Training Course on Civil/Structural Codes and Inspection

BMA Engineering, Inc.

Overall Outline

7000. General Construction Methods

- Objective and Scope
  - Fundamental and analytical methods for defining means and methods for the planning, selection and utilization of construction equipment and methods
  - Present and discuss
    - General construction methods at different project stages
    - Selected construction equipment
    - Construction safety relating to equipment operation

7000. General Construction Methods

- Objective and Scope (cont.)
  - Items not covered:
    - Engineering economics
    - Planning
    - Cost analysis

7000. General Construction Methods

- 7100 — Site preparation: earthwork and equipment
- 7200 — Substructure construction: foundations
- 7300 — Superstructure construction
- 7400 — Advanced construction methods

7000. General Construction Methods

- Site preparation: excavation and earthmoving
  - Planning for Earthwork
  - Geotechnical Materials and Compaction Properties
  - Clearing and Ripping
  - Dozing and Scraping
  - Excavating , Loading and Hauling
  - Compacting and Grading
  - Hauling and Trucking
  - Compressed Air Systems
  - Drilling and Blasting

7000. General Construction Methods

- Substructure construction: foundations
  - Production of Crushed-Stone Aggregate
  - Dewatering Systems
  - Piles
- Superstructure construction
  - Concrete Construction
  - Concrete Forms
  - Steel Construction and Connections
  - Composite Structures
  - Cranes

7000. General Construction Methods

- Advanced construction methods
  - *Advanced Construction Methods for New Nuclear Power Plants, AdvancedConstruction.pdf from http://www.iaea.org*

Site Preparation: Excavation and Earthmoving

- **Planning for Earthwork**
- Geotechnical Materials and Compaction Properties
- Clearing and Ripping
- Dozing and Scraping
- Excavating , Loading and Hauling
- Compacting and Grading
- Hauling and Trucking
- Compressed Air Systems
- Drilling and Blasting

Planning for Earthwork

- A plan and cost estimate for an earthwork project requires the determination of the following items:
  1. The quantities involved (e.g., volume or weight)
  2. The haul distances
  3. The grades for all segments of the hauls

Planning for Earthwork

- Contract Document
  – Construction documents present, as information available to bidders, geotechnical data gathered during the design phase
  – Geotechnical data:
    - There is a distinction between interpretations for **design** and interpretations for ***construction***

Basic Factors Effecting Earthwork Productivity

- Material type
- Water
- Extent of work area
- Job size
- Length of hauls
- Haul route conditions

Job Management Factors Effecting Productivity

- Project organization
- Suitable equipment
- Maintenance practices
- Skill and morale of work force

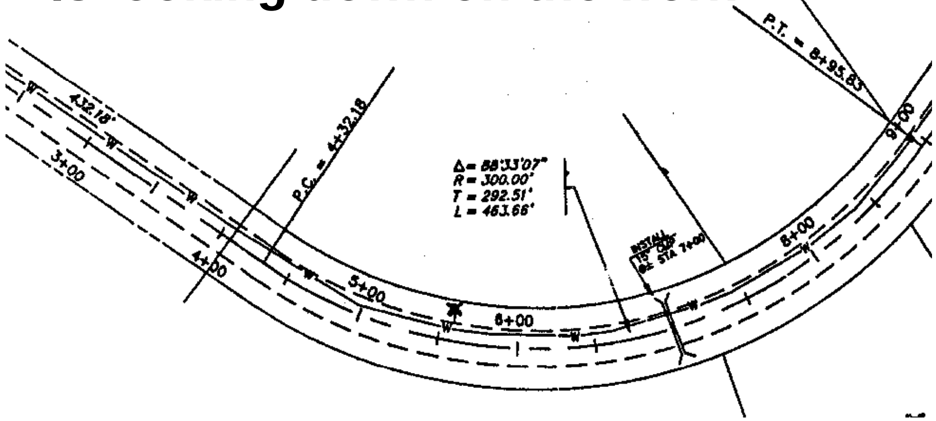
Graphical Presentation of Earthwork

- Three kinds of views are use to show earthwork construction:
  - Plan view
  - Profile view
  - Cross section view

Graphical Presentation of Earthwork

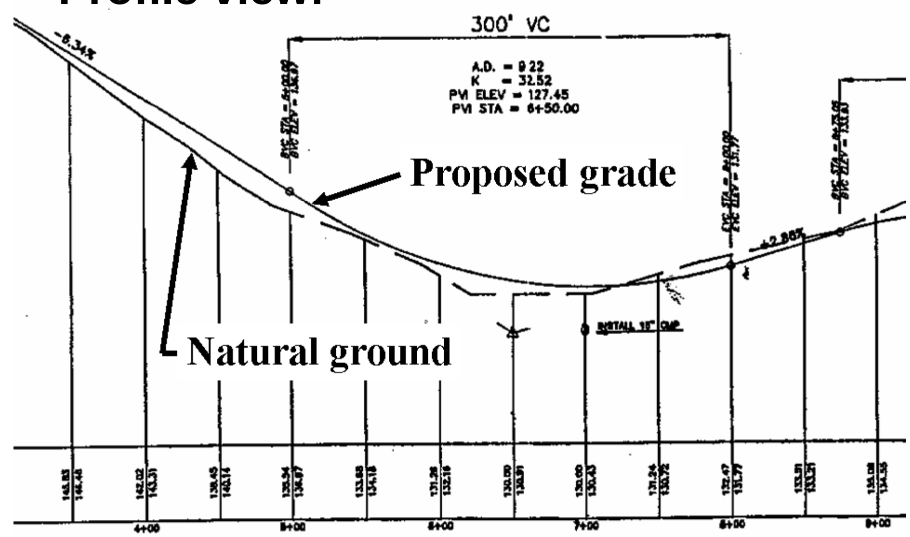
Plan view:

Is looking down on the work



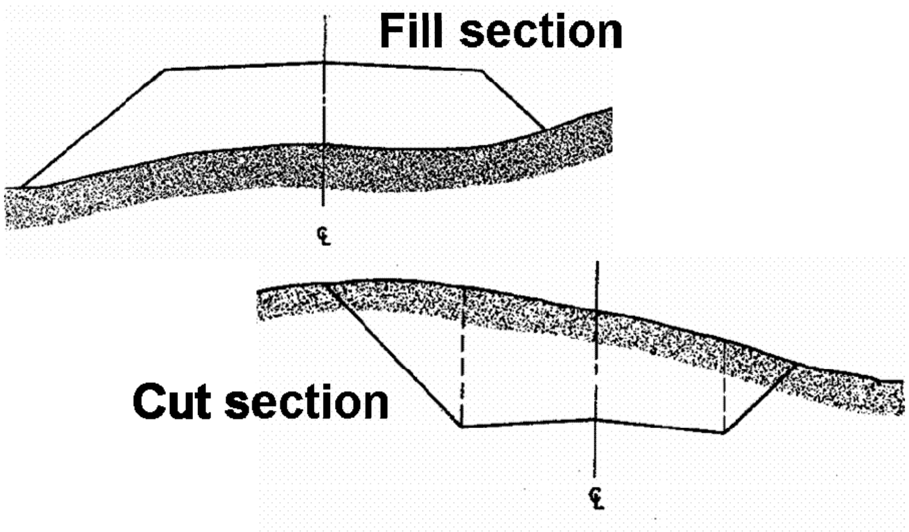
Graphical Presentation of Earthwork

Profile view:



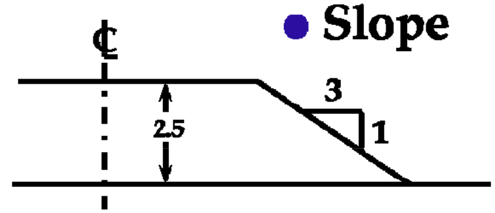
Graphical Presentation of Earthwork

Cross-section view:

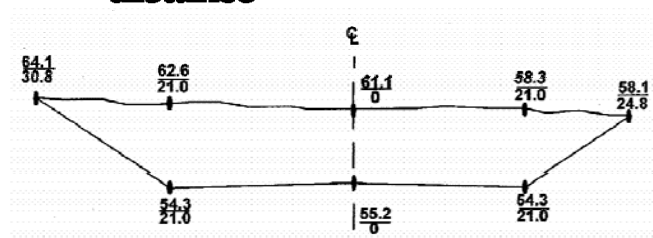


Surveyor's Notations

- **Slope**



- **Elevation and horizontal distance**



Earthwork Quantities

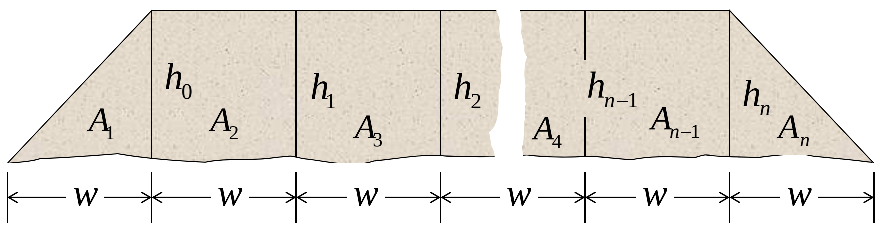
- Earthwork computations involve:
  - Calculating earthwork volumes
  - Balancing cuts and fills
  - Planning the most economical material hauls
- The exactness with which earthwork computations can be made is dependent on the extent and accuracy of the field measurements portrayed on the drawings

End-Area Determination

- Digitizing Tablet
  - Tablet with a wire mesh grid embedded into it
  - Computerized devices
- Planimeter
  - Drafting instrument used to move a tracing point around the perimeter of plotted area.
- Trapezoidal Computations
  - Computations based on breaking the drawing into small parts

End-Area Determination

- General Trapezoidal Formula

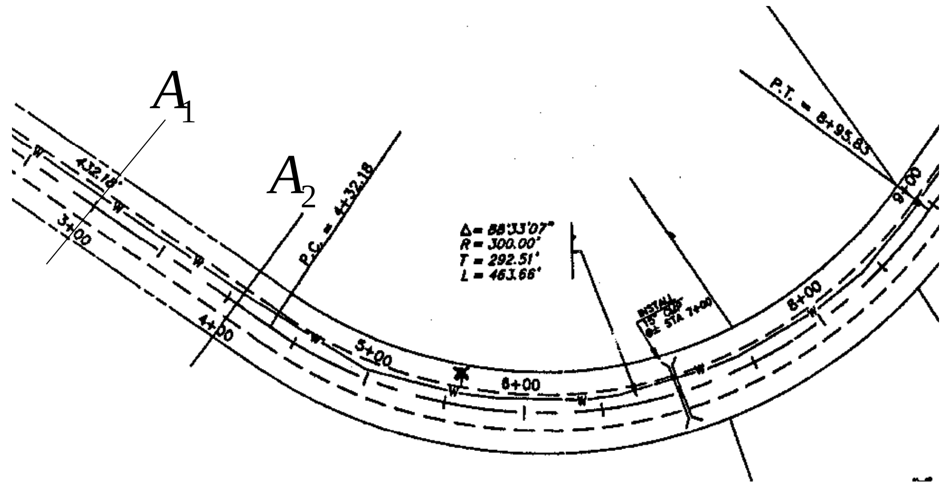


$$\text{Area} = A_1 + A_2 + A_3 + A_4 + \cdots + A_{n-1} + A_n$$

$$\text{Area} = \left(\frac{h_0}{2} + h_1 + h_2 + \cdots + h_{n-1} + \frac{h_n}{2} \right) \times w$$

Volume

Average End Area



Volume

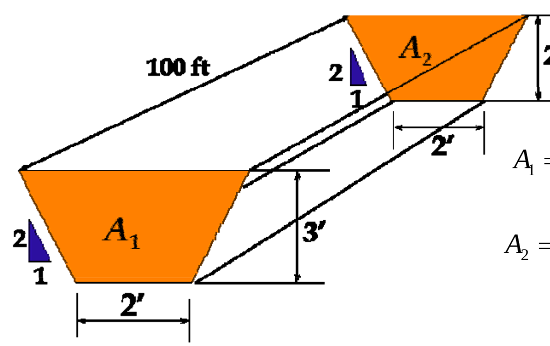
Average End Area

$$\text{Volume} = \frac{L}{C}\left(\frac{A_1}{2} + A_2 + A_3 + \ldots + \frac{A_n}{2} \right) \quad (3)$$

when *L* is a constant between stations, i.e., one station of 100 ft

Example

Calculate the volume between two end areas 100 ft apart as shown in the figure



$$A_1 = 2\times 2 + 2\left(\frac{1}{2}(2\times 1)\right) = 6\ \text{ft}^2$$

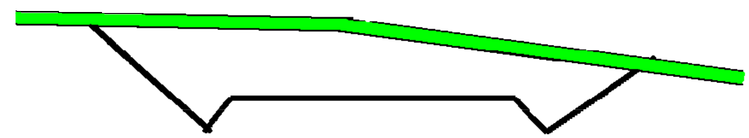
$$A_2 = 2\times 3 + 2\left(\frac{1}{2}(3\times 1.5)\right) = 10.5\ \text{ft}^2$$

$$\text{Volume, cy} = \frac{A_1 + A_2}{2}\times\frac{L}{27} = \frac{6+10.5}{2}\times\frac{100}{27} = \boxed{30.5\ \text{cy}}$$

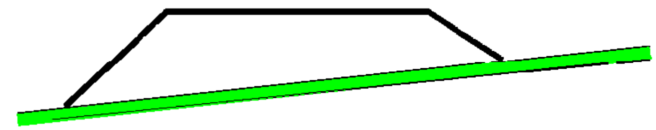
Stripping

- The upper layer of material encountered in an excavation is often topsoil (organic) resulting from decomposition of vegetative matter
- This material is not suitable for use in an embankment, and it must be handled in a separate excavation operation
- It can be collected and wasted, or stockpiled for later different use

Stripping



For cut sections subtract the stripping.



For fill sections the stripping is a cut quantity plus, an equal quantify must be added to the embankment quantity.

Net Volume

- The computed volumes from the cross sections represent two different material states:
  - Volumes from the fill cross section represent compacted volume. The notation for compacted cubic yards is **ccy**
  - Volumes from the cut cross section represent in situ or bank volume. The notation for bank cubic yards is **bcy**

Net Volume

- Must adjust either the cut (work in compacted cubic yards, ccy) or fill (work in bank cubic yards, bcy)
- In general, a swell factor of 0.9 can used to perform the conversion from ccy to bcy or vise versa:

$$\text{bcy} = \frac{\text{ccy}}{0.9}$$

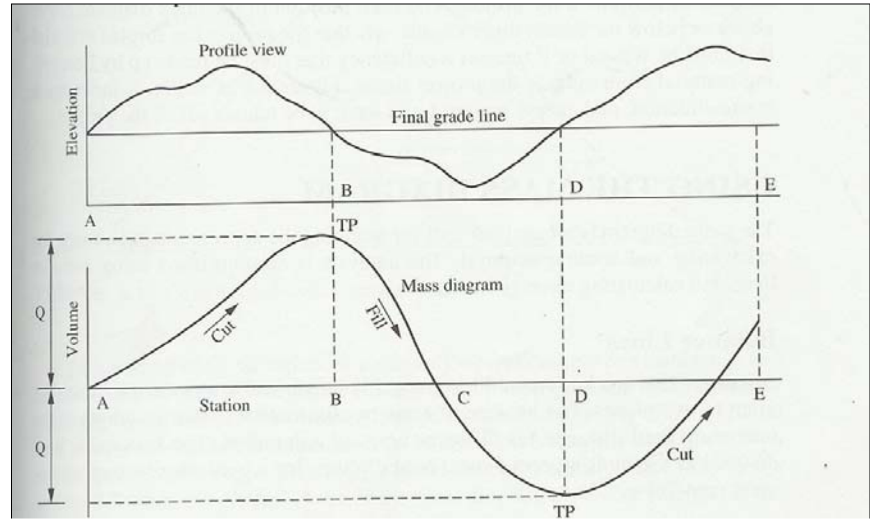
- For a specific soil, tables are available for swell factor value

Mass Diagram

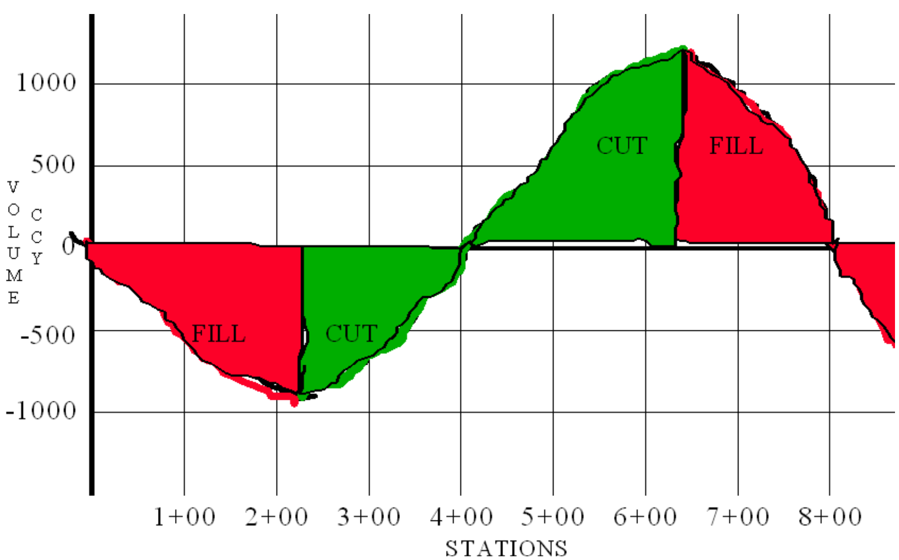
- Earthmoving is basically an operation where material is moved from high spots and deposited in low spots with the making up of any deficit with borrow or the wasting of excess cut material
- Definition:

  "A mass diagram is a graphical means for measuring haul distance (stations) in terms of earthwork volume (cubic yards)"

Mass Diagram

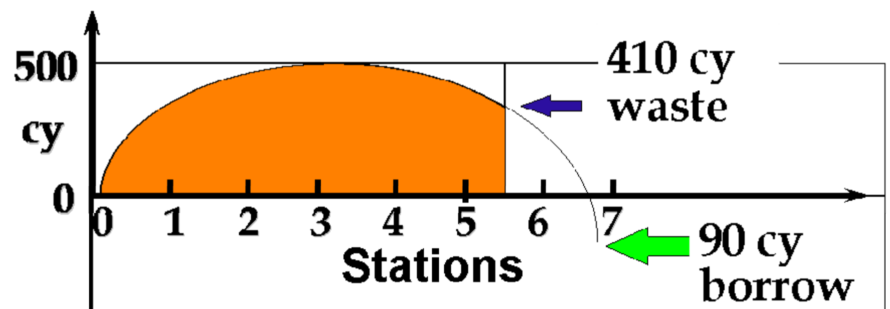


Mass Diagram



Mass Diagram

- **Final position**



Above the zero line indicates waste.

Below the zero line indicates borrow.

Site Preparation: Excavation and Earthmoving

- Planning for Earthwork
- **Geotechnical Materials and Compaction Properties**
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Types of Geotechnical Materials

- Homogeneous material such as steel and concrete are easy to predict their behavior
- Heterogeneous material such as earths are hard to predict their behavior and properties because they are rarely uniform

Types of Geotechnical Materials

Generally, the soil types are found in nature in some mixed proportions. Table 4.1 presents a classification system based on combinations of soil types.

TABLE 4.1 | Unified soil classification system

Symbol	Primary	Secondary	Supplementary
GW	Coarse-grained soils	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range of grain size
GP	Coarse-grained soils	Poorly graded gravels, gravel-sand mixtures, little or no fines	Predominantly one size or a range of intermediate sizes missing
GM	Gravel mixed with fines	Silty gravels and gravel-sand-silt mixtures—may be poorly graded	Predominantly one size or a range of intermediate sizes missing
GC	Gravel mixed with fines	Clayey gravels, gravel-sand-clay mixtures, which may be poorly graded	Plastic fines
SW	Clean sands	Well-graded sands, gravelly sands, little or no fines	Wide range in grain sizes
SP	Clean sands	Poorly graded sands, gravelly sands, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing
SM	Sands with fines	Silty sands and sand-silt mixtures, which may be poorly graded	Nonplastic fines or fines of low plasticity
SC	Sands with fines	Clayey sands, sand-clay mixtures, which may be poorly graded	Plastic fines
ML	Fine-grained soils	Inorganic silts, clayey silts, rock flour, silty very fine sands	Plastic fines
CL	Fine-grained soils	Inorganic clays of low to medium plasticity, silty sandy or gravelly clays	Plastic fines
OL	Fine-grained soils	Organic silts and organic silt-clay of low plasticity	
MH	Fine-grained soils	Inorganic silts, clayey silts, elastic silts	
CH	Fine-grained soils	Inorganic clays of high plasticity, fat clays	
OH	Fine-grained soils	Organic clays and silty clays of medium to high plasticity	

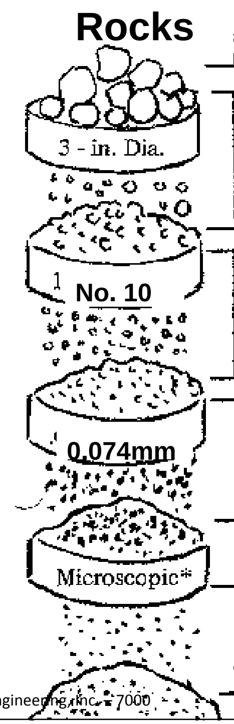
Types of Geotechnical Materials

Symbol classification	
COARSE GRAINED MATERIAL Symbol G—Gravel grain size from 3″ to No. 4 sieve size S—Sand grain size from No. 4 to 200 sieve size	Subdivision W—Well graded, little or no fines P—Poorly graded, little or no fines M—Concentration of silty or nonplastic fines C—Concentration of clay or plastic fines
FINE GRAINED MATERIAL Symbol M—Silt very fine grain size, floury appearance C—Clay finest grain size, high dry strength—plastic O—Organic matter partly decomposed, appears fibrous, spongy and dark in color	Subdivision L—Low plastic material, lean soil H—High plastic material, fat soil

Types of Soil

- A constructor is concerned primarily with five types of soil:
  - Gravel
  - Sand
  - Silt
  - Clay
  - Organic matter
  - Combinations of these types

Types of Soil



Gravel
pass 3-in, retained on No. 10

Sand
from lower limit gravel to No. 200

Silt, noncohesive
smaller than 0.074 mm but larger than 0.005 mm

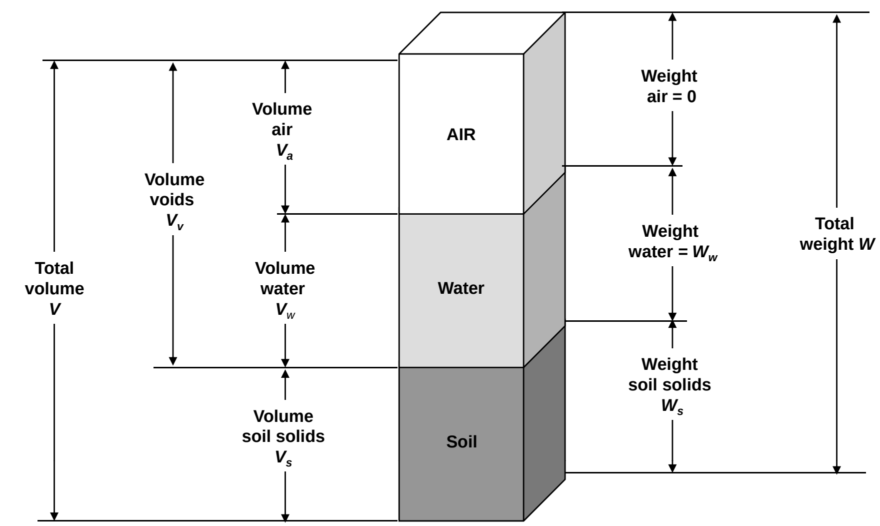
Clay, cohesive

Types of Soil

- Rock can be formed by one of the three different means:
  - Igneous rocks solidifies from molten masses
  - Sedimentary rocks formed in layers settling out of water solutions
  - Metamorphic rocks are transformed from material of the first two by heat and pressure

Soil Weight-Volume Relationships

$$Unit\ weight\,(\gamma) = \frac{\text{total weight of soil}}{\text{total soil volume}}$$

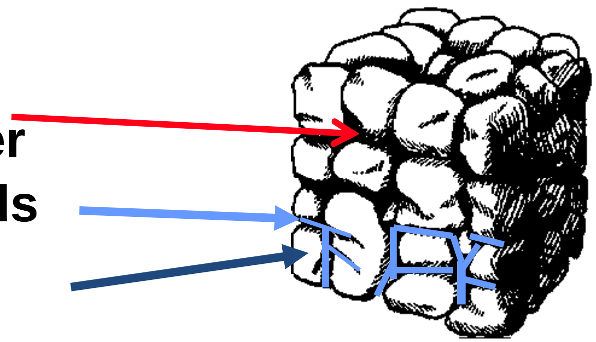


Soil Weight-Volume Relationships

$$Unit\ weight\,(\gamma) = \frac{\text{total weight of soil}}{\text{total soil volume}}$$

Total volume includes

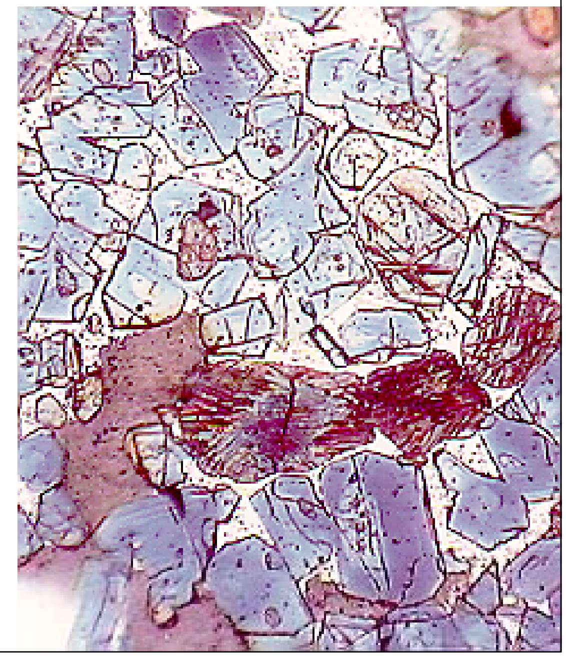
Air
Water
Solids



Soil Weight-Volume Relationships

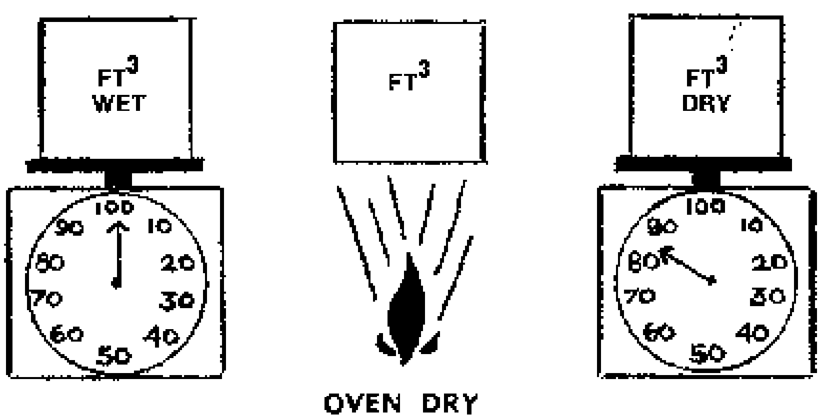
Air, Water and Solids

That's what it looks like under the microscope



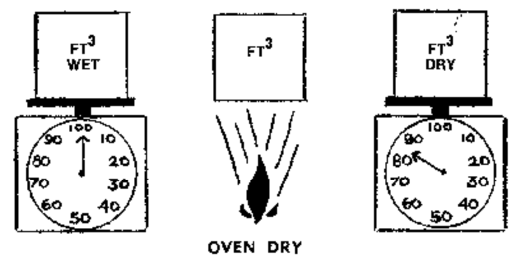
Soil Weight-Volume Relationships

γ drive off the water γ_d



Soil Weight-Volume Relationships

water content



$$\textbf{Water content} = \frac{\textbf{Wet weight} - \textbf{Dry weight}}{\textbf{Dry weight}}$$

Soil Weight-Volume Relationships

$$\text{Unit Weight } (\gamma) = \frac{\text{total weight of soil}}{\text{total soil volume}} = \frac{W}{V}$$

$$\text{Dry Unit Weight } (\gamma_d) = \frac{\text{weight of soil solids}}{\text{total soil volume}} = \frac{W_s}{V}$$

$$\text{Water Content } (\omega) = \frac{\text{weight of water in soil}}{\text{weight of soil solids}} = \frac{W_w}{W_s}$$

Soil Weight-Volume Relationships

$$\text{Void Ratio } (e) = \frac{\text{volume of voids}}{\text{volume of soil solids}} = \frac{V_v}{V_s}$$

$$\text{Porosity } (n) = \frac{\text{volume of voids}}{\text{total soil volume}} = \frac{V_v}{V}$$

$$\text{Specific Gravity } (G_s) = \frac{\text{weight of soil solids}}{\text{volume of solids}}\left(\frac{1}{\text{unit weight of water}}\right) = \frac{W_s}{V_s}\frac{1}{\gamma_w}$$

$$\text{Degree of Saturation } (S) = \frac{\text{volume of water in voids}}{\text{volume of voids}} = \frac{V_w}{V_v}$$

Soil Weight-Volume Relationships

$$\text{Void Ratio } (e) = \frac{V_v}{V_s} = \frac{V_v}{V - V_v} = \frac{\left(\frac{V_v}{V}\right)}{1-\left(\frac{V_v}{V}\right)} = \frac{n}{1-n}$$

$$\text{Porosity } (n) = \frac{e}{1+e}$$

$$\text{Total Volume } (V) = V_v + V_s = V_a + V_w + V_s$$

Soil Weight-Volume Relationships

$$\text{Moist Unit Weight } (\gamma) = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{W_s\left(1+\frac{W_w}{W_s}\right)}{V} = \frac{W_s(1+\omega)}{V}$$

$$\gamma_d = \frac{W_s}{V}$$

From the above two equations:

$$\gamma_d = \frac{\gamma}{1+\omega}$$

$$W_s = \frac{W}{1+\omega}$$

Soil Weight-Volume Relationships

Relationships Between Unit Weight, Void Ratio, Moisture Content, and Specific Gravity

$$\gamma = \frac{W_s + W_w}{V} = \frac{G_s\gamma_w + \omega G_s \gamma_w}{1+e} = \frac{G_s\gamma_w(1+\omega)}{1+e}$$

$$\gamma_d = \frac{W_s}{V} = \frac{G_s\gamma_w}{1+e}$$

$$S = \frac{\omega G_s}{e}$$

$$\gamma_{at}\ \text{(saturated unit weigth of soil)} = \frac{\gamma_w(G_s + e)}{1+e}$$

Soil Weight-Volume Relationships

Relationships Between Unit Weight, Porosity, and Moisture Content

$$\gamma = \frac{W_s + W_w}{V} = G_s\gamma_w(1-n)(1+\omega)$$

$$\gamma_d = \frac{W_s}{V} = G_s\gamma_w(1-n)$$

$$\gamma_{sat} = [G_s(1-n)+n]\gamma_w$$

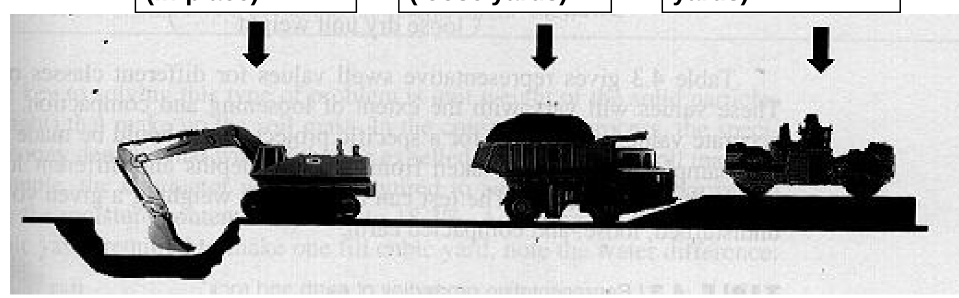
$$\omega = \frac{n}{(1-n)G_s}$$

Soil Consistency Limits

- Certain limits of soil consistency were developed to differentiate between highly plastic, slightly plastic, and nonplastic materials:
  - Liquid Limit (LL)
  - Plastic Limit (PL)
  - Plasticity Index (PI)

Volumetric Measures

1.0 cubic yards natural conditions (in-place) = **1.25 cubic yards after digging (loose yards)** = **0.90 cubic yards after compaction (compacted yards)**



Volumetric Measures

Soil volume is measured in one of three states:

Bank Cubic Yard (bcy):	1 cu yd of material as it lies in the *natural* state
Loose Cubic Yard (lcy):	1 cu yd of material after it has been disturbed by a loading process
Compacted Cubic Yard (ccy):	1 cu yd of material in the compacted state, also referred to as a net in-place cubic yard

Shrinkage And Swell Factors

$$\text{Shrinkage Factor} = \frac{\text{Compacted Dry Unit Weight}}{\text{Bank Dry Unit Weight}} = \frac{\gamma_{Cd}}{\gamma_{Bd}}$$

$$\text{Shrinkage \%} = \frac{\text{Compacted Unit Weight - Bank Unit Weight}}{\text{Compacted Unit Weight}} \text{X}\,100$$

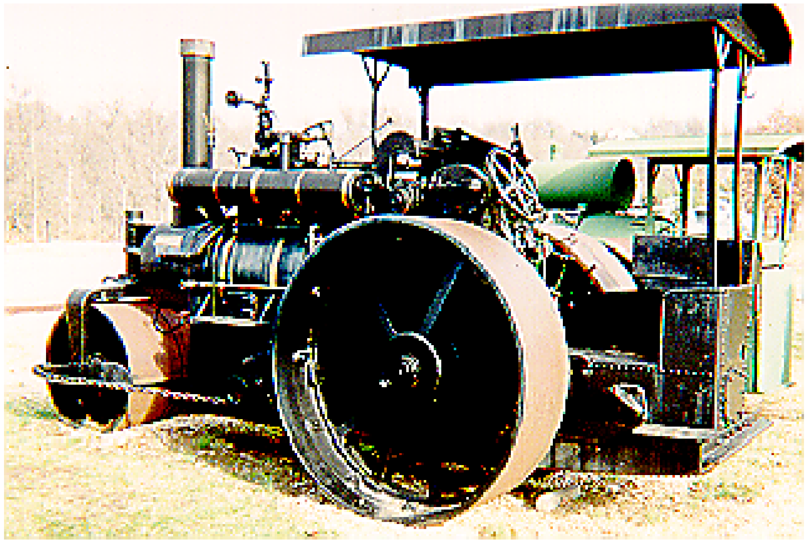
$$\text{Swell Factor} = \frac{\text{Loose Dry Unit Weight}}{\text{Bank Dry Unit Weight}} = \frac{\gamma_{Ld}}{\gamma_{Bd}}$$

$$\text{Swell \%} = \left(\frac{\text{Bank Unit Weight}}{\text{Loose Unit Weight}} - 1\right) \text{X}\,100$$

Swell Values

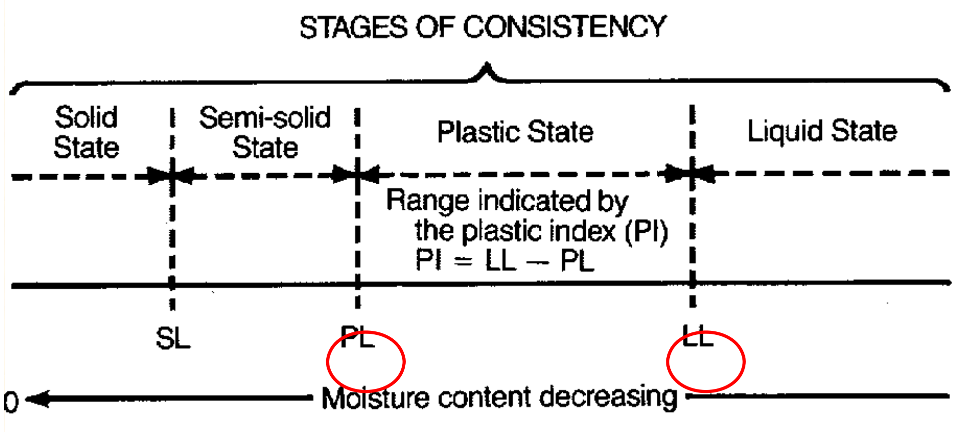
Material	Bank weight lb/cu yd	Bank weight kg/m³	Loose weight lb/cu yd	Loose weight kg/m³	Percent swell	Swell factor
Clay,dry	2,700	1,600	2,000	1,185	35	0.74
Clay, wet	3,000	1,780	2,200	1,305	35	0.74
Earth, dry	2,800	1,660	2,240	1,325	25	0.80
Earth, wet	3,200	1,895	2,580	1,528	25	0.80
Earth and gravel	3,200	1,895	2,600	1,575	20	0.83
Gravel, dry	2,800	1,660	2,490	1,475	12	0.89
Gravel, wet	3,400	2,020	2,980	1,765	14	0.88
Limestone	4,400	2,610	2,750	1,630	60	0.63
Rock, well blasted	4,200	2,490	2,640	1,565	60	0.63
Sand, dry	2,600	1,542	2,260	1,340	15	0.87
Sand, wet	2,700	1,600	2,360	1,400	*15*	0.87
Shale	3,500	2,075	2,480	1,470	40	0.71

Compaction Specification and Control



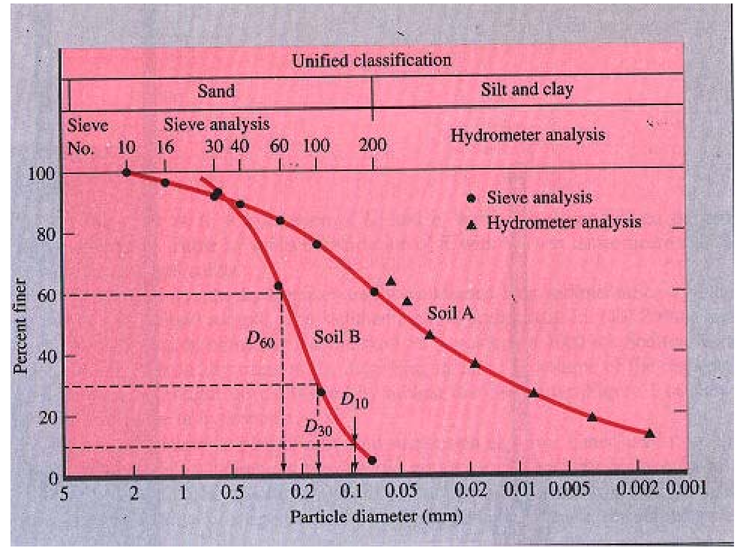
Compaction Specification and Control

Soil Limits

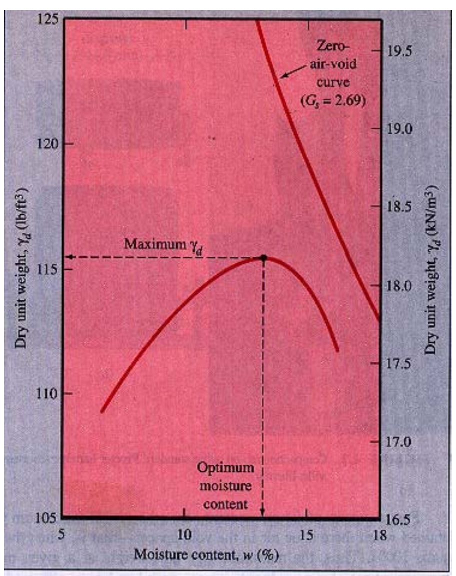


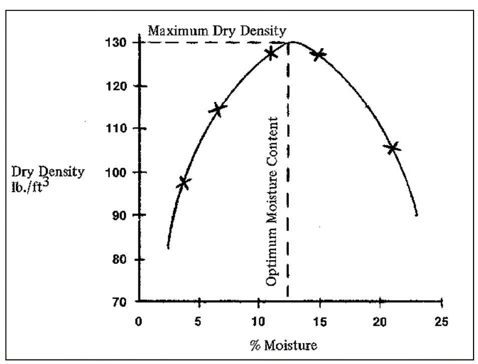
Compaction Specification and Control

Soil Gradation (Particle-size Distribution)



Compaction Specification and Control





Compaction Specification and Control

- Maximum Dry Density/Optimum Moisture (cont'd)
  - This <u>percent of water</u>, which corresponds to the maximum dry density (for a given compactive effort), is known as the **<u>optimum water content</u>**

Compaction Tests

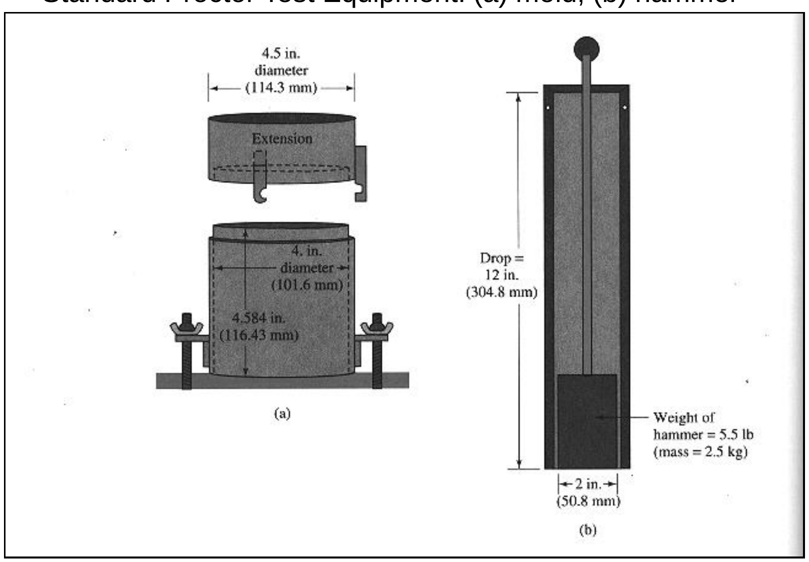
- The standard laboratory tests that are used for evaluation of maximum dry unit weights (γ_d's) and optimum moisture contents for various soils are:
  1. The Standard Proctor Test (ASTM D-698 and AASHTO T-99)
  2. The Modified Proctor Test (ASTM, D-1557 and AASHTO T-180)

Compaction Tests

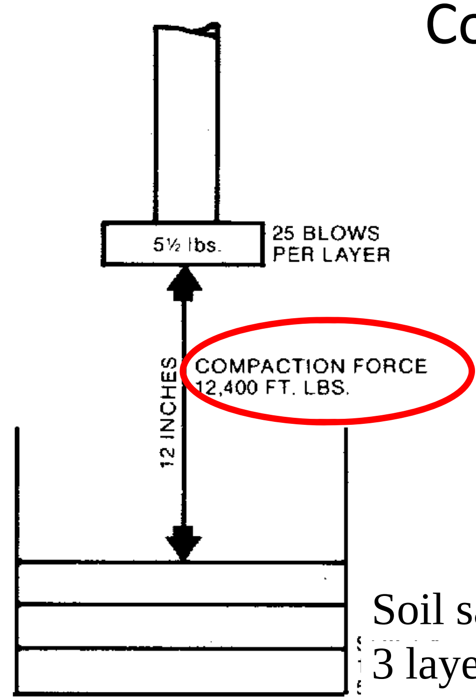
- Standard Proctor Test
  - The soil is compacted in a mold that has a volume of 1/30 ft^3 (943.3 cm^3)
  - The diameter of the mold is 4 in. (101.6 mm)
  - During the laboratory test, the mold is attached to a base plate at the bottom and to an extension at the top
  - The soil is mixed with varying amounts of water and then compacted in three equal layers by a hammer that deliver 25 blows to each layer

Compaction Tests

Standard Proctor Test Equipment: (a) mold; (b) hammer



Compaction Tests



Proctor Test

Standard Proctor

ar

AASHTO T-99

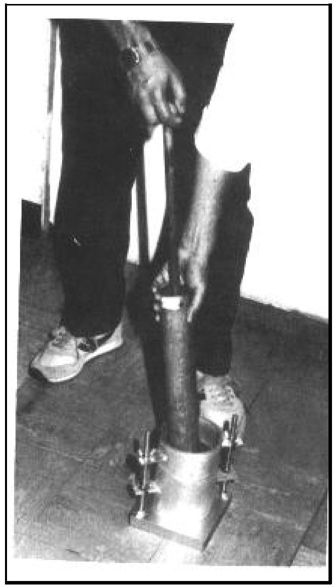
Soil sample 1/30 cubic foot

3 layers

Compaction Tests

Compaction of Soil using Standard Proctor Hammer

(courtesy of John Hester, Carterville, IL)



Compaction Tests

- Standard Proctor Test (continued)
  – The hammer weighs 5.5 lb (mass = 2.5 kg) and has a drop of 12 in. (304.8 mm)
  – For each test, the moist unit weight of compaction γ can be calculated as

$$\gamma = \frac{W}{V_m}$$

where

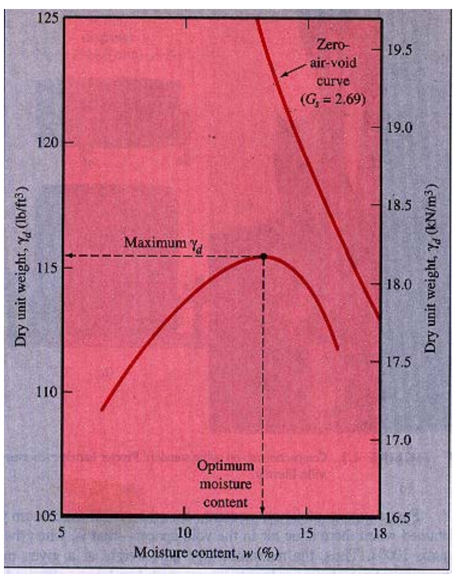
W = weight of compacted soil in mold

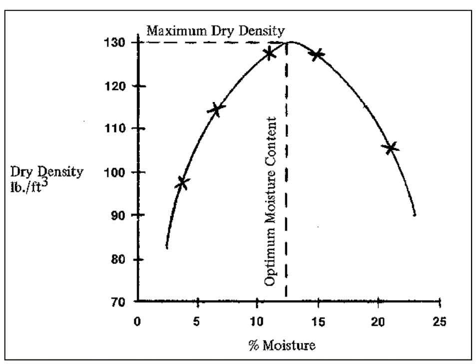
V_m = volume of mold (1/30 ft^3)

For each test, the moisture content w of the compacted soil is determined in the laboratory. With known moisture content, the dry unit weight γ_d can be calculated as

$$\gamma_d = \frac{\gamma}{1+\omega}$$

Compaction Specification and Control





Compaction Tests

- Standard Proctor Test (continued)

$$\gamma_{\text{zav}} = \frac{G_s \gamma_w}{1+e}$$

For 100% saturation, $e = \omega G_s$, so

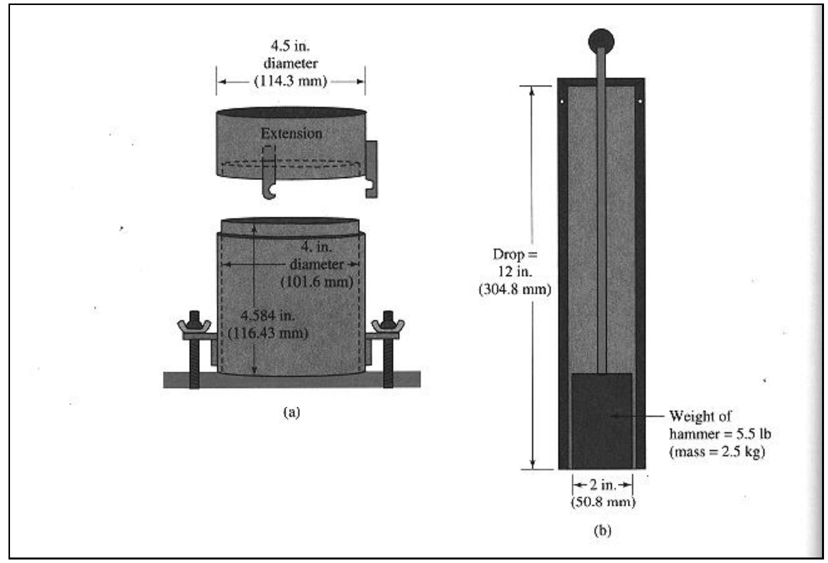
$$\gamma_{\text{zav}} = \frac{G_s \gamma_w}{1+\omega G_s}$$

Compaction Tests

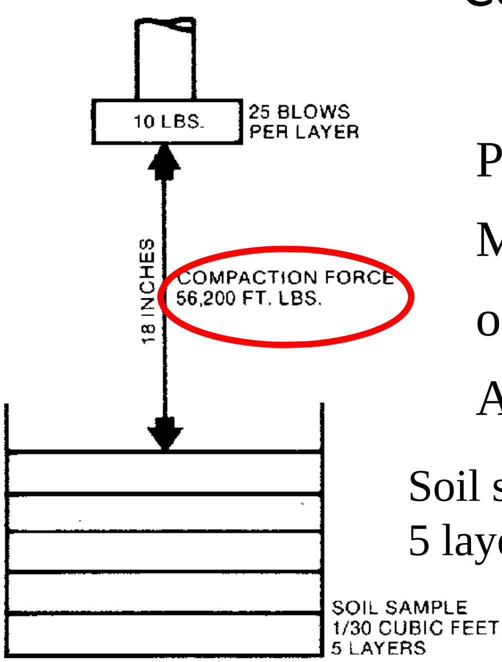
- Modified Proctor Test
  - The soil is compacted in a mold that has a volume of 1/30 ft^3 (943.3 cm^3)
  - The diameter of the mold is 4 in. (101.6 mm)
  - During the laboratory test, the mold is attached to a base plate at the bottom and to an extension at the top (see Figure)
  - The soil is mixed with varying amounts of water and then compacted in five equal layers by a hammer that deliver **25** blows to each layer

Compaction Tests

Modified Proctor Test Equipment: (a) mold; (b) hammer



Compaction Tests



Proctor Test

Modified Proctor

or

AASHTO T-180

Soil sample 1/30 cubic foot
5 layers

Compaction Tests

- Modified Proctor Test (cont'd)
  - The hammer weighs 10 lb (mass = 4.54 kg) and has a drop of 18 in. (457.2 mm)
  - For each test, the moist unit weight of compaction g can be calculated as

$$\gamma = \frac{W}{V_m}$$

Compaction Tests

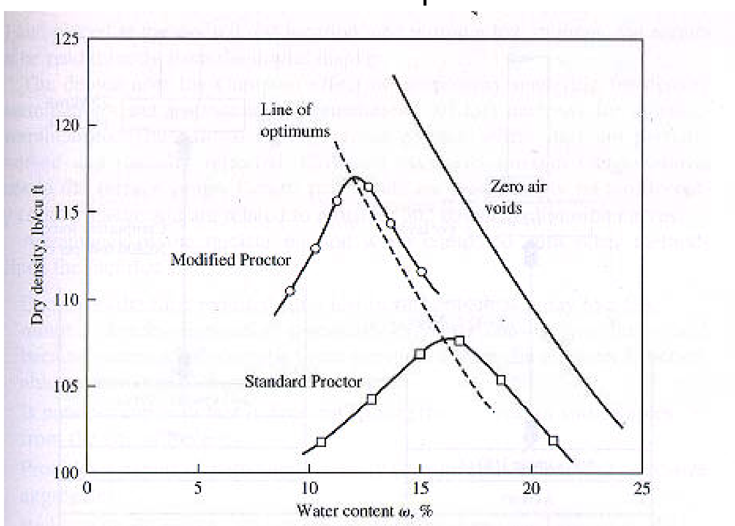
- Modified Proctor Test (cont'd)
  - ***W* = weight of compacted soil in mold**
  - **V_m = volume of mold (1/30 ft^3)**
  - For each test, the moisture content ω of the compacted soil is determined in the laboratory
  - With known moisture content, the dry unit weight γ_d can be calculated

Compaction Tests

- Modified Proctor Test (cont'd)
  - The values of γ_d determined from the above equation can be plotted against the corresponding moisture contents for the soil as shown in the figure of next slide

Compaction Tests

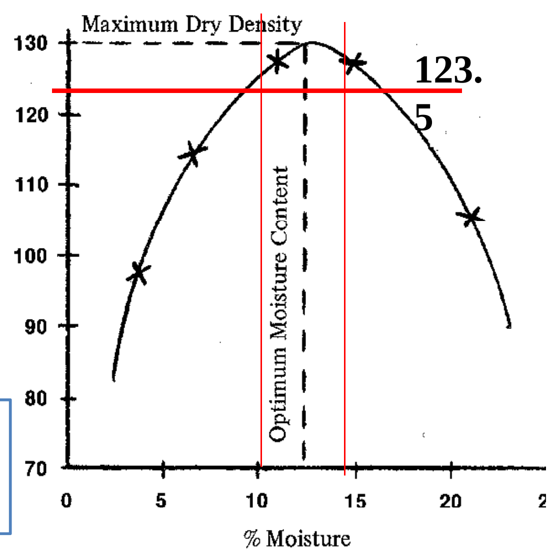
Standard and Modified Compaction Curves



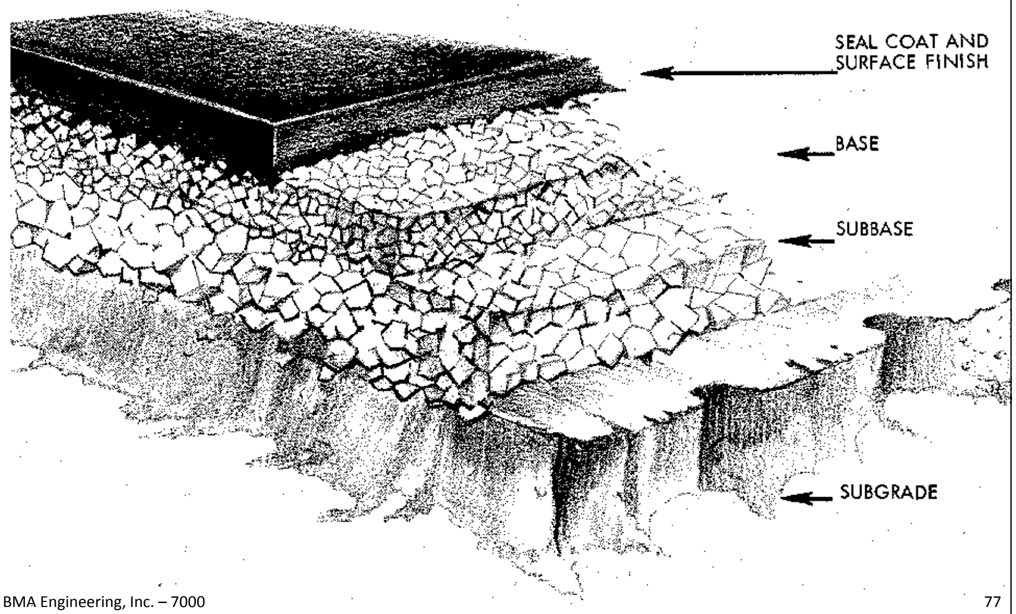
Compaction Specifications

The specification also sets a minimum density, 90% or 95% of max. dry density for a specific test

Lift. A layer of soil placed on top of soil previously placed in an embankment. The term can be used in reference to material as spread or as compacted



Compaction



Specifications for Field Compaction

- The specification for field compaction can be based either on
  1. relative compaction *RC* or
  2. relative density D_r

$$RC\,(\%) = \frac{\gamma_{d\,(\text{field})}}{\gamma_{d\,(\text{max, lab})}} \times 100 \qquad D_r = \frac{1}{(1 - R_0)}\left[1 - \frac{R_0}{RC}\right] \qquad R_0 = \frac{\gamma_{d\,(\text{min})}}{\gamma_{d\,(\text{max})}}$$

Specifications for Field Compaction

- ASTM Test Designation D-2049 provides a procedure for the determination of the minimum and maximum dry unit weights of granular soils
- For sands, this done by using a mold with a volume of 0.1 ft^3 (2830 cm^3)

Specifications for Field Compaction

- For determination of the minimum dry unit weight, sand is loosely poured into the mold from a funnel with a 1/2-in (12.7-mm) diameter spout
- The average height of the fall of sand into the mold is kept at about 1 in (25.4 mm)

$$\gamma_{d\,(\text{min})} = \frac{W_s}{V_m}$$

where
W_s = weight of sand required to fill the mold
V_m = volume of the mold (0.1 ft^3)

Specifications for Field Compaction

- The maximum dry unit weight is determined by vibrating sand in the mold for 8 min
- A surcharge of 2 lb/in^2 (13.8 kN/m^2) is added to the top of the sand in the mold
- The mold is placed on a table that vibrates at a frequency of 3600 cycles/min and that has an amplitude of vibration of 0.025 in (0.635 mm)

Specifications for Field Compaction

- The value of $\gamma_{d(\max)}$ can then be determined at the end of the vibrating period with the knowledge of the weight and volume of sand
- An empirical formula has been developed by Lee and Singh (1971) to give a relationship between *RC* and D_r

Specifications for Field Compaction

For granular soils, the relationship is given as

$$RC\,(\%) = 80 + 0.2\,D_r$$

According to Lee and Singh (1971), the correlation between RC and Dr was based on the observation of 47 soil samples

Compaction Control

- Field verification tests of achieved compaction can be conducted by any of several accepted methods:
  1. Sandcone
  2. Balloon
  3. Nuclear

Compaction Control

- The first two methods are destructive tests. They involve
  - excavating a hole in the compacted fill and weighing the excavated material
  - determining the water content of the excavated material
  - measuring the volume of the resulting hole

Compaction Control

- Disadvantages of using sandcone and balloon methods:
  1. Time-consuming to conduct sufficient tests for statistical analysis
  2. Problems with oversized particles
  3. Determination of water content takes time

Nuclear Compaction Test

- Nuclear methods are used extensively to determine the water content and density of soils
- The instrument required for this test can be easily transported to the fill, placed at the desired test location, and within a few minutes the results can be read directly from the digital display

Nuclear Compaction Test

- Advantages of the nuclear method when compared with other methods include the following:
  1. Decreases the time required for a test from as much as a day to a few minutes, thereby eliminating potentially excessive construction delays
  2. It is nondestructive in that it does not require the removal of soil samples from the site of the tests
  3. Provides a means of performing density tests on soils containing large-sized aggregates and on frozen materials
  4. Reduces or eliminates the effect of the personal element, and possible errors. Erratic results can be easily and quickly rechecked

Nuclear Compaction Test

- Disadvantages of the nuclear method when compared with other methods include the following:
  1. Nuclear test instruments, it not used properly, present a potential source of radiation that can be harmful to humans

Geogauge

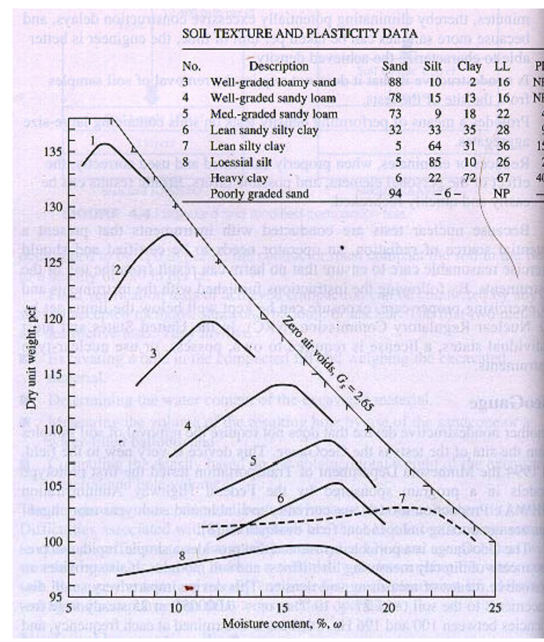
- A Geogauge device is a nondestructive devise that does not require the removal of soil samples from the site of the tests
- This device is very *new* to the field
- The Minnesota Department of transportation tested the first prototype models in 1994
- This portable device can provide a *simple*, *rapid*, and *precise* means of directly measuring lift stiffness and soil modulus

Laboratory Versus Field

- Maximum dry density is only a maximum for a specific compaction effort (input energy level) and the method by which that effort is applied
- If more energy is applied in the field, a density greater than 100% of the laboratory value can be achieved
- Dissimilar materials have individual curves and maximum values for the same input energy as shown in the following figure

Laboratory Versus Field

Comparison Curves for Eight Soils Compacted according to AASHTO T99 (Highway Research Board)

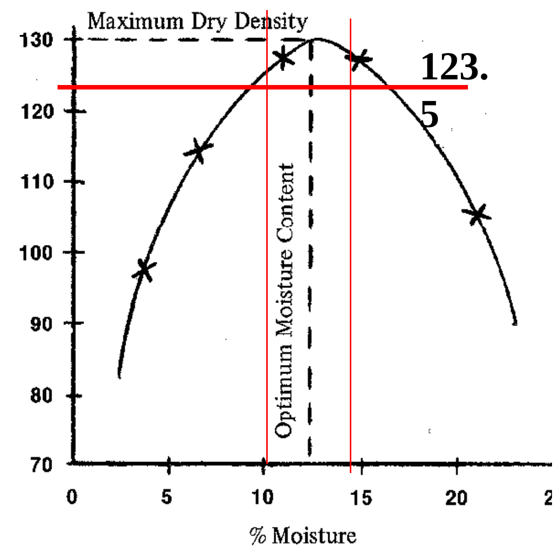


Soil Processing

- The optimum water content (ω)
  - **Fine-grained soils** – from 12 to 25%
  - **Well-graded granular** – from 7 to 12%
  - **Normal Practice** to work at ±2% of optimum or 95% of maximum dry unit weight

Compaction Specifications

The specification also sets a minimum density, 90% or 95% of max. dry density for a specific test



Site Preparation: Excavation and Earthmoving

- Planning for Earthwork
- Geotechnical Materials and Compaction Properties
- **Clearing and Ripping**
- Dozing and Scraping
- Excavating , Loading and Hauling
- Compacting and Grading
- Hauling and Trucking
- Compressed Air Systems
- Drilling and Blasting

Land-clearing Operations

- Crawler tractors equipped with either bulldozer blades or special clearing blades are excellent machines for land clearing
- Clearing operations are always preferable and usually necessary before undertaking earth-moving operations

Clearing and Grubbing

Land-clearing Operations

- Trees brush and even grass and weeds make earth handling very difficult
- If these organic materials ale allowed to become mixed into an embankment, their decay over time will cause settlement of the fill

Dozer with clearing blade

Clearing

Land-clearing Operations

1. Removing all trees and stumps including- roots
2. Removing all vegetation above tile surface of the ground only stumps and roots in the ground
3. Disposing of vegetation by stacking and burning
4. Knocking all vegetation down, then chopping or crushing it to or into the surface of the round. or burning it later
5. Killing or retarding the growth of brush by cutting the roots below the surface of the ground

Rakes for Root Removal



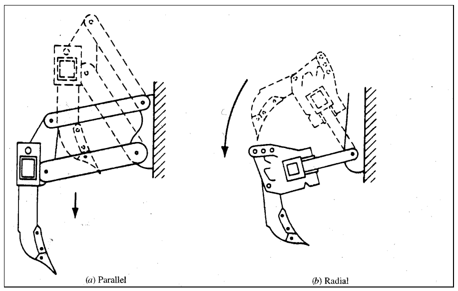
Ripping Rock

- Rippers are used to tear and split hard ground, weak rock, or old pavements and bases
- Heavy ripping is accomplished with crawler tractors because of the power and tractive force available from such machines
- Rock that was considered to be unrippable a few years ago is now ripped with relative ease, and at cost reductions-including ripping and hauling with scrapers-amounting to as much as 50% when compared with the cost of drilling, blasting, loading with loaders, and hauling with trucks

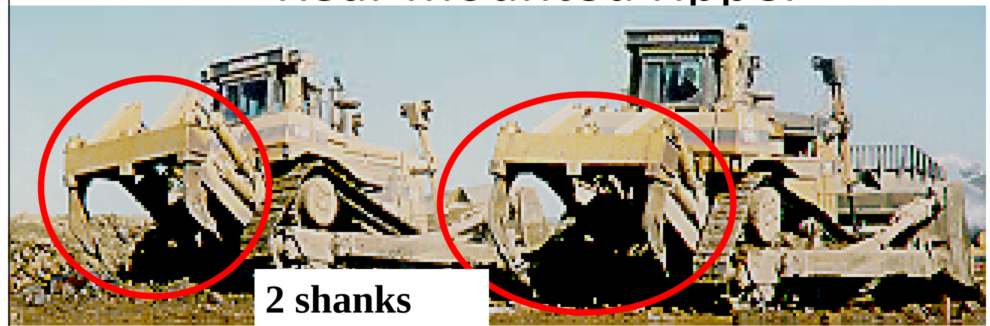
Ripping Rock

- The major developments responsible for the increase in ripping rock include:
  - Heavier and more powerful tractors
  - Improvements in the sizes and performance of rippers, to include development of impact rippers
  - Better instruments for determining the rippability of rocks
  - Improved techniques in using instruments and equipment

Ripping Rock



Rear mounted ripper



Effectiveness Of Ripper

The effectiveness of a ripper depends on

1. Down pressure at the ripper tip
2. The tractor's usable power to advance the tip:
   (a) Function of power available
   (b) Tractor weight
   (c) Coefficient of traction
3. Properties of the material being ripped:
   (a) Laminated
   (b) Faulted
   (c) Weathered, etc.

Rippability of Rock

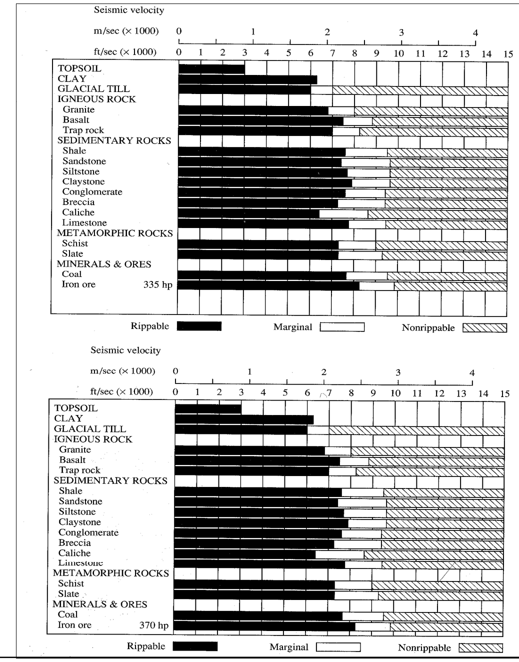
- Before selecting the method of excavation, it important to determine if the rock can be ripped or it will be necessary to drill and blast
- This involves the study of the rock type and the determination of the rock's density
- Igneous rocks lack stratification and cleavage, and hence, they are hard and sometimes impossible to rip
- Rippability depends on the speed at which sound waves travel through rock

Rippability of Rock

- Seismographic methods for determining with reasonable accuracy whether the a rock can be ripped:
  - Rocks that propagate sound waves at low velocities are rippable
  - Rocks that propagate sound waves at high velocities are not rippable
- Rippability data on various rocks and soils are available from the equipment manufacturers
- Rippability data are usually based on velocity ranges for different types of soil and rocks

Rippability of Rock

Ripper Performance for Caterpillar 335 and 370 HP Crawler Tractors with Multi and or Single-shank Rippers. Estimated by seismic wave velocities (Caterpillar Inc.)



Site Preparation: Excavation and Earthmoving

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Dozers

- Dozers (Tractors) are self-contained units that are designed to provide tractive power for drawbar work
- Consistent with their purpose as a unit for drawbar work, they are low center of gravity machines
- The larger the difference between the line-of-force transmission from the machine and the line of resisting force the less effective the utilization of developed power

Dozer Uses

- Typical project applications are:
  - Land clearing
  - Dozing (pushing materials)
  - Ripping
  - Towing other pieces of construction equipment
  - Assisting scrapers in loading

Dozer Uses

Dozing

Pushing materials

Assisting scrapers

Types of Dozers

1. Crawler (track laying) Tractor

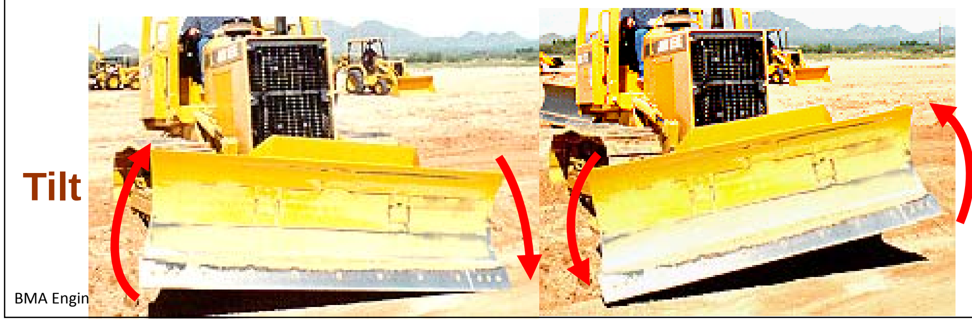
2. Wheel Type Tractor
   a. Single-axle
   b. Two-axle
      Single -axle drive
      Two-axle drive

Comparison of Performance

FOR TRUCK TYPE TRACTOR	FOR 4-WHEEL TRACTOR	FOR 2-WHEEL TRACTOR
The usual tractor weight	Use weight on drivers shown on spec sheet or approximately 40% of vehicle gross weight	Use weight on drivers shown on spec sheet or approximately 50% of vehicle gross weight

Surface	Rubber tires	Crawler tracks
Dry, rough concrete	0.80-1.00	0.45
Dry, clay loam	0.50-0.70	0.90
Wet, clay loam	0.40-0.50	0.70
Wet sand and gravel	0.30-0.40	0.35
Loose, dry sand	0.20-0.30	0.30
Dry snow	0.20	0.15-0.35
Ice	0.10	0.10-0.25

Dozer's Blades



Blades

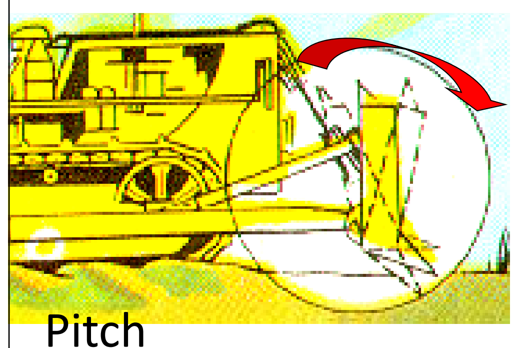
- The blade attached to the tractor to create a bulldozer must be matched to the expected work task
- Basic earth-moving blades are curved in the vertical plane in the shape of a "C"
- Along the bottom length of the blade hard steel plates are bolted – these plates make up the cutting edge of the blade

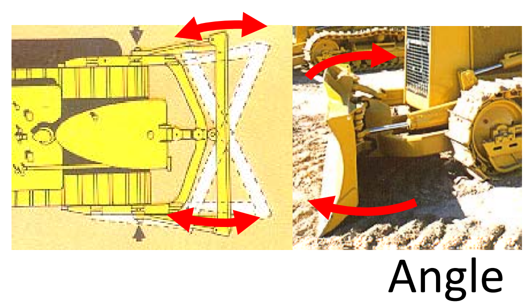
Blade Mounting

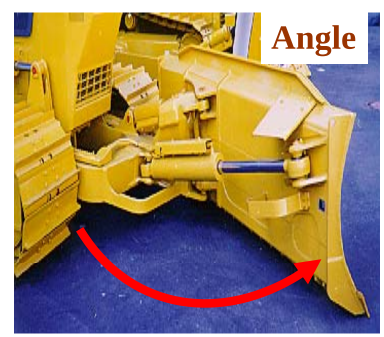
C- frame Blade Mount - outside the tracks

C- frame Blade Mount - inside the tracks

Blade Adjustments







Dozer Operation

GPS and computer graphics

Visibility

Dozer Production Estimating

- The factors that control dozer production rates are:
  1. Blade type
  2. Type and condition of material
  3. Cycle time

Dozer Production Estimating

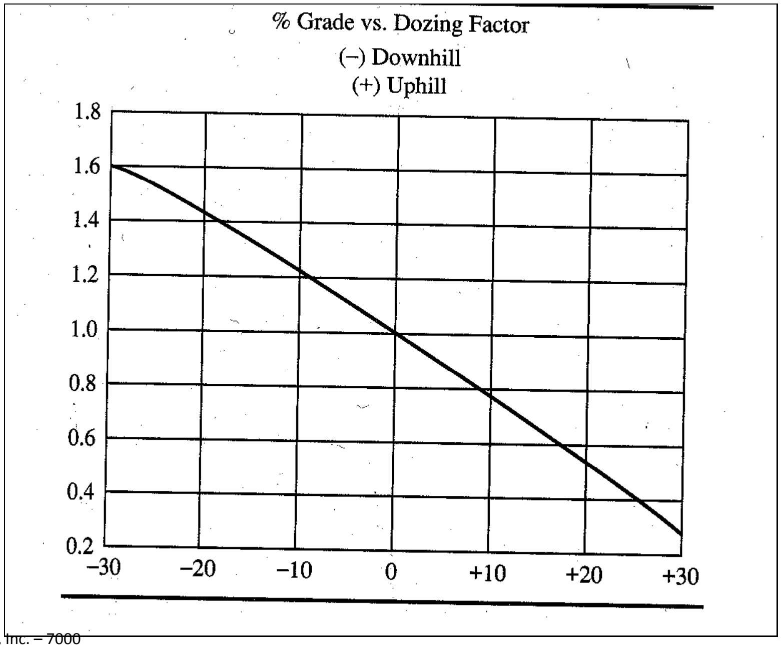
Material-type - Clay

Material-type - Sand

Correction Factors for Dozer Production

	Track-type Tractor	Wheel-type Tractor
Operator		
Excellent	1.00	1.00
Average	0.75	0.75
Poor	0.60	0.50
Material		
Loose stockpile	1.20	1.20
Hard to cut; frozen		
with tilt cylinder	0.80	0.75
without tilt cylinder	0.70	-
cable controlled blade	0.60	-
Hard to drift; (dry, non-cohesive material) or very sticky material	0.80	0.80
Rock, ripped or blasted	0.60 to 0.80	-
Slot dozing	1.20	1.20
Side-by-side dozing	1.15 to 1.25	1.15 to 1.25
Visibility		
Dust, rain, snow, fog or darkness	0.80	0.80
Job efficiency		
50-min per hour	0.83	0.83
40-min per hour	0.67	0.67
Direct drive transmission (0.1-min fixed time)	0.80	-
Grades	See following graph	See following graph

Grade Correction Factor



Scrapers

Applications of Scrapers

Dozer: short haul, less than 300ft

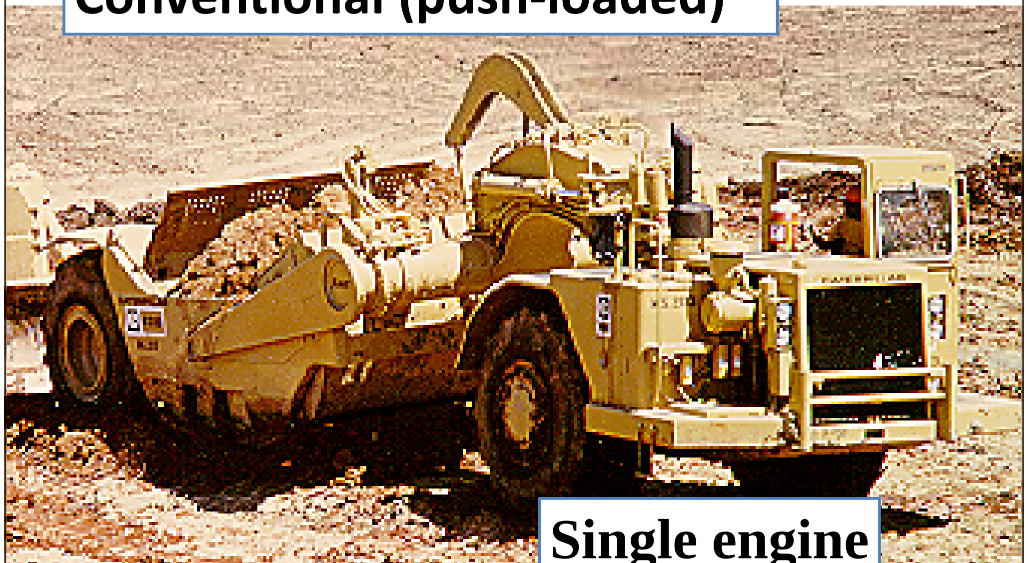
Scraper: medium haul up to 3,000 ft

Types of Scrapers

- Available types include:
  - Push-loaded (conventional)
    - Single-powered axle
    - Tandem-powered axles
  - Self-loading
    - Push-pull, tandem-powered axles
    - Elevating
    - Auger

Configurations

Conventional (push-loaded)



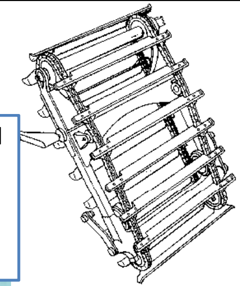
Single engine

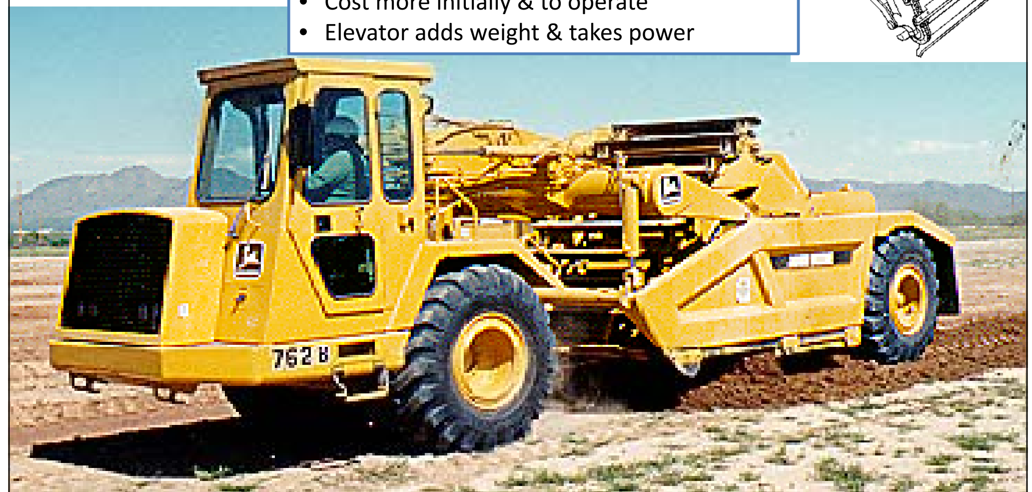
Configurations

Elevating

Elevating scrapers are good for short hauls and in favorable material:

- Can work alone in the cut
- Cost more initially & to operate
- Elevator adds weight & takes power





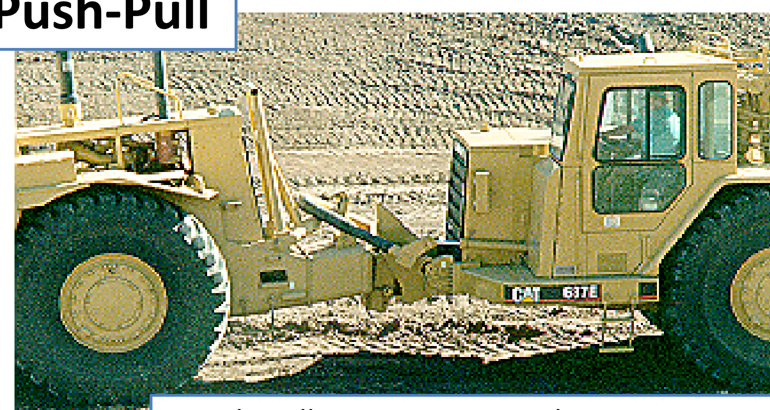
Configurations

Tandem powered twin engine

- Tandem powered (twin engine) scrapers are good for jobs having adverse grades and poor footing
- Owning and operating cost are about 25% higher

Configurations

Push-Pull

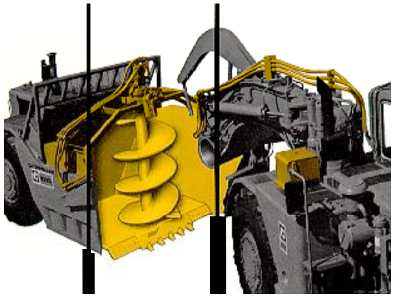


- Push-Pull scrapers can work as a team or can operate individually with a pusher.
- Tire wear will increase in rock or abrasive materials because of more slippage from the four-wheel drive action

Tractors-pulled Scrapers

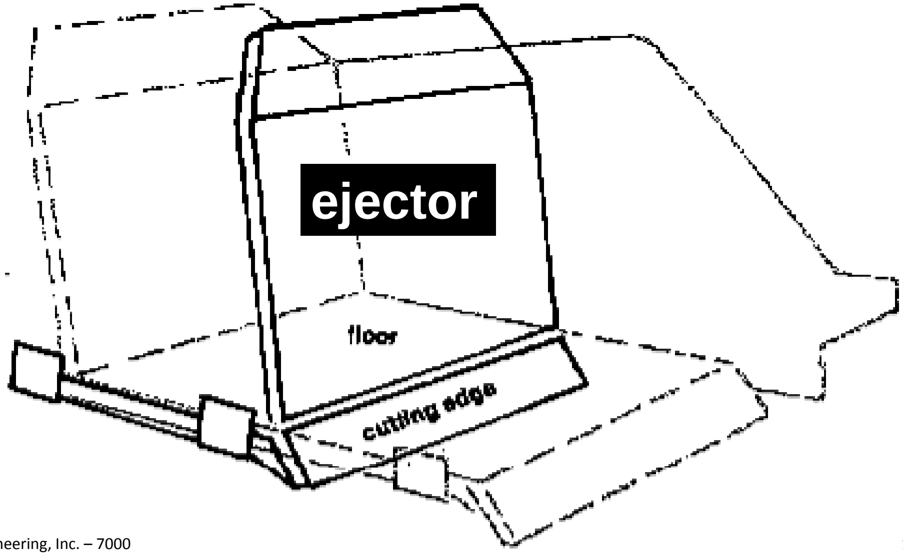
- Tractor-pulled scrapers are designed to load, haul, and dump loose materials
- The advantage of tractor-scraper combinations is their versatility

Configurations

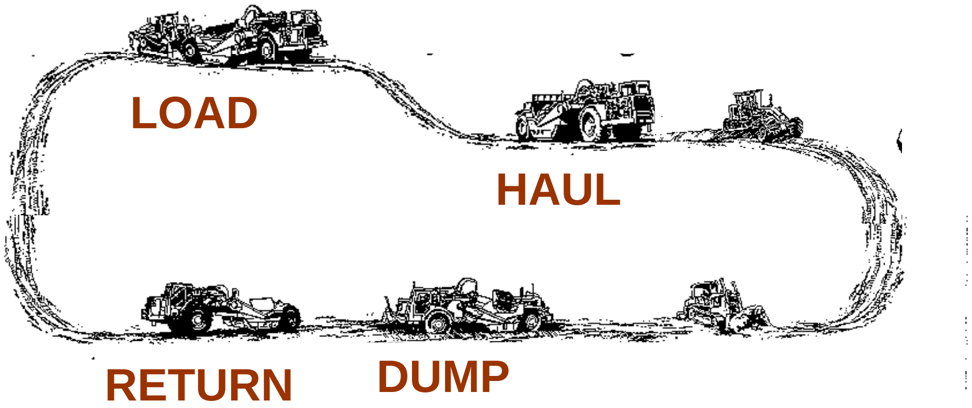


Scraper BOWL

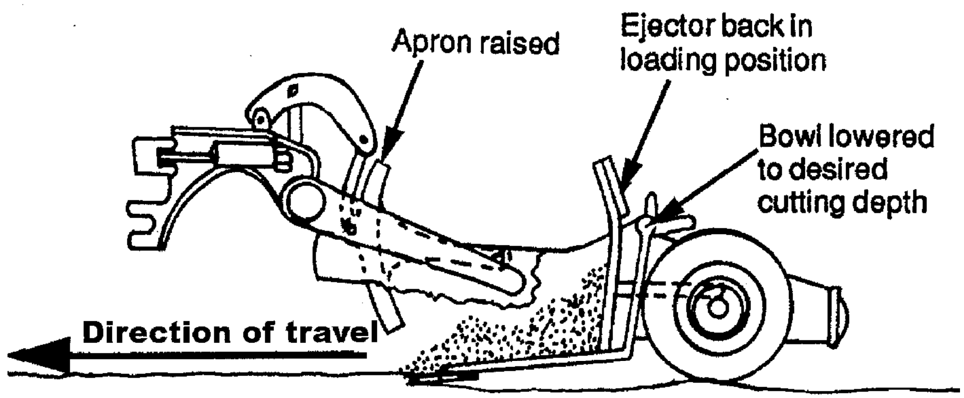
Load-carrying part of a scraper



Scraper Work Cycle

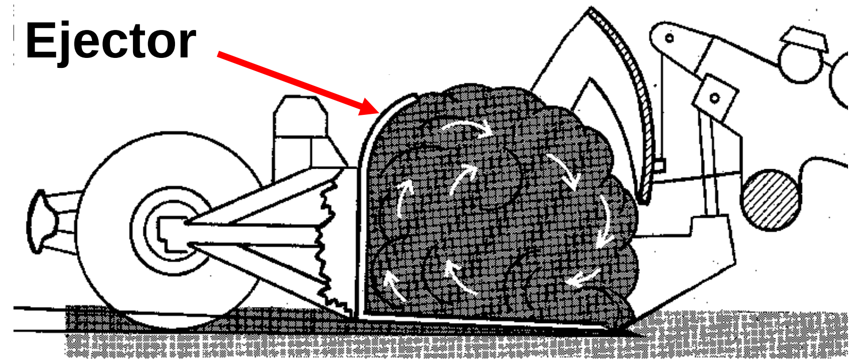


Cutting and Loading



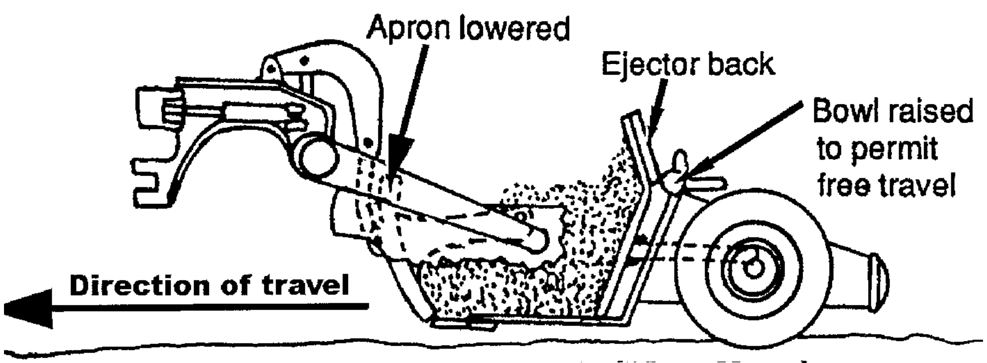
For maximum production both single- and tandem-engine scrapers need the assistance of a push tractor

Cutting and Loading



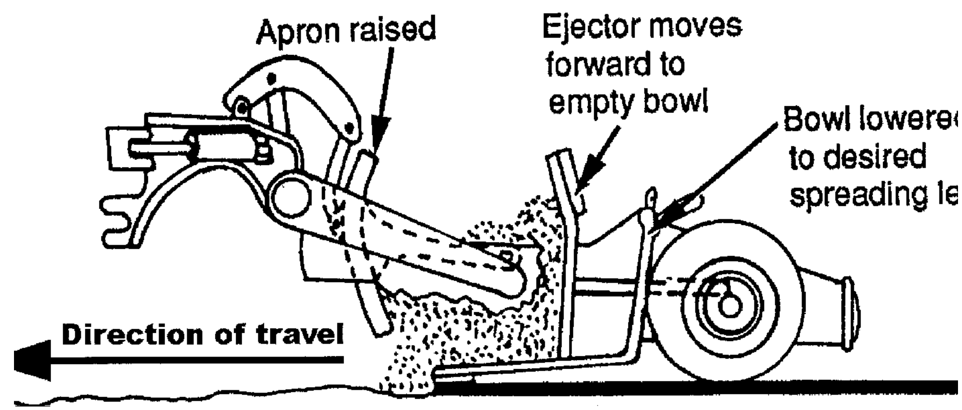
- **Dirt enters horizontally and rolls back to fill corners**
- **Curved ejector top keeps load "boiling" to heap high**

Hauling



- **Apron lowered to capture the material**
- **Keeping the bowl low enhances stability**

Spreading the Load



- **Dumping and spreading is one continuous operation**

Site Preparation: Excavation and Earthmoving

- Planning for Earthwork
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Excavation

- Common Excavation refers to ordinary earth excavation
- Rock Excavation cannot be done by ordinary earth handling equipment
  - Rock materials must be removed by drilling and blasting or by some other methods
  - This normally results in a considerably greater expense than earth excavation

Excavation

- Muck Excavation includes materials that will decay or produce subsidence in embankments
  - It is usually a soft organic material having a high water content
  - Typically, it would include such things as decaying stumps, roots, logs, and humus
  - These materials are hard to handle and can present special construction problems both at their point of excavation, and in transportation and disposal

Excavation

- Unclassified Excavation refers to the materials that cannot be defined as soil or rock
  - The removal of common excavation will not require the use of explosives, although tractors equipped with rippers may be used to loosen consolidated formations

Excavation: Terminology

- Aggregate, course: Crushed rock or gravel, generally greater than 1/4 in. in size
- Aggregate, fine: The sand or fine-crushed stone used for filling voids in coarse aggregate, Generally it is less than 1/4 in, and greater than a No. 200 sieve in size
- Backfill: Material used in refilling a cut or other excavation
- Bank measure: A measure of the volume of earth in its natural position before it is excavated

Excavation: Terminology

- Binder: Fine aggregate or other materials that fill voids and hold coarse aggregate together
- Borrow pit: A pit from which fill material is mined
- Cohesion: The quality of some soil particles to be attracted to like particles, manifested in a tendency to stick together, as in clay
- Cohesive materials: A soil having properties of cohesion
- Compacted volume: A measurement of the volume of a soil after it has been subjected to compaction

Excavation: Terminology

- Grain-size curve: A graph showing the percentage by weight of soil sizes contained in a sample
- Granular material: A soil, such as sand, whose particle sizes and shapes are such that they do not stick together
- Impervious: A material that resists the flow of water through it is termed impervious
- In situ: Soil in its original or undisturbed position
- Lift: A layer of soil placed on top of previously placed embankment material. The term can be used in reference to material as spread or as compacted

Excavation: Terminology

- Optimum moisture content: The water content, for a given compactive effort, at which the greatest density of a soil can be obtained
- Pass: A working passage (trip) of an excavating, grading, or compaction machine
- Plasticity: The capability of being molded
- Rock: The hard, mineral matter of the earth's crust, occurring in masses and often requiring blasting to cause breakage before excavation can be accomplished

Excavation: Terminology

- <u>Shrinkage:</u> A soil volume reduction usually occurring in fine-grained soils when they are subjected to moisture
- <u>Soil:</u> The loose surface material of the earth's crust, created naturally from the disintegration of rocks or decay of vegetation, that can be excavated easily using power equipment in the field

Soil Excavation

Brystar Contracting uses Komatsu excavators as its main production machines, including this new PC200LC-8 equipped with KOMTRAX. "We don't worry about downtime with them, and that's why Komatsu is our excavator of choice," said Owner/President Bryan Phelps. "We use the larger excavators for everything from mass excavation to digging trenches and setting pipe and structures in utility work."

Excavator

Brystar Contracting Operator Kyle Turner loads dirt with a PC400LC-7 excavator at the Cattail Marsh project for the city of Beaumont.

Dozer

A Brystar Contracting operator uses a Komatsu D39PX dozer to grade a cell at the Cattail Marsh project for the city of Beaumont. "We especially like the D39PX models. In this area, the ground is often wet, and with the wider tracks we're able to work in conditions that would normally slow or stop machines with narrow tracks," said Owner/President Bryan Phelps.

Hydraulic Excavators

Hoe

Soil Excavation

Truck

Scraper

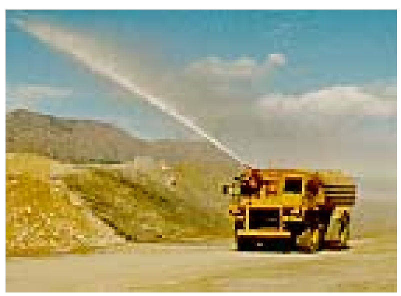
Soil Processing

- Adding Water to Soil
  - Water must be added prior to compaction if the water content (*w*) is below the optimum moisture range
  - Water can be added to soil at the borrow pit or in-place (at the construction site)

Soil Processing

- When it necessary to add water, the following items are to be considered:
  - Amount of water required
  - Rate of water application
  - Method of application
  - Effects of the climate and weather

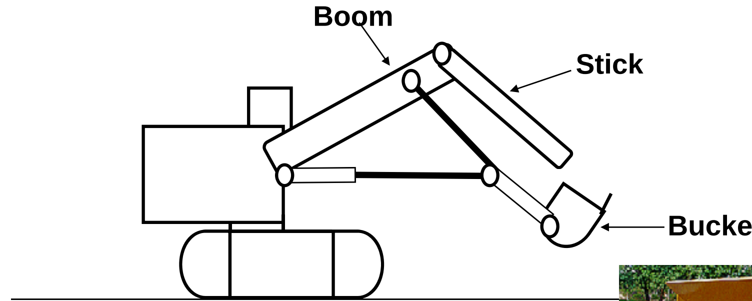
Adding Water To Soil



Loading and Hauling

Wheel and Track Loaders

Front Shovels

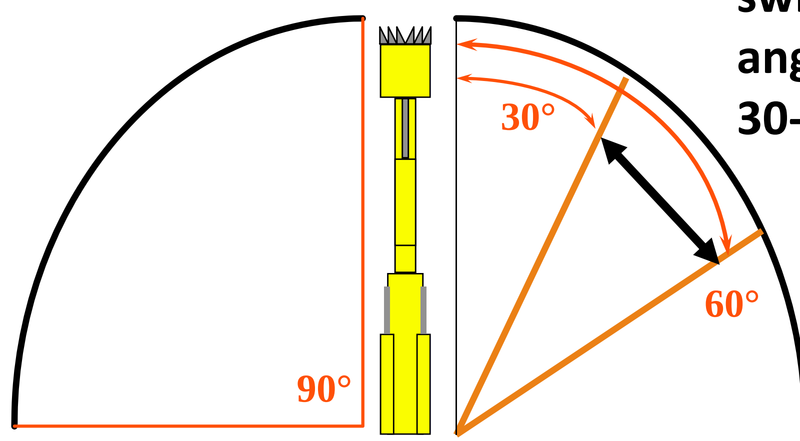


EXCAVATORS can usually be equipped with several different size and type buckets

Shovel Production

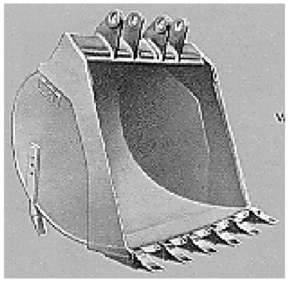
- Typical cycle element times under average conditions, for 3 to 5-cu-yd shovels, will be
  - Load bucket 7-9 sec
  - Swing with load 4-6 sec
  - Dump load 2-4 sec
  - Return swing 4-5 sec

Swing Angle?

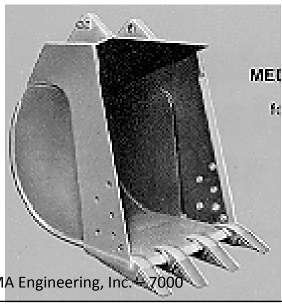


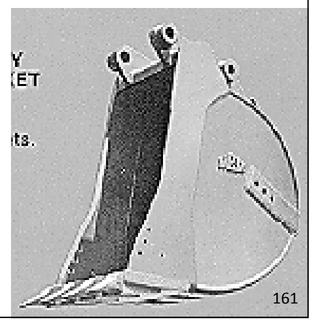
swing angle of 30-60º

Hoe Buckets



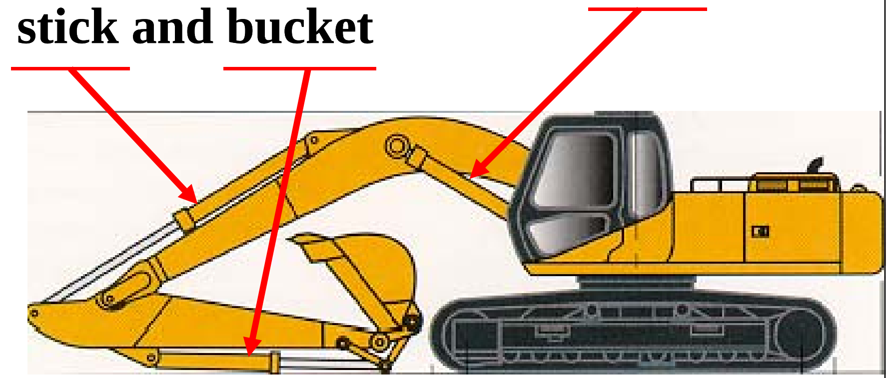
There are special buckets for everything from light sand to hard rock digging





Hydraulic Hoes

Bucket penetration (break out force) is developed by the hydraulic cylinders of the boom stick and bucket



Hydraulic Hoes

The hoe can be track or wheel mounted

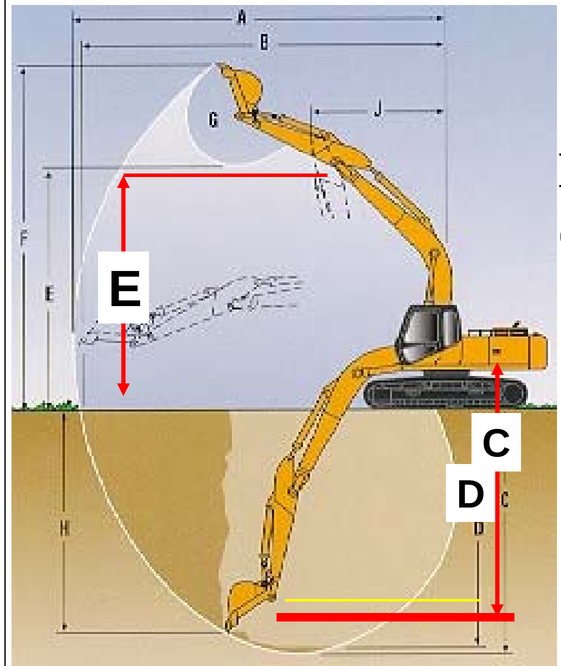
Hydraulic Hoes

These machines offer precision and efficiency

Production Estimating

Consider cycle times accounting for loads dumped into haul units, machine size, and cut depth

Depth of Cut



Manufacturer's data

C. Maximum dig depth

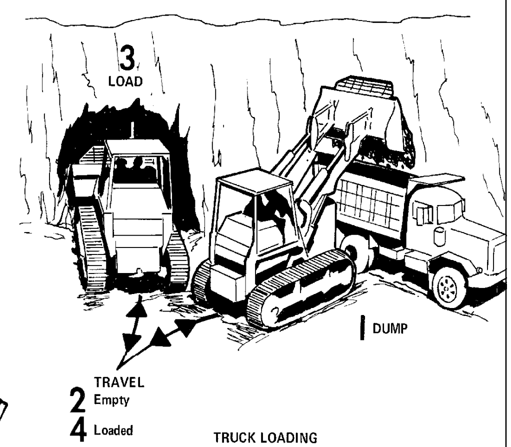
D. Dig depth, level bottom

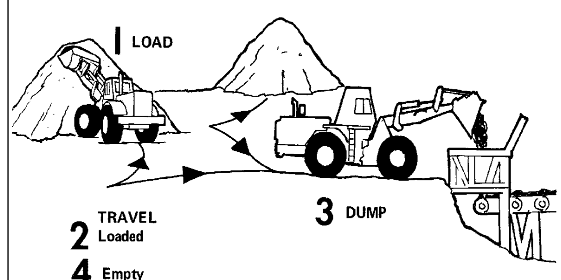
E. Reach to load haul unit

Loaders

Wheel and track loaders

Loader Production





Trenching Machines

- The term "trenching machine" applies to the wheel- and ladder type machines
- These machines are satisfactory for digging utility trenches for water, gas, and oil pipelines; shoulder drains on highways; drainage ditches; and sewers where the job and soil conditions are such that they may be used
- They provide relatively fast digging, with positive depths and widths of trenches, reducing expensive finishing

Trenching Machines

- These machines are capable of digging any type of soil but are generally not suitable for rock
- They are available in various sizes for digging trenches of varying depths and widths
- They are usually crawler-mounted to increase their stability and to distribute the weight over a great area

Site Preparation: Excavation and Earthmoving

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- **Compacting and Grading**
- Hauling and Trucking
- Compressed Air Systems
- Drilling and Blasting

Compaction of Geotechnical Materials

- Engineering properties of soils can be improved by compaction
- Compaction can:
  - Reduce or prevent settlements
  - Increase strength
  - Improve bearing capacity
  - Control volume changes
  - Lower permeability

Compaction of Geotechnical Materials

- Typically, a uniform layer, or lift, of soil from 4 to 12 in thickness is compacted by means of several passes of heavy mechanized compaction equipment
- It should be noted that good compaction can cost more money

Compaction Specifications

- Specifications governing compaction may be one of the following types:
  a. Method only (often termed "recipe“)
  b. End result only (often termed "performance")
  c. Method and end result

Field Compaction

- Densification is accomplished by:
  – Static weight (pressure)
  – Kneading (manipulation)
  – Impact (sharp blow)
  – Vibration (shaking)

Field Compaction

- Ordinary compaction in the field is accomplished by means of rollers
- Several types of rollers are used:
  – Smooth wheel rollers (drum rollers)
  – Pneumatic rubber-tired rollers
  – Sheepsfoot rollers (Tamping rollers)
  – Vibratory rollers

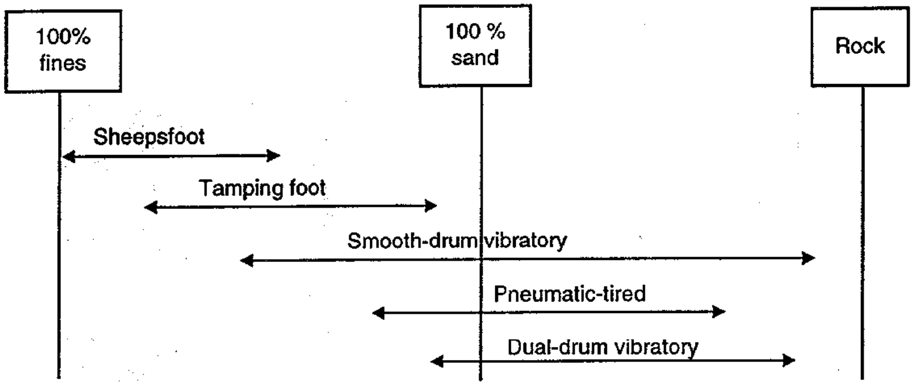
Smooth-wheel Rollers

- Smooth-wheel rollers are suitable for proof-rolling subgrades and for finishing operation of fills with sandy and clayey soils
- They provide 100% coverage under the wheels with ground contact pressures as high as 45 to 55 lb/in^2
- They are not suitable for producing high unit weights of compaction when used on relatively thick layers

Smooth-wheel Rollers

Compaction

Roller Capabilities



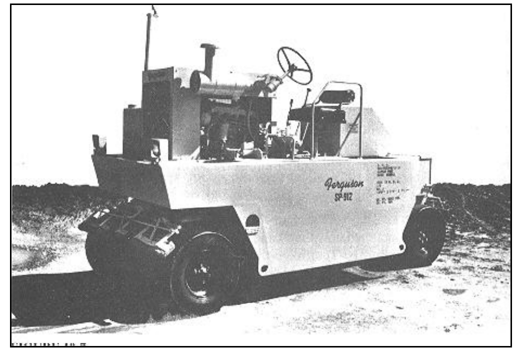
Pneumatic Rubber-tired Rollers

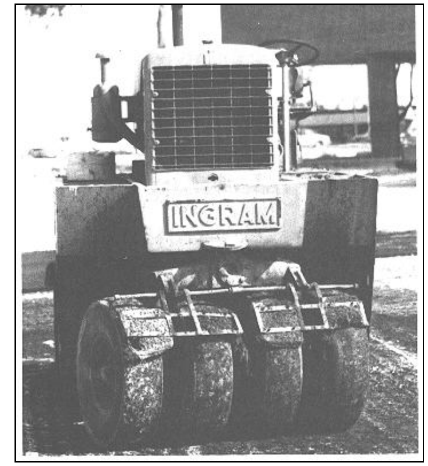
- Pneumatic rubber-tired rollers are better in many than smooth-wheel rollers
- They are heavily-loaded wagons with several rows rows of tires
- The tires are closely spaced, four to six in a row
- They provide 70% to 85% coverage under the wheels with ground contact pressures as high as 85 to 100 lb/in^2

Pneumatic Rubber-tired Rollers

- Pneumatic-tired (rubber-tired) rollers are suitable for compacting most granular soils
- They are not effective in compacting fine-grained clays
- They compact by static-load and kneading action

Pneumatic Rubber-tired Rollers

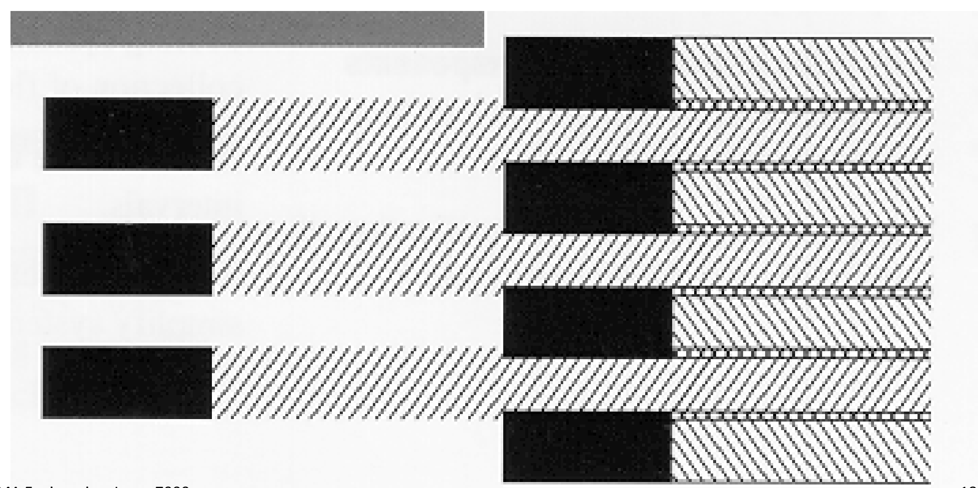




Pneumatic Rubber-tired Rollers

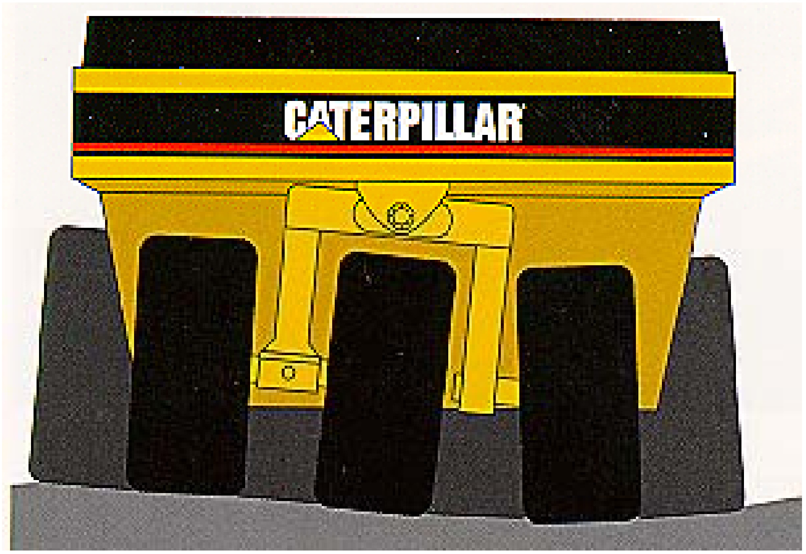
Pneumatic Rubber-tired Rollers

Front and rear tire paths overlap



Pneumatic Rubber-tired Rollers

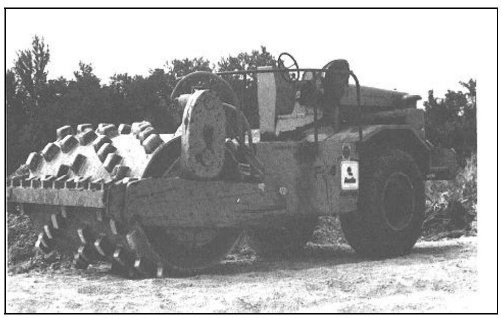
All-wheel oscillation

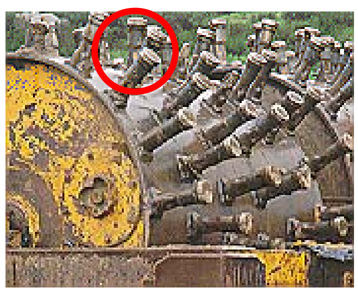


Sheepsfoot Rollers

- Sheepsfoot rollers are drums with a large number of projections
- The area of each of these projections may range from 4 to 13 in^2
- These rollers are most effective in compacting clayey soils
- The contact pressure under the projections can range from 200 to 1000 lb/in^2

Sheepsfoot Rollers





Tamping Foot Compactor

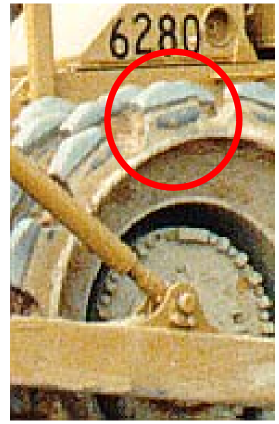
It is suitable for compacting all fined-grained soils, but is generally not suitable for use on cohesionless granular soils

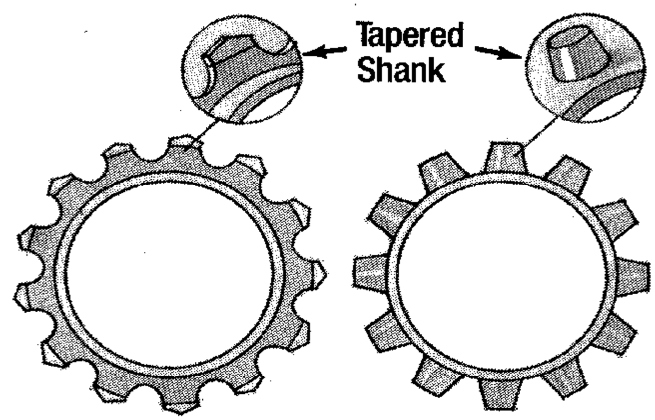
Tamping Foot Compactor

Pad Configuration

Tamping foot

Pad foot





Tamping Foot Compactors

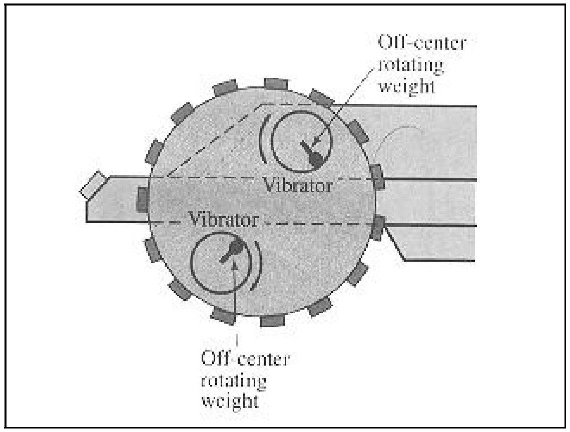
- This roller compacts the soil from the bottom of the lift to the top
- Lift thickness is generally limited to 8 inches compacted depth
- This type roller does not adequately compact the upper 2 or 3 inches of a lift
- Therefore, for the last lift it should be followed with a pneumatic or smooth-drum roller

Vibratory Rollers

- Vibratory rollers are very efficient in compacting granular soils
- Vibrators can be attached to the following rollers:
  - smooth-wheel rollers (see picture)
  - pneumatic rubber-tired rollers
  - sheepsfoot rollers

Vibratory Rollers

- Principles of Vibratory Rollers
- The vibration is Produced by rotating off-center weights



Smooth Drum Vibratory Soil Compactors

- This roller uses vibratory action in conjunction with ballast weight of the drum to compact
- One of the most effective means of attaining density for cohesionless materials
- It is a relatively light roller, therefore maximum loose-lift depth is 9 inches

Vibratory Soil Compactors

Padded drum

Dual-drum

Dual Drum Vibratory Compactors

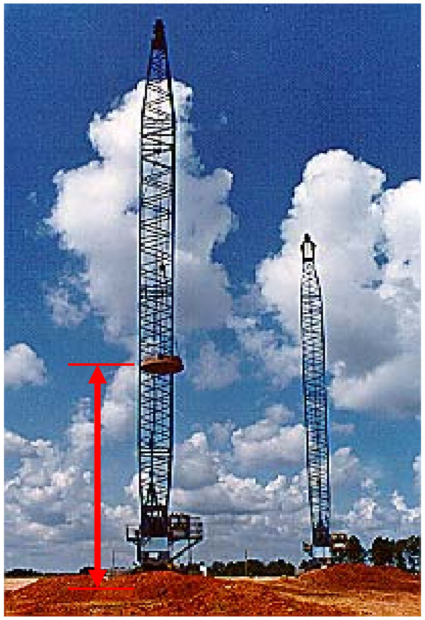
- Use this roller to compact cohesionless subgrade, base courses, wearing surfaces, and asphalt
- Because it compacts from the top down, only relatively shallow lifts (less than 4 inches) can be worked

Dynamic Compaction

- Dynamic compaction is a technique that has gained popularity in the U.S. for the densification of granular soil deposits
- The method can produce densification to depth greater than 35 ft
- This process primarily consists of dropping a heavy weight repeatedly on the ground at regular intervals
- The weight of the hammer varies over a range of 18 to 80 kips
- The height of the hammer drop varies between 25 to 100 ft
- Conventional cranes are used to drop the weights

Dynamic Compaction

This is a 20 ton weight dropped from 42 ft



Dynamic Compaction

Usually only make contact with about 50% of the actual ground surface being compacted

Can achieve densification to a depths of about 30 ft using 30 ton weights and 100 ft drop heights

Dynamic Compaction

- The degree of compaction achieved at a given site depends on the following factors:
  - Weight of the hammer
  - Height of the hammer drop
  - Spacing of the locations at which the hammer is dropped

Vibratory Plate Compactors

For granular soils and asphalt

Rammers

Also known as a backfill tamper

Self-contained hand operated for use in confined spaces

Trench Rollers

Wheel Attachment Compactors

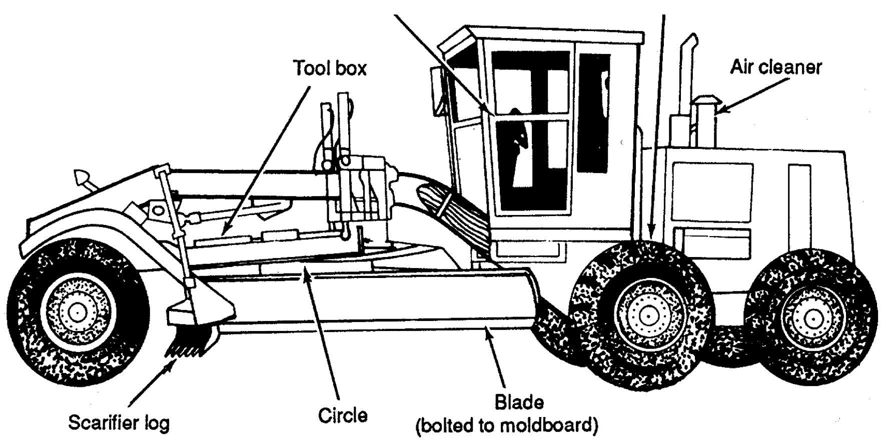
Soil Stabilization

- Admixtures are used to stabilize soils in the field, such as
  - Lime
  - Lime-fly ash
  - Cement
- The main purposes are
  - modify the soil
  - expedite construction
  - improve the strength and durability of the soil

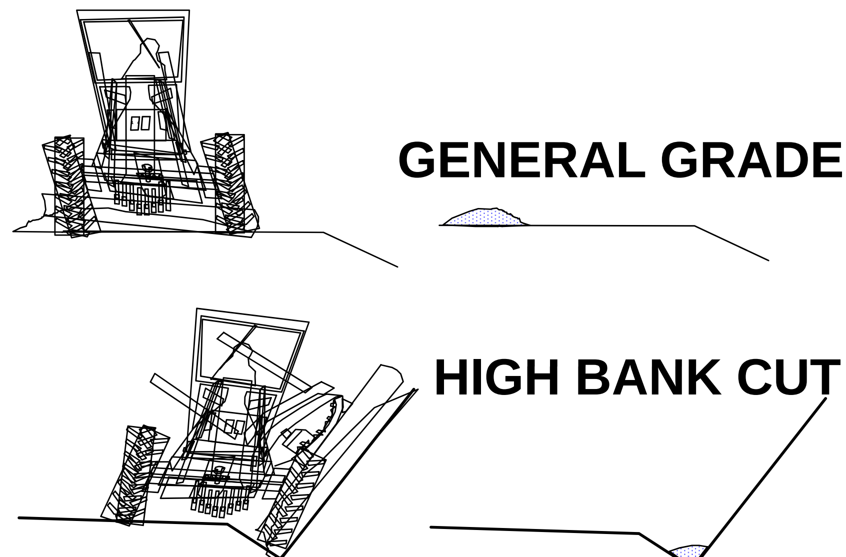
Graders

- Graders are multipurpose machines used for:
  - Finishing
  - Shaping bank
  - Sloping
  - ditching

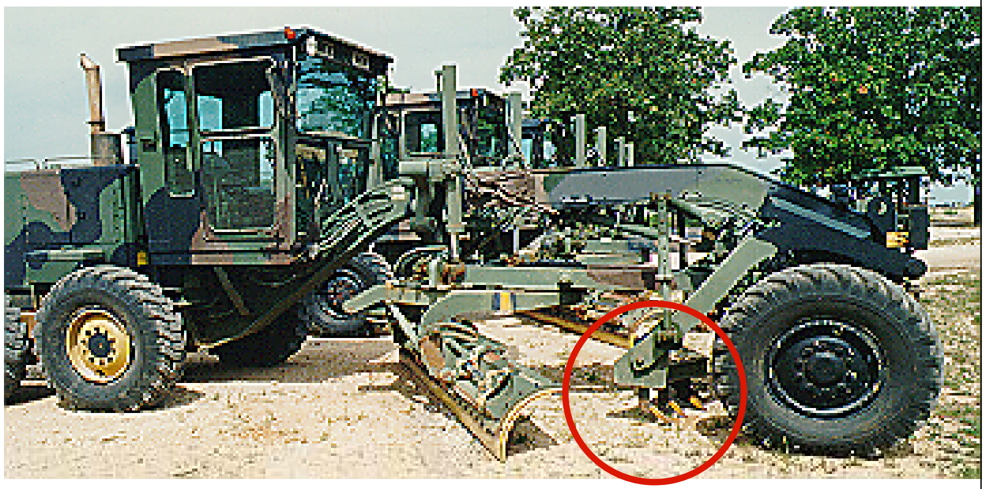
Graders



Blade Position of Graders



Scarifier
Front mounted scarifier



Rippers
Rear mount ripper

Laser Blade Controls

Moldboard and Its Angles

Gradalls

Trimmers

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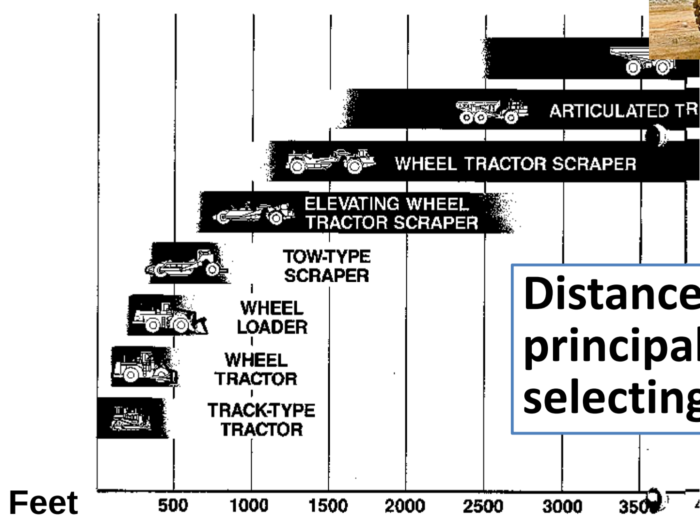
Trucks



Distance is the principal factor in selecting haul units.

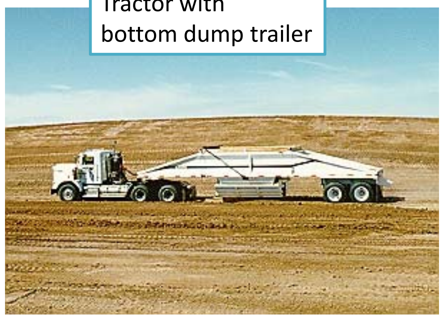
Trucks Classification

- Trucks may be classified according to a number of factors including:
  1. The size and type of engine-gasoline, diesel, butane, propane
  2. The number of gears
  3. The kind of drive-two-wheel, four-wheel, six-wheel, etc.
  4. The number of wheels and axles and arrangement of driving wheels
  5. The method of dumping the load-rear-clump, side-dump
  6. The class of material hauled-earth, rock, coal, ore, etc.
  7. The capacity, in tons or cubic yards

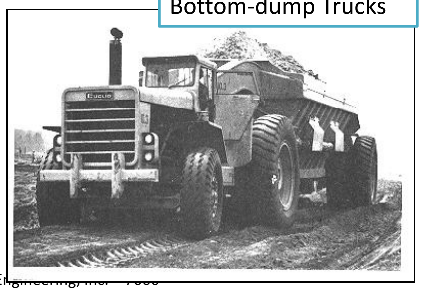
Trucks Classification

Highway rear-dump

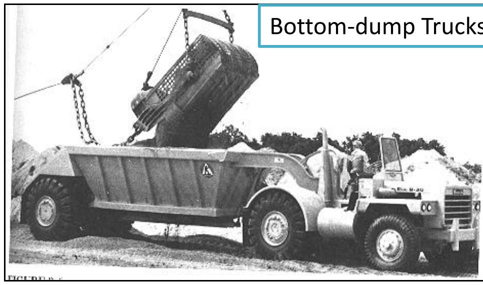
Tractor with
bottom dump trailer



Bottom-dump Trucks



Bottom-dump Trucks



Trucks Classification

Articulated truck

Articulated truck

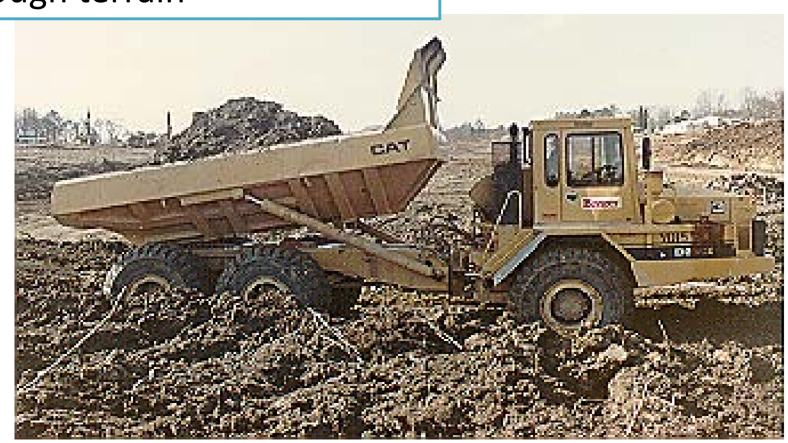
Bottom dump trailer deposits a wind row of material

Articulated Trucks

Retainer plate to increase load capacity.

Trucks Classification

Articulated trucks can operate on rough terrain



Trucks Classification

Trucks to move the fleet

Special trailers for heavy loads

Equipment Tires

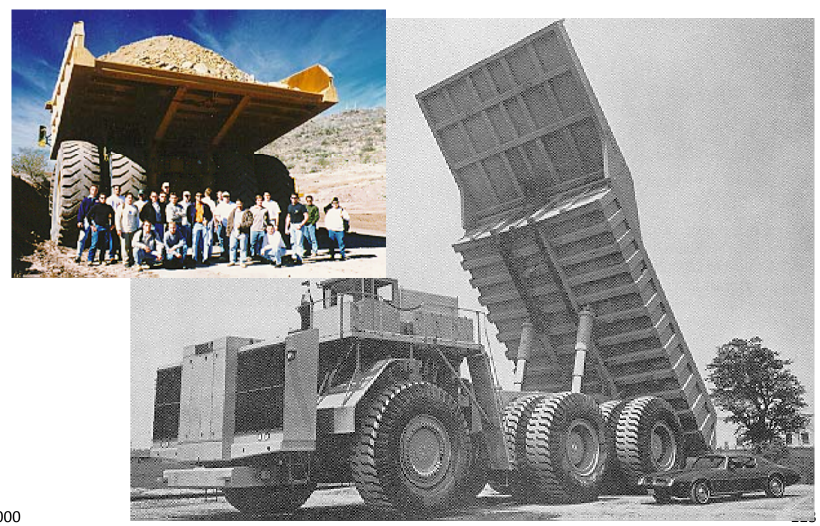
Tires are about 35% of a truck's operating cost

Overload a truck and you abuse the tires

Tires are designed for a wide range of applications

Equipment Tires

The Terex Titan, the world's largest truck at 350-ton was designed around the tires



Safety

Safety officers

Work procedures

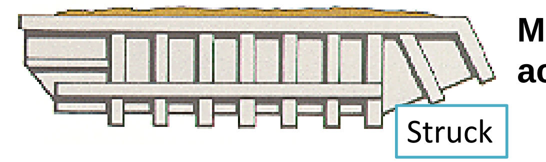
Training

Know the equipment and limitations

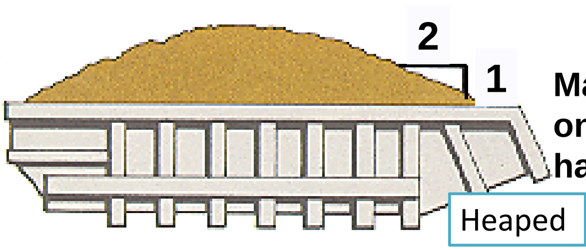
Follow accepted practices

Truck Capacity

Manufacturer's specification sheets will list both struck and heaped capacities:

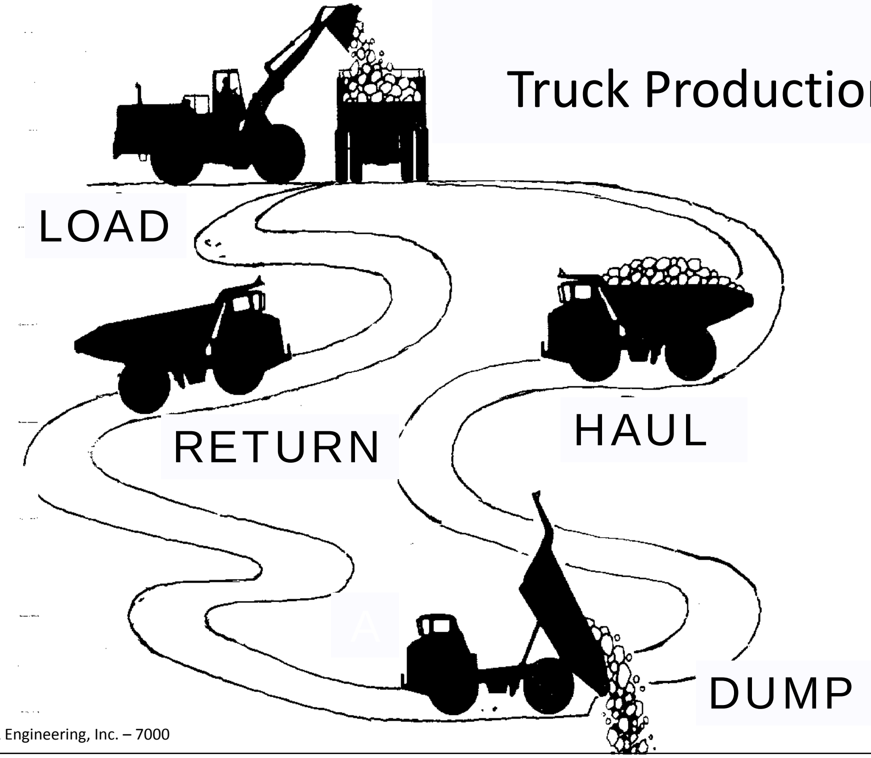


Material measured straight across the top of the body



Material measured based on a 2:1 slope above hauler bodies

Truck Production



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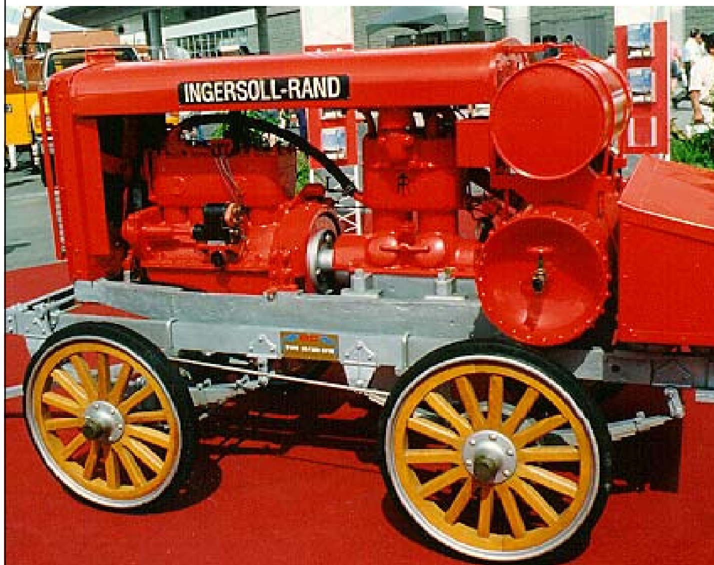
- Drilling and Blasting

COMPRESSED AIR



Uses of Compressed Air

- Compressed air is used for:
  - Drilling rock
  - Driving piles
  - Operating hand tools
  - Pumping
  - Cleaning

Pump

Paving Breaker

Selecting an Air Compressor

- Compressor capacity and operating pressure depend on the tools used
- Engine and compressor lose power and capacity as altitude increases and temperature rises
- Compressors are rated based on the cubic feet of atmospheric air they take in each minute with a specific discharge pressure, usually 100 psi

The capacity of an air compressor is rated at a barometric pressure of 14.7 psi, (sea level).

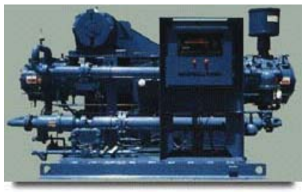
At higher altitudes the capacity of the compressor is reduced.
This is a result of Boyle's law

Tank Mounted Compressors

Model	Motor (HP)	ASME Receiver size (GAL)	Capacity (ACFM)	Max Pressure (PSIG)	Package Dimensions LxWxH	Net Net Weight (lb)
2340D2	2	80 (Hor.)	7	175	67x22x42	440
2340N2	2	80 (Vert.)	7	175	36x19x69	550
2340D3	3	80 (Hor.)	9.1	175	67x22x42	440
2340N3	3	80 (Vert.)	9.1	175	36x19x69	550
2340L5	5	60 (Vert.)	15.2	175	35x19x70	450
2475N5	5	80 (Vert.)	17	175	37x28x70	500
2475D5	5	80 (Hor.)	17	175	69x23x45	535
2475N7.5	7.5	80 (Vert.)	24.2	175	37x28x70	510
2545D10	10	80 (Hor.)	35.2	175	68x29x47	730
2545E10	10	120 (Hor.)	35.2	175	72x29x52	835
2545N10	10	80 (Vert.)	35.2	175	42x29x74	730
2545K10	10	120 (Vert.)	35.2	175	42x30x77	835
7100E10	10	120 (Hor.)	37.2	175	72x28x57	1035
7100E15	15	120 (Hor.)	50.5	175	72x28x57	1100
3000E20	20	120 (Hor.)	73.5	175	72x34x61	1360
3000E25	25	120 (Hor.)	85.2	175	72x34x61	1410
3000E30	30	120 (Hor.)	100.7	175	72x34x61	1460
Gas Engine Driven						
2475F11G (Kohler)	11	30 (Hor.)	19	175	44x22x46	440
2475X11G (Kohler)	11	4 (Hor.)	19	175	42x27x28	360
2475F11GH (Honda)	11	30 (Hor.)	19	175	44x22x40	425

Reciprocating Compressors

ESV OPERATIONAL DATA						
					Nominal	
Model	psig	bar (g)	ACFM*	m^3/hr	HP	kw
7x5	125	8.6	94	160	25	18.7
10x7	125	8.6	128	212	30	22.4
10x7	125	8.6	167	284	40	29.9
10x7	125	8.6	213	362	50	37.3
11x7	100	6.9	275	467	60	44.8



PHE OPERATIONAL DATA						
					Nominal	
Model	psig	bar (g)	ACFM*	m3/hr	HP	kw
10&5x7	500	34.5	320	544	125	93.3
12&5x7	500	34.5	383	651	150	111.9
12&7x7	250	17.2	511	868	150	111.9
12&5&4x7	750	51.7	350	595	150	111.9
12&7&5x7	400	27.6	528	897	200	149.3
14&6x9	500	34.5	560	952	200	149.3
17&9x9	350	24.1	830	1411	250	186.4
17&9&4.5x9	650	44.8	920	1563	350	261

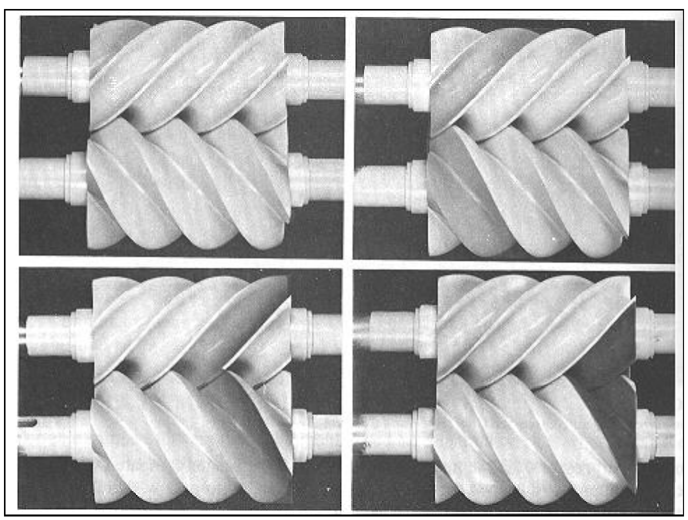
Rotary Compressors

These machines offer several advantages compared with reciprocating compressors, such as compactness, light weight, uniform flow, variable output, maintenance-free operation, and long life

	Free Air Delivery - CFM							
Nominal Horsepower	XF 100 psig	EP 125 psig	HP 140 psig	Receiver gallons	Length inches	Width inches	Height inches	Weight pounds
3		8		80	51	30	51	600
5		14		80	51	30	51	600
7.5		27		120	71	30	51	800
10		35		120	71	30	51	800
20		72		120	78	40	64	1,405
25		91		120	78	40	64	1,470
30		109		120	78	40	64	1,504
60	270	250	235	n/a	77	45	67	2,520
75	324	300	285	n/a	77	45	67	2,775
100	416	400	378	n/a	77	45	67	2950

Rotary Screw Compressors

The Operation of Helical Rotors of Screw Compressor

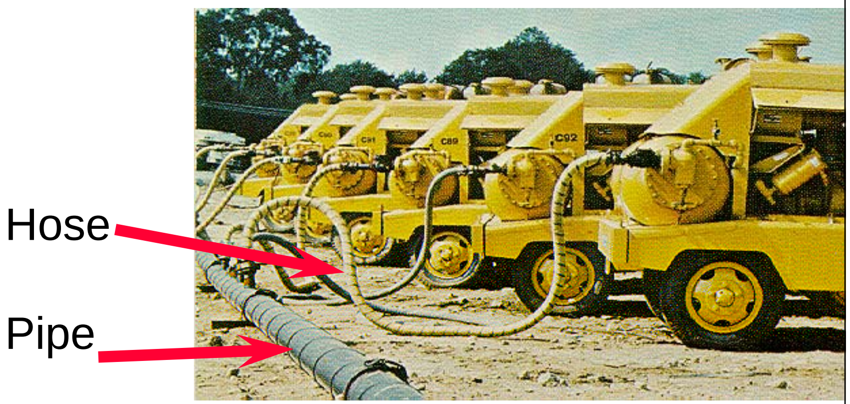


Portable Compressors

- Portable compressors are more commonly used on construction sites where it is necessary to meet frequently changing job demands
- The compressors may be mounted on rubber tires steel wheels, or skids. They are usually powered by gasoline or diesel engines and are available in single- or two-stage, reciprocating or rotary types

Practical Issues

What will be the pressure at the end of a compressed air pipeline used to transmit 3,000 cfm of free air?



Site Preparation: Excavation and Earthmoving

- Planning for Earthwork
- Geotechnical Materials and Compaction Properties
- Clearing and Ripping
- Dozing and Scraping
- Excavating , Loading and Hauling
- Compacting and Grading
- Hauling and Trucking
- Compressed Air Systems
- **Drilling and Blasting**

Drilling and Blasting: Rock Excavation

Drilling and Blasting: Rock Excavation

DRILLING ROCK & EARTH

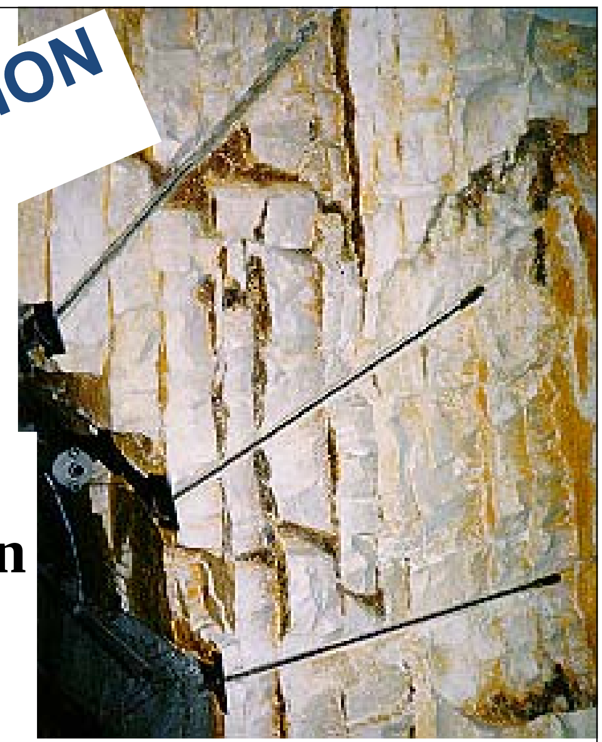
DRILLING ROCK

CONSTRUCTION DRILLING

- Blast holes for removal of rock, in a construction excavation or for quarrying

CONSTRUCTION DRILLING

- Rock anchor/bolts in excavations and tunnels

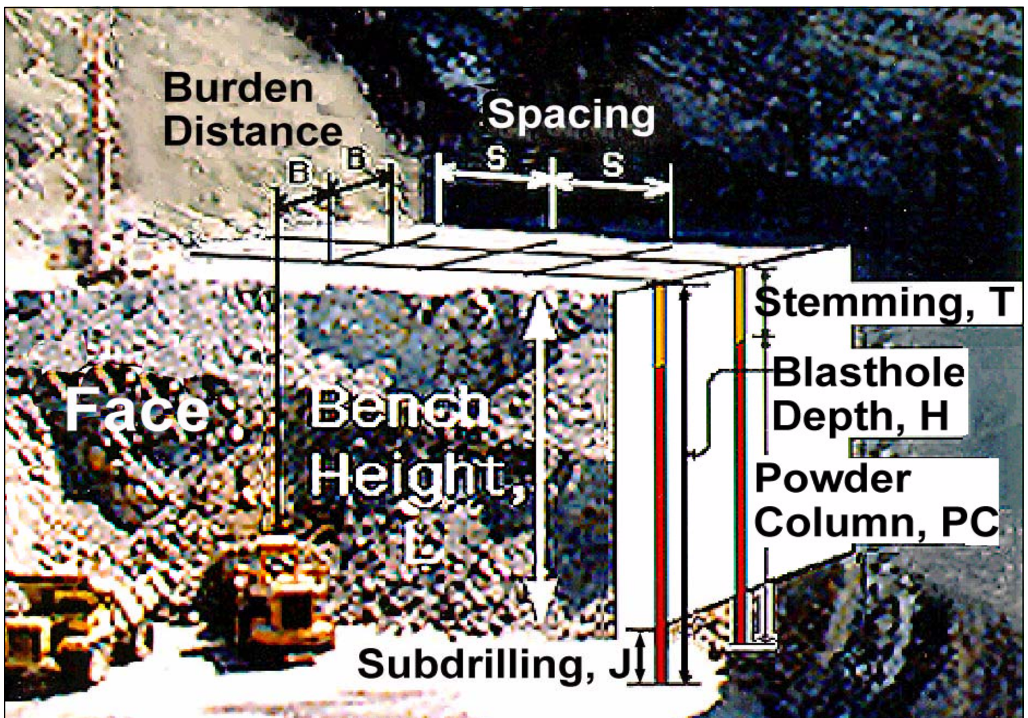


CONSTRUCTION DRILLING

- Foundations

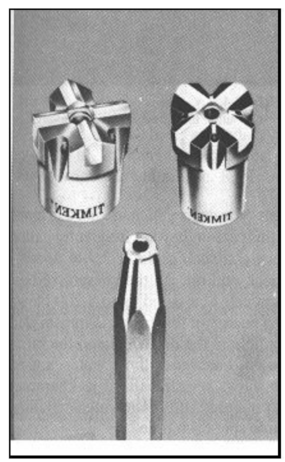
CONSTRUCTION DRILLING

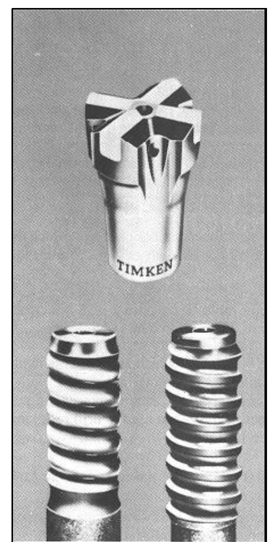
- Foundation grouting

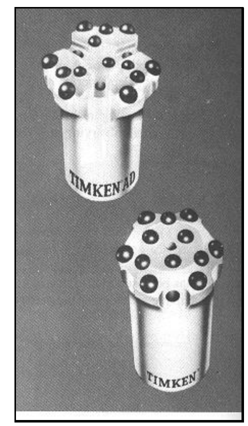


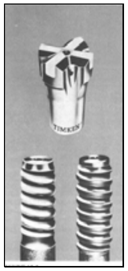
Bits

Removable Tapered-Socket-Type Rock Bit









Bit Type

Button Bit

Bottom-drive Bits:
The figure illustrates the removable bottom-drive bits, which are available in gauge sizes varying from 1.5 in (38 mm) to 6 in (152 mm)

Insert Bit

Jackhammers

- Jackhammers are hand-held air-operated percussion-type drills which are used primarily for drilling holes in a downward direction
- They are classified according to their weight, such as 45 or 55 lb
- <u>A complete drilling unit consists of a hammer, drill steel, and bit</u>

Drifters

- Drifter drills are similar to jackhammers in operation, but they are larger and used as mounted tools for drilling down, horizontal, or up holes
- They vary in weight from 75 to 260 lb and are capable of drilling holes up to 4 in. in diameter

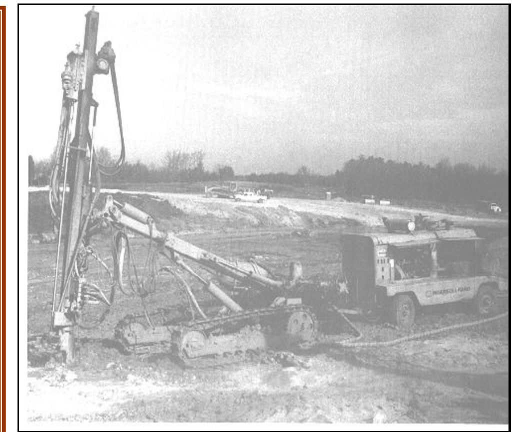
Wagon Drills

- Wagon drills consist of drifters mounted on masts, which are mounted on wheels to provide portability
- Wagon drills are used extensively to drill holes up to 4.5 in. in diameter and up to 30 ft or more in depth

Track-mounted Drills

- The track-mounted drills have substantially replaced the wagon drill on construction projects
- Track-mounted drills production rate may be 3 or more times that of a wagon drill because of their ability to move quickly to a new location and the use of the hydraulically operated boom for positioning the drill

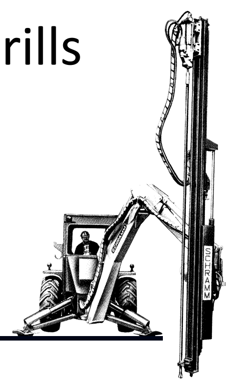
Track-Mounted Drills



Air-track Drill and Air Compressor

Wheel-Mounted Drills

- Wheel-mounted drills are similar in sizes and capacities to the track-mounted drills
- Wheel-mounted drills require a more nearly level ground surface to operate

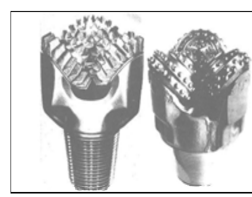


Piston Drills

- These are percussion-type drills with the hollow drill tube attached to the piston
- The stroke and rotation of the piston are adjustable to give the best performance for the particular type of rock being drilled

Rotary Percussion Drills

- Rotary percussion drills require special carbide bits, with the carbide inserts set at a different angle from those used with standard carbide bits



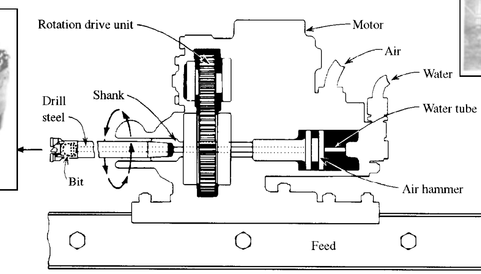


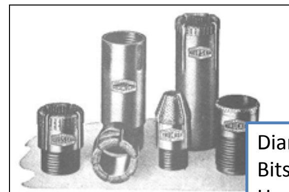
FIGURE 13-9
Rotary-percussion drill. *(Joy Manufacturing Company.)*

Rotary Drills

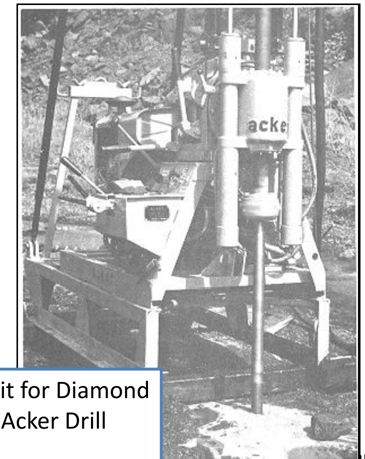
- A rotary drill is self-propelled drill which is mounted on a truck or on a crawler tracks
- A tricone roller-type bit is used in the drilling. It is attached to the lower end of a drill pipe
- As the bit is rotated in the hole, a continuous blast of compressed air is forced down through the pipe and the bit to remove the rock cuttings and to cool the bit

Diamond Drills

- Diamond drills are used primarily for exploration drilling, where cores are desired for the purpose of studying the rock structure.
- A drilling rig consists of:
  - a diamond bit
  - a core barrel
  - a joined driving tube
  - a rotary head to supply the driving torque



Diamond-Point Bits (Sprague & Henwood, Inc.)



Drilling Unit for Diamond Core Drill (Acker Drill Company)

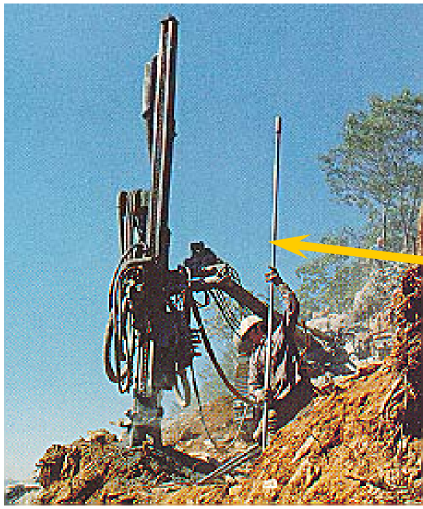
Selecting Drilling Method and Equipment

- Holes are drilled for various purposes, such as:
  - To receive charges of explosives
  - For exploration
  - For ground modification by the injection of grout
- Many factors affect selecting equipment, such as
  - The size of the project and nature of the terrain
  - Size of cores required for exploration and required depth
  - Hardness of the rock & its formation (fractures)
  - Desired outcome for rock handling or crushing
  - The availability of water for drilling purposes
  - Purpose: blasting, exploration, or grout injection

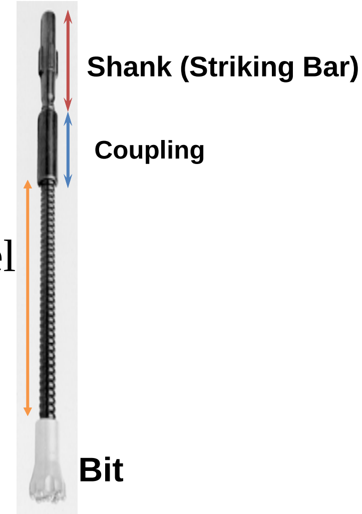
Selecting Drilling Method and Equipment

- The pattern selected for drilling holes to be loaded with explosives will vary with:
  - The type and size drill used
  - The depth of the holes
  - The kind of rock
  - The maximum rock breakage size permissible
  - Other factors

Drilling Operations

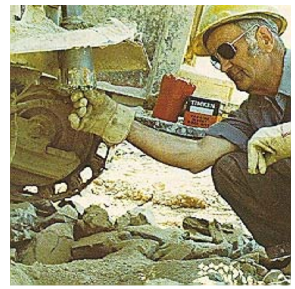


Steel



Drilling Operations

May have to lower the mast



Bits, shanks, couplings and steel are all high wear items that must be replaced frequently

Drilling Earth

- In the construction and mining industries holes are drilled into the earth for many purposes, including, but not limited to:
  - Obtaining samples of soil for test purposes
  - Locating and evaluating deposits of aggregate
  - Locating and evaluating deposits of minerals
  - Permitting the installation of cast-in-place piles or shafts
  - Enabling driving of load-bearing piles into hard formations
  - Providing wells for supplies of water
  - Providing shafts for ventilating mines, tunnels, and other underground facilities
  - Providing horizontal holes through embankments, such as those for the installation of utility conduits

Blasting Related Topics

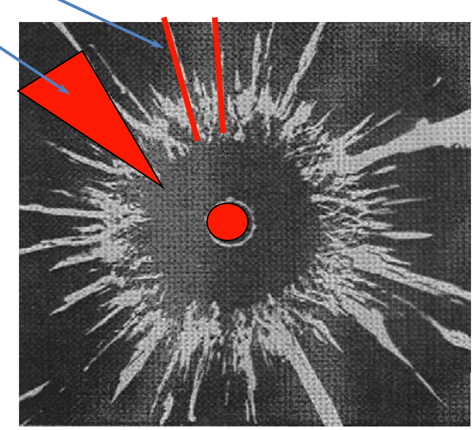
- Blast design
- Powder factor
- Vibration
- Trench rock
- Presplitting
- Production

Blas Design

- *BLAST DESIGN* is not an exact science, but by considering the rock formation it is possible to produce the desired result
- This is a step-by-step procedure for designing the blast hole layout and calculating the amount of explosives for blasting rock
- “Blasting” is performed to break rock so that it may be quarried for processing in an aggregate production operation, or to excavate a right-of-way
- Blasting is accomplished by discharging an explosive that has either been placed in an unconfined manner, such as mud capping boulders, or is confined as in a borehole

Blas Design

- Rock breakage results from gas pressure in the blasthole
- Radial cracking
- Individual wedges
- Flexural rupture
- Stiffness ratio = $\frac{\text{bench height}}{\text{burden distance}}$
- Burden is the distance to the most critical dimension in the blast design (to the free face of the excavation)



Commercial Explosives

- There are four main categories of commercial high explosives:
  1. Dynamite
  2. Slurries
  3. ANFO (common use in construction)
  4. Two-component explosives

ANFO = ammonium nitrate / fuel oil

ANFO is an explosive used extensively on construction projects (Texas City, 16 April 1947)

Initiating Devices

- It is common practice to fire several holes or rows of holes at one time
- Fragmentation, backbreake, vibration, and violence of a blast are all controlled by the firing sequence of the individual blastholes
- Electric cap explosion
  - Passing an electric current through a wire bridge, similar to an electric light bulb filament
  - Current (~1.5 amps) heats the bridge to ignite a heat-sensitive flash compound
  - The ignition sets off a primer which in turn fires a base charge in the cap

Delay Devices

- Delay blasting caps are used to obtain a specified firing sequence
- These caps are available for delay intervals varying from a small fraction of second to about 7 seconds
- When explosives charges in two or more rows of holes parallel to the face are fired in one shot, it is desirable to fire the charges in the holes nearest the face a short time ahead of those in the second row

Detonating Cords

- The detonating cord is a non-electric initiation system consisting of a flexible cord having a center core of high explosive
- It is used to detonate dynamite and other cap-sensitive explosives

Stemming

- Stemming is the adding of an inert material, such as drill cuttings, on top of the explosive in a blasthole for the purpose of confining the energy of the explosive
- To function property the material used for stemming must lock into the borehole

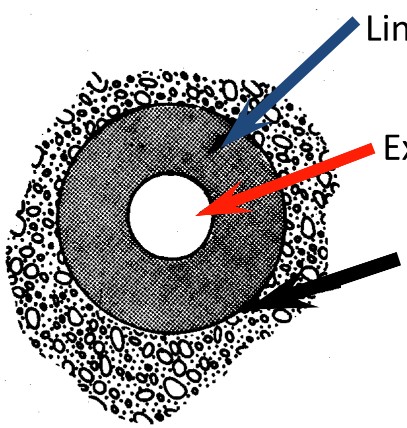
Blasthole Size

- The size (diameter) of the blasthole will affect blast considerations concerning fragmentation, air blast, flyrock, and ground vibration
- The economics of drilling is the second consideration in determining blasthole size

Explosive diameter and blasthole size are the same

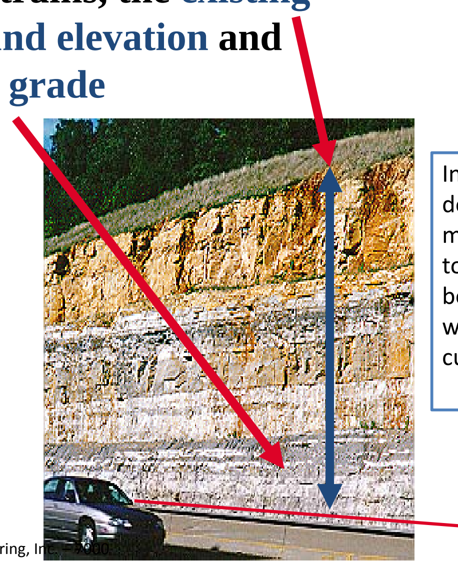
Blasthole Size

- Larger holes are usually more economical to drill but they introduce possible blast problems
- Explosive diameter and bore hole diameter may not be the same

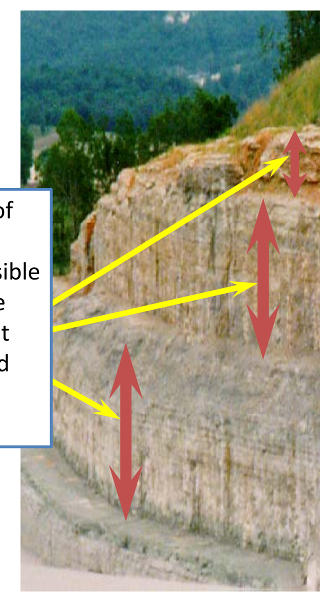


Stiffness Ratio

The bench height is usually set by physical constrains, the existing ground elevation and plan grade



In the case of deep cuts it may be possible to adjust the bench height with stepped cuts

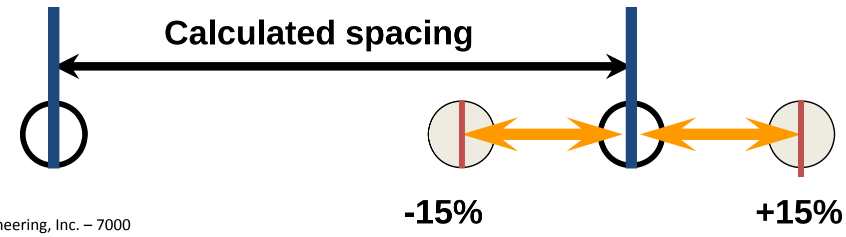


Stiffness Ratio

The bench height should be matched to the reach of the excavation equipment (optimum height of cut).

Spacing

- Proper spacing of blastholes is controlled by the initiation timing and the stiffness ratio
- When holes are spaced too close and fired instantaneously, venting of the energy will occur with resulting air blast and flyrock
- When the spacing is extended, there is a limit beyond which fragmentation will become harsh
- Spacing in the field should be within plus or minus 15% of the calculated value



Spacing and Sequencing

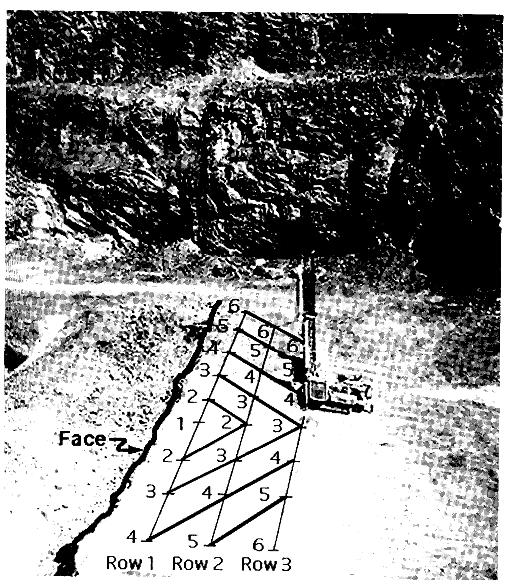
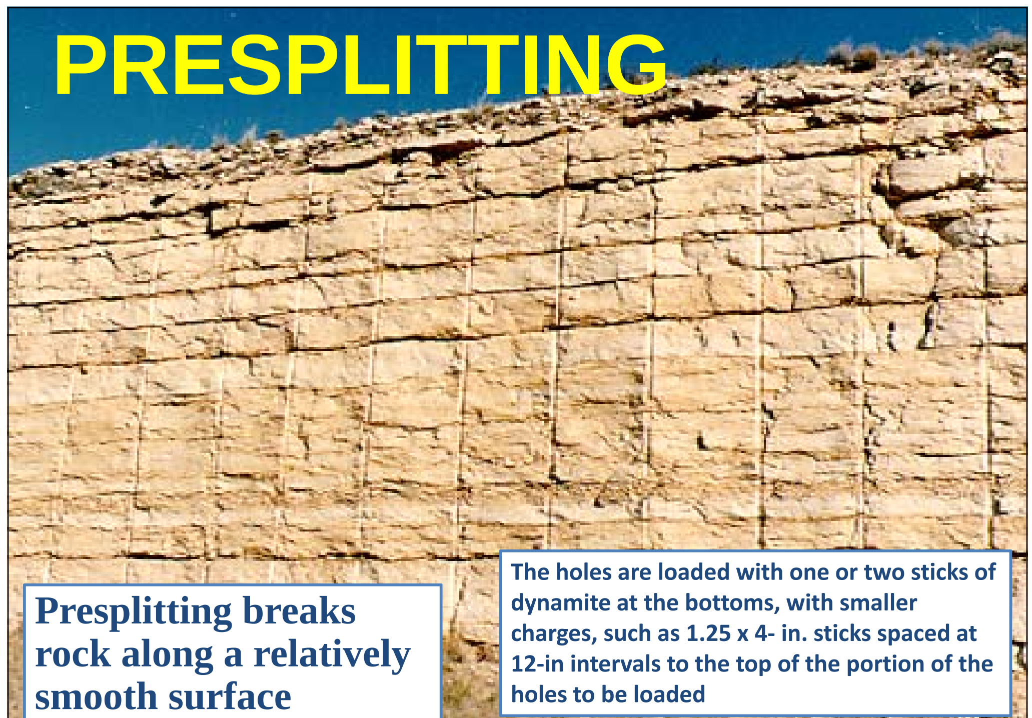


FIGURE 14-2
V-pattern (square corner) firing sequence with progressive delays, numbers indicate firing order.

PRESPLITTING



Presplitting breaks rock along a relatively smooth surface

The holes are loaded with one or two sticks of dynamite at the bottoms, with smaller charges, such as 1.25 x 4- in. sticks spaced at 12-in intervals to the top of the portion of the holes to be loaded

Safety Considerations

- An accident involving explosives may easily kill or cause serious injury
- The prevention of such accidents depends on careful planning and observation of proper blasting practices
- There are federal and state regulations concerning the transportation and handling of explosives
- Safety information on specific products is provided by the manufacturer

Safety Considerations

- In addition to regulations and product information, there are recommended practices, such as the evacuation of the blast area during the approach of an electrical storm whether electric or nonelectric initiation systems are used
- A good source for material on recommended blasting safety practices is the Institute of Makers of Explosives in New York City
- Misfire: In shooting charges of explosives, one or more charges may fail to explode. This is referred to as a "misfire"
- It is necessary to dispose of this explosive before excavating the loosened rock
- The most satisfactory method is to shoot it if possible

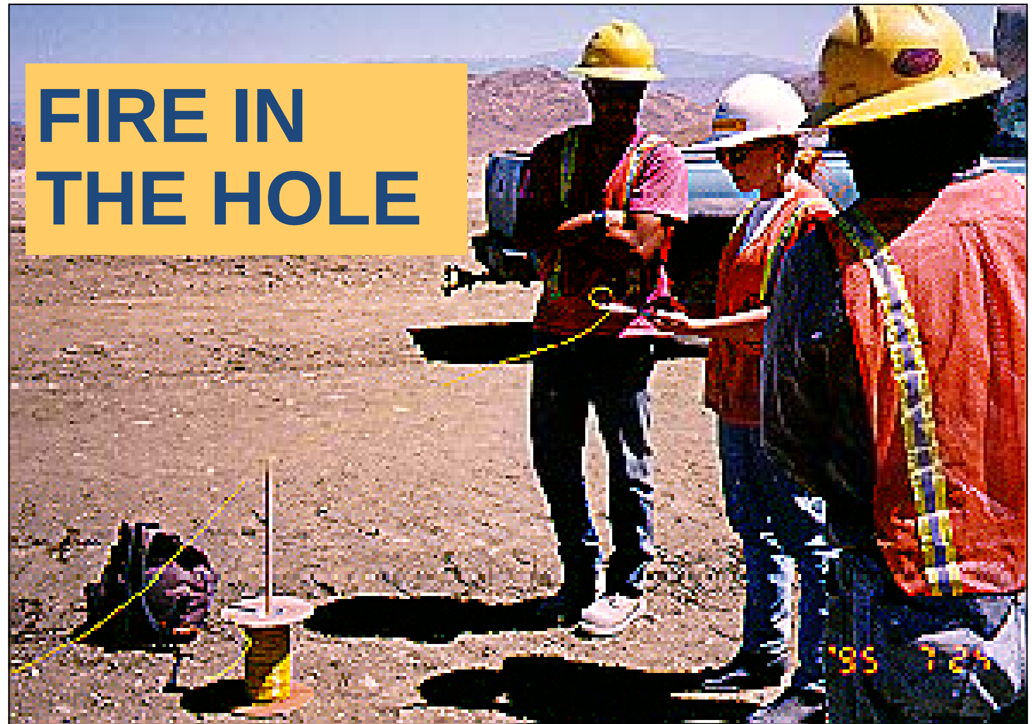
SPACING don't forget -- SAFETY

Factors Affecting Vibration

Some of the critical factors that should be considered are to control vibration:

1. Burden
2. Spacing
3. Subdrilling
4. Stemming Depth
5. Type of Stemming
6. Bench Height
7. Number of Decks
8. Charge Geometry
9. Powder Column Length
10. Rock Type
11. Rock Physical Properties
12. Geological Features
13. Number of Holes in a Row
14. Number of Rows
15. Row-to-Row Delays
16. Initiator Precision
17. Face Angle to Structure
18. Explosive Energy


VIBRATION
How many holes at one time.


FIRE IN THE HOLE


FIRE IN THE HOLE

Where to get more information

- Blasters' Handbook, E. I. du Pont de Nemours & Co., Wilmington, DE
- Rock Blasting and Overbreak Control, National Highway Institute, Washington, DC

7000. General Construction Methods

- Substructure construction: foundations
  - **Production of Crushed-Stone Aggregate**
  - Dewatering Systems
  - Piles
- Superstructure construction
  - Concrete Construction
  - Concrete Forms
  - Steel Construction and Connections
  - Composite Structures
  - Cranes

Production of Crushed-Stone Aggregate

- The production of crushed-stone aggregates involves:
  - Drilling
  - Blasting
  - Loading
  - Transporting
  - Crushing
  - Screening
  - Product handling and storage

Production of Crushed-stone Aggregate

- In operating a quarry and crushing plant, the drilling pattern, the amount of explosives, the size shovel or loader used to load the stone, and the size of the primary crusher should be coordinated to assure that all stone from the quarry can be economically utilized
- The quality and its control is an important comsideration

Recommended Minimum Sizes of Primary Crushers

Recommended minimum sizes of primary crushers for use with shovel buckets of the indicated capacities

Capacity of bucket [cu yd (cu m)]		Jaw crusher [in. (mm)][†]		Gyratory crusher, size of openings [in. (mm)][‡]	
$\frac{3}{4}$	(0.575)	28 × 36	(712 × 913)	16	(406)
1	(0.765)	28 × 36	(712 × 913)	16	(406)
$1\frac{1}{2}$	(1.145)	36 × 42	(913 × 1, 065)	20	(508)
$1\frac{3}{4}$	(1.340)	42 × 48	(1, 065 × 1, 200)	26	(660)
2	(1.530)	42 × 48	(1, 065 × 1, 200)	30	(760)
$2\frac{1}{2}$	(1.910)	48 × 60	(1, 260 × 1, 525)	36	(915)
3	(2.295)	48 × 60	(1, 260 × 1, 525)	42	(1,066)
$3\frac{1}{2}$	(2.668)	48 × 60	(1, 260 × 1, 525)	42	(1,066)
4	(3.060)	56 × 72	(1, 420 × 1, 830)	48	(1,220)
5	(3.820)	66 × 86	(1, 675 × 2, 182)	60	(1,520)

[†] The first two digits are the width of the opening at the top of the crusher, measured perpendicular to the jaw plates. The second two digits are the width of the opening, measured across the jaw plates.

[‡] The recommended sizes are for gyratory crushers equipped with straight concaves.

Types of Crushers

- Crushers are classified according to the stage of crushing which they accomplish, such as: Primary, Secondary & Tertiary
- A primary crusher receives the stone directly from a quarry after blasting, and produces the first reduction in size
- The output of the primary crusher is fed to a secondary crusher, which further reduces the stone size. Some of the stone may pass through four or more crushers before it is reduced to the desired size
- The degree of breakage is spread over several stages as a means of closely controlling product size and limiting waste material

Types of Crushers

- As stone passes through a crusher, the reduction in size may be expressed as
  reduction ratio = crusher feed size/product size
- The sizes are usually defined as the 80% passing size of the cumulative size distribution
- For jaw crusher, the ratio can be estimated by the gape as
  Gape = distance between the fixed and moving faces at the top, divided by the distance of the open-side setting at the bottom

Types of Crushers

- Crushers are also classified by their method of mechanically transmitted fracturing energy to the rock
- Jaw, gyratory, and roll crushers work by applying compressive force
- Impact crushers such as single rotor and hammer mill apply high-speed impact force to accomplish fracturing
- Next table lists the major types of crushers

Major Types of Crushers

TABLE 17-2
ypes of crushers

Crusher type	Reduction ratio range
Jaw	
a. Double toggle	
(1) Blake	4:1–9:1
(2) Overhead pivot	4:1–9:1
b. Single toggle: Overhead eccentric	4:1–9:1
Gyratory	
a. True	3:1–10:1
b. Cone	
(1) Standard	4:1–6:1
(2) Attrition	2:1–5:1
Roll	
a. Compression	
(1) Single roll	Maximum 7:1
(2) Double roll	Maximum 3:1
Impact	
a. Single rotor	to 15:1
b. Double rotor	to 15:1
c. Hammer mill	to 20:1
Specialty crushers	
a. Rod mill	
b. Ball mill	

Jaw Crushers

- Jaw crushers operate by allowing stone to flow into the space between two jaws, one of which is stationary while the other is movable
- The distance between the jaws diminishes as the stone travels downward under the effect of gravity and the motion of the movable jaw, until the stone ultimately passes through the lower opening
- The toggle as the weakest part
- The size of the feed is a key factor in selecting this type of a crusher

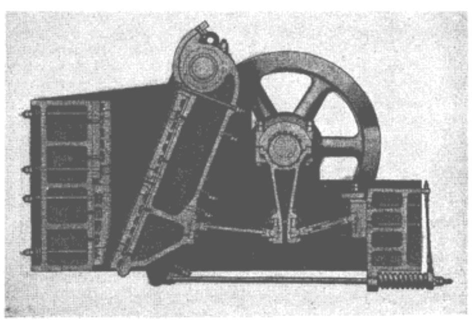


FIGURE 17-1
Blake-type jaw crusher. (*Fiat-Allis Construction Machinery, Inc.*)

Gyratory Crushers

- Gyratory crushers are characterized by a gyrating mantle mounted within a deep bowl
- Gyratory crushers provide continuous crushing action and are used for both primary and secondary crushing of hard, tough, abrasive rock

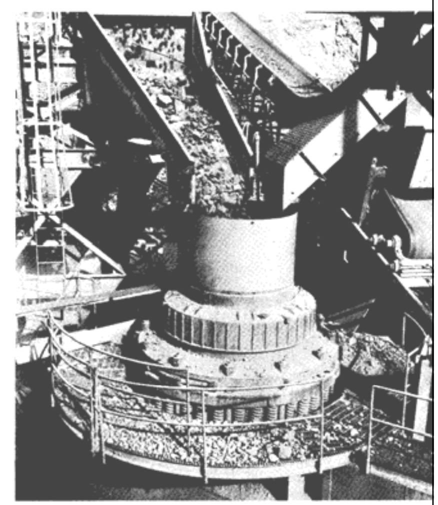


FIGURE 17-5
Gyrosphere crusher in an aggregate plant. (*Telesmith Division, Barber-Greene Company.*)

Gyratory Standard Cone Crusher

- Cone crushers are used as secondary or tertiary crushers
- Cone crushers are capable of producing large quantities of uniformly fine crushed stone

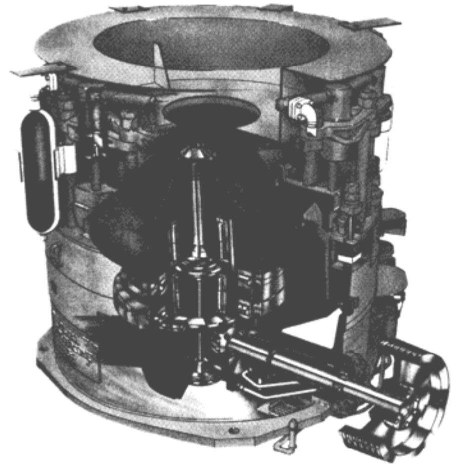


FIGURE 17-6
Rollercone crusher. (*Cedarapids Inc., A Raytheon Company.*)

Roll Crushers

- **Roll crushers** are used for producing additional reductions in the sizes of stone after the output of a quarry has been subjected to one or more stages of prior crushing
- A roll crusher consists of a heavy cast-iron frame equipped with either one or more hard-steel rolls, each mounted on a separate horizontal shaft

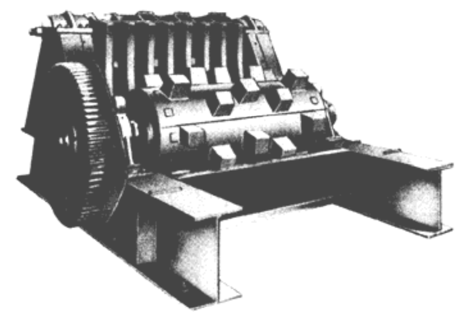
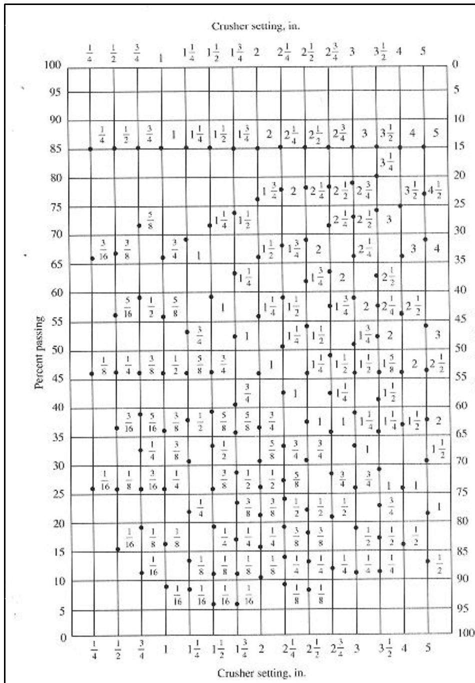


FIGURE 17-7
Cutaway of single roll crusher showing deep-ribbed pitman and segment-type rotor. Breaker plate with ribs provides concentrated crushing action between teeth and ribs and acts as a sizing anvil for close control of product size. (*Grundler Crusher & Pulverizer Company.*)

Sizes of Stone Produced by Crushers

Analysis of the Size of Aggregate Produced by Jaw and Roll Crushers

Crusher setting (in.) versus Percent passing/Percent retained)



Feed Size

- The maximum size of material that may be fed to a roll crusher is directly proportional to the diameter of the rolls
- If the feed contains stones that are too large, the rolls will not grip the material and pull it through the crusher
- The angle of nip, *B*, in the figure 2 has been found to be 16.76^0

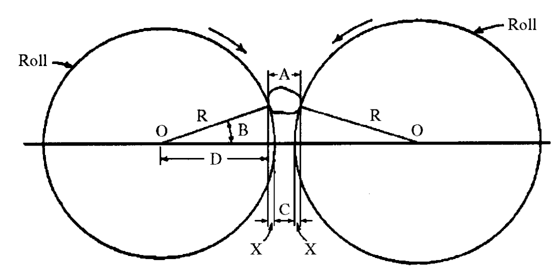


FIGURE 17-8
Crushing rock between two rolls.

Capacity of Roll Crusher

- The capacity of a roll crusher will vary with:
  - The kind of stone
  - The size of feed
  - The size of the finished product
  - The width of rolls
  - The speed at which the rolls rotate
  - The extent to which the stone is fed uniformly into the crusher

Impact Crushers

- In impact crusher stones are broken by the application of high-speed impact forces against the aprons within the crusher unit using:
  - Single rotor
  - Double rotor
- Material flows freely to the bottom of the units without any further size reduction

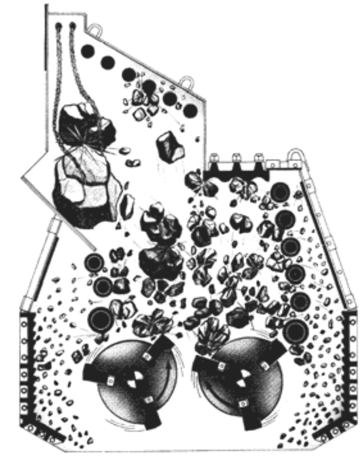
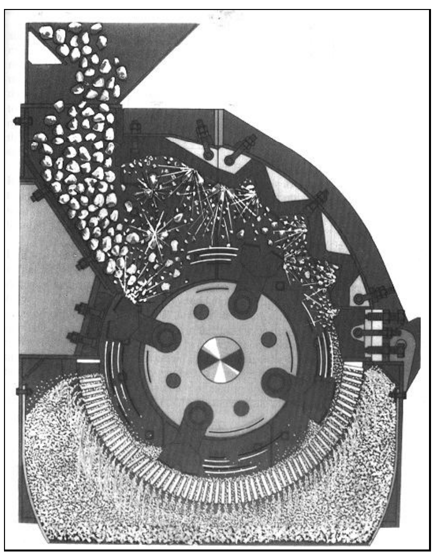


FIGURE 17-9
Cutaway showing double rotor impact breaker. *(Iowa Manufacturing Company.)*

Impact Crushers: Hammer Mills

- Most widely used impact crusher, used for primary or secondary crushing
- Consists of a housing frame, a horizontal shaft, a number of arms and hammers attached to a spool which is mounted on the shaft, one or more manganese-steel or other hard-steel breaker plates, and a series of grate bars whose spacing may be adjusted to regulate the width of openings through which the crushed stone flows



Rod Mill

- A rod mill is a circular steel shell that is lined on the inside with a hard wearing surface
- Rod mill is equipped with a suitable support or trunnion arrangement at each end and a driving gear at one end
- It is operated with its axis in a horizontal position
- The rod mill is charged with steel rods, whose lengths are slightly less than the length of the mill

Ball Mill

- A <u>ball mill</u> is similar to a rod mill but it uses steel balls instead of rods to supply the impact necessary to grind the stone
- Ball mills will produce fine material with smaller grain sizes than those produced by a rod mill

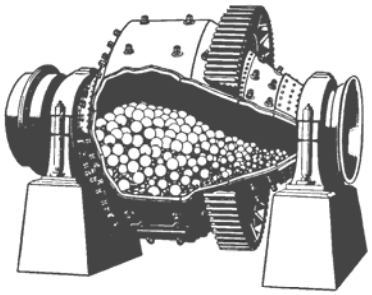
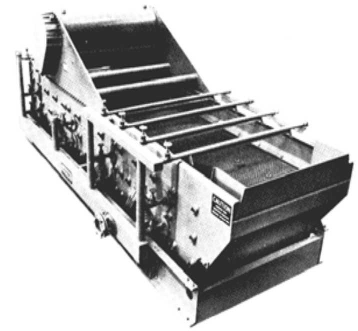


FIGURE 17-12
Section through a conical ball mill.

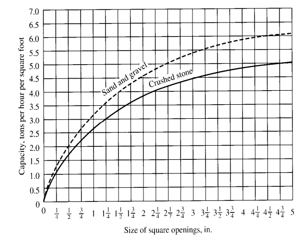
Screening Aggregate

- Persons who are responsible for preparing the specifications for the use of aggregate realize that crushing and screening cannot be done with complete precision, and accordingly they allow some tolerance in the size distribution

FIGURE 17-20
Flat vibrating screen. (Cedarapids Inc., A Raytheon Company.)



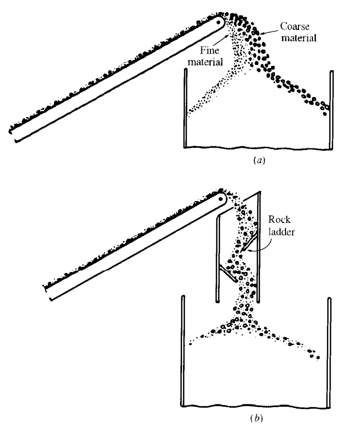
Triple-deck screen with bars for washing aggregate. (*Iowa Manufacturing Company.*)



Screen-capacity chart.

Handling Crashed-stone Aggregate

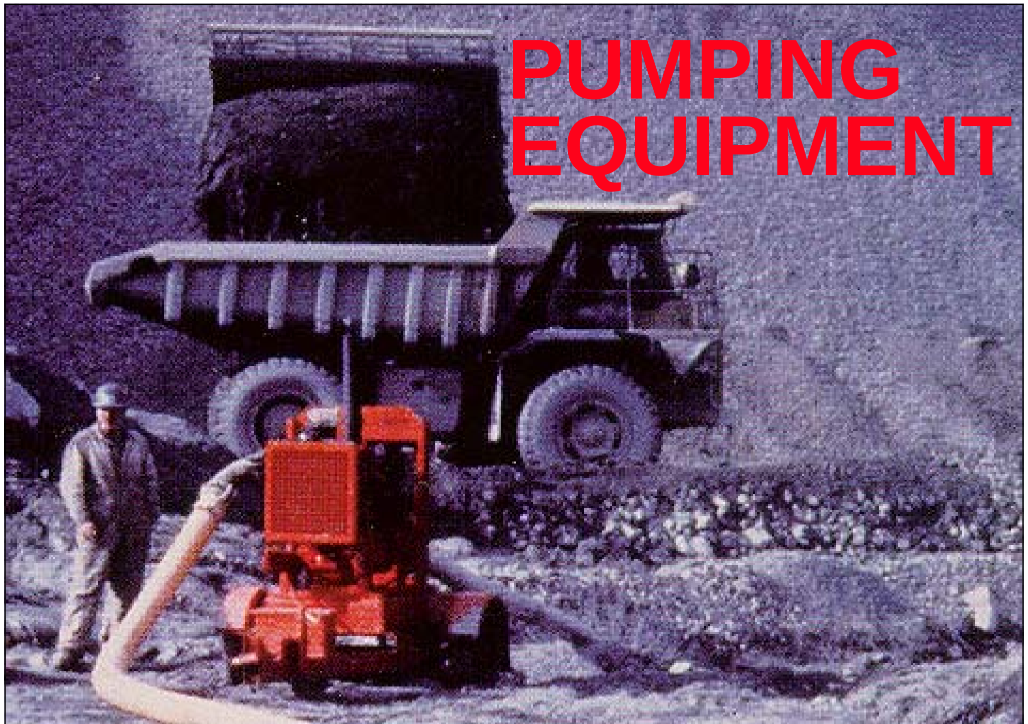
- After stone is crushed and screened to provide the desired size ranges, it is necessary to handle the stone carefully or the large and small particles may separate, thereby destroying the blend in sizes which is essential to meeting graduation requirements
- If aggregate is permitted to flow freely off the end of a belt conveyor, especially at some height above the storage pile, the material will be segregated by sizes



Method of preventing the segregation of aggregate discharge from a conveyor belt.

7000. General Construction Methods

- Substructure construction: foundations
  - Production of Crushed-Stone Aggregate
  - **Dewatering Systems**
  - Piles
- Superstructure construction
  - Concrete Construction
  - Concrete Forms
  - Steel Construction and Connections
  - Composite Structures
  - Cranes



Uses of Pumps

- Pumps are used extensively on construction projects for:
  - Removing water from pits, tunnels, and other excavations
  - Dewatering cofferdams
  - Furnishing water for jetting and sluicing
  - Furnishing water for many types of utility services
  - Lowering the water table for excavations
  - Foundation grouting

Pump Selection

- The factors that should be considered in selecting pumps for construction applications include:
  - Dependability
  - Availability of repair parts
  - Simplicity to permit easy repairs
  - Economical installation and operation
  - Operating power requirements

Classification of Pumps

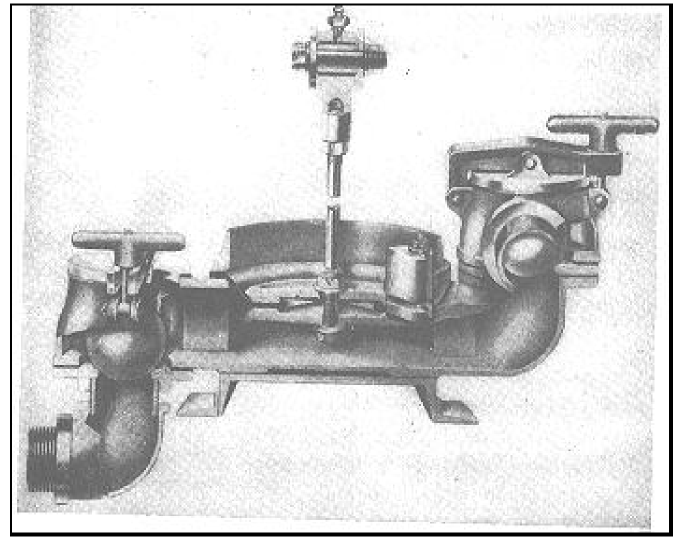
- The pumps commonly used on construction projects may be classified as:
  - Displacement
    - Reciprocating
    - Diaphragm
  - Centrifugal
    - Conventional
    - Self-priming
    - Air-operated

Reciprocating Pumps

- A **reciprocating pump** operates as the result of the movement of a piston inside a cylinder
- **<u>Double-acting pump</u>**: When the piston is moved in one direction, the water ahead of the piston is forced out of the cylinder. At the same time additional water is drawn into the cylinder behind the piston. Regardless of the direction of movement of the piston, water is forced out of one end and drawn into the other end of the cylinder
- **<u>Single-acting pump</u>**: If water is pumped during a piston movement in one direction only, the pump is classified as single-acting pump
- If a pump contains more than one cylinder, mounted side by side, it is classified as a duplex for two cylinders, triplex for three cylinders, etc.

Diaphragm Pumps

Section through a Diaphragm Pump



Centrifugal Pumps

- A centrifugal pump contains a rotation element, called an <u>impeller,</u> which imparts to water passing through the pump a velocity sufficiently great to cause it to flow from the pump, even against considerable pressure
- A mass of water may possess <u>energy due to either its height above a given datum or its velocity</u>
  - The former is <u>potential</u>, whereas the latter is <u>kinetic energy</u>. One type of energy can be converted into the other under favorable conditions.

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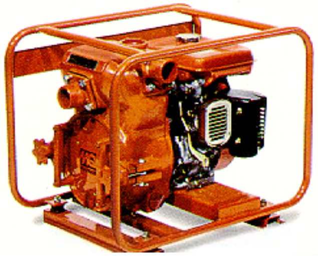
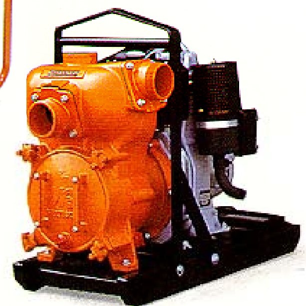
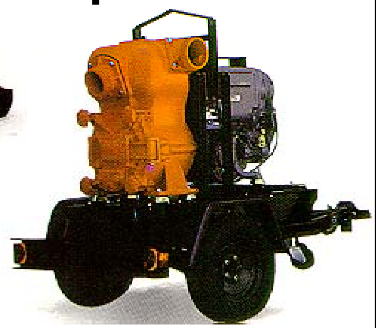
CENTRIFUGAL



2” gas powered



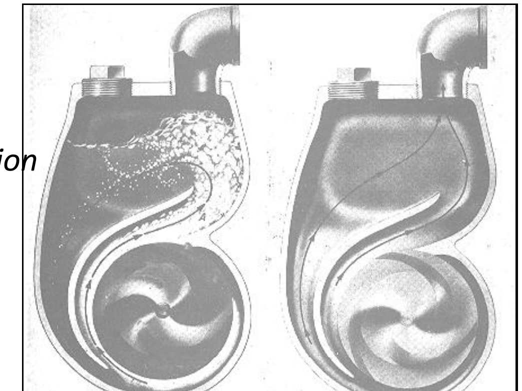
4” diesel powered



6” diesel powered

Self-priming Centrifugal Pumps

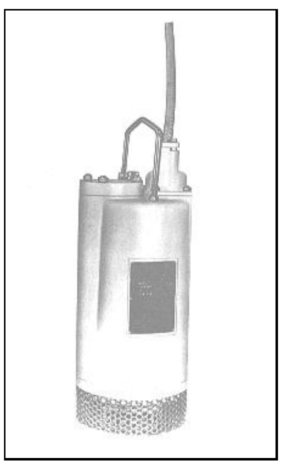
- In construction projects, sometimes pumps must be set above the surface of the water which is to be pumped
- This is why self-priming centrifugal pumps are more suitable than conventional types on construction projects
- The operation of a centrifugal pump is illustrated in next slide
- A check valve on the *suction side* of the pump permits the chamber to be filled with water prior to the starting the pump



(a) Priming Action. (b) Pumping Action

Submersible Pumps

- Submersible pumps are very useful in dewatering
  - Tunnels
  - Foundation pits
  - Trenches
  - Others

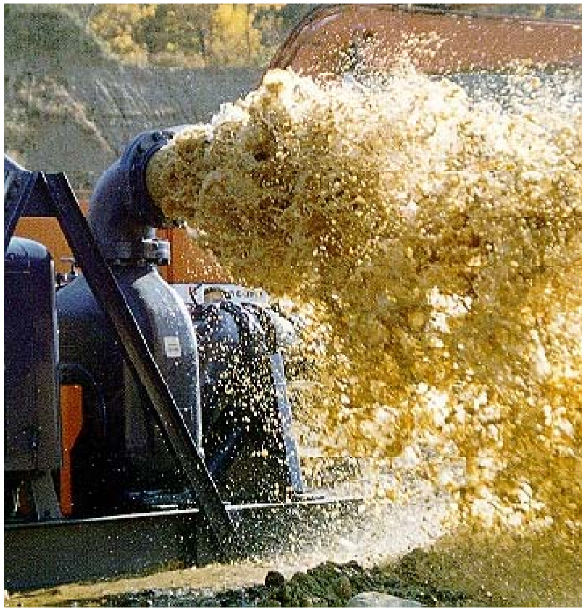


Multistage Centrifugal Pumps

- If a centrifugal pump has a single impeller, it is described as a single-stage pump
- If there are two or more impellers and the water discharge from one impeller flows into the suction of another, it is described as multistage pump
- These pumps are useful for pumping against high heads of pressure
- Pumps of this type are used sometimes to supply water for jetting, where the pressure may run as high as several hundred pounds per square inch (psi)

Pump Selection

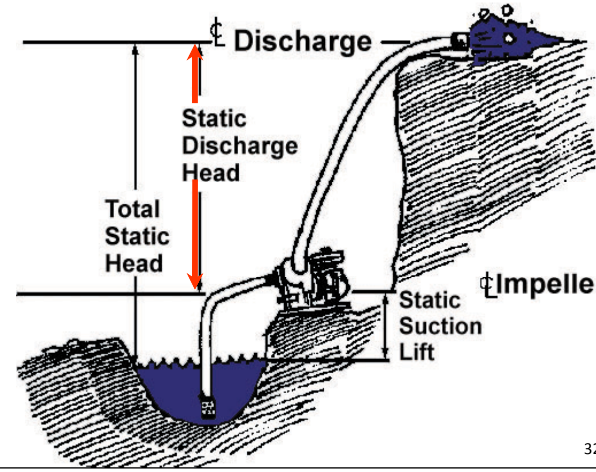
What size centrifugal pump is required to handle the 200 gpm from the previous example?



Terminology

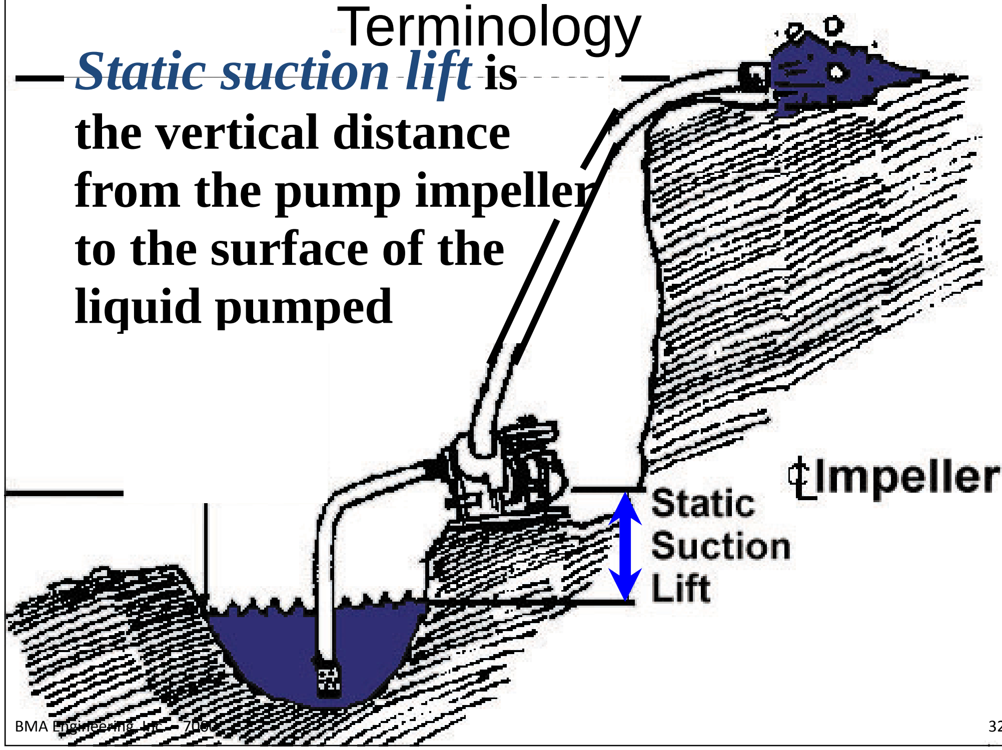
Static discharge head **is the vertical distance from the pump impeller**

to the point of discharge.



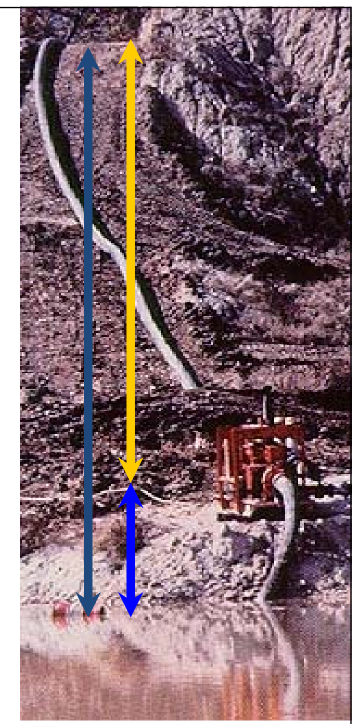
Terminology

Static suction lift **is the vertical distance from the pump impeller to the surface of the liquid pumped**



Terminology

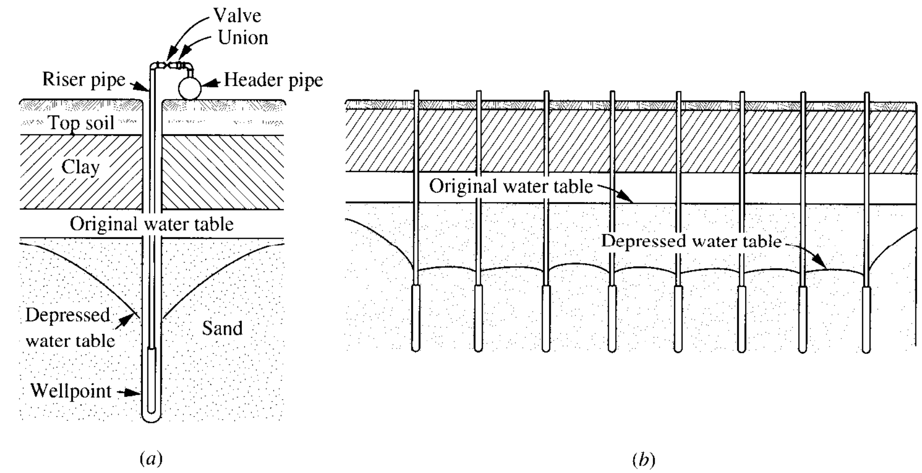
Total static head **is the static *suction lift* plus the static *discharge head*.**



Wellpoint Systems

- In excavating below the surface of the ground, the contractor may encounter groundwater prior to reaching the bottom of a pit
- While the water may be permitted to flow into sumps located in the pit and then removes by pumps, the presence of such water usually creates a nuisance and interferes with the construction operations
- The installation of a wellpoint system along or around the pit may lower the water table below the bottom of the excavation, thus permitting the work to take place under relatively dry conditions

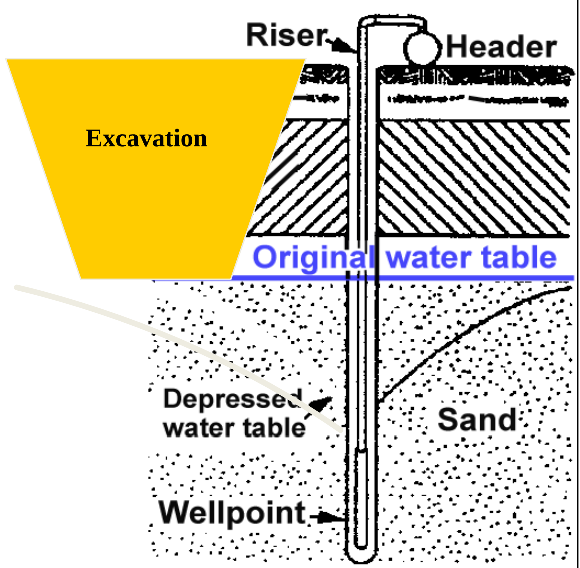
Wellpoint Systems



Lowering the water table adjacent to wellpoints.

Predraining Methods

Produce a cone of depression in the water table so that the excavation can take place in the dry



Deep Wells

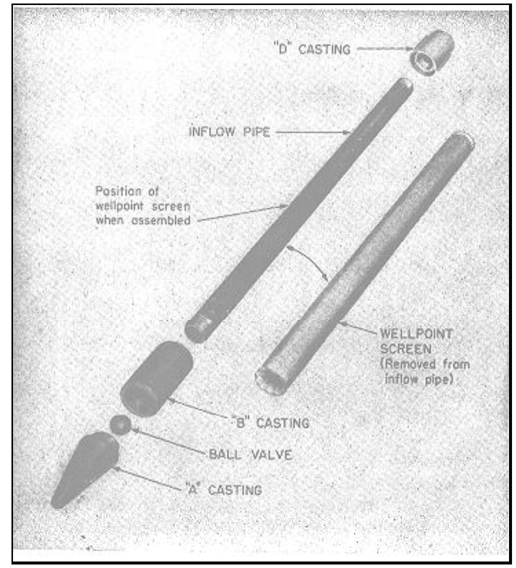
Large-diameter deep wells are suitable for lowering the water table when the soil becomes more pervious with depth or the excavation penetrates or is underlain by sand or coarse granular soils.

Wellpoint Systems

- *A* ***wellpoint*** is a perforated tube enclosed in a screen, which is installed below the surface of the ground in order to collect and remove water from the ground
- The essential parts of wellpoint system is shown in next slides
- The principle by which a wellpoint system work is illustrated in next slides

Wellpoint Systems

The Essential parts of a Wellpoint System



Wellpoint Systems

Lowering Water Table Adjacent to Welllpoints

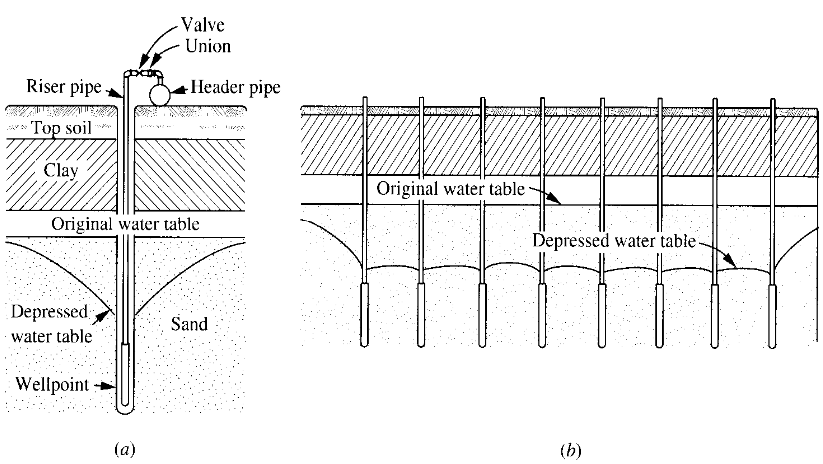
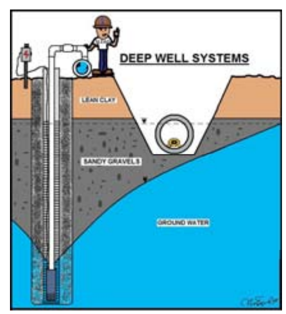
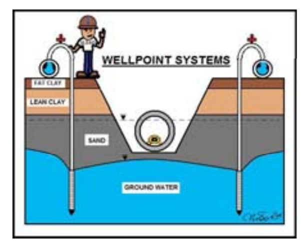


FIGURE 16-10
Lowering the water table adjacent to wellpoints.

Wellpoint Systems

- Dewatering Systems





Slurry Walls

- A mixture of bentonite (i.e., impure clay) and water is called slurry
- Slurry Walls or Slurry Trench technology stops groundwater and helps to dewater jobsites
- Uses:
  - At waste sites to contain contaminated groundwater
  - At "clean" sites to dewater excavations
  - To stabilize dams, levees, and similar structures

Slurry Walls

Steps of slurry wall construction:

- Excavate soils in trench
- Keep excavation stable with slurry
- Place reinforcing steel cage
- Place concrete from the bottom using a pipe, which displaces slurry for recovery/recycling

7000. General Construction Methods

- Substructure construction: foundations
  - Production of Crushed-Stone Aggregate
  - Dewatering Systems
  - **Piles**
- Superstructure construction
  - Concrete Construction
  - Concrete Forms
  - Steel Construction and Connections
  - Composite Structures
  - Cranes

Types of Piles

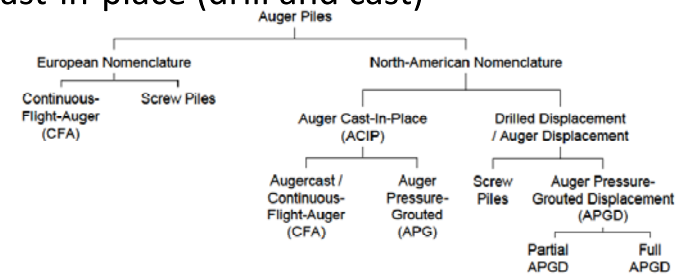
- On the basis of use:
  - Load bearing
  - Sheet
- On the basis of materials:
  - Steel
  - Wood (treated or untreated)
  - Concrete (Precast, reinforced or prestressed)
  - Composite

Crawler crane w/ single acting air hammer and hydraulic leads.

Driving 12-in. concrete piles.

Types of Load-bearing Piles

1. Timber
   a. Untreated
   b. Treated with a preservative
2. Concrete
   a. Precast-prestressed
   b. Cast-in-place with shells
   c. Augered cast-in-place (drill and cast)



Types of Load-bearing Piles

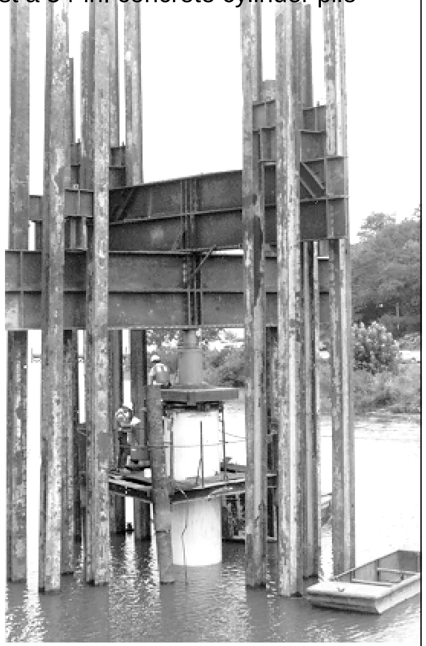
3. Steel
   a. H section
   b. Steel pipe
4. Composite
5. Sheet
   a. Steel
   b. Prestressed concrete
   c. Timber

Site Investigation and Test Pile Program

- For projects of intermediate to large scale a thorough site investigation can be very cost effective
- The geotechnical information gathered from borings can be used to determine the soil characteristics and the depths to strata capable of supporting the design loads
- The number of blows per foot, from geotechnical tests such as the standard **penetration test**, is normally recorded during the soil sampling operations and can be extremely valuable for use in predicting pile lengths. From this information pile types, sizes, and capacities may be chosen
- Once a pile type has been selected, or if several types are deemed practical for use on a particular project, a test pile program should be conducted

Load Test (Direct or by Reaction Beam)

Reaction frame and hydraulic jacks used to load test a 54-in. concrete cylinder pile



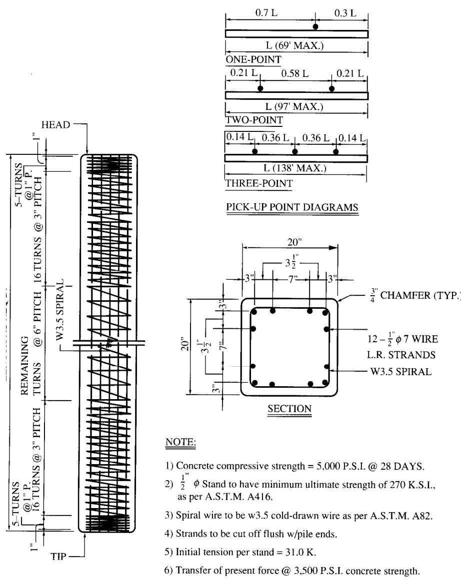
- A reaction frame or beam is attached to the reaction piles and spans over the top of the test pile so that the test load may be applied by utilizing an hydraulic jack
- The jack is located between the reaction beam and the top of the test pile
- As the load is applied by the jack, the reaction beam transfers the load to the test pile, putting it in compression and putting the reaction piles in tension

Load Test

- For either type test, direct load or reaction, the magnitude of the applied test load is normally 2 to 3 times the design bearing capacity of the pile
- Any sudden or rapid movement of the pile indicates a failure of the pile

Precast-prestressed Concrete Piles

- Precast-prestressed concrete piles are normally manufactured at established plants utilizing approved methods in accordance with the PCI MNL-116-85 "Manual for Quality Control"
- Specifications for many projects, such as those used by state highway departments, require the piles to be manufactured at PCI certified plants
- Square and octagonal piles are cast in horizontal forms on casting beds, whereas cylinder piles are cast in cylindrical forms and then centrifugally spun



GURE 15-4
pical details of a 20-in. square prestressed concrete pile. (*Bayshore Concrete Products, Chesapeake, Inc.*)

Precast-prestressed Concrete Piles

- Advantages:
  - High resistance to chemical and biological attacks
  - Great strength
  - A pipe may be installed along the center of the pile to facilitate jetting
- Disadvantages:
  - It is difficult to reduce or increase the length
  - Large sizes require heavy and expensive
  - handling and driving equipment
  - The inability to obtain piles quickly by purchase may delay the starting of a project
  - Possible breakage of piles during handling or driving produces a delay hazard

Cast-in-place Concrete Piles

- As the name implies, cast-in-place concrete piles are constructed by depositing the freshly mixed concrete in place in the ground and letting it cure there
- The two principal methods of constructing cast-in-place concrete piles are:
  - Driving a metallic shell and leaving it in the ground, and then filling the shell with concrete.
  - Driving a metallic shell and filling the resulting void with concrete as the shell is pulled from the ground

Cast-in-place Concrete Piles

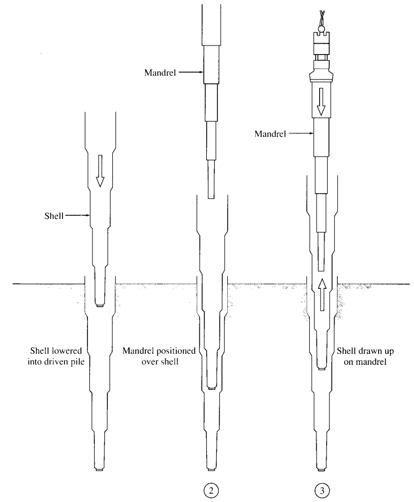


FIGURE 15-8
Shell-up procedure for Raymond step-taper piles.

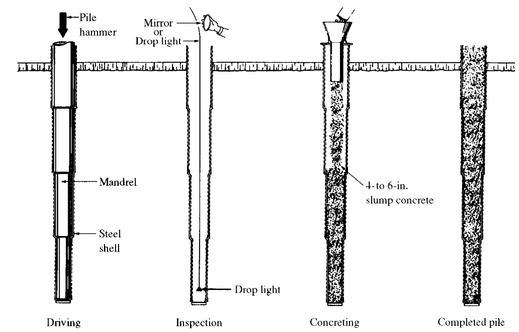


FIGURE 15-9
Installation sequence for Raymond step-taper piles.

Cast-in-place Concrete Piles

- Advantages:
  - The lightweight shells may be handled and driven easily
  - The variations in length do not present a serious problem -- the length of a shell may be increased or decreased easily
  - Shells may be shipped in short lengths and assembled at the job
  - The excess reinforcing, to resist stresses caused only by handling the pile, is eliminated
  - The danger of breaking a pile while driving is eliminated
  - Additional piles may be provided quickly if they are needed
- Disadvantages:
  - A slight movement of the earth around an unreinforced pile may break it
  - An uplifting force, acting on the shaft of an uncased and unreinforced pile, may cause it to fail in tension
  - The bottom of a pedestal pile may not be symmetrical

Steel Piles

- In constructing foundations that require piles driven to great depths, steel piles probably are more suitable than any other type
- A commonly used type is Steel **H section piles**
  - Steel piles may be driven through hard materials to a specified depth to eliminate the danger of failure due to scouring, such as under a pier in a river
  - Steel piles may be driven to great depths through poor soils to bear on a solid rock stratum

Steel Piles

- **Steel-pipe piles**. These piles are installed by driving pipes to the desired depth and, if desired, filling them with concrete
- A pipe may be driven with the lower end closed with a plate or steel driving point, or the pipe may be driven with the lower end open

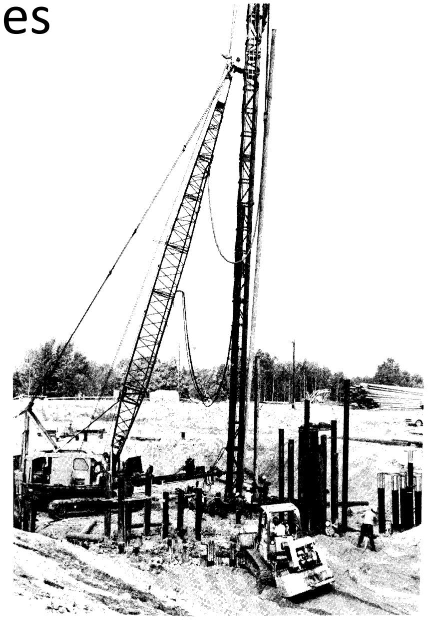


FIGURE 15-10
Driving No. 5 gauge 12-in. monotube piles up to 200 ft long with a 37,000 ft-lb steam hammer. (*The Union Metal Manufacturing Company.*)

Composite Piles

- When extremely hard soils or soil layers are encountered, it may be cost-effective to consider the use of a composite pile
- The top portion of the pile would be a prestressed concrete pile and the tip would be a steel H pile embedded into the end of the concrete pile
- The composite design is suggested for marine applications, where the concrete pile section offers resistance to deterioration and the steel pile tip enables penetration of hard underlying soils

Sheet Piles

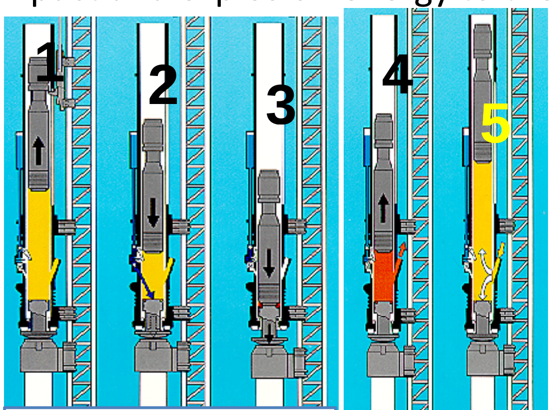
- Sheet piles are used primarily to retain or support earth
- Sheet piles are commonly used for bulkheads and cofferdams and when excavation depths or soil conditions require temporary or permanent bracing to support the lateral loads imposed by the soil or by the soil and adjacent structures
- Sheet piles supported loads include any live loads imposed by construction operations
- Sheet piles can be made of steel, concrete, or timber
- Each of sheet pile types can support limited loads without additional bracing or tieback systems
- When the depth of support is large or when the loads are great, it is necessary to incorporate a tieback or bracing system with the sheet piles

Pile Hammers

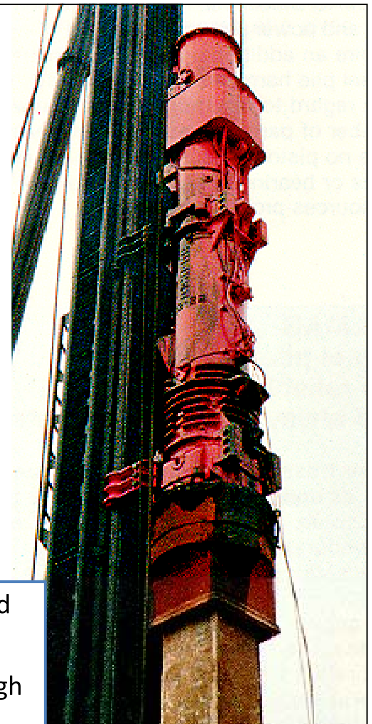
- The function of a pile hammer is to furnish the energy required to drive a pile. Pile driving hammers are designated by type and size
- The hammer types commonly used include the following:
  1. Drop
  2. Single-acting steam or compressed air
  3. Double-acting steam or compressed air
  4. Differential-acting steam or compressed air
  5. Diesel
  6. Hydraulic
  7. Vibratory drivers

Diesel Hammers

Diesel hammers impart compression, impact and explosion energy to the pile

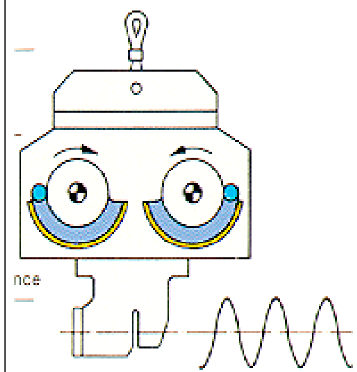


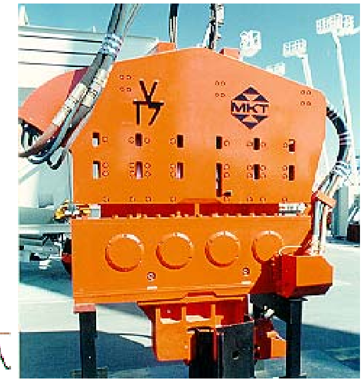
1. Raise the piston to start
2. Injection of diesel fuel and compression
3. Impact and explosion
4. Exhaust ports exposed and gases escape
5. Draws fresh air through the exhaust ports

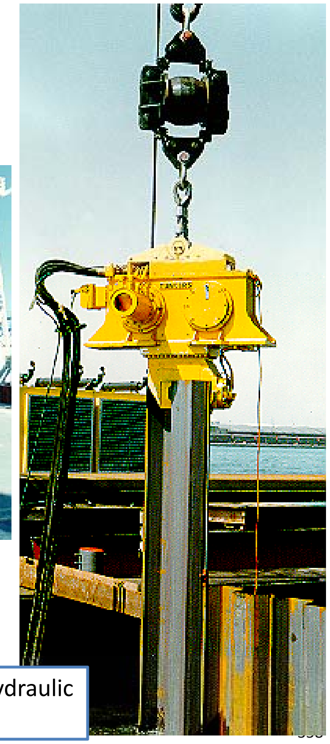


Vibratory Hammers

Vibratory hammers use exciting shafts rotating in opposite directions



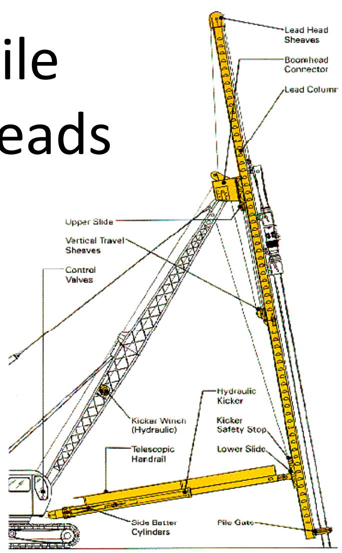




Can be driven by hydraulic or electric motors

Hydraulic Leads

Pile Leads



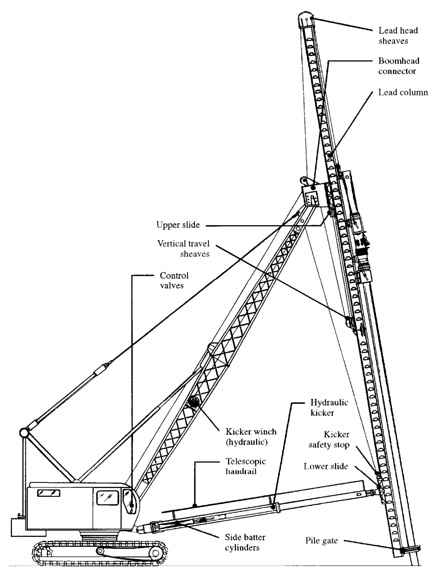
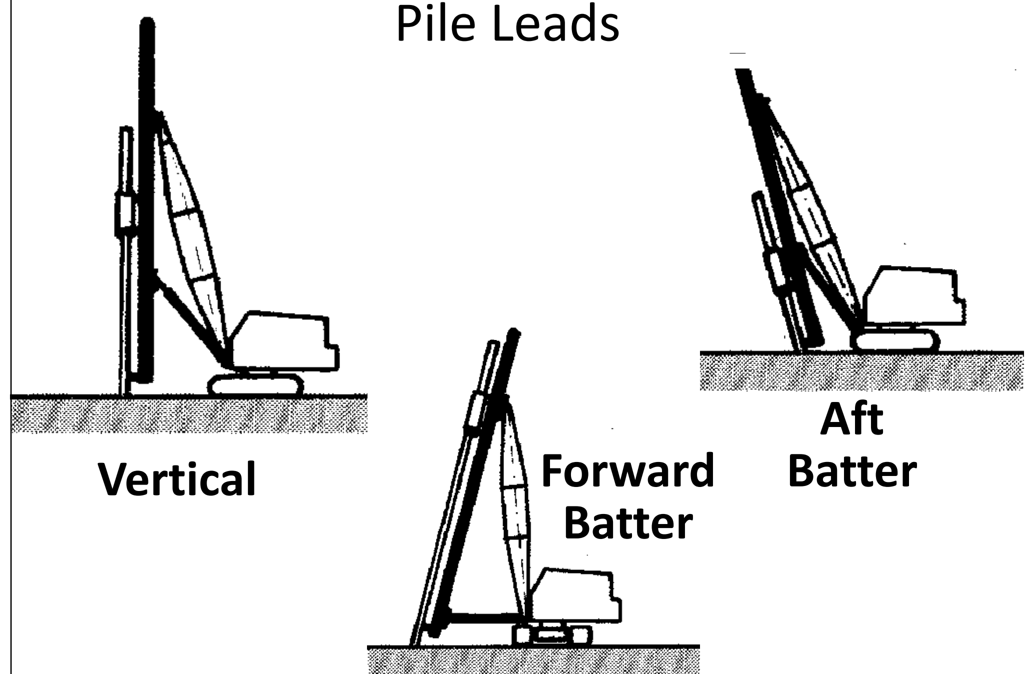


FIGURE 15-25
Vertical travel leads (hydraulic) attached to a crawler crane. (*Berminghammer Corporation Limited.*)

Pile Leads

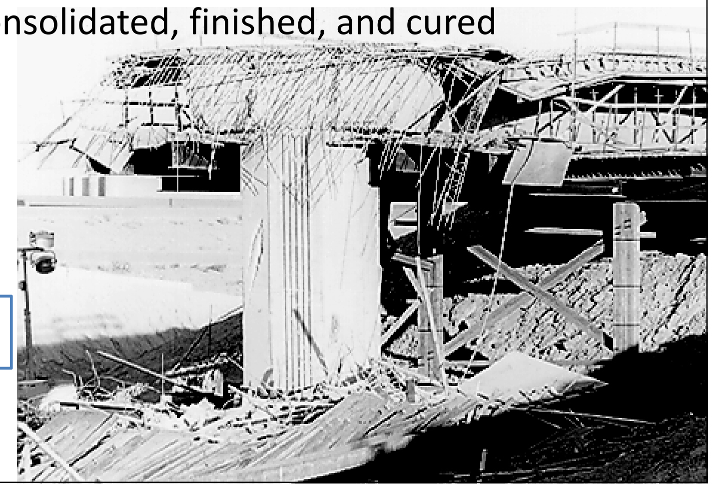


7000. General Construction Methods

- Substructure construction: foundations
  - Production of Crushed-Stone Aggregate
  - Dewatering Systems
  - Piles
- Superstructure construction
  - **Concrete Construction**
  - Concrete Forms
  - Steel Construction and Connections
  - Composite Structures
  - Cranes

Fresh Concrete

- To the designer, fresh concrete is of little importance
- To the constructor, fresh concrete is all-important, because it must be mixed, transported, placed, supported, consolidated, finished, and cured



Structural collapse during construction

Concrete Ingredients

- Concrete is a mixture of cement, fine and coarse aggregates, and water
- Water is the key ingredient for chemical reaction for curing

Add Water

↓

Cement + Aggregates = Concrete

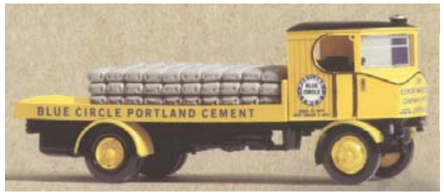
Concrete Strength

- The plastic mix is placed and consolidated in the formwork and, then cured to facilitate the acceleration of the chemical hydration reaction of the cement-water mix, resulting in *hardened concrete*
- The finished product has
  - High **compressive strength**
  - Low **resistance to tension** (weak in tension)

Portland Cement

The raw materials that make cement are:

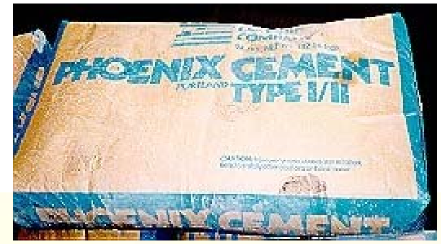
1. Lime (CaO), from limestone
2. Silica (SiO2), from clay
3. Aluminum (Al2O3), from clay



Specific gravity:
3.12 and 3.16

Unit weight:
94 lb/ft^3 (for commercial sack)

Cement Truck



Concrete Plant Standards

- Cement of cementitious materials shall be batched by weight
- Aggregates shall be batched by weight
- Water shall be batched by weight or volume

Batch Plant

- Accurately proportions aggregate and cement
- Water is measured in the mixer truck

Mixer Truck

Mixer Truck

Hauling Concrete

- Transit mixer truck
- Maximum duration 1 ½ hr or 300 drum revolutions from introduction of water until placement
- Using dump or agitor trucks, 30 minute maximum haul at 70 to 90 degrees

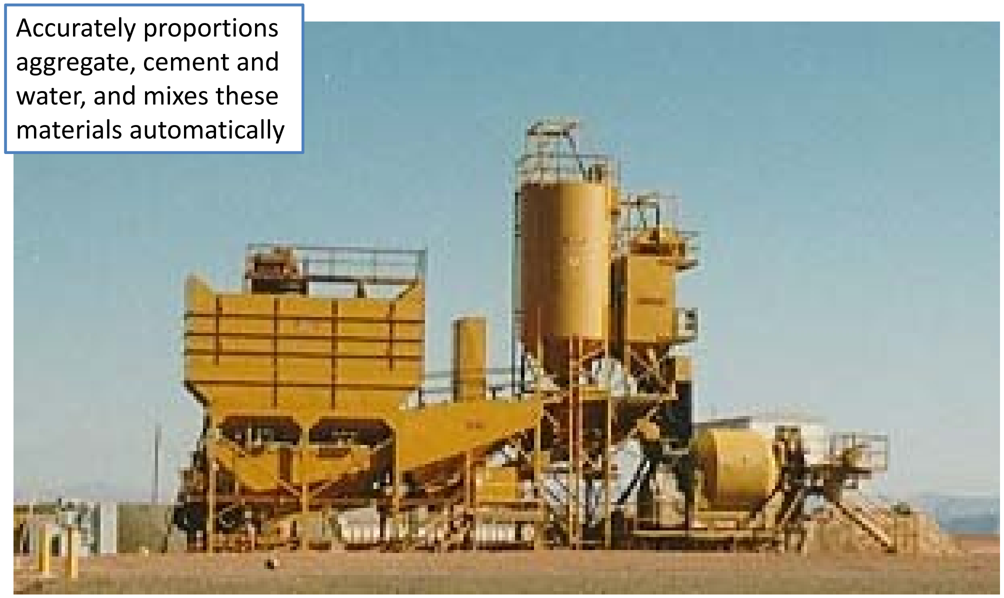
Mixer Truck

Mixer Drum

Cable & Bucket System

Central Mix Plant

Accurately proportions aggregate, cement and water, and mixes these materials automatically



Central Mix Plant

Conveyor System

Conveyor System

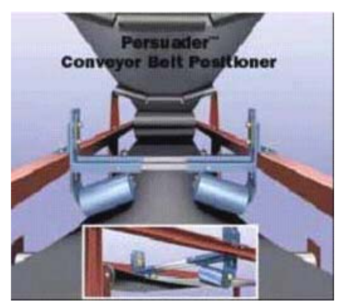
Belt-Conveyor Systems

- Belt-conveyor systems are used extensively in the field of construction
- Belt-conveyor systems frequently provide the most satisfactory and economical method of handling and transporting materials, such as earth, sand, gravel, crushed stone, mine ores, cement, concrete, etc.
- Because of the continuous flow of materials at relatively high speeds, belt conveyors have high capacities
- <u>Example:</u> During the construction of the Channel Tunnel (between England and France) conveyors were used to move up to 2,400 tons of spoil per hour from the tunnel headings

Belt-Conveyor System

The essential parts of a belt-conveyor system include:

– A continuous belt, idlers
– A driving unit, driving and tail pulleys
– Take-up equipment
– A supporting structure



Portable Belt-Conveyor System

- A conveyor for transporting materials a short distance may be a portable unit or a fixed installation
- This machine is available in lengths of 33-60 ft, with belt widths of 18, 24, and 30 in
- It is self-powered with a gasoline-engine drive through a shaft and gearbox to the driving pulley
- The operating features include swivel wheels, a V-type truck, a hydraulic hoist, a low mast height, and anti-friction bearings throughout

Conveyor Belt

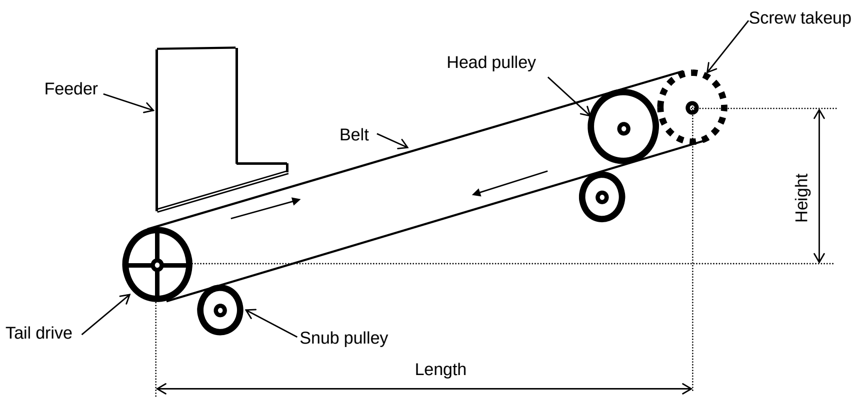
El Abra, Chile

El Abra, Chile

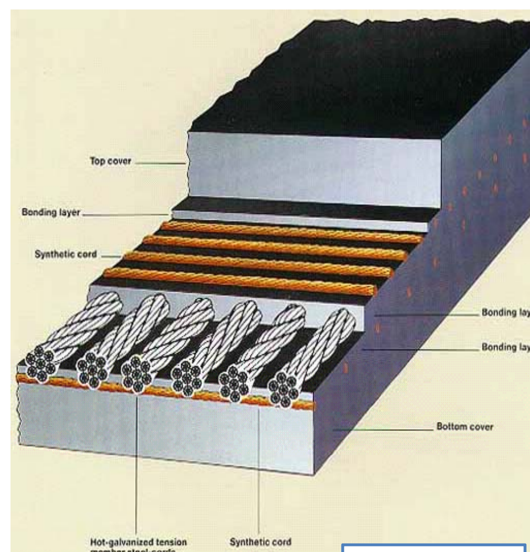
Ruhrkohle, Germany

Newman, Western Australia

Components of Conveyor Belt

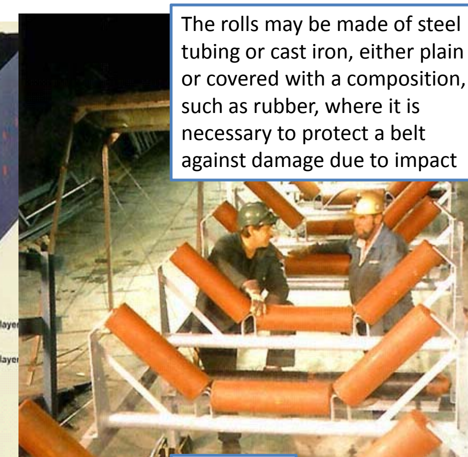


Components of Conveyor Belt



Conveyor Belt

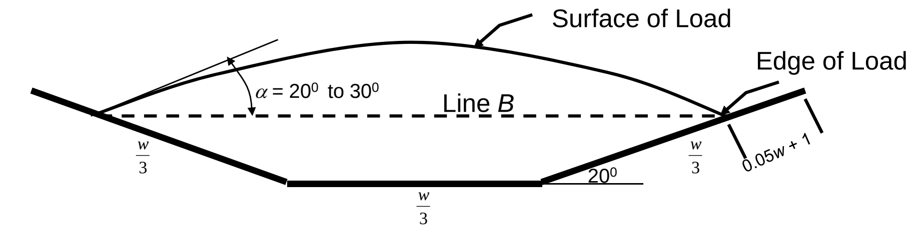
The rolls may be made of steel tubing or cast iron, either plain or covered with a composition, such as rubber, where it is necessary to protect a belt against damage due to impact



Belt Idlers

Cross-section Area of a Load on a Conveyor Belt

$\alpha =$ angle of slope



Concrete Pumping

PUMPING

Concrete Pumping

- A trailer-mounted boom concrete pump because it uses a remote-controlled articulating robotic arm (called a boom) to place concrete with pinpoint accuracy
  - Boom pumps are used on most of the larger construction projects as they are capable of pumping at very high volumes and because of the labor saving nature of the placing boom
  - They are a revolutionary alternative to truck-mounted concrete pumps

Concrete Pumping

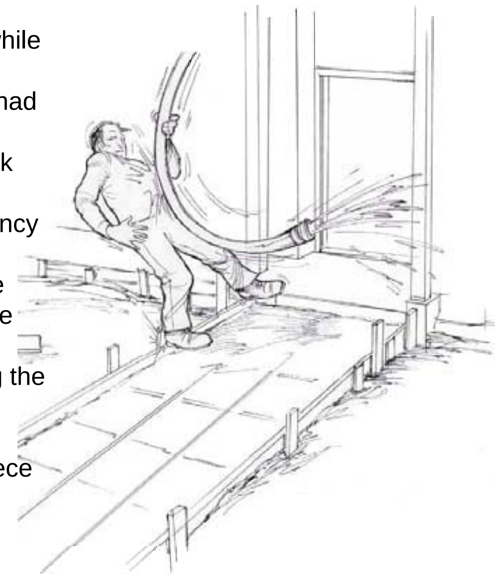
- A truck-mounted concrete pump or placed on a trailer, and it is commonly referred to as a line pump or trailer-mounted concrete pump
- This pump requires steel or rubber concrete placing hoses to be manually attached to the outlet of the machine
- Those hoses are linked together and lead to wherever the concrete needs to be placed
- Line pumps normally pump concrete at lower volumes than boom pumps and are used for smaller volume concrete placing applications such as swimming pools, sidewalks, and single family home concrete slabs and most ground slabs

Concrete Pumping-Hazards

- Electrocution (most common)
- Hose whipping out and striking someone
- Not using safety slings for hoses
- One person to give directions and to call out directions
- Not using safety protections: Hard hat; Snug-fitting work clothes; Safety goggles or safety glasses; Heavy duty work shoes or boots and gloves; Rubber boots and gloves (for clean-out); Breathing mask (if exposed to cement dust)
- Use of large aggregate or inadequate mix design
- Small discharge nozzle to prevent air from going back into the hose
- Monitoring and maintaining appropriate pressure
- Monitoring temperature of hydraulic oil while pumping
- Air entrapped in the line. Any time that air is introduced into the line, you must keep all personnel a reasonable and prudent distance from the end hose when the pump is being restarted. Air will be present in the system: When priming at the beginning of the pour; When restarting after a move; When removing system from the placing line; When opening the line to remove a blockage; When adding extra system to the line; When pumping and the hopper goes empty

Concrete Pumping-Hazards

- A concrete pump truck was pumping concrete into the walkway of a house while a worker held the end hose
- The rubber hose was 20 feet long and had a coupling device attached at the end
- The operator of the concrete pump truck noticed that the concrete had stopped flowing out, and he pushed the emergency stop button and the pumping stopped; however, compressed air trapped in the supply line behind a blockage forced the blockage to clear suddenly
- Concrete burst out of the hose, causing the hose to whip out
- The worker holding the hose fell backwards and struck his head on a piece of scrap lumber and later died of his injuries



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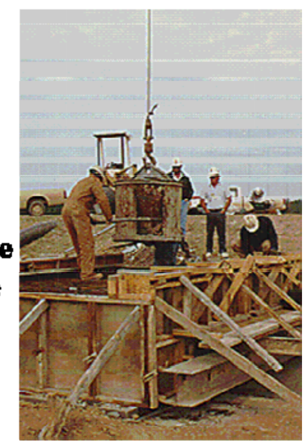
  - Cranes

Concrete Forms

Very important to prevent segregation of the coarse aggregate during placement.



Form Systems

Slipform Paver

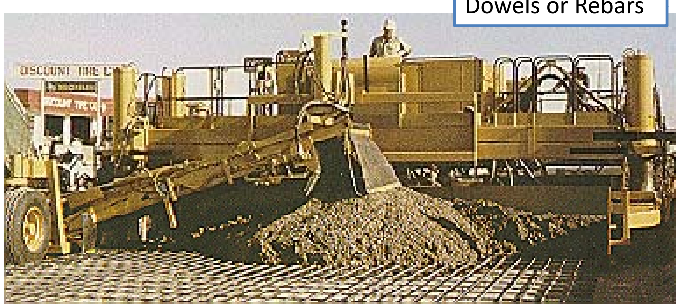
Paving a Middle Lane

Slipform Paver

Slipform Paver over Bars

Side Feeder

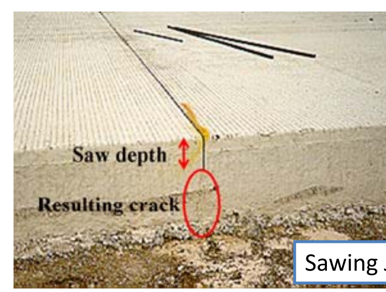
Side Feeder over Dowels or Rebars



Resulting Concrete Pavement

Smoothness

Sawing Joints



Sawing Joints

Slipform Paver

Consolidation

Consolidation is normally achieved through the use of mechanical vibrators

7000. General Construction Methods

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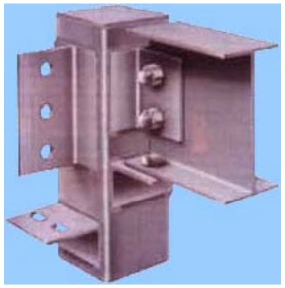
Superstructure Construction

- Steel Construction

Steel Construction

- Connections



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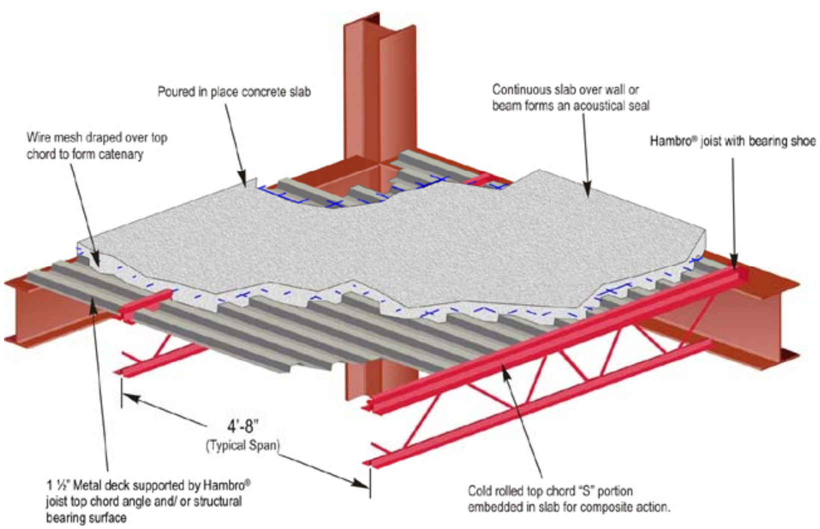
Composite Construction



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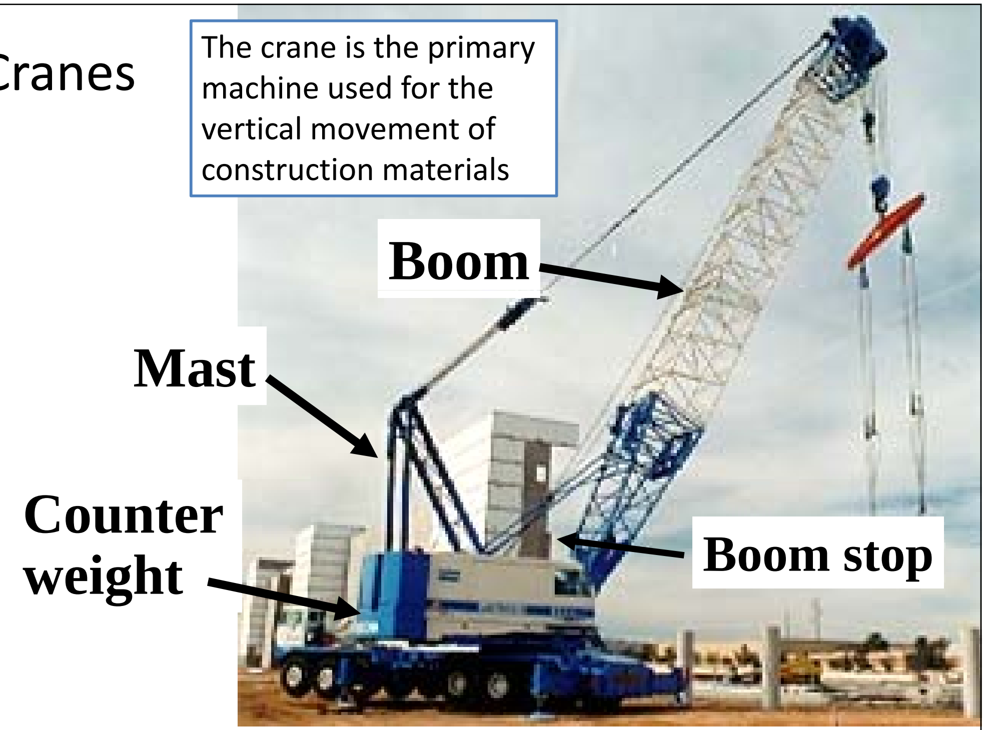
CRANES

Cranes

The crane is the primary machine used for the vertical movement of construction materials

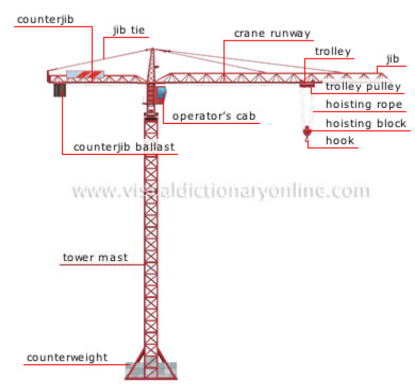


Cranes

- Each type of crane is designed and manufactured to work economically in a specific site situation
- Types:
  - Crawler
  - Hydraulic truck
  - Lattice-boom truck
  - Rough-terrain
  - All-terrain
  - Heavy lift
  - Modified cranes for heavy lift
  - Tower

Used for Modular Construction

- Tower Cranes



Used for Modular Construction

- For Cast-in-Place, Composite and Sandwich Structures

Crawler Cranes

- The *full revolving superstructure* of this type of unit is mounted on a pair of continuous parallel crawler tracks
- Manufacturers have different option packages available which permit the configuration of the crane to a particular application, standard lift, tower unit, or duty cycle
- Units in the low-to-middle range of lift capacity have good lifting characteristics and are capable of duty-cycle work such as handling a concrete bucket

Crawler Cranes

Dual hoists for large loads

Crawler Cranes

- Machines of 100-ton capacity and above are built for lift capability and do not have the heavier components required for duty-cycle work
- The universal machines incorporate heavier frames, have heavy duty or multiple clutches and brakes, and have more powerful swing systems
- These designs allow for quick changing of drum laggings which vary the torque/speed ratio of cables to the application

Hydraulic Truck Cranes

- If a job requires crane utilization for a few hours to a couple of days a hydraulic truck crane should be given first consideration because of its case of movement and setup.
- The hydraulic multisection telescoping boom is a permanent part of the full revolving superstructure. In this case the superstructure is mounted on a multiaxle truck/carrier

Lattice-Boom Truck Cranes

Rough-terrain Truck Cranes

- These cranes are mounted on two-axle carriers
- The operator's cab may be mounted in the upper works allowing the operator to swing with the load
- On many models the cab is located on the carrier. This is a simpler design because controls do not have to be routed across the turntable. In turn these units have a lower cost

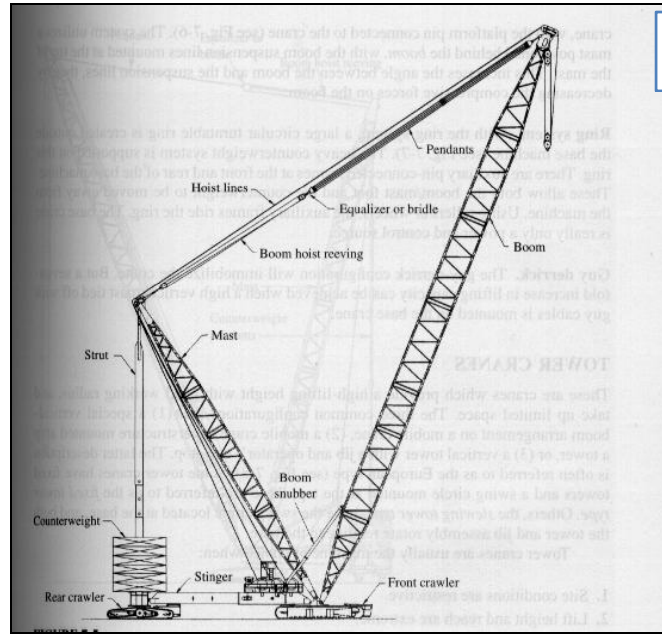
All-Terrain Truck Cranes

- The all-terrain crane is designed with an undercarriage that is capable of long-distance highway travel
- All-terrain truck carrier has four wheel-drive and four wheel-steer, large tires, and high ground clearance

Heavy Lift Cranes

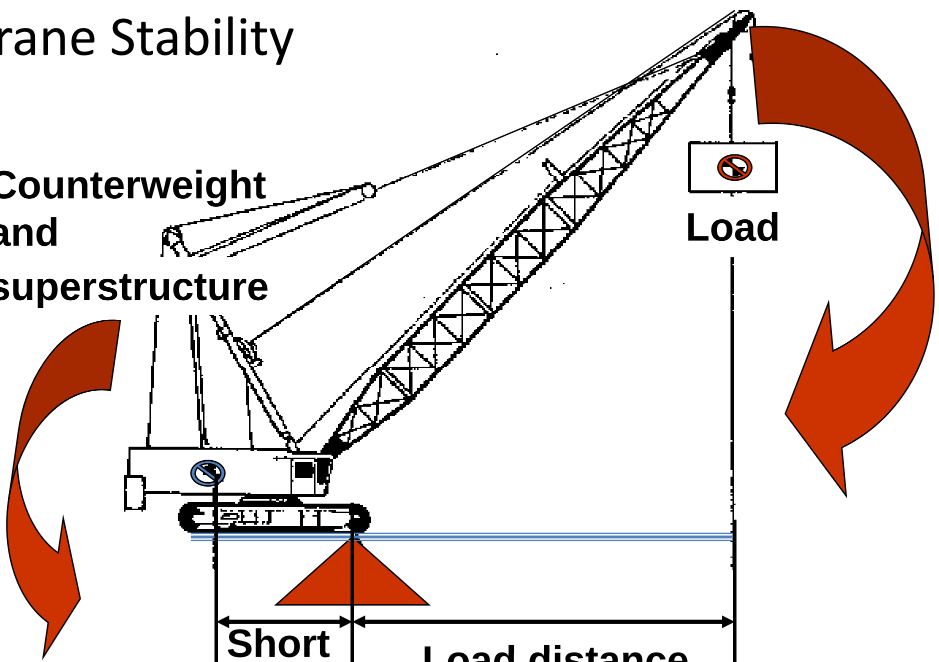
- Heavy lift cranes are machines that provide lift capacities in the 600 through 2,000 short-ton range
- Heavy lift cranes consist of a boom and counterweight each mounted on independent crawlers that are coupled by a stinger. This configuration utilizes a vertical strut and inclined mast to decrease compressive forces in the boom

Heavy Lift Cranes



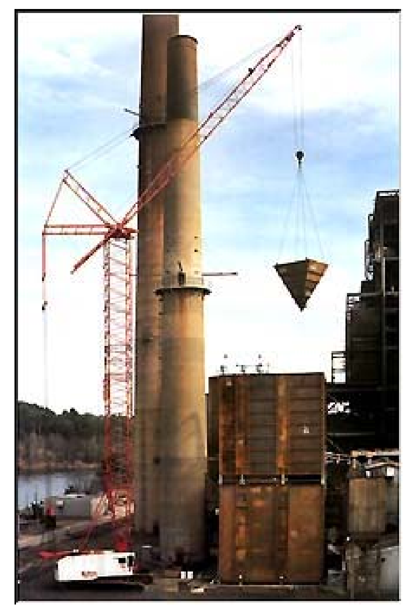
Components of Heavy Lift Crane

Crane Stability

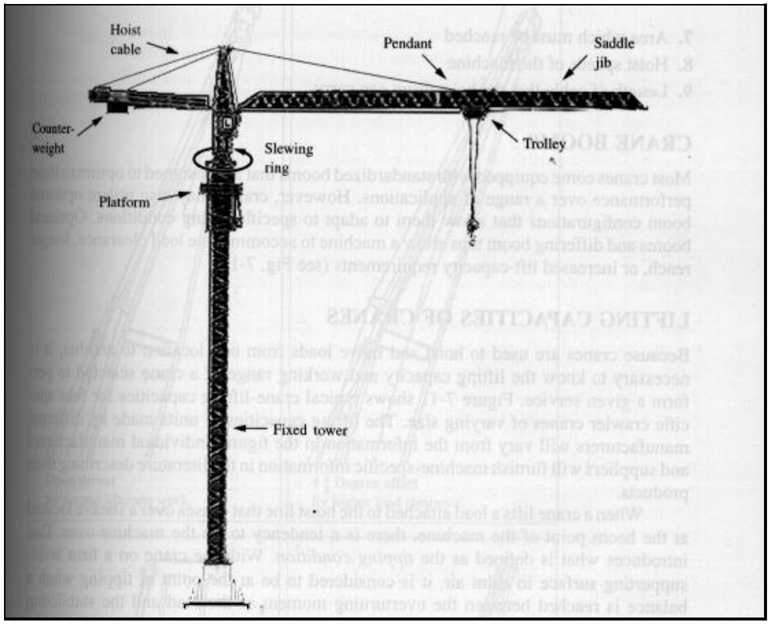


Tower Cranes

- These are cranes that provide a high-lifting height with good working radius, and take up limited space
- The three common configurations are:
  - A special vertical boom arrangement on a mobile crane
  - A mobile crane superstructure mounted atop a tower
  - A vertical tower (European type) with a jib and operator's cab atop



Components of a Tower Crane



Uses of Tower Cranes

- Tower cranes are usually the machines of choice when:
  - Site conditions are restrictive
  - Lift height and reach are extreme
  - There is no need for mobility

Crane Safety

- Crane related *fatalities:*

– Energized power lines	50%
– Overturning	19%
– Load dropped	14%
– Boom collapsed	12%
– Two-block	5%

Overturning

Crane *accidents:*

– Overturning	61.0%
– Overload	12.5%
– Rigging	12.5%
– Road accidents	10.0%

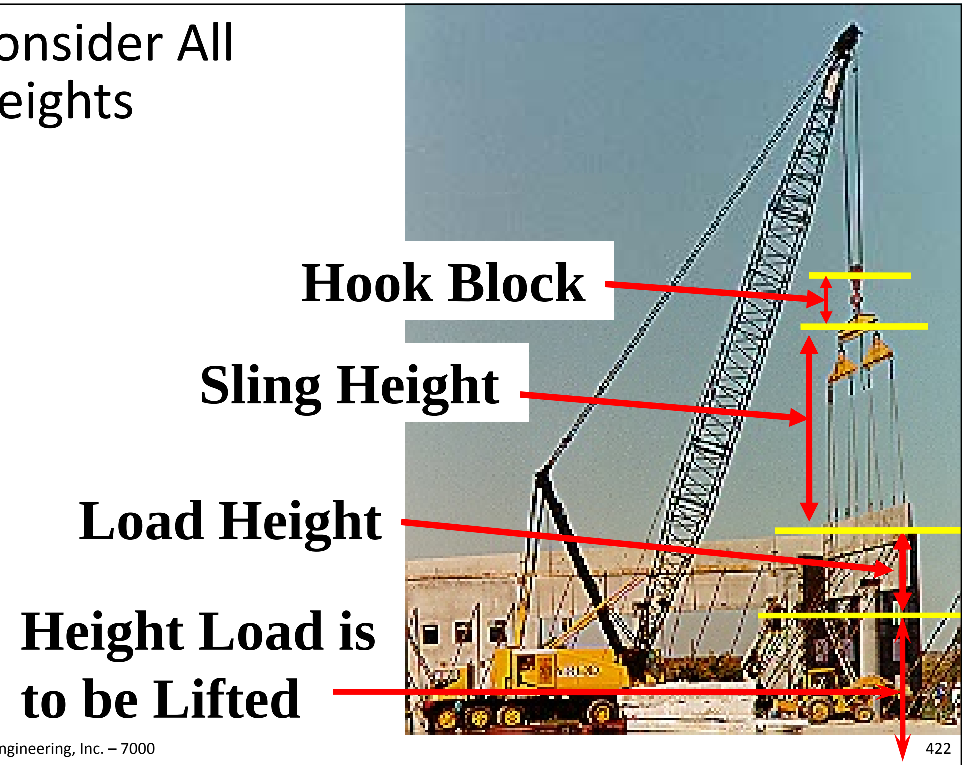
Crane Selection Factors

- Tower cranes are usually the machines of choice when:
  - Height of reach required
  - Working envelope
  - Maximum load
  - Time
  - Duty cycle

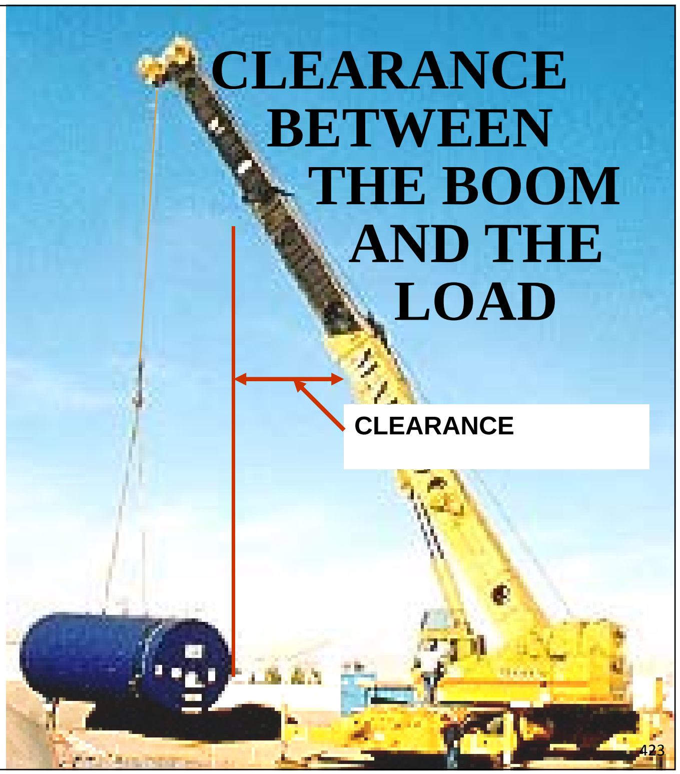
Height of Reach Required

- Tower cranes are usually the machines of choice when:
  - Height load is to be lifted
  - Height of the load
  - Sling height
  - Hook block height
  - Size of the load

Consider All Heights



Size of the Load



Rated Loads

- The rated load for a crane as published by the manufacturer is based on ideal conditions
- A partial safety factor in respect to tipping is introduced by the Power Crane and Shovel Association (PCSA) rating standards, which state that the rated load of a lifting crane shall not exceed the following percentages of tipping loads at specified radii:
  - Crawler-mounted machines, 75%
  - Rubber-tire-mounted machines 85%
  - Machines on outriggers, 85%

Rated Loads

- In addition to PCSA there are other groups that recommend rating criteria
- The Construction Safety Association of Ontario recommends that for rubber-tire-mounted machines, on rubber a factor of 0.75 should be utilized
- Load capacity will vary depending on the quadrant position of the boom with respect to the machine's undercarriage
- In the case of crawler cranes the three quadrants which should be considered are:
  - Over the side
  - Over the drive end of the tracks
  - Over the idler end of the tracks

Rated Loads: Crawler Cranes

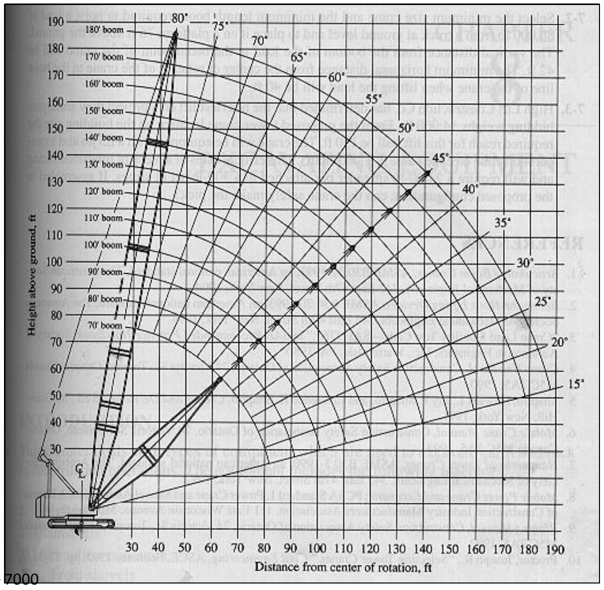
- Crawler-crane quadrants are usually defined by the longitudinal centerline of the machine's crawlers
- The area between the centerlines of the two crawlers is considered over the end and the area outside the crawler centerlines is considered over the side

Rated Loads: Wheel-Mounted Cranes

- In the case of wheel-mounted cranes the quadrants of consideration will vary with the configuration of the outrigger locations
- If a machine has only four outriggers, two on each side, one located forward and one to the rear, the quadrants are usually defined by imaginary lines running from the superstructure center of rotation through the position of the outrigger support
- In such a case the three quadrants to consider are:
  - Over the side
  - Over the rear (of the carrier)
  - Over the front (of the carrier)

A Sample Load Range Chart

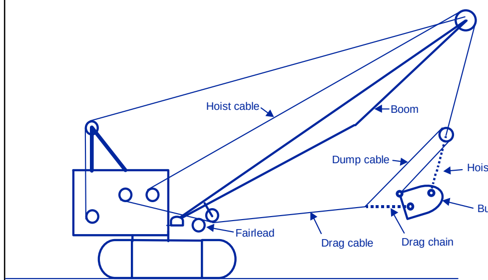
Working Ranges for a 200-ton Crawler Crane (Manitowoc Eng. Co)

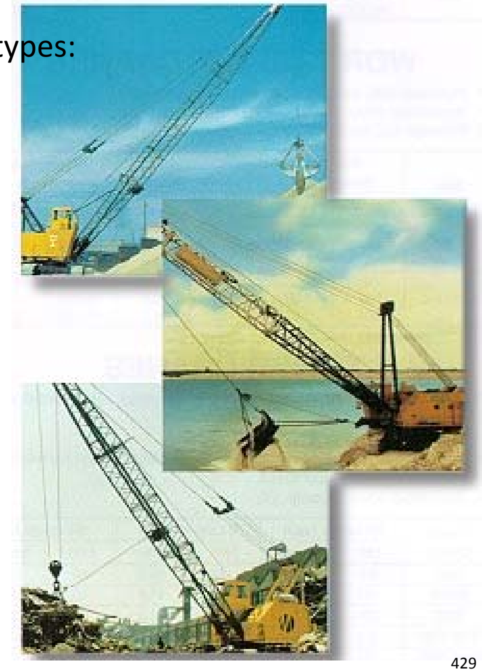


Dragline, Clamshell And Magnet Cranes

Draglines may be divided into three types:

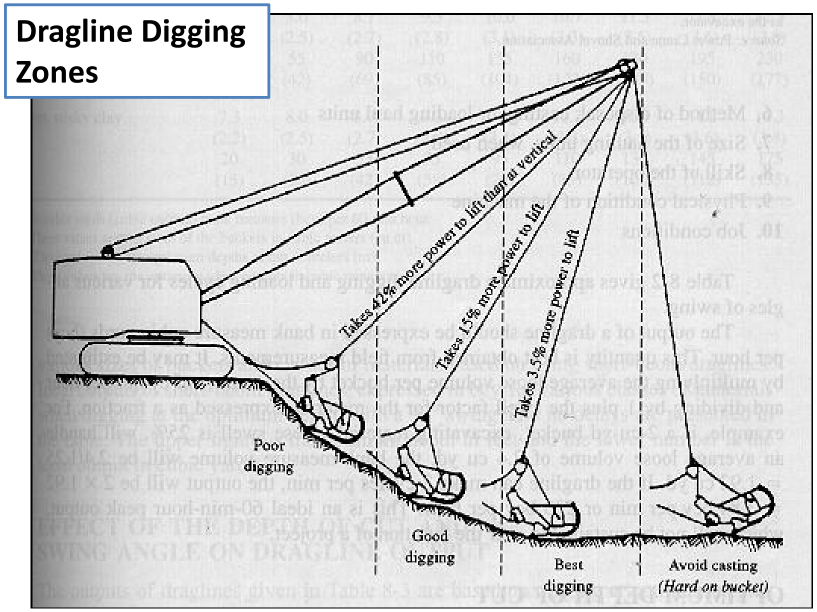
- Crawler-mounted
- Wheel-mounted, self-propelled
- Truck-mounted



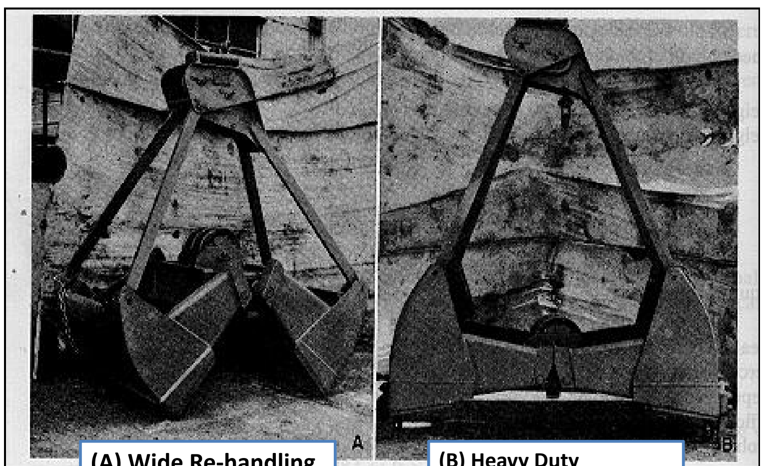


Operation Of A Dragline

Dragline Digging Zones



Clamshells



(A) Wide Re-handling Clamshell bucket

(B) Heavy Duty Clamshell Bucket

Production Rates for Clamshells

- Because of the variable factors which affect the operations of a clamshell, it is difficult to give dependable production rates
- The variable factors affecting operations include:
  - The difficulty of loading the bucket
  - The size load obtainable
  - The height of lift
  - The angle of swing
  - The method of disposing of the load
  - The experience of the operator

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7000. General Construction Methods

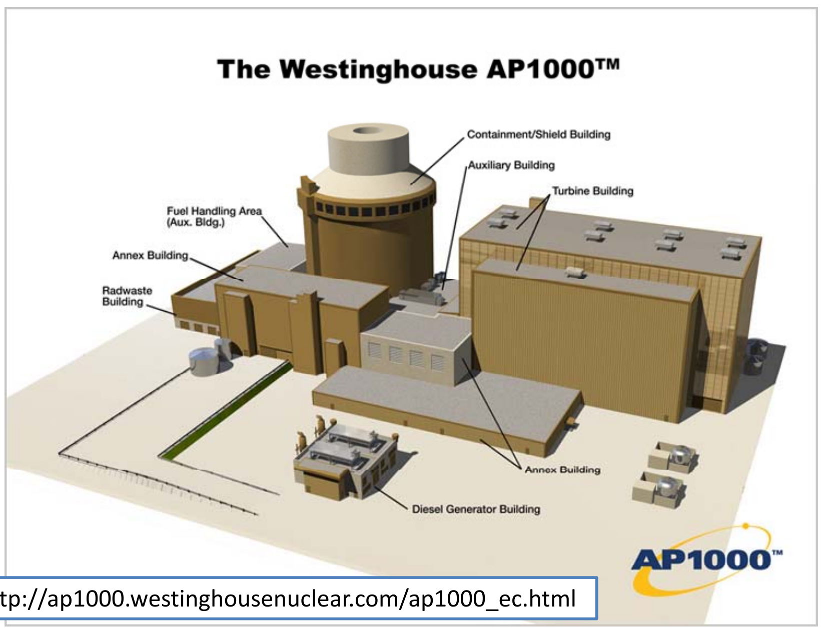
- **Advanced construction methods**

Table ...: Reactors built recently using advanced construction methods [References: 1, 2, 3, 4, 5]

Reactor	Country	Construction period (months)*	Start of commercial operation	Type of reactor (approx. MW(e)) **
Kasiwazaki Kariwa-6	Japan	48	Nov. 1996	ABWR (1350)
Kasiwazaki Kariwa-7	Japan	48	Jul. 1997	ABWR (1350)
Lingao-1	China	60	May 2002	PWR (1000)
Lingao-2	China	62	Jan. 2003	PWR (1000)
Qinshan 3-1	China	54	Dec. 2002	PHWR (720)
Qinshan 3-2	China	58	Jul. 2003	PHWR (720)
Tarapur-3	India	75	Aug. 2006	PHWR (540)
Tarapur-4	India	66	Sep. 2005	PHWR (540)
Shin Kori-1	Republic of Korea	54 (planned)	Dec. 2010 (planned)	PWR (1000)
Olkiluoto-3	Finland	70 (planned)	Jun. 2012 (planned)	EPR (1600)
Kudankulam-1	India	84 (planned)	Mar. 2009 (planned)	PWR (917)

* The construction period is generally considered to be the time from the first major pour of concrete for the main plant building to the commercial operation date.
** ABWR = advanced boiling water reactor; EPR = European pressurized water reactor; PHWR = pressurized heavy water reactor; PWR = pressurized water reactor

Advanced Construction Methods



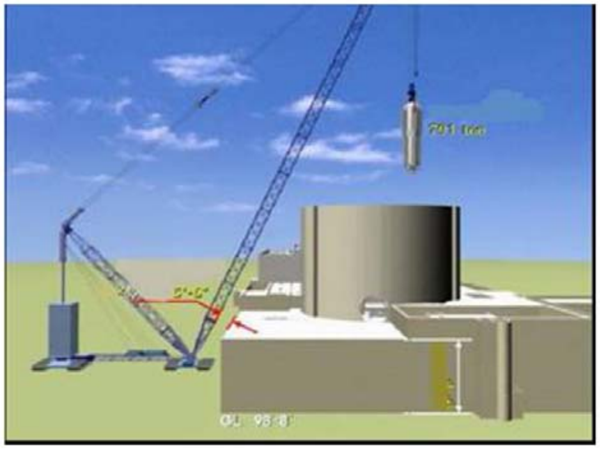
http://ap1000.westinghousenuclear.com/ap1000_ec.html

Advanced Construction Methods

- Open Top Installation
  - Constraints on installing major components inside the reactor and containment building can have a major impact on the construction schedule
  - In the past, the walls of the reactor and containment building were constructed with temporary openings to allow the entry of large equipment
  - In open top installation, the reactor and containment building is built with a temporary roof with an opening through which major pieces of equipment, such as the reactor vessel and steam generators, can be lowered into position using very heavy lift (VHL) cranes.
  - Today's VHL cranes can lift equipment weighing more than 1000 tonnes, with very long reach

Advanced Construction Methods

- Open Top Installation



Advanced Construction Methods

- Open Top Installation
- Very Heavy Lift Cranes

Advanced Construction Methods

- Modularization with Prefabrication and Pre-assembly
  - A module is an assembly consisting of multiple components such as structural elements, piping, valves, tubing, conduits, cable trays, reinforcing bar mats, instrument racks, electrical panels, supports, ducting, access platforms, ladders and stairs
  - Modules may be fabricated at a factory or at a workshop at the plant site, and multiple modules can be fabricated while the civil engineering work is progressing at the site in preparation for receiving the modules
  - This reduces site congestion, improves accessibility for personnel and materials, and can shorten the construction schedule. It can also significantly reduce on-site workforce requirements

Advanced Construction Methods

- Advanced Welding Technology
  - Nuclear power plant construction involves numerous welds to connect both components of structures and components of pressurized systems. It also involves weld cladding, which refers to one metal being deposited onto the surface of another to improve its performance characteristics
  - Quality welding is both crucial and time consuming, and techniques to increase the rate at which weld metal can be deposited while maintaining high quality can reduce construction times
  - Recent advanced welding technologies that meet this objective include gas metal arc welding, gas tungsten arc welding and submerged arc welding
  - In addition, automatic welding equipment that makes it easier to weld in narrow spaces can further decrease construction times

Advanced Construction Methods

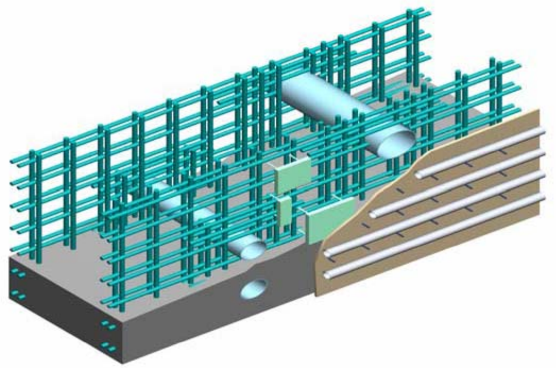
- Steel Plate Reinforced Concrete and Slip-forming
- Composite Construction

Advanced Construction Methods

- Reinforcement Details

Advanced Construction Methods

- Steel-Plate Reinforced Concrete Structures



Advanced Construction Methods

- Steel-Plate Reinforced Concrete Structures

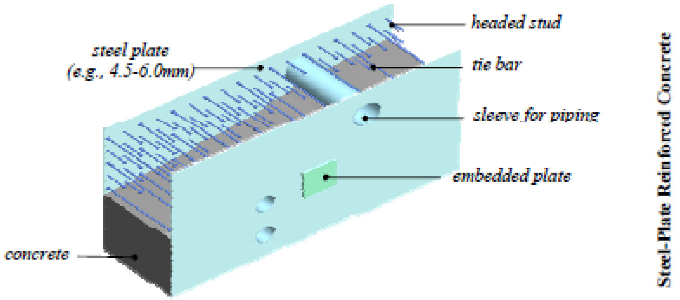
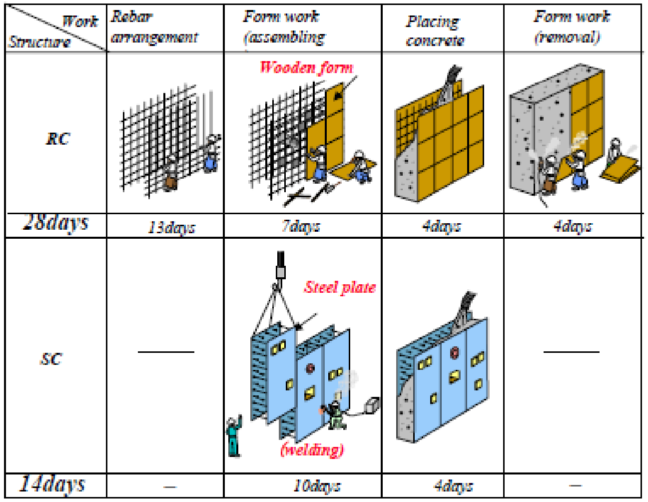


Figure A-1. Comparison of Reinforced Concrete Construction (Reference 1)

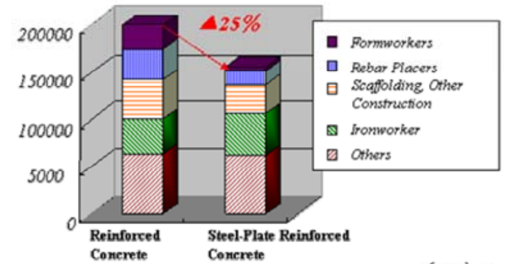
Advanced Construction Methods

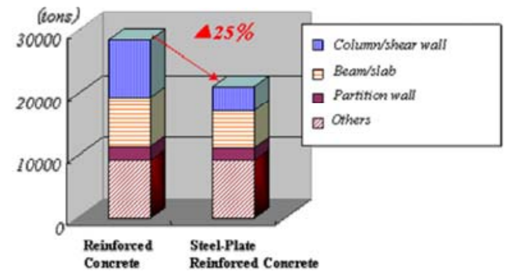
- Comparison of Construction Schedule



Advanced Construction Methods

- Comparison of Construction Schedule





Advanced Construction Methods

- Advanced Concrete Composition
  - Advances in the composition of concrete to improve strength, workability, and corrosion resistance
  - Examples are self-compacting concrete, high performance concrete and reactive powder concrete
  - These are used not only in nuclear power plants but in other large civil projects such as bridges, highway, large buildings and dams

Advanced Construction Methods

- All Weather Construction and Working Around the Clock
  - To ensure that work can continue in all weather conditions, an all weather cover dome can be put over the reactor building
  - This method was used, for example, at Kashiwazaki-Kariwa-6 in Japan
  - Working around the clock, both indoors and outdoor, can save considerable time at critical stages of construction, for example during excavation, concrete pouring, structural steel erection, and various welding activities

Advanced Construction Methods

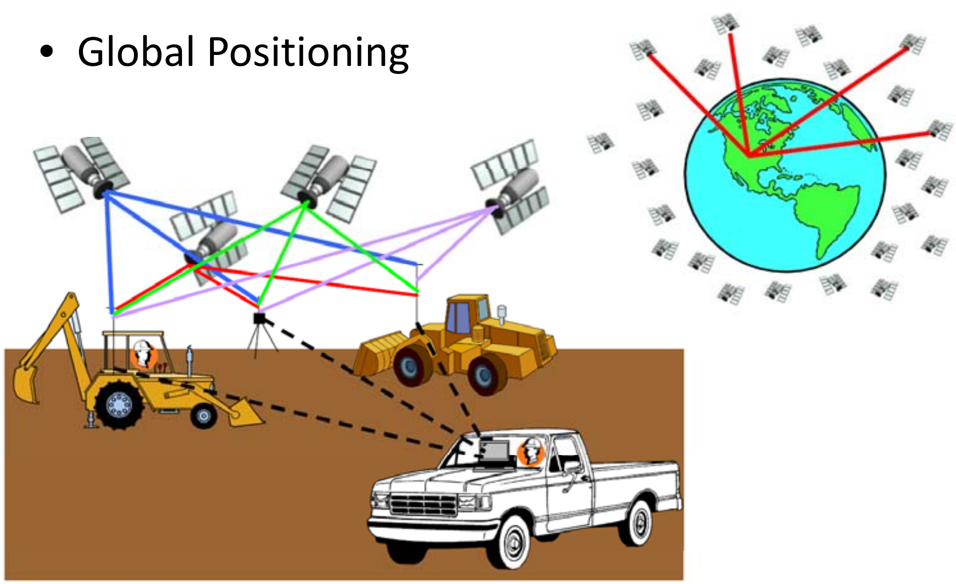
- Advanced Excavation Methods
  - The area completion schedule management method has been applied in the Republic of Korea at Shin-Kori-1 and -2
  - This approach replaces design and procurement schedules that used to progress system by system or, for a given building, floor by floor with an approach that divides each level of each building into zones
  - This allows more detailed scheduling of material purchase and the issuance of construction drawings to best integrate requirements in all zones
  - The approach is also used to schedule integrated installation work and set priorities among civil, mechanical, electrical and other needed work in each zone

Advanced Construction Methods

- Prefabricated Fiber Reinforced Concrete

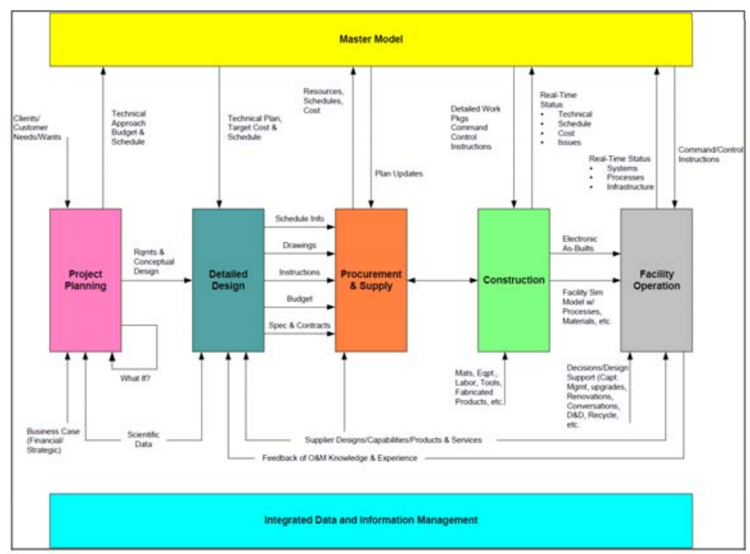
Advanced Construction Methods

- Global Positioning



Advanced Construction Methods

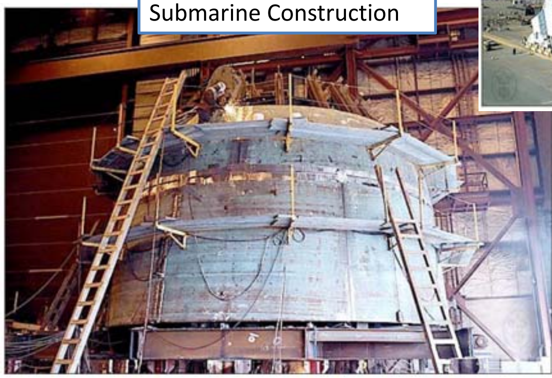
- Information Management



Advanced Construction Methods

- Modular Construction

Ship Construction

Submarine Construction


Advanced Construction Methods

- Refer to the following Handout:

  Advanced Construction Methods for New Nuclear Power Plants, AdvancedConstruction.pdf from http://www.iaea.org

7000. General Construction Methods

- Objective and Scope Met
  - Fundamental and analytical methods for defining <u>means and methods</u> for the planning, selection and utilization of construction equipment and methods
  - Present and discuss
    - General construction methods at different project stages
    - Selected construction equipment
    - Construction safety relating to equipment operation

7000. General Construction Methods

- Objective and Scope Met (cont.)
  - Items not covered:
    - Engineering economics
    - Planning
    - Cost analysis

7000. General Construction Methods

- 7100 — Site preparation: earthwork and equipment
- 7200 — Substructure construction: foundations
- 7300 — Superstructure construction
- 7400 — Advanced construction methods

Overall Outline