Excavating and Lifting

Introduction

- Excavator: A power-driven digging machine
- Three Major types of excavators:
  - Hydraulic excavators: backhoe
  - Cable-operated crane-shovel family
    - Shovels
    - Draglines
    - Hoes
    - Clamshells
  - Dozers, loaders, and scrapers
Introduction II

Figure 3-1  Hydraulic excavator. (Courtesy of Volvo Construction Equipment North America, Inc.)

Introduction III

Dragline

Clamshell

Figure 3-7  Components of a hydraulic shovel.
Hydraulic vs. Cable Operated Excavators

- Advantages of hydraulic excavators over cable operated machines
  - Faster cycle time
  - Higher bucket penetrating force
  - More precise digging
  - Easier operator control

Excavator and Crane-shovels

- Excavators and crane-shovels consist of three major assemblies:
  - Carrier/Mounting: includes crawler, truck, and wheel mountings
  - Revolving Superstructure contains the power and control units (Revolving deck or turntable)
  - Front-end Assembly
Excavator and Crane-shovels II

• Crawler mountings
  – Provides excellent on-site mobility,
  – Its low ground pressure enables it to operate in areas of low trafficability
  – Widely used for drainage and trenching work as well as for rock excavation

• Truck and wheel mountings
  – Provides greater mobility between job sites
  – Less stable than crawler mountings
  – Requires better surfaces over which to operate

Excavator and Crane-shovels III

• Truck vs. wheel mountings
  – Truck mountings
    • Use modified truck chassis as a carrier
    • Separate stations for operating the carrier and the revolving superstructure
    • Capable of highway travel of 80 km/h or more
  – Wheel mountings
    • Single operator’s station to control both the carrier and the revolving superstructure
    • Highway travel is limited to 48 km/h or less
**Excavator Production**

- Production = 
  Volume per cycle x cycles per hr x E

- We need to know the volume of material actually contained in one bucket load:
  - Plate line capacity
  - Struck capacity
  - Water line capacity
  - Heaped volume

**Excavator Production II**

- Plate line capacity
  - Bucket volume contained within the bucket when following the outline of the bucket sides

- Struck capacity
  - Bucket capacity when the load is struck off flush with the bucket sides; no allowance for bucket teeth
Excavator Production III

• Water line capacity
  – Assumes a level of material flush with the lowest edge of the bucket
  – Material level corresponds to the water level that would result if the bucket were filled with water

• Heaped volume
  – The maximum volume that can be placed in the bucket without spillage based on a specified angle of repose for the material in the bucket

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Excavator Production IV

• Bucket fill factors were developed to make it easier for us to estimate the volume of material in one bucket load

• The nominal bucket volume is multiplied by a bucket fill factor (bucket efficiency factor) to estimate the volume of material in one bucket load

<table>
<thead>
<tr>
<th>Material</th>
<th>Bucket Fill Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common earth, loam</td>
<td>0.80–1.10</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>0.90–1.00</td>
</tr>
<tr>
<td>Hard clay</td>
<td>0.65–0.95</td>
</tr>
<tr>
<td>Wet clay</td>
<td>0.50–0.90</td>
</tr>
<tr>
<td>Rock, well-blasted</td>
<td>0.70–0.90</td>
</tr>
<tr>
<td>Rock, poorly blasted</td>
<td>0.40–0.70</td>
</tr>
</tbody>
</table>
Hydraulic Excavators (Backhoe)

- The most common form is the backhoe
  - Primarily designed to excavate below grade
  - Positive digging action
  - Precise lateral control
  - It digs by pulling the bucket back toward the machine

Hydraulic Excavators (Backhoe) II

- The backhoe is widely used for trenching work
  - Excavating trenches
  - Laying pipe bedding
  - Placing pipe
  - Pulling trench shields
  - Backfilling the trench

- The best measure of production in trench excavation is the length of trench excavated per unit of time
- Therefore, the dipper width should be chosen which matches the required trench width as closely as possible
Mini excavators

- Advantages:
  - Compact size
  - Hydraulic power
  - Light weight
  - Maneuverability
  - Versatility
  - Ability to operate with full 360-degree swing
  - Low ground pressure

Hydraulic Excavators (Backhoe) III

Production Estimating

Production (LCM/h) = C x S x V x B x E

Where
C = cycles/h
S = swing-depth factor
V = heaped bucket volume (LCM)
B = bucket fill factor
E = job efficiency
Hydraulic Excavators (Backhoe) V

• Finding “Cycles per hour”
• Prepared from manufacturing data
• “C” depends on:
  – Type of material
  – Machine size

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Wheel Tractor</th>
<th>Small Excavator: 1 yd (0.76 m³) or Less</th>
<th>Medium Excavator: 1½–2½ yd (0.94–1.72 m³)</th>
<th>Large Excavator: Over 2½ yd (1.72 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft (sand, gravel, loam)</td>
<td>170</td>
<td>250</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>Average (common earth, soft clay)</td>
<td>135</td>
<td>200</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>Hard (tough clay, rock)</td>
<td>110</td>
<td>160</td>
<td>130</td>
<td>100</td>
</tr>
</tbody>
</table>

Hydraulic Excavators (Backhoe) VI

• Finding “Swing-depth factor”
• “S” depends on:
  1. Depth of cut as a % of maximum
  2. Angle of swing: angle between digging and dumping positions

<table>
<thead>
<tr>
<th>Depth of Cut (% of Maximum)</th>
<th>45</th>
<th>60</th>
<th>75</th>
<th>90</th>
<th>120</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.33</td>
<td>1.26</td>
<td>1.21</td>
<td>1.15</td>
<td>1.08</td>
<td>0.95</td>
</tr>
<tr>
<td>60</td>
<td>1.28</td>
<td>1.21</td>
<td>1.16</td>
<td>1.10</td>
<td>1.03</td>
<td>0.91</td>
</tr>
<tr>
<td>70</td>
<td>1.16</td>
<td>1.10</td>
<td>1.05</td>
<td>1.00</td>
<td>0.94</td>
<td>0.83</td>
</tr>
<tr>
<td>90</td>
<td>1.04</td>
<td>1.00</td>
<td>0.95</td>
<td>0.90</td>
<td>0.85</td>
<td>0.72</td>
</tr>
</tbody>
</table>
Hydraulic Excavators (Backhoe) VII

1. Depth of cut as a percentage of maximum
   • Manufacturers publish maximum depth of cut for each machine, bucket size, and material
2. Angle of swing: angle between digging and dumping positions
   • The smaller the angle, the higher the production

<table>
<thead>
<tr>
<th>Depth of Cut (% of Maximum)</th>
<th>Angle of Swing (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45</td>
</tr>
<tr>
<td>30</td>
<td>1.33</td>
</tr>
<tr>
<td>50</td>
<td>1.28</td>
</tr>
<tr>
<td>70</td>
<td>1.16</td>
</tr>
<tr>
<td>90</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Hydraulic Excavators (Backhoe) VIII

• Adjustment factor for trench production
  – In trenching work, a fall-in factor should be applied to excavator production to account for the work required to clean out material that falls back into the trench from the trench walls
  – Production should be multiplied by the adjustment factor

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose (sand, gravel, loam)</td>
<td>0.60–0.70</td>
</tr>
<tr>
<td>Average (common earth)</td>
<td>0.90–0.95</td>
</tr>
<tr>
<td>Firm (firm plastic soils)</td>
<td>0.95–1.00</td>
</tr>
</tbody>
</table>
• Example 3-2
Find the expected production in LCM/h of a small hydraulic excavator. Heaped bucket capacity is 0.57 m$^3$. The material is sand and gravel with a bucket fill factor of 0.95. Job efficiency is 50 min/hr. Average depth of cut is 4.3 m. Maximum depth of cut is 6.1 m and average swing is 90°.

Solution

Production (LCM/h) = C x S x V x B x E

= 250 x 1 x 0.57 x 0.95 x (50/60)

= 112.8 LCM/h
Problem 8

A hydraulic excavator-backhoe is excavating the basement for a building. Heaped bucket capacity is 1.15 m$^3$. The material is common earth with a bucket fill factor of 0.9. Job efficiency is estimated to be 50 min/hr. The machine’s maximum depth of cut is 7.3 m and the average digging depth is 4.0 m. Average swing angle is 90°. Estimate the hourly production in bank measure.

Solution

Standard cycles/h = 160
%maximum depth = 4/7.3 = 0.55
Swing-depth factor = 1.075
Heaped bucket volume = 1.15 LCM
Bucket fill factor = 0.9
Job efficiency = 50/60
Load factor = 0.8

Production (BCM/h)
= C x S x V x B x E x load factor
= 160 x 1.075 x 1.15 x 0.90 x (50/60) x 0.8
= 118.7 BCM/h
Example
A small hydraulic excavator will be used to dig a trench in soft clay (bucket fill factor is 0.9) The minimum trench size is 0.61 m wide by 1.83 m deep. The excavator bucket available is 0.76 m wide and has a heaped capacity of 0.57m³. The maximum digging depth of the excavator is 5.3 m. The average swing angle is expected to be 90°. Estimate the hourly trench production in linear meters if job efficiency is 50 min/h

Solution
Production (BCM/h)
= C x S x V x B x E x adj factor for trench
= 200 x 1.14 x 0.57 x 0.90 x (50/60) x 0.925
= 90 LCM/h

= 90 (LCM/h) * 0.77 (load factor for clay) = 69.3 BCM/h
= 69.3 (BCM/h) / (0.76 x 1.83)
=49.8 linear meter / hr
Hydraulic Excavators (Backhoe) XV

Job Management

• In selecting the proper excavator for a project, consideration must be given to:
  – Maximum depth
  – Working radius
  – Dumping height required
  – Adequate clearance for the carrier, superstructure, and boom during operation

• When lifting pipe into place do not exceed load given in the manufacturer’s safe capacity for the situation

Shovels I

• The shovel is mostly used for:
  – Hard digging above track level
  – Loading haul units

• The ability of the shovel to form its own roadway as it advances is a major advantage
Shovels II

• Shovels are capable of developing high breakout force with their buckets
  – However, the material being excavated should be such that it will stand as a vertical bank (i.e., a wall of material that stands perpendicular to the ground)
  – We call such a wall: digging face
  – Digging face is easily formed when digging a bank or hillside
  – When the material to be excavated is located below ground level, the shovel must dig a ramp down into the material until a digging face of suitable height is created (ramping down)

Shovels III

• Shovel buckets can be front-dump or bottom-dump:

  • Front-dump
  • Lighter
  • Has a production advantage
  • Lower Cost
  • Requires less maintenance

• Bottom-dump
  • Provide greater reach and dump clearance
  • Produce less spillage

Figure 3-7 Components of a hydraulic shovel.
Shovels IV

- Selecting a shovel: In selecting a shovel, two main factors should be considered:
  - Cost per cubic meter
  - Job conditions under which the shovel will operate

Shovels V

- Cost per cubic meter: One should consider the following factors:
  - The size of the job; a job that involves large quantity of material may justify the higher cost of a larger shovel
  - The cost of transporting the machine; a large shovel will involve more cost than a smaller one
  - The combined cost of drilling, blasting, and excavating; for a large shovel, these costs may be less than for a small shovel, as a large machine will handle more massive rocks than a small one. Large shovel may permit savings in drilling and blasting
Shovels VI

Job conditions under which the shovel will operate: The following job conditions should be considered:

- If the material is hard to excavate, the bucket of the large shovel that has higher digging pressure will handle the material more easily.
- If the blasted rock is to be excavated, the large-size bucket will handle larger individual pieces.
- The size of available hauling units should be considered in selecting the size of a shovel:
  - Small hauling units/ small shovel; vice versa.
  - The haul unit capacity should be approximately five times excavator bucket size.

Shovels VII

Production Estimating

Production (LCM/h) = \( C \times S \times V \times B \times E \)

Where

- \( C \) = cycles/h
- \( S \) = swing-depth factor
- \( V \) = heaped bucket volume (LCM)
- \( B \) = bucket fill factor
- \( E \) = job efficiency
Production (LCM/h) = C x S x V x B x E

Example:
Find the expected production in LCM/h of a 2.3 m³ hydraulic shovel equipped with a front-dump bucket. The material is common earth with a bucket fill factor of 1.0. The average angle of swing is 75° and job efficiency is 0.8.
**Solution:**
Production (LCM/h) = C x S x V x B x E

\[= 150 \times 1.05 \times 2.3 \times 1.0 \times 0.8\]

\[= 289.8 \text{ LCM/h}\]

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**Problem 2:**
A 2.68 m³ (heaped) hydraulic shovel with a bottom dump bucket is excavating tough clay. The swing angle is 120°, and job efficiency is 75%. Estimate the shovel’s hourly production in bank measure.
\[ \text{Solution:} \]
Production (BCM/h)  
\[ = C \times S \times V \times B \times E \times \text{load factor} \]
\[ = 150 \times 0.94 \times 2.68 \times 0.8 \times 0.75 \times 0.77 \]
\[ = 174.6 \text{ BCM/h} \]

Shovels XIV

Job management

- The two major factors controlling shovel production are:
  - Swing angle between digging and dumping: should be kept to a minimum
  - Lost time during the production cycle: haul units must be positioned to minimize the time lost as units enter and leave the loading position