Unit	1078
Title	Describe Soils and Aggregates
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BC Forest Safety

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Feedback is welcome and may be sent to training@bcforestsafe.org.

Cover photo credit: Chris Cole, RPF, P. Eng. Soil sample taken near Revelstoke, BC

Table of Contents

Unit Introduction

What you will learn in this unit

By the end of this unit, you will be able to demonstrate knowledge of:

- Soils
- Rock types
- Aggregates
- Compaction

Why it's important for you to learn this unit

This module focuses on the types of soils and aggregates that are used in road building in the forestry sector as well as methods to minimize erosion and control sediment from entering water courses during and after construction.

This module also provides the basic training needed to recognize workplace hazards associated with soil types and soil/water interactions.

Are you ready to take this unit?

To take this unit, it is recommended that you have completed the following unit:

- 1002 – Describe Forestry Industry

Does this unit apply to you?

This unit applies to All Road Building Equipment occupations.

Section 1078-01: Soils

What you need to know about this section

By the end of this section, you will be able to demonstrate knowledge and ability of the following key points:

1.1 Soil types

1.2 Suitability of soil types for construction

1.3 Soil characteristics

1.4 Soil classifications

1.5 Methods to minimize erosion

1.6 Sediment control technique

Key Point 1.1: Soil Types

There are many soil types in BC and it is helpful to understand the difference between them to know how to work with them, and which tools will be the most effective.

Soil formation

Soil forms from weathering rock and the accumulation of organic material from dead and decaying organisms.

Soil types

Soil can be classified as:

- Cohesive – loam, silt, and clay
- Non-cohesive – sand and gravel. Coarse grained, the particles lie side by side without bonding
- Organic

Cohesive soils

Cohesive soils such as loam, silt, or clay are fine grained and the particles in the soil bond to each other.

- Cohesive soils have shear strength. It is possible to make a vertical cut in silts and clays and it remain standing, unsupported, for some time. This cannot be done in dry sand. In clay and silts, therefore, some other factor must contribute to shear strength. This factor is called **cohesion**. It results from the mutual attraction, which exist between fine particles and tends to hold them together in a solid mass without the application of external forces.
- Clay consist of very fine microscopic particles which hold water to increase their volume, and release moisture to decrease their volume.

Non-cohesive soils

- Granular soils for example: sand
- Have no shear strength
- An apparent cohesion in sand can be noticed when water is present. Sand grains stick together due to negative pore pressure (building sandcastles is an example). Sand stand in slopes when wet but will not stand when dry or saturated.
- Strength, bearing capacity and slope stability are all derived from internal friction for granular soils (sand & gravel) and can be increased due by grading, packing density and grain angularity.

- Coarser grained soils are more permeable to water and, unless saturated, may have very little water in their voids.
- If well consolidated and confined, they form a foundation that is almost as stable as rock.

Organic soils

Organic soils are composed primarily of organic matter are usually associated with wetlands and riparian areas.

Most of these soils are saturated with water for prolonged periods of time, have little strength and are not suitable for road construction.

Course aggregates are made at a rock quarry for specific engineering purposes such as a roadway base, drainage rock, etc. Photo credit: Chris Cole, RPF, P. Eng.

Soil Types—Self-Quiz

1. Cohesive soils are:

   ☐ Coarser grained

   ☐ Saturated with water

   ☐ Fine grained

   ☐ More permeable to water

2. An example of a non-cohesive soil is:

   ☐ Sand

   ☐ Clay

   ☐ Organic

   ☐ Histosolic

Now check your answers on the next page.

Soil Types—Self-Quiz Answers

1. Cohesive soils are:

   Answer: Fine grained

2. An example of a non-cohesive soil is?

   Answer: **Sand**

Key Point 1.2: Suitability of Soil Types for Construction

This section gives an overview of which soil types are suitable for different purposes in construction.

Preparing future home site for footings near Shuswap Lake, BC.
Source: Chris Cole, P. Eng.

How different soils affect foundations

In general, soil will be more stable the more rock and compacted sand/gravel it contains.

Soil type	**Suitability for construction**
Organic	Not a good choice because it changes structure and shifts
Clay	Not a good choice as it changes its structure and shifts due to how it retains water
Sand	Drains easily but may not have good cohesion.
Gravel	Good for construction, must have finer textured soils mixed with the smaller rock to allow for good compaction.
Loam	A good soil type because it has evenly balanced

	properties and is a mixture of sand, silt and clay
Silt	Not a good choice because it’s cold and drains poorly
Rock	Is good for foundations if it is level

Source: https://www.ramjack.com/blog/2015/august/different-soils-how-they-affect-foundations/

The impact of building on the wrong soil can increase the risk of weather-related incidents.

Reference

BC Forest Safety

Read Safety Alert: Heavy Rainfall Increases Washout and Landslide Risk

When you are finished, continue in this section.

SAFETY ALERT

Forestry Harvesting Operations

Heavy Rainfall Increases Washout and Landslide Risk

Location: South Coast Region (Vancouver Island, northern Fraser Valley)

Date: November 15, 2017

Details: Recent heavy rainfalls have significantly increased the risk of road washouts and landslides.

Learnings & Suggestions:

Brief your crew on the risks of flooding and landslides, including the following:

- Road washouts can occur quickly and may surprise drivers. Consider that roads may wash out behind crews, leaving them stranded.
- Field crews often cross and work adjacent to streams and rivers. Postpone work next to water until conditions improve.
- The soil next to bridges and culverts may be eroded by heavy rains and high stream flows. Sometimes this erosion cannot be easily seen. Be cautious and assess crossings from a safe distance before driving over them.
- Travelling at night during flood conditions is not recommended. The limited visibility can result in not being able to spot washouts in time to stop.
- The heavy rains can cause water saturated soils which are prone to landslides. Fast flowing streams and rivers can also erode the base of slopes causing them to slide. Avoid work in steep areas with weak soils until conditions improve.

- Crews responsible for inspecting and repairing roads and water crossings need to be extremely careful. Don't risk getting too close and being caught up in fast rising or fast flowing water.

- Make sure your emergency response plans include procedures on how to respond to severe weather incidents.

The points above were taken from a Monthly Safety Alert from earlier in the year. Use this link to view the entire alert: http://www.bcforestsafe.org/node/2964

For more information: Gerard Messier, BCFSC messier@bcforestsafe.org

Ice lenses

If the soil does not drain well, ice lenses may form during freezing conditions. Once an ice lens forms, it tends to grow as more water particles are drawn and collect at the ice lens formation.

This action of ice growth may cause the area to expand, often pushing upward on the soil and the structure above causing physical damage. When conditions warm and the ice lenses melt, this creates a large void space resulting in further mechanical damage to the structure above or resulting in a pothole in a road surface.

CAUTION!
The soil next to bridges and culverts may be eroded by heavy rains and high stream flows. Sometimes this erosion cannot be easily seen. Therefore, be cautious and assess crossings from a safe distance before driving over them.

Soil Types for Construction—Self-Quiz

1. Which of the following soil types are best for construction?

   ☐ Silt

   ☐ Loam

   ☐ Peat

   ☐ Clay

2. Soil that is mixed with aggregate will be more stable for construction and drains better.

   ☐ True

   ☐ False

Now check your answers on the next page.

Soil Types for Construction—Self-Quiz Answers

1. Which of the following soil types are best for construction?

   Answer: **Loam**

2. Soil that is mixed with aggregate will be more stable for construction and drains better?

   Answer: **True**

Key Point 1.3: Soil Characteristics

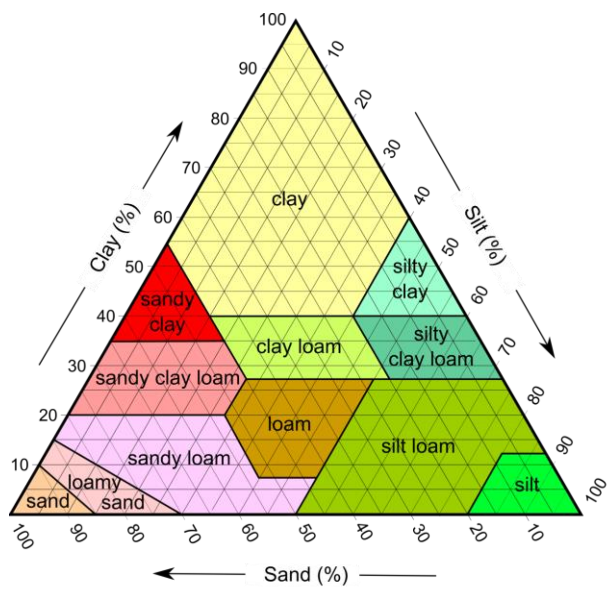
Recognizing soil characteristics may give advance warning to soil related workplace hazards. While working around machinery when soil is disturbed, such as in road building, the trained eye can quickly identify soil characteristics that identify the soil suitability for various construction purposes such as roadway ballast, road surfacing, or drainage structures.

Soil characteristics include the following:

- Gradation
- Permeability
- Density
- Shear strength
- Load bearing capacity
- Plasticity and elasticity
- Adhesion and cohesion

Gradation

The following diagram shows how the soil type changes as the clay, sand, and silt percentages change. For example, as the clay percent increases, and the silt and sand percentages decrease, the soil can be classified as loam. Loam has balanced properties that make it an ideal soil type for construction.



Soil types according to their clay, silt and sand composition. Source: USDA

For building or bridge foundations and for permanent roadways, a well graded, granular substrate is often used. Well graded means the soil has a mixture of particle sizes required to compact tightly and bind as a larger mass.

In comparison, a poorly graded soil such as pure sand, would not compact due to the void spaces around each particle. In road building, a coarse granular material such as crushed rock or gravel is added to the soil to facilitate drainage.

Soil gradation is an indicator of other engineering properties such as compressibility, shear strength, and hydraulic conductivity. Gradation of soil often controls the water drainage of the roadway or construction site.

A well graded soil is a soil that contains particles of a wide range of sizes and has a good representation of all particle sizes.

A poorly graded soil is a soil that does not have a good representation of all sizes of particles in the mixture. Poorly graded soils are more susceptible to erosion and soil liquefaction than well graded soils.

A sieve analysis of a soil sample taken from the field will provide the sand, silt, and clay content.

Image showing soil sieve pans. Source unknown

Permeability

Permeability is a term used to describe the ability for the water to pass through the soil. For example, when installing a new septic field, a permeability test is required to ensure the excess water from the septic system will either drain or evaporate through the soil. In resource road building, the soil material that the road is built from must compact well as well as drain well to prevent rutting and support heavy truck loading.

A soil with a low permeability will restrict or prevent the flow of water through the soil. If too much water is retained in the soil, the roadway may deteriorate, and ruts or potholes may form causing further damage.

Density

Soil density is the mass of the soil per unit of weight, generally discussed in terms of kg/m^3.

The density of soil is highly dependent on the moisture content and the type of parent material, or rock the soil is made from. The level of compaction and organic materials in soil also have a great impact on the soil density.

The following table provides the approximate density of common soil materials.

Material	Est. density (kg/m3)
Pure water	1000
Dry gravel	1600
Wet gravel	1800
Dry clay	2000
Wet clay	2300
Concrete	2400
Air (at sea level)	1.23
Douglas-fir logs (green)	780

Shear Strength

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. Shear stress is a force that causes layers or parts to slide upon each other in opposite directions. The shear resistance of soil is a result of friction and interlocking of particles, and possibly cementation or bonding at particle contacts.

Shear strength is generally dependent on soil moisture or water content. For example, if a “red solo cup” filled with dry sand, when turned upside down on a desk it will result in a “pile of dry sand” – a cone shape with a very low sloped angle of repose.

A cup filled with damp sand, when turned upside down will result in a sandcastle like cup shape. The water in the sand creates surface tension between the sand particles, holding them together, making the cup shape. With moisture, the sand has increased shear strength.

If additional water is added to the base of the sand cup (e.g., the tide comes in on your sand castle), the increased water will fill the voids between the sand and reduce sand inter-particle friction, reduce surface tension, and the sand cup shape will collapse on the desk due to reduced shear strength of the sand.

Dirty sand or sand with small amounts of silt and clay mixed in will have greater shear strength because the voids between the soil particles will be smaller and the surface area for the soil to bond will be greater, compared to pure clean sand.

Load bearing capacity

Bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil.

Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety.

Foundation design

A foundation is that part of a structure which transmits loads directly to the underlying soil. If a soil stratum near the surface is capable of adequately supporting the structural loads it is possible to use footings (also known as a shallow foundation).

A footing is a relatively small slab giving separate support to part of the structure. A footing supporting a single column is called an individual footing or pad, one supporting a closely spaced group of columns is called a combined footing and one supporting a load-bearing wall is called a strip footing.

A raft is a relatively large single slab, usually stiffened with cross members, supporting the structure.

If the soil near the surface is incapable of adequately supporting the structural loads, piles, or other forms of deep foundations such as piers or caissons, are used to transmit the loads to suitable soil (or rock) at greater depth.

In addition to being located on adequate loading bearing material, a foundation should be below the depth which is subjected to frost action and, where appropriate, the depth to which seasonal swelling and shrinkage of the soil takes place. Consideration must also be given to the problems arising from excavating below the water table if it is necessary to locate foundations below this level.

Plasticity and Elasticity

Plasticity (consistency limits)

Plasticity is the property of a soil by which it undergoes deformation without cracking or fracturing. The consistency limits represent the amount of water in a soil when it changes from one state to another. The four simple states are:

- Solid
- Semi-solid
- Plastic
- Liquid

The state with the least amount of water in the soil is the solid state. When water is added the soil becomes plastic, meaning it can change shape easily without cracking or falling apart (you could roll a soil worm in your hands). This is what is referred to as the soil's plasticity. When it has enough moisture to roll, but not so much that it turns to liquid or mud.

When a soil changes to the liquid state is enters a state when it will flow. For example, this is when a landslide may occur on a gentle slope. The following video shows this transformation in state, also known as soil liquefaction, when an entire landscape turns to a liquid state. This point of change from plastic to liquid states is called the liquid limit of the soil.

Video 1:15
YouTube—the Jakarta Post
Crazy! Satellite Timelapse Shows Liquefaction During Indonesia Earthquake
https://www.youtube.com/watch?v=3NSXmTfASM0
When you are finished, continue in this section.

Elasticity

Elasticity is a soil parameter that describes soil stiffness. It is most commonly used in determining the amount the soil settles under static loads (a non-moving load such as a bridge footing – with no traffic travelling on the bridge).

Adhesion and Cohesion

Adhesion generally refers to the attraction or absorption or water molecules to a surface or material such as soil particles.

Cohesion is a term that refers to the attraction or connecting of water molecules to each other. The force of gravity often plays a role in soils as water works its way down through the soil material.

Cohesion is also in play during the process of freezing when ice lenses are formed. As ice crystals form during freezing, the surrounding water molecules get used up in the crystallization process, which draws other surrounded water molecules towards the ice formation via the action associated with cohesion.

Video 3:02
YouTube—PUExtension
Soil Basics: Adhesion and Cohesion
https://www.youtube.com/watch?v=n6sjXkOOjSI
When you are finished, continue in this section.

Soil Characteristics—Self-Quiz

1. Which of these is *not* a soil characteristic?

   ☐ Shearing resistance

   ☐ Permeability

   ☐ Gradation

   ☐ Bearing capacity

   ☐ Pedon

2. The state characteristics of a soil can be described by which of the following:

   ☐ Solid, liquid, gas

   ☐ Solid, plastic, liquid

   ☐ Plastic, elastic, permeable

   ☐ Liquid, solid, well-graded

3. “Dirty sand” or sand with smaller silt and clay particles mixed in will have greater shear strength than pure “clean sand”.

   ☐ True

   ☐ False

Now check your answers on the next page.

Soil Characteristics—Self-Quiz Answers

1. Which of these is not a soil characteristic?

   Answer: **Pedon**

2. The characteristics of a soil can be described in which of the following three states:

   Answer: **Solid, plastic, liquid**

3. “Dirty sand” or sand with smaller silt and clay particles mixed in will have greater shear strength than pure “clean sand”

   Answer: **True**

Key Point 1.4: Soil Classifications

It is essential that a standard language should exist to describe soils. A comprehensive description should include information on soil texture, consistency, structure and color.

Texture

Soil texture is the relative proportion of various particle size of a soil. While particles less than 2mm is sizes make up fine textured soils (clay, silt and sand), coarse fragments consist of particles greater than 2 mm in diameter. The size of 2mm is used because this is greatest particle size that will allow the surface tension of water to hold the shape of a soil together in a mass unsupported by a container (see “red solo cup” example in above Section 1.3 “shear strength”).

Texture is estimated visually as a percentage of the whole soil: %stones + % cobbles + % gravels + % fine fraction = 100%. The relative proportion of fine fraction particles (sand, silt and clay) are estimated using their unique properties of "feel" to the bare hand. Sand can always be felt as individual grains, but silt and clay generally cannot.

Dry silt feels floury, and wet silt is slippery or soapy but not sticky. Dry clay forms hard lumps, is very sticky when wet, and plastic when moist.

Most soils are a mixture of sand, silt and clay, so the graininess, slipperiness or stickiness will vary depending upon how much of each particle size is present. As the amount of clay increases, soil particles bind together better, form stronger casts and longer, stronger soil worms when rolled between your hands.

As sand and silt increase, the soil binding strength decreases, and only weak to moderately strong worms can be formed. The various classes of soil texture are named by a combination of the dominant particle size, the term loam meaning a relatively even mix of the three.

The field determination of soil texture is subjective and can be done consistently with training and experience. Some common field tests include the following:

- Graininess test
- Moist cast test
- Stickiness test
- Worm test
- Taste test

Graininess Test

Rub the soil between your fingers. If sand is present, it will feel "grainy". Determine whether sand comprises more or less than 50% of the sample.

Moist Cast Test

Compress some moist soil by clenching it in your hand. If the soil holds together (i.e., forms a "cast"), then test the durability of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.

Stickiness Test

Wet the soil thoroughly and compress between thumb and forefinger. Degree of stickiness is determined by noting how strongly the soil adheres to the thumb and forefinger upon the release of pressure, and how much it stretches. Stickiness increases with clay content.

Worm Test

Roll some moist soil between the palms of your hands to form the longest, thinnest worm possible. The more clay there is in the soil, the longer, thinner and more durable the worm will be.

Taste Test

Work a small amount of soil between your front teeth. Silt particles are distinguished as fine "grittiness", unlike sand which is distinguished as individual grains (i.e., graininess). Clay has no grittiness at all.

Structure

The term “soil horizon” describes the major layers or zones of a soil, each of which has structural and chemical characteristics. The structure of soil is often discussed by using these layers. However, during road construction, these layers may be disturbed or mixed up so soil structure is described using other physical characteristics.

Soil Horizons. Source: Chris Cole, P. Eng.

Types of soil horizons or layers

Soils can also be classified according to the kinds and degrees of soil horizons present (L, F, H, O, A, B, C)

A, B, C are mineral horizons that are formed at or near to the soil surface. Common descriptors include:

- *Ah* - surface mineral horizon; often called topsoil
- *Ae* - surface or near-surface mineral horizon; appears bleached or ashy
- *O* - poorly drained organic horizons. Is divided into *Of* (fibric), *Om* (mesic), *Oh* (humic)
- *L, F, H* – well-drained organic layers found on top of mineral horizons

Soil profile – a vertical section of soil (often can be seen in a soil pit), and where the different layers or horizons can be seen.

Organic soils

Although we often think of soils as being purely mineral in content, organics play a large roll in soil processes and behavior.

Organic soils contain a significant proportion of decayed plant matter which usually produces a distinctive odour and often a dark brown, dark grey or bluish grey color. Peats consist predominantly of plant remains, usually dark brown or black in color and with a distinctive odour.

Consistency

Related to fine textured soils, consistency of soil is the physical state of soil with respect to moisture content. Consistency means the relative ease with which soil can be deformed.

The moisture content at which the soil change from one state to another state is called “consistency limits.” There are four different states of soil as described in Key Point 1.3 (**Plasticity**) earlier. They are:

- solid
- semi-solid
- plastic
- liquid

Sample references:

http://www.nzsoils.org.nz/Topic-Describing_Soils/Soil_Consistence/

https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/soil-consistency

Color

Soil color is commonly used to describe and classify soil horizons. Color is a property of soils that allows us to know some of its most important characteristics, such as mineral composition, age and soil processes. Together with other physical properties, color helps us to differentiate between types of soil horizons.

The presence of water in the soil profile during long periods of time also affects soil color as a result of changes in the oxidation rate.

Dark colors are usually due to the presence of organic matter. The darker the surface horizon the more organic matter content is assumed.

Whitish or very light color is the result of the presence of calcium and magnesium carbonates, gypsum or other more soluble salts. In other cases, light color is due to a relatively high proportion of sand (quartz crystals).

Red soil is usually a result of alteration of clay minerals. Weathered clay minerals release aluminum and iron oxides.

Gleyic color patterns are groups of spots of red, yellow and gray colors. This property appears in soils or horizons that are waterlogged for at least one part of the year.

Soil Classifications—Self-Quiz

1. Soil texture is the relative proportion of various particle size of a soil?

   ☐ True

   ☐ False

2. In soils, what do spots of red, yellow or grey color indicate:

   ☐ High sand content

   ☐ Highly compacted soil

   ☐ Organic material is present

   ☐ Soil is waterlogged for part of the year

Now check your answers on the next page.

Soil Classifications—Self-Quiz Answers

1. Soil texture is the relative proportion of various particle size of a soil?
   Answer: **True**
2. In soils, what do spots of red, yellow or grey color indicate:
   Answer: **Soil is waterlogged for part of the year**

Key Point 1.5: Methods to Minimize Erosion

Erosion occurs when the top layer of soil is lost due to wind and water.

Soil disturbance is inevitable from most road construction activities. Control of soil erosion and the movement of the eroded soils (often called sediment) during road construction are therefore important concerns especially when close to water.

Erosion control deals with the source of soil erosion, and sediment control addresses the control and retention of sediment. As erosion control is usually more effective than sediment control, ensure that the primary goals are, first, to minimize erosion of the disturbed sites; and, second, to limit the transport of sediment from these sites.

Soil Erosion Control Techniques

Source: https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/resource-roads/engineering-publications-permits/engineering-manual/road-construction/soil-erosion-sediment-control.

To minimize surface soil erosion after road construction, cover all exposed soils that are subject to weathering (e.g., silty and sandy non-cohesive soils and clayey and other cohesive fine-grained soils) with grass and legume vegetation. A variety of erosion seed mixes are available that provide for rapid germination and long- term growth to create a solid sod layer. Take care to ensure that the seed species selected are compatible with domestic livestock. Establish this vegetative cover to protect and hold soil by:

- Decreasing the erosive effects of rain drop impact on soil particles;
- Decreasing runoff velocity and volumes
- Promoting water infiltration into the soil

Apply the cover as soon as slopes are completed, rather than after the entire road project is complete. Prompt revegetation by dry broadcast (by hand or spreader) or by hydroseeding not only assists with erosion control; it also helps to prevent the spread of noxious weeds.

Other soil erosion control techniques include, but are not limited to, the following:

- Only work on sensitive sites during periods of dry weather and use equipment that will create the least disturbance;
- Follow local rainfall shutdown guidelines;

- Temporary diversion or impoundment of stream flow using diversion ditches and berms to reduce the exposure of disturbed soil to flowing water during stream-crossing structure construction, or construction of rock-lined ditches or channels to provide a durable erosion-resistant surface; and
- Installation of rock, straw bale, or sandbag check dams across a defined ditch or channel, or placement of riprap (rock) on a slope, to reduce water velocity and scour potential.

For more detailed information on control of soil erosion and sediment transport, refer to the *Ministry of Forests' Best Management Practices Handbook: Hillslope Restoration in British Columbia*.

Methods to Minimize Erosion—Self-Quiz

1. Control of soil erosion and the subsequent transport of sediment during road construction are not important concerns where there is indirect connectivity to water.

   ☐ True

   ☐ False

Now check your answers on the next page.

Methods to Minimize Erosion—Self-Quiz Answers

1. Control of soil erosion and the subsequent transport of sediment during road construction are not important concerns where there is indirect connectivity to water.

   Answer: **False**

Key Point 1.6: Sediment Control Techniques

Soil disturbances can result from road construction. Sediment control involves techniques that should be used along with erosion control techniques. Erosion control has a higher level of effectiveness than sediment control – because erosion control addresses the source of soil erosion, whereas sediment control addresses the control and retention of sediment.

Source: https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/resource-roads/engineering-publications-permits/engineering-manual/road-construction/soil-erosion-sediment-control.

Sediment Control Techniques

To minimize sediment transport away from the road and other construction sites, consider using the following sediment control techniques:

- Install silt fencing to retain sediment and collect and detain runoff
- Install retention berms, sediment basins and traps
- Minimize traffic throughout the area and select equipment that will create the least disturbance
- For stream culvert installations, use a temporary diversion or impoundment of stream flow to reduce the exposure of disturbed soil to flowing water

Controlling water and limiting the transportation of sediment is an important long term consideration when constructing and maintaining roads. A road with good ditching, appropriate cross drain (culvert) placement, appropriate road surface material and sloping will all contribute to minimizing the movement of sediment.

Sediment Control Techniques—Self-Quiz

1. Erosion control is more effective than sediment control.

   ☐ True

   ☐ False

Now check your answers on the next page.

Sediment Control Techniques—Self-Quiz Answers

1. Erosion control is more effective than sediment control?

   Answer: **True**

Section 1078-02: Aggregates

What you need to know about this section

By the end of this section, you will be able to demonstrate knowledge of the following key points:

2.1 Rippable and non-rippable rocks

2.2 Characteristics of aggregates

2.3 Aggregate processing

2.4 Common products and uses for aggregate

Key Point 2.1: Rippable and Non-Rippable Rocks

The rippability of rock is the measure of the ability to excavate or remove the material with typical excavation equipment. Ripping is typically performed by tractor-mounted equipment. The size of the tractor (dozer) is determined by the ripping assessment of the rock. The hardness of each material will determine the ease of rippability. Rock that is too hard to be ripped is fragmented with explosives.

Rock can be classified as rippable, marginally rippable, or non-rippable.

Rippable

Characteristics of rock that make is rippable include:

- Frequent planes of weakness such as fractures, faults, and laminations
- Weathered rocks
- Rocks with moisture permeating the formations
- Highly stratified rocks
- Brittle rocks
- Rocks with low "shear strength"
- Rocks with low seismic velocity

Some examples of rippable rock include shale, sandstone, and conglomerate.

Non-rippable

Rock types that make ripping difficult include:

- Massive boulders
- Rocks with no planes of weakness
- Crystalline rocks
- Non-brittle energy absorbing rock fabrics
- Rocks with high "shear strengths”

Some examples of non-rippable rock include granite, limestone, and basalt.

YouTube Video 1:58
Caterpillar D8H dozer ripping through hard rocks
https://www.youtube.com/watch?v=cKwkr3Ed14g
When you are finished, continue in this section.

Rippable and Non-Rippable Rocks—Self-Quiz

1. Which of the following are rippable rock types?

   ☐ Basalt

   ☐ Granite

   ☐ Shale

   ☐ Limestone

2. How is a roadway built through non-rippable rock?

   ☐ A much larger machine is brought in to dig the rock out

   ☐ The roadway is relocated to an alternative location

   ☐ The rock is drilled and blasted into smaller pieces that can be moved by the excavator

   ☐ Any of the three answers may be feasible

Now check your answers on the next page.

Rippable and Non-Rippable Rocks—Self-Quiz Answers

1. Which of the following are rippable rock types?

   Answer: **Shale**

2. How is a roadway built through non-rippable rock?

   Answer: **Any of the three answers may be feasible**

Key Point 2.2: Characteristics of Aggregates

The term aggregates refers to coarse material such as sand and gravel, formed by erosion of rock substances.

Aggregates are used extensively in the construction industry either in the building of new roads or as one of the main ingredients in concrete. Aggregates are also used as base material under foundations, roads, and railroads.

Aggregates are, by definition, a collection of loose materials such as sand, gravel and crushed stone. They are sourced from quarries and pits. Aggregates are sorted into piles based on size, and often mixed in proportions specified by highway building standards or a Professional Engineer's requirements for a specific construction purpose.

Borrow Pit Development for Road Re-surfacing Project. Source: Chris Cole, P. Eng.

Types of Aggregates

The following are the types of aggregates:

- granite aggregates
- limestone aggregates
- gravel/ballast aggregates
- secondary aggregates
- sand

Granite aggregates

This is the best aggregate for high-grade concrete. It comes in a variety of shades, like grey, red and pink, so it can also be used as a decorative feature. Granite itself is composed of feldspar, quartz and mica crystals, which dictate the color of the stone.

Limestone aggregates

Limestone aggregates are created by crushing sedimentary rock. It is commonly used in road construction and reinforced concrete.

Gravel/ballast aggregates

Gravel aggregates are sourced by sifting quarried rock and crushing natural stone. Gravel aggregates don't possess as much strength as their granite aggregates, but they are often cheaper to purchase.

Gravel aggregates are used for foundations and concretes, as well as products made of reinforced concrete and materials used in road construction.

Secondary aggregates

Obtained by crushing construction waste (concrete, bricks and asphalt), secondary aggregates are designed as an effective, low cost option to other materials.

Uses of secondary aggregates include the following:

- large scale filler for concrete
- road construction
- maintenance works
- reinforcing weak soils

Sand

Sand is a mixture of different rocks types and is used to provide bulk and strength for materials like asphalt and concrete. Sand combines with water and other aggregates to form the solid, durable concrete that is used in countless applications all over the world. It also plays a key role in the binding agent in asphalt.

Characteristics of Aggregates—Self-Quiz

1. Granite is a type of aggregate material made up of feldspar, quartz and mica crystals?

   ☐ True

   ☐ False

2. Sand is an aggregate because it is a mixture of different rock types.

   ☐ True

   ☐ False

Now check your answers on the next page.

Characteristics of Aggregates—Self-Quiz Answers

1. Granite is a type of aggregate material made up of feldspar / quartz and mica crystals?

   Answer: **True**

2. Sand is an aggregate because it is a mixture of different rock types?

   Answer: **True**

Key Point 2.3: Aggregate Processing

The first stage of aggregate processing involves quarrying, where a large deposit of desirable aggregate is identified and extracted from the ground (usually by blasting). It is taken to a processing area where aggregates are fed through a crusher.

Larger, useable chunks are screened out and the remaining material is taken to a second crusher or feeder. The quarried rock undergoes primary and secondary crushing at processing plants. The crushed rocks are then sorted into sizes and moved by conveyors to bins or is stockpiles for later use.

The following video describes the aggregate manufacturing process.

Video 3:12

Cardinal Aggregate Quarry & Processing Operation (Ohio)
https://www.youtube.com/watch?v=cTwidiB15I8

Note: This video is from the United States and some of the safety practices such as high visibility clothing do not meet BC requirements.

When you are finished, continue in this section.

Aggregate Processing—Self-Quiz

1. Processing involves separating aggregate into different sizes and textures (rough or smooth type) and material types.

   ☐ True

   ☐ False

Now check your answers on the next page.

Aggregate Processing—Self-Quiz Answers

1. Processing involves separating aggregate into different sizes and textures (rough or smooth type) and material types.

   Answer: **True**

Key Point 2.4: Common Products and Uses for Aggregate

Aggregates refer to all types of quarry material. Aggregates are used extensively in the construction industry either in the building of new roads or as one of the main ingredients in concrete.

The primary aggregate products include:

- Concrete aggregates
- Crushed stone
- Gravel
- Recycled construction aggregates
- Sand

In addition to roads, they are also used to build and maintain bridges, playing fields, buildings, water lines, sewer systems, and other physical infrastructure.

Granite aggregates (several different sizes)

Depending on how granite is ground it can be used:

- As a subbase for road building
- For road building concrete mixes
- As a firm base in parking lots, walking paths, and driveways.
- For construction of industrial spaces

Gravel aggregates

These are generally used for road foundations and reinforced concrete.

Limestone

Limestone aggregates are generally used for road construction and reinforced concrete objects.

Section 1078-03: Compaction

What you need to know about this section

By the end of this section, you will be able to demonstrate knowledge of the following key points:

3.1 Compaction principles

3.2 Compaction equipment

3.3 Compaction testing

3.4 Compacting levels

Key Point 3.1: Compaction Principles

Soil compaction refers to the disruption and reduction of the large pores within the soil. Once a soil is compacted, the bulk density and the strength of the soil are increased.

The measurement of a soil's bulk density provides a relative value of soil compaction. The porosity of a soil can be related to the bulk density measurement with further laboratory procedures.

Bulk density is expressed as weight per volume of soil. Variation in bulk density can occur on a year-to-year basis, as freezing and thawing, wetting and drying cycles and cultivation can alter the basic structure of a soil.

The bulk density of high organic mineral soils and peats is much lower than that of mineral soils.

There are a variety of different benefits to soil compaction, including: prevention of soil settlement and frost damage, increased ground stability, reduced hydraulic conductivity and mitigating undesirable settlement of structures, such as paved roads, foundations and piping.

Soil compaction is defined as the method of mechanically increasing the density of soil. In construction, this is a significant part of the building process.

Soil Compaction from a Construction Perspective

Compaction is the process of increasing the density of a soil by packing the particles closer together and reducing the volume of air. There is no significant change in the volume of water in the soil.

In the construction industry, for example during the construction of fills and embankments, loose soil is placed in layers ranging between 75 and 450 mm in thickness. Each layer is then compacted to a specified standard using rollers, vibrators, or rammers.

In general, the higher the degree of compaction the higher will be the shear strength and the lower will be the compressibility of the soil.

An engineered fill is when the soil has been selected, placed, and compacted to an appropriate specification to achieve engineering performance. This is generally based on past experience. The goal is to ensure that the resulting fill possesses properties that are adequate for the function of the fill. This contrasts with non-engineered fills which have been placed without regard to a subsequent engineering function.

The degree of compaction of a soil is measured in terms of dry density. For example, the mass of solids only per unit volume of soil. The dry density of a given soil after compaction depends on the water content and the energy supplied by the compaction equipment (referred to as the compactive effort).

The compaction characteristics of a soil can be assessed by means of standard on site or laboratory tests which are described in Key Point 3.3.

Easiest soils to compact

The particle sizes determine how easy or difficult the soil is to compact. Soil can be broken down into four basic groups:

- Clay – has the smallest particle size
- Silt
- Sand
- Gravel

Generally, the easiest soils to compact have small particle sizes (such as clay) and are spherical and smooth.

CAUTION!
Beware of over-compaction as this can negate the purpose for compacting the soil.

Compaction Principles—Self-Quiz

1. Soil compaction is defined as the method of mechanically increasing the density of soil.

   ☐ True

   ☐ False

2. The particle sizes determine how easy or difficult the soil is to compact.

   ☐ True

   ☐ False

Now check your answers on the next page.

Compaction Principles—Self-Quiz Answers

1. Soil compaction is defined as the method of mechanically increasing the density of soil.

   Answer: **True**

2. The particle sizes determine how easy or difficult the soil is to compact.

   Answer: **True**

Key Point 3.2: Compaction Equipment

The type of soil used will determine the type of compaction equipment needed. Some machines work better for compacting clay soil, while others perform better with sand or loam soil types.

You will also need to consider the amount of space you are working in as some equipment functions better in tight spaces (vibratory plates) while larger equipment (rollers) needs more space.

Plate compactor, picture from Chris Cole, P. Eng.

The following are the three basic types of compaction machines:

- eammers
- vibratory plates
- rollers

Rammers

Rammers have a relatively small footprint. Manually controlled power rammers are used for the compaction of small areas where access is difficult or where the use of larger equipment would not be justified. They are also used extensively for the compaction of backfill in trenches. They do not operate effectively on uniformly graded soils.

Vibratory plates

Vibratory plates are best suited for compacting sand and small gravel soils. This equipment, which is suitable for most soil types, consists of a steel plate with upturned edges, or a curved plate, on which a vibrator is mounted.

The unit is guided manually and propels itself slowly over the surface of the soil. There are small versions that travel only forward, and larger ones that can move backward and forward.

Rollers

Rollers are generally suitable for coarse soils. There are walk-behind and ride-on models, static and vibratory rollers, smooth-drum and padded or sheepsfoot designs. They can be either towed or self-propelled.

Pneumatic-tired rollers

Suitable for a wide range of coarse and fine soils but not for uniformly graded material. The wheels are mounted close together on two axles, the rear set overlapping the lines of the front set to ensure complete coverage of the soil surface.

Sheepsfoot rollers

This type of roller consists of hollow steel drums with numerous tapered or club-shaped feet projecting from their surfaces. The mass of the drums can be increased by ballasting.

Sheepsfoot rollers are most suitable for fine soils, both plastic and non-plastic, especially at dry water contents. They are also suitable for coarse soils with more than 20% of fines.

Grid rollers

These rollers have a surface consisting of a network of steel bars forming a grid with square holes. Grid rollers provide high contact pressure but little kneading action and are suitable for most coarse soils.

Vibratory rollers

These are smooth-wheeled rollers fitted with a power-driven vibration mechanism. They are used for most soil types and are more efficient if the water content of the soil is slightly wet. They are particularly effective for coarse soils with little or no fines.

Source: https://www.multiquip.com/multiquip/pdfs/Soil_Compaction_Handbook_low_res_0212_DataId_59525_Version_1.pdf.

Compaction Equipment—Self-Quiz

1. Which type of compaction equipment is best used for the compaction of small areas where access is difficult?

   ☐ Vibratory plates

   ☐ Rammers

   ☐ Rollers

Now check your answers on the next page.

Compaction Equipment—Self-Quiz Answers

1. Which type of compaction equipment is best used for clay soil?

   Answer: **Rammers**

Key Point 3.3: Compaction Testing

Compaction testing is the best way to ensure that the soil has been compacted according to the engineering specifications.

By conducting an accurate Soil Compaction Test, you can ensure longevity to structures like buildings, roads and other construction sites. Not only is this necessary to bring the construction site up to meet safety codes and design requirements, it will also save you money in the future and create a more stable structure that has limited risk of collapse or settling from unstable ground.

Source: http://www.vertekcpt.com/blog/soil-compaction-test-intro#.XSIIcY97mUm.

The following soil compaction tests are used:

- Standard proctor compaction test
- Nuclear test
- Sand cone test
- Balloon densometer

Standard Proctor Compaction Test

The Standard Proctor Compaction Test can be performed in a lab. The testing first determines the maximum density achievable for the soil and uses it as a reference for field testing.

It also is effective for testing the effects of moisture on the soil's density.

Nuclear Test

A nuclear test is a field test performed on-site. It is a quick and fairly accurate way to measure the density and moisture content of the compacted soil.

This test utilizes a radioactive isotope source at either the surface of the soil, or from a probe placed in the soil (called direct transmission). When activated the isotope sources gives off photons, usually gamma rays, which radiate back towards detectors on the bottom of the unit. Dense soil absorbs more radiation than loose soil, so based on the amount of gamma rays picked up by the detectors the soil density can be determined.

Water content can also be measured with the nuclear test by emitting neutron radiation into the soil. Neutrons loose energy when they collide with hydrogen atoms, so based on the amount of moderated neutrons the detector reads the moisture content can be determined.

Despite the ease and accuracy of this type of field test, the negative aspects include the use of radiation and a high cost to conduct.

Sand Cone Test

A sand cone test is a field test performed on-site. It is an inexpensive method of soil compaction testing and is fairly accurate if conducted correctly.

The most important variable to consider is that the sand is consistently dry throughout the testing. Any change in moisture content will skew the results.

To begin, a small hole is dug in the compacted soil. This soil is removed and weighed, then dried and weighed again to determine the moisture content. The hole's specific volume is measured by filling it with a pre-calculated amount of dry sand from a jar and cone device. The dry weight of the soil removed is divided by the volume of dry sand needed to fill the hole, which gives us the density of the compacted soil in lbs. per cubic ft. This can be compared to the maximum Proctor density determined earlier to get the relative density of the compacted soil.

Balloon Densometer

A balloon densometer is a field test performed on-site. It is similar to a sand cone test; the difference is the volume of the sample hole is measured by forcing a liquid filled balloon into the test hole.

Compaction Testing—Self-Quiz

1. The primary goal of compaction testing is to ensure:

    ☐ That the effects of moisture on the soil's density remain the same

    ☐ That the soil contains the same volume of aggregates as before compaction

    ☐ That the soil has been compacted according to the engineering specifications

    ☐ That the sand is consistently dry throughout the testing

2. Which of the tests is performed in a laboratory environment?

    ☐ Balloon densometer

    ☐ Standard Proctor Compaction test

    ☐ Sand cone test

    ☐ Nuclear test

Now check your answers on the next page.

Compaction Testing—Self-Quiz Answers

1. The primary goal of a compaction testing is to ensure:

   Answer: **That the soil has been compacted according to the engineering specifications**

2. Which of the tests is performed in a laboratory environment?

   Answer: **Standard Proctor Compaction test**

Key Point 3.4: Compacting Levels

Soil compaction is an important part of the construction process. It is used for support of structural entities such as building foundations, roadways, walkways, and earth retaining structures.

When an area is to be filled or backfilled the soil is placed in layers called lifts. The ability of the first fill layers to be properly compacted will depend on the condition of the natural material being covered. If unsuitable material is left in place and backfilled, it may compress over a long period under the weight of the earth fill, causing settlement cracks in the fill or in any structure supported by the fill.

To determine if the natural soil will support the first fill layers, an area can be proof rolled. Proof rolling consists of using a piece heavy construction equipment (typically, heavy compaction equipment or hauling equipment) to roll across the fill site and watching for deflections to be revealed.

Layering

The type of soil and rock material is important for layering. Usually compaction testing is not done on forestry roads, except when installing bridges and culverts and retaining walls.

In urban or civil dirt road construction, the Engineer will specify the material specs, mix and the density required, and this is usually tested through simple on-site tests such as “standard proctor” tests.

The soil must be compacted within 95% of the density it was before it was excavated. When soil is compacted for roads, buildings, or bridges, it is compacted into layers (max. 15 cm deep), so that the compaction effort of the compactor machine makes the soil dense.

If the soil layer is too thick, or if the compaction machine is too light or small, then only the top few inches of soil may get compacted, and the lower layer will not get compacted.

If the soil is loose, and not compacted, water may enter the small spaces in the soil and the soil will turn to mud. The soil may also pull in water from surrounding areas during freezing to make ice lenses and “frost heaves” or bumps, and then turn into pot holes when it melts. Therefore, the soil has to be compacted as a solid mass to prevent water from coming and going, and hold firm as a road driving surface.

Project Specifications

To ensure adequate soil compaction is achieved, project specifications will indicate the required soil density or degree of compaction that must be achieved. These specifications are generally recommended by a geotechnical engineer in a geotechnical engineering report.

The soil type and physical characteristics have a great influence on how the materials should be compacted in given situations.

Compaction is conducted by using heavy equipment. In sands and gravels, the equipment usually vibrates, to cause re-orientation of the soil particles into a denser configuration. In silts and clays, a sheepsfoot roller is frequently used, to create small zones of intense shearing, which drives air out of the soil.

To determine if adequate compaction is done the soil density is compared to the maximum density determined by a laboratory test.

Soil used for road construction and bridge footings must be compacted to a certain density. This is to prevent erosion, sedimentation, soil cracking, or rutting, which happens when the soil becomes muddy and soft when trucks drive over it with heavy loads.

Learning Point

During road construction, it’s necessary to compact the soil into layers to ensure that no loose soil or moisture remains in the lower depths.

Compacting Levels—Self-Quiz

1. Who generally creates the project specifications that indicate the required soil density or degree of compaction that must be achieved?

   ☐ Mechanical engineer

   ☐ Geotechnical or Civil engineer

   ☐ Geographical engineer

   ☐ Electrical engineer

2. Over-compaction can lead to which of the following problems?

   ☐ Erosion and sedimentation

   ☐ Soil cracking

   ☐ Rutting

   ☐ All of these answers

Now check your answers on the next page.

Compacting Levels—Self-Quiz Answers

1. Who generally creates the project specifications that indicate the required soil density or degree of compaction that must be achieved?

   Answer: **Geotechnical or Civil Engineer**

2. Over-compaction can lead to which of the following problems?

   Answer: **All of these answers**