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ENGINEERING GEOLOGY II

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Chapter 1

Introduction to Engineering Geology

Geology is the branch of science that deals with the study of earth, its history, structures and the processes that act upon it.

Engineering Geology on the statutes of IAEG is defined as the science devoted to investigation, study and solution of environmental and engineering problems which may arise due to the interaction between the geology and human activities and also the prediction of or development of measures to control such hazards.

Scope of Engineering Geology:

- Nature of soil materials can be found.
- Useful for river control and construction of dams, highways.
- Provides knowledge about materials used in construction.

1.1 Engineering Geological System (EGS):

The lithology of the intact rock, structural geological information, tectonics of the area, mechanical properties of the rock mass, mechanical behavior of the ground mass, earthquake and seismicity and hydrogeological condition of the area are the important parameters for the evaluation of EGS.

Lithology: Lithology provides information on composition, texture, structure and origin of rocks.

Geological Structures: Geological structures are classified as primary structure and secondary structure. Primary structures are those structures that are formed during the formation of rocks. Secondary structures are those structures that are formed after the formation of rocks.

(Detail on primary and secondary structures are discussed in Geology I).

Hydrogeology: Hydrogeology is the branch of geology that refers to the study of groundwater and the geologic process of surface water.

Geomorphology: Geomorphology deals with the form and morphology of the earth surface.

Weathering: Weathering is defined as the phenomenon in which breaking of Earth's rocks, soils and minerals occur through direct contact with the atmosphere.

Earthquake: It is defined as the shaking or trembling caused by the sudden release of energy.

EGS occurs in four different phases as Planning, Design, Construction, and Maintenance phases.

1.2 Important rock forming minerals and their engineering significance:

QUARTZ -SiO_2

FELDSPAR

ORTHOCLASE - $KAlSi_3O_8$

PLAGIOCLASE - $NaAlSi_3O$ -- $CaAl_3Si_2O$

MICA

MUSCOVITE - $KAl_3Si_3O10(OH)_2$

BIOTITE - $K(Mg,Fe)3AlSi_3O10(OH)_2$

FERRO MAGNESIAN MINERALS

HORNBLENDE - Ca2Na(Mg,Fe)4(Al,Fe,Ti)3Si6O22(O,H)2

PYROXENE - $Ca(Mg,Fe,Al)(Si,Al)2O_6$

OLIVINE - $(Fe,Mg)2SiO_4$

CALCITE- $CaCO_3$

GYPSUM -$CaSO_4.2H_2O$

HALITE -NaCl

Engineering importance

- The response of rocks or minerals to weathering, erosion, and tectonic processes are useful in making estimates of site condition.
- Different minerals have different weathering stability. i.e. clay minerals swell after saturation with water
- Carbonate minerals dissolve completely in water which contains dissolved CO2.
- The minerals which are crystallized at greater depth are chemically unstable at surface conditions.
- The chemical weathering changes the certain silicate minerals like feldspar into insoluble clay minerals

- Orientation of platy micas and foliated structure reduce the strength of the rock.
- Deformed and fractured minerals found in metamorphic rocks may reduce the strength of the rock.

1.3 Engineering Geological Maps: Their Classification and Preparation:

The graphical representation of purpose specific geological information or data obtained from the field which can be quantified with reference to the north at the certain scale in engineering geological map. Maps used for engineering geologic applications includes:

- Site or project specific soil and rock units.
- Landforms.
- Drainage characteristics, and slope and other conditions related to development, such as existing cut and fill slopes, roads, proposed building footprints, etc.

Mapping should be done on a suitable plan metric or topographic base map or aerial photograph, at an appropriate scale with satisfactory horizontal and vertical control. Each map or photo should include the date and source of the base.

They can be classified as analytical and comprehensive. The analytical map provides information on individual components of the geological environment (deals about seismic hazard). The comprehensive map provides information on geological zoning.

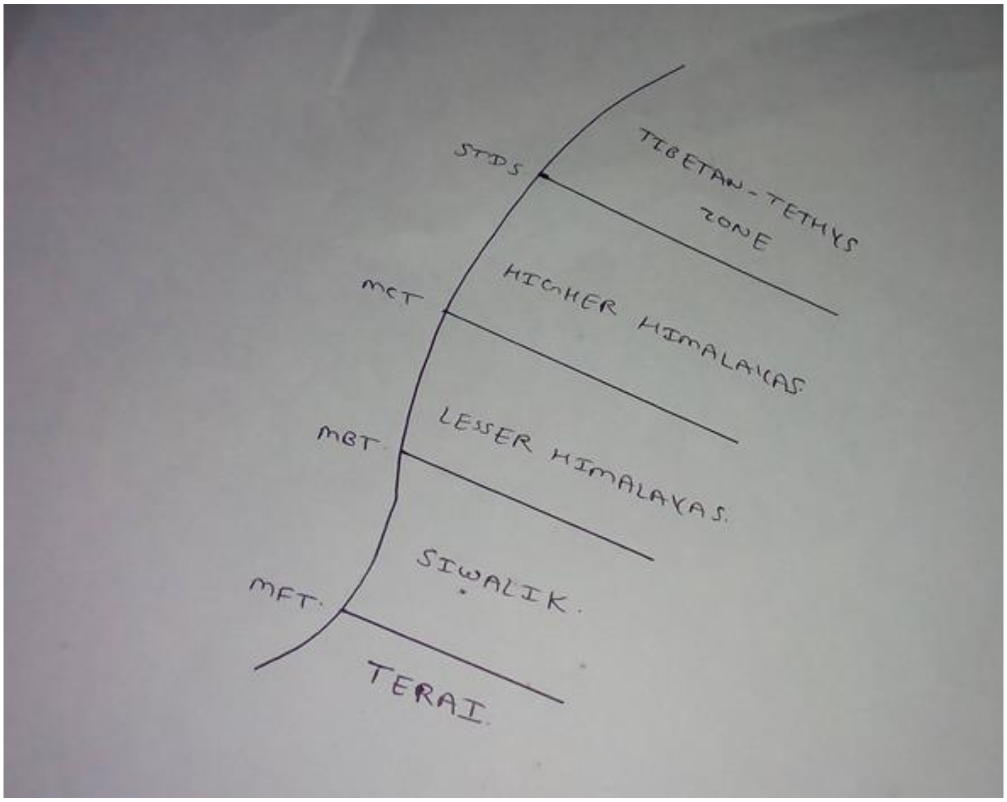
Bibliography:

Dhar, M.S., and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

Chapter 2

Engineering Geology in Himalayas

2.1 Major discontinuities system of the Nepal Himalaya and their engineering significance:



Main Frontal Thrust (MFT), Main Boundary Thrust (MBT) and STDS are active thrusts. Main Central Thrust (MCT) is a dead thrust but it is a crushed zone. The maximum earthquake potential in MFT, MBT and MCT are 6.5, 8 and 7.5 respectively.

2.2Major engineering geological problems of the Terai, Siwaliks, Lesser Himalaya, and the Higher Himalaya, Tibetan –Tethys zone and their mitigation

TECTONIC ZONES	HAZARDS	CAUSES	CONTROL MEASURES
Terai	River flooding.		Civil Engineering Works. Proper Drainage Management.
Siwalik	Soil erosion. Hill and gully erosion. Landslides.	Soft and fragile rocks. High slope. Active MFT. Toe cutting by river.	Bio-engineering. Drainage Management. Detailed geological investigation before construction.
Lesser Himalayas	Landslide. Soil erosion. River toe cutting.	High slope, fold, faults. Active MBT. Weak rock. Concentrated precipitation. Deforestation. Improper land use.	Civil engineering structure. Drainage management. Bio-engineering.
Higher Himalayas	Rock fall, GLOF, Landslide.		Civil engineering Structure. Location of Glacier Lake.
Tibetan-Tethys Zone	Rock fall, Landslide.		Civil Engineering Works.

2.3 Engineering geological information system in Nepalese context:

- Geological map.
- Landslide and engineering geological map.
- Book, journals, reports.
- Metadata
- Web portals.

Bibliography:

Dhar, M.S. and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

Chapter 3

Hydrogeology

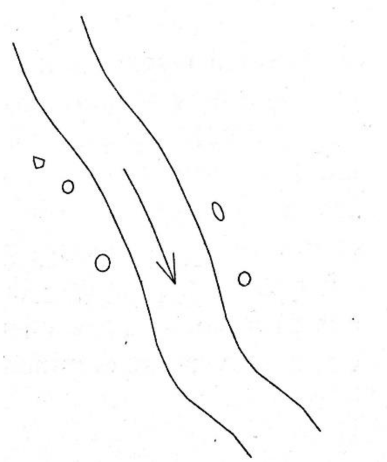
Hydrogeology is the branch of geology that refers to the study of groundwater and the geologic process of surface water.

3.1 River Chanel Morphology:

River is a mass of water that flows from high gradient to the low gradient carrying various materials. The path along which the river flows is called river channel morphology.

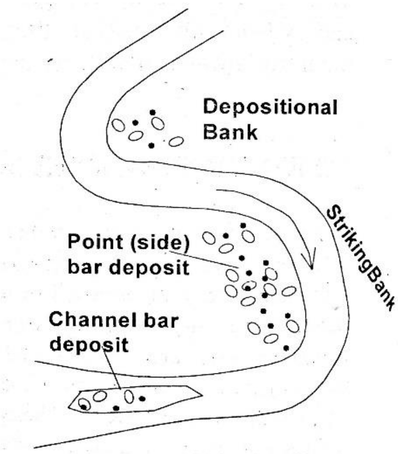
Types of River Channels

Straight River: This type of river flows through straight path. This type of river has high gradient and flows from high altitude with erosional rate more than the depositional rate. Deep scouring along the river path is more than that of side cutting in this type of river channels. They are dominant in mountains.



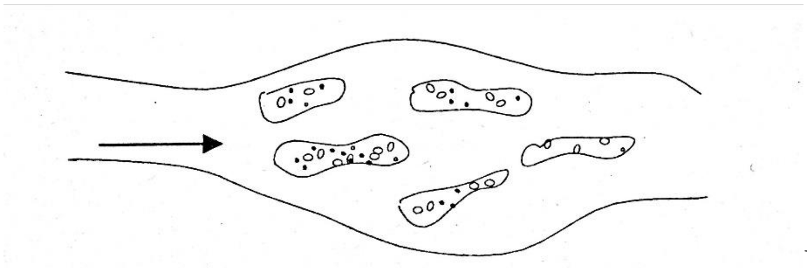
Straight River

Meandering River: This type of river flows through a zig zag path. This type of river has moderate gradient such that river strikes in one end and return to other direction in a zig zag path. The rate of erosion and the rate of deposition are almost equal. Side cutting is more than deep scouring in this type of river channel. They are dominant in lesser Himalayas.



Meandering River

Braided River: In braided river channel a single river path is diverted into several paths and may converge into single later. The gradient of river is low and the depositional rate is higher than that of the erosional rate. They are dominant in Terai region.


Braided River

3.2 Origin, type and movement of groundwater, porosity, permeability and hydraulic transmissivity of different rocks and sediments.

Groundwater: Water that is available below the earth's surface is termed as groundwater.

Porosity: It is defined as the ratio of volume of void to the total volume. It is expressed in percentage.

Porosity =μ = Volume of void/Total volume.

Permeability: It is the ability of an earth material to transmit the fluid.

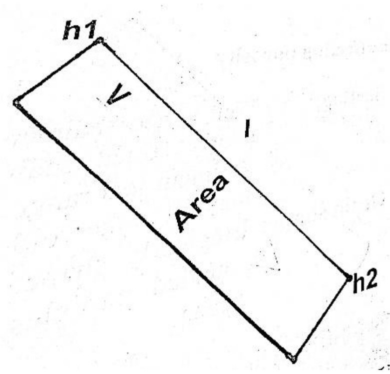
Permeability = k = Kμ/ρg

Hydraulic Conductivity (K): It is defined as the flow velocity per unit hydraulic gradient. It gives the measures of how easily a particular fluid will pass through a particular earth materials.

Hydraulic Transmitivity: It is defined as the rate at which water of prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. It measures in m^2/day.

Hydraulic Gradient: Difference in hydraulic head at two points divided by the length is termed as hydraulic gradient.

Darcy's Law: Darcy's Law is the fundamental constitutive relationship that we use to understand the movement of fluids in earth's crust.



Darcy's Law

If h_1 and h_2 be the head at two places with spacing of length 'L'. Then we have

$V \propto h_1 - h_2$

$V \propto 1/L$

$\therefore V = KI$

Where,

$I = (h_1 - h_2)/L$ is called the Hydraulic Gradient.

$Q = VA$

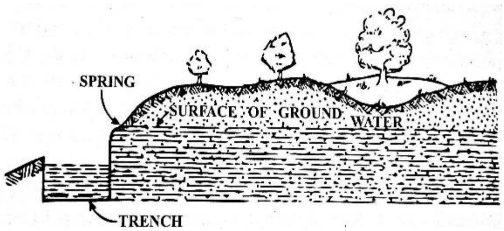
$\therefore Q = KIA.$

Springs

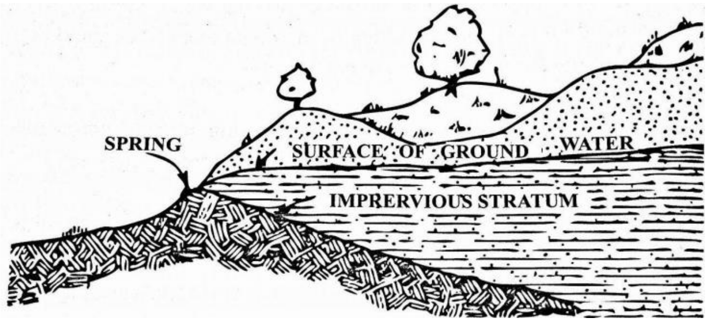
A place where ground water naturally comes to the surface at the intersection of the water table and land surface is termed as spring.

Types of springs:

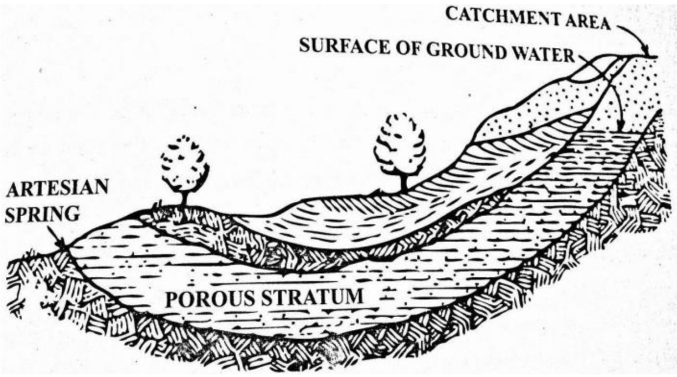
Gravity Springs:



Depression Spring



Contact or Surface Spring



Artesian spring

- **Depression springs:** Springs formed where ground surface intersects the water table.
- **Contact springs:** Created by a permeable water bearing formation over lying a less permeable formation that intersects the ground surface.
- **Artesian springs:** Result from release of water under pressure from confined aquifers either at an outcrop of the aquifer or through an opening in the confining bed.

Non Gravity Springs:

- **Tabular/Fracture Springs:** It is issuing from rounded channels such as lava tubes, of fractures on impermeable rocks connecting on ground water.

3.3 Geological factors for formation of different hydrological conditions

- **River Channel Morphology.**

It is a term that describes the shape of river channels and how they change over time.

- **Geological Discontinuities.**

Geological discontinuity is a plane or surface that marks a change in physical or chemical characteristics in a soil or rock mass.

- **Geotechnical Properties of soil.**

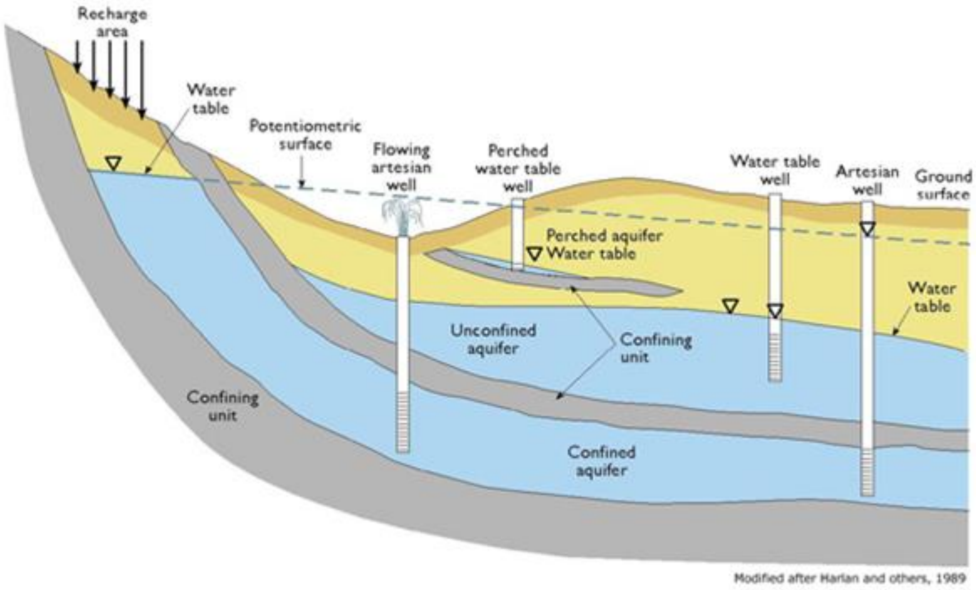
Geotechnical properties of soil includes various parameters as porosity, permeability and so on.

- **Geological Structures.**

Geological structures as faults, folds are also responsible for formation of different hydrological conditions.

3.4 Different types of aquifer system of Nepal (Terai, hills and mountains)

The water bearing strata from where we can easily extract ground water is called aquifer. Aquifer that lies between the impermeable layers is called confined aquifers and those aquifer that lies between the impermeable layer and the open (free) surface is known as unconfined aquifer. Those aquifer that occurs in patches are called perched aquifer.



Aquifers

All three types (Confined, Unconfined and Perched) of aquifer are present in Terai region. Unconfined aquifers are present in Hill and Mountains. All three types of aquifer are present in midlands i.e. Kathmandu and Pokhara.

Bibliography:

Dhar, M.S. and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

Chapter 4

Engineering geology in site selection, investigation & construction/excavation

4.1 Introduction, types and methods

Site investigation is a process of site exploration consisting of boring, sampling and testing so as to obtain geotechnical information for a safe, practical and economical geotechnical evaluation and design.

The Importance of Site Investigation

- To study the general suitability of the site for an engineering project.
- To enable a safe, practical and economic design to be prepared.
- To determine the possible difficulties that may be encountered by a specific construction method for any particular civil project.
- To study the suitability of construction material (soil or rock).

Elements of Site Investigation

- Desk study to collect all the relevant data and information,
- Reconnaissance of site works
- Planning program after reviewing the above
- Ground or soil exploration includes boring, sampling and testing,
- Laboratory testing (also field if necessary)
- Preparation and documentation of SI report
- Engineering design stages
- Review during construction and monitoring.

Procedure of Engineering in site Selection

Surface Exploration

1. **Interpretation of Topographic maps**

-Land surface - relief and position

-Man-made features

-Position of gullies, ridges, hills, mountains, plains

-Scale

2. **Aerial photographs and geological Maps**

- **Air photo:**

-shape, size, pattern, shadow, tone

-Provides both regional and local site features

-Geological information bedding, fault, fold etc.

- **Geological Maps:**

-Geological structures

-Structural attitude of strata

-Thickness of each formation

3. Engineering geological map

-Terrain evaluation

-Geological hazard

-Degree of weathering

-Geomorphological units, fan, hills

-Construction material survey.

Sub-Surface exploration

Geophysics

-Provides depth of rock thickness, fault, fold etc.

Methods:

1. Gravity: Measures the density of materials.
2. Magnetic: Magnetic susceptibility and natural remnant magnetism.
3. Electrical Method: Electrical resistivity.
4. Seismic Method: Elastic properties of material-seismic waves.

Bore-hole drilling it is direct method or sub surface exploration. Deep drilling are performed either by cable tool method or by one of several rotary methods.

Different types of drilling techniques:

1. Cable Tool Method
2. Rotary Method
3. Test Pit
4. Trench
5. Auger boring

4.2 Geology in the selection of the roads and canal alignment

SITE SELECTION FOR ROADS

Topography: Topography controls the alignment of roads. So topographical maps is needed which reveals the land features as valleys, hills for setting up the alignment.

Lithology: Lithology provides information on composition, texture, structure and origin of rocks. The base material through which alignment need to be set need to be favorable for blasting operation and need to be stable.

Geological Structures: Joints and fault zones need to be avoided during the selection of road alignment.

Weathering: Permeability contrast may arise due to variation in state of weathering which may lead to adverse condition of slips and falls. So weathered rocks need to be avoided as far as possible.

4.3 Geology in site investigation of buildings, bridges, dams and reservoirs

SITE SELECTION FOR DAMS

- **Topography:** Narrow part of valley with seep rocky slope.
- **Lithology:** Rock foundation (Hard Rock)

-Limestone can create problem by making caverns

-The weaker rocks are vulnerable to deformation and differential movements.

-Phyllites and slates exhibit large variation in strength

-If there is no discontinuities, dolerites, basalts, amphibolite, granulite, gneisses, quartzite, sandstone and massive dolomite have sufficient high bearing strength, and make very good foundation rocks.

- **Geological Structures**:
  - Dam axis should be perpendicular to the geological structures.
  - Steep dipping towards the upstream bedding is favorable.
  - Dipping upstream of anticline limb is good.
  - Less jointed.
  - Dam founded on fault zone is very unfavorable.

  - Free from slope stability problems
  - Earthquakes
  - Groundwater condition (Acidic water is sensitive to carbonate formations)
  - Construction material should be near
  - Permeability of the rock
  - Fresh rock condition
  - Hidden channels(cave)
  - Environmental Impact Assessment (EIA).

SITE SELECTION FOR RESERVOIRS

- **Topography:** Broad natural valley ended with narrow gorge where a barrier could be placed.
- **Groundwater condition:** The amount of leakage of water from the reservoir is controlled by the depth of water table.
- **Permeability:** The rocks which are highly fissured, intensely jointed, faulted or have solution channels, cause serious leakage from the reservoir.
- **Silting of Reservoir:** The amount of silt produced and supplied depends mainly upon the lithological character and topography of the catchments area.
- **Lithology:** The rocks exposed in the reservoir rim must be resistant to solution, erosion and free of voids to leak the water.

SITE SELECTION FOR BRIDGES

Geological Investigation:

- Abutment and piers must be in strong rock.
- Poorly cemented, thinly bedded and soft sedimentary rocks should be avoided.
- Presence of harder rocks over weaker layers, rock heterogeneity, zones of weathering are not suitable for bridge heterogeneity, zones of weathering are not suitable for bridge foundation.

- **Geological structure:**

– Stable from plane, wedge and toppling failure.

– Fault zone should be avoided.

–Types of river channel:

– River should be straight and narrow channel.

– Meandering river can damage the abutment.

– Drainage should be avoided.

Favorable Condition for Bridges

- Minimum bank cutting.
- Competent bed.
- Narrow span.
- Strike should be across the river.
- Less jointed.
- Filling should not be clay.
- Less geological structures.
- Water drainage should be studied.

SITE SELECTION FOR BUILDINGS

- Ground Condition.

- Bed rock at surface.

- Bed rock at shallow deep.

- Bed rock at deep depth.

- Stability depends upon compression and shearing. (Consolidation).

4.4 Geology in the selection of tunnel and other underground structures

- **Lithology:**

– Hard rock is most favorable, i.e. Quartzite, granite.

– Soft rock rives the problems of squeezing and swelling

– Water table

- **Geological structure**:

– Horizontal direction: Pressure distribution in all direction.

- **Attitude of rock:** Tunnel driven parallel to the strike create the problem.

– Folded rock.

– Fault zone.

– Joint system.

– Ground water condition.

– Gases in tunnel.

– Temperature in tunnel.

– Stability of tunnel entrance.

- **Over break**

Excave material to maintain the perimeter to tunnel is known as over break.

- Geological factors which govern the amount of over break are:

- The nature of rock.

-Orientation and spacing of rock.

-Orientation of bedding plane.

4.5 ENGINEERING GEOLOGICAL DOCUMENTATION DURING TUNNELING (UNDERGROUND EXCAVATION)

- Site Investigation (Calculation of RMR and Q-values).
- Recording of Rock (fracture) pattern in the face of tunnel. (Face tunneling).
- Measurement of attitude of bed.
- Information of rock type and properties in every meter.
- Preparation of Daily > Weekly > Monthly > Yearly Reports.
- Completion Report.

Bibliography:

Dhar, M.S. and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

Chapter 5

Geological Hazards

5.1 Introduction

Geologic hazard is an adverse geologic conditions capable of causing damage or loss of property and life and can be classified as natural and artificial geological hazards.

Natural: Flood, Earthquakes, Landslides, etc.

Artificial: Bombing, Firing, etc.

GEOLOGICAL FACTORS THAT CAUSES HAZARDS IN NEPAL HIMALAYAS

- Geological Discontinuities.
- Steep and fragile topography.
- Erosion by streams, glaciers, river bank cutting.
- Landslide and different types of mass movements.
- Depth and degree of weathering.
- Geotechnical Properties.

5.2 Major Geological Hazards:

Erosion

Erosion includes weathering and transport. The process by which water, ice, wind or gravity moves fragments of rock and soil. The process by which water, ice, wind or gravity moves fragments of rock and soil.

Floods

High water stages in which water over flows its natural or artificial banks onto normally dry land, such as a river inundating its floodplain are known as floods. They cause damage to lives, property, infrastructure and crops.

Flood hazard

The risk of damage to lives; livelihoods or property because of the floodwater is called a flood hazard.

Types of Floods

RIVER FLOOD

Flooding along rivers is usual. Some floods occur seasonally and some when winter or spring rains; coupled with melting snows, fill river basins with too much water, too quickly. **Floods in Koshi, Sunkoshi, Mahakali are RIVER FLOOD.**

COASTAL FLOOD

Winds generated from tropical storms and hurricanes or intense offshore low-pressure systems can drive ocean water inland and cause significant flooding. Coastal flooding can also be produced by sea waves called tsunamis sometimes referred to as tidal waves. These waves are produced by earthquakes or volcanic activity.

URBAN FLOOD

As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization decreases the ability to absorb water 2 to 6 times over what would occur on natural terrain. During periods of urban flooding, streets can become swift moving rivers, while basements can become death traps as they fill with water. **(Water is not absorbed by the soil due to the pavings provided.)**

Flash Flood

A flood that rises and falls quite rapidly with little or no advance warning, usually as the result of intense rainfall over a relatively small area. Flash floods can be caused by situations such as a sudden excessive rainfall, the failure of a dam, or the thaw of an ice jam.

ICE JAM

Floating ice can accumulate at a natural or manmade obstruction and stop the flow of water thereby causing floods.

Effects

- **Physical damage** – structures damaged or collapsed by washing water.
- **Casualties and pubic health** – people and livestock deaths caused by drowning. Outbreak of epidemics, diarrhea, viral infections, malaria.
- **Water supplies** – contamination of water (wells, ground water, and piped water supply). Clean water may be unavailable.
- **Crops and food supplies** – sudden food shortage can be caused due to loss of entire harvest, spoiling of grains when saturated in water along with loss of animal fodder.

Flood Mitigation Strategies (Watershed Management, Construction of reservoirs, Building on elevated areas, Flood Hazard zoning Map**)**

- Structural
- Non-Structural

Structural Measures:

1. **Water Shed Management:** Timely cleaning, silting and deepening of natural water reservoir and drainage channels (both urban and rural) must be taken up.
2. **Reservoirs:** The entire natural water storage place should be cleaned on a regular basis. Encroachments on tanks and ponds or natural drainage channel share to be removed well before the onset of monsoon.
3. **Natural water retention Basins:** Construction and protection of all the flood protection embankments, ring bunds and other bunds. Dams and levees can also be constructed which can be used as temporarily storing space which reduced the chances of lower plains getting flooded.
4. **Buildings on elevated area:** The buildings in flood prone areas should be constructed on an elevated area and if necessary on stilts and platform.

Non Structural Measures:

a) **Flood Plain Zoning:** Flood plain zoning, which places restrictions on the use of land on flood plains, can reduce the cost of flood damage. Local governments may pass laws that prevent uncontrolled building or development on flood plains to limit flood risks and to protect nearby property. Landowners in areas that adopt local ordinances or laws to limit development on flood plains can purchase flood insurance to help cover the cost of damage from floods.

b) **Flood Forecasting and warning:** These are issued for different areas mostly by the Central water Commission/ Meteorological Department and by the State Irrigation/ Flood Department.

5.3 Types of Mass Movements

The downward or outward movement of material due to gravity is called mass movement.

Mechanism of mass movement:

Factor of Safety = Shearing resistance of materials/Magnitude of shearing force.

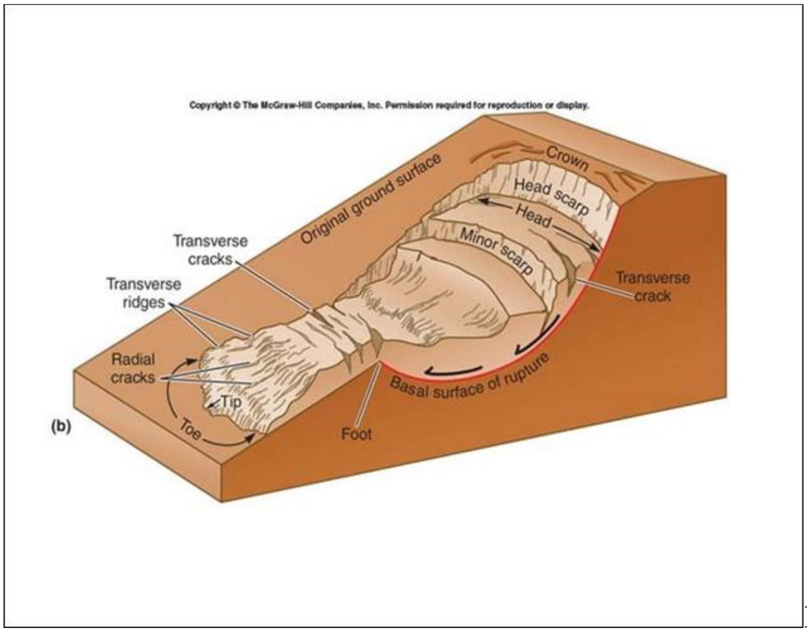
If Factor of Safety < 1 then mass movement occurs.

Mass Movement		
Slope Failure	**Landslide**	**Debris Flow**
Movement of weathered surface soil layer/rock of steep slope (small dimension and rapid flow) Falling of materials while constructing roads.	Movement of large sediment block, which has clear slide surface. Large dimension, slow and continuous movement mainly affected by groundwater.	Movement of deposited or eroded sediments along the stream. Rapid movements including large volume of water through the stream.

Landslide

Landslide is defined as the down slope transport of mass of soil and rock material along a slip surface under the influence of gravitational forces.

Landslide Features



Landslide

- **Main Scarp:** A steep surface on the undisturbed ground around the periphery of the slide, caused by the movement of slide material away from undisturbed ground. The projection of the scarp surface under the displaced material becomes the surface of rupture.
- **Minor Scarp:** A steep surface on the displaced material produced by differential movements within the sliding mass.
- **Head:** The upper parts of the slide material along the contact between the displaced material and the main scarp.
- **Top:** The highest point of contact between the displaced material and the main scarp.
- **Toe of Surface of Rupture:** The intersection (sometimes buried) between the lower part of the surface of rupture and the original ground surface.
- **Toe:** The margin of displaced material most distant from the main scarp.
- **Tip:** The point on the toe most distant from the top of the slide.
- **Foot:** The portion of the displaced material that lies downslope from the toe of the surface of rupture.
- **Main Body:** That part of the displaced material that overlies the surface of rupture between the main scarp and toe of the surface of rupture.
- **Flank:** The side of the Landslide.
- **Crown:** The material that is still in place, practically un-displaced and adjacent to the highest parts of the main scarp.
- **Original Ground Surface:** The slope that existed before the movement which is being considered took place. If this is the surface of an older landslide, that fact should be stated.
- **Left and Right:** Compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewed from the crown.
- **Surface of Separation:** The surface separating displaced material from stable material but not known to have been a surface of which failure occurred.
- **Displaced Material:** The material that has moved away from its original position on the slope. It may be in a deformed or unreformed state.
- **Zone of Depletion:** The area within which the displaced material lies below the original ground surface.
- **Zone of Accumulation:** The area within which the displaced material lies above the original ground surface.
-

Causes of Landslide

Geological factors	**Morphological causes**	**Physical causes**	**Human causes**
Weak materials Sensitive materials Weathered materials Sheared materials	Slope angle Uplift Rebound Fluvial erosion	Intense rainfall Rapid snow melt Prolonged precipitation Rapid drawdown	Excavation Loading Drawdown Land use change

Jointed or fissured materials Adversely orientated discontinuities Permeability contrasts Material contrasts	Wave erosion Glacial erosion Erosion of lateral margins Subterranean erosion Slope loading Vegetation change	Earthquake Volcanic eruption Thawing Freeze thaw Shrinks well Groundwater changes Other mass movements	Water management Mining Quarrying Vibration Water leakage

Type of movement			Type of material		
			Bedrock	Engineering soils	
				Predominantly fine	Predominantly coarse
Falls animation			Rockfall	Earth fall	Debris fall
Topples animation			Rock topple	Earth topple	Debris topple
Slides	Rotational animation		Rock slump	Earth slump	Debris slump
	Translational	Few units Many units	Rock block slide Rock slide animation	Earth block slide Earth slide	Debris block slide Debris slide
Lateral spreads			Rock spread	Earth spread	Debris spread
Flows			Rock flow	Earth flow	Debris flow videoclip
			(Deep creep)	(Soil creep)	
Complex and compound			Combination in time and/or space of two or more principal types of movement		

Landslide Classification

Falls: The abrupt movement of slope material that separates from cliff and steep slopes is called falls.

Toppling: The block of rock that tilt or rotates forward about a pivot below the center of gravity of the displaced mass is called toppling.

Slides: It is a downslope movement of soil or rock mass occurring dominantly on the surface of rupture or on relatively thin zones of intense shear strain.

Translational Slides: The mass displaces along the planar or undulating surface of rupture in translational slides.

Rotational Slides: It moves along a surface of rupture that is curved and concave.

Spread: The failure caused by liquefaction whereby, saturated, loose and cohesion less sediments are transformed into the liquid state is called spread.

Flow: The rapid movement of materials as a viscous mass where inter granular movements predominates over the shear surface movements is called flow.

Comparison between Landslide and Slope Failures:

	Landslide	**Slope Failure**
Geology	Occurs in place with specific geology.	Not much related with geology.
Characteristics of soil	Mainly in clayey soil.	Often takes place in sandy soils.
Condition of Movement	Velocity: 0.001 to 10mm per day.	Velocity: >10mm/day.
Condition of soil mass	Disturbance to soil mass is small.	Disturbance to soil mass is high.
Cause of Movement	Influenced by ground water.	Influenced by surface and sub-surface water.
Scale of moving mass	Large	Small
Gradient of slope	Gentle	Steep

Mitigating Measures:

- Afforestation.
- Construction of check dams.
- Proper use of bioengineering practices.

5.4 EARTHQUAKE AND SEISMICITY

- The shaking or trembling caused by the sudden release of energy.
- Usually associated with faulting or breaking of rocks.
- Continuing adjustment of position results in aftershocks.

Elastic Rebound Theory

- Explains how energy is stored in rocks.
- Rocks bend until the strength of the rock is exceeded.
- Rupture occurs and the rocks quickly rebound to an unreformed shape.
- Energy is released in waves that radiate outward from the fault.

The point beneath the Earth's surface where the rocks break and move is called the focus of the earthquake. The focus is the underground point of origin of an earthquake. Directly above the focus, on the Earth's surface, is the epicenter. Imaginary lines joining the points of same intensity of the earthquakes are known as isocheimal and the imaginary line joining the points of focus and epicenter is called seismic vertical.

Seismometer:

Seismometer are the instruments that measures the ground movements. The framework of the seismometer moves when the earth moves. The suspended heavy weight and then pen beneath remains relatively stationary. As the concrete base moves the stationary pen draws an ink line on paper on the rotating drum.

The Focus and Epicenter of an Earthquake

- The point within Earth where faulting begins is the focus, or hypocenter.
- The point directly above the focus on the surface is the epicenter.

Seismic Waves

- Response of material to the arrival of energy fronts released by rupture.

- Two types:

– Body waves

- P and S

– Surface waves

- R and L

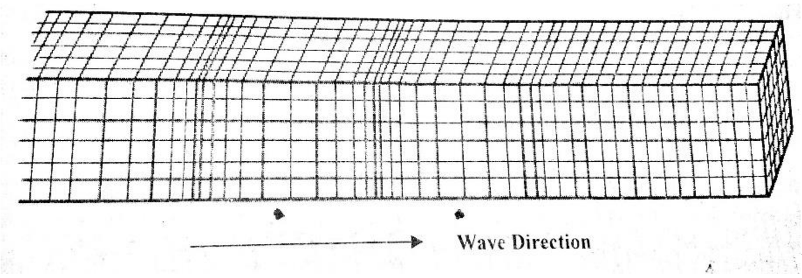
Earthquake waves are known as seismic waves. There are three main types of seismic waves. Each type of wave has a characteristic Speed and manner of travel.

Body Waves: P and S waves

- Body waves

– P or primary waves

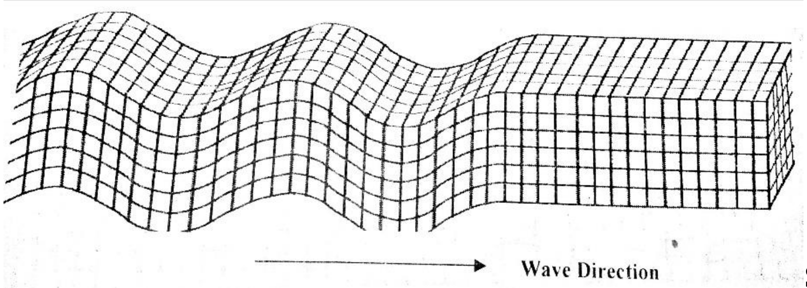
- Fastest waves
- Travel through solids, liquids, or gases (core, mantle and core)
- Compressional wave, material movement is in the same direction as wave movement



P Waves

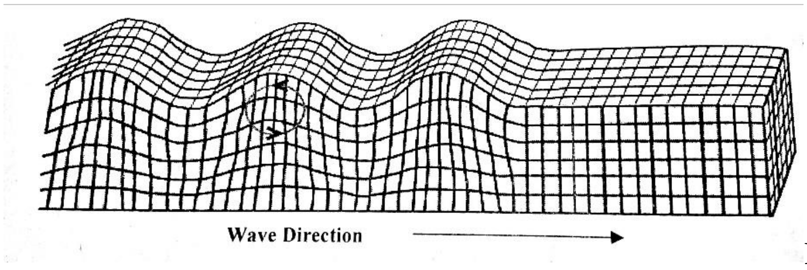
– S or secondary waves

- Slower than P waves
- Travel through solids only (Reflects from the crust mantle boundary)
- Shear waves - move material perpendicular to wave movement.

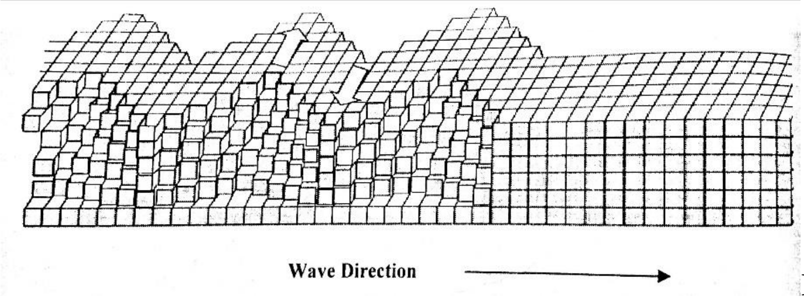


S Waves

- **Surface Waves: R and L waves**



R Waves



L Waves

– Travel just below or along the ground's surface.

– Slower than body waves; rolling and side-to-side movement.

– Especially damaging to buildings.

The slowest-moving seismic waves are called surface waves, or L waves. L waves arrive at a given point after primary and secondary waves do. L waves originate at the epicenter. Surface waves travel along the surface of the earth, rather than down into the earth. Although they are the slowest of all the earthquake waves, L waves usually cause more damage than P or S waves.

Earthquake on the basis of Depth:

Shallow Earthquake: Focus up to 60km below the surface.

Intermediate Earthquake: Focus in between 60-300km.

Deep-seated Earthquake: Focus below 300-700km.

Earthquake on the basis of Cause:

Tectonic (caused by faulting and folding in the crust due to tectonic activities).

Non tectonic (Due to denudation, volcanic earthquakes, due to collapse of cavity rocks).

Effects of Earthquakes

- **Physical damage:** Damage occurs to human settlements, buildings, structures and infrastructure, especially bridges, elevated roads, railways, water towers, water treatment facilities, utility lines, pipelines, electrical generating facilities and transformer stations.
- **Casualties:** The casualty rate is often high, especially when earthquakes occur in areas:

1. a) Of high population density, particularly when streets between buildings are narrow and buildings themselves are not earthquake resistant, and/ the ground is sloping and unstable;
2. b) Where adobe or dry-stone construction is common with heavy upper floors and roofs.

- **Public Health:** The most widespread medical problems are fracture injuries. Other health threats may occur if:

1. a) There is secondary flooding.
2. b) Water supplies are disrupted and contaminated water is used (although to date no documented significant outbreaks of water-borne diseases have followed an earthquake).
3. c) People are concentrated into high density relief camps.

- **Water Supply:** Severe problems are likely because:
- Piped (municipal) water systems may be seriously damaged or become

- Contaminated, especially if sewage systems have also been damaged.
- Reservoir dams may be broken.
- Open wells may be blocked by debris.
- Earthquakes can change levels in the water table with the possible effect of drying up wells and surface springs.
- **Transport Network:** Severely affected due to failure of roads and bridges, turns in railway track alignment, failure of runway.
- **Electricity and communication:** All links affected. Tower collapse, transponders collapse, transformers collapse.
- **Food Supply:** Food distribution and marketing systems may be disrupted. Irrigation works may be damaged. In areas where earthquakes give rise to flooding or a tsunami strikes, food stocks and standing crops may be lost. Typically, however, earthquakes do not reduce the local food supply.

Difference between Magnitude and Intensity of Earthquake:

Magnitude	Intensity
Energy released by earthquakes.	Measures the effect on human and buildings.
It is an absolute quantity.	It is a relative measure.
Measured in Richter scale.	Measured in Modified Mercalli.
Measured by Seismometer.	Measured with direct observation.
Same all over.	Highest at epicenter.

Glacial Lake Outburst Flood (GLOF):

The sudden discharge of large volumes of water with debris from glacial lakes causes glacial lake outburst flood in valleys downstream. These result in serious death tolls and destruction of valuable natural resources such as forests, farms, and costly mountain infrastructures. Glacial lakes are potentially unstable because their end moraines are composed of unsorted and unconsolidated boulders, sands, gravels, etc. The degree of destruction caused by GLOF depends upon the volume of water in the lake and the rapidity and completeness of the drainage. Some lakes may drain quite slowly and are harmless others emptying within a very short time may be catastrophic. The Hindu-Kush Himalayan region has suffered several GLOF events.

Mitigating Measures:

- Draining of lakes.
- Making moraine stronger using ground improvement techniques such that it holds water.

5.7 Engineering Evaluation of geological hazards and risks:

Hazard	Risk
It characterizes the potentiality of the natural events.	It charaterizes the consequences of the natural events.
It is the source of risk that may cause damage.	It is a potential loss of life and property.
It may be classified as relative absolute and monitored hazard.	Risk analysis involves analysis of physical risks, risks of failure of structure.

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Dhar, M.S. and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

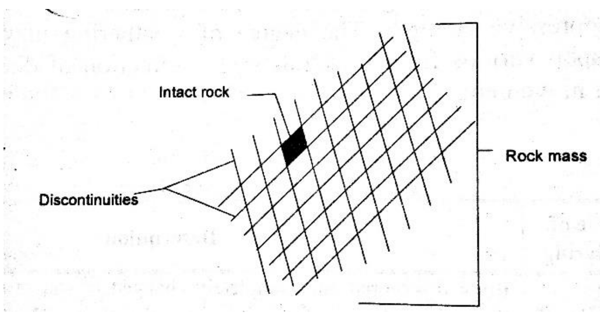
Chapter 6

Measurement, analysis and interpretation of structural geological data

Intact rock does not contain any discontinuities.

Rock mass contains discontinuities.

Rock Mass = Intact Rock + Discontinuities



Rock Mass and Intact Rock

Characteristics of Discontinuities:

- **Orientation of Discontinuities** (Dip, Strike, Dip Amount)
- **Spacing of Discontinuities** (Greater Spacing, Greater Strength)
- **Continuity** (Larger Discontinuity, weaker strength)
- **Separation and infilling of discontinuities** (Clay infilling – low strength due to high chances of sliding (water seepage) and sand infilling – high strength)
- **Surface Characteristics** (Rough surface is good as smooth surface leads to Sliding).
- **Ground Water Condition** (Dry – Good Strength, Wet – Weak Strength)
- **Intact Rock Strength**
- **RQD**

Classification of Rock Mass

- Franklin et.al. (1971)
- Terzaghi (1946)
- Bienia Wisk
- Rock Quality Designation. (RQD).

Rock Mass Rating/Bieniawski:

It is a geo mechanical classification system of rocks developed by Bieniawski between 1972 and 1973.

Parameters:

- Strength of intact rock.
- RQD.
- Spacing of discontinuities.
- Ground water condition.
- Surface characteristics.
- Orientation of discontinuities.

CLASS	**RATING VALUE**	**ROCK QUALITY**
I	100-81	Very Good Rock
II	80-61	Good Rock
III	60-41	Fair Rock
IV	40-21	Poor Rock
V	<21	Very Poor Rock

Q-System:

Q = RQD *J_r* J_w/ J_n * J_a * SRF

Where,

RQD = Rock Quality Designation

RQD = 115.0 – 3.3 J_v (For Field)

J_v – Joint Volume (Joint Volume in 1 m^3)

J_r - Joint roughness number (Obtained from surface Characterstics)

J_n – Joint set number.

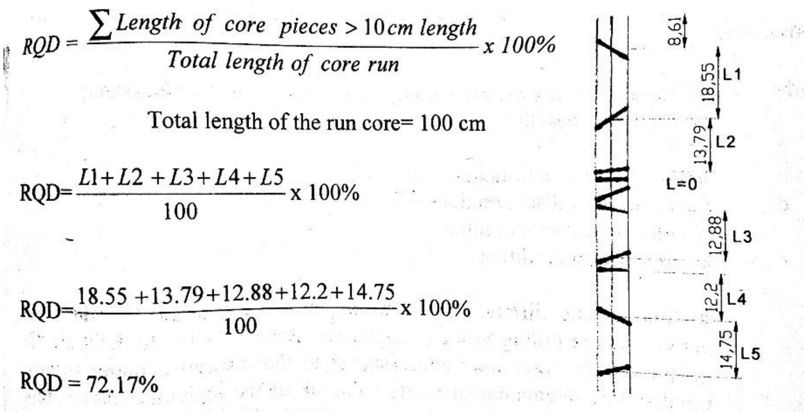
J_w – Joint water Reduction Factor.

J_a – Joint alteration number.

SRF – Stress Reduction Factor.

Q-VALUE	ROCK QUALITY
0.001-0.01	Exceptionally Poor
0.01-0.1	Extremely Poor
0.1-1	Very Poor
1-4	Poor
4-10	Fair
10-40	Good
40-100	Very Good
100-400	Extremely Good
400-1000	Exceptionally Good

Rock Mass Classification based on RQD:



Procedure for measurement and calculation of RQD

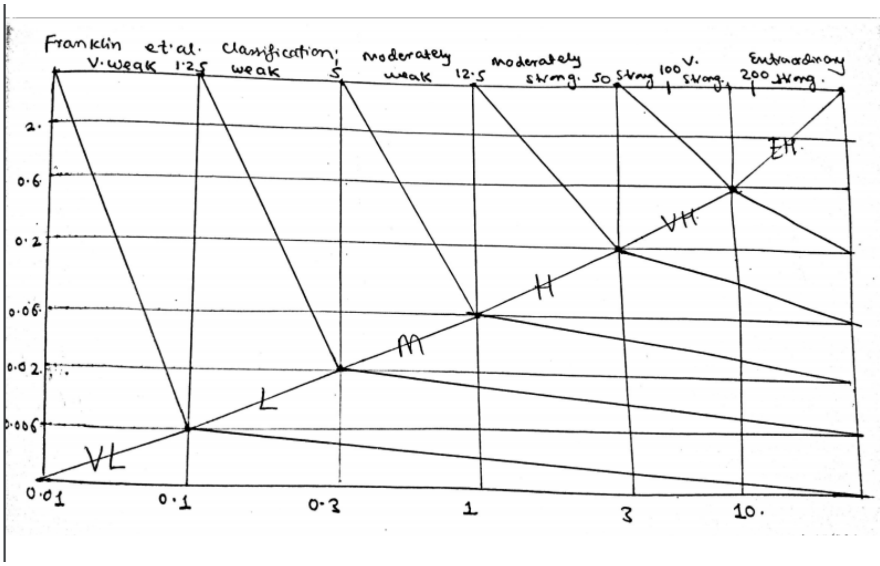
RQD (%)	Rock Mass Quality
<25	Very Poor
25 - 50	Poor
50 -75	Fair

75 - 90	Good
90 - 100	Excellent

Terzaghi Classification:

ROCK TYPE	**CHARACTERSTICS**
Intact Rock	Rock with no joints.
Stratified Rock	Rock with little strength along the bedding plane.
Moderately Jointed Rock	Rock Mass jointed but cemented.
Blocky and Seamy Rock	Jointed rock mass without any cementing of joints.
Crushed Rock	Rock that has been reduced to sand size particles without any chemical weathering.
Squeezing Rock	Rock containing considerable amount of clay.
Swelling Clay	Rock that squeezes primarily from mineral swelling.

Franklin et.al Classification:



Franklin et.al. Classification

Stereonet:

The orientation of a dipping (inclined) plane may be represented by thinking that this plane passes through the centre of projected sphere and intersects the lower hemisphere of the sphere in the form of great circle. This plate is known as spherical projection. The joining of spherical projection to the zenith is called stereographic projection.

Kinematic Analysis or Stability Analysis:

Kinematic analysis is the method used for analyzing the potential for various modes of rock slope failure which occur due to the presence of unfavorably oriented discontinuities.

Plane Failure:

- Slope and rock dip in the same direction.
- The joint plane and hill plane should dip in same direction.
- The inclination of joint plane should be less than the hill plane.
- The strike of the hill slope and joint plane should differ between 20^o.
- The inclination of joint plane > The internal friction angle.

Toppling Failure:

- Dipping in opposite direction.
- No role of internal friction angle.

Wedge Failure:

- Wedge / natural slope should dip in the same direction.
- The dipping of the wedge should be less than the dip of the hill slope.
- The strike difference should be between 20^o.
- The dip of the wedge should be greater than the internal friction angle.

Guidelines for excavation and support of 10 m span rock tunnels in accordance with the RMR system (After Bieniawski 1989).

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock *RMR*: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock *RMR*: 61-80	Full face , 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock *RMR*: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock *RMR*: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock *RMR*: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Guidelines for excavation and support of 10 m span rock tunnels in accordance with the RMR system (After Bieniawski 1989).

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Chapter 7

Geology and Construction Materials

7.1 Aggregates and construction materials

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, recycled concrete and geosynthetic aggregates. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads.

Clay

Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These reactions, among other changes, cause the clay to be converted into a ceramic material. Because of these properties, clay is used for making pottery items, both utilitarian and decorative, and construction products, such as bricks, wall and floor tiles. Used in the cores of dams, or as a barrier in landfills.

Used for making clay pots, mud mortar, furnaces, dams, metals refining.

Sand

Sand are cheaper than cement and imparts strength to the structures and are used to make artificial reefs, artificial islands, brick, mortar, concrete, sand casting, sand bags, etc.

Limestone

Limestone is used for the manufacture of cement and for the construction of sculpture. They are also used as agriculture lime to reduce acidity.

Marbles

Marbles are usually used for decorative purposes and flooring purposes. As they are resistant to heat and fire they are used in furnaces.

Slate

Slate was used as knife in the past. It is used for flooring and roofing purposes. Due to its fireproof property it was used as electric switchboards and was also used as blackboards in schools.

7.2 Requirements for selection of borrow areas

In the past borrow areas were selected largely on the basis of material types and quantities and haul distances. Today, borrow areas receive much more attention and must be carefully planned and designed, because of considerations such as environmental aspects, increasing land values, and greater recognition of the effects of borrow areas with respect to under seepage, uplift pressures, overall levee stability, and erosion.

Selection of Borrow Materials

- **Location**
- **Size and shape**
- **Slopes**
- **Depths**
- **Drainage**
- **Flow condition**
- **Environmental aspects**
- **Clearing**

7.3 Searching, exploration and reserve estimation for construction materials

Reserve Estimation

Q=V*T

Where, Q= Reserve in terms of Tonnage V= volume of ore body

T= Tonnage factor (Specific gravity)

Sp. Gravity of limestone is 2.6 V=S*t

Where, S= cross sectional area

t= Strike length

Cross Sectional Method:

If we assume the distance between neighboring sections be 50m and the density of the ore to be 4gm/cm^3

T = 50*4*5595 = 1.119 million ton where 5595 is the total surface area.

Isopach Method:

This method uses calculation of area and thickness of horizontal bed of sediments directly measuring areal extent of the deposit from the map using grid method.

Extended Area Method:

This method is suitable when bore holes are in grid. The area covered by the outer grid is extended half the distance of grid interval so as to cover each bore holes with the same surface area.

Block Method:

In this method, few blocks are defined depending on thickness and material properties. The surface area is calculated using triangular area method. The thickness of each block is obtained by taking the average of the thickness of the deposit of interest in particular exploratory openings.

7.4 Use of geological, engineering GEOLOGICAL and topographic maps AND aerial photograph in searching of the construction materials (use of different map for construction material survey)

Interpretation of topographic maps

It provides relief and helps to plot the contour. It also gives information on:

– Land surface-relief and position.

– Man-made features.

– Position of gullies, ridges, hills, mountains, plains.

Aerial photographs and geological Maps

This map provides information on:

1. Shape, size, pattern, shadow, tone
2. Provides both regional and local site features
3. Geological information bedding, fault, fold, etc.

Geological Maps

Geological maps provide information on the following topics:

1. Geological structures.
2. Structural attitude of strata.
3. Thickness of each formation.

Engineering geological map

Engineering geological map helps to acquire knowledge on:

- Terrain evaluation.

- Geological hazard.

- Degree of weathering.

- Geomorphological units, fan, hills.

- Construction material survey.

7.5 Application of geomorphology in searching of construction materials

Geomorphology is the scientific study of landforms and the processes that shape them. Geomorphologists seek to understand why landscapes look the way they do, to understand landform history and dynamics and to predict changes through a combination of field observations, physical experiments and numerical modeling. This broad base of interest contribute to many research styles and interests within the field.

Bibliography:

Dhar, M.S. and Ghimire, P.C., 2006, Engineering Geology, Swargadwari Offset Press, Sankhamul, Kathmandu.

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