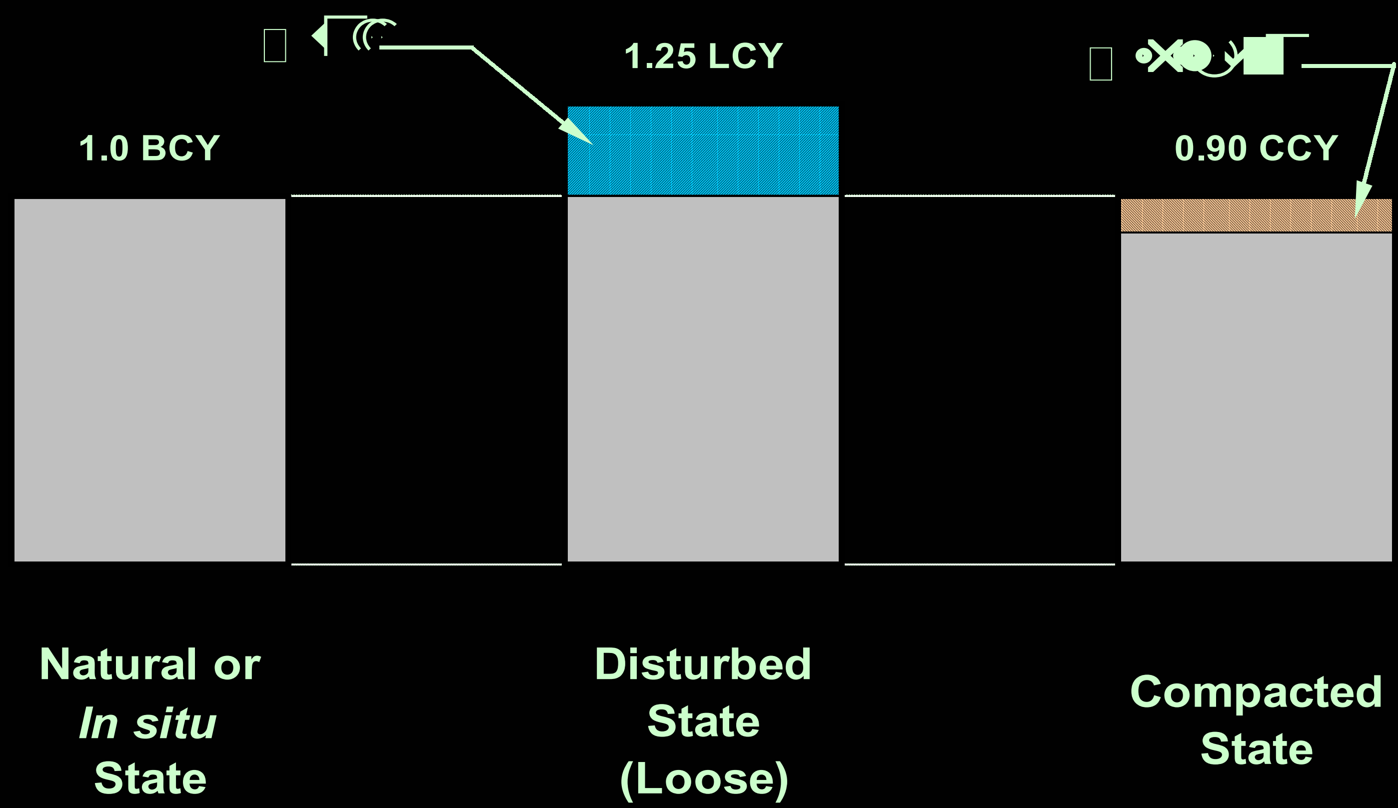
Construction Management & Engineering
CIEG 467-013



Earthwork

Soil Volume Changes



Earthwork

$$\text{Swell (\%)} = \left[\frac{\text{weight/bank volume}}{\text{weight/loose volume}} - 1 \right] \times 100$$

$$\text{Shrinkage (\%)} = \left[1 - \frac{\text{weight/bank volume}}{\text{weight/compacted volume}} \right] \times 100$$

Earthwork

$$\text{Load Factor} = \frac{\text{weight/loose volume}}{\text{weight/bank volume}}$$

$$\text{Load Factor} = \frac{1}{1 + \text{swell}}$$

Earthwork

$$\text{Shrinkage Factor} = \frac{\text{weight/bank unit volume}}{\text{weight/compacted unit volume}}$$

Shrinkage Factor = 1 - shrinkage

Earthwork Volumes

- Sitework
  - Usually lump sum contract work
  - Traditional Method = averaging cut/fill depths x plan area (using a grid)
  - Modern Method = any number of software packages such as PAYDIRT®
  - Computer programs compare the existing surfaces against various proposed surfaces i.e.: subgrade, base grade, finish grade

Earthwork Volumes

- Highway & Trench Excavation
  - Usually unit-price line item
  - Traditional Method = average end area measured from cross sections by planimeter, cross multiplication, strip and tic = all very laborious
  - Modern Method = digitize cross sections for computation by electronic spreadsheet, or any number of software packages such as TERRAMODEL®

Earthwork Volumes

…..Highway & Trench Excavation

- Some computer programs convert sections to surfaces and vice versa
- Programs can prepare mass haul diagrams and other reports

Soil Behavior

- Soil Density (wet or dry)
- Soil Compaction
- Consolidation
- Moisture Content
- Stability
- Compressible Soils
- Expansive Clays

Compaction

- Increased bearing capacity
- Reduce compressibility
- Reduce permeability
- Improve stability
- Heavy/highway vs. building foundation compaction operations

Compaction

Five factors affecting compaction

1. Physical & chemical properties
2. Moisture content
3. Method of compaction
4. Amount of compactive effort
5. Thickness of layer or “lift” being compacted

Compaction

<u>Methods of Compaction</u>

1. Static weight
2. Impact
3. Vibration
4. Manipulation or kneading
5. Percolation

Consolidation

- Primary consolidation results from the expulsion or extrusion of water from the voids in fine-grained soil
- Causes settlement in structures and embankment over a period of time
  - Methods of accelerating consolidation include placing a surcharge and/or installing sand columns or wick drains
- Secondary consolidation is the rearrangement of cohesive soil grains

Mass Haul Diagrams

- diagrammatic representation of earthwork volumes along a linear profile
- horizontal stationing is plotted along the X-axis
- net earthwork values are plotted along the Y-axis

Mass Haul Diagrams

- An *Earthwork Profile* is a plot of the net earthwork along a roadway or airstrip
- Net cut values are plotted above the X-axis (positive Y value)
- Net fill values are plotted below the X-axis (negative Y value)
- Presents a picture of the earthwork requirements

Mass Haul Diagrams

- A *Mass Haul Diagram* is a continuous curve representing the cumulative volume of earthwork along the linear profile of a roadway or airfield
- the vertical coordinate is a plot of the cumulative earthwork from the origin to that point

<u>Mass Haul Diagrams</u>

- upward sloping curves indicate (rising left to right) indicate a cut
- downward sloping (falling left to right) curves occur in a fill section
- peaks indicate a change from cut to fill and valleys occur when the earthwork changes from fill to cut

Mass Haul Diagrams

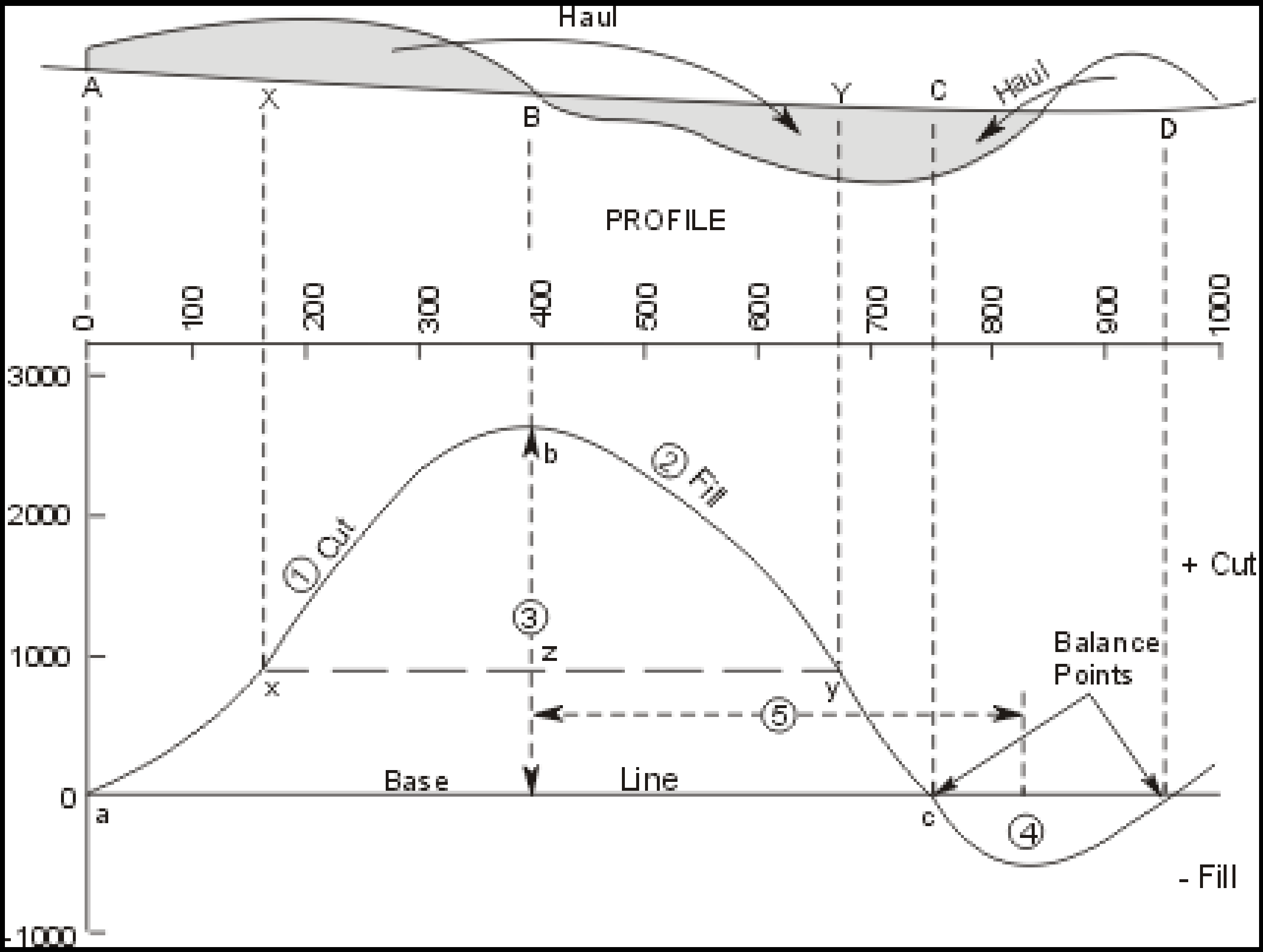
- The accumulated volume of earthwork at the horizontal axis (Y=0) is 0
- When a horizontal line intersects two or more points along the curve, the accumulated volumes at those points are equal
- A negative value at the end of the curve indicates that borrow is required to complete the fill
- A positive value at the end of the curve indicates that a waste operation will be the net result

Mass Haul Diagrams

To construct the Mass Haul Diagram manually:

- Compute the net earthwork values for each station, applying the appropriate shrink factor
- Net cuts have a positive value, net fills have a negative value
- The value at the first station (origin) = 0
- Plot the value of each succeeding station which equals the cumulative value to that point, i.e., the value at i = net cut/fill$_{a+b+c+\ldots i}$

Mass Haul Diagram



Mass Haul Diagrams

To construct & analyze the Mass Haul Diagram manually:

- Identify the the resulting balanced sections, which are bounded by points that intersect the X-axis
- Draw a horizontal line midway between the peak or valley and the X-axis. The scale length of that line is the average length of haul within that balanced section
- Determine earthwork volumes within each balanced section
- Determine whether there is an overall balance, waste or if borrow is required

Earthwork

Clearing & Grubbing

- removal of trees, shrubs, and other vegetation
- removing stumps and root mat at least 2' (600mm) below subgrade
- less removal required for embankment heights > 5'
- topsoil striping
- muck excavation

Earthwork

Prior to starting any earthwork:

- verify location of underground utilities through “Miss Utility” or local “one-call” system
  - check for utilities not included in one-call system
  - dig test pits to confirm actual locations
- note location of aerial utilities for equipment and truck clearances
- confirm that all applicable permits and approvals have been secured

Earthwork

Prior to starting any earthwork:

- Install all required E&SC devices
- Review soil borings and other geotechnical information
- Observe existing drainage patterns
- Plan access and excavation patterns
- Determine handling of spoils
- Verify original ground surfaces (compare against existing contours or cross sections shown on the plan)

Keys to Successful Earthwork Operations

1. control surface and subsurface water
2. maintain optimum moisture range by drying, mixing , or wetting
3. identify and monitor cut & fill quantities
4. good layout (horizontal & vertical control)
5. minimize handling - minimize stockpiling

Keys to Successful Earthwork Operations

6. optimize haul lengths
7. minimize cycle time
8. proper selection and sizing of excavators and haul units
9. alternate haul unit wheel paths
10. experienced personnel in the field

Equipment Functions

- Excavating
- Loading
- Hauling
- Placing (dumping & spreading)
- Drying
- Ripping
- Boring or tunneling
- Compacting
- Grading
- Finishing

Equipment Classifications

- Function
- Configuration
- Power Units -- Gas vs. diesel vs. gas turbine
- Running Gear -- track (crawler) vs. wheel (rubber tire)
- Activation - conventional (gears, pulleys, cable) vs. hydraulic

Diesel vs. Gas Power Units

Advantages of diesel over gas

- Less need for servicing
- Longer life
- Lower fuel consumption
- Lower- priced fuel
- Lower fire hazard
- Low CO emissions

Running Gear

Tracks

- greater traction
- less ground pressure
- better on steep grades
- not prone to damage from surface
- drawbar pull

Wheels

- greater mobility
- greater speed
- does not scar or damage paved surfaces
- encounters rolling resistance
- rimpull force

Traction

Rolling Resistance Factor (lb/ton) =	40 + (30 x in. penetration)
Rolling Resistance Factor (kg/t) =	20 + (6 x cm penetration)
Grade Resistance Factor (lb/ton) =	20 x grade (%)
Grade Resistance Factor (kg/t) =	10 x grade (%)

Traction

Grade Resistance (lb) = GVW (tons) x Gr. Resistance Factor (lb/ton)

Grade Resistance (kg) = GVW (t) x Gr. Resistance Factor (kg/t)

or

Grade Resistance (lb) = GVW (lb) x Grade

Grade Resistance (kg) = GVW (kg) x Grade

Excavation Equipment






Excavation Equipment

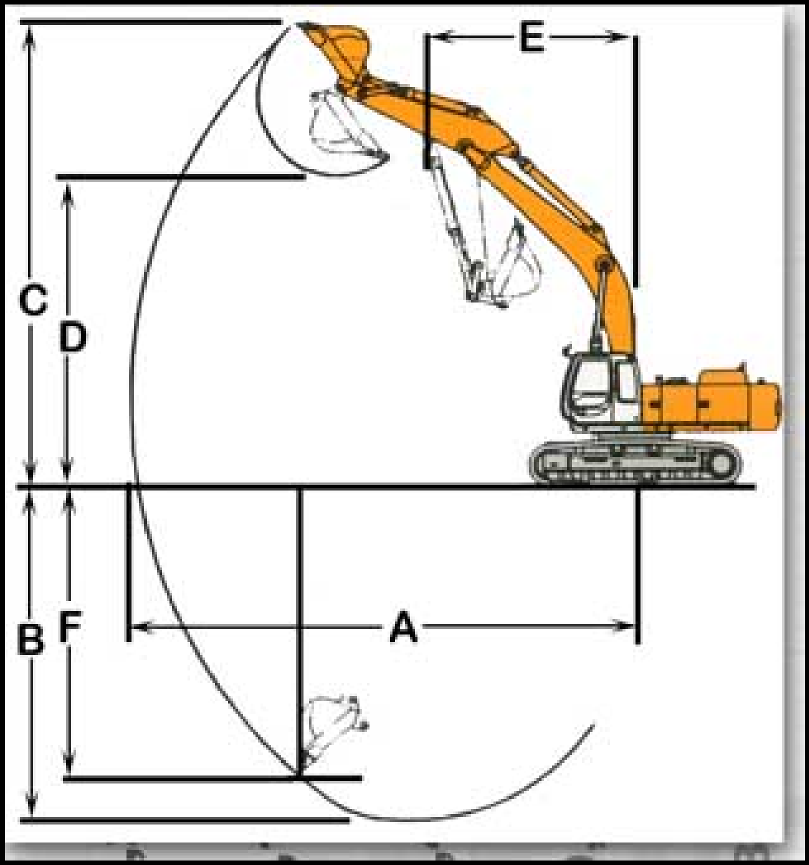
- Hydraulic Excavators
- Backhoes
- Draglines & Clamshells
- Telescoping-boom Hydraulic Excavators
- Dozers/Tractors/Rippers
- Front End Loaders

Excavation Equipment

- Scrappers (pans)
- Trenchers
- Boring/Tunneling
- Motor Graders
- Auto Graders
- Compaction Equipment
  - Rollers & Tampers

Hauling Equipment

Excavation Equipment



Excavation Equipment

Excavation Equipment

Compaction Equipment





Erosion & Sedimentation Control Devices

Erosion & Sedimentation Control Devices

Also referred to as "construction practices"

- Silt fence – plain or reinforced
- Construction entrances
- Stone or rock check dams
- Earth berms
- Sediment traps – single or multi-stage
- Dewatering devices
- Straw-coconut blankets
- Seeding & mulching – establish vegetation ASAP

Slope Stability

- Function of the natural angle of repose, density, surface and subsurface water flow
- Early stabilization of surfaces is critical i.e. seeding, mulching, erosion blanket
- Upward tracking of slopes slows sheet flow
- Eliminate points of concentrated flow using berms or using slope drains as outlets
- Slopes can be “softened” if space permits
- Difficult slopes may require riprap, gabions, or other measures for permanent stabilization

Riprap

- Riprap placed on geotextile and crushed stone cushion
- Placed by excavator or clamshell, arranged by hand
- Unit price in tons or SY (SM)

Benching

- Benching is used to properly patch or extend a slope
- Benching is also used to temporarily support equipment for other work elements
- Bench detail must be wide enough to support a dozer % slope in towards the roadway to resist sliding