Engineering Geology

Short notes for B.Tech Civil · GATE CE

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I. Introduction and Earth Structure

- **Engineering geology** = use of geology for planning, design and construction of civil works (dams, tunnels, bridges, roads, buildings).
- Why civil engineers need it: choose safe sites, know rock and soil behaviour, predict hazards, find construction materials and groundwater.
- Branches: physical geology, mineralogy, petrology, structural geology, hydrogeology, seismology, geomorphology.

➤ Interior of the earth

Layer	Approx. depth	Notes
Crust	0 to about 35 km (continents), about 7 km (oceans)	Sial (continental), sima (oceanic)
Mantle	Down to about 2900 km	Mostly silicate rock; upper part partly molten (asthenosphere)
Outer core	2900 to 5150 km	Liquid iron-nickel (S-waves do not pass)
Inner core	5150 to 6371 km	Solid iron-nickel

- **Moho discontinuity**: crust–mantle boundary. **Gutenberg discontinuity**: mantle–core boundary.
- **Plate tectonics**: the lithosphere is broken into plates; boundaries are divergent, convergent and transform. Most earthquakes and volcanoes occur at boundaries.

➤ Weathering

- **Physical**: frost action, temperature change (exfoliation), unloading. **Chemical**: oxidation, hydration, carbonation, solution. **Biological**: roots, burrowing animals.
- Products: residual soils, laterite (hot humid climate), black cotton soil (from basalt).

2. Mineralogy

- **Mineral** = naturally occurring inorganic solid with a definite chemical composition and crystal structure.

➤ Physical properties

- Colour, **streak** (colour of powder, more reliable), lustre (metallic, vitreous, pearly, silky), hardness, cleavage, fracture, specific gravity, form.

➤ Mohs hardness scale

Hardness	Mineral
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

REMEMBER Finger nail about 2.5, copper coin about 3, knife blade about 5.5, glass about 5.5. Quartz scratches glass.

➤ Important rock-forming minerals

Mineral	Key identification
Quartz	Hardness 7, no cleavage, conchoidal fracture, glassy
Feldspar (orthoclase, plagioclase)	Hardness 6, two cleavages, most common mineral group
Mica (muscovite, biotite)	One perfect cleavage, thin flexible sheets
Hornblende, augite	Dark, ferromagnesian
Olivine	Olive green, in basic rocks
Calcite	Hardness 3, fizzes with dilute HCl
Clay minerals	Kaolinite, illite, montmorillonite (swelling)

3. Petrology (Rocks)

Igneous rocks

- Formed by cooling of magma. **Intrusive (plutonic)**: slow cooling, coarse grains (granite). **Extrusive (volcanic)**: fast cooling, fine grains (basalt). **Hypabyssal**: medium (dolerite).
- Forms: batholith, laccolith, sill (parallel to beds), dyke (cuts across beds), lava flows.

Silica content	Class	Example
> 66%	Acidic	Granite, rhyolite
52 to 66%	Intermediate	Diorite, andesite
45 to 52%	Basic	Gabbro, basalt
< 45%	Ultrabasic	Peridotite

- Deccan Traps of India are thick basalt lava flows.

Sedimentary rocks

- Formed by deposition, compaction and cementation of sediments; show **stratification** (layers) and may contain fossils.
- Clastic: conglomerate (rounded gravel), breccia (angular), sandstone, siltstone, shale. Chemical: limestone, rock salt, gypsum. Organic: coal, some limestones.

Metamorphic rocks

- Formed by heat, pressure and fluids acting on existing rocks. Types: contact (thermal) and regional (dynamo-thermal).
- **Foliation**: parallel arrangement of minerals (slaty cleavage, schistosity, gneissose banding).

Parent rock	Metamorphic rock
Shale	Slate → phyllite → schist
Sandstone	Quartzite
Limestone	Marble
Granite	Gneiss
Coal	Graphite

- **Rock cycle**: igneous → weathered → sedimentary → metamorphic → melted → igneous (any path possible).

> **TIP** For a dam site, massive granite, gneiss, quartzite and basalt are good; shale, clay-rich, cavernous limestone and highly jointed rocks are poor.

4. Structural Geology

- **Strike**: direction of a horizontal line on a bed. **Dip**: max angle of the bed with horizontal, measured at right angles to strike. Measured by a clinometer compass.

> **FORMULA** Apparent dip: $\tan \alpha = \tan \delta \times \sin \beta$, δ = true dip, β = angle between strike and the section line.

> **EXAMPLE** True dip $\delta = 30°$, section line at $\beta = 40°$ to the strike. $\tan \alpha = \tan 30° \times \sin 40° = 0.5774 \times 0.6428 = 0.3711$, $\alpha = 20.4°$.

➤ Folds

- Bends in rock layers due to compression. **Anticline**: arch (convex up), oldest rocks at core. **Syncline**: trough, youngest at core.
- Parts: limbs, axial plane, hinge, crest, trough. Types: symmetrical, asymmetrical, overturned, recumbent, isoclinal, plunging.
- Tunnels: along the crest of an anticline rock is in tension and fractured, but groundwater moves away; in a syncline core rock is compressed and water collects.

➤ Faults

- **Fault** = fracture along which rocks have moved. Parts: hanging wall, footwall, throw, heave.

Fault	Movement
Normal	Hanging wall moves down (tension)
Reverse	Hanging wall moves up (compression)
Thrust	Low-angle reverse fault
Strike-slip	Horizontal movement along strike
Graben / horst	Down-dropped / uplifted block between faults

- Faults are planes of weakness and seepage paths; avoid active faults at dam sites.

Joints and unconformities

- **Joints** = fractures without movement (columnar joints in basalt, sheet joints in granite). They reduce strength and raise permeability.
- **Unconformity** = a gap in the geological record (erosion surface). Types: angular unconformity, disconformity, nonconformity.

5. Earthquakes

- **Focus (hypocentre)**: point of origin inside the earth. **Epicentre**: point on the surface directly above.
- Causes: tectonic (most), volcanic, collapse, reservoir-induced (Koyna, 1967).

Seismic waves

Wave	Type	Notes
P (primary)	Body, longitudinal	Fastest; passes through solids and liquids
S (secondary)	Body, transverse	Slower; only through solids
Love (L)	Surface	Horizontal shearing
Rayleigh	Surface	Rolling motion; slowest; most damage

- **Magnitude** (Richter): measures energy; logarithmic. One unit rise = 10 times amplitude and about 31.6 times energy.
- **Intensity** (Modified Mercalli, I to XII): measures effect / damage at a place.

EXAMPLE Magnitude 7 vs magnitude 5. Amplitude ratio = 10^2 = 100. Energy ratio = 10^(1.5 x 2) = 10^3 = about 1000 times.

- IS 1893:2016 divides India into seismic zones II to V. Zone factors: II = 0.10, III = 0.16, IV = 0.24, V = 0.36.
- Earthquake-resistant practice: avoid soft storeys and irregular plans, use ductile detailing, avoid liquefiable sites.

6. Landslides and Groundwater

Landslides (mass movement)

- Types: fall, topple, slide (rotational, translational), flow (debris, mud), creep.

- Causes: steep slopes, water (raises pore pressure), weak rocks, beds dipping towards the slope, cutting at the toe, earthquakes, deforestation.
- Prevention: drainage (most effective), retaining walls, rock bolts, slope flattening, vegetation, grouting.

➤ Groundwater

- **Aquifer** (sand, gravel, jointed rocks), **aquiclude** (clay), **aquitard** (silty clay), **aquifuge** (massive granite).
- Porosity (storage) vs permeability (flow): clay has high porosity but very low permeability.
- **Springs** occur where the water table meets the ground surface. **Artesian wells** in confined aquifers flow freely if the head is above the ground.
- Groundwater problems in works: seepage under dams, inflow in tunnels, uplift, softening of shale, dissolution of limestone (karst).

7. Site Investigation and Rock Mechanics

➤ Geophysical methods

- **Electrical resistivity**: finds groundwater, depth to bedrock, clay layers (Wenner and Schlumberger arrangements).
- **Seismic refraction**: finds depth of layers and rock quality from wave velocities (needs velocity to increase with depth).

FORMULA Two-layer seismic refraction: depth $z = (xc / 2) \times \sqrt{[(V2 - V1) / (V2 + V1)]}$, xc = crossover distance.

EXAMPLE V1 = 500 m/s, V2 = 2000 m/s, crossover distance xc = 40 m. $z = 20 \times \sqrt{(1500/2500)} = 20 \times 0.7746 = 15.5$ m.

- Other: gravity, magnetic, ground penetrating radar. Direct methods: test pits, boreholes, drilling with core recovery.

➤ Rock quality

FORMULA RQD = (sum of core pieces 10 cm or longer / total core run length) x 100.

RQD (%)	Rock quality
0 to 25	Very poor
25 to 50	Poor
50 to 75	Fair
75 to 90	Good
90 to 100	Excellent

EXAMPLE Core run 150 cm. Pieces of 10 cm or longer: 25, 18, 12, 30, 15 cm (total 100 cm). RQD = 100/150 x 100 = 66.7%, so fair rock.

- **RMR (Bieniawski)**: rates strength, RQD, joint spacing, joint condition, groundwater (+ adjustment for orientation). Total 0 to 100; classes I (very good) to V (very poor).
- **Q-system (Barton)**: used for tunnel support design.

8. Geology for Civil Works

Work	Key geological checks
Dams	Strong, impervious foundation; no active faults; beds dipping upstream preferred; no cavities
Reservoirs	Watertight basin; no leaky limestone or porous beds; stable banks; low siltation
Tunnels	Stable rock, low groundwater, avoid fault zones and shear zones; good if driven across strike of hard rock
Bridges	Firm rock or soil at pier sites; check scour and weathered layers
Roads	Stable slopes; avoid cutting with beds dipping towards the road
Buildings	Bearing strength, expansive soils, seismic zone, water table

- **Remote sensing and GIS**: satellite images for lineaments (faults), landslides, land use and groundwater potential mapping.

9. Most Asked Questions (practice)

1. Describe the internal structure of the earth with discontinuities.
2. Explain physical properties of minerals; write Mohs scale.
3. Classify igneous rocks by mode of occurrence and silica content.
4. Explain metamorphism and its types with examples.
5. Define strike and dip; find apparent dip for given data.
6. Explain folds and faults; how do they affect dams and tunnels?
7. Explain seismic waves, magnitude and intensity; seismic zones of India.
8. Causes and prevention of landslides.
9. Explain electrical resistivity and seismic refraction methods.
10. Define RQD and RMR; list geological requirements of a dam site.

TIP For exams, draw neat sketches of folds, faults and earth layers. GATE CE rarely asks geology directly, but RQD, seismic waves and rock types help in foundation and tunnel questions.