THE UNIVERSITY OF ZAMBIA
SCHOOL OF MINES

FISRT SEMESTER 8TH May 2023

Engineering Geology GGY3051 Test 1: THEORY

INSTRUCTIONS: Answer all questions. Illustrate your answers wherever possible.
All questions carry equal marks.
TIME: 2 Hours

1.

i. Briefly explain why **silicates** form the **most common groups of minerals** on earth.

- **Because silicon & oxygen are the two most abundant elements in Earth's crust and they readily bond together to form silicate tetrahedron**

✓ More than 70% of the earth's crust is made up of silicon and oxygen.

✓ Oxygen and **silicon** combine to form silicates, which are thus the most common groups of minerals and also most common rock forming minerals [2 Marks].

ii. Describe the **three major classes of rocks** and the **criteria** used to categorise rocks into these three classes.

- The three major classes of rocks are:

  i. **Igneous rocks** – formed by crystallization of molten magma [2 Marks]

  ii. **Sedimentary rocks** – formed by consolidation of sediments [2 Marks]

  iii. **Metamorphic rocks** – formed by transformation of pre-existing rocks under high pressure and temperature [2 Marks]

- The criteria used to categorise rocks into these three classes is origin or **genesis** or **formation** [1 Mark]

iii. List two common **examples of rock types** in each of the three main classes of rocks mentioned in (ii).

- Some of the common igneous rocks are as follows [1 Mark]:

  Granite

Diabase

Basalt

Diorite etc

- Some of the common sedimentary rocks are as follows [1 Marks]:

Sandstones

Shale

Mudstone

Limestone

Chert

etc

- Some of the common metamorphic rocks are as follows [1 Marks]:

Gneiss

Schist

Slate

Quartzite

Marble

Amphibolite

Etc

iv. What are **primary geological structures**? Give an example of a primary geological structure.

- Primary geological structures are those **formed at the same time as the formation of the rock** [1 Marks].
- Example of a primary geological structure is **bedding or ripple marks** [in sedimentary rocks [1 Mark]

v. Igneous rocks are formed by crystallization of molten magma and include volcanic and plutonic rocks. **What is** the **difference** between a **plutonic rock** and **volcanic rock**?

- Plutonic [or Intrusive] igneous rocks are formed when lava flow crystallises **inside the earth.** Typical examples are diorite, gabbro, and granite [1 Marks].
- Volcanic [or Extrusive] igneous rocks are formed when volcanic lava erupts and is cooled on the **surface of the earth**. Typical examples are andesite, basalt, obsidian, pumice, and rhyolite [1 Marks].
- Plutonic rocks are coarser grained than volcanic rocks

vi. What **factors** influence:

a) The **formation of metamorphic rocks**? [1 Mark]

- Metamorphic rocks were formed from previously existing rocks due to **high pressure** and **temperature.**
- [Volcanoes, meteors, earthquakes, and plate-tectonic movements could generate huge pressures and very high temperatures]

b) The type of **structures** and **textures** of **metamorphic** rocks? [2 Marks]

- **Chemical composition of the parent rocks** or rock materials
- The **metamorphic path** [in terms of **temperatures** and **pressures**]

vii. What **geologic events** are implied if **a granitic body is found exposed** at the surface? [1 Mark]

✓ **Faulting and**

✓ **Erosion**

2.

i. What is **Ground Mass in engineering geology**? give three **examples of Ground Mass** in relation to civil engineering structures.

- Ground mass can be defined as that **volume of ground which will be influenced by, or will influence, the engineering works or process.**
- The ground mass influenced by the engineering work is generally very much larger than the mass in direct contact with the engineering work [1 Mark].
- Examples of ground mass in relation to engineering structures: [3 Marks]

✓ The ground influenced by the engineering work could be, for example, that volume of ground stressed by the extra load of a building, a bridge or a dam:

1. In a tunnel the mass could consist of the volume of ground affected by the withdrawal of support caused by tunnel excavation and that volume of ground from which water has been lost by drainage into the tunnel excavation.
2. Dams built in valleys may be endangered by landslides from valley sides – these may be of some antiquity and of natural origin, but new movement may be triggered by the construction process. In such circumstances the involved "mass" would extend into these landslides, which could be situated well outside the construction site.
3. The mass may also be that of an engineering work constructed from naturally occurring geological materials such as earth and rock fill dams, breakwaters, bunds and dykes.

ii. Rocks are involved in many civil engineering projects and rock is characterized in terms of Intact Rock and Rock Mass. Explain:

a) The **difference** between **Intact Rock Strength** and **Rock Mass Strength**? [1 Mark]
Why is there a difference and why is the difference of **importance in engineering** geology? [2 Marks]

- Intact Rock Strength is a fundamental & quantitative engineering property defined as **amount of applied stress at rock failure/rupture**.

- The applied stress may be:
  - Compressive → for compressive Strength
  - Tensile → for Tensile Strength
  - Shear → for Shear Strength

- Rock Mass Strength and deformability is **primarily controlled by a combination of intact rock props and discontinuities [**i.e. their occurrence, nature and characteristics**]** and extent of weathering.
  - In rock masses cohesion can be zero.

- Importance **-** in Engineering Geology emphasis is given to masses [rock mass or ground mass] **because engineering works are built on ground masses, and it is the reaction of the mass which must be calculated or designed for.** Therefore, Intact rock strength must be studied in the context of it's contribution to mass strength.

b) The **difference** between **Rock Mass** and **Ground Mass** [2 Marks].

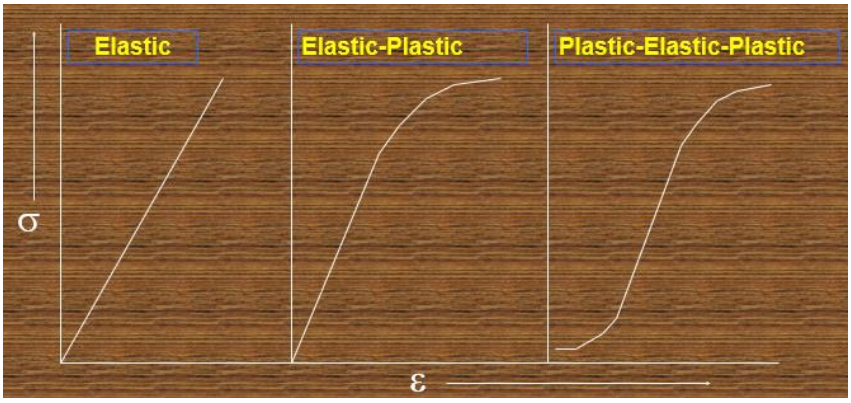
- Rock Mass is a **volume of material made up of rock and discontinuities, that will influence or be influenced by engineering processes or work**.

- Ground mass is **that volume of ground which will be influenced by, or will influence, the engineering process or work.**

c) **Classes of geological materials** on the basis of **shear strength** and **deformability**. Illustrate the categories/ classes **with the aid of diagrams [**3 Marks].

- Deformability:

1. **Elastic**
2. **Elastic-Plastic**
3. **Plastic -Elastic- Plastic**



- Shear strength

  Shear strength of soil is: $\tau = C + \sigma_n * \tan \Phi$:

  i. c = 0 – non-cohesive (sandy) soils
  ii. Φ= 0 – saturated cohesive (clay) soils
  iii. c & Φ – cohesive (loamy or silty) soils

d) The **characteristics of discontinuities** that influence the **strength** and **deformability** of rock masses arising from engineering construction [4 Marks].

- Any 4 of the following should earn full marks:

1. **Orientation** [or geometry] – orientation relative to the direction of imposed stresses
2. **Spacing** – the more closely spaced the discontinuities are the weaker the strength of the intact rock and rock mass.
3. **Continuity** – the more continuous the discontinuity the weaker the rock mass.
4. **Surface characteristics** (roughness/waviness – has important influence on shear strength of discontinuities as it provides friction between two adjacent rocks; weathering / alteration; physical properties of material filling up the space) - Physical weathering results in changes in size and number of discontinuities in rock mass.
5. **Chemical weathering** of rock mass is enhanced by movement of groundwater through network of discontinuities
6. **Thickness & nature of filling** material (if present)
7. **Physical Properties of adjacent rock**
8. **Presence of water**

e) The **significance of discontinuities** in engineering geology? [2 Marks]

- Discontinuities **influence the strength** and **deformability of rock mass** arising from engineering construction on or within the rock mass:
  - ✓ They act as conduits & stores for groundwater
  - ✓ If sedimentary rock layers dip in the same direction as slope, upper layers may slide over the lower ones
  - ✓ May impair performance of engineering structures, if not adequately taken into consideration
  - ✓ May act as conduits for contaminants to the groundwater store (aquifer)
  - ✓ Can also be a problem to mining. For instance, occurrence of joints, bedding and/or faults might cause failure of slopes in open pit excavations or mine tunnels. They might allow water to flow from surface into mine openings.

f) The **key considerations** when evaluating rock mass strength? [2 Marks]

- ✓ **Occurrence & nature of discontinuities**
- ✓ **Knowledge of intact rock props**
- ✓ **Extent of weathering**

3. The figures below show a bridge whose foundation was founded on rock with discontinuities.

Fig. 1

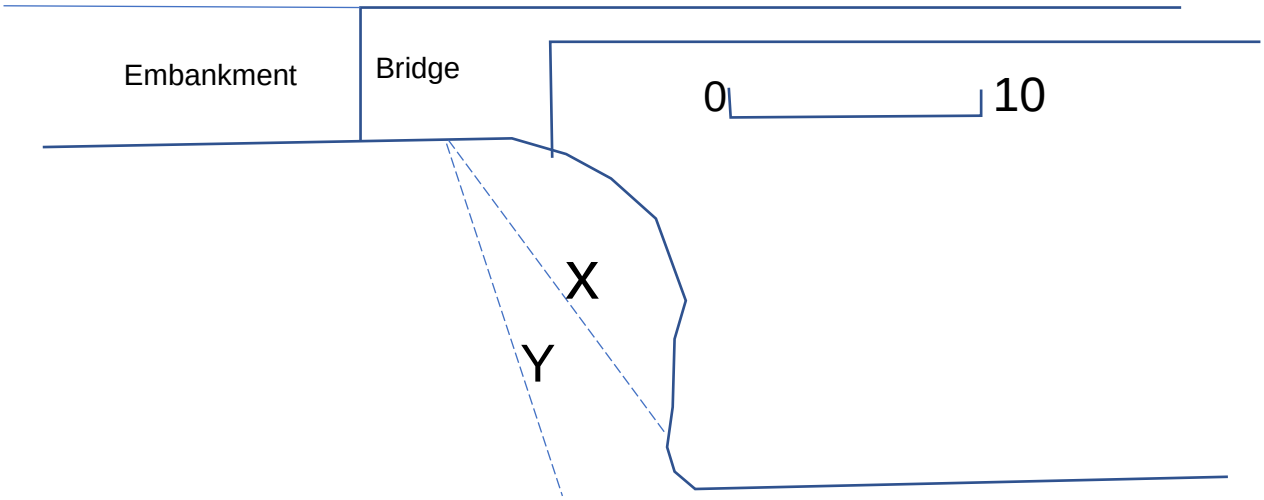
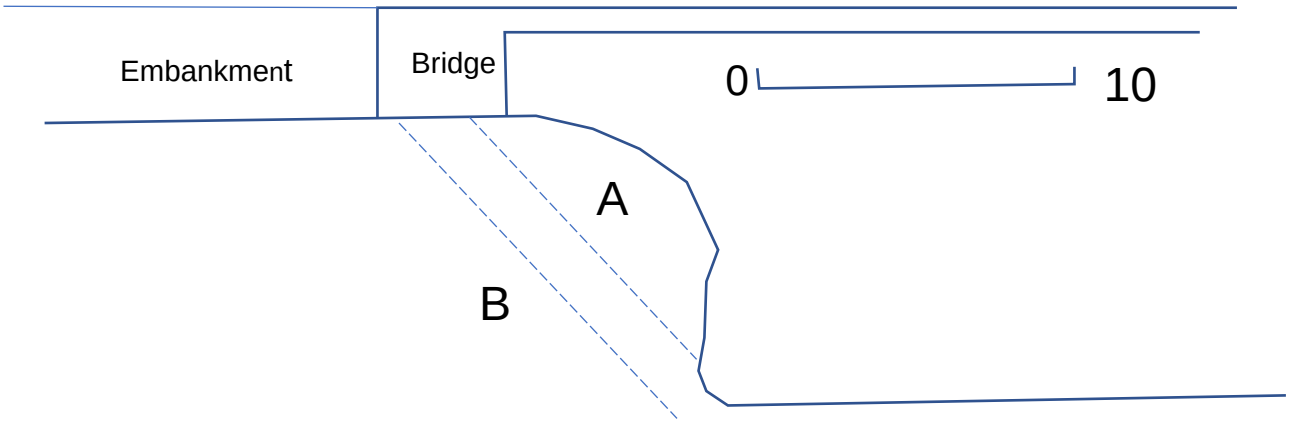


Fig. 2



i. With respect to the first figure, briefly explain why discontinuity '**X'** may permit sliding of the foundation under the bridge whereas discontinuity '**Y'**, with similar characteristics to discontinuity '**x'**, would not pose a hazard to the foundation.

- Discontinuity X may allow sliding because **it daylights (outcrops) on the slope** [5 Marks]
- Discontinuity Y poses no hazard because **it does not daylight (outcrop) on the slope** [5 Marks]

ii. From the second figure, briefly explain why discontinuity '**A'** may induce sliding of the foundation whereas Discontinuity **'B'** poses no hazard although it has the same dip as '**A'**.

- Discontinuity '**B'** poses no hazard because although it has the same dip as '**A'**, **it does not outcrop on the slope. [5 Marks]**

iii. Explain the two important characteristics of discontinuities being illustrated in the two figures? [5 Marks]

- The two important characteristics are:

✓ **location (or distribution) of discontinuities relative to the engineering process or works** and

✓ **orientation of discontinuities**, such as bedding planes, faults and joints, with respect to the engineering stress or processes.

4.

a) Mention **three types of direct stresses** caused by **tectonic forces/ processes** and **the type of plate boundaries** likely to cause each type of stress. [3 Marks]

1. **Tensional stress - Divergent** – plate boundaries (move away from each other)

2. **Compressional stress - Convergent** – plate boundaries (move towards each other
3. **Shear stress - Transform** – plate boundaries (grind horizontally against one another (strike-slip motion)

b) **What type of stress creates faults**? [3 Marks]

i. Compressional stresses

ii. Tensional stresses

iii. Shear stresses

i. Describe the geological structures **hanging wall** and **footwall** [1 Marks].

✓ Footwall – **surface underlying inclined fault plane**.

✓ Hanging wall – **surface overlying inclined fault plane.**

ii. Mention three **geometrical features of a fold**. [3 Marks]

i. Fold **hinge** line

ii. Fold **limbs**

iii. Fold **axial plane** or **axis**

iii. Mention **two main types of folds** and give **two examples of each** [2 Marks]

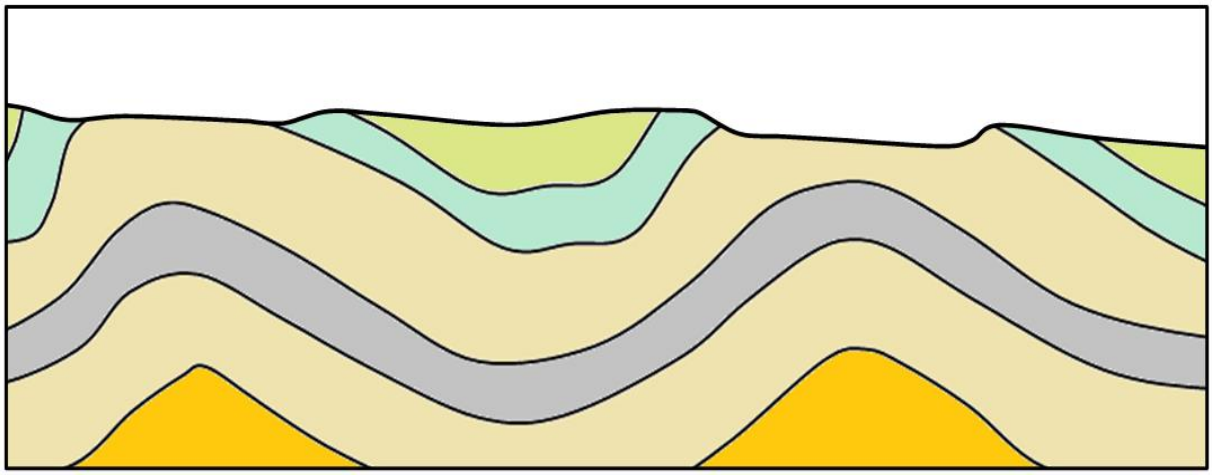
i. **Symmetrical folds** – examples are **open fold** and **isoclinal fold**

ii. **Asymmetrical folds** – examples are **overturned fold** and **recumbent fold**

iv. Label the **types of folds** in the diagram below [1 Mark]

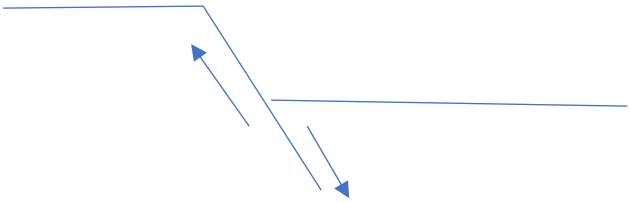
✓ **Asymmetrical Fold** – on the left

✓ **Symmetrical fold** – on the right

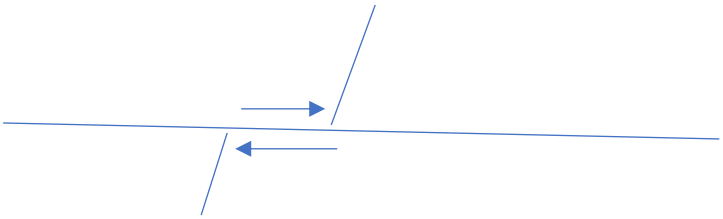


c) Give **geological descriptions of the three types of fault movements** and provide simple sketches to illustrate your explanation. [3 Marks]

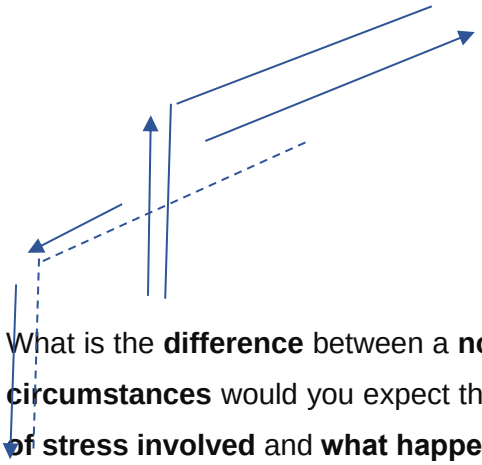
i.In a **dip-slip fault**, movement is parallel to the dip of the fault surface.



ii.A **strike-slip fault** indicates horizontal motion parallel to the strike of the fault surface.



iii.An **oblique-slip fault** has both strike-slip and dip-slip components'



d) What is the **difference** between a **normal fault** and a **reverse fault**, and under what **circumstances** would you expect these faults to form? In each case state the **kinds of stress involved** and **what happens to the earth's crust**. [3 Marks]

- ✓ **Normal Fault** – are generally steeply inclined, along which h**anging-wall block has moved relatively downward.**
- ✓ **Reverse Fault-** are generally steeply inclined, along **which hanging-wall block has moved relatively upward.**
- ✓ **Normal Fault -** is formed under **tensional stresses** and the **crust lengthens.**
- ✓ **Reverse Faulting** is formed under **compressional stresses** and the **crust shortens.**

e) What **type of fault** is associated with **lengthening** of the earth's **crust**? **Normal Fault** [1 Mark]

5. **Site Investigations** are carried out in stages, with each stage building up enough information to allow execution of the next:

i. **What is** a Site Investigation?

SI is a Process by which: **Geologic, Geotechnical & Other relevant surface & sub-surface data/information which affect construction and/or performance of an engineering or building project – are acquired to inform the detailed design of the project/structure** [5 Marks]

ii. Mention **two objectives** of a site investigation, the various stages involved in Site Investigation and outline the key activities involved at each stage

Objectives [any two]: [5 Marks]

- ✓ **To assess suitability of a site & its environs** for proposed project
- ✓ **To provide data for effects of proposed project on its environment** → distress to neighbouring structures resulting from loss of ground &/or lowering of GW Table (which would lead to legal action).
- ✓ To **explore & locate sources of construction materials**.
- ✓ To **observe & record any conditions that may have led to failure of existing or former structures**
- ✓ Where alternatives exist, **to advise on suitability of alternative sites**

Stages involved in SI: [10 Marks]

1. **Project conception stage**

   Activities;

- ✓ **Using secondary data to investigate**: History and previous use of site; any defects /failures of existing or former buildings attributable to foundation conditions; any special features – possibility of earthquakes, flooding, seasonal swelling & shrinkage of ground.

2. **Preliminary investigation**

   Activities;

- ✓ **Carrying out limited exploration using relatively simple & inexpensive techniques to:** Establish basic knowledge, and define the main factors that would influence feasibility, cost & safety of project.

3. **Main investigation stage**

   Activities;

- ✓ **Getting detailed & appropriate parameters for foundation design**: Geotech. props of ground mass through extensive lab & in situ testing –

permeability, shear strength. etc. Distribution of alluvium; ground conditions within zone affected by foundation pressures – geophysical surveys, etc. groundwater levels in various strata

4. **Construction investigation stage**

   Activities:

   - ✓ Monitoring, recording and assessing for discrepancies from results of the Main Investigation and those encountered during construction.

5. **Post construction investigation stage**

   Activities;

   - ✓ **Monitor behaviour of completed engineering work computed on basis of data acquired in earlier stages & comparing with predicted performance**; If behaviour of structure is not same as anticipated, need for further investigations. If there are anomalies, their cause must be established & remedial measures undertaken before severe damage/failure can occur.
   - ✓ **Reveals discrepancies between forecast and actual conditions**.
   - ✓ **Observes anomalies of project behaviour**
   - ✓ **Establishes causes of these anomalies** in order to undertake appropriate remedial measures before severe damage / failure occurs.