GEO TECHNICAL ENGINEERING

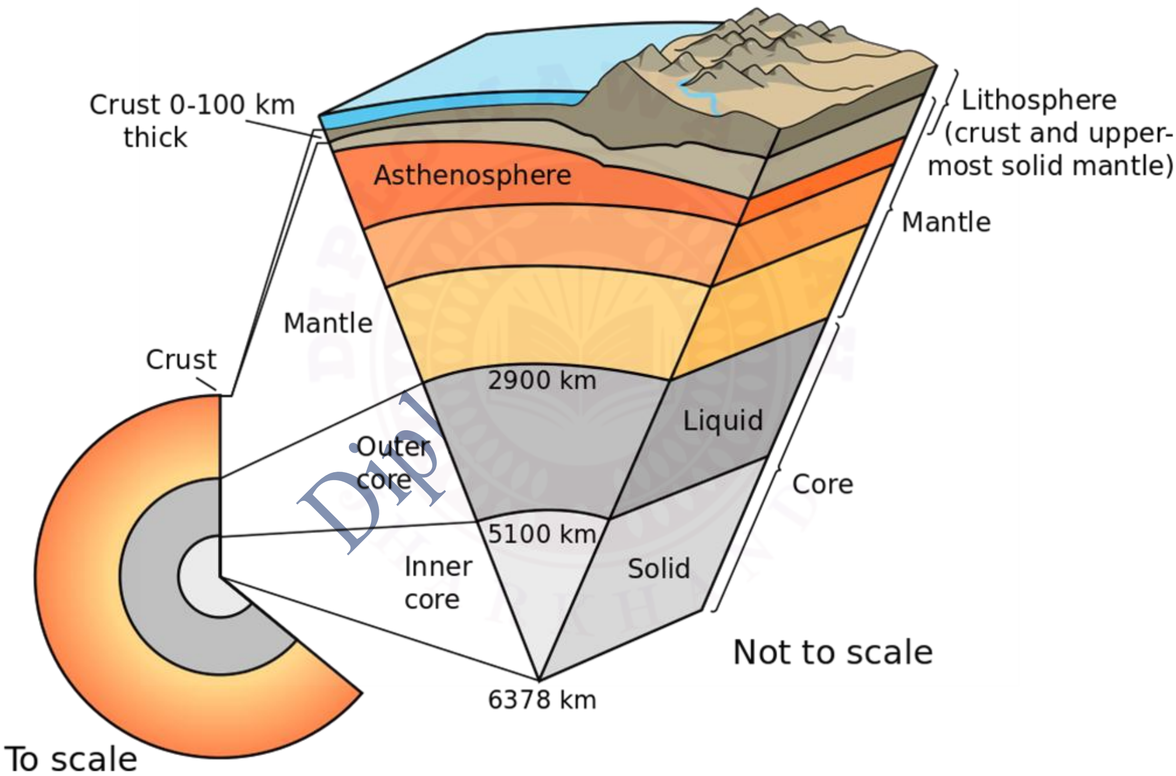
DIPLOMA WALLAH

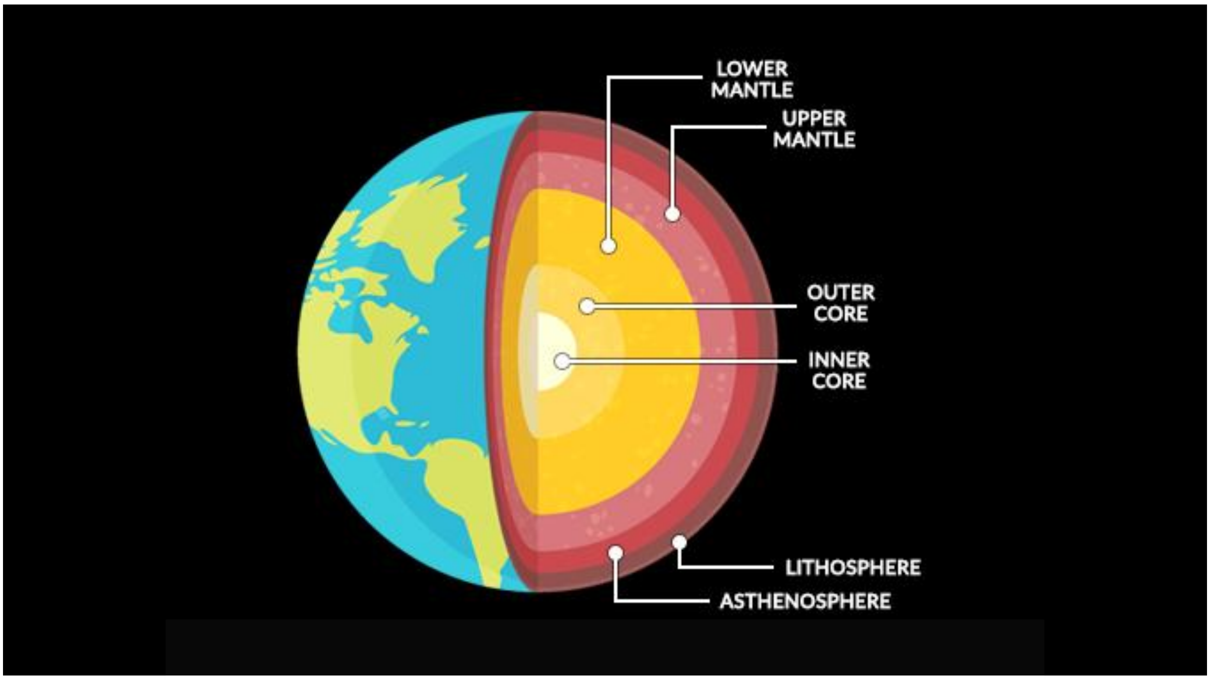
CIVIL

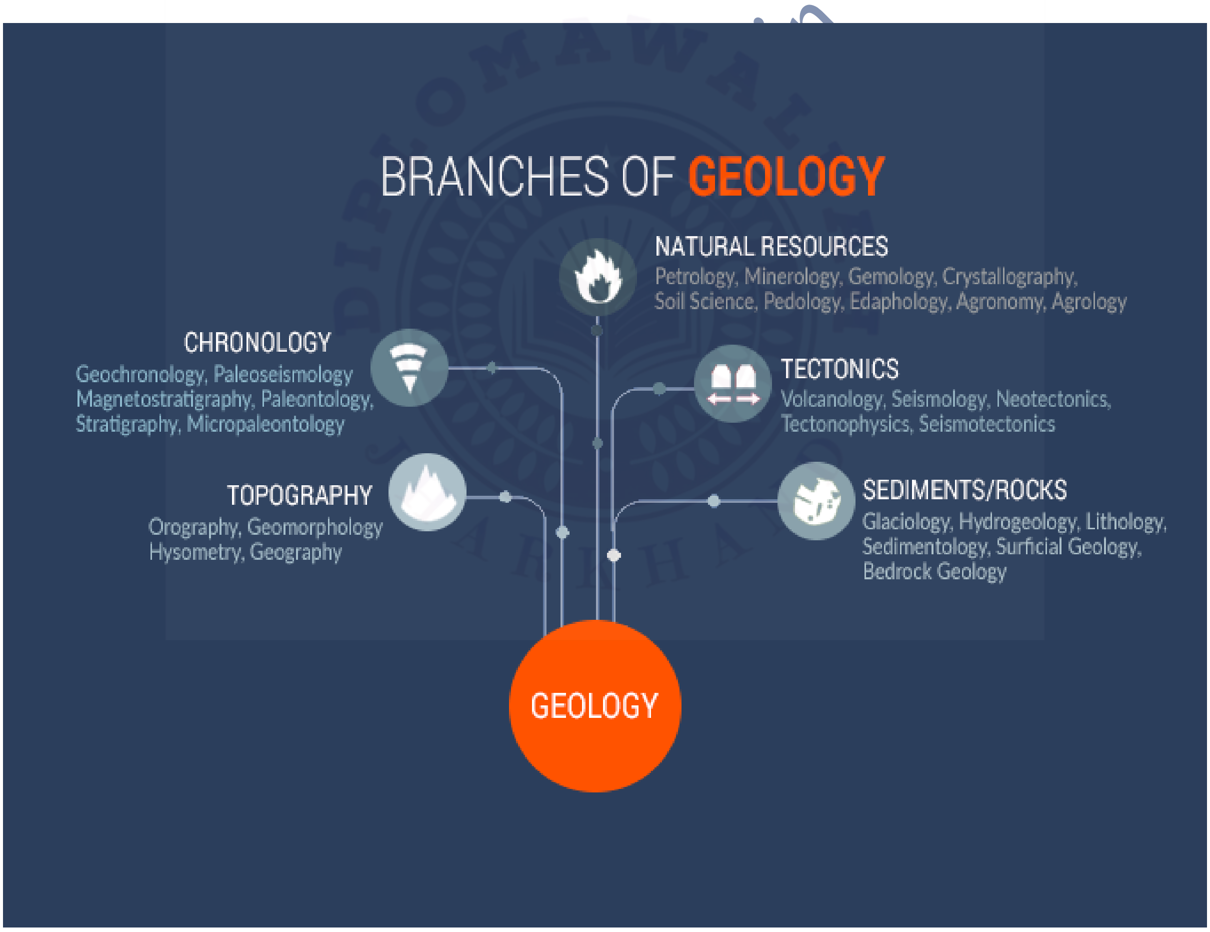
Jharkhand University Of Technology (JUT)

Unit I: Overview of Geology and Geotechnical Engineering

1.1 Introduction to Geology: Branches, Importance of Geology, Composition of Earth




LOWER MANTLE
UPPER MANTLE
OUTER CORE
INNER CORE
LITHOSPHERE
ASTHENOSPHERE


BRANCHES OF GEOLOGY
NATURAL RESOURCES
Petrology, Minerology, Gemology, Crystallography, Soil Science, Pedology, Edaphology, Agronomy, Agrology
CHRONOLOGY
Geochronology, Paleoseismology Magnetostratigraphy, Paleontology, Stratigraphy, Micropaleontology
TECTONICS
Volcanology, Seismology, Neotectonics, Tectonophysics, Seismotectonics
TOPOGRAPHY
Orography, Geomorphology Hysometry, Geography
SEDIMENTS/ROCKS
Glaciology, Hydrogeology, Lithology, Sedimentology, Surficial Geology, Bedrock Geology
GEOLOGY

Main and Allied Branch of Geology

Main Branch	Allied Branch
Physical Geology	Engineering Geology
Mineralogy	Mining Geology
Petrology	Geophysics
geomorphology	Geohydrology
Historical Geology	Geochemistry
Economic Geology	rock mechanics
	Oceanography

What is Geology?

Geology is the science concerned with the solid Earth — its materials (rocks, minerals, soils), its structure (layers, faults, folds), and the processes (weathering, erosion, plate tectonics, sedimentation) that act over time to change it. (Vardhaman) In the context of civil engineering, geology provides the essential knowledge about what lies beneath the surface, and how that influences the behaviour of foundations, slopes, and structures.

Branches of Geology

Here are some of the main branches relevant to civil/engineering geology:

- **Mineralogy**: Study of minerals — their chemical composition, crystalline structure, physical properties.
- **Petrology**: Study of rocks — origin (how they formed), classification, history.
- **Structural Geology**: Study of the deformation of Earth's crust — folds, faults, shearing, joints.
- **Geomorphology**: Study of landforms and the processes shaping them (rivers, wind, glaciers).
- **Engineering Geology**: Application of geological knowledge to engineering works — investigating ground conditions, stability, materials. (Aybu)

- **Environmental Geology**: Study of how geological factors affect the environment, hazards, groundwater, etc.

Importance of Geology in Civil Engineering

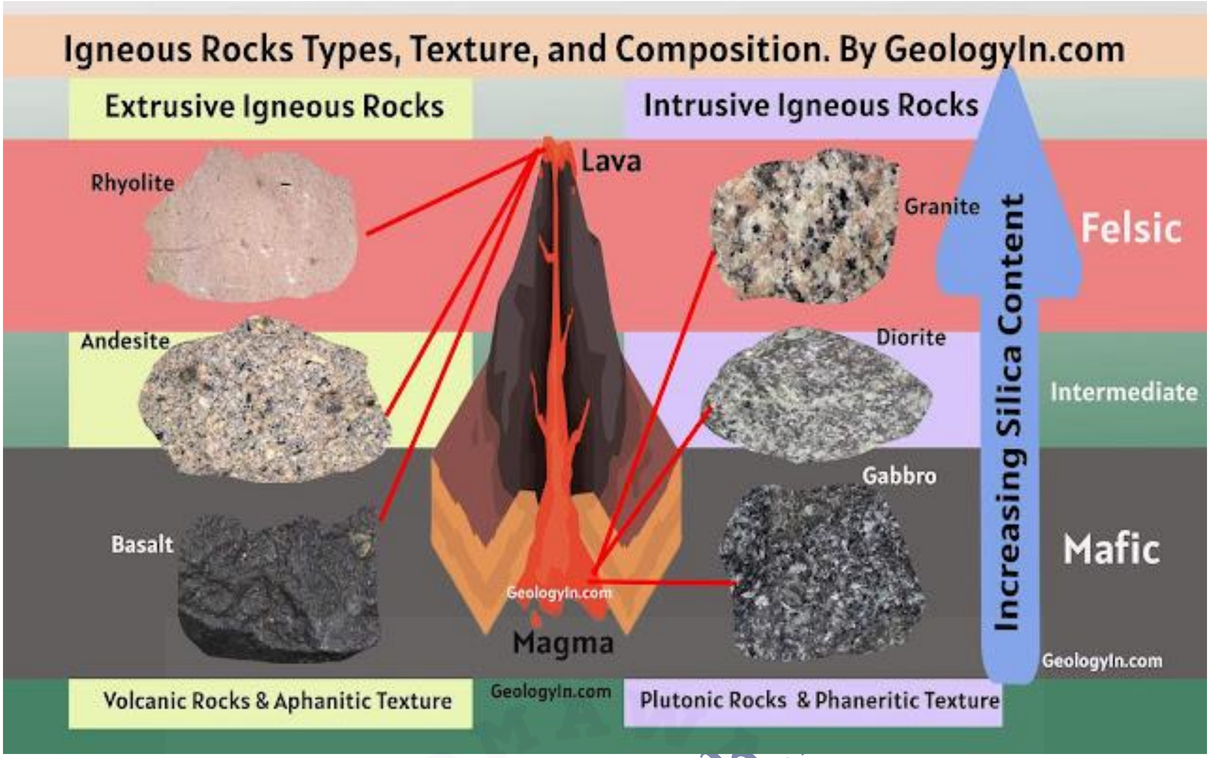
- Every civil engineering project involves earth and its features: if you are building a foundation, you are interacting with soil and rock; if you are cutting into a hill or excavating for a dam, geology matters. (Vardhaman)
- Geology helps determine **site conditions**: what type of rock/soil is present, is there groundwater, are there faults or landslide-prone slopes. For example, geologists and engineers must collaborate to check whether a site is safe from hazards like landslides or earthquakes. (Cypress Environment & Infrastructure)
- Material choice is influenced by geology: the type of rock used, the aggregate for concrete, the soil for backfill – geological knowledge helps in selection based on strength, durability, weathering behaviour.
- Planning, design and cost are affected: if the ground is weak or has complex geology, more expensive foundations or ground improvement may be needed. (Vardhaman)

Composition of the Earth

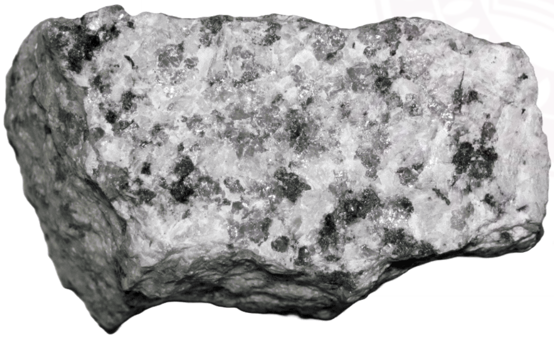
The Earth can be divided into layers:

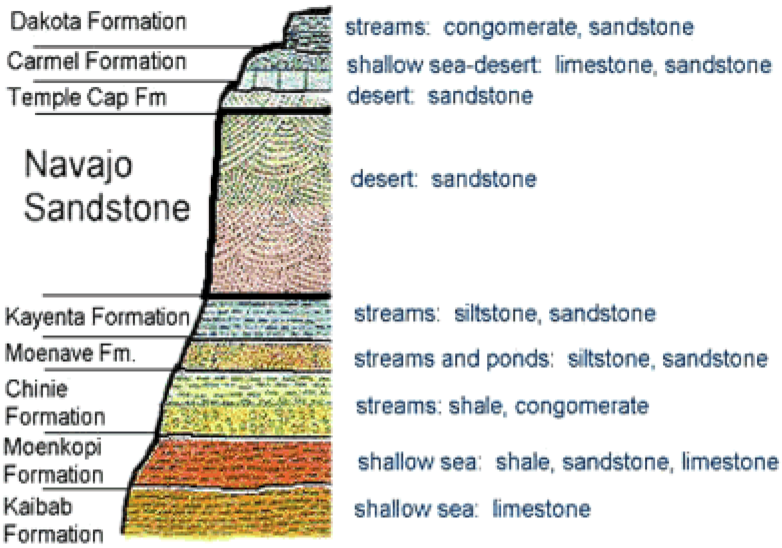
- **Crust**: The outer skin of the Earth – continental and oceanic crust – made of various rock types and materials.
- **Mantle**: Beneath the crust, composed of semi-solid rock which slowly flows over geological time.
- **Core**: Inner parts of the Earth (outer core liquid, inner core solid), composed largely of iron and nickel.
  Within the crust and upper mantle — where most civil engineering activity is relevant — we deal with rocks, soils, weathering layers, and their properties. The weathering of crustal rock leads to soil formation, which becomes the medium for many civil engineering structures.

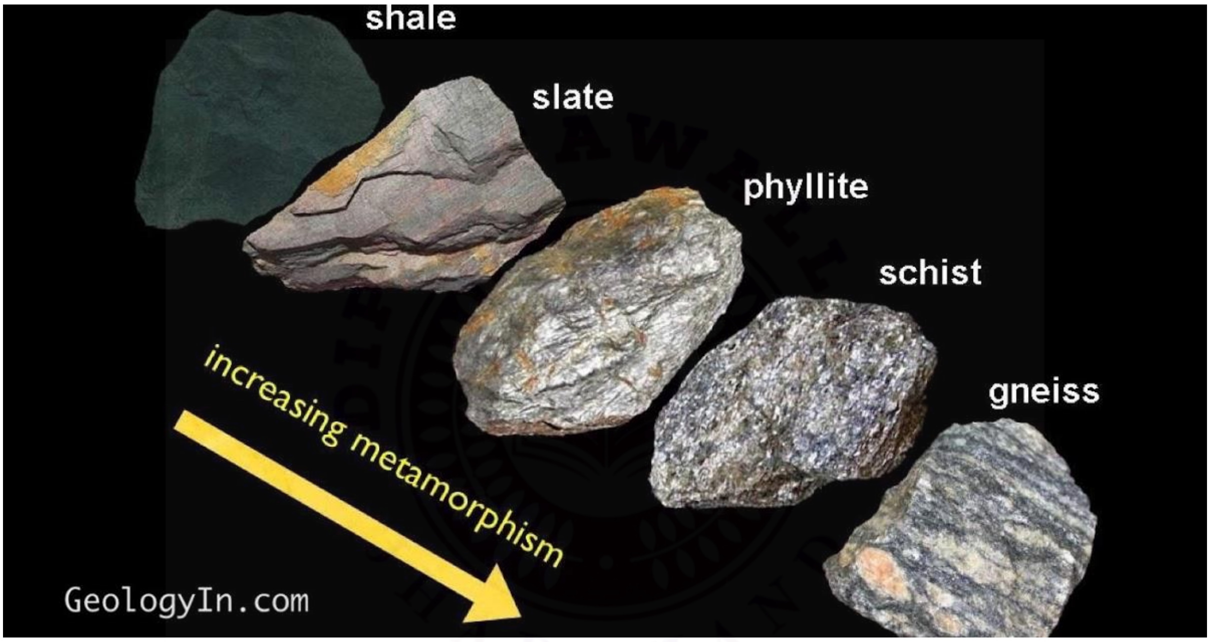
1.2 Petrology: Definition of a Rock, Classification based on their Genesis (Mode of Origin), Formation, Classification and Engineering Uses of Igneous, Sedimentary and Metamorphic Rocks

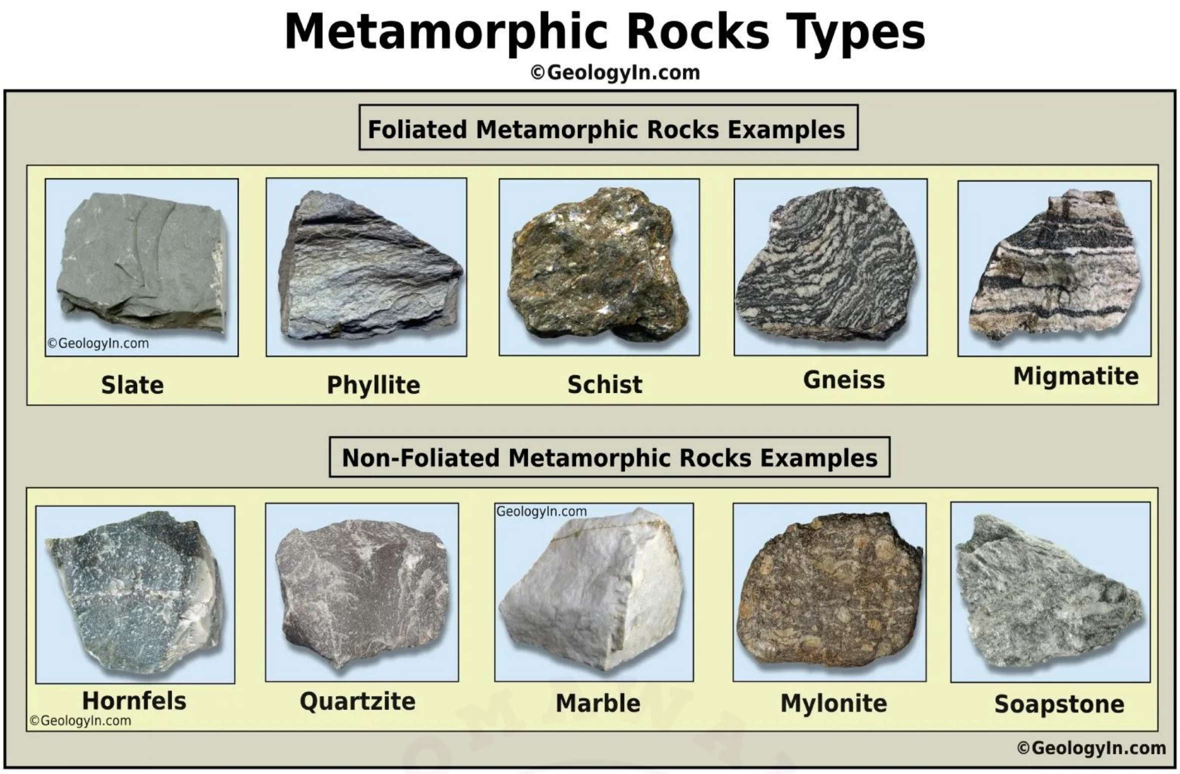


Granite Basalt




Dakota Formation
streams: congomerate, sandstone
Carmel Formation
shallow sea-desert: limestone, sandstone
Temple Cap Fm
desert: sandstone
Navajo Sandstone
desert: sandstone
Kayenta Formation
streams: siltstone, sandstone
Moenave Fm.
streams and ponds: siltstone, sandstone
Chinle Formation
streams: shale, congomerate
Moenkopi Formation
shallow sea: shale, sandstone, limestone
Kaibab Formation
shallow sea: limestone


shale
slate
phyllite
schist
gneiss
increasing metamorphism
GeologyIn.com



Definition of a Rock

A rock is a naturally occurring solid aggregate composed of one or more minerals, or mineral-like matter. It may also include certain non-mineral materials such as glasses or fossil remains. Rocks serve as the building blocks of the Earth's crust. (Aybu)

Classification Based on Mode of Origin (Genesis)

Rocks are classified into three major groups by their origin:

- **Igneous rocks**: Formed when molten rock material (magma or lava) cools and solidifies.
  - Intrusive (plutonic) igneous rocks form below the surface (coarse-grained)
  - Extrusive (volcanic) igneous rocks form at the surface (fine-grained) Example: granite (coarse), basalt (fine).
- **Sedimentary rocks**: Formed by the deposition, compaction and cementation of sediments derived from weathered rock, organic matter, or chemical precipitates. They often show layers or bedding.
- **Metamorphic rocks**: Formed by the transformation of pre-existing rocks (igneous or sedimentary) under heat, pressure, and chemically active fluids, without melting. Such changes alter mineralogy, texture, structure (e.g., foliation).

Formation, Classification & Engineering Uses

Igneous rocks:

- Formation: Cooling and crystallisation of magma or lava.
- Classification: Based on mineral composition (felsic, intermediate, mafic) and texture (coarse, fine).
- Engineering uses: Many igneous rocks (e.g., granite, basalt) are high strength, durable, and used as strong foundation bedrock. As aggregate in concrete and road base. Their relatively low porosity and high compressive strength make them favourable in many engineering situations—provided they are unweathered and not heavily fractured.

Sedimentary rocks:

- Formation: Weathering of pre-existing rocks → transport → deposition → compaction/cementation.
- Classification: Clastic (sandstone, shale), chemical (limestone, rock salt), organic (coal).
- Engineering uses: Some sedimentary rocks like well-cemented sandstone or limestone can serve as good foundation materials, aggregates, or decorative stone. However, their layered nature, bedding planes, variability in strength, presence of fossils or voids means they may pose challenges (weak planes, dissolution risks). For example, limestone may dissolve in water (karst), shale may be weak under weathering.
- Practical example: The famous Sun Temple of Konark (Konark, India) is made up of chlorite, laterite, khondalite stones (metamorphic / weathered rock types) — illustrating how selection of rock type matters for long-term durability.

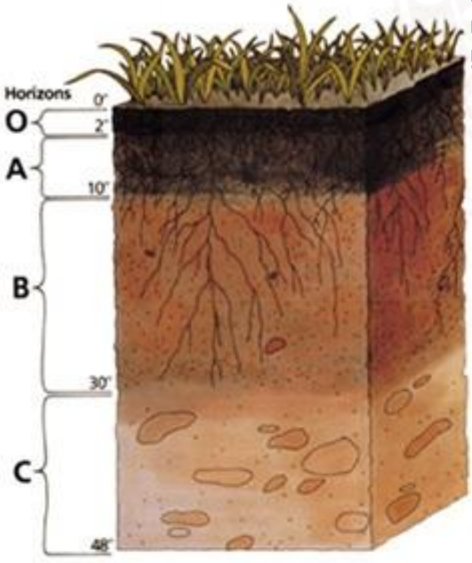
Metamorphic rocks:

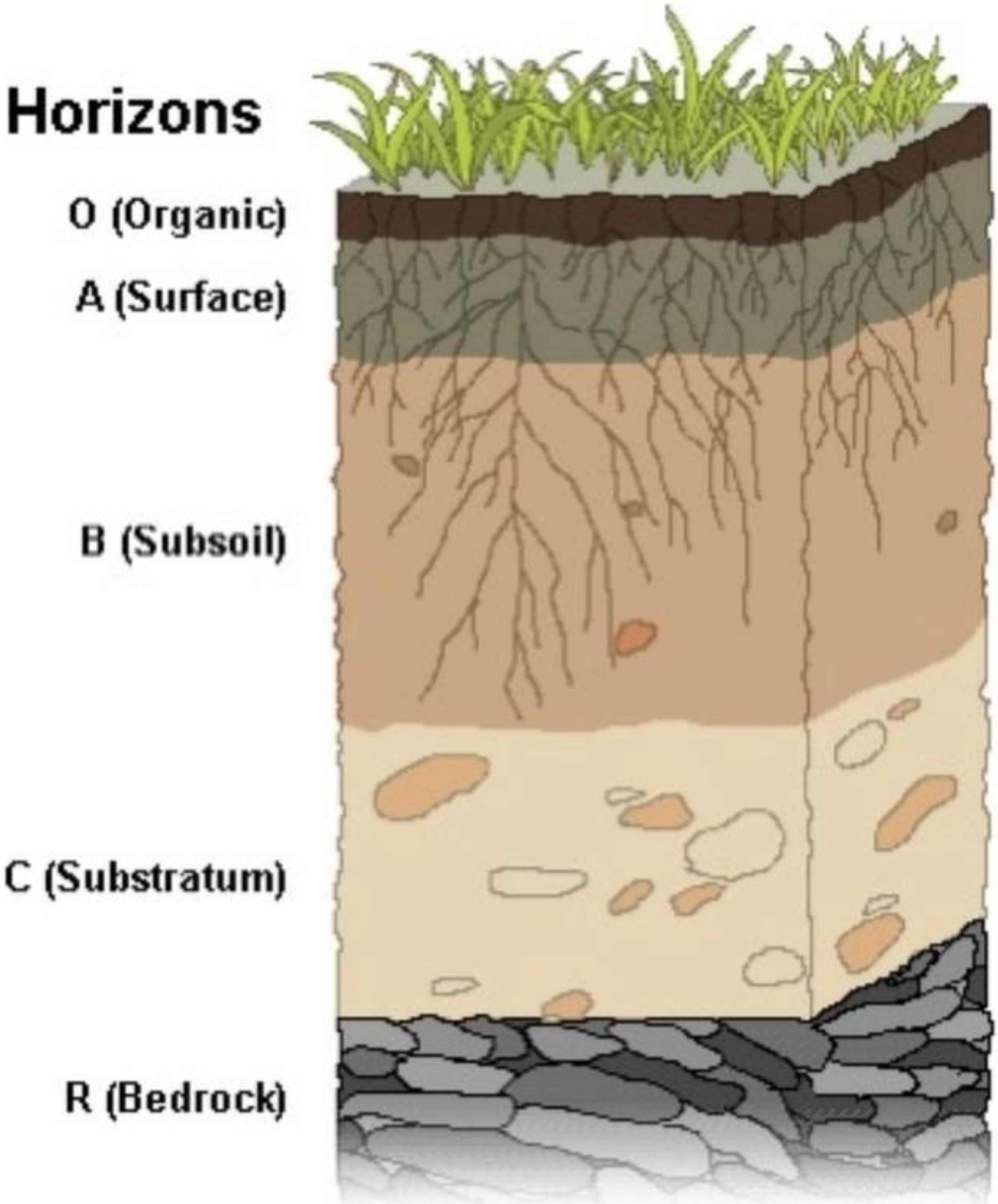
- Formation: Pre-existing rocks undergo metasomatism, recrystallisation under pressure & temperature, forming new mineral assemblages and textures (e.g., schistosity, gneissic banding).
- Classification: Foliated (slate, schist, gneiss) vs non-foliated (marble, quartzite).
- Engineering uses: Metamorphic rocks can provide strong, stable foundation material if foliations or planes of weakness are not oriented unfavourably relative to loads. Foliated rocks may present discontinuities (planes of weakness) which may govern failure. Thus detailed geological and geotechnical investigation is vital.

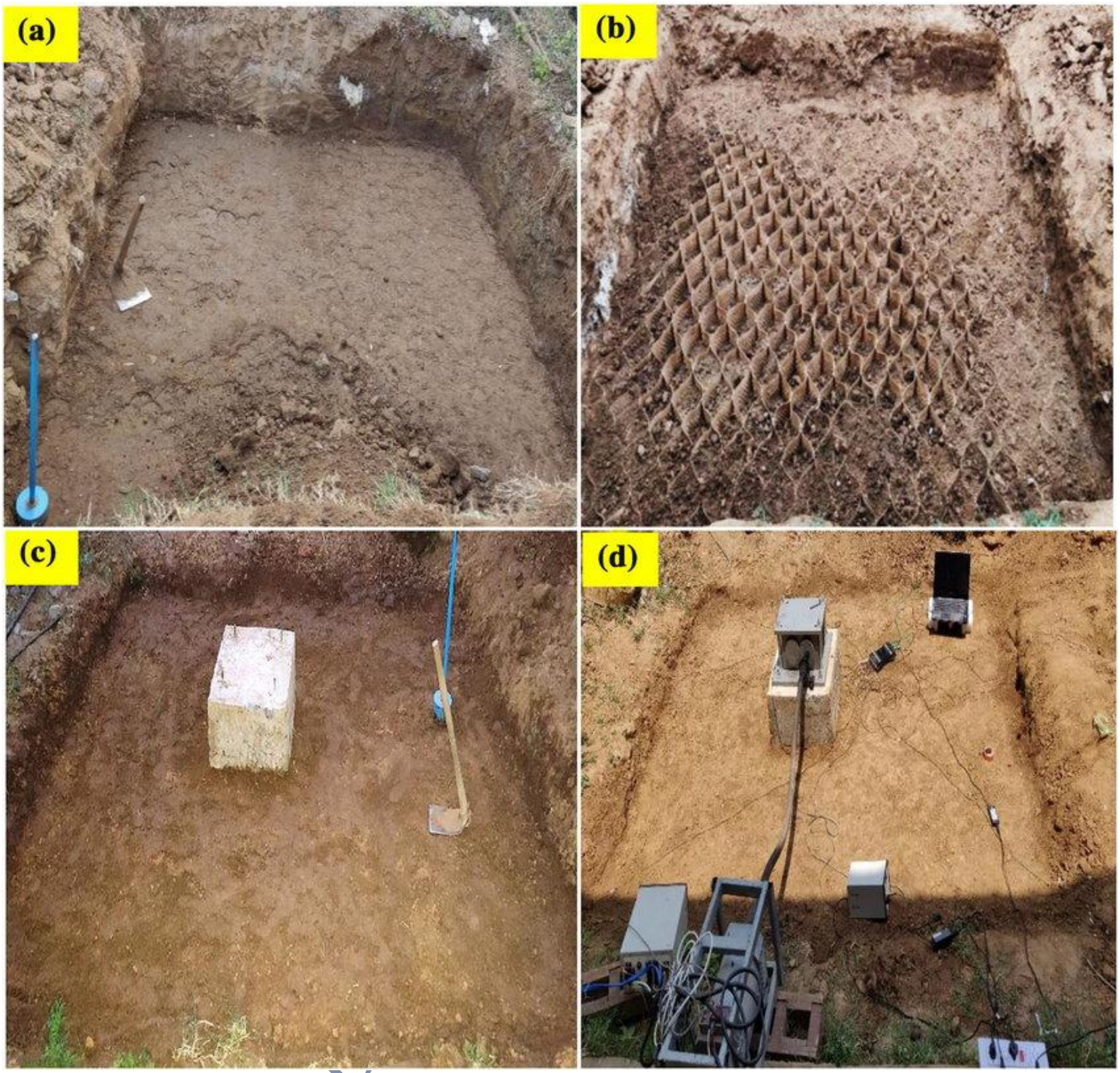
Key Engineering Considerations for Rock Types

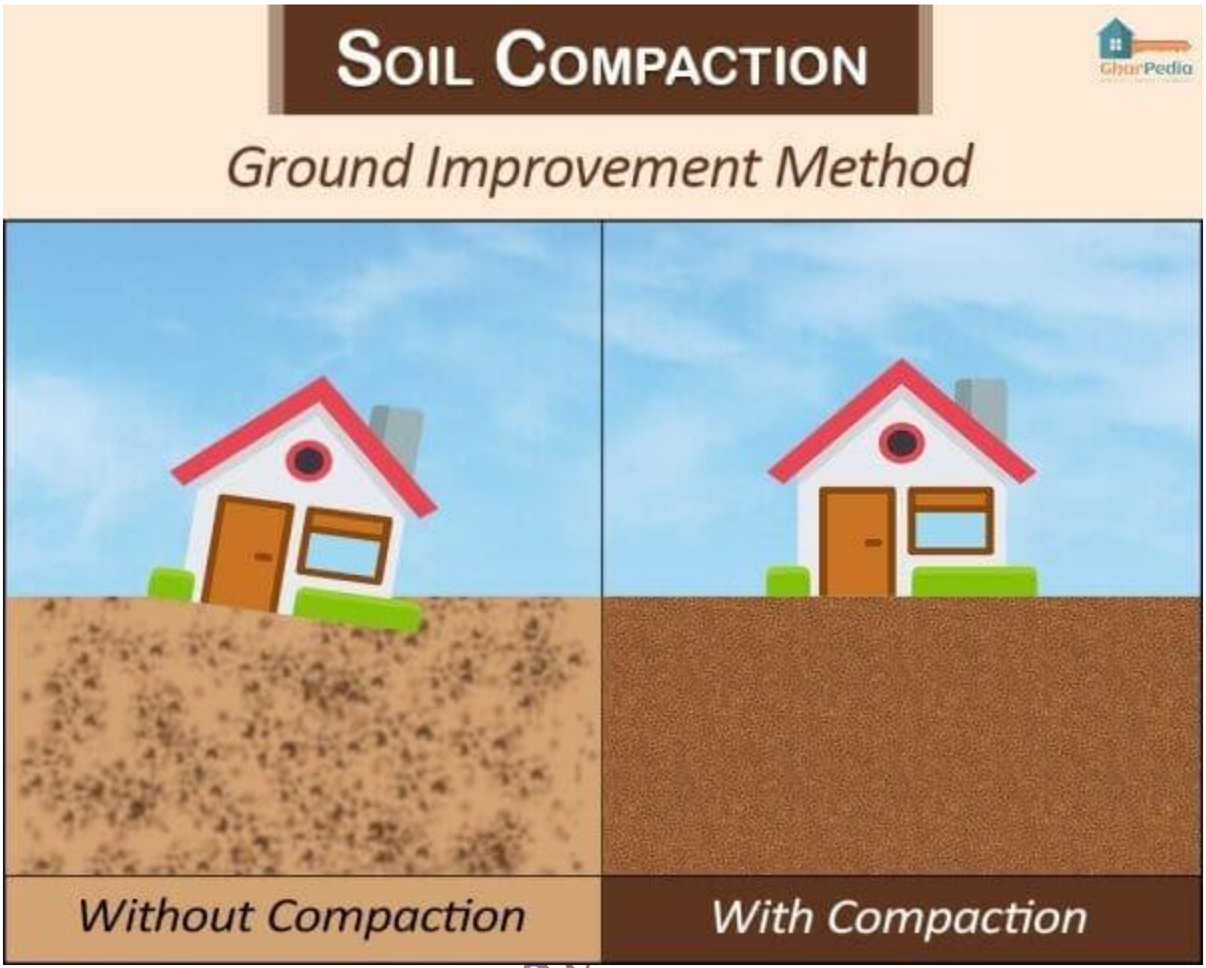
- **Strength**: Unweathered igneous and hard metamorphic rocks typically have high compressive strength.
- **Discontinuities**: Foliation, joints, faults in rocks (especially metamorphic and sedimentary) reduce strength and stability—these act as planes of weakness. For example, in geotechnical engineering, discontinuities in rock mass are important. (Wikipedia)
- **Weathering & durability**: Even high-strength rock may degrade with weathering (freeze–thaw, chemical attack).
- **Porosity/permeability**: Impact on drainage and stability (water in rock mass may cause pressure, reduce strength).
- **Variability**: Sedimentary and metamorphic rocks often show heterogeneity (bedding, metamorphic grade) which must be accounted for.
- **Material suitability for aggregate or fill**: Quality, abrasion resistance, chemical stability vary with rock type; local geology influences material cost and durability.

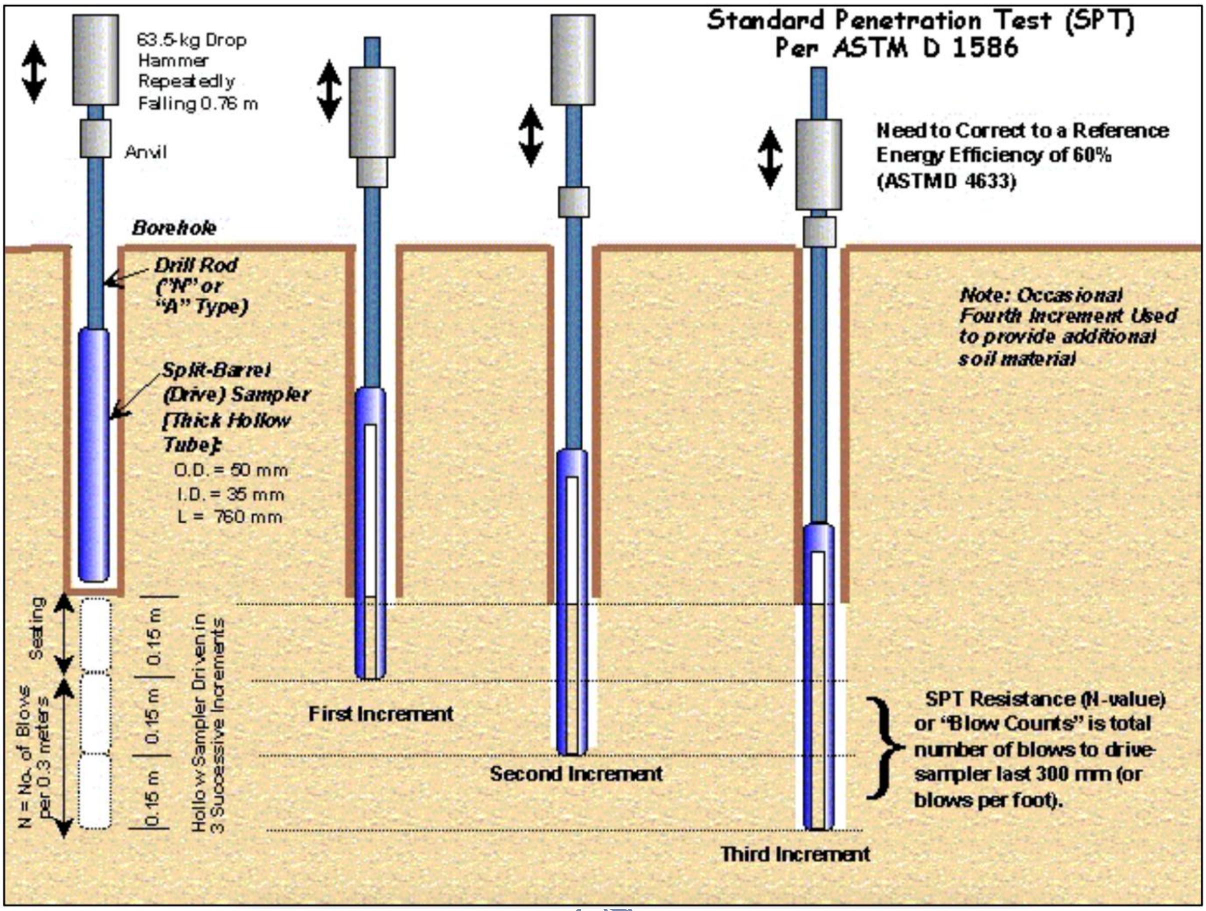
1.3 IS Definition of Soil, Importance of Soil in Civil Engineering as Construction Material for Foundation Bed of Structures




Horizons
O (Organic)
A (Surface)
B (Subsoil)
C (Substratum)
R (Bedrock)


(a)
(b)
(c)
(d)


SOIL COMPACTION
GharPedia
Ground Improvement Method
Without Compaction
With Compaction



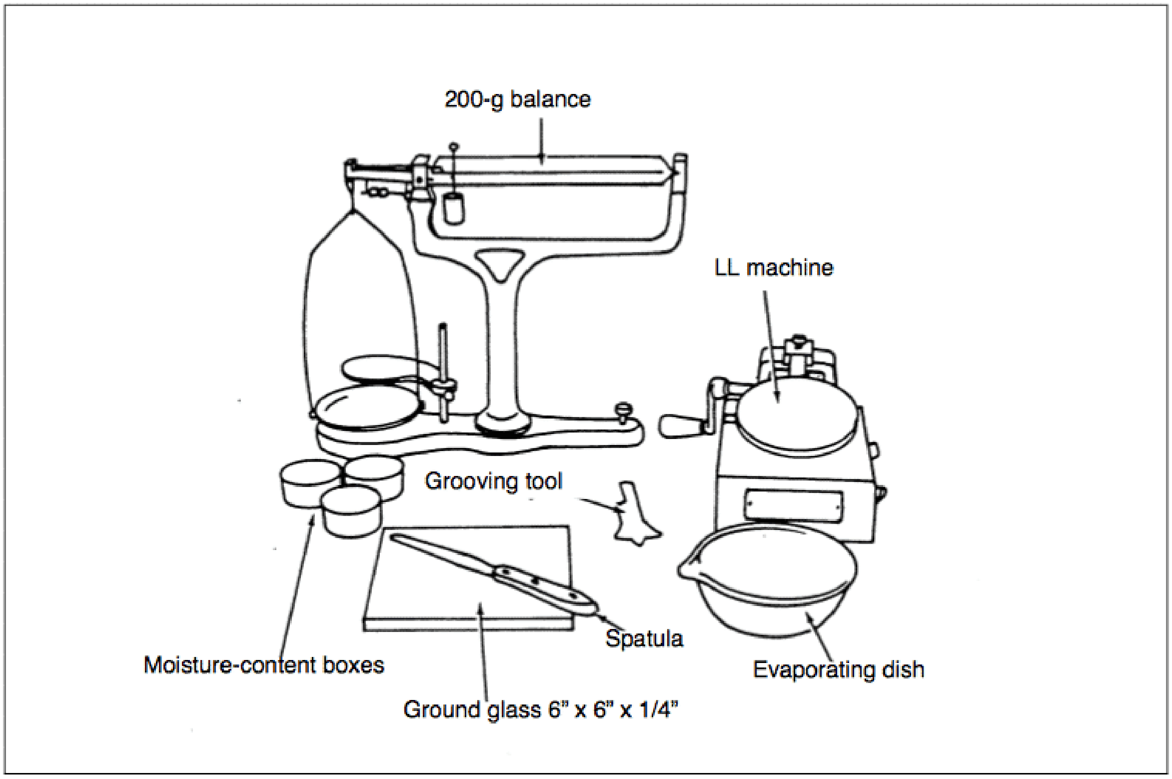


Figure 2-45. Equipment for the LL and PL tests

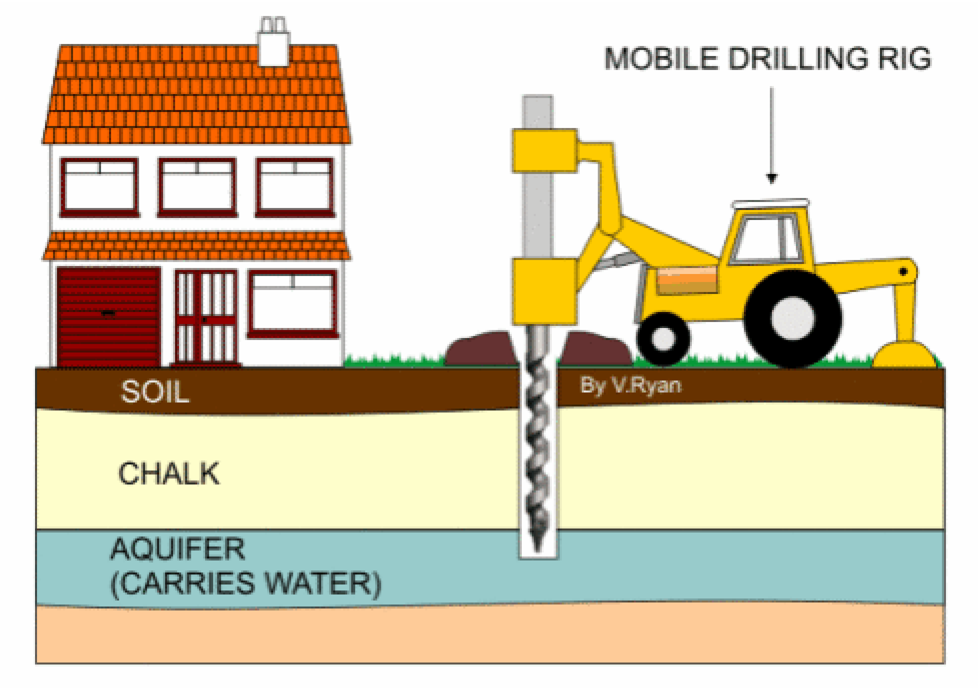
Definition of Soil (IS Context)

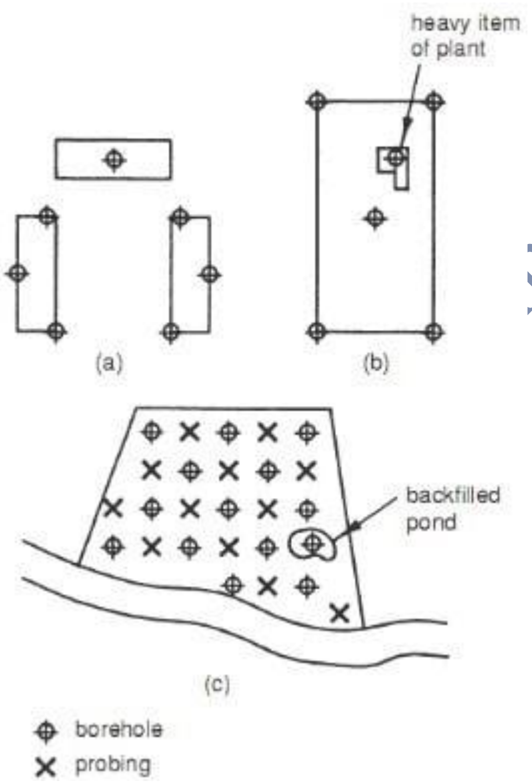
While the specific Indian Standard (IS) definition may vary slightly with each code, in general soil is defined as the naturally occurring material on the Earth's surface (upper crust) consisting of mineral particles, organic matter, water and air, resulting from weathering of rocks and biological activity. It is the material into which foundations are placed, and which supports structures. Many civil engineering references note: "The study of engineering geology and soil mechanics is essential because most civil engineering structures are built on or of soil." (Vardhaman)
In the Indian context, soils that cannot be excavated by hand spade are often classified as rock; those which can be excavated by spade fall within the soil classification (in older classification schemes).

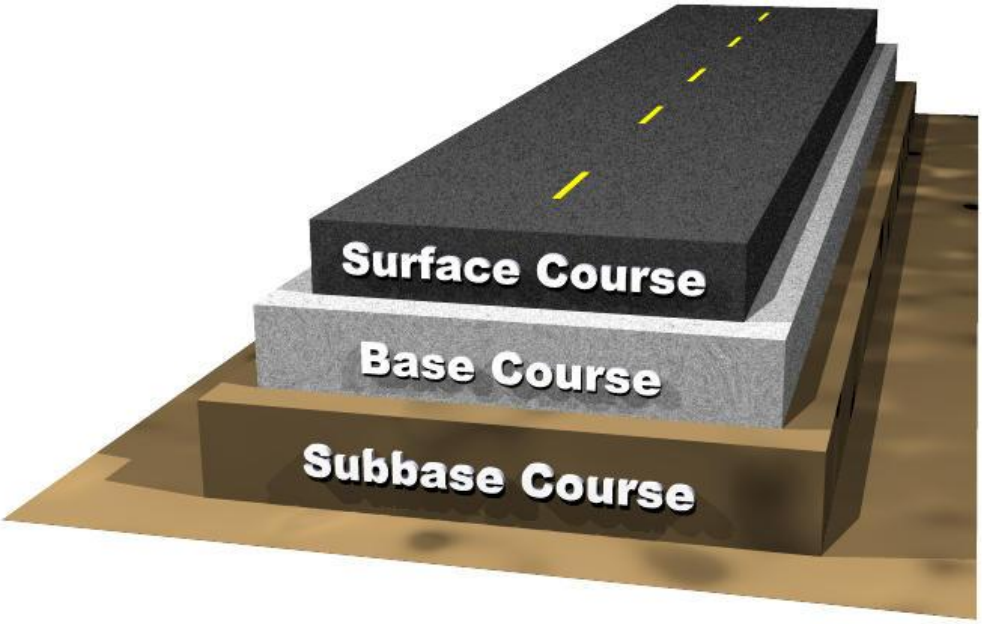
Importance of Soil in Civil Engineering

- Soil acts as the **foundation bed** for virtually all civil engineering structures: buildings, bridges, pavements, embankments. The condition and behaviour of the soil determine how well the structure will perform.
- Soil as construction material: Soils are also used as backfill, embankment fill, for earthen dams, embankments, road subgrades. Their mechanical properties — compaction, shear strength, permeability — are critical.
- Key soil properties affecting engineering behaviour: grain size distribution, void ratio, moisture content, density/compaction, plasticity, shear strength, compression/settlement characteristics, permeability. For example, soil gradation influences compressibility and hydraulic conductivity. (Wikipedia)
- Settlement of soil: If soil is weak, compressible or has high water content, loading from structures may cause settlement which can crack or tilt structures.
- Bearing capacity: The soil must be able to support the loads imposed by the structure. If bearing capacity is exceeded, foundation failure will occur.
- Stability: Soil slopes, embankments, retaining structures depend on soil shear strength and drainage. Poorly drained or saturated soils can cause failures.
- Ground improvement: In unsuitable soils, techniques like compaction, replacement, reinforcement, drainage are needed — so geotechnical engineering interfaces closely with soil behaviour.
- Overall, without proper understanding of soil, one cannot design safe and economically efficient foundations, pavements or earthworks.

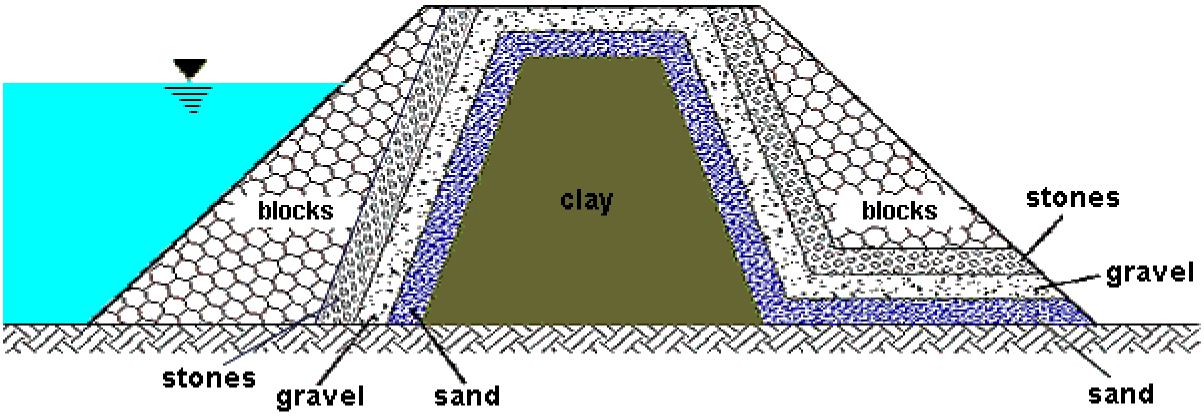
1.4 Field Applications of Geotechnical Engineering for Foundation Design, Pavement Design, Design of Earth Retaining Structures, Design of Earthen Dam

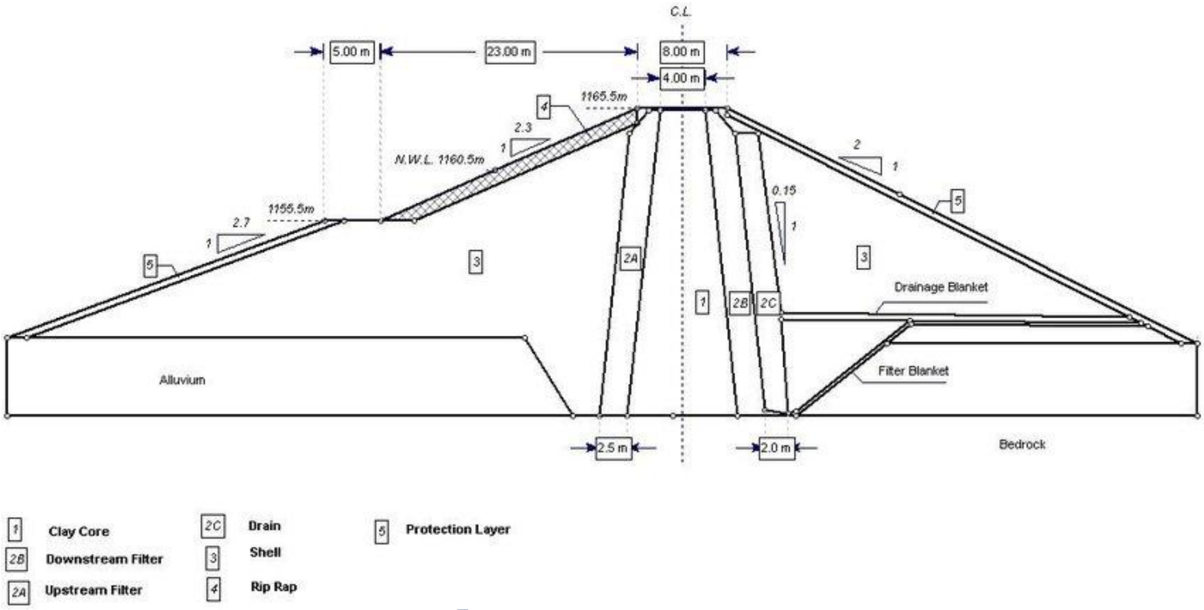

MOBILE DRILLING RIG
SOIL
By V.Ryan
CHALK
AQUIFER
(CARRIES WATER)

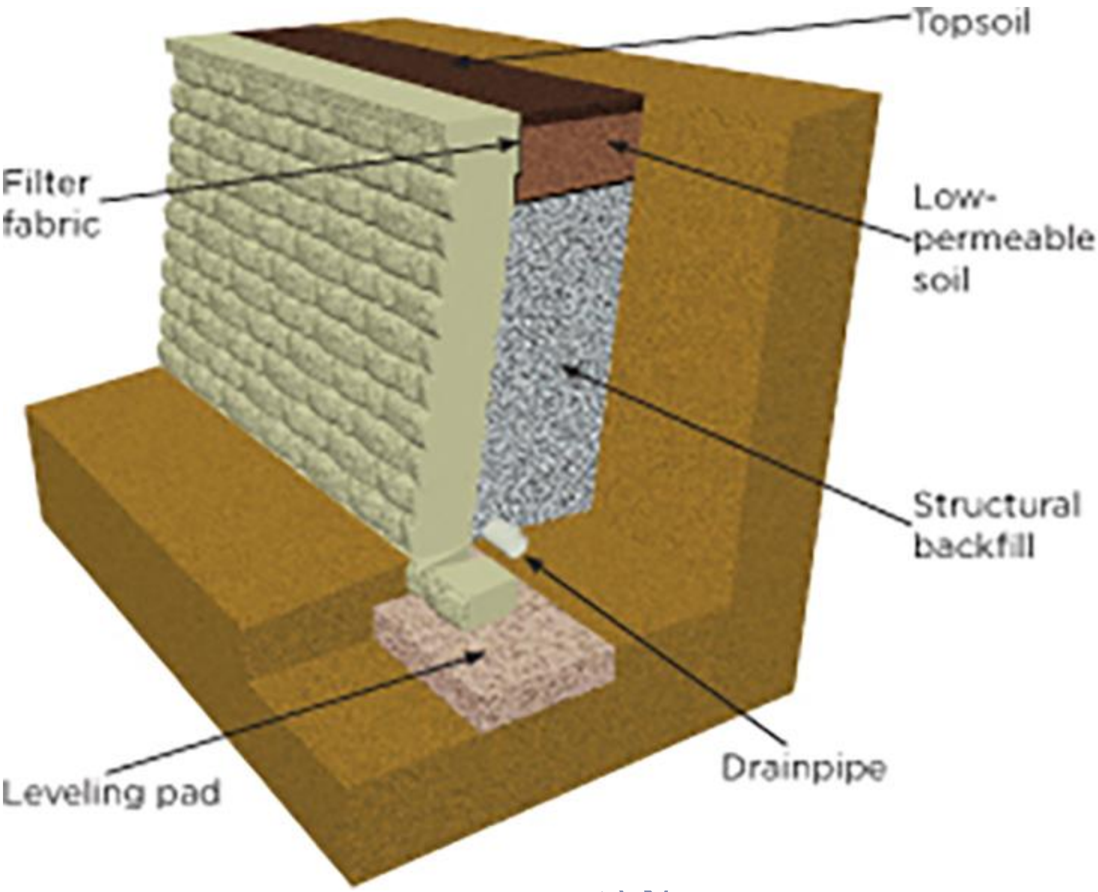

heavy item
of plant
(a)
(b)
backfilled
pond
(c)
borehole
probing

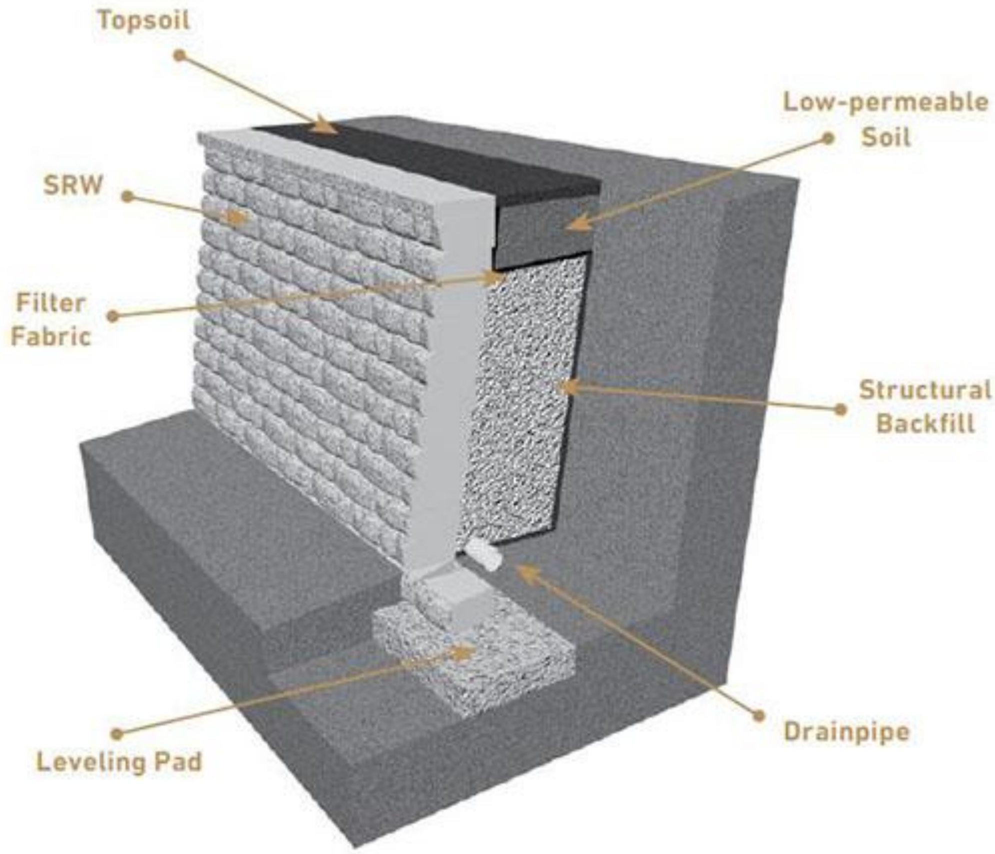

Surface Course
Base Course
Subbase Course


CAT


blocks
clay
blocks
stones
gravel
stones
gravel
sand
sand


C.L.
5.00 m
23.00 m
8.00 m
4.00 m
1165.5m
2.3
1
N.W.L. 1160.5m
1155.5m
2.7
1
2
1
0.15
1
Drainage Blanket
Filter Blanket
Alluvium
Bedrock
2.5 m
2.0 m
1 Clay Core
2B Downstream Filter
2A Upstream Filter
2C Drain
3 Shell
4 Rip Rap
5 Protection Layer


Topsoil
Filter fabric
Low-permeable soil
Structural backfill
Leveling pad
Drainpipe


Topsoil
Low-permeable Soil
SRW
Filter Fabric
Structural Backfill
Drainpipe
Leveling Pad

What is Geotechnical Engineering?

Geotechnical Engineering is a specialised branch of civil engineering that deals with the behaviour of earth materials (soils and rocks) and their interaction with man-made structures. (ccee.udel.edu)
It uses principles of soil mechanics and rock mechanics to analyse, design and construct foundations, slopes, earth retaining works, embankments, tunnels, and dams. (Holistique Training)

Major Field Applications

A. Foundation Design

- Before foundation design, **site investigation** is essential: drilling boreholes, collecting soil/rock samples, performing in-situ tests (for example standard penetration tests, SPT) and laboratory testing. These provide parameters like shear strength, compressibility, permeability. (Intertek)
- Based on soil/rock profiles and load characteristics, geotechnical engineers decide appropriate foundation type: shallow foundations (spread footings, mat/raft) when soil is good; or deep foundations (piles, caissons) when soil is weak or load is heavy.
- Design must ensure safe bearing capacity and acceptable settlement levels. Soil improvement may be needed (compaction, preloading, stabilization).
- Also, account for ground water, adjacent structure loads, possible liquefaction in seismic zones.

B. Pavement Design

- The pavement structure sits on top of a **subgrade** (the prepared soil or rock layer). The quality and strength of the subgrade govern pavement behaviour — excessive deformation, cracking or rutting can occur if subgrade is weak.
- Geotechnical engineers assess the soil's modulus, drainage conditions, compaction quality, frost susceptibility. Soil and rock mechanics principles help determine thickness of pavement layers.
- Subgrade improvement (stabilisation, geosynthetics) may be applied if soil is problematic.

C. Design of Earth Retaining Structures

- Retaining walls, anchored walls, sheet pile walls, reinforced soil walls are used when soil is retained by a vertical or sloped structure. Geotechnical design involves computing lateral earth pressures (active, passive), surcharge loads, wall stability (sliding, overturning, bearing failure) and backfill behaviour.

- Proper drainage behind the wall is critical — saturated back-fill leads to higher pressures. Soil type (cohesive vs granular) affects wall design.
- Interface between wall structure, soil, anchors (if used) must be considered, as well as possible seismic loads, settlement of retained soil, as well as long-term durability of the wall materials.

D. Design of Earthen Dam

- An earthen dam is a massive engineered earth structure; geotechnical engineering is central. Key considerations include:
    - Selection of suitable fill materials (core, shell, upstream, downstream zones) based on geology and borrow sources.
    - Foundation preparation: removing unsuitable soils, providing cutoff trenches, controlling seepage.
    - Stability of slopes (both upstream and downstream) under static and seismic loading, considering pore-water pressures, settlement, internal erosion.
    - Drainage systems, filters, toe drains to manage seepage and erosion internally.
    - Monitoring and instrumentation: piezometers, inclinometers to track performance over time.
    - Risk mitigation: landslides, overtopping, piping, internal erosion — all require geotechnical analysis of soils and rock, groundwater behaviour, and site geology.

Why These Applications Matter

- The subsurface is often the greatest unknown in a project — the risk of failure or excessive movement is high if ground conditions are not properly studied. For example, geotechnical issues have caused building damage, slope failures, dam breaches. (Intertek)
- Early geotechnical investigation and design can **reduce costs** (by optimising foundations, avoiding overdesign), **improve safety**, and **extend life** of structures.
- Sustainable development: By understanding site geology and soil/rock behaviour, engineers can choose efficient designs, minimise environmental disturbance, reuse local materials, and avoid unnecessary excavation or remediation.
- Integration with geology: Because ground behaviour depends on geological history (rock type, faulting, weathering, groundwater), geotechnical engineers

must work closely with geological engineers and geologists. (Engineering Management Institute)

Summary

In summary, this unit sets the foundation for your study of geotechnical engineering in civil/automobile engineering context. You now understand:

- What geology is, its branches, why it matters for engineering.
- How rocks are classified (igneous, sedimentary, metamorphic), how they form, and how their properties influence engineering decisions.
- What soil is and why soil behaviour is critical in construction – as foundation bed and as a material.
- How geotechnical engineering applies in the field: foundations, pavements, retaining structures, dams — all of which rest on or use earth materials, and whose behaviour we must understand and design for.

Diploma Wallah

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