**UNIT: 1 INTRODUCTION**

**GEOLOGY** (in Greek, Geo means Earth, Logos means Science) is a branch of science dealing with the study of the Earth. It is also known as earth science. The study of the earth as a whole, its origin, structure, composition and the nature of the processes which have given rise to its present position is called as geology. Geology comprises the following branches:

1. Crystallography

2. Mineralogy

3. Petrology

4. Geophysics

5. Geochemistry

6. Structural Geology

7. Stratigraphy

8. Physical Geology

9. Geomorphology

10. Paleontology

11. Hydrogeology

12. Engineering Geology

13. Photo Geology

14. Economic Geology

15. Mining Geology

**Crystallography**: The study of the characters of crystals is known as crystallography. Crystals are bodies bounded by flat faces ( surfaces), arranged on a definite plane due to internal arrangements of atoms.

**Mineralogy:** The study of the characters of minerals ( eg: quartz, pyroxene, amphibole, mica, chlorite, garnet) is known as Mineralogy. A mineral is a naturally occurring homogeneous substance, inorganically formed with a definite chemical composition, with a certain physical properties and crystalline structures.

Note: Coal, oil etc are considered as minerals THOUGH they arises by organic matter under exceptional conditions .

**Petrology:** The study of rocks in all their aspects including their mineralogies, textures, structures (systematic description of rocks in hand specimen and thin sections); origin and their relationships to other rocks.

**Geophysics**: The section of the earth which include the structure, physical conditions and evolutionary history of the earth as a whole.

**Geochemistry:** The study of chemical composition of minerals and rocks of the earth.

**Structural Geology**  is the study of rock structures such as folds that have resulted from movements and deformation of the earth’s crust.

**Stratigraphy:** The study of the stratified rocks especially their sequence in time, the character of the rocks and correlation of beds at different localities.

**Physical Geology**: It deals with the geological processes which bring about changes in the crust and upon the surface of the earth. It also deals with the surface features of the earth ( land forms ) or its topography

**Geomorphology**: The description and interpretation of land forms.

**Palaeontology** is the study of ancient life, determination of environment, evolution of organisms etc..

**Hydrogeology**-- the study of the geological factors relating to earth’s water.

**Mining Geology** deals with the method of mining of rocks and mineral deposits on earth’s surface and subsurface.

**ENGINEERING GEOLOGY:** the principles and methods of geology is adopted for the purpose of civil engineering operations. Broadly speaking, engg geology has two divisions:

1. The study of raw materials
2. The study of the geological characteristics of the area where engineering operations are to be carried out such as Groundwater characteristics; the load bearing capacity of rocks; the stability of slopes; excavation; rock mechanics etc for civil engineer.

**SCOPE OF GEOLOGY:** In Civil Engineering

* Geology provides necessary information about the construction materials at the site used in the construction of buildings, dams, tunnels, tanks, reservoirs, highways and bridges.
* Geological information is most important in planning stage, design phase and construction phase of an engineering project.
* Geology is useful to know the method of mining of rock and mineral deposits on earth’s surface and subsurface.
* Geology is useful for supply, storage and filling up of reservoirs with water.

**IMPORTANCE OF GEOLOGY FROM CIVIL ENGINEERING POINT OF VIEW**

* Before constructing roads, bridges, tunnels, tanks, reservoirs and buildings, selection of site is important from the point of stability of foundation.
* Geology provides a *systematic knowledge of construction materials and*  their properties.
* The knowledge about the nature of the rocks in tunneling and construction of roads.
* The *foundation problems* of dams, bridges and buildings are directly related with geology of the area where they are to be built.
* The *knowledge of ground water* is necessary in connection with excavation works, water supply, irrigation and many other purposes
* The knowledge of *Erosion, Transportation and Deposition* (ETD) by surface water helps in soil conservation, river control.
* *Geological maps* and sections help considerably in *planning* many engineering projects.
* If the geological features like faults, joints, beds, folds are found, they have to be suitably treated. Hence, the *stability of the rock structures* is important.
* Pre-geological survey of the area concerned reduces the *cost* of planning work.

Minerals, Rocks and soils constitute earth materials. They play a vital role in the site evaluation and operations in civil engineering practice.

Whether it is tunneling, hydro-electric projects, ground water development, foundation for structures, study of slope stability etc.. a basic understanding of the earth materials is essential.

Thus, study of minerals, rocks and soils forms the first step in civil engg point of view. Hence, a civil engineer should know the introduction of Geology and its branches and importance of a few branches such as Physical Geology, Petrology; Structural Geology and so on ……

**IMPORTANCE OF PHYSICAL GEOLOGY, PETROLOGY & STRUCTURAL GEOLOGY**

**IMPORTANCE OF PHYSICAL GEOLOGY:** It deals with the geological processes which bring about changes in the crust and upon the surface of the earth. It also deals with the surface features of the earth ( land forms ) or its topography. The earth is concentrically divided into a number of spheres viz., (1) Atmosphere ; (2) Hydrosphere and (3) Lithosphere .

The outermost sphere is Atmosphere which consists of several gases and vapours and envelopes the earth. Atmosphere is essentially a mixture of N2  and O2  with smaller quantities of vapour, CO2 etc… Geologically atmosphere is important as the medium of climate and weather. Hydrosphere includes the natural waters of the earth ie., oceans, seas, lakes, rivers, streams and underground water. Lithosphere is the outer part of the earth’s crust consisting of rocks and minerals.

**The geological processes include Denudation, Deposition, Earth movements, Igneous activity and metamorphism**.

**Denudation**: The sum of the processes which result in the general lowering of the land surfaces or when erosion takes place, fresh country rock surfaces will be exposed and this process is called DENUDATION. Denudation consists of weathering, transportation and erosion.

Weathering is the process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes. Weathering is the initial stage in the process of denudation.

Transportation is the main agency by which materials are moved by means of Gravity, running water ( rivers, streams ); Ice ( glaciers ); Wind etc..

Erosion: Mechanical disintegration or chemical decomposition of rocks and their subsequent displacement is called as erosion or erosion is the destructive process due to the effect of the transporting agents. The chief agents of erosion are running water, wind etc..

**Deposition** : The material is transported mechanically and deposit (eg: sand ).

**Earth movements** include the uplift and depressions of land areas & sea floors.

**Igneous activity** includes emission of lavas, gases, other volcanic products etc

**Metamorphism:** The process by which changes are brought about in rocks within the earth’s crust by the agencies of Heat, Pressure and Chemical fluids.

Thermal metamorphism : heat alone acts

Dynamic metamorphism : involves stress to break up the rocks

Regional/Dynamothermal metamorphism: Both heat & pressure involves

Retrograde metamorphism : produces lower grade metamorphic rocks

Auto Metamorphism : chemical adjustment in newly solidified igneous rocks, brought about by a decrease in temperature .

**Geological works of Rivers**

A river is one of the major geological agent which carries out its work. The work is mainly divided into three stages, namely

1. River Erosion
2. River Transportation
3. River Deposition

**River Erosion:** Erosion means mechanical disintegration or chemical decomposition of rocks are transported from the site with the help of natural agencies like wind and running water (or) subsequent displacement. River is a powerful eroding agent and carries out its work in different ways such as hydraulic action, solution and abrasion / attrition etc.

* Hydraulic action: The physical breakdown of rocks take place naturally and greater the movement greater will be the erosion. In the initial and youth stages, the rivers acquire more considerable kinetic energy. When such water dashes against rock forcefully, it will break and this will be more effective if
1. The rocks are already weathered.
2. They are porous and are not well cemented.
3. Those posses fractures, cracks etc.
* Solution: This process, is a part of hydraulic action which involves only chemical decay of rocks. This is an invisible process and very effective under favourable conditions.
* Attrition:This is a mechanical weathering process. When the rock fragments hit the rocks which are already exposed, abrasion take place. Thus the rock fragments during abrasion undergo wear and tear which is called attrition.

During transportation, heavier and larger materials move slowly while finer and lighter material move fast.. When attrition take place the angular edges disappear and spherical, ellipsoidal stones etc are formed after a long journey.

**River Transportation**: A river transports its material physically as well as in a solution form. The transport system is divided into three groups.

1. **Bed load** comprises heavier particles of sand, pebbles, gravels etc.. which are transported mainly by their rolling, skipping, along the bottom of stream.
2. **Suspended load** consists of silt, fine sands, clay etc.. and such load is carried by river in its body of water in suspension. As the river is moved, the load is also carried along with it. Thus load is transported continuously without break till conditions are favourable. This type of natural suspension and separation of sediments account to their size is called Sorting.
3. **Dissolved load:** Material is transported in a solution condition. The ability to transport the sediments is influenced by river velocity, density etc..

**River Deposition** is the last phase of geological work of a river. Among the different kinds of river deposits, a few are listed below:

**Alluvial cones and fans:** River sediment is known as alluvium. If the deposit is spread over a small area but has a relatively steep slope, it is called an alluvial cone. On the other hand, if the deposit is spread over a large area and has a gentle slope, it is called an alluvial fan.

**Placer deposits**: The placer deposits are characteristically composed of heavier metals such as Gold, Platinum, Chromite, magnetite, Rutile, Ilmenite, Monazite etc. which are commonly economic minerals.

Eg: Rand placer deposit of South Africa is famous for gold.

**Delta deposits**: Most of the rivers reach this stage just before they merge with the sea. Rivers Ganga and Brahmaputra have built up the best deltaic regions of the world. Deltas are very fertile and valuable for agriculture.

**Natural levees**. During the time of floods, the river carries a very large scale of river dumps along its course on either side which are known as natural levees. Eg silt, clay .

**MEANDER DEVELOPMENT**

A meander in general is a bend in a (moving with smooth twists & turns) water coarse. A meander bend is formed when the moving water in a stream erodes the out banks and widens its valley. If the river encounters any obstacle, it shall not have the capacity to uproot it and therefore it takes a diversion and continues its downward coarse.. This is responsible for the formation of deposits known as placer deposits.

By virtue of its relatively weak condition the river compulsorily undergoes a number of curves or bends which makes its path zig-zag. These bends are called meanders and the phenomenon is known as Meandering. Meandering is therefore a characteristic feature of the mature stage.

In due course of time these bends become more and more acute due to deposition of sediments along the inner curve and erosion along the outer curve. Ultimately under favourable conditions such as floods, these loops are cut off from the main course of the river. Such cut off bodies of water which are curved in plan are called **cut off lakes** or **horse shoe lakes** or **ox bow lakes**.

**Delta:** A delta is a landform that is formed at the mouth of a river where the river flows into an ocean, or sea. Deltas are formed from the deposition of the sediment carried by the river as the flow leaves the mouth of the river. Over long periods of time, this deposition builds the characteristic geographic pattern of river delta.

**Development of delta:** The favourable conditions for the formation of delta are:

1. The river should have large amount of load.
2. The river should have totally exhausted its energy at the time of its merger with the sea.
3. The oceans at the mouth of the river should not be turbulent otherwise as & when loose sediments are deposited they are washed away by the waves and currents of the sea.

During delta formation the prevailing conditions will be such that the river will be shallow and will change its direction and velocity frequently. Under such conditions deltas develop a typical structure known as **cross bedding**.

The delta will have gently incline bottom layers of fine sediments known as bottom set beds. These are overlain by steeply inclined middle layers of coarse sediments known as forest beds. Above these again gently dipping layers of the mixture of finer and coarser sediments occur. They are known as top set beds. Though all these three sets of beds are inclined towards the sea, they differ in the amount of inclination and hence they are not parallel. Such a peculiar bedding phenomenon is known as cross bedding.

**VALLEY DEVELOPMENT**

**VALLEYS:** In geology, a valley is a depression with predominant extent in one direction. A very deep river valley may be called a **canyon or gorge**. The terms U-shaped and V-shaped are descriptive terms of geography to characterize the form of valley. Most valleys belong to one of these two main types or a mixture of them, at least with respect of the cross section of the slopes or hills.

**FORMATION AND DEVELOPMENT:** A valley is an extended depression in the Earth's surface that is usually bounded by hills or mountains and is normally occupied by a river or stream.

Valleys are one of the most common landforms on the Earth and they are formed through erosion or the gradual wearing down of the land by wind and water. In river valleys for example, the river acts as an erosional agent by grinding down the rock or soil and creating a valley. The shape of valleys varies but they are typically steep-sided canyons or broad plains, however their form depends on what is eroding it, the slope of the land, the type of rock or soil and the amount of time the land has been eroded.

There are three common types of valleys which include V-shaped valleys, U-shaped valleys and flat floored valleys.

**V-SHAPED VALLEYS/ RIVER VALLEYS:** A V-shaped valley, sometimes called a river valley, is a narrow valley with steeply sloped sides that appear similar to the letter "V" from a cross-section. They are formed by strong streams, which over time have cut down into the rock through a process called down cutting. These valleys form in mountainous and/or highland areas with streams in their "youthful" stage. At this stage, streams flow rapidly down.

* An example of a V-shaped valley is the [Grand Canyon](http://usparks.about.com/od/grandcanyon/p/gc_overview.htm) in the Southwestern United States. After millions of years of erosion, the Colorado River cut through rock of the Colorado Plateau and formed a steep sided canyon V-shaped canyon known today as the Grand Canyon.
* The original natural large river valleys of the world such as Nile, Ganges, Amazon, Mississippi etc.



**U-SHAPED VALLEYS/ GLACIAL VALLEYS:** A U-shaped valley is a valley with a profile similar to the letter "U." They are characterized by steep sides that curve in at the base of the valley wall. They also have broad, flat valley floors. U-shaped valleys are formed by glacial erosion. U-shaped valleys are found in areas with high elevation and in high latitudes, where the most glaciation has occurred. Large [glaciers](http://geography.about.com/od/geographyintern/a/glaciers.htm) that have formed in high latitudes are called continental glaciers or ice sheets, while those forming in mountain ranges are called alpine or mountain glaciers.

Due to their large size and weight, glaciers are able to completely alter topography. This is because they flowed down pre-existing river or V-shaped valleys during the last glaciations and caused the bottom of the "V" to level out into a "U" shape as the ice erode the valley walls, resulting in a wider, deeper valley. For this reason, U-shaped valleys are sometimes referred to as glacial troughs.

One of the world's most famous U-shaped valleys is Yosemite Valley in California. It has a broad plain that now consists of the Merced River along with granite walls that were eroded by glaciers during the last glaciations.

**FLAT FLOORED VALLEYS:** The third type of valley is called a flat-floored valley and are formed by streams, but they are no longer in their youthful stage, and are instead considered mature. The valley floor gets wider, because of the stream gradient (moderate or low), the river begins to erode the bank of its channel instead of valley walls.

Over time, the stream continues to meander and erode the valley's soil, widening it further. With flood events, the material that is eroded and carried in the stream is deposited which builds up the floodplain of the valley. During this process, the shape of the valley changes from a V or U shaped valley into one with a broad flat valley floor. An example of a flat-floored valley is the [Nile River Valley](http://geography.about.com/od/specificplacesofinterest/a/nile.htm).

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**IMPORTANCE OF PETROLOGY:** Rocks are divided according to their origin into 3 groups viz., IGNEOUS, SEDIMENTARY and METAMORPHIC. The study of rocks in all their aspects including their mineralogies, textures, structures; origin and their relationships to other rocks plays a major role in civil engineering operations.

**Igneous Rocks** are formed when hot molten rock material called magma solidifies (or) igneous rocks form through cooling and crystallization of molten rock material. If the molten material is below the Earth’s surface, it is called magma or else it comes out about the surface , it is known as lava.

The molten material of rock is semi-solid in nature and consists of liquid , gas and earlier formed crystals. The volatiles ( elements and compounds which are dissolved in a silicate melt ) are dominantly water vapour, CO2  and elements like O2, Si, Al, Ca, Na, K, Fe and Mg.

**Sedimentary Rocks** are formed due to weathering and erosion of the pre-existing rocks. Sedimentary rocks are classified on the basis of the character of the material and process which leads to its deposition. In addition, the depositional environment plays a major role in the formation of sedimentary rocks ie. deposited the material by wind action or water action.

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| Sedimentary rocks |
| Greywacks | arkose  | sandstone  | limestone |
| Chert | Conglomerate  | shales | Dolomite  |
| Siltstone  | Mudstone/claystone | Breccia |  |

Arkoses are indicative of erosion under arid conditions and rapid burial conditions whereas Greywacks are a common rock type of geosynclines

**Metamorphic Rocks** are formed through the transformation of the pre-existing rocks under increased temperature and pressure conditions. This process of transformation is known as metamorphism. Formation of metamorphic rock from a pre – existing ( igneous or sedimentary ) rock is controlled by the following parameters:

 Composition of the rock ; Temperature ; Pressure ;

 Chemically active fluids ( common fluid is water )

 Foliation ( under differential stress conditions )

 Non-foliation ( under hydrostatic stress )

Examples for metamorphic rocks are:

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| Quartzite | Hornfels | Marble |
| Amphibolite | Eclogite | Schist |
| Gneiss | Khondalite | Slate |
| Phyllite  |  |  |

Among the igneous and metamorphic rocks; Granites; Quartzites; Gneisses and Basalts are suitable for construction of a dam. Pure sandstones have good compressive strength but presence of inter layers of shales decrease its strength.

Limestones usually contains cavities in them. Adequate treatment in terms of grout – filling of the cavities is to be taken in such cases.

Schists, Phyllites, Shales, Siltstones and clay stones are relatively incompetent and need proper attention. Clay , if present is totally excavated since clay is incompetent as it swells on saturation with water. Contacts of igneous intrusive (dyke) and the host rocks often are fractured and jointed and hence such site is studied with proper care.

Eg: Nagarjuna sagar dam:. Contact of a dolerite dyke with the host rock ( granite gneisses ), a weak zone was identified along the contact. Excavation followed by back – filling with grout was adopted.

**The goal is to give:**

1) A meaningful sampling of the approaches and philosophy behind petrologic studies for stability of civil engineering constructions;

2) An appreciation for the diversity, complexity and geological significance of the rocks that comprise the earth for long durable constructions;

3) A basis for understanding the importance of petrology in the civil engg. constructions and

4) To provide *an opportunity* to further development for particular construction.

**IMPORTANCE OF STRUCTURAL GEOLOGY:** Geological structures are the evidences of crustal deformation. Depending on the process involved, the following various types of structures develop in the geological formations.

**FOLDS**: Folds are best displayed by stratified formations such as sedimentary or volcanic rocks or their metamorphosed equivalents. Folds can be seen in Gabbro, Granite gneiss, iron formations etc..

**FAULTS:** When formations subjected to stress deform resulting in the development of fractures or a fracture in rock along which there has been an observable amount of displacement can be seen.

**JOINTS:** Joints are fractures or openings in the rock formations. These differ from the faults in that there is no displacement along them.

**UNCONFIRMITIES**: An unconformity represents a long interval of non – deposition during which erosion takes place.

The earth’s crust is broken into 13 major plates which are in constant movement ( 1 to 2 cm per year ) due to the convection currents in the interior of the earth. The movements of tectonic plates in the earth crust affect the solid rocks which cause folds; faults, joints etc… study of these aspects are very important to a civil engineer in construction projects. Strike and dip of beds or formations ( layers ) or joints also important for site location.

**Importance of geological structures in Civil engineering operations:**

* The formations at the dam site should be dipping towards upstream or horizontal. This will counter the seepage compared the situation where the formations dip in the downstream direction.
* Foundations will have greater stability as the load is normal to the horizontal formations or formations with low dips.
* Presence of faults in the formations is not suitable for a dam site.
* Extensive joints in the rocks also threatens the safety of the structure
* Presence of folds ( anticlinal or synclinal structures ) in the foundation material contributes to the seepage problem.

A [**dam**](http://en.wikipedia.org/wiki/Dam) is a barrier across flowing water that obstructs, directs or slows down the flow, often creating a [reservoir](http://en.wikipedia.org/wiki/Reservoir_%28water%29), [lake](http://en.wikipedia.org/wiki/Lake) or impoundments. Most dams have a section called a [*spillway*](http://en.wikipedia.org/wiki/Spillway) *or* [*weir*](http://en.wikipedia.org/wiki/Weir) over which water flows, either intermittently or continuously.

Dam failures are comparatively rare, but can cause immense damage and loss of life when they occur. **Common causes of dam failure include:**

* [Spillway](http://en.wikipedia.org/wiki/Spillway) design error ([South Fork Dam](http://en.wikipedia.org/wiki/South_Fork_Dam))
* Geological instability caused by changes to water levels during filling or poor surveying ([Malpasset](http://en.wikipedia.org/wiki/Malpasset%22%20%5Co%20%22Malpasset)).
* Sliding of a mountain into the dam lake; in the case of [Vajont Dam](http://en.wikipedia.org/wiki/Vajont_Dam), filling the reservoir caused geological failure in valley wall ([Lawn Lake Dam](http://en.wikipedia.org/wiki/Lawn_Lake_Dam), [Val di Stava](http://en.wikipedia.org/wiki/Val_di_Stava_Dam_collapse) )
* Extreme rainfall ([Shakidor Dam](http://en.wikipedia.org/wiki/Shakidor_Dam%22%20%5Co%20%22Shakidor%20Dam))
* Human, computer or design error ([Dale Dike Reservoir](http://en.wikipedia.org/wiki/Dale_Dike_Reservoir),)
* [Internal erosion](http://en.wikipedia.org/wiki/Internal_erosion), especially in earthen dams.

**CAUSES FOR FAILURE OF DAMS ------ CASE STUDIES**

The most common causes of dam failures includes the following considerations:

1. Failure due to earthquake

2. Failure due to landslide

3. Failure due to chemical weathering of foundation rocks ( Alkali-Silica Reaction ,

 Sulfate & Chloride on concrete)

4. Failure due to physical weathering (temperature variations, or by heavy rain, or by

 physical breaking).

5.Failure due to increase of fractures in geological structures (fault, folds & unconformities).

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| 1.The **St. Francis Dam** was a [concrete](http://en.wikipedia.org/wiki/Concrete) [gravity-arch dam](http://en.wikipedia.org/wiki/Gravity-arch_dam), designed to create a [reservoir](http://en.wikipedia.org/wiki/Reservoir_%28water%29). The dam was built between 1924 and 1926 under the supervision of [William Mulholland](http://en.wikipedia.org/wiki/William_Mulholland)**The dam Height is** 195 feet (59 m) & its l**ength is** 608 feet (185 m). The dam was constructed on the foundation of Schists and conglomerates and in turn, separated by a distinct fault. In addition, conglomerates also had veins of gypsum, a soluble mineral and hence both Schists and conglomerates are unsuitable to serve as a foundation to such a dam. Several temperature and contraction cracks appeared in the dam when the reservoir had reached full capacity. Enormous leakage of stored water occurred through the conglomerate and the dam failed by sliding in 1928 resulting more than killing of 450 peopleHuge concrete block from the west abutment of the dam was carried out by dam water . The block is approximately 63 feet long, 30 feet high, and 54 feet wide. It was concluded that the disaster was primarily caused by the  [landslide](http://en.wikipedia.org/w/index.php?title=Paleomegalandslide&action=edit&redlink=1) on which the western abutment of the dam was built. 1. **Hales Bar Dam** was a [hydroelectric dam](http://en.wikipedia.org/wiki/Hydroelectric_dam) located on the [Tennessee River](http://en.wikipedia.org/wiki/Tennessee_River) in [Marion Country, Tennessee](http://en.wikipedia.org/wiki/Marion_County%2C_Tennessee), USA. The height of the dam is 113 feet with a length of 2315 feet. The Hales Bar Dam was constructed on the foundation of cavernous limestones. Such rocks are naturally weak both physically and chemically. To improve the site conditions and to reduce the seepage, the large openings were filled up by using more than 3000 tons of cement and 1100 barrels of asphalt. The dam was planned to complete in 1909, but numerous difficulties brought by the soft bedrock ie limestone upon which the dam was built.

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| Leaks began to appear almost immediately after completion. However. in 1919, engineers attempted to minimize the leakage by pumping hot asphalt into the dam's foundation. This was temporarily successful, but by 1931, a study leaking at a rate of 1,000 cubic feet per second was noticed .  |

In the late 1950s, however, the water below Hales Bar Dam, was again leaking, this time at an alarming 2,000 cubic feet per second. **Dye tests** carried out in 1960 suggested that many of the leakage channels had interconnected, increasing the possibility of a future dam failure.  |  |



Huge concrete block from the west abutment of the dam . The block is approximately 63 feet long, 30 feet high, and 54 feet wide

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Hales Bar Dam in 1949, after various improvements

**3. Kaila Dam, Gujarat, India:** The Kaila Dam in Kachch, Gujarat, India was constructed during 1952 - 55 as an earth fill dam with a height of 23.08 m above the river bed and a crest length of 213.36 m. The storage of full reservoir level was 13.98 million cubic mts. The foundation was made of shale. The spillway was of ogee shaped and ungated. The depth of cutoff was 3.21 m below the river bed. Inspite of a freeboard allowance of 1.83 m at the normal reservoir level and 3.96 m at the maximum reservoir level the energy dissipation devices first failed and later the embankment collapsed due to the ***weak foundation bed*** in 1959.

**4 . Kodaganar Dam, Tamil Nadu, India:** This dam was constructed in 1977 on Cauvery River as an earthen dam with regulators. The dam was 15.75 m high above the deepest foundation, having a 11.45 m of height above the river bed. The storage at full reservoir level was 12.3 million cubic mts. The dam failed due to overtopping by flood waters which flowed over the downstream slopes. There was an ***earthquake*** registered during the period of failure although the foundation was strong. Water gushed over the rear slopes, as a cascade of water was eroding the slopes. Breaches of length 20 m to 200 m were observed. It appeared as if the entire dam was overtopped and breached.

**5. Tigra Dam ( Madhya Pradesh, India, 1917 ):** This was a masonry gravity dam of 24 m height, constructed for the purpose of water supply. A depth of 0.85 m of water overtopped the dam over a length of 400 m. This was equivalent to an overflow of 850 m3s-1(estimated). Two major blocks were bodily pushed away. The failure was due to ***sliding.*** The dam was reconstructed in 1929.

**List of major dam failures**

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| --- | --- | --- | --- |
| **Dam/incident** | **Year** | **Location** | **Details** |
|  |  |  |  |
| [Austin Dam](http://en.wikipedia.org/wiki/Austin_Dam) | 1911 |  [Pennsylvania](http://en.wikipedia.org/wiki/Austin%2C_Pennsylvania), [U S](http://en.wikipedia.org/wiki/United_States) | Poor design, use of dynamite to remedy structural problems. |
| [St. Francis Dam](http://en.wikipedia.org/wiki/St._Francis_Dam) | 1928 | [Valencia, California](http://en.wikipedia.org/wiki/Valencia%2C_California), [Los Angeles](http://en.wikipedia.org/wiki/Los_Angeles_County) , [U S](http://en.wikipedia.org/wiki/United_States) | Geological instability of canyon wall that could not have been detected with available technology of the time, that assessed developing cracks . |
| [Malpasset](http://en.wikipedia.org/wiki/Malpasset) | 1959 | [Côte d'Azur](http://en.wikipedia.org/wiki/C%C3%B4te_d%27Azur), [France](http://en.wikipedia.org/wiki/France) | Geological fault possibly enhanced by explosives work during construction; initial geo-study was not thorough. |
| [Baldwin Hills Reservoir](http://en.wikipedia.org/wiki/Baldwin_Hills_Reservoir) | 1963 | [Los Angeles, California](http://en.wikipedia.org/wiki/Los_Angeles%2C_California), [U S](http://en.wikipedia.org/wiki/United_States) | [Subsidence](http://en.wikipedia.org/wiki/Subsidence) caused by [over-exploitation](http://en.wikipedia.org/wiki/Over-exploitation) of local oil field |
| [Vajont Dam](http://en.wikipedia.org/wiki/Vajont_Dam) | 1963 | [Italy](http://en.wikipedia.org/wiki/Italy) | Filling the reservoir caused geological failure in valley wall, leading to 110 km/h landslide into the lake; Valley had been incorrectly assessed stable. |
| [Buffalo Creek Flood](http://en.wikipedia.org/wiki/Buffalo_Creek_Flood) | 1972 | [West Virginia](http://en.wikipedia.org/wiki/West_Virginia), [U S](http://en.wikipedia.org/wiki/United_States) | Unstable loose constructed dam created by local [coal mining](http://en.wikipedia.org/wiki/Coal_mining) company, collapsed in heavy rain |
| [Teton Dam](http://en.wikipedia.org/wiki/Teton_Dam) | 1976 | [Idaho](http://en.wikipedia.org/wiki/Idaho), [U S](http://en.wikipedia.org/wiki/United_States) | Water leakage leading to dam failure. |
| [Laurel Run Dam](http://en.wikipedia.org/wiki/Laurel_Run_Dam) | 1977 | [Pennsylvania](http://en.wikipedia.org/wiki/Pennsylvania), [U S](http://en.wikipedia.org/wiki/United_States) | Heavy rainfall and flooding that over-topped the dam. |
| [Machchu-2 Dam](http://en.wikipedia.org/wiki/Morvi_dam_failure) | 1979 | [Gujarat](http://en.wikipedia.org/wiki/Morbi), [India](http://en.wikipedia.org/wiki/India) | Heavy rain and flooding beyond spillway capacity. |
| [Peruća](http://en.wikipedia.org/wiki/Peru%C4%87a) Dam detonation | 1993 | [Croatia](http://en.wikipedia.org/wiki/Croatia) | detonation of pre-positioned [explosives](http://en.wikipedia.org/wiki/Explosives) |
| [Saguenay Flood](http://en.wikipedia.org/wiki/Saguenay_Flood) | 1996 | [Quebec](http://en.wikipedia.org/wiki/Quebec), [Canada](http://en.wikipedia.org/wiki/Canada) | constant rain. Post-flood enquiries discovered that the network of dikes involvement |
| Ringdijk Groot-Mijdrecht | 2003 | [Wilnis](http://en.wikipedia.org/wiki/Wilnis), [Netherlands](http://en.wikipedia.org/wiki/Netherlands) | Peat dam became lighter than water during droughts and floated away |
| [Hope Mills Dam](http://en.wikipedia.org/wiki/Hope_Mills_Dam) | 2003 | [North Carolina](http://en.wikipedia.org/wiki/North_Carolina), [United States](http://en.wikipedia.org/wiki/United_States) | Heavy rains caused earthen dam and bank to wash away |
| [Big Bay Dam](http://en.wikipedia.org/wiki/Big_Bay_Dam) | 2004 | [Mississippi](http://en.wikipedia.org/wiki/Mississippi), [U S](http://en.wikipedia.org/wiki/United_States) | A small hole in the dam, grew bigger and led to failure. |
| [Shakidor Dam](http://en.wikipedia.org/wiki/Shakidor_Dam) | 2005 | [Pakistan](http://en.wikipedia.org/wiki/Pakistan) | extreme rain |
| [Taum Sauk reservoir](http://en.wikipedia.org/wiki/Taum_Sauk_pumped_storage_plant) | 2005 | [Lesterville, Missouri](http://en.wikipedia.org/wiki/Lesterville%2C_Missouri), [U S](http://en.wikipedia.org/wiki/United_States) | dam continued to fill. Minor leakages caused for failure |
| [Campos Novos Dam](http://en.wikipedia.org/wiki/Campos_Novos_Dam) | 2006 | [Campos Novos](http://en.wikipedia.org/wiki/Campos_Novos), [Brazil](http://en.wikipedia.org/wiki/Brazil) | Tunnel collapse |
| [Kyzyl-Agash Dam](http://en.wikipedia.org/wiki/Kyzyl-Agash_Dam) | 2010 | [Kazakhstan](http://en.wikipedia.org/wiki/Kazakhstan) | Heavy rain and snowmelt |
| [Hope Mills Dam](http://en.wikipedia.org/wiki/Hope_Mills_Dam) | 2010 | [North Carolina](http://en.wikipedia.org/wiki/North_Carolina), [U S](http://en.wikipedia.org/wiki/United_States) | [Sinkhole](http://en.wikipedia.org/wiki/Sinkhole) caused dam failure |
| [Delhi Dam](http://en.wikipedia.org/wiki/Delhi_Dam) | 2010 | [Iowa](http://en.wikipedia.org/wiki/Iowa), [US](http://en.wikipedia.org/wiki/United_States) | Heavy rain, flooding. |
| [Ajka alumina plant accident](http://en.wikipedia.org/wiki/Ajka_alumina_plant_accident) |  2010 | [Hungary](http://en.wikipedia.org/wiki/Hungary) | Failure of concrete impound wall  |
| [Fujinuma Dam](http://en.wikipedia.org/wiki/Fujinuma_Dam) |  2011 | [Japan](http://en.wikipedia.org/wiki/Japan) | Failure due to [2011 Tōhoku earthquake](http://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami). |

**WEATHERING OF ROCKS - IT’S EFFECT & IMPORTANCE w r t**

**DAMS, RESERVOIRS, TUNNELS**

The process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes etc is called as **weathering**.. (or) weathering is a process involving disintegration and decomposition of rocks. The disintegrated and the altered materials stay at the site of formation. If these materials are transported from the site with the help of natural agencies such as wind, running water etc, the process is called as erosion. Weathering is categorized as a mechanical, chemical, biological..

**Mechanical weathering:**  In mechanical weathering, the process involves only fragmentation or break down of the rock into smaller fragments / pieces. In nature, the physical breaking of rocks are caused by several processes. Waterfalls, landslides during their fall cause extensive breakdown of rocks. Thus gravity contributes to mechanical disintegration of rocks. However, all the processes involve widening of the fractures, resulting in the detachment of blocks surrounded by the weak planes. The different types of processes in mechanical weathering are:

*Frost wedging*: The presence of water in the cracks of the rocks freezes during the night time and melts during the day time. Freezing of water involves an increase in the volume because of which the walls of cracks are wedged ultimately resulting in the detachment blocks surrounded by the weak planes.

*Expansion and contraction process*: Solar radiation causes heating, which results in thermal expansion during day time and drop in the temperature during the night time causes contraction. The expansion and contraction are confined only to the surface layers of the rock and results often in the fracturing and detachment of top layers of the rocks.

*Fracturing through pressure releases*: Rocks at depth are confined under high pressures. However, if the rock material is uplifted due to tectonic processes to relatively lesser depths, it is subjected to lesser pressure conditions. So, the release of pressure leads to the deformation of rock and generates the fractures.

*Effect of vegetation*: During the growth of vegetation in rocky terrains, the roots penetrate into the existing weak planes and gradually the cracks are widened leading to physical breakdown of rock masses.

**Mechanical** or **physical weathering** involves the breakdown of rocks through direct

contact with atmospheric conditions, such as heat, water, ice and pressure.

**Chemical weathering**: Chemical weathering involves chemical reactions resulting in the alteration of the rock leading to the formation of new alteration products. Water is the best fluid that directly affects rocks by way of Dissolution; Leaching (making porous); Hydration; Oxidation, Hydrolysis etc

*Dissolution / Carbonation:* In case of carbonate rocks such as limestone, dolomite, marble when the river water traverses in these rocks; carbonates are dissolved, resulting in the reduction of their sizes.

Surface water contain O2  and its combination with water results in the formation of carbonic acid. Production of carbonic acid lowers the pH, resulting in the attack some of the minerals which are present in the rocks.

*Leaching*: means removable of soluble content from the rocks by water. Water is the powerful leaching agent which affects leaching for the most of the materials when come in contact with water. Eg: laterite is a porous rock and very weak when compared to its fresh parent rock.

*Hydration* is the process where in hydroxyl molecules are injected into the molecular structures of minerals thereby bringing about the decomposition of minerals.

K2 Al2O3 6 SiO2 + H2O + CO2 K2CO3 + Al2O3 2 SiO2 2H2O + 4 SiO2

 (K – feldspars) (Hydration) (Kaoline) (silica)

Due to hydration process, anhydrous pyroxenes are changed over to amphiboles while Amphiboles may be altered to Biotite. Biotite change over to Chlorite whereas Anhydrite ( CaSO4 ) alters to Gypsum ( CaSO4 2H2O) ) during hydration.

*Oxidation*: The decomposition of minerals in a rock during chemical weathering is brought about by O2 in water. For eg pyroxene changes into limonite because of oxidation through the following reaction.

4FeSiO3 + O2 + 2H2O 4 FeO (OH) + 4 SiO2

(pyroxene) (limonite) (silica)

Pyrite ( FeS2) converts into Haematite ( Fe2O3) during oxidation process

*Hydrolysis:* In case of decomposition of minerals, instead of water molecule, only hydrogen of water enters into the mineral structure. This is called hydrolysis.

 K AlSi3 O8 + H+ H AlSi3O8  + K+

 Orthoclase feldspars ion Silicic acid ion

In addition, CO2; O2; N2 of atmospheric gases which take part in the weathering of rocks.

**Chemical weathering**, involves the direct effect of atmospheric chemicals in the breakdown of rocks, minerals...

**Biological weathering** involves breakdown of rocks by living organisms (Bacteria & fungi ). Living organisms release organic acids viz., Oxalic acid; Phenolic acid; Folic acid, Acetic Acid, Humic acid etc.. which cause decomposition of rocks. Some of the microorganisms penetrate into mineral crystals and remove specific ions from the inter layers. Eg: removal of K+  from mica layers by fungi is an example of this type.

Man is also responsible for unnatural weathering of rocks for construction of buildings, dams, bridges etc…

**Weathering effect over the properties of rocks:**

* Weathered minerals exhibit change in color intensity or different colors.
* They will be less compact, and hence their specific gravity will be less.
* Their hardness will decrease so that the minerals become softer and weak.
* They become less transparent or tend to become opaque.
* The minerals loss their original shine and exhibit a dull luster.
* Weathered minerals loose their internal cohesion & become easily powdered.
* Weathered rocks usually appear as brown,red & yellow colors on the surface.

The degree of weathering is controlled by several parameters. These are:

1. Rock mass characteristics: The ultrabasic and basic igneous rocks ( Peridotite, Dunite, Gabbro ) decompose rapidly to acidic igneous rocks (Granite).

Similarly, carbonate rocks weather rapidly due to chemical solvents. Among the metamorphic rocks, quartzite is most stable whereas weathering of schists and phyllite is relatively faster. Rocks with folding and faulting undergo rapid weathering. The weak zones facilitate mechanical and chemical weathering by natural agencies.

1. Climate: It includes temperature and rainfall. In general, weathering is faster in regions with high temperature and high rainfall

As the temperature increases the vibration of atoms and ions in the rock mineral structures are more ultimately leading to the development of cracks. Rate of chemical weathering doubles with an increase of temp by 10o C.

Rainfall contributes to the growth of organisms ( bacteria ) which produces CO2.

1. Relief: If the topography is undulating and the slopes are steep, the weathered material erode continuously from the site. Consequently fresh surface of the rocks expose.
2. Time: If the weathering has continued over a long period of time, thick zone of alteration develops. eg: Bauxite deposits results from the decay and weathering of aluminum bearing rocks often igneous rocks.

**IMPORTANCE OF WEATHERING**

Weathering transports smaller fragments, pieces etc after the process of weathering. Weathering initiates the erosion of rock, causing alterations in minerals as well as in the surface layers. Weathering is a process that applies major role of engineering mechanics, e.g. kinematics (study of bodies which are in motion), dynamics and fluid mechanics to predict the mechanical behavior of erosion. Together, soil and rock mechanics are the basis for solving many engineering geologic problems with references to dams, reservoirs and tunnels.

Advantages of weathering from civil engineering point of view:

* Weathering produces soil which is vital for agriculture and for the production of agricultural crops.
* Weathering makes rocks into porous and permeable which allow the movement of groundwater in case of hard rocks like granites.
* Economic minerals like bauxite deposits are also form due to weathering.
* Oxidation of chemical weathering is important in the formation of some ore deposits particularly sulphides.

Disadvantages of weathering from civil engineering point of view:

* Weathering is not a welcome process, because it reduces the strength, durability and good appearance of rocks.
* Therefore, the weathered rocks are unfit to be at the site of foundation in case of civil structures like dams and bridges.
* Since weathered rocks are characterized by loose characters ie strength, durability etc, they become unfit for the formation of road metal or as a building stone.
* Weathered rocks are being weak, therefore unsuitable for tunneling.
* Occurrence of weathered zone in the upstream side creates silting problem in case of reservoirs as the accumulation of rapid silt reduces the reservoir capacity.
* Loose boulders due to weathering along steep slopes may turn out landslides which is civil engineering hazard.

**Engineering classification of weathered rock masses**: The engineering classification of weathered rock masses can be categorized into **Qualitative and Quantitative** approached.

Qualitative approach is very useful for the preparation of weathering maps for project sites in civil engineering practice.

The degree of weathering in a rock mass is arrived on the basis of change in its strength, alteration on its surface and the development of fractures. The rock mass is categorized into 6 grades. Table shows the grades of weathering in a rock masses :

|  |  |  |  |
| --- | --- | --- | --- |
| Description  | Code  | Grade | Basis of grading  |
| Unweathered  | UW | I | Rock mass is fresh. No alteration  |
| Slightly weathered | SW | II | Discolouration present along cracks  |
| Moderately weathered | MW  | III | Increase in the extent of fracturing & partly modifies into soil |
| Highly weathered | HW | IV | Material is discolored. Loss of strength can be observed. More than half of the material is converted to soil |
| Completely weathered | CW | V | Lost original strength. Rock mass changed to soil  |
| Residual weathered  | RW | VI | Total conversion to soil. No original fabric |

Quantitative approaches also reveals the weathering status, geodurability etc.. of rock masses.

1. Based on ultrasonic velocities, Lliev (1967) classified the weathered rock masses as : C = (VF – VW / VF ) where C = coefficient of weathering

 VF = velocity in fresh rock & VW = velocity in weathered rock.

|  |  |
| --- | --- |
| Grade | Coefficient |
|  Fresh | 0 |
| Slightly weathered  | 0 – 0.2 |
| moderately weathered  | 0.2 – 0.4  |
| Strongly weathered  | 0.4 – 0.6  |
| Very strongly weathered  | 0.6 – 1.0 |

1. This classification was proposed by Oliver by incorporating UNIAXIAL COMPRESSIVE STRENGTH ( UCS ) & SWELLING INDEX (means the change in length on swelling to the original length of sample ) for rock masses.

VLS=Very Low Strength; LS=Low Strength; MS=Medium strength; HS=High strength

 0.1 VLS LS MS HS VHS

Swelling index Very poor

 poor

 0.001 good

 Mod poor

 0.0001 fair Excellent

 1 10 100 Uniaxial Compressive Strength ( MPa)

This method is essentially meant for assessing the weathered status of the rock mass for TUNNELLING OPERATIONS.

**Effect of weathering of a common rock GRANITE:**

Among different rocks, Granite ( an acidic rock ) is one of the most abundant rock on the earth’s surface. Therefore, it will be appropriate to analyse the process of weathering in granite.

Granite consists of quartz, feldspars ( orthoclase, plagioclase ), and accessory minerals ( amphiboles, pyroxenes; biotite / muscovite, magnetite / haematite, rutile, zircon, apatite, garnet..)

During the oxidation, feldspars in granite converts into sericite and then to kaolinite thereby silica removed from the reaction by ground water.

Feldspars sericite ( mica ) kaolinite ( clay )

Quartz minerals remain unchanged whereas muscovite or biotite becomes chlorite on decomposition. Pyroxenes ( augite / diopside ) decompose and pass into hornblende or breakdown into chlorite.

The above changes due to weathering causes failure of civil construction projects and hence the study of weathering of rocks is important for any civil project.

Finally, Geological considerations such as Topography and geomorphology of the site, impact of geological structures; Lithology of the formations ; Identification of weak zones in addition to weathering of rocks plays an important role in civil engineering constructions.

**Effect of weathering on other rocks:** On the other hand, the decomposition of basic rocks (basalt, gabbro) which contain ferro magnesium silicates produce soluble materials (clay); iron-oxides; less silica.

Disintegration (mechanical weathering) produce rough angular materials which may from form on the mountain top or accumulate at the foot hills. These loose accumulations are called **TALUS or SCREE.**

The finest particles are usually removed from a scree by percolating water and the fine angular fragments get cemented. So, a cemented scree is known as **BRECCIA. CHERT and FLINT** also may occur in residue when limestones undergo weathering.

**MULTIPLE CHOICE QUESTIONS FROM UNIT – 1**

1. Hydrogeology is a branch of geology deals with ground water [C ]

A) Occurrence B) Movement C) A and B D) None

2. Which one of the following is not an endogenous geological aspect [B ]

 A) Volcanoes B) Rivers C) Earthquakes D) Ground Water

3. During youth stage of river formation, it is capable of causing [D ]

 A) Erosion B) Local deposition C) Deltas D) Waterfalls

4. Hardness of Quartz is [C ]

A) 2 B) 5 C) 7 D) 8

5. Feldspars may be described as aluminum silicates of [D ]

A) Sodium B) Calcium C) Potassium D) All of the above

6. The crust of the earth is called [C ]

A) Atmosphere B) Stratosphere C) Lithosphere D) Pyrosphere

7. Grain size of clay sediment is [A ]

 A) **<**0.01m B) 1 to 2 mm C) >200mm D) 1 to 2.2 mm

8. coal is considered as [B]

 A) Rock B] mineral C] both a & b D) None

9. Physical breaking of rocks is called as [C]

 A) Erosion B) Transportation C) Disintegration D) Decomposition

10. Chemical decay of rocks is called as [D]

 A) Erosion B) Transportation C) Disintegration D) Decomposition

11. The presence of water in the cracks of the rocks freezes during the night time and melts during the day is called as [C]

 A) chemical weathering B) Decomposition C) Frost Wedging (D) None

12. Removable of soluble content from the rocks by water is called as [B]

 A) Hydration B) Leaching C) Oxidation D) Hydrolysis

13. Hydroxyl molecules are injected into the molecular structures of minerals thereby bringing about the decomposition of minerals is called as [A]

 A) Hydration B) Leaching C) Oxidation D) Hydrolysis

14. Production of carbonic acid lower the value of [D]

 A) EC B) TDS C) both A & B D) pH

**FILL IN THE BLANKS**

1. When erosion takes place, fresh country rock surfaces will be exposed and this process is called DENUDATION.

2. Rock fragments during abrasion undergo wear & tear which is called as ATTRITION

3. Cut off water bodies from meanders during floods are called OX-BOW LAKES

4. The color of mineral powder is called the STREAK of mineral.

5. The angle between cleavage sets can be measured by GONIOMETER

6. The rock fragments thrown out at the time of volcanic eruption are called PYROCLASTS..

7. Mineralogically, shales are mainly made up of Montmorillonite .

8. The term is applied to chemical adjustment in newly solidified igneous rocks, brought about by a decrease in temperature AUTO METAMORPHISM.

9. GEOMORPHOLOGY deals with the description & interpretation of land forms

10. The principles and methods of geology is adopted for the purpose of civil engineering operations is called as ENGINEERING GEOLOGY.

11. The knowledge of EROSION, TRANSPORTATION & DEPOSITION by surface water helps in soil conservation, river control.

12. CANYON is a deep valley.

13. Material is transported in a solution condition is called as DISSOLVED LOAD

14. River sediment is known as ALLUVIUM.

**15.** If the river sediment / deposit is spread over a small area but has a relatively steep slope, it is called as ALLUVIAL CONE.

16. If the river sediment / deposit is spread over a large area and has a gentle slope, it is called as ALLUVIAL FAN

17. During the time of floods, the river carries a very large scale of river dumps along its course on either side which are known as NATURAL LEVEES

18. Silt and clay are examples for NATURAL LEVEES.

19. A DELTA is a land form that is formed at the mouth of a river.

20. GRAND CANYON is the example for V-shaped valley.

**WORDS and their MEANINGS**

|  |  |
| --- | --- |
| canyon | A deep valley  |
| Convection currents | Occur in the core and mantle of the earth providing forces which produce certain structural effects at the earth’s surface. |
| decomposition | Chemical decay of rocks. |
| deformation | A structural term used to describe any change in attitude, shape or volume of a bed or layer after its formation. The related terms used which include folds, faults, schistosity etc.. |
| **DIP** | It is a vector quantity and is represented by angle of inclination wrt the bedding plane |
| disintegration | Physical breaking of rocks  |
| erosion | The disintegrated and the altered products are transported from the site with the help of natural agencies like wind and running water.  |
| geosyncline | An elongated basin which become filled with very thickness of sediments. Eg: gulf of Mexico. |
| Hydrology | the study of all waters in and upon the earth. It includes underground water, surface water, rain fall etc… NOT UNDER GEOLOGY |
| Rock mechanics:  | The study of the mechanical properties of a rock including the determination of physical properties such as crushing strength; bending strength; shear strength; inter angle of friction ; porosity and permeability; density etc..  |
| stress | Internal forces within a body tending to change the shape or volume of the body. |
| **STRIKE**  | The direction of strike indicates the extension or continuation of formations.  |
|  |  |