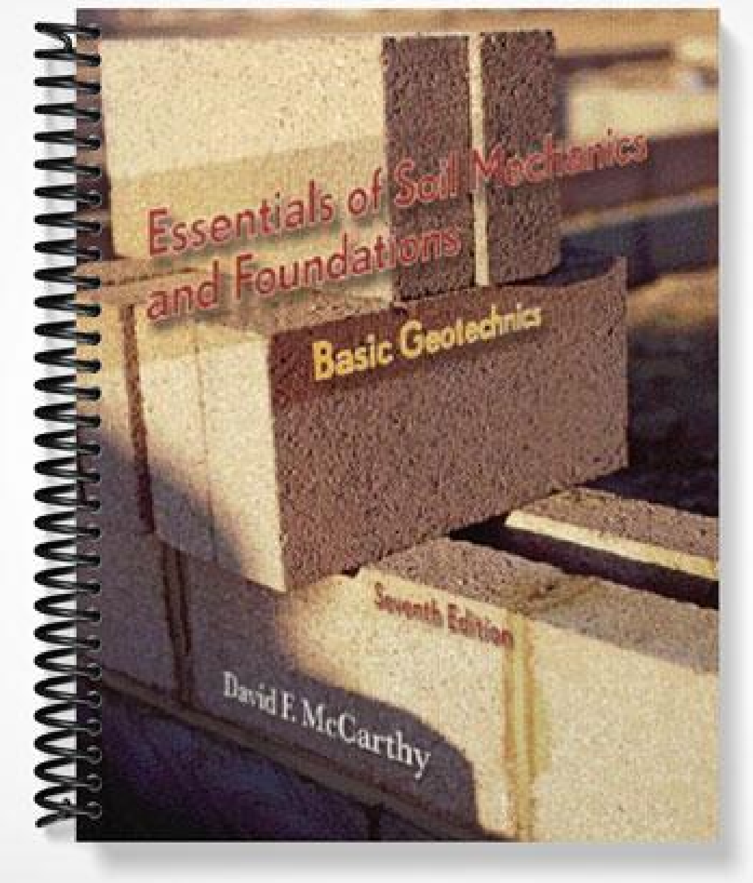
SOLUTIONS MANUAL



Instructor's Manual
to accompany

Essentials of Soil Mechanics and Foundations
Basic Geotechnics

Seventh Edition

David F. McCarthy, P.E.

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Glossary - Geotechnical Terms

Adsorbed water Water bound to soil particles because of the attraction between electrical charges existing on soil particle surfaces and (dipole) water molecules.

Aeolin deposit Soil formation resulting from the accumulation of soil particles transported then deposited by action of winds (typically, particles small enough to become air-borne such as the silt sizes).

Aquifer Soil or rock layer (stratum) in which groundwater flows easily (i.e., a stratum which is a carrier of, or subsurface travel route for, groundwater). Typically, aquifers consist of coarse-grained soils or fractured, seamy rock.

Aquitard Type of soil or rock layer (stratum) that restricts or prevents the movement of subsurface water. Typically, equitards consist of fine-grained soils such as silts and clays or sound rock (solid, not fractured or seamy).

Arching The transfer of stress from a yielding part of a soil mass to an adjacent, less yielding or restrained part of the mass.

Artesian condition Condition where an underground flow of water rises above the elevation of the buried soil zone through which flow is occurring (the aquifer) possibly rising to or spouting above the ground surface because of the high water pressures within the flowing volume.

Asthenosphere Relates to the zonal cross-sectioning of the planet earth, being the "weak rock" zone section of the earth's mantle under the lithosphere; this "weak rock" zone is in a semi-solid or plastic condition where viscous type movements tend to occur.

Atterberg limits The liquid limit, plastic limit, and shrinkage limit for soil. The water content where the soil behavior changes from the liquid to the plastic state is the liquid limit; from the plastic to the semisolid state is the plastic limit; and from the semisolid to the solid state is the shrinkage limit.

Axisymmetric strain Load-induced strain movements occurring in the three axial directions (a 3-dimensional strain condition compared to the 2-dimensional plane-strain condition).

Backfill Soil material placed back into an area that has been excavated, such as against structures and in pipe trenches.

Bearing capacity The pressure that can be imposed by a foundation onto the soil or rock supporting the foundation.

Boring The method of investigating subsurface conditions by drilling into the earth. Frequently, soil or rock samples are also extracted from the boring for classification and testing.

Borrow Soil or rock material obtained from an off-site source for use as fill on construction and projects.

Caisson A large structural chamber used to keep soil and water from entering into a deep excavation or construction area. Caissons may be installed by being sunk in place or by systematically excavating below the bottom unit to the desired depth.

Capillarity The movement of water, due to effects other than gravity, through very small void spaces that exist in a soil mass. Water movement occurs in very small channels such as capillary-sized openings because of the affinity between soil and water, which acts to increase the boundary of contact between the two materials, and the surface tension property developed by water in contact with air. Capillary flow can occur in a direction opposite to that of the pull of gravity.

Chemical weathering. The process of weathering whereby chemical reactions such as hydration, solution, oxidation, and ion exchange break down and possibly change rock and soil materials.

Clays (clay minerals) Very small soil particles having a crystalline (layered) structure, created as the result of the chemical alteration of primary rock minerals. Most clay particles, because of their mineralogical composition, are flat or platelike in shape, with a large surface area to mass ratio. Clay particle dimensions are often smaller than 0.002mm.

Coarse-grained soil Those soil types having particles large enough to be seen without visual assistance. The coarse-grained materials include the sand and gravel (or larger) soil particles.

Cohesion The bonding or attraction between particles of fine-grained soil that creates shear strength.

Compaction The process of increasing the density or unit weight of a soil (frequently fill soil) by rolling, tamping, vibrating, or other mechanical means.

Compressibility The change, or tendency for change, that occurs in the thickness of a soil mass when it is subjected to compressive loading.

Conduit Pipe that is buried in a soil mass or passes through a soil embankment and carries water or other fluid materials, electrical cables, and the like.

Consolidation The process by which compression of a newly stressed clay soil occurs simultaneously with the expulsion of water present in the soil void spaces. Initially, the newly imposed stress acting on the clay is imparted onto the water in the soil voids (pore water), and not onto the soil particles. Because of the increased pressure, the water is gradually forced out of the soil. As the pore water pressure is reduced, the magnitude of stress being imposed onto the soil particles is correspondingly increased. Compression of the clay layer occurs only as rapidly as pore water can drain from the soil, and this is related to the permeability of the soil layer.

Contamination (groundwater, soil) A degradation or lowering of the quality (of groundwater or soil) which affects suitability for conventional usage. The condition occurs because of exposure to, inclusion of, or mixing with undesirable biological, chemical, or radioactive substances.

Density The mass per unit of volume. In reference to soil, the term also is used to indicate weight per unit volume (i.e., unit weight); though not identical, density is synonymous with unit weight.

Desiccation A condition where a drying soil shrinks because of lost water content, frequently accompanied by cracks forming in the surface zones,because of the reduction in the overall volume.

Dewatering The procedure used to remove water from a construction area, such as pumping from an excavation or location where water covers the planned working surface; the procedure used to lower the groundwater table in order to obtain a "dry" area in the vicinity of an excavation that would otherwise extend below water.

Dilatency A condition for soil where the surface of a volume becomes noticeably wetter when shaken or vibrated because of movement of the included moisture as some void spaces temporarily change/enlarge to permit free passage of water (moist silts typically will exhibit dilatency but clays will not because of the strong bonds between soil particles and the water molecule – clay particle surfaces).

Dispersive clays Clay soils that deflocculate in still water and erode when exposed to a low-velocity flow of water. A clay-pore water system that has a high concentration of sodium ions tends to have high dispersivity.

Ditch conduits Conduits installed in narrow ditches or trenches that are subsequently backfilled.

Drawdown The lowering of the level of the groundwater table that occurs in the vicinity of a water well (on dewatering equipment) when it is pumped.

Dynamic compaction The procedure whereby surface and near-surface zones of soil or fill are compacted by dropping a heavy weight (commonly 5 to 15 tons) from a relatively great height (drops of 10 to 30m (30 to 100 ft) are typical). Multiple poundings are provided at each drop location, and closely spaced drop locations are utilized to improve a construction site.

Earth pressure Normally used in reference to the lateral pressure or force imposed by a soil mass against an earth-supporting structure such as a retaining wall or basement wall, or on a fictitious vertical plane located within a soil mass. The coefficient of earth pressure refers to the ratio of lateral pressure to vertical pressure existing at a point in a soil mass.

Earthquake The shaking and movement of the earth which results when a release of energy occurs because of deep rock fracturing or shifting, volcanic eruption, or a large explosion.

Earthquake intensity A numerical scale of reference to indicate the damage and other effects resulting at a given geographical location because of an earthquake.

Earthquake magnitude Value used to indicate the relative severity of earthquake events; the numeric value is obtained by taking the logarithm (base 10) of the maximum seismic wave amplitude (in 0.001 mm) recorded by a seismograph positioned 100 km from an earthquake epicenter.

Effective stress The actual particle-to-particle contact stress (or pressure) existing between soil grains. This stress compensates for the possible buoyancy influence of water pressure. Effective stress relates directly to the shear strength possessed by a soil.

Expansive clays Clay soils that experience significant volume expansion in the presence of water and shrink upon drying. Clays including the montmorillonite mineral are especially noted for their volume-change characteristics.

Fill Earth placed in an excavation or other area to raise the surface elevation. Also referred to as earth fill or soil fill. Structural earth fill refers to the material that is placed and compacted in layers in order to achieve a uniform and dense soil mass which is capable of supporting structural loading.

Fines or Fine-grained Refers to silt- and clay-sized particles that exist in a soil mixture (particles smaller than 0.074 mm).

Flocculated structure Grouping of small soil particles such as clays and which attach to adjacent flocs to result in a honeycombed-type assembly.

Flow line The path of travel traced by moving water as it flows through a soil mass.

Flow net A graphical or pictorial method used to study the flow of water through a soil. Used to indicate the paths of travel followed by moving water and the subsurface pressures resulting from the presence of the water.

Footing Type of foundation typically installed at a shallow depth and constructed to provide a relatively large area of bearing onto the supporting soil.

French drains A gravel-filled trench that functions as an underground drainage passage for carrying or intercepting subsurface water; functions as a drainage conduit without the requirement of a pipe (but may also include a pipe embedded within the gravel material).

Fricton, internal The particle (solid-to-solid) friction developed by cohesionless soils, and the property responsible for most of the shear strength that this type of soil can develop. The angle of internal friction, f, refers to the arc tan value of the sloped line that results from graphing the relationship between shear strength and the imposed normal stress for a soil. This strength property also applies to fine-grained soils when the effect of consolidation or drainage on the shearing resistance of those soils is being studied.

Frost heave A condition where the occurrence of low temperatures in a soil causes original water in the soil voids, and subsequently attracted water, to freeze and expand, resulting in an overall expansion in the low-temperature soil zone; the condition is typically noticeable as a rise/heave in the ground surface.

Gabions Stone-filled steel wire baskets that can be assembled or stacked like building blocks to act as retaining walls or provide slope and erosion protection.

Geosynthetics Sheetlike materials along with other shapes manufactured of durable, nondegradable synthetics, such as polyester, polypropylene. polyethylene, polyvinylchlorides, butyl (synthetic) rubber, etc. to be used in construction assemblies that are in contact with the ground or included in earth fill, to provide functions which enhance the performance of the construction, such as reinforcement or drainage.

Groundwater table The surface of the underground supply of gravitational water (water free to flow due to the effect of gravity); excludes adsorbed or bonded water. Also referred to as the phreatic surface.

Head Shortened form of the phrase pressure head, referring to the pressure resulting from a column of water or elevated supply of water. Pressure would be computed from $\delta_w h$, where δ_w is the unit weight of water and h is the height or elevation of the water supply. The h term is the pressure head.

Heave Upward movement of soil and foundations supported on soil, caused by expansion occurring in the soil as a result of such factors as freezing or swelling due to increased water content. Frost heave refers to the vertical soil movement that occurs in freezing temperatures as ice layers or lenses form within the freezing soil and cause the soil mass to expand.

Hydraulic conductivity (a/k/a coefficient of permeability) A term reflecting the ease or difficulty for liquids and gasses to flow through a soil by traveling in the void spaces; a high hydraulic conductivity indicates flow can occur rapidly, and vice-versa.

Hydraulic gradient Mathematical term indicating the difference in the water or liquid pressure head existing between two locations divided by the distance between these same locations. Given the designation i (typically used to study the subsurface flow of water).

In situ Refers to soil when it is at its natural location in the earth and in its natural condition.

In-situ testing Relates to a testing procedure performed on soil at the in-place position in the deposit (typically performed in a bore-hole or test pit excavation); the tested soil is not removed from the natural location.

Isotropic Pertaining to a soil formation where the properties are the same in all directions.

Landslide The relatively rapid lateral and downhill movement of a generally well-defined earth mass or land form due to gravitational forces.

Lateral pressure coefficient, K Ratio of lateral (or horizontal) soil pressure developed or imposed at a given depth in a soil mass compared to the vertical pressure at the same location.

Laterite The category of residual soil formed from the weathering of igneous rock in tropical regions that, through the process of its formation, will include high concentrations of iron and aluminum sesquioxides with low concentrations of silica.

Leachate Liquid flowing from a solid waste landfill (usually, mostly water) which includes contaminants or becomes polluted because of contact with the solid waste.

Limit equilibrium A method of analysis used to evaluate the stability of soil mass (such as in a slope or foundation support) that could be involved in movement associated with failure. The method involves determining the soil shear strength on an assumed failure surface as required to maintain equilibrium or stability, and compares this value with the actual shear strength of the soil; this comparison indicates if equilibrium will exist or if the limits of equilibrium will be exceeded.

Liquefaction Loss of strength occurring in saturated cohesionless soil exposed to shock or vibrations (caused by earthquake, explosions, etc.) when the soil particles momentarily lose contact; the material then behaves as a fluid.

Lithosphere Relates to the zonal cross-sectioning of the planet earth, being the zone of solid rock material that forms the upper section of the earth's mantle (the lithosphere is the zone underlying the continental crust and ocean crust that forms the actual surface-most rock and soil zone of the planet).

Love waves Earthquake-related shear-type seismic waves which travel along the earth's surface zone.

Mechanical weathering The process of weathering whereby physical forces, such as frost action and temperature changes, break down or reduce rock to smaller fragments without involving chemical changes.

Mineral A naturally formed chemical element or compound having a definite chemical composition and usually a characteristic crystal form.

Overconsolidation ratio (OCR) The ratio of the maximum vertical effective stress ever imposed on to a soil deposit (or developed within the deposit) compared to the currently existing effective stress, a summary term that reflects the past history of the deposit. Ratio values greater than one indicate that at some past time the soil was subjected to overburden loading greater than the weight of the present overburden (additional loading such as from the weight of glacial ice or a now-eroded layer of soil). Ratio values less than one represents a "new deposit" (still being formed) that has not fully adjusted (e.g., compressed) to the effects of the existing overburden.

Penetration test Term generally applied to subsurface investigative methods for determining a strength-related property of a soil by measuring the resistance to advancement of penetration or boring equipment.

Penetrometer The category of apparatus used for subsurface investigation and having a relatively small cross-section that can enter or pass through a soil deposit by utilizing a pushing or impact driving force. A measured resistance to advancement against penetration provides an indication of soil shear strength and load support capability. Some types of apparatus also obtain a soil sample at a desired location or depth.

Permafrost The permanently frozen ground located in the northern regions of the earth.

Permeability The ability of water (or other fluid or gas) to flow through a soil by traveling through the void spaces. A high value for the coefficient of permeability indicates that flow occurs rapidly, and vice versa.

Phase diagram Diagram used in the analytical procedure to determine (calculate) physical properties of a soil deposit such as the soil unit weight, void ratio and water content.

Pier Category applied to columnlike concrete foundations, similar to piles. The pier is generally considered the type of deep foundation that is constructed by placing concrete in a deep excavation large enough to permit manual inspection. Pier is also used frequently to indicate heavy masonry column units that are used for basement-level and substructural support.

Piezometer Mechanical apparatus used to measure pore water pressure developed at a particular depth/position in a soil deposit.

Pile The relatively long, slender, columnlike type of foundation that obtains supporting capacity from the soil or rock some distance below the ground surface.

Pipe bedding Preparation of the surface that is to support a buried conduit. Established bedding classes consider effects of contouring the supporting surface to the shape of the pipe, extent of compaction, and placement of a supporting material such as concrete or gravel. Generally, preparation of bedding reduces the stresses that will develop in the pipe (conduit) from an overlying fill.

Piping Erosion by subsurface water moving through a soil zone, which results in the formation of continuous tunnels or "pipes" through which water then travels rapidly. Progressive erosion or cave-in of the ground results. The condition is associated with the movement of water through permeable dam foundations.

Plane strain A state of strain in which all displacements that arise from deformation are parallel to one particular plane (a 2-dimensional strain condition as compared to the 3-dimensional axisymmetricial strain condition).

Plasticity Term applied to fine-grained soils (particularly clays) to indicate the soils' (plus included water's) ability to flow or be remolded without raveling or breaking apart.

Plate tectonics The concept that the earth's outer zone consists of a small number (10 to 25) of large thick plates that "float" on a viscous underlayer and can move more or less independently. The continents are carried on the plates and move with them; oceans are similarly carried on the plates and expand or shrink as the distances between continents change.

Plume (contaminated plume) The subsurface zone being affected by the spread of a moving/flowing volume of contaminated ground water or other type liquid contaminent.

Poisson's ratio The ratio of lateral unit strain to the longitudinal unit strain in a body that has been stressed longitudinally within its elastic limit.

Pore pressure Water pressure developed in the voids of a soil mass. Excess pore pressure refers to pressure greater than the normal hydrostatic pressure expected as a result of position below the water table.

Porosity The relative volume of open space (pores or voids) existing within the total volume occupied by a soil or rock mass. Mathematically, porosity n is equal to the volume of void spaces divided by total volume of the soil or rock material (the total volume consists of the volume of void spaces plus the volume of solids).

Pressuremeter An instrument used to determine the in situ strength of a soil zone through measurement of the pressure-related lateral expansion of a flexible cylinder that is at a known depth in a borehole.

Primary (P) wave Earthquake-related seismic or shock wave that travels through the earth with a compression-dilation (push-pull) type of oscillation.

Projecting conduits Conduits in areas where earth fill or earth embankment will be placed above the installation.

Radon An invisible, odorless, tasteless gas formed from the decay of uranium, radium, and polonium found in some rock, soil, and waste materials.

Rayleigh waves Earthquake-related seismic waves that travel along the earth's surface zone with a rolling or rippling motion.

Reinforced earth Earth structures such as embankments, retaining walls, and dams that are constructed in layers reinforced with fabrics, strips, or fibers to increase the strength of the soil mass.

Relative density Term applied to sand deposits to indicate a relative state of compaction compared to the loosest and most dense conditions possible.

Retaining wall A vertical structure designed to resist the lateral pressure of soil and water behind it.

Revetment A protective wall, assembly or facing of stone, concrete, or other durable material built to separate an embankment or shore structure from wave erosion.

Riprap The layer of boulders or crushed rock materials, typically ranging from 150 to 600 mm (6-in to 24-in) in size, placed as a covering to protect the surface of earth dams and earth slopes, against erosion.

Rollers, compaction The category of construction equipment utilized to compact (or densify) soil by rolling it. The compaction force typically results from the heavy weight of the equipment and/or vibrations transmitted from the equipment into the soil.

Sand The category of coarse-grained soil whose particle sizes range between about 0.07 mm and 5 mm in diameter.

Secondary (S) waves Earthquake-related shear type seismic waves that travel through the earth, causing up-and-down and side-to-side oscillations.

Seepage Generally refers to the quantity of water flowing through a soil deposit or soil structure such as an earth dam. Also may refer to the quantity of subsurface water leaking into a building's underground (basement) area.

Seismic Pertaining to an earthquake or earth vibration, including one that is artificially induced.

Seismic exploration The method of determining subsurface soil and rock conditions (without excavation) by inducing a shock wave into the earth and measuring the velocity of the wave's travel through the earth material. This seismic velocity indicates the type of earth material.

Seismogram The oscillating-line record of ground movements measured by the seismograph during an earthquake event.

Seismograph Instrument to measure the horizontal and vertical movements or vibrations that occur within the earth or at the surface because of earthquake or other seismic waves.

Settlement The downward vertical movement experienced by structures or a soil surface as the underlying supporting earth compresses.

Shear strength The ability of a soil to resist shearing stresses developed within a soil mass as a result of loading imposed onto the soil.

Sheetpiling A pile with a generally flat cross section, made to interlock with adjoining sections to form a thin diaphragm wall or bulkhead; used to resist the lateral force of retained earth or water when part of temporary and permanent structures.

Sieve Pan or traylike equipment having a screen or mesh bottom; used in laboratory or field work to separate particles of a soil sample into their various sizes.

Silt The category of fine-grained soil particles (individual soil grains whose particle size is smaller than 0.074 mm or too small to be seen without visual aid) whose mineralogical composition remains similar to the rock they were derived from.

Soil sampler Apparatus used during a subsurface investigation to obtain samples of soil from a desired depth to identify the soil type and for testing.

Soil stabilization Treatment of soil to improve its properties; includes the mixing of additives and other means of alterations such as compaction or drainage.

Solid waste Solid throwaway or disposable materials such as garbage and trash (nonliquids) generated by the residential and commercial sector of civilization, and the nonusable residue or remains of mining and manufacturing operations.

Solid waste (or sanitary) landfill Area or project where solid waste is buried as a means of disposal. Typically, small volumes of solid waste such as a daily supply are discharged into an open excavation, then covered with a layer of soil; a landfill site consists of many buried zones or cells of waste, each enveloped with soil. Modern solid waste landfills will include a synthetic bottom liner to function as a barrier to prevent the solid waste from contaminating the surrounding earth, and a synthetic capping cover when the site is filled to function as a top seal.

Sump Small excavation or pit provided in the floor of a structure, or in the earth, to serve as a collection basin for surface water and near-surface underground water.

Taxonomy (soil taxonomy) A method of soil classification based on natural relationships responsible for the soil formation and behavior.

Terra-probe A method of compacting thick surficial and sand zones through the use of a vertically tubular probe; the probe is vibrated to the desired depth, then slowly withdrawn while continuing to vibrate. Closely spaced probe locations are utilized to compact a construction site.

Test pit A manually or machine-dug excavation in soil so to expose the soil types and identify conditions, possibly to classify the soils and perform in-place testing or obtain samples for lab testing, and to determine the elevation position of the ground water table (if penetrated).

Thixotrophy The feature where a disturbed fine-grain soil material loses some of the bonding strength between particles because of disturbance and breakdown of the particle-to-particle structure, but then regains strength with passage of time.

Till Description given to glacially transported formations consisting of a heterogeneous mixture of fine-grained and coarse-grained material (i.e., a glacial till).

Unit weight The weight per unit volume of a material such as soil, water, concrete, etc. Typically expressed as pounds per cubic foot (lb/ft^3) or kilonewtons per cubic meter (kN/m^3) [also mistakenly as grams per cubic centimeter or kilograms per cubic meter, the units that define density].

Vadose zone The subsurface soil zone that lies directly above the position of the groundwater table. Usually, this zone is partially saturated with water that has migrated upward via capillary movement from the water table.

Vibroflotation A method of compacting thick surficial sand zones through the use of a horizontally vibrating cylinder termed a Vibroflot. The Vibroflot is jetted to a desired depth and slowly brought to the surface while it continues to vibrate. The process typically compacts the soil in a 5-ft zone surrounding the Vibroflot, and a series of penetrations are provided to compact a construction site. Sand is added to the zone surrounding the Vibroflot to make up the volume lost by compaction.

Void ratio The total volume occupied by a soil mass includes the soil particles plus void spaces (which in nature always exist between the particles because of their irregular shape). The void ratio is the ratio of the void space volume to the volume of soil solids.

Water content The ratio of the quantity of water in a soil (by weight) to the weight of the soil solids (dry soil), typically expressed as a percentage.

Well point The perforated end section of a wellpipe that permits the groundwater to be drawn into the pipe for pumping.

SOLUTIONS TO CHAPTER PROBLEMS

CHAPTER 1

(1-1) List should include occurrence of events such as earthquake, landslides, land subsidence and extreme settlement, cave-in from presence of sink holes (cavities), severe erosion.

(1-2) Igneous rock--formed from the cooling and hardening of molten rock.
Sedimentary rock--formed from the accumulated deposits of soil particles and certain organisms which have become hardened by pressure or cemented by minerals.
Metamorphic rock--formed where igneous or sedimentary rock have been subjected to the combined effects of heat, pressure and plastic flow.

(1-3) Texture of igneous rock is influenced by the rate at which the original molten rock cooled; rapid cooling results in a fine texture, whereas slow cooling produces a coarser texture.

(1-4) Typically, expect most igneous and metamorphic rock formations to be hard and durable; sedimentary rock formations can be sound and durable but compared to igneous and metamorphic rock more inconsistencies are expected because of presence/inclusion of foreign materials at the time of formation, or weak bonding and cementing.

(1-5) Color--rock types which are basic are dark while acidic types are light in color.

(1-6) Soil sediments may become hardened into sedimentary rock by great pressure or from the presence of minerals which cement the particles together.

(1-7) Shales are estimated to comprise approximately half of the rock exposed at the earth's surface and closest to the surface beneath the soil cover. Reasons relate to the surficial accumulation of sedimentary materials which are transposed to rock by geologic occurrences.

(1-8) Metamorphosis results when a rock material is subject to a combination of heat, pressure and plastic flow. These factors cause a change in the original rock minerals and structure.

(1-9) Generally, most igneous and metamorphic rocks are usually thought to be sound formations for foundation support, whereas certain types of sedimentary rock such as shale and some types of limestone can be poorer. There are exceptions to this generalization.

(1-10) Sinkhole topography is most prevalent in sedimentary rock formations such as limestones and shales because of inclusion of nondurable materials at the time of the rock formation, with underground erosion beginning and progressing in the weak materials due to flow of subsurface water.

(1-11) (I) The great volume of water taken by the glaciers reduced the depths of the major oceans (by approximately 125 to 150-m, or 400 to 500 ft), and a resulting effect was that ocean shore lines were located (extended) beyond the present-day limits , (ii) the considerable weight of the thick glacial ice sheets depressed (pushed down) the covered land surfaces (after the glaciers receded, the land tended to rebound/rise).

(1-12) Loess soils are wind-transported silt deposits whose stable structure can be broken down by water or vibration.

(1-13) A glacial terminal moraine would be expected to include soils of all sizes (from boulders or cobbles, to gravel, sand, silt and clay).

(1-14) The event(s) where a soil deposit is overrun by a large heavy glacier can cause the compressive loading associated with the development of sedimentary rocks such as the shales and the conglomerate-sandstone formations.

(1-15) Sand and gravel size particles rapidly drop from a flowing body of water when velocity decreases occur because of change of depth or change of direction, whereas smaller silt and clay particles remain in suspension in the moving water.

(1-16) For a given volume of flow, greater water velocities will occur in narrow, shallow streams. If the stream channel deepens or widens, the flow velocity decreases and the larger soil particles (e.g., gravel and sand sizes) which had been in suspension drop out. Smaller particles such as silt and clay will remain in suspension to be carried downstream.

(1-17) Natural levees occur where flowing rivers overflow their banks in periods of heavy precipitation and land surface runoff. The larger soil particles carried by the flowing water quickly drop from suspension when the overflowing water loses velocity as it tops the channel banks. Thus, natural levees typically consist of coarse soil.

(1-18) Sand or a sand-gravel mixture.

(1-19) If a terminal moraine dams up a valley area, the melt water from the receding glacier will be trapped in the resulting basin, creating a lake.

(1-20) If a natural basin exists in an area underlain by relatively impervious earth, and routes of water flow into the basin area, the water will be collected and stored, even though the created lake area is above the elevation of the natural ground water elevation.

(1-21) Old lake sites are frequently filled in with fine-grain silt and clay soils that have been carried by water flowing to the area. Coarse particles fall out of suspension where inflowing water (streams, rivers) enters the lake area, whereas the finer particles stay in suspension until reaching the quieter main body of the lake.

(1-22) Filled-in lakes often include fine-grained silt and clay soil particles which were deposited in an underwater environment; the result is a relatively loose soil structure with high water content, thereby creating a compressible soil deposit.

(1-23) Eskers are primarily coarse-grain soil deposits forming along locations where rivers flowed on or within glaciers. Drumlins represent deposits of till (mixture of soil sizes) dropped by the moving glacier; typically drumlins are in the form of long hills, the hills extending in the direction of glacier movement.

(1-24) Eskers, kames, lake deltas.

(1-25) Glacial till is typically a mixture of soil particle sizes. If the till had been deposited beneath the glacier, or at some subsequent time overrun by a glacier, the material is typically very dense and compact, and will provide excellent foundation support (an advantage).

(1-26) If sodium present during the deposition period is subsequently leached from the soil by percolating surface water or subsurface flow, the material loses strength and increases in sensitivity, and a less stable mass results.

(1-27) Typical beach deposits represent a good source of sand, a desirable material for construction fill and an important ingredient of portland-cement concrete and asphalt-cement concrete.

(1-28) (a) Residual soil formations are based on the characteristics of the parent rock; the variation/change from soil to rock (surface downward) is gradational/gradual. Even the well-weathered zones (virtually all soil, possibly including rock fragments, etc.) can show the fabric of the original rock structure. The texture or fabric of transported soil tends to be more consistent/uniform across the depth of each stratum with properties representative of particulate materials.

(b) Transported soil deposits are prevalent in temperate and cold climatic regions; geologic conditions associated with deposits of transported soils include glaciation, severe earthquakes, severe weather (winds, rainfall, snow, temperature variations)

(c) Residual soil formations are prevalent in humid tropic regions, in areas absent of significant erosive forces to move/transport the newly formed soil materials (no glaciation, infrequent floods, etc.)

(1-29) Residual soil formation change gradationally (from soil to weathered rock to sounder rock) with depth; the soil zones that are weathered rock possess many of the textural and strength properties of the parent rock. Transported soils tend to be more uniform in texture/type through the depth of each soil stratum; strength versus depth variations are due to geologic and climatic conditions (such as effects of weight of overriding glaciers, erosion of soil overburden, wetting and drying, etc.) Properties of disturbed residual soils tends to be approximately similar unless the deposit was overconsolidated-compressed (such as from the previous weight of overriding glaciers, previous weight of now-eroded soil overburden, etc.) In clays, disturbance breaks cohesive bonds between particles to reduce shear strength and resistance to deformation (but some of the properties are regained with time).

(1-30) a. Expected areas of future earthquake:
--west coast of North America, Alaska
--west coast of South America, Central America
--regions of southern Europe, North Africa, and western Asia surrounding the Mediterranean Sea
--Japan, Indonesia
--east central Asia (China, northern India)

b. Expected areas of future volcanic activity:
--west coast of South America
--west coast of North America, Alaska
--Greenland/Iceland area
--Japan, Indonesia

(1-31) Throughout the asthenosphere some zones apparently are at a higher temperature due to channels of heat energy moving from the deeper mantle, and such high energy zones migrate-mix with the surrounding asthenosphere by the principle of convection.

(1-32) On a comparative basis, continental crust rock materials have lower specific gravity than ocean crust and the lithosphere-asthenosphere rock materials. Lithosphere and asthenosphere rock are similar, and heavier than ocean and continental crust. Ocean crust is intermediate to continental crust and lithosphere-asthenosphere.

(1-33) Where plates of lithosphere carrying continental crust converge, mountain ranges result as the crust rock is compressed accordion-style as a result of the crusts colliding (for both plates the continental crusts “float” and do not subduct.

(1-34) Ocean crust which subducts when plates converge converts to magma which eventually rises through the overlying plate and crust material to create volcanic mountains.

(1-35) Speculation: (i) as the newly forming molten earth cooled, the contraction of materials in the outer zone resulted in shrinkage stress fracturing.

(ii) as zones of lithosphere were subjected to movement in different directions in prehistoric times because of changes in the underlying asthenosphere and mantle (the conditions thought to be the reason for present day plate movements), the sections of lithosphere were pushed, pulled or sheared, causing fracture at weak and/or highly stressed regions.

(1-36) Continents originally in polar regions have migrated to tropical regions as a result of plate movement.

CHAPTER 2

(2-1) Coarse grains: gravels and sands;

Fine grain: silts and clays.

Division based primarily on particle size; coarse grain particles size and general shape visible/recognized without magnification (unaided vision) while fine-grain particles require magnification (visual assistance) to observe shape. Additionally, moist fine-grain soils typically (but not always) exhibit plastic behavior while coarse-grain soils are non-plastic.

(2-2) Plastic refers to the ability of a fine-grained soil to be remolded, and retain the remolded shape without cracking, breaking or segregating.

(2-3) Mineralogical composition and the electrical charges existing on the surfaces of particles which adsorb water molecules, and the extremely small particle size along with the large surface area to mass ratio which results in a high ratio of adsorbed water to particle mass.

(2-4) Sand and silt particles are, on a relative basis, equidimensional, whereas clay particles are generally flat and plate-like.

(2-5) Silica tetrahedral and alumina octahedral which combine together in a sheetlike (crystalline) arrangement.

(2-6) Water which becomes bonded to a clay particle because of the attraction resulting from negative charges on the clay particle and positive charge of the water molecule, or, because of cations (which hold the negative end of water molecules) that are attracted to the clay particle.

(2-7) Molecules of water have the oxygen and hydrogen atoms arranged so the center of gravity of the positive and negative electrical charges do not coincide, the result being a molecule which has a negative charge toward one end and a positive charge toward the other end. The positive end of the water molecule will be attracted to the negative charge existing on the surface of a clay particle, and, the negative end of a water molecule will be attracted to cations present in the subsurface water (and the cations are attracted to the negative surfaces of clay particles). The resulting attracted water is the adsorbed water film surrounding the clay particle, and is responsible for the plasticity possessed by a clay-water mass.

(2-8) The diffuse double layer refers to the zone surrounding a clay particle where water molecules are strongly attracted to the particle (bonded or oriented water) because of attractions between molecules comprising the particle surface and molecules of water and/or other minerals present in groundwater.

(2-9) The ratio of adsorbed water to particle mass is many times greater for clays than for the larger sand and gravel size materials.

(2-10) Highly expansive clays are typically related to the presence of the montmorillonite mineral which have a high affinity for water, attracting the water molecules into the surfaces between the layers of the montmorillonite sheets which comprise the particle. Clays which include the mineral illite also can experience expansion in the presence of water but the condition is not as widespread as for clays with the montmorillonite mineral.

(2-11) Applications that take advantage of the water flow barrier feature of expansive clays include conditions where "waterproofing" is desired/required, such as on the exterior of basement walls, subsurface structures, earthen blankets where necessary to prevent water penetration such as the ground surface on the upstream side of dams, for the base lining and lining cover for sanitary landfills, etc.

(2-12) The (shear) strength of a granular soil is generally greater when the material is in a dense condition and has a low void ratio.

(2-13) Typically, the coarse-grain deposit where the accumulation of particles exhibits a loose structure is vulnerable to having a large volume change occur (collapse).

(2-14) Collapsible gravel typically have been water transported and deposited materials which include a high percentage of coarse-grain particles but also a significant percentage of fine-grain particles. A geologic feature in the rapid deposition followed by extensive drying.

(2-15) Deposits of saturated cohesionless sands in a loose condition are vulnerable to liquefaction when shock or vibration occurs; liquefaction results when the soil particles surfaces momentarily loose contact and the soil deposit temporarily loses much of the shear strength.

(2-16) a. In the flocculent structure, the contact between most particles is through an edge to face arrangement, the result being to create a soil deposit having a high void ratio but one which is relatively strong. In the dispersed structure, there is more of a parallel arrangement of particles and a tendency toward a smaller void ratio than with the flocculent structure.

b. flocculent

c. dispersed.

(2-17) Thixotrophy is a strength-gain-with-time property attributed to remolded clays. This phenomena occurs when particles in a disturbed clay undergo small movements (reorientation) which result in an increased attraction or bond between particles.

(2-18) Dispersive clays are the type of clays which deflocculate (lose bonding/attraction between particles) and erode in the presence of low-velocity and still-water. Soil surfaces and embankments which include dispersive clays are susceptible to extreme erosion and subsurface piping.

(2-19) Lateritic soils typically are residual formations occurring in tropical regions (high temperature, high rainfall climates). The soil deposit has been leached of the silica and calcium carbonate minerals but retain high concentrations of iron and aluminum sesquioxides. Relating to typical uses of soil for construction projects (embankments, road materials, etc.) laterites tend to become unstable (with particles breaking down etc.) with the worse conditions occurring where the soil is exposed to water.

(2-20) Advantages of learning that problem soils exist at a planned building site:

- Serves as an early warning of special needs or techniques for the foundation design and construction, and to plan and accomplish site earth work.
- Allows the researching of other older construction methods and the evaluation of performance (which procedures work well, which do not)
- Can check/examine existing structures in the same geographic-geologic area to note conditions/performances

(3-1) $M_s = 11.78\ kg$, $M_w = 14.56 - 11.78 = 2.78\ kg$

$w\% = [M_w / M_s](100\%) = (2.78/11.78)(100\%) = 23.6\%$

(3-2) $w\% = \frac{W_w}{W_s}(100\%) = \frac{W_T - W_s}{W_s}(100\%) = \frac{29.4^\# - 25.9^\#}{25.9^\#}(100\%) = 13.5\%$

(3-3) a $w\% = \left(\frac{135\ g - 117\ g}{117\ g}\right)(100\%) = 15.4\%$

b. $\rho_{wet} = 26.50\ kg / .013\ m^3 = 2038.5\ kg/m^3$

$\rho_{dry} = 2038.5 / 1.154 = 1766.5\ kg/m^3$

(3-4) a. $W_T = 42^\#$, $V_T = 0.34\ ft^3$

for small sample, $M_T = 150$ gm, $M_s = 125$ gm, $M_w = 25$ gm, get $w\% = 20\%$

for $w = 20\%$, obtain dry soil wt. $= \frac{42^\#}{1 + w/100} = \frac{42^\#}{1.20} = 35^\#$

b. wet unit wt. $= \frac{W_T}{V_T} = \frac{42^\#}{0.34\ ft^3} = 123.5$ pcf

dry unit wt. $= \frac{W_s}{V_T} = \frac{35^\#}{0.34\ ft^3} = 103$ pcf

(3-5) $G_s = \frac{M_s}{V_s\ \rho_w} = \frac{250\ gm}{(95\ cm^3)(1\ gm/cm^3)} = 2.63$

(3-6) Let $V_s = 1$ unit, $e = 0.8$ unit

$W_s = V_s G_s \gamma_w = 1.0\ ft^3 (2.70)(62.4\ lb/ft^3) = 168.48\ lb$

$\gamma_{dry} = (168.48\ lb)/(1 + 0.8) = 93.6\ pcf = 14.7\ kN/m^3$

$M_s = V_s G_s \gamma_w = 1.0\ m^3 (2.70)(1\ Mg/m^3) = 2.70\ Mg$

$\rho_{dry} = (2.70\ Mg)(1 + 0.8) = 1.5\ Mg/m^3 = 1500\ kg/m^3$

(3-7) $V_s = M_s/(G_s\rho_w) = (.059\ Mg)/(2.65 \times 1\ Mg/m^3)$

$= .02226\ m^3$

$V_v = .035\ m^3 - .02226\ m^3 = .0127\ m^3$

$e = V_v/V_s = .0127/.02226 = 0.57$

(3-8) $V_s = \dfrac{W_s}{G_s \gamma_w} = \dfrac{107\ \#}{(2.70)(62.4\ \#/ft^3)} = 0.636\ ft^3$

$V_v = V_T - V_s = 1.00 - 0.636 = 0.364\ ft^3$

$e = \dfrac{V_v}{V_s} = \dfrac{0.364}{0.636} = 0.57$

$n = \dfrac{V_v}{V_T} = \dfrac{0.364}{1.00} = .36 = 36\ \%$

(3-9) $V_s = M_s/(G_s\rho_w) = 1.36\ kg/(2.70 \times 1000\ kg/m^3) = .0005037\ m^3$

$V_v = .000943\ m^3 - .0005037\ m^3 = .0004393\ m^3$

$e = V_v/V_s = .0004393/.0005037 = 0.87$

$\rho_{dry} = M_s/V_T = 1.36\ kg/.000943\ m^3 = 1442.2\ kg/m^3$

$\gamma = (1.4422\ Mg/m^3)(9.81\ kN/m^3$ per $Mg/m^3)$ .... refer Table 2-1

$= 14.15\ kN/m^3 = 89.99\ lb/ft^3$

(3-10) $V_s = \dfrac{27\ \#}{(2.75)(62.4\ \#/ft^3)} = 0.158\ ft^3$

$V_v = 0.250 - 0.158 = 0.092\ ft^3$

$e = \dfrac{V_v}{V_s} = \dfrac{0.092}{0.158} = 0.58$

(3-11)

$W_s = 31^{\#}$

$W_w = 38.2 - 31 = 7.2^{\#}$

$V_w = \dfrac{7.2^{\#}}{62.4^{\#}/ft^3} = .115\ ft^3 = V_v$

$V_T = 0.30\ ft^3$

$V_s = V_T - V_v = 0.30 - 0.115 = 0.185\ ft^3$

$e = \dfrac{V_v}{V_s} = \dfrac{.115}{.185} = 0.62$

$G_s = \dfrac{W_s}{V_s \gamma_w} = \dfrac{31^{\#}}{(.185\ ft^3)(62.4^{\#}/ft^3)} = 2.68$

(3-12)

$e = \dfrac{V_v}{V_s} = 1.20 \qquad G_s = 2.72$

$V_s = \dfrac{V_T}{1+e} = \dfrac{1.0}{1+e} = \dfrac{1}{2.2} = 0.455\ ft^3$

$W_s = V_s G_s \gamma_w$

$= (.455)(2.72)(62.4) = 77^{\#}$

$\gamma_{dry} = \dfrac{W_s}{V_T} = \dfrac{77^{\#}}{1.0\ ft^3} = 77\ pcf$

(3-13)

$V_s = M_s/(G_s \rho_w) = 27.5\ kg/(2.71 \times 1000\ kg/m^3)$

$= .01015\ m^3$

$V_v = .015 m^3 - .01015 m^3 = .00485\ m^3$

$e = .00485 m^3/.01015\ m^3 = 0.48$

$M_w = 31\ kg - 27.5\ kg = 3.5\ kg, \quad w\% = 3.5 kg/27.5\ kg = 12.7\%$

$V_w = 3.5 kg/1000\ kg/m^3 = .0035\ m^3$

$\%\ Sat = [(.0035)/(.00485)](100\%) \doteq 72\%$

(3-14)

$e_1 = 0.80 \qquad \left[\text{Since } V_s = \dfrac{V_T}{1+e}\right] \qquad e_2 = 0.50$

$V_s = \dfrac{1}{1.80} = 0.555\ ft^3 \qquad V_s = \dfrac{1}{1.50} = 0.667\ ft^3$

$W_s = (.555)(2.70)(62.4) \qquad W_s = (.667)(2.70)(62.4)$

$= 93.5^{\#} \qquad = 112^{\#}$

$\gamma_{dry} = 93.5\ pcf \qquad \gamma_{dry} = 112\ pcf$

Increase in dry density (dry unit weight)

$= 112 - 93.5 = 18.5\ pcf$

(3-15) Show $e = \frac{n}{1-n}$

$$\frac{n}{1-n} = \frac{V_v/V_T}{1 - V_v/V_T} = \frac{V_v}{V_T - V_v} = \frac{V_v}{(V_v+V_s)-V_v}$$

$$= \frac{V_v}{V_s} = e$$

(3-16)

$M_T = 45.6\ kg$, $V_T = 0.021\ m^3$

$M_s = 39.1\ kg$, $M_w = 6.5\ kg$, $V_w = .0065\ m^3$

$V_s = M_s/(G_s \rho_w) = (39.1\ kg)/(2.73 \times 1000\ kg/m^3) = .0143\ m^3$

$V_v = V_T - V_s = .021 - .0143 = .0067\ m^3$

$e = V_v/V_s = (.0067)/(.0143) = 0.47$

$w\% = [(6.5)/(39.1)](100\%) = 16.6\%$

$\%\ Sat = (V_w/V_v)(100\%) = 97\%$

(3-17)

$W_T = 63^{\#}$ $W_s = 51^{\#}$ $V_T = 0.50\ ft^3$ $G_s = 2.65$

$$V_s = \frac{W_s}{G_s \gamma_w} = \frac{51^{\#}}{(2.65)(62.4^{\#}/ft^3)} = .308$$

$$V_v = V_T - V_s = 0.50 - 0.308 = 0.192\ ft^3$$

$$e = \frac{V_v}{V_s} = \frac{.192}{.308} = 0.62$$

$$\%\ Sat = \frac{V_w}{V_v} = \frac{(12^{\#}/62.4^{\#}/ft^3)}{.192\ ft^3} \times 100\% = \frac{.192}{.192} \times 100\%$$

$$= 100\%$$

$$w\% = \frac{W_w}{W_s}(100\%) = \frac{12}{51}(100\%) = 23.5\%$$

(3-18)

$M_T = M_{wet} = 56\ kg$ $\quad V_T = 0.028\ m^3$

$M_s = M_{dry} = 49\ kg$ $\quad G_s = 2.72$

$M_w = (56-49)\ kg = 7\ kg$

$$\rho_{wet} = \frac{M_T}{V_T} = \frac{56\ kg}{.028\ m^3} = 2{,}000\ kg/m^3$$

$$\gamma_{wet} = \left[2000\frac{kg}{m^3} \times 1000\frac{gm}{kg} \times \frac{1}{(100\ cm/m)^3}\right](62.4\frac{lb}{ft^3}\ \text{per}\ \frac{gm}{cm^3})$$

$= 124.8$ pcf

$$\rho_{dry} = \frac{M_s}{V_T} = \frac{49\ kg}{.028\ m^3} = 1750\frac{kg}{m^3} \quad \text{and} \quad \gamma_{dry} = 109.2\ \text{pcf}$$

water content, $w\% = \frac{M_w}{M_s}(100\%) = \frac{7\ kg}{49\ kg}(100\%) = 14.3\%$

void ratio, $e = V_v/V_s$

where $V_s = \frac{M_s}{G_s \rho_w} = \frac{49\ kg \times 1000\ gm/kg}{(2.72)(\frac{1\ gm}{10^{-6}\ m^3})} = \frac{49 \times 10^{-3}}{2.72} = .018\ m^3$

$V_v = V_T - V_s = (.028 - .018)\ m^3 = .010\ m^3$

$e = .010/.018 = 0.556$

$V_w = 7.0\ kg = .007\ m^3$

$\%\ Sat = V_w/V_v = (.007/.010)\ m^3\ (100\%) = 70\%$

(3-19)

$W_T = 417\ gm \quad V_T = 276\ cm^3 \quad M_s = 225\ gm \quad G_s = 2.70$

$$w\% = \frac{M_w}{M_s}(100\%) = \frac{417-225}{225}(100\%) = 85\%$$

$$V_s = \frac{M_s}{G_s \rho_w} = \frac{225\ gm}{(2.70)(1\ gm/cm^3)} = 83.5\ cm^3$$

$$V_v = 276 - 83.5 = 192.5\ cm^3$$

$$e = \frac{V_v}{V_s} = \frac{192.5}{83.5} = 2.31$$

$$\%\ Sat = \frac{V_w}{V_v} \times 100\% = \frac{W_w}{V_v} \times 100\% = \frac{192}{192.5} \times 100\% \cong 100\%$$

(3-20) $G_s = 2.69 \qquad e = 0.65 \qquad w = 10\%$

$$V_s = \frac{V_T}{1+e} = \frac{1}{1.65} = 0.606 \ {}^3$$

$$W_s = (.606)(2.69)(62.4) = 102 \ \#$$

$$\gamma_{dry} = \frac{W_s}{V_T} = \frac{102 \ \#}{1 \ ft.^3} = 102 \ pcf$$

$$W_w = \frac{w\%}{100\%}(W_s) = (.10)(102\#) = 10.2\#$$

$$\gamma_{wet} = 102 + 10.2 = 112.2 \ pcf$$

$$V_w = \frac{10.2\#}{62.4 \#/ft^3} = 0.164 \ ft.^3$$

$$V_v = V_T - V_s = 1.00 - 0.606 = 0.394 \ ft.^3$$

$$\% \ Sat = \frac{V_w}{V_v} \times 100\% = \frac{.164}{.394} \times 100\% = 42\%$$

(3-21) $M_T = 700 \ gm \qquad V_T = 425 \ cm^3 \qquad M_s = 450 \ gm$

Saturated, $S = 100\%$

$$M_w = 700 - 450 = 250 \ gm, \ \therefore V_w = 250 \ cm^3$$

$$V_s = V_T - V_w = 425 - 250 = 175 \ cm^3$$

$$G_s = \frac{s}{V_s} = \frac{450 \ gm}{(175 \ cm^3)(1 \ gm/cm^3)} = 2.57$$

(3-22) $G_s = 2.70 \qquad S = 100\% \qquad w = 20\%$

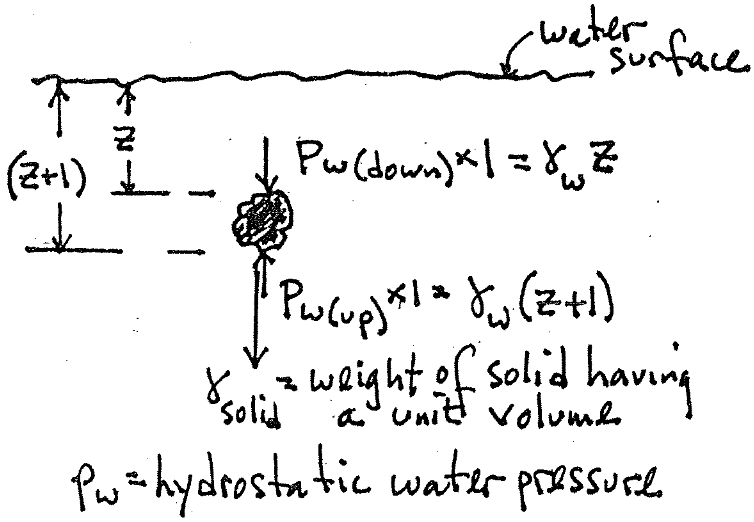
Since $Se = wG_s$

$$e = \frac{wG_s}{S} = \frac{(.20)(2.70)}{1.00} = 0.54 (\pm)$$

(3-23) (a) Effective soil weight references the intergranular weight (or weight/force) acting at the points where soil particle surfaces are in contact.

(b) The intergranular weight (or force) acting at the contact points between particles effects the soil shear strength and resistance to volume changes (strains, defomation, etc.)

(3-24) Refer Equation 2-19, footnote on Page 79, and diagram below



Submerged weight of solid =

$= \gamma_{solid} + P_{w(down)} - P_{w(up)}$

$= \gamma_{solid} + \gamma_w z - \gamma_w (z+1)$

$= \gamma_{solid} - \gamma_w (1)$ regardless of location depth z

(3-25)

$\gamma_{dry} = 18.06\ kN/m^3 = 115\ lb/ft^3$

$V_s = (18.06\ kN/m^3)/(2.75 \times 9.81\ kN/m^3) = 0.67\ m^3$

$V_v = 1.0\ m^3 - 0.67\ m^3 = 0.33\ m^3$

$W_w = (0.33\ m^3)(9.81\ kN/m^3) = 3.24\ kN$

$= (0.33\ ft^3)(62.4\ lb/ft^3) = 20.6\ lb$

a. $\gamma_{sat} = 18.06 + 3.24 = 21.3\ kN/m^3$

$= 115 + 20.6 = 135.6\ lb/ft^3$

b. $e = V_v / V_s = (0.33)/(0.67) = 0.493$

$\gamma_{sub} = [(G_s - 1)/(1+e)](\gamma_w) = [(2.75-1)/(1.493)]\gamma_w$

$= 1.172(\gamma_w) = 1.172(62.4\ lb/ft^3) = 73.1\ lb/ft^3$

$= 1.172(\gamma_w) = 1.172(9.81\ kN/m^3) = 11.5\ kN/m^3$

c. $\rho_{sub} = [(G_s - 1)/(1+e)]\rho_w = 1.172(1\ Mg/m^3) = 1.17\ Mg/m^3$

(3-26) $G_s = 2.65 \quad \gamma_{wet} = 120 \text{ pcf} \quad w = 15\%$

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + w\%/100\%} = \frac{120}{1.15} = 104.5 \text{ pcf}$$

$$V_s = \frac{W_s}{G_s \gamma_w} = \frac{104.5}{(2.65)(62.4)} = 0.633 \text{ ft}^3$$

$$V_v = 1.00 - 0.633 = 0.367 \text{ ft}^3 = V_w \text{ if sat.}$$

If saturated, $W_w = V_w \gamma_w = (.367)(62.4) = 22.9^{\#}$

$$W_T = 104.5 + 22.9 = 127.4^{\#}$$

$$\therefore \quad \gamma_{sat} = 127 \text{ pcf}$$

a. γ_{sub} is approximately $\frac{1}{2}(120) = 60$ pcf

b. $\gamma_{sub} = \gamma_{sat} - \gamma_w = 127.4 - 62.4 = 65$ pcf

$$= \frac{(G_s - 1)\gamma_w}{1 + e} = \frac{(2.65 - 1)(62.4)}{1.58} = 65 \text{ pcf}$$

(3-27) a. $\rho_{sub} \cong \frac{1}{2} \rho_{wet} \cong \frac{1}{2}(2.22 \text{ Mg/m}^3) \cong 1.11 \text{ Mg/m}^3$

b. $\rho_{sub} = \left[(G_s - 1)/(1+e)\right] \rho_w$

where $M_s = M_T/(1 + \frac{w\%}{100\%}) = 2.2/1.10 = 2.0 \text{ Mg/m}^3$

$$V_s = (M_s)/(G_s \rho_w) = (2.0)/(2.69 \times 1)$$

$$= 0.743 \text{ m}^3$$

$$V_v = 1 - 0.743 = 0.257 \text{ m}^3$$

$$e = 0.345$$

$$\rho_{sub} = \left[(2.69 - 1)/(1.345)\right](1 \text{ Mg/m}^3) = 1.26 \text{ Mg/m}^3$$