Applied geotechnics and engineering geology – CVEN3203

Engineering Geology

Geological time and plate tectonics

What are joints?

Joints are the equivalent of cracks in geology. Joints are a brittle fracture surface in rocks along which little or no displacement has occurred. They run perpendicular to the bedding plane (layers between two beds of materials).

What is the geological time scale and how was it formed?

The geological time scale was developed from the study of the formation of rock layers in the Earth's crust, which enabled geologists to 'date' geological events sequentially. Scientists divide the earth into several periods – the "Geological time scale", according to rock strata and sorts of fossils found in each one. Geological time divides the history of the earth into arbitrary periods.

Deposition: the geological process in which sediments, soil and rocks are added to a platform or land mass.

What are the main factors affecting material deposition?

The main factors affecting material deposition and life forms have been the global climate, plate tectonics, and the make up of the atmosphere.

Contour line: a line on a map joining points of equal height above or below sea level

What are the 4 eras?

- **Precambrian: earliest part of Earth's history (88% of Earth's geologic time)**
- **Palaeozoic: era of ancient life – characterised by fossils of invertebrates, primitive amphibians etc.**
- **Mesozoic: era of middle life, characterised by fossils of dinosaurs**
- **Cenozoic: era of recent life, characterised by mammals and modern forms of plants and invertebrates**

These eras are divided into periods, which are divided into epochs, which are divided into ages.

What is the law of superposition?

For any undisturbed sequence of rocks deposited into layers (sedimentary rock), the youngest layer is on the top and the oldest on bottom. This means as we move up in the layers of rock, we find more detailed fossils. Between the layers of rocks are bedding planes, which represent periods of extinction, as in the next layer the fossils have changed. Hence, we see an evolutionary process as we go up the layers.

What are the two types of crust?

- **Oceanic crust: thinner layer of crust, 5-10 km thick. It consists of heavy mafic materials (iron and magnesium rich) and has a high specific gravity. It hence sinks down.**

- Continental crust: thicker layer of crust, 20-80 km thick. It consists of lighter Felsic materials (Feldspar and quartz rich) with a specific gravity around 2.65. It is hence a much lighter layer and floats.

The crust is floating on ductile mantle, and below the mantle is a core which is part liquid and part solid, with the heavier minerals in the middle.

What is the theory of continental drift?

It was proposed by Alfred Wegener in 1915 and suggests that a super continent Pangaea existed around 200 million years ago and are now pulling apart. The mechanism is plate tectonics.

What is the mechanism of plate tectonics?

The lithosphere consists of the upper zone of the mantle, and is broken into large sections known as plates which float upon the mantle. Convection currents develop in the mantle due to the heating of molten rock which moves up to the crust where it is cooled and moves back down. This process occurs very slowly. These convection currents in the mantle result in a drag on the bottom of the plates which causes them to be dragged around the surface of the planet.

What is the evidence for continental drift?

- The continents look like components of a jig saw puzzle
- Fossil and rock (type and age) comparisons on the edges of continents – correlations exist between fossils in similar age rocks
- Correlation of mountain chains
- Paleoclimatic evidence (glaciers and reefs) e.g. south of Adelaide has glacial soil suggesting it was once connected to the poles
- Paleomagnetism: magma containing minerals which are magnetic is deposited and flows, these minerals start to align themselves with poles which have flipped many times
- The large amount of seismic activity at plate boundaries – earthquakes are common along plate boundaries due to stress build up and release as plates attempt to slide against, into or apart from one another.
- Movement can now be measured by surveyors

The earth has drastically changed over the last 4.5 billion years. This includes changes in the atmosphere, climate, sea level and position of continents on the earth's surface

Rock elements were formed under vastly different environmental conditions compared with today

The condition of a rock mass will be related to the conditions that existed when it was first formed and the environments that it has been subjected to since then. Understanding the rock type and formation is critical to understanding types of geological structures one might come across in a particular area.

What is the difference between low and high energy environments?

High energy environments have large particles deposited (e.g. sands, clays) whilst low energy environments have fine particles deposited e.g. silts, peats.

Bearing capacity of shallow foundations

Strength of soil generally increases with depth

What are the requirements of a foundation?

- Design is economical
- Adequate safety: bearing capacity, sliding, allowable settlement, overturning
- Small seasonal changes: drying, frost, heave → shrinkage, heaving in expansive soil
- Construction problems: stability of excavation, bottom heave, ground water (fully saturated soil, water table close to surface etc.), vibrations (causing liquification), noise
- Environmental effects: permanent lowering of the ground water level

How do you choose a foundation?

- Primary factor affecting foundation choice: subsurface soil quality (poor quality – deep foundation, high quality – shallow foundation), ground water conditions, structural requirements (allowable deformation, applied load)
- Secondary factors: construction access, methods and site conditions, environmental factors, building codes and regulations, impact on surrounding structures, construction schedule, construction risks

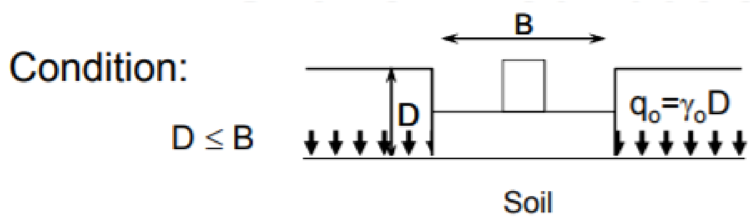
Footing design

Foundation type	Application	Applicable soil conditions
Single footing, strip footing	Under individual columns, walls, bridge piers	Soil bearing capacity is adequate for applied load. May use on firm layer over soft layer. Immediate and differential settlements must be checked.
Mat foundation	Under columns with very heavy loads, reduces total and differential settlements	Soil bearing capacity is not large. Over half of the building area may be covered if single footings are used. Settlement is excessive if single footings area used.
Pile foundation	Under columns with very heavy loads, in groups to carry wall loads	Soil near the surface is poor. Soils of high bearing capacity are 20-50 m below ground surface.

Bearing capacity of shallow foundations comes from the base. In pile foundations this resisting comes from the shift, the friction between the pile and the soil, and the base.

Shallow foundations

Shallow foundations: depth <= width of foundation



Types: strip footings (consider 1 unit length in analysis), circular, square, rectangular footings, special footings (combine footings due to large load eccentricity)

Area of foundation > 0.5 area of land → connect shallow foundations and design a mat foundation (one large slab, load applied to this)

qu – ultimate capacity of foundation → decrease value to safe load qu/F – factor of safety

qs – maximum service load (from allowable settlement)

Maximum allowable load: qa = min(qs, qu/F)

How can we determine qu (ultimate bearing capacity)?

We use approximation solution – exact solution lies somewhere in between – these methods converge to the exact solution

- **Lower bound analysis: gives a lower qu in comparison with exact solution**
  - **Assume failure mode**
  - **The state of stresses at failure is assumed**
  - **Failure load is obtained based on stress compatibility – collapse cannot occur at any load less than the failure load**
  - **Failure load is less than or equal to the true ultimate capacity**
- **Upper bound analysis: gives a higher qu in comparison with exact solution**
  - **Failure mechanism is assumed**
  - **Failure load is obtained based on deformation compatibility – by equating external work to internal work done at collapse mechanism**
  - **Failure load is greater than or equal to true ultimate capacity – collapse must occur for any load greater than the failure load**

Bearing capacity equations

Shallow strip footing (continuous footing): $q_u = cN_c + q_0 N_q + 0.5\gamma B N_\gamma$

- q_u – ultimate bearing capacity
- c – cohesion
- q_0 – surcharge
- γ – unit weight of soil
- B – the least dimension of rectangular footings or diameter of circular footings
- N_c, N_q, N_γ – bearing capacity factors – functions of ϕ

Square footing: $q_u = 1.3cN_c + q_0 N_q + 0.4\gamma B N_\gamma$

Circular footing: $q_u = 1.3cN_c + q_0 N_q + 0.3\gamma B N_\gamma$

Hansen equation

$\phi \neq 0$ – drained boundary condition

$$q_u = cN_c s_c d_c i_c g_c b_c + q_0 N_q s_q d_q i_q g_q b_q + 0.5\gamma B N_\gamma s_\gamma d_\gamma i_\gamma g_\gamma b_\gamma$$

- $N_q = \tan^2(45 + \frac{\phi}{2}) \times e^{\pi \tan\phi}$
- $N_\gamma = 1.5(N_q - 1)\tan\phi$
- $N_c = (N_q - 1)\tan\phi$
- c – cohesion
- i – inclination factor, when loads act other than normal to the footing
- s – shape factor (shape of footing)
- g – ground factor, the slope of the ground on which the footing is built
- d – depth factor – the depth of the footing base below the surface
- b – base factor, for a footing with an inclined base

$\phi = 0$ – undrained boundary condition

$$q_u = 5.14c_u(1 + s_{cu} + d_{cu} - i_{cu} - b_{cu} - g_{cu}) + q_0$$