Chapter

Introductory Chapter: Engineering Geology

Essa Georges Lwisa

1. Introduction

Engineering geology is the application of geology to the engineering study for the purpose of ensuring that the geological aspects related to the site, scheme, construction, process and maintenance of engineering works are recognized and taken in consideration [1].

Engineering geologists provide geological and geotechnical endorsements, analyzes, and designs related to human development and different kinds of structures. The field of engineering geology is primarily in the field of Earth-structure interactions, or the investigation of how Earth or Earth processes affect human structures and human activities [2].

Topics of Engineering Geology are:

- Rocks and geological structures: rock types, structures, plate tectonic. Engineering geological maps.
- Geo hazards: boundary hazards, ground subsidence, land slide, slope failure.
- Geological masses: mass fabric, ground mass description, weathering, rocks discontinuities.
- Field tests and measurements: tests in boreholes and excavations, engineering geophysics, seismic methods, electrical and magnetic methods.
- Ground improvement: shallow and deep impaction, grout treatment, bentonite suspension, ground anchor
- Water reservoirs and dams: dam design parameters, geological influences upon the selection of reservoir sites, dam foundations, dam seismicity.

2. Rocks and geological structures

Geologic structures are usually the result of the powerful tectonic forces that occur within the earth. These forces fold and break rocks, form deep faults, and build mountains. Repeated applications of force can create a very complex geologic picture that is difficult to interpret.

2.1 Rock types

Types of rocks are igneous, sedimentary and metamorphic. Igneous rocks are formed when molten rocks cools and solidifies. Sedimentary rocks arise when particles settle down out of water or air, or by precipitation of minerals from the water. Pile up in layers. Metamorphic rocks result when existing rocks are altered by heat, pressure, or reactive fluids, such as hot water rich in minerals [3].

2.2 Rock structures

Most rocks are not uniform all the time. On a scale best measured in millimeters or centimeters, they are made up of individual mineral grains that differ in size, shape and composition. The geometric properties of these small rock features and the relationships between them form rock texture. Rocks also commonly differ on larger scales, and are best measured in centimeters to meters to kilometers. The disparate and small-sized individual features of the rocks are called "structures". Our mission is to find out if there are rock structures that can provide clues to the formative environment of rocks: whether they are igneous, sedimentary or metamorphic.

There are many rock structures. Geologists usually divide them into "primary" and "secondary" structures [4].

- Elementary structures that were formed before or at the same time that matter is in the process of converting to rocks.

- Secondary Structures, imposed on rocks after they have already formed.

2.3 Plate tectonic

Plate tectonics is a scientific theory that describes the large-scale movement of seven large plates and the movements of many smaller plates from the Earth's lithosphere, since tectonic processes on Earth began between 3.3 and 3.5 billion years ago. The model is based on the concept of continental drift, an idea that developed during the early decades of the twentieth century. The theory of plate tectonics was accepted by the geological scientific community after sea floor propagation was validated in the late 1950s and early 1960s [5].

The lithosphere, the planet's rigid outermost layer, is divided into tectonic plates. The Earth's lithosphere consists of seven or eight main plates and many minor plates. When the plates encounter, their relative movement controls the type of boundary: convergent, divergent, or transformational. Earthquakes, volcanic activity, mountain building, and oceanic trench formation occur along these plate boundaries. The relative movement of the plates usually ranges from 0 to 100 mm per year [5].

2.4 Engineering geological maps

The Engineer Geological Mapping is a guide to the principles, concepts, methods, and practices involved in geological mapping, as well as applications of geology to engineering [6].

3. Geo hazards

Geographical hazards are geological and environmental conditions and involve long-term or short-term geological processes. Geographical risks can be relatively small features, but they can also reach huge proportions (for example, a landslide or submarine) and affect the local and regional social economy to a large extent (for example, a tsunami) [7].

3.1 Boundary hazards

There are three different types of converging plate boundaries recognized: continental, oceanic -oceanic, and continental - continental.

An oceanic ocean border is when two oceanic plates meet. Usually one plate submerges under the other and in the process a deep trench forms in the ocean and can also lead to the formation of undersea volcanoes [7].

A continental oceanic boundary is when an oceanic plate meets a continental plate and the denser oceanic plate descends below the continental plate [7].

The continental boundary is when two continental plates meet and neither of them subsides below the other because the continental rocks are relatively light and resist downward movement [7].

3.2 Ground subsidence

Subsidence is the sinking or settling of the Earth's surface. It can happen through a number of processes. Land subsidence may result from settling of local low-density soils, or the cavity of natural or man-made voids underground. Subsidence may occur gradually over many years as sagging or depressions form on the earth's surface. In rare cases, a sudden landing such as a dangerous ground hole may swallow any part of the structure in that location, or leave a dangerous, steep hole [8–10].

3.3 Land slide

A landslide may be defined as the movement of a mass of rock, debris, or land down a slope. Landslides are a kind of "mass wasting", which refers to any downward movement of soil and rocks under the straight influence of gravity. The word "landslide" includes five slope movement patterns: falls, slides, slides, spreads and flow [8, 11].

Landslides have several causes. Slope movement happens when forces acting on the lower slope surpass the force of the earth materials that make up the slope. Causes contain aspects that increase the effects of slope forces and aspects that contribute to a decrease or increase in strength. Landslides can start on slopes that are already on the edge of movement due to precipitation, snowmelt, changes in water level, table erosion, changes in groundwater, earthquakes, volcanic activity, disturbance caused by human activities, or any combination of these factors. Earthquake vibration and other aspects can also activate underwater landslides. These landslides are called undersea landslides. Sub-sea landslides sometimes cause tsunamis that damage seaside areas [9, 11].

3.4 Slope failure

Slope failure is the phenomenon of suddenly collapsing slope due to poor self-holding capacity of the earth under the influence of rain or earthquake. Due to the sudden collapse of the slope, many people fail to escape from it if it occurs near a residential area, resulting in a high death rate [12].

4. Geological masses

The size of the land that will be affected or will affect the engineering work. All rocks and many soil masses have discontinuities and their presence in rocks or soil mass is of prime importance for all engineering work in rocks or soil.

Mass movement, also called mass wasting, is the movements of soil and rock debris down slopes in response to gravitational pull, or the rapid or gradual sinking of the Earth's surface in a mostly vertical direction. Previously, the term mass wasting referred to a variety of processes by which large masses of cortical material are transported by gravity from one place to another. More recently, the term mass movement has been replaced to include processes of mass wasting and inundation of confined areas of the Earth's surface. The group movements on the ramps and the submersible group movements are often assisted by the water and the importance of both types is the role that each plays in changing the earthly shapes [13, 14].

4.1 Mass fabric

In geology, the texture of rocks defines the spatial and geometric formation of all the elements that make up it. In sedimentary rocks, the tissue developed depends on the deposition environment and can offer evidence on current developments at the time of precipitation. In structural geology, fabrics could deliver evidence on both the direction and size of strains that have controlled a particular piece of deformed rock.

Fabric types: [15, 16].

- Primary fabric
- Shape fabric
- Crystallographic preferred orientation
- S-fabric
- L-fabric
- Penetrative fabric
- Magnetic fabric.

4.2 Ground mass description

General term from the fine-grained, not discernible part of a rock. In igneous rocks, this is the part of the rock that is not phenocrysts, and can help in determining the composition of extrusive rocks. In sedimentary rocks, it typically refers to the fine-grained components, namely mud. In metamorphic rocks, it is usually referring to material between porphyroblasts or a low-grade rock with only microscopic mineralization [17].

A matrix or ground mass of rock is the mass of fine-grained substantial into which grains, crystals, or large holes are incorporated.

The matrix of igneous rocks contains of fine-grained, usually microscopic, crystals in which bigger crystals are fused. This porphyry tissue is revealing that magma was cooled in multi stages.

A sedimentary rock matrix is a fine-grained sedimentary material, such as clay or silt, in which larger grains or lumps are incorporated. It is also used to describe the rock material in which the fossil is included [7, 17].

4.3 Weathering

Weathering is the collapse of rocks on the Earth's surface by rainwater, temperature extremes, and biological activity. It does not involve removing rock material. There are three types of weathering, physical, chemical and biological [18].

4.4 Rocks discontinuities

Discontinuity in geotechnical engineering (in the geotechnical literature it is often referred to as a joint) is a surface or surface that indicates a change in the physical or chemical properties of a soil or rock mass. The discontinuity can be, for example, bedding, schistosomiasis, foliation, joint, splitting, fracture, cleft, crack or failed plane. Mechanical and integral discontinuities are separated. Interruptions may occur multiple times with the same mechanical properties on a large scale in a discontinuity group, or they may be a single interruption. The discontinuity causes the mass of soil or rock to anisotropy [7, 19].

5. Field tests and measurements

Geophysical surveys are primary sources for both qualitative and quantitative data regarding ground conditions, and they form an essential part of many on-site investigations. There are several reasons for this, perhaps the most important of which is that it provides, for design purposes, parameters that represent a more realistic assessment of geotechnical ground conditions than is usually the case with laboratory tests. The samples used for laboratory tests, due to their small size, may not be sufficiently representative of the ground from which they are taken. In particular, it may not have widespread discontinuities, found in rocks or soil masses, which greatly affect the engineering properties of the materials in question. Moreover, the sampling inevitably involves some disturbances in stress conditions and water content of soil and rocks so that the parameters obtained in the laboratory are not fully representative of the conditions at the site [20].

5.1 Tests in boreholes and excavations

Geotechnical investigations are performed by geotechnical engineers or engineering geologists to obtain information about the physical properties of soil works and proposed soil foundations for the proposed structures and to fix the distress of earthworks and structures caused by subterranean conditions. This type of investigation is called site inspection. In addition, geotechnical investigations are also used to measure the thermal resistance of soil or backfill materials required for underground transmission lines, oil and gas pipelines, radioactive waste disposal and solar thermal storage facilities. The geotechnical investigation will include surface exploration and subsurface exploration of the site. Sometimes, geophysical methods are used to obtain data about sites. Subsurface exploration usually includes soil sampling and laboratory testing of recovered soil samples.

Some of the on-site tests are: standard penetration test, dynamic cone penetration test, cone penetration test [7, 21].

5.2 Engineering geophysics

Engineering geophysics consists of the spatial studies of the Earth's surface and subsurface. The geophysical signal is measured, processed and analyzed in order to discover anomalies in the subsurface and determine the composition and physical properties of rocks, layers, etc. This information is essential in engineering planning, calculations and infrastructure project design, energy and environment [8, 22].

Use of geophysical methods to obtain information for civil engineering. The goal is usually to describe not only the geometry of the Earth's interior but also its nature (for example, its elastic properties as determined by measurements of seismic velocities and density). Shallow, gravitational, magnetic, and electrical seismic reflection and refraction methods and sampling methods are commonly used to find bedrock depth and sediment strength for foundation purposes, to determine the rupture (qv) susceptibility of rocks, to measure the degree of rupture, to detect underground cavities, to detect pockets of gas near the surface, to determine The dangers of buried pipelines under the sea floor, buried pollutant barrels, and landfill safety. In water-covered areas, high-powered sphygmomanometers, sparks, gas pistols, and other seismic reflection methods employ high frequencies (up to 5 kHz) to obtain reflections from shallow façades so that bedrock and the nature of the filling material can be diagnosed. Such methods are also used to locate large pipelines on the sea floor or to bury them on the sea floor by the prominent deflections they generate. It is usually limited to a shallow breakout of over 1,000 feet [22].

5.3 Seismic methods

Seismic tomography is a technique for imaging the Earth's interior with seismic waves produced by earthquakes or explosions. P and S waves and surface waves can be used for tomography models with different resolutions based on seismic wavelength, wave source distance, and seismometer array coverage [23].

Reflective seismology (or reflection seismic) is a technique of geophysics exploration that uses principles of seismology to approximation the properties of the Earth's interior from reflected seismic waves [24].

Seismic refraction is a geophysical standard governed by Snell's law of refraction. The seismic refraction method uses the refraction of seismic waves by rocks or soil deposits to characterize the subterranean geological conditions and geological building [24].

Seismic refraction is browbeaten in engineering geology, geotechnical engineering, and exploration geophysics. Seismic refraction traversal (seismic lines) are performed using a mixture of seismometers or geophones and a power source [24].

The procedures are based on the fact that seismic waves have different velocities in different types of soil or rocks. Waves are refracted when they cross boundaries between different types of soil or rocks. These methods allow the fortitude of general soil types and the estimated depth of stratigraphic boundaries or bedrock [24].

5.4 Magnetic and electrical methods

Magnetic techniques, including aeromagnetic surveys to map magnetic anomalies.

An aeromagnetic survey is a common type of geophysical survey that is performed with a magnetometer on board a plane or pulled behind it. This principle is similar to the magnetic survey conducted with a handheld magnetometer, but it allows for much larger areas of the Earth's surface to be quickly covered for regional reconnaissance. Plane typically flies in a grid-like pattern with line spacing and elevation to determine data accuracy (and cost per unit area of scan) [25].

Electrical techniques, including electrical resistivity tomography and induced polarization [26].

Stimulated polarization (IP) is a geophysical imaging technique used to determine the electric chargeability of subsurface materials, such as ores [27, 28].

Konrad Schlumberger originally discovered the effect of polarization when measuring the resistance of rocks [27, 28].

Induced polarization is a widely used geophysical method in mineral exploration and mine operations [27, 28].

IP scanning can be performed in both time area and frequency area mode [28].

Electromagnetic methods, such as magnetotellurics, ground penetrating radar, transient/time-domain electromagnetics and SNMR [29, 30].

Magnetotellurics (MT) is an electromagnetic geophysical method for inferring subsurface electrical conductivity from measurements of natural and geoelectric magnetic field anisotropy at the Earth's surface. Search depth ranges from 300 meters underground by recording higher frequencies up to 10 km or deeper with sounding for prolonged periods [29, 30].

Ground penetrating radar (GPR) is a geophysical method that uses radar pulses to photograph the Earth's interior. It is a non-intrusive way to survey below the surface to check underground facilities such as concrete, asphalt, minerals, pipes, cables or masonry [31, 32].

Transient electromagnetism, is a geophysical exploration method in which electric and magnetic fields are induced by transient pulses of an electric current and the subsequent decay response is measured [33, 34].

6. Ground improvement

Ground improvement refers to a technology that improves the engineering properties of a mass of treated soil. Usually the properties that are modified are shear strength, stiffness, and permeability. Floor improvement has evolved into a sophisticated tool to support foundations for a variety of structures [35].

6.1 Shallow and deep impaction

Soil compaction is the process in which pressure is applied to the soil causing concentration as air is exiled from the pores between the soil grains. The compaction is usually the result of heavy machinery compressing the soil [35, 36].

The available techniques can be classified as: Static, Impact, Vibrating, Gyrating, Rolling, and Kneading [35, 36].

6.2 Grout treatment

A ground remediation operation performed to accomplish one of two things, either to reduce water flow or to improve the properties of the ground by drilling wells in the foundation and injecting material under pressure into the subsurface foundation [35, 37].

Each hole in the filler project is an extension of previous exploration pits and the data collected is used to increase the understanding of subsurface conditions. Injectable materials used for filler range from cementitious plaster materials (particles) to a variety of chemical slurries [37].

Filling foundations in dams and canals to reduce water flow are among the oldest applications of fillers, dating back to the early nineteenth century with plaster curtains in use since the 1890s [37].

6.3 Bentonite suspension

The different kinds of bentonite are called after their main element, like potassium, sodium, calcium, and aluminum. Bentonite is usually made by weathering volcanic ash, regularly in the presence of water. However, the term bentonite, as well as a similar clay called Tonstein, has been used to describe clay layers of uncertain origin. For industrial purposes, there are two main classes of bentonite: sodium and calcium bentonite. In stratigraphy and tephrochronology, fully demixed ash layers (weathered igneous glass) are commonly referred to as K-bentonites when the predominant clays are lit. In addition to montmorillonite and the attachment of other common clays that are sometimes prevalent are kaolin. Clays dominated by kaolinite are commonly referred to as tonsteins and are commonly associated with charcoal [35, 38, 39].

6.4 Ground anchor

Ground anchors are a device designed to support structures, most commonly used in geotechnical and construction applications.. Ground anchors are used in temporary and permanent applications [35].

Ground anchors are commonly used in civil engineering and construction projects, and have a variety of applications, including: [35].

- Retaining walls.
- Structural support of temporary buildings and structures,
- Tethering marine structures.
- Supporting guyed masts.
- Anchoring utility poles.
- Landscape, anchoring trees, often semi-mature transplants.
- General security, as in anchoring small aircraft.
- Sporting activities, such as slacklining or abseiling.

7. Water reservoirs and dams

The reservoir is an non-natural lake in which water is stored. Most reservoirs are made by building dams across rivers. A reservoir can also be made from a natural lake whose outlet has been blocked to control the water level. The dam controls the amount of water that streams from the reservoir [40].

7.1 Dam design parameters

Design criteria for earth dams are: [41].

- Sufficient capacity is provided for the drainage and the float basin so there is no risk of overflow of the dam.
- The leakage flow across the bridge is controlled so the amount lost does not interfere with the target of the dam and there is no erosion or erosion of the soil. In this regard, the leakage line should remain well within the downstream front of the dam and the part of the weir should be drained on the downstream side of the impermeable core.
- The uplift pressure caused by the leakage from below is not enough to cause the pipes.

- Bridge slopes are stable under all tank operating conditions, including rapid drawdown and during continuous leakage under a full tank.

- The stresses imposed by the bridge on the foundation are less than.

- The upstream face is properly protected ((stone throw, riprap, revetment) from abrasion caused by the movement of waves, and the lower face (anti-arms, grass) is protected from the impact of rain.

7.2 Geological influences upon the selection of reservoir sites

Topography: In the geological sense, topography is the composition of the Earth's surface, and includes the location, size and shape of physical features such as hills, hills, valleys, streams, and lakes. Topographic maps show these features. Examination of a topographic map combined with a survey of the land is often sufficient to determine the overall topographical suitability of the dam and the location of the proposed reservoir. This is the first and easiest step in determining the feasibility of a proposed project [25].

Hydrology and Hydrogeology: Hydrology is the science related to the Earth's water, its distribution and phenomena. For a dam and reservoir project to be successful, it must have an adequate and continuous supply of water suitable for the tank's intended uses. Hydrological information and investigations will be required to varying degrees, depending on the size of the project. Annual rainfall, the ratio of the catchment area to the reservoir area, and the size of the stream flow must be known in all seasons of the year. It is also necessary to study groundwater science to determine whether the groundwater will contribute to the reservoir or whether the reservoir will lose water to the groundwater system. Tank capacity, maximum and minimum tank yield must also be known so that water commitments do not exceed the amount of water available [25].

Geology: To properly judge the feasibility of the proposed dam and reservoir project, it is necessary to know the type, distribution and succession of rocks and other geological units in the project area, for the stability of the dam and water - the ability to maintain the reservoir is directly related to them. The aspects of geology that must be evaluated to determine the suitability of a project site include:

- The directions of the units, whether flat or tilted.

- The depth and extent of weathering.

- The presence and condition of breaks, such as open or closed joints, faults, or solution channels.

- The presence of layers of sand or silt and old soil areas.

The engineering properties of the geological units are directly related to the type of rocks or unconsolidated material involved, and thus to the geology [25].

7.3 Dam foundations

A site investigation shall be carried out prior to construction to verify the nature of the foundation. By knowing the actual foundation condition at the site, the earth dam can then be designed accordingly. An embankment foundation is said to be suitable if it is able to provide stable support for the bridge under all conditions of saturation and loading and that it provides adequate leakage resistance to avoid excessive water loss [42, 43].

The foundation of the dam may be broadly classified into three types which are rock foundations, coarse-grained material foundations and fine-grained material foundation [43].

These foundations may need to be treated to stabilize any weakness and also to reduce leakage. On the other hand, rock foundation must be inspected for erosive leakage and excessive uplift pressure. If such conditions exist, the foundation must be considered grouting [9, 43].

7.4 Dam seismicity

Induced earthquakes refer to the earthquakes and slight tremors that result from human activity that alter the stresses and stresses on the Earth's crust. Most of the induced earthquakes are of low magnitude [44].

Seismic hazard from induced seismic activity can be assessed using techniques similar to natural earthquakes, although one account for unstable earthquakes. Earthquakes vibrating from induced earthquakes appear to be similar to those observed in natural tectonic earthquakes, although differences in rupture depth need to be taken into account. This means that ground motion models derived from natural seismic recordings can be used, which are often more numerous in robust motion databases compared to induced earthquake data. Then, a risk assessment can be performed, taking into account earthquake risk and the vulnerability of vulnerable items (such as local residents and building stock). Finally, risk can, in theory at least, be mitigated, either through modifications of the risk or reduced exposure or vulnerability [44].

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Author details

Essa Georges Lwisa
Chemical and Petroleum Engineering Department, United Arab Emirates University, Al Ain, UAE

*Address all correspondence to: essa.lwisa@outlook.com; essa.lwisa@uaeu.ac.ae

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