1.1 INTRODUCTION

The planet Earth is in a constant state of change due to the geological processes. They modify the Earth’s surface by causing erosion and destruction of existing rocks; deposition and formation of new sediments in the seabeds; creation of new rocks underground and thereby subsequently affecting further deformation to them with time, adding to the complexity of ground conditions. The driving force for all these geological processes is the energy from the hot interior of the Earth.

Geology is the science that deals with the origin, age, composition, internal structure, surface features and history of the Earth. It includes the processes taking place inside the Earth, discovering its mineral wealth, and techniques to preserve the Earth. It also deals with the evolution and modifications of various surface features like mountains, rivers, coastlines, etc. Geology may also be defined as an applied science to advance our understanding of the processes that can result in natural disasters such as earthquakes, tsunamis, landslides, floods, etc. Therefore, it may be said that geology is the study of the Earth.

The application of geology to civil engineering projects is known as ‘engineering geology’. It may be defined as the application of geological data, techniques, and principles for the study of
1. Naturally occurring rock and soil materials, and surface and sub-surface fluids
2. Interaction of introduced materials and processes with the geologic environment, and geological factors affecting the planning, design, construction, operation and maintenance of engineering structures
3. Recognition, protection, development and remediation of groundwater resources

Application of the geologic sciences to engineering practices ensures that the geological factors affecting the location, design, construction, operation and maintenance of engineering works are recognized and adequately provided for. The significance of site selection for dams, reservoirs, tunnels, airports, etc., cannot be over-emphasized. Further, groundwater exploration, watershed development and groundwater pollution, which are covered in the water resource
engineering, also require some knowledge of the geology. Furthermore, problems associated with identification of sites prone to earthquakes and landslides, and their solutions also need a sound knowledge of geology.

Precise geological survey for important projects is carried out by geologists to foresee and solve the site-specific problems. However, civil engineers also must have a sound knowledge of geology to appreciate and understand the geological reports prepared by geologists, and use the data for solving the site specific problems. The principal objective of acquiring an in-depth knowledge of geology is to prevent disasters, protect and save life, as well as design structures against damage caused by geologic conditions.

Although the traces of know-how of geology in its rudimentary form, are available to the ancient mankind, but specific application of the science of geology is supposed to have originated in the eighteenth century. Probably it started with excavations in rocks and kinds of soil, speculations were made about the origin and nature of rocks, and relationships between similar rocks at other places were correlated. However, in the later nineteenth century, both engineering and geology advanced to refinement. In the early twentieth century, with the developments in soil mechanics, the importance of geology became apparent and gained importance in planning, design and construction of civil engineering projects. In due course of time, failure of structures emphasized expert assessment of geological conditions for big civil engineering projects and necessitated the employment of geologists to provide expert opinion. It must be remembered that a lack of knowledge about the nature of the ground conditions may cost lives, money, and result in the consequential delay in completing the project. Also, the success of a civil engineering project is totally dependent on the findings based upon geological investigations.

1.2 SCOPE OF ENGINEERING GEOLOGY

The objective of engineering geology is to meet the requirement of an engineering project, and involves the study of rock types and the structures associated with them. As defined in the previous section, engineering geology deals with the application of geology for a safe, stable and economic design and the construction of a civil engineering projects. For a civil engineer, therefore knowledge of the fundamentals of engineering geology is as essential as those of mechanics, strength of materials, theory of structures, etc. The knowledge of the geology of an area and geological features in planning, design and construction of civil engineering projects is not only desirable but essential as well.

Most civil engineering projects either involve excavation of soil and rocks, and/or involve loading the Earth by building structures on it. The excavated rocks may form part of the project, e.g. reservoir, or may be used as construction material. Geologists work hand-in-hand with civil engineers for the site selection and ground treatment for important civil engineering projects such as dams, reservoirs, tunnels, etc. Study of engineering geology is important for the reasons to follow:
1. It enables a geologist to understand the nature of geological information that is essential for the safe design and construction of a civil engineering project. Further, he is responsible for interpreting site specific geological data and for providing conceptual models representing the morphology, geological structures and classification of the rock units.

2. It enables a civil engineer to understand engineering implications of certain conditions related to the area of construction, which are essentially geological in nature. Further, he develops an appreciation of the relevance and importance of geologic observations and interpretations.

It may be noted that a civil engineer is neither expected nor required to undertake geological investigations of the area. However, he/she must be capable of understanding, analyzing and critically discussing a geological report of the area prepared by a geologist. With adequate knowledge of engineering geology, a civil engineer becomes capable of deriving maximum useful information pertaining to the geological conditions of the project site. In fact, while executing the construction, the task of a geologist is to specify the probable difficulties and the civil engineer is supposed to overcome them. The scope of engineering geology with reference to projects such as dams, tunnels, tube railways, water resource development, town and regional planning, etc., can not be overemphasized. Some of the applications of engineering geology are presented in the sections to follow.

1.3 INFRASTRUCTURE DEVELOPMENT

Some of the important civil engineering projects that are indicators of the prosperity and economic growth of a country are power plants, multi-storey buildings, dams and reservoirs, aerodromes and airports, embankments and retaining structures; and linear structures e.g. highways, bridges, tube railways, tunnels, irrigational and navigational canals and water bodies, pipelines for oil, gas and water transport, etc. The feasibility, planning, design, economy, and the safety of the project may depend on the geological conditions of the site of construction. Therefore for planning, design and construction of civil engineering projects, the geological information about the site of construction (or excavation) and about the excavated natural materials of construction is of great importance.

1.3.1 Planning

During the planning stage of a civil engineering project, there may be several possible optional sites/routes. The objective of the engineering geologic studies is to give a comparative evaluation of all the options so as to confirm the most feasible and optimum one. However, for proper planning of an engineering project the information related to topography, hydrology and geology of the area form the base for deriving economy and achieving intended serviceability and life time safety, and making it cost effective.


- **Topography**

Topographic maps providing details of relief features of the probable sites for the project are prepared, if not available. The relative pros and cons of the probable proposed sites are studied. From the topographic maps, the presence and nature of slopes, size, contours, depths of valleys and gorges, and the rate of change of elevation in various directions are determined. These parameters then help to decide the most suitable site for construction.

- **Geology**

The geological maps of different scales for the proposed site are useful in depicting the petrological character and structural behaviour of rock types. From these maps, information regarding the fracturing and displacement of the site rocks undergone in the past can be understood. Furthermore, the information related to availability of construction materials in the area can also be had. The information with regards to the location and the limit of exploratory operations (location of test boreholes, trial pits, etc.) for subsurface investigations, ground improvements, etc., is decided, based upon the geological maps.

- **Hydrology**

Surface water and groundwater have great bearing over the stability and cost of engineering structures. Hydrological maps are useful in establishing the distribution and geometry of the surface water channels, their occurrence and depth below the surface of the Earth. Such data is of great importance in proper planning of most civil engineering projects.

### 1.3.2 Design

In most cases, the geological characters and conditions finally dictate the engineering design of the project. For example, if a choice is to be made for the type of dam amongst earthen, gravity and arch dams, the geological conditions of the site will govern. The profile of the gorge or the valley, the strength of the rocks at the base and on the embankments need very thorough testing and analysis before deciding the final size, shape and other design parameters of the dam.

Some of the geological characters that have a direct or indirect bearing upon the design of a proposed project, in general, are the following:

1. The existence of hard bed rocks and their depth and inclination with the surface.
2. The mechanical properties along and across the site of the proposed project. The important properties are compressive strength, shear strength, transverse strength, modulus of elasticity, porosity and permeability, resistance to decay and disintegration.
3. Presence, nature and distribution pattern of planes of structural weakness—joints, faults, folds, cleavage, schistosity and lineation, etc.
4. The position of groundwater table in its totality including points of recharge and discharge and variations during different periods of the year. This also governs the stability of foundations for civil engineering structures.
5. Seismic character of the area and prediction about future seismicity.

1.3.3 Construction

For the execution of civil engineering projects, geological background is of great importance. Selection of appropriate construction materials derived from the natural bedrocks requires geological base. Desired durability and expected life of structures can be ensured from the knowledge of mineralogy and petrology of the natural materials such as sand, gravel, crushed rocks and soil.

In geologically sensitive areas, such as coastal belts, seismic zones, and permafrost regions, an in-depth knowledge of geological history of the project area is a must.

In coastal areas, behaviour of rocks towards waves, currents and marine environment must be fully understood, both at the planning stage and during the execution of the work. This may require special types of construction and construction techniques.

In regions of high seismicity, since lightweight structures are preferable, the weight of construction materials becomes a crucial factor. Geological knowledge is of great importance in handling problems concerned with earthquakes and landslides. Furthermore, in earthquake prone areas, the soil type is of utmost importance; some of the soils liquefy under strong ground motions.

In permafrost regions, the soil remains permanently frozen up to a certain depth, all the time. This presents problems that can be solved only by a proper understanding of the ground below.

Construction of underground projects e.g. tunnels require a thorough knowledge of the geological characters and the settings of rocks that may be encountered. The same type of rock may behave differently under different natural rock settings. Rocks, being anisotropic in character, do not behave according to empirical thumb rules. Therefore, stability of a structure constructed on rocks, or through rocks, or with aggregate from rocks depends considerably on the understanding of the nature of rocks.

1.4 WATER RESOURCES DEVELOPMENT

In the area of water resources engineering, projects ranging from groundwater exploration to watershed development, groundwater pollution and groundwater conservation, all require a sound geological understanding of the area under consideration. Studies concerned with reservoir-induced seismicity to understand the side effects are of utmost importance in constructing large dams.

Water resources comprise of the surface water and the groundwater. To access and manage these resources, geology of the area plays a vital role. The water-bearing properties of rock bodies, (aquifers), and factors that influence storage, movement and yield of water from aquifers are essentially geological problems.
They require thorough geological knowledge about the disposition of strata for designing a dependable water supply project. The knowledge of sub-surface soil, rocks, folds, faults, joints and lineaments is essential for an estimation of infiltration/recharge of the surface run-off.

Water is depleting fast and becoming most sought for the survival of mankind. Scientists, technologists and engineers all are equally concerned to explore new resources and means to conserve the existing ones. Geological information is of fundamental importance in the exploration and exploitation of water resources of a region for surface and sub-surface reserves of water.

For surface water resource, which is in the form of river system, the details of lineaments and nature of rocks govern the flow of surface run-off. Different rocks have different permeability and water absorption capacity. The siltation of river system is also influenced by the geology of the river course. There are several major and minor basins which have huge reserves of surface water as well as groundwater. The water resource estimation and its management are carried out basin-wise. The problems related to the quality and quantity of water is governed by the nature of soil/rocks in the basin. The geogenic contamination of water in particular basins are controlled by the nature of rocks and minerals. Therefore, it is necessary to understand the geology of the particular basin of interest.

To manage the water resource in the form of groundwater, the role of the rain water harvesting has become the most important technique of water conservation. Since, it involves the principles of sub-surface infiltration/recharge, the different soils and rocks have to be understood properly to make the sub-surface recharge effective. Hence, a proper understanding of sub-surface geology is necessary before attempting the rain water harvesting project.

Another approach to address the expected future scarcity of water involves finding out ways and means for utilizing frozen waters spread over millions of square kilometer areas in mountains and in Polar Regions in the form of glacial ice. This has opened up a field of importance for the water resource engineers in the near future.

1.5 TOWN PLANNING AND REGIONAL PLANNING

Towns grow during the passage of time. The need for education, employment and business are some of the factors for the migration of people from remote and rural areas to urban areas. A town planner is concerned with the utilization of land in the best and most aesthetic manner to meet the social needs of the people in different areas. The town planner must be capable of fully understanding the state of equilibrium already achieved between the surface features and the prevailing environment and also their intricate relations with each other.

Increase of population in metros and other industrial hubs necessitates gradual advances over the natural lands within and outside the existing towns and cities. Migration of people from other parts of the country require construction of
additional housing facilities, community buildings, commercial complexes, water-supply projects, roads, metros and so on.

The suitability of a particular site for an identified project, from an engineering point of view, is decided by civil engineers in consultation with an engineering geologist. But primarily, it is the town planner who must have a background of geology so as to judiciously make a decision regarding allocation of lands for different requirements; every meter of land taken out from the natural system for any construction activity will affect the system as a whole. A change affected in the natural set up of an area due to a proposed new project consequently leads to a series of changes in the adjoining and even distant area. However, the new area so developed should not introduce any major element of disequilibria in the natural set up.

1.6 **DISCIPLINES INVOLVED IN ENGINEERING GEOLOGY**

Most civil engineering projects such as dams, tunnels, bridges, sky-scrappers, etc., require a knowledge of Earth and applied aspects of geology during their planning, design, construction phases, and environmental impact analysis. This involves several geological disciplines such as *Mineralogy*—consisting in identification of different types of minerals and study of their physical and optical properties; *Petrology*—dealing with different types of rocks; *Structural geology*—concerned with structures of rocks; *Physical geology*—involving natural forces that bring about changes upon the Earth’s surface; *Geomorphology*—study of the effects of weathering (physical disintegration, chemical decomposition, and biological activity) and subsequent erosion due to natural agencies such as sea, river, wind, and moving glaciers; and *Hydrology*—study of water resources. These are described in detail in the chapters to follow. Since application of remote sensing in the field of geology is gaining popularity because of the inherent advantages of the technique, a chapter is introduced at the end.

**Summary**

This chapter discusses the role and importance of geology for civil engineers. Various disciplines of geology involved in site selection for safe and economical construction of civil engineering projects are introduced. Engineering geology deals with the rocks and soils that make the foundation of various civil engineering structures. It also provides information and properties of various valuable stones to be used aesthetically and economically as construction materials.

The importance of a geologist and civil engineer for safe and reliable construction of civil engineering projects is presented. The role of engineering geology in the development of infrastructure is discussed.
Terminology

Topography
Consists of the study of surface shape and features on the Earth’s surface. It is concerned with local details including relief (quantitative measurement of vertical elevation change in a landscape) and natural and artificial features. Topography involves the recording of the relief of terrain, the 3-D quality of the surface and the identification of landforms (mounds, plateau, hill, valley and water-bodies).

Hydrology
Comprises of the study of water resources, both the groundwater and surface water of the Earth. It involves the study of distribution, conservation and use of the water of the Earth and its atmosphere.

Contour
A line connecting points of same elevation (height).

Embankments
These are human-made mounds of earth or stones built to confine the flow of water in any drainage or stream, or to support a road or railway.

Permafrost Region
The regions at or below the freezing point of water for at least three years. Most of the areas near the North and South poles fall in this category.

Rock Anisotropy
Different behaviour of rocks along different axes is known as rock anisotropy. Most common rock-forming minerals are anisotropic, i.e. they have different physical and mechanical properties along different axes, and are responsible for rock anisotropy.

Aquifer
These are water-bearing strata capable of holding and transmitting water.

Geogenic Contamination
The contamination caused by leaching of rocks or soil.

Exercises

1. (a) Define geology. Why should civil engineers study geology?
   (b) What are the main disciplines of geology that a civil engineer must have a knowledge of?

2. (a) What is engineering geology and how is it relevant to civil engineering?
   (b) At what stage of the project engineering geological studies must be carried out?

3. Lack of attention to geological aspects may lead to hazard. Comment!
Multiple-Choice Questions

1. Knowledge of geology is important for civil engineers to understand
   (a) the geological reports prepared by the geologist
   (b) to prevent disasters
   (c) the sub-surface water availability
   (d) all the above

2. During surveying for a civil engineering project, topographic maps are prepared for:
   (a) specifying the site location
   (b) understanding relief features of the probable site
   (c) specifying the structural behaviour of rock types
   (d) depicting petrological characters of rock types

3. Which of the following is not covered in geomorphology?
   (a) Physical disintegration of rocks
   (b) Structures of rocks
   (c) Sub-surface water
   (d) Hydrology

4. Which of the following is matched correctly?
   (a) Geology Human body
   (b) Hydrology Valleys, gorges and other landforms
   (c) Topography Slopes, contours, etc.
   (d) Seismology Fold, faults and joints

5. Which of the following is not matched correctly?
   (Branch of Geology) (Deals with)
   (a) Petrology Types of rocks
   (b) Physical Natural forces bring changes
   (c) Geomorphology Landforms due to natural agencies
   (d) Structural geology Groundwater condition

Answers to MCQs

1. (d) 2. (b) 3. (a) 4. (c) 5. (d)