening rock or coal to control stress buildup. This has been practiced in various mines. In coal mines, destressing the active working face is the most logical method to prevent bumps.

1. Volley Firing

Destressing by volley firing has successfully reduced the number of rock and coal bumps in underground mines. In the volley firing method, explosives are used to fracture the coal face to a certain depth before mining. The method is used prior to face advance or entry development to advance the abutment zone away from the active working face. Longwall face stress relief is accomplished by drilling into previously located high-stress zones. The blast holes are loaded with 1.0 to 1.5 kg of permissible explosives, stemmed, and detonated. The drill pattern consists of a series of 50 mm diameter holes, 3.0 to 4.0 m deep, drilled on approximately 1.0 m centers. Depth of hole depends on the required daily advance of the face and on the location and magnitude of the stress abutment ahead of the face.



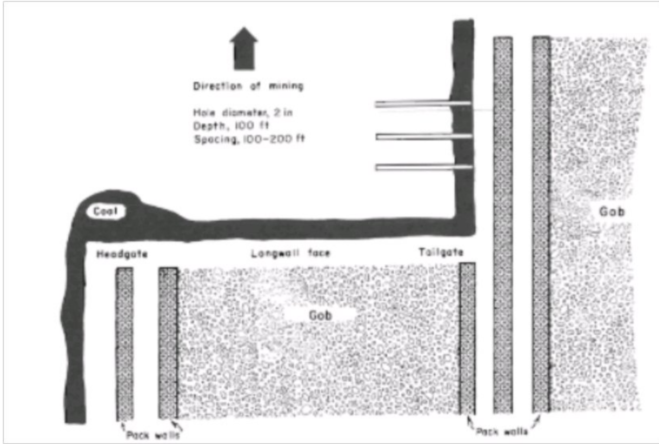
Volley firing drill-hole pattern for development entries

The corners of the advancing longwall face require a radial drilling pattern, using combinations of two or three holes angled at 10° and 45° to relieve high stress in both the face and rib areas. Destressing a longwall development section or room and-pillar entry working face may also be required. Holes are angled into the rib in a pattern similar to that for the corners of the longwall face. The drill holes do not extend deeply into the rib because blasting the rib effectively reduces the load-carrying area of the pillar. The depth and angle of the rib holes thus depend on the size of the pillar, the distance of the abutment zone from the face and entry, and other local conditions. **In volley firing, workers drill only small-diameter holes and then retreat to a safe distance while the holes are fired to destress the area**.

2. Hydraulic Fracturing

This method involves the injection of fluid under pressure to overcome compressive stresses and to cause material failure by creating fractures or fracture systems in a porous medium.

Hydraulic fracturing is most effective in the roof and coal seam ahead of the longwall face. This method is time consuming and not recommended for use on the face because it interferes with production. Experiments conducted in Poland have shown the beneficial effects of hydraulic fracturing of the roof ahead of the longwall face. Significant decreases in the number of seismic events during mining occurred in zones where the roof had been hydraulically fractured as compared with zones that had not been prefractured. During fluid infusion, the number of seismic events increased an indication that the fracturing process probably caused stress redistribution.



a) Drilling a borehole for hydraulic fracturing and injecting the water.

b) Sealing up the borehole with cement and injecting water until it reaches the adequate pressure value

Hydraulic fracturing pattern ahead of longwall face

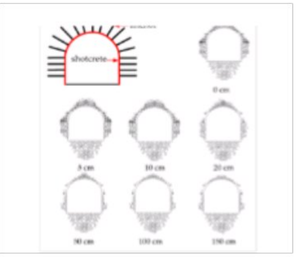
Auger Drilling

In this method, stress relief is induced by drilling holes into a highly stressed area. Depending on the magnitude of the stress, a hole or series of holes in a coal seam will structurally weaken the seam and cause failure of the coal. This is done with large-diameter auger-drilled holes as a stress-relief method. The holes were 15.0 cm in diameter and maintained not less than 10.0 m ahead of the face. The drill was positioned approximately 15.0 m from the face, and barricades were constructed between the drill and the coal face. Violent bumps were triggered during drilling; however, mine personnel were protected by the barricades. In addition, the auger drilling operation was performed on nonproduction shifts to minimize the number of workers present in the mine.

Long boreholes 15.0 to 25.0 meter with large diameters spacing between holes 3.0 to 4.5 m, have been used to relieve stress at mining faces in mines. The relationship among hole diameter, number of boreholes, and relief depends on conditions at each mine. In the United Kingdom, for instance, the borehole length does not exceed 10.0 m, even for a 50.0 to 60.0 mm diameter hole. In France and Belgium, the spacing between holes on the longwall face is 3.0 to 4.0 m. **Furthermore, two adjacent holes should not be drilled simultaneously**

Rapid Combined Support

Rockburst is prevented through providing radial support stress to rock, controlling the deformation of rock, improving the stress condition of rock and reducing the break of rock. Meanwhile, the harm of a rockburst is controlled by shortening support operation time, increasing support early strength. In this simulation, the same anchor and different thickness (0.05 m, 0.1 m, 0.2 m, 0.5 m, 1.0 m and 1.5 m) of shotcrete was adopted to study on the failure range of surrounding rock and the failure state of shotcrete.



Plastic zone in surrounding rock with different shotcrete thickness.

With increase of shotcrete thickness, the plastic zone in the surrounding rock of the sidewall and vault decreased gradually, while the plastic zone in the surrounding rock of the bottom changed little. Support could improve the stress condition of surrounding rock, and the thicker the shotcrete is, the better the effect is. Increasing the thickness of shotcrete could reduce the damage zone of shotcrete itself, effectively controlling the occurrence of a rockburst

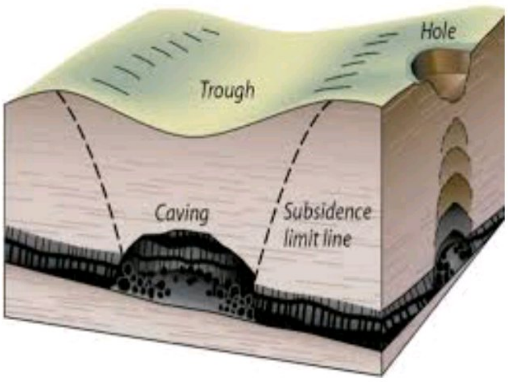
We know that the timely construction of high-strength support structure was an important part of rockburst prevention and control

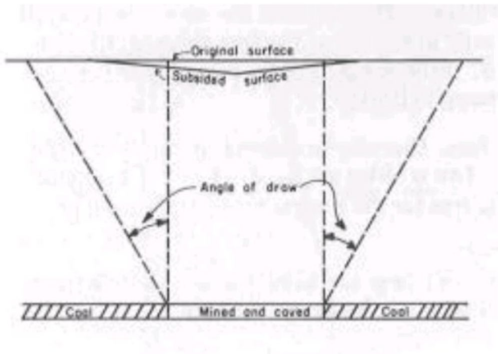
Unit IV 10-12-2020

Lecture 1

Subsidence

Subsidence is the sudden sinking or gradual downward settling of the ground's surface with little or no horizontal motion. The definition of subsidence is not restricted by the rate, magnitude, or area involved in the downward movement. It may be caused by natural processes or by human activities.





Subsidence, a natural process, it takes place when the voids created by extracting solids or liquids beneath the Earth's surface. It is controlled by many factors including

1. Mining methods

2. Depth of extraction,

3. Thickness of deposit, and

4. Topography

5. Properties of the rock mass above the deposit.

The impacts of subsidence are potentially severe in terms of damage to surface utility lines and structures, changes in surface-water and ground-water conditions, and effects on vegetation and animals. Although subsidence cannot be eliminated, it can be reduced or controlled in areas where deformation of the ground surface would produce dangerous or costly effects.

Unit IV 12-12-2020

Lecture 2

Types of Subsidence

The downward movement of overlying rock will induce lateral movement of rock toward the cavity. Deformations eventually reach the ground surface and may form subsidence depressions, open fractures, pits, and troughs.

Depending upon several factors including mining methods and rock properties, the changes at the surface may occur almost concurrently with mining or they may be delayed and take place with dramatic suddenness more than 100 years after mining.

Mine subsidence will appear in two forms:

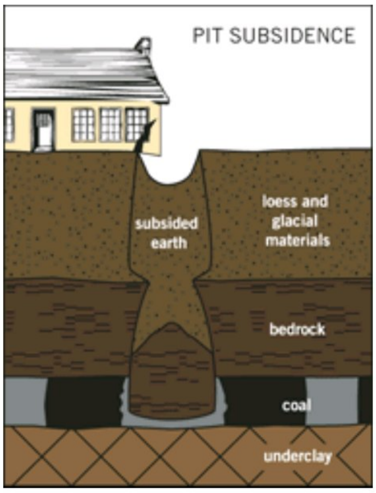
1. (a) Pit

   (b) Sag

2. Sink Hole

1. Pit subsidence

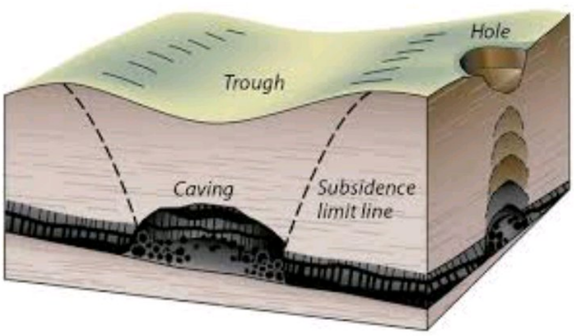
Pit subsidence forms a bell-shaped hole, usually 2 to 3 m deep and from 1 to 15 m across. The mine will most likely be shallow, less than 30 m deep, and the bedrock over the mine less than 15 m thick and consisting of weak rock materials such as shale. Ground movement will be swift and sudden.



Pit subsidence forms a bell-shaped hole 6-8 feet deep and from 2-40 feet across and occurs when a shallow mine roof collapses

Sag subsidence

Sag subsidence, the most common type of mine subsidence, appears as a gentle depression in the ground and can spread over an area as large as several acres. The first signs may appear suddenly within a few hours or days, with gradual movement continuing anywhere from a couple of years to more than a decade. Frequently, damage is subtle and perhaps dismissed as normal wear and tear until multiple signs appear. Sag subsidence can develop over mines of any depth and are usually caused when coal pillars, left intact by miners to support the mine roof, disintegrate or collapse.



Subsidence troughs over abandoned mines usually occur when the overburden sags downward due to the failure of remnant mine pillars or by punching of the pillars into a soft mine roof or floor. The resultant surface effect is a large, shallow yet broad depression in the ground which is usually elliptical or circular in shape. Subsidence is usually greatest at the center of the trough and it progressively decreases until the limit of the impacted surface area is reached. Horizontal ground movements also occur within a subsidence trough

2. Sinkhole Subsidence

Sinkhole subsidence occurs in areas overlying underground mines which are relatively close to the ground surface. This type of subsidence is fairly localized in extent and is usually recognized by an abrupt depression evident at the ground surface as overburden material collapses into the mine void. Sinkhole subsidence is perhaps the most common type of mine subsidence and has been responsible for extensive damage to many structures throughout the years.

Sinkholes are common where the rock below the land surface is limestone or other carbonate rock, salt beds, or in other soluble rocks, such as gypsum,[12] that can be dissolved naturally by circulating ground water. Sinkholes also occur in sandstone and quartzite terrains.

As the rock dissolves, spaces and caverns develop underground. These sinkholes can be dramatic, because the surface land usually stays intact until there is not enough support. Then, a sudden collapse of the land surface can occur.

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Unit IV 17-12-2020

Lecture 3

Angle Of Draw

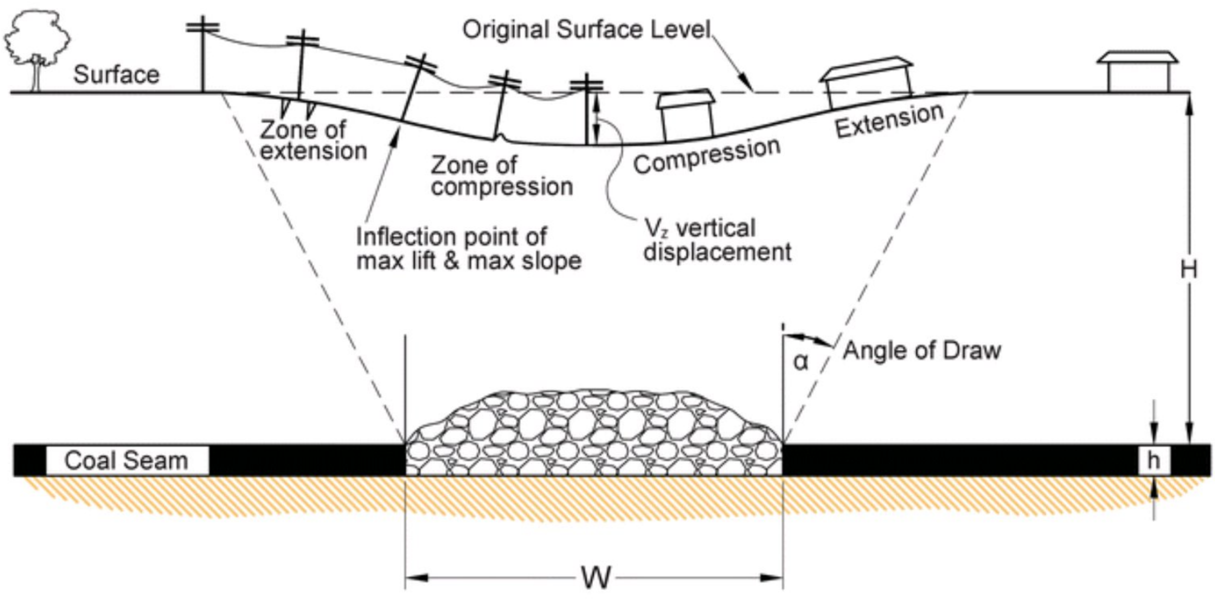
Mining subsidence is a problem in many countries. Subsidence analysis and prediction rely heavily on input of subsidence limit angles. It is particularly significant at mine planning and approval stage that how much land is acquired due to subsidence is fully assessed.

1. To know how much land has to be acquired on surface.

2. Safe and economical design of mines

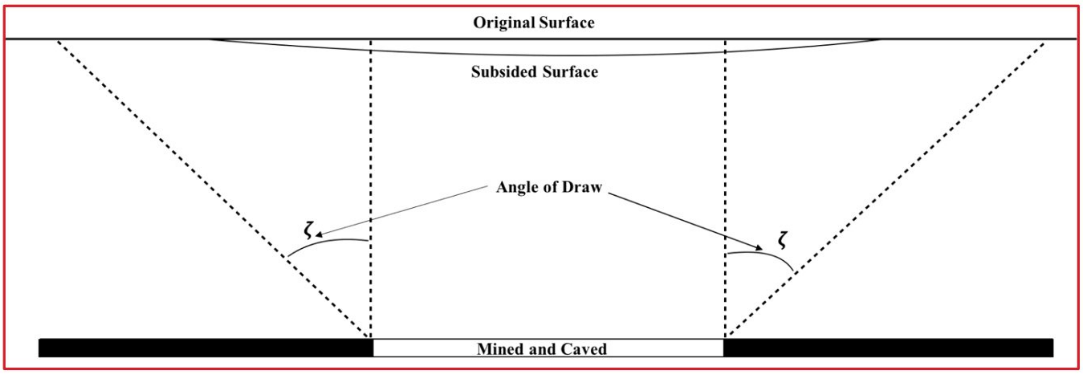
3. Reliable and accurate evaluation of the limit angles at a given mine field.

The subsidence mechanism has been well established. Of all the techniques used in subsidence analysis , the most important parameter, yet often been overlooked is the **angle of draw (also called limited angle),** which determines the extent of subsidence influence at surface level



The **Angle of Draw** is the angle between the edge of an underground working and the point of the surface to which subsidence may ex- tend.

The angle of inclination between the vertical at the edge of the working and the zero subsidence point at the surface is termed the limit angle or angle of draw. For this a vertical line is drawn up to surface from the edge of the working (decoaled area). Another line is drawn from edge of the working to surface at zero pint of subsidence. The angle between these two lines is **Angle of Draw**.

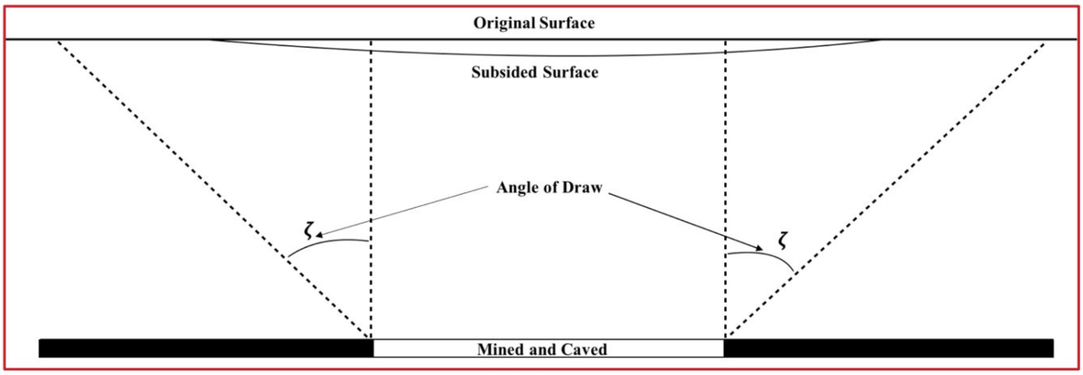


Angle of Draw gets even more complex to analyze and study. In general, a large number of coal seams are left with incomplete extractions and without subsidence, on account of no proper studies done on the effects of subsidence for extractions in multiple seams in underground coal mines. Due to lack of the knowledge of subsidence behavior of strata overlying coal seams in India more than **1500 million tonnes** of coal is lying without being mined.

Unit IV 24-12-2020

Lecture 4

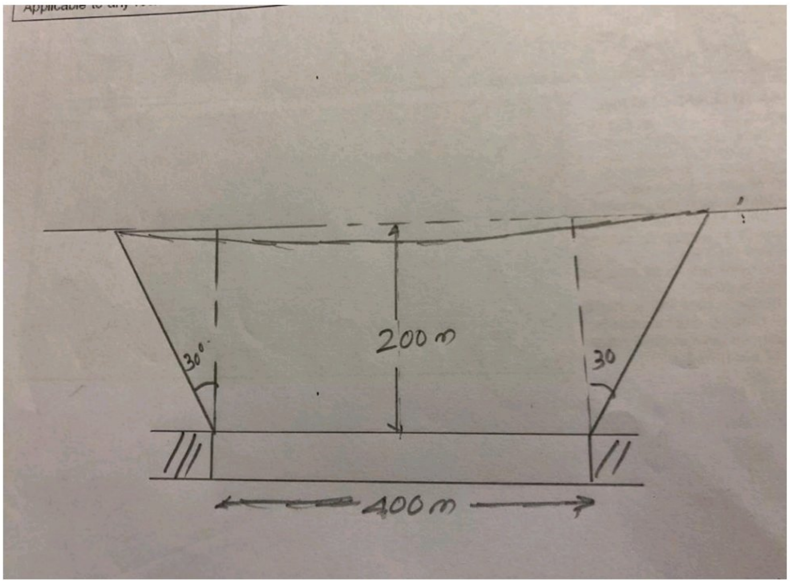
Numerical On angle of Draw



Numerical 1

A mine at a depth of 200 m , total coal 400 m in length has been taken. If the angle of draw is 30 degree, Calculate the total length of the surface affected.

Solution



Given

Depth = 200 m

Angle of draw 30 degree

Tan 30 = P/B

Here P=x (assume)

B = 200 m

Tan30 = x/200

X =200 * 0.57735

=115.47 m

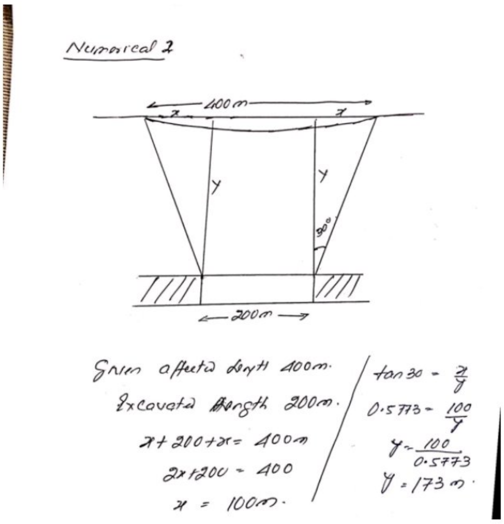
Total Distance= 115.47 +400+115.47

Total affected length on surface 630.94 m

Numerical 2

The total affected length on surface by subsidence is 400m. The area which is excavated in underground is 200m in length. The angle of draw is 30 degree. Find the depth of the mine.

Solution



Given

Total Length at surface is 400 m

Length of excavated area 200 m

Hence x+200 +x=400

2x= 400-200

X=100

Tan 30 = x/y

0.5773= 100/y

Y= 100/0.5773

Y= 173.22 m

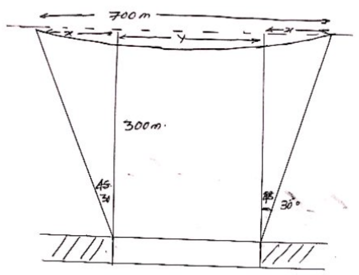
Depth of the mine 173.22 meter

Numerical 3

An underground coal mine is at depth of 300 m. Angle of draw of this mine is 30 degree. Total length affected on surface due to subsidence is 700 m. find the total length of excavated area in underground.

Solution

Numerical 3



Given - Angle of draw 30°.

Total length $x+y+x = 700\ m$.

$\tan 30 = \frac{P}{b}$

$= \frac{x}{300}$

$0.5773 = \frac{x}{300}$

$x = 0.5773 \times 300$

$= 173.19$

$700 = 2x + y = 2 \times 173.19 + y$.

$y = 700 - 2 \times 173.19 = 700 - 346.38$

$= 353.62\ m$.

Given

Angle of draw 30 degree

Depth of seam 300 m

Total length affected = 700 m

Tan30 = P/B

Here P is X (assumed)

B = 300

Hence tan 30 = x/300

0.5773 = x/300

X = 0.5773*300

= 173.19 m

Assume length of excavated area is y(assumed)

Hence x+y+x= 700

$173.19+y+173.19=700$

$Y= 700- (173.19+173.19)$

$Y= 700- 346.38$

$Y= 353.62$ m

Length of excavated area is 353.62 m

Unit IV 26-12-2020/07-01-2021

Lecture 5

Factors affecting angle of draw

INFLUENCING PARAMETERS FOR ANGLE OF DRAW

There are many factors which could affect the angle of draw. Some affect to a huge extent while some only affect a little. Some of the factors are as follows:

- The nature of overlying strata
- Nature of the roof
- The existence of faults and their positions
- Universal Compressive strength of Over- burden
- The thickness of the seam
- Width of the panel
- The dip of the bed and the direction of working in relation to it
- The depth from the surface
- The surface contour

Nature of overburden strata

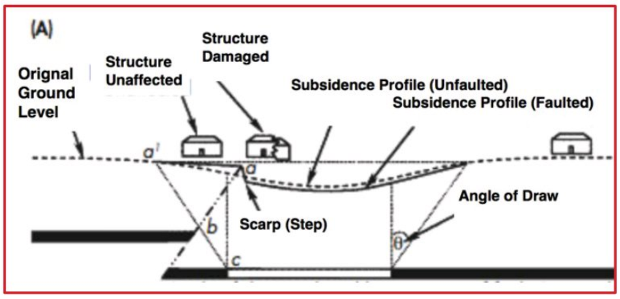
Harder and more coherent the strata are, the lesser the angle of draw. Softer and less coherent the strata is, the more is the angle of draw. Strata heavily charged with water will tend to move more readily than dry strata on account of lubricating effects of water and more subsidence is produced. Permeability of strata will have considerable effect upon the propagation of fractures and earth movements generally

Nature of the roof

The modulus of elasticity (E) of the roof strata determines the bending resistance. If the roof is hard angle of draw is less. If the roof is soft angle of draw is more.

The existence of Faults and their positions

Faults are break in the continuity of the strata and subsidence tends to run into the fault plane thus affecting the angle of draw. It depends upon the direction of working with respect to the strike of the fault plane. When faults are parallel to face line the tendency for subsidence is higher. When the faults are not parallel then the system becomes complicated by the natural break of the fault. The slope of the fault also affects the angle of draw and when it is flat it tends to increase the draw enormously.



The angle of draw is reduced by the presence of fault

Universal Compressive Strength of Overburden

The effect of overburden strength on the subsidence limit characteristics has been analyzed. Compressive Strength (UCS) as strength index for a bed/beam in the overburden in a finite element model (FEM). The results indicated that the higher the strength of the overburden stratum, the lesser is the angle of draw i.e. the extent of effect of subsidence will also be less in area of strong rock mass overburden.

The Thickness of the seam

Thick seams when worked by slicing in descending order with caving will result in more subsidence and also in increased angle of draw. This is because; as the super adjacent strata get broken before the lower lifts are worked and hence behaves as a pulverized mass. This particular behavior can be found in Eastern Coal Mines.

Width of the panel

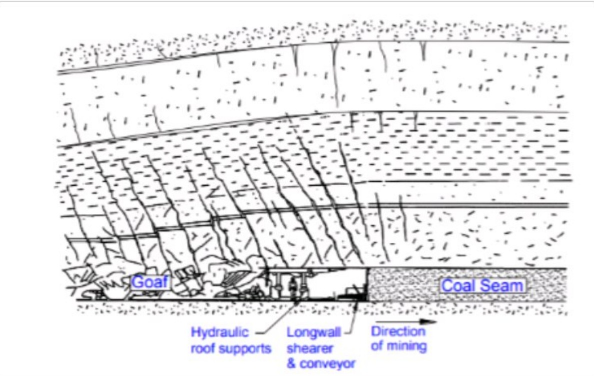
The width of the panel will not at all affect the angle of draw. The width of the panel will only affect the surface area affected by the subsidence. In general, for wide extraction panels, the stronger the overburden rocks or the shallower the mining, the smaller the Angle of draw.

The dip of the bed and the direction of working in relation to it

According to observations for the Seams dipping at different angles, the angle of draw at the dip side of the panel is greater than the angle of draw at the rise side of the panel. For such inclined seams, the surface subsidence trough is displaced towards the deeper edge of the opening, and depending on the inclination and the depth of the seam. The subsidence trough can also be located outside the edge of the opening. Subsidence is maximum at the point normal to the center and not directly above the centre as for horizontal seams. The angle of draw is not constant and it depends upon the dip of the seam. Angle of draw is smallest at the rise edge of the opening and increases towards the dip of the edge.

Depth from the surface

Depth only has effect on the amount of area affected due to subsidence. Depth doesn't affect the angle of draw if only the strata behavior remains constant. If the strata behavior is heterogeneous then the variation in the angle of draw becomes complex and depends on various factors.



The surface contour

Surface damage is more in the vicinity of steep slopes in flat areas. The horizontal movements are greatly increased in undulating ground resulting in more disastrous effects and apparently the angle of draw is increased. The effects are disastrous when the subsidence area encapsulates the hills in a certain area and causes huge landslides.

Unit IV 14-01-2021

Lecture 6

Damages due to Subsidence

Mine Subsidence" means lateral or vertical ground movement caused by a failure initiated at the **mine** level, of manmade underground **mines**, **mines** that directly **damages** residences or commercial buildings.

Basically subsidence damages are caused due to two types of ground disturbances

1. Due to continuous ground disturbances

2. Due to discontinuous ground disturbances

1. Due to continuous ground distance

The continuous ground disturbances may be divided into following categories

a) Vertical subsidence

b) Horizontal displacement

c) Slope and curvature

d) Compression and tension in the horizontal direction

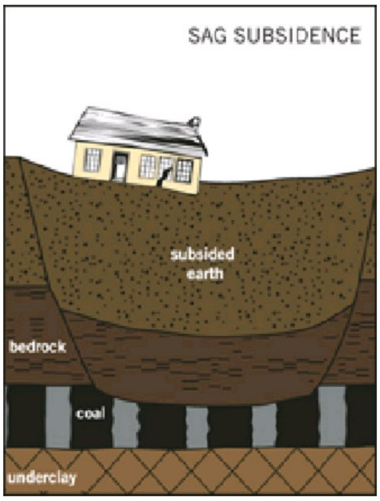
A) Vertical subsidence

If it is in super critical area then there is less damage to the structure. But when there is differential movement towards the edges of super critical area then structure damage may be large. There may be damage to tall building, chimneys etc.

B) Horizontal displacement

In case of Horizontal displacement there will be damage to the structure. There may be compression or tension as the result the structure at the bottom is disturbed and the whole structure may collapse.

C) Slope and curvature



This causes distortion of structure due to shear strain. It results into bending of the structure and load bearing walls.

D) Compression and tension in the horizontal direction

Tensile strain causes at the convex portion of the building. As a result cracks may occur at weak points, such as doors, windows opening. Compressive stress causes at the concave portion of building. This may cause buckling of slabs, brick walls, foundation slabs, rafts etc.

2. Discontinuous ground disturbance

This may result into fissures, steps and potholes. These are very common in Bord and Pillar method workings, which are as follows.

a) Cracks

These are open cracks ranging from 0 cm centimeter to any meter.

b) Fissures

Wide fissures develops due to sudden rush of water along with sand. This may take place during development and depillaring operation.

c) Steps

If the surface is weak then steps are found and the ground will slide along the plane and form steps on the surface. Steps may range from few cm to many meter wide also.

d) Pot Holes

This may result from local fall collapsing of the ground and they may be as large from few cms to many meter wide and deep

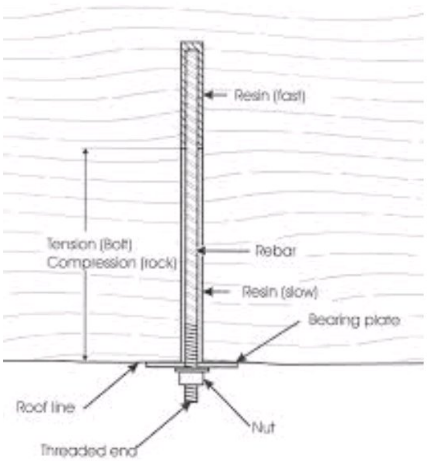
Unit V 28-01-2021

Lecture 1

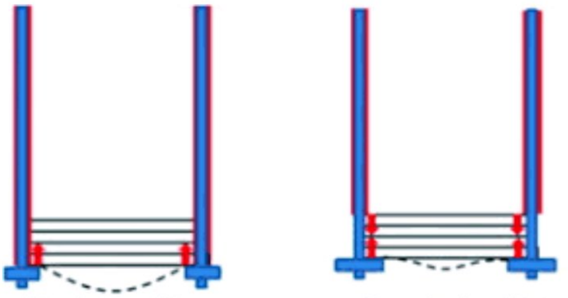
Roof Bolting in underground Mines

What is the necessity of Roof Bolting

Roof bolting can be ranked as one of most important technological developments in the field of ground control in the entire history of mining. It is an essential component in the design of underground excavations and has been used to provide an overall ground improvement scheme since the middle of the last century. Roof bolting has become the primary support system in the coal mining industry and all underground coal mines in India are mined under supported roofs. Roof bolts dramatically reduce the number of fatalities each year and they were initially hailed as "one of the great social advances of our time.



A system of **roof** support in mines. Boreholes usually from 3 to 12 ft (1 to 4 m) long are drilled upward in the **roof**, and **bolts** of 5/8 to 1 in (2 to 2.5 cm) or more in diameter are inserted into the holes and anchored at the top by a split cone, mechanical anchor, or resin grout.



The main function of roof bolting is to bind stratified or broken rock layers together to prevent roof falls. In order to achieve this objective four basic theories have been established for roof bolting.

Because it is more economic than other methods; it saves material and manpower consumption. Most important of all, roof bolting is more effective and efficient because it is an active support method, utilising the rock to support itself by applying internal reinforcing stresses.

Unit V 29-01-2021

Lecture 2

Roof Bolting in underground Mines

Theories of Roof Boting

The four theories are

- Simple skin support;
- Suspension of a thin roof layer from a massive bed;
- Beam building of laminated strata; and
- Keying of highly fractured and blocky rock mass

Simple skin support

A strong, massive roof subjected to low stress levels can be essentially "self-supporting", meaning that a major roof collapse is unlikely to occur. However, cracks, joints, cross-bedding, or slickensides can create occasional hazardous loose rock at the skin of the excavation. Pattern bolting is therefore required to prevent local loose rock from falling, but the bolts may be relatively short and light. Skin control is also an important secondary function of roof bolts, along with the other three support mechanisms.

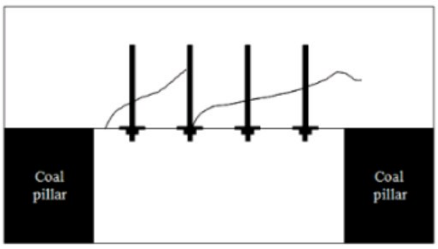


Figure 2-11 Simple skin support

The suspension mechanism

It is the most easily understood roof bolting mechanism. When an underground opening is made in an environment represented in the laminated immediate roof tends to sag and separates from the overlying strong layer. The sag and separation of the immediate roof can be reduced by clamping the laminations together and suspending them from the self -supporting main roof.

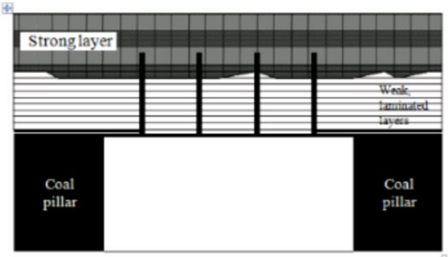


Figure 2-12 Suspension mechanism

Beam-building mechanism

In many practical situations, the strata overlying a roadway is thinly laminated. Often there is no competent bed within a distance of a few metres into the roof that could serve to suspend the thin layers on roof bolts. In these cases, the beam-building mechanism, as shown in Figure , is more effective. As a result, the horizontal movements between these layers will be greatly reduced and the combined thick beam will be more stable . Full-column resin bolts are required for this mechanism.

Figure 2-13 Beam-building mechanism

Keying

When the roof strata are highly fractured and blocky, or the immediate roof contains one or several sets of joints with different orientations, roof bolting can significantly increase frictional forces along fractures, cracks, and weak planes. Sliding and/or separation along discontinuities is thus prevented or reduced, as shown in Figure. This keying effect mainly depends on active bolt tension or, under favorable circumstances, passive tension due to rock mass movement. It has been shown that bolt tension produces stresses in the stratified roof, which are compressive both in the direction of the bolt and orthogonal to the bolt. Superposition of the compressive area around each bolt forms a continuous compressive zone in which tensile stresses are reduced and the shear strengths of discontinuities are improved, as shown in Figure.

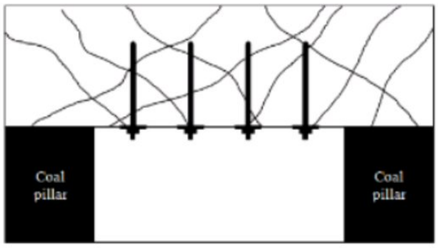
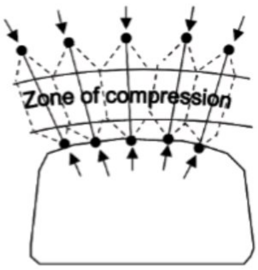


Figure 2-14 Keying effect of bolting



Compression zone created by keying (after Lu

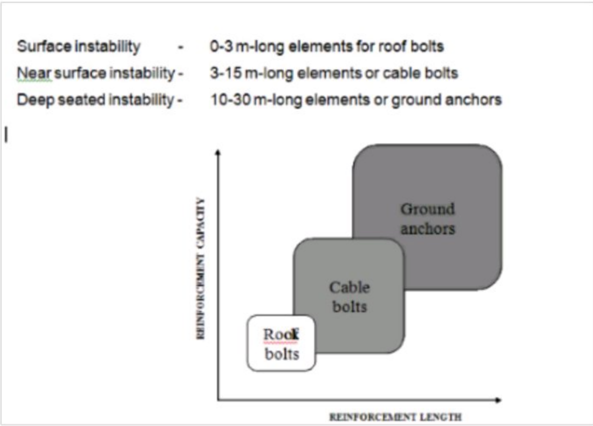
Unit V 30-01-2021

Lecture 3

Roof Bolting in underground Mines

Types Of Roof Bolting

1. Roof bolting
2. Cable bolting
3. Ground anchoring



The length-capacity relationships that have evolved for roof bolts, cable bolts, and ground anchors

There are eight types of roof bolts used in the coal mining industry.

1. Mechanical anchors;
2. Resin point anchors;
3. Full-column single-resin-type bolts;
4. Full-column slow/fast-resin combination bolts
5. Friction rock stabilizers
6. Wooden dowels
7. Fiberglass dowels

8. Spin-to-stall resin bolts.

The mechanical anchor bolt, the oldest design in use in underground coal mines, was the main roof support used in the coal mining industry due to the rapid rate of installation. Today, the fully grouted roof bolt is considered superior to the mechanical anchor bolt because of a better anchorage capacity and load transfer capability. Currently, more than 95 per cent of roof bolts installed in India are full-column resin bolts.