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. This is a prerequisite of a good machine.
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.

Typical project applications are:
- Land clearing
- Dozing (pushing materials)
- Ripping
- Towing other pieces of construction equipment, and
- Assisting scrapers in loading.
CHAPTER 6. DOZERS

DOZING

Pushing material
CHAPTER 6. DOZERS

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
CHAPTER 6. DOZERS

TYPES OF DOZERS

Wheel-type tractor  Crawler-type tractor

PERFORMANCE CHARACTERISTICS OF TRACTORS

The usable force available to perform work is often limited by traction. This limitation is dependent on the coefficient of traction of the surface being traversed and on the weight carried by the drive wheels.
CHAPTER 6. DOZERS

PERFORMANCE CHARACTERISTICS OF TRACTORS

- Traction or requirements can also be met by proper tire selection. Wider tires provide greater contact area and increase flotation.
- It should be noted, that rimpull charts are based on standard equipment including tires. Larger tires will reduce developed rimpull.

CRAWLER DOZERS

- Suitable for jobs that require high tractive effort.
- Rated by size and weight.
- Weight is important:
  - Tractive effort is a function of weight and coefficient of traction.
  \[
  \text{Tractive Effort (Force)} = \text{Coefficient of Traction} \times \text{Weight}
  \]
CRAWLER DOZERS

Table 1. Coefficient of Traction for Various Surfaces

<table>
<thead>
<tr>
<th>Surface</th>
<th>Rubber Tires</th>
<th>Crawler Tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry, rough concrete</td>
<td>0.80 – 1.00</td>
<td>0.45</td>
</tr>
<tr>
<td>Dry, clay</td>
<td>0.50 – 0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>Wet, clay</td>
<td>0.40 – 0.50</td>
<td>0.70</td>
</tr>
<tr>
<td>Wet sand and gravel</td>
<td>0.30 – 0.40</td>
<td>0.35</td>
</tr>
<tr>
<td>Loose, dry sand</td>
<td>0.30 – 0.50</td>
<td>0.30</td>
</tr>
<tr>
<td>Dry snow</td>
<td>0.20</td>
<td>0.15 – 0.35</td>
</tr>
<tr>
<td>Ice</td>
<td>0.10</td>
<td>0.10 – 0.25</td>
</tr>
</tbody>
</table>

TYPES OF CRAWLER DOZERS

1. Crawler tractors with direct drive

Some manufacturers' specifications list two sets of drawbar pulls (rated and maximum). Rated pull should be used for continuous operation, while the maximum is the drawbar pull that is exerted for a short time period while the engine is lugged.
TYPES OF CRAWLER DOZERS

2. Crawler dozers with torque converters and power-shift transmission.

Torque-converter drives and power-shift transmission eliminates shifting of gears. They allow for automatic selection of speed which is best suited for the load pulled by the tractor.

Note: The available pull which a crawler dozer can exert on a load that is being towed is called the drawbar pull of a tractor.

PERFORMANCE DATA - CRAWLER

Specifications and Performance Data for Three Crawler Tractors Equipped with Direct Drive

<table>
<thead>
<tr>
<th>Approximate operating weight (lb)</th>
<th>18,500</th>
<th>32,000</th>
<th>47,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flywheel (hp)</td>
<td>93</td>
<td>160</td>
<td>235</td>
</tr>
<tr>
<td>Drawbar (hp)</td>
<td>75</td>
<td>128</td>
<td>187</td>
</tr>
<tr>
<td>Ratio (lb/hp)</td>
<td>197</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

Performance Data

<table>
<thead>
<tr>
<th>Gear, forward</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1.7</td>
<td>150</td>
<td>1.5</td>
<td>132</td>
<td>1.5</td>
<td>132</td>
</tr>
<tr>
<td>Second</td>
<td>2.7</td>
<td>238</td>
<td>2.2</td>
<td>193</td>
<td>1.9</td>
<td>152</td>
</tr>
<tr>
<td>Third</td>
<td>3.2</td>
<td>326</td>
<td>3.1</td>
<td>272</td>
<td>2.7</td>
<td>238</td>
</tr>
<tr>
<td>Fourth</td>
<td>5.2</td>
<td>458</td>
<td>4.6</td>
<td>405</td>
<td>3.5</td>
<td>307</td>
</tr>
<tr>
<td>Fifth</td>
<td>6.8</td>
<td>598</td>
<td>5.9</td>
<td>518</td>
<td>4.6</td>
<td>405</td>
</tr>
<tr>
<td>Six</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gear, reverse</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
<th>Speed mph</th>
<th>Drawbar pull (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>2.1</td>
<td>185</td>
<td>1.8</td>
<td>158</td>
<td>1.5</td>
<td>132</td>
</tr>
<tr>
<td>Second</td>
<td>3.3</td>
<td>290</td>
<td>2.5</td>
<td>220</td>
<td>2.6</td>
<td>176</td>
</tr>
<tr>
<td>Third</td>
<td>4.6</td>
<td>405</td>
<td>3.7</td>
<td>325</td>
<td>2.7</td>
<td>238</td>
</tr>
<tr>
<td>Fourth</td>
<td>6.4</td>
<td>563</td>
<td>5.4</td>
<td>475</td>
<td>3.6</td>
<td>317</td>
</tr>
<tr>
<td>Fifth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Usable pull will depend on weight and traction of fully equipped tractor.
CHAPTER 6. DOZERS

PERFORMANCE DATA - CRAWLER

Performance Chart for a 200HP 45,560 lb Track-Type Dozer with Power Shift (Caterpillar, Inc)

Figure 1:

WHEEL DOZERS

- Most wheel dozers (tractors) are equipped with torque converters and power-shift transmissions, some are direct drive. For this reason their performance is different.
PERFORMANCE DATA - WHEEL-TYPE DOZERS

Specifications for Single-Axle Tractors

| Approximate operating weight (lb) | 32,200 | 17,740 |
| Engine (hp)                     | 275     | 180     |
| Ratio (lb/hp)                    | 117     | 198     |
| Tire Sizes (in)                  | 24 X 29 | 21 X 25 |

Performance Data

<table>
<thead>
<tr>
<th>Speed Gear</th>
<th>Speed mph</th>
<th>Speed Km/h</th>
<th>Rimpull (lb)</th>
<th>Speed mph</th>
<th>Speed Km/h</th>
<th>Rimpull (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>2.16</td>
<td>3.48</td>
<td>25,000</td>
<td>3.41</td>
<td>5.50</td>
<td>15,850</td>
</tr>
<tr>
<td>Second</td>
<td>4.18</td>
<td>6.73</td>
<td>17,100</td>
<td>7.25</td>
<td>11.70</td>
<td>7,450</td>
</tr>
<tr>
<td>Third</td>
<td>7.15</td>
<td>11.50</td>
<td>10,050</td>
<td>12.63</td>
<td>20.35</td>
<td>4,280</td>
</tr>
<tr>
<td>Fourth</td>
<td>12.18</td>
<td>19.60</td>
<td>5,880</td>
<td>22.28</td>
<td>35.90</td>
<td>2,420</td>
</tr>
<tr>
<td>Fifth</td>
<td>20.00</td>
<td>32.20</td>
<td>3,580</td>
<td>35.03</td>
<td>56.35</td>
<td>1,540</td>
</tr>
<tr>
<td>Reverse</td>
<td>2.79</td>
<td>4.49</td>
<td>25,000</td>
<td>4.35</td>
<td>7.00</td>
<td>12,440</td>
</tr>
</tbody>
</table>

Note: Rimpull limited by maximum traction resulting from weight on tires

Figure 2:
Performance Chart for a 216HP 45,370 lb Two-Axle Wheel-type Tractor with Power Shift (Caterpillar, Inc)
COMPARISON OF PERFORMANCE

Usable pull/rimpull will depend on the weight and traction of fully equipped dozer.

Even though, the engine can develop a certain drawbar pull or rimpull force, all of the pull may not be available to do the work.

Usable force = (coefficient of traction) x (weight on powered running gear)

---

Table 2

<table>
<thead>
<tr>
<th>Surface</th>
<th>Rubber tires</th>
<th>Crawler tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry, rough concrete</td>
<td>0.80-1.00</td>
<td>0.45</td>
</tr>
<tr>
<td>Dry, clay loam</td>
<td>0.50-0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>Wet, clay loam</td>
<td>0.40-0.50</td>
<td>0.70</td>
</tr>
<tr>
<td>Wet sand and gravel</td>
<td>0.30-0.40</td>
<td>0.35</td>
</tr>
<tr>
<td>Loose, dry sand</td>
<td>0.20-0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Dry snow</td>
<td>0.20</td>
<td>0.15-0.35</td>
</tr>
<tr>
<td>Ice</td>
<td>0.10</td>
<td>0.10-0.25</td>
</tr>
</tbody>
</table>
Example 1

Consider a track-type and a wheel-type dozers with power shift having drawbar and rimpull of 45,560 lb and 45,370 lb, respectively. If the project working surface is dry clay loam, what are the usable pull for each tractor?

Example 1 (cont’d)

Track-type Dozer:
Coefficient of Traction = 0.90 (see Table 2)

Usable Drawpull = 45,560 X 0.90 = 41,004 lb

Wheel-type Dozer:
Coefficient of Traction = 0.60 (see Table 2)

Usable Drawpull = 45,370 X 0.60 = 27,222 lb
Example 1 (cont’d)

General Notes

- The two machines have approximately the same operating weight and flywheel power.
- However, because of the effect of traction, the track-type dozer can supply one and a half times the usable power.

Example 1 (cont’d)

General Notes (cont’d)

- The coefficient of traction for wheels is less than that of tracks for most soil conditions.
- Therefore, a wheel-type dozer must be considerably heavier than a crawler dozer in order to develop the same amount of usable force.
A dozer is a tractor unit which has a blade attached to its front. The blade is used to push, shear, cut, and roll material ahead of the tractor.

The dozer is an effective and versatile earthmover.

Dozers are used as both support and production machines on many construction projects, where they may be used from start to finish for such operations as:
- Clearing land of timber and stumps.
- Moving earth and rock for short haul (push) distances, up to about 300 ft.
PUSHING MATERIALS

General Information

- Spreading earth and rock fills.
- Back-filling trenches.
- Helping to load tractor-pulled scrapers.
- Clearing the floors of borrow and quarry pits.
- Opening up pilot roads through mountains and rock terrain.

Blades

Dozers are mounted with blades that are perpendicular to the direction of travel, whereas angle-dozers are mounted with blades set at an angle with the direction of travel. The former push the earth forward, whereas the latter push it forward and to one side.
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
CHAPTER 6. DOZERS

BLADES

Blade-Mounting

C-frame Blade Mount - inside the tracks

BLADES

Blade-Dozer Performance
✓ A bulldozer's pushing potential is measured by two standard ratios:
  ▪ Horsepower per foot of cutting edge.
  ▪ Horsepower per loose cubic yard of material retained in front of the blade.
CHAPTER 6. DOZERS

BLADES

- **Horsepower per foot (hp/ft)** provides an indication of the ability of the blade to penetrate and obtain a load.
- The higher this ratio, the more aggressive the blade.
- **Horsepower per loose cubic yard (hp/lcy)** measures the blade's ability to push a load.
- A higher ratio means that the bulldozer can push a load at a greater speed.

CHAPTER 6. DOZERS

BLADE ADJUSTMENTS

**Tilt**: The vertical movement of a blade end is known as tilt. This movement is within the vertical plane of the blade. Tilting permits concentration of tractor driving power on limited length of blade.
Blade Adjustments

Tilting

BLADE ADJUSTMENTS

Pitch: The control which allows the operator to vary the angle of attack of the blade cutting edge with the ground is a pitch. It is the movement of the top of the blade toward or away from the tractor.
BLADE ADJUSTMENTS

Angling: Turning the blade so that it is not perpendicular to the direction of the tractor’s travel is angling. This causes the pushed material to roll off the trailing end of the blade. Rolling material off one end of the blade is called “side casting”
Blade Adjustments

Angle
Dozer Operation

GPS and computer graphics

Visibility
DOZER PRODUCTION
ESTIMATING

- A bulldozer has no set volumetric capacity.
- There is no hopper or bowl to load.
- The amount of material that the dozer moves depends on the quantity which will remain in front of the blade during the push.

The factors that control dozer production rates are:

1. Blade type.
2. Type and condition of material.
3. Cycle time.
Material-type: Clay

Material-type: Sandy
DOZER PRODUCTION ESTIMATING

The load that a blade will carry can be estimated by several methods:

1. Manufacturer's blade rating
2. Previous experience (similar material, equipment, and work conditions)
3. Field measurements

Manufacturers may provide a blade rating based on SAE practice J1265.

\[
\begin{align*}
V_s &= 0.8 WH^2 \\
V_u &= V_s + ZH(W - Z) \tan x°
\end{align*}
\]

Where

- \( V_s \) = capacity of straight or angle blade, in Icy
- \( V_u \) = capacity of universal blade, in Icy
- \( W \) = blade width, in yd, exclusive of end bits
- \( H \) = effective blade height, in yd
- \( Z \) = wing length measured parallel to the blade width, in yd
- \( x \) = wing angle
A procedure for measuring blade loads:

- Obtain a normal load:
  - The dozer pushes a normal blade load onto a level area.
  - Stop the dozer's forward motion. While raising the blade, move forward slightly to create a symmetrical pile.
  - Reverse and move away from the pile.

- Measurement
  - Measure the height \( (H) \) of the pile at the inside edge of each rack.
  - Measure the width \( (W) \) of the pile at the inside edge of each rack.
  - Measure the greatest length \( (L) \) of the pile. This will not necessarily be at the middle.
✓ Computation:
  ▪ Average both the two-height and the two-width measurements. If the measurements are in feet, the blade load in loose cubic yards (lcy) is calculated by the formula:

  \[
  \text{Blade load (lcy)} = 0.0139 \times H \times W \times L
  \]
Example 2

The measurement from a blade-load test were \( H_1 = 4.9 \text{ ft}, \ H_2 = 5.2 \text{ ft}, \ W_1 = 6.9 \text{ ft}, \ W_2 = 7.0 \text{ ft}, \) and \( L = 12.6 \text{ ft}. \) What is the blade capacity in loose cubic yards for the tested material?

\[
H = \frac{4.9 + 5.2}{2} = 5.05 \text{ ft}, \quad W = \frac{6.9 + 7.0}{2} = 6.95 \text{ ft}
\]

Blade Load (lcy) = 0.0139HWL = 0.0139(5.05)(6.95)(12.6) = 6.15 lcy

CYCLE TIME

The sum of the time required to push, backtrack, and maneuver into position to push represents the complete dozer cycle.

Dozing is generally performed at slow speed, 1.5 to 2 mph.
CHAPTER 6. DOZERS

CYCLE TIME

Return Speed is usually the maximum that can be attained in the distance available.

For distances less than 100 ft, the operator cannot get the machine past the second gear.

The Formula to calculate dozer production in loose cubic yards per a 60-min hour is given by

\[
\text{Production (lcy/hour)} = \frac{60 \text{ min} \times \text{Blade Load}}{\text{Push Time} + \text{Return Time} + \text{Maneuver Time}}
\]
Example 3

Assume that the blade load calculated in Example 2 was for a track-type tractor equipped with a power shift. The tractor will be used to push a silty sand material. The average push distance is 90 ft. What production can be expected in loose cubic yards?

Blade load = 6.15 lcy (Example 2)
Push Time: 2 mph (sandy material)

\[
\text{Push Time} = \frac{90 \text{ ft}}{5280 \text{ mi}} \times \frac{1}{2 \text{ mi/hr}} \times 60 \text{ min/hr} = 0.51 \text{ min}
\]

Example 3 (cont’d)

Return Time: (see performance chart)
Maximum speed = 4 mph (second gear, less than 100 ft)

\[
\text{Return Time} = \frac{90 \text{ ft}}{5280 \text{ mi}} \times \frac{1}{4 \text{ mi/hr}} \times 60 \text{ min/hr} = 0.26 \text{ min}
\]

Adjusted Return Time = 0.26 + 0.05 = 0.31 min

Production = \[
\frac{60 \text{ min} \times 6.15 \text{ lcy}}{0.51 \text{ min} + 0.31 \text{ min} + 0.05 \text{ min}} = 424 \text{ lcy/hr}
\]
Example 3 (cont’d)

Performance Chart for a 200HP 45,560 lb Track-Type Dozer with Power Shift (Caterpillar, Inc)

Example 4

Assume a percent swell of 0.25 for the silty sand of the previous example (Example 3) and that job efficiency will equal a 50-min hour. What is the actual production that can be expected in bank cubic yard? If the machine has an owning and operating cost of $32.50 per hour and the operator cost $9.50 per hour, what is the cost for pushing the silty sand?

\[
\text{Swell\%} = \left(\frac{\text{Loose unit weight}}{\text{Bank unit weight}} - 1\right) \times 100
\]

\[\Rightarrow \text{Swell} + 1 = \frac{\text{Loose unit weight}}{\text{Bank unit weight}}\]

Hence

\[
\text{Bank unit weight} = \frac{\text{Loose unit weight}}{\text{Swell} + 1}
\]
Example 4 (cont’d)

Efficiency \((E) = \frac{50 \text{ min}}{60 \text{ min}} = 0.833\)

Production \(= \frac{424 \text{ lcy}}{1 + 0.25} \times (E) = \frac{424}{1.25} \times (0.833) = 283 \text{ bcy/hr}\)

Unit cost \(= \frac{32.50 + 9.50}{283} = \$0.150 \text{ per bcy}\)

PRODUCTION FORMULAS

- Manufacturers have developed production formulas for use in estimating the amount of material that bulldozers can push.
- The following production formula is developed by International Harvest (IH) and can be used as a rule-of-thumb formula for a power-shift crawler tractor:
International Harvest (IH) Formula

Production (lcy) = \( \frac{\text{net hp} \times 330}{D + 50} \)

where

- net hp = net horse power at the flywheel for a power-shift crawler tractor
- \( D \) = one-way push distance, in ft

Example 5

A power-shift track-type tractor with 200-HP will be used to push material 90 ft. Use the IH formula to calculate the Icy production which can be expected for this operation.

Production (lcy) = \( \frac{\text{net hp} \times 330}{D + 50} \)

= \( \frac{200 \times 330}{90 + 50} \) = 471 lcy

Note: Realistically, the production will be less than 471 lcy because there are some other factors that can effect the production such as: efficiency, operator, weather condition (visibility), material, etc.
Production curves for estimating the amount of material that Caterpillar bulldozers can push are usually available by the manufacturers.

These curves are published in the Caterpillar Performance Handbook.

Production estimate obtained from those curves are based on a set of ideal conditions:

- 100% efficiency (60-min hour).
- Power-shift machines with 0.05-min fixed time.
- Soil density of 2,300 lb per lcy.
Ideal conditions (cont’d)

- Coefficient of traction:
  - Track machines, 0.5 or better
  - Wheel machines, 0.4 or better
- Hydraulic-controlled blades

Dozing production estimating curves for straight blade Caterpillar D3, D4, D5, D7, 814, 824, and 834 tractors (Caterpillar Inc.)

Figure 1
PRODUCTION CURVES

Dozing production estimating curves for universal blade Caterpillar D7 through D11 tractors (Caterpillar Inc.)

Figure 2

CORRECTION FACTORS FOR DOZER PRODUCTION

Table 1

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

grades
GRADE CORRECTION FACTOR

In the calculation of production rates, the curve values must be adjusted by a total correction factor, which reflect the job conditions.

Figures 1 and 2 present the Caterpillar curves, and Tables 1 and Figure 3 give the correction factors for different conditions.
CALCULATION OF PRODUCTION RATE

The following formula is used to calculate the production rates from Caterpillar curves:

\[ \text{Production (licy)} = \text{max production from curve} \times \text{total correction factor} \]

where

\[ \text{total factor} = \text{product of the correction factors} \]

Example 6

A D7G crawler tractor with a straight blade is to be used in a slot-dozing operation. The material is dry, non-cohesive silty sand and is to be moved a distance of 300 ft from the beginning of the cut. Dozing is downhill on 10% grade. The operator will have average skill, the tractor will have a power-shift transmission, and both visibility and traction are assumed to be satisfactory. The material weighs 108pcf in the bank state and is estimated to swell 12% in the loose state. Job efficiency is assumed to be equivalent to a 50-min hour.

Calculate the direct cost of the proposed earth-moving operation in dollars per bcy. Assume that the owning and operating (O & O) cost for the tractor is $32.50 per hour and the operator’s wage is $10.85 per hour.

Note: slot dozing is dozing method whereby the operator makes use of the side walls from previous passes to hold material in front of dozer blade.
### Example 6 (cont’d)

**SOLUTION**

A D7G with straight blade and a distance of 300 ft:

Ideal production = 170 lcy/hr (from Figure 1)

From Table 1:

- Operator (average) = 0.75
- Material (dry, non-cohesive) = 0.80
- Slot Dozing = 1.20
- Job Efficiency (50-min hour) = 0.83

From Figure 3:

- Grade (-100) = 1.24

Material Weight Correction:

\[
\gamma_B = 108 \text{ pcf} = 108 \times 27 = 2916 \text{ lb/bcy}
\]

Swell = 12%, therefore, \( \frac{2916}{1.12} = 2604 \text{ lb/lcy} \)

Standard Condition is 2,300 lb/lcy

hence,

\[
\text{Material Weight Correction} = \frac{2300}{2604} = 0.88
\]

Total Correction = \( 0.75 \times 0.80 \times 1.20 \times 0.83 \times 1.24 \times 0.88 = 0.652 \)

Production (lcy) = max production from curve \( \times \) total correction factor

\[
\text{Production} = 170 \frac{\text{lcy}}{\text{hr}} \times 0.652 = 111 \frac{\text{lcy}}{\text{hr}} = 111 \times \frac{1}{1.12} = 99 \frac{\text{bcy}}{\text{hr}}
\]

Cost:

- Owning and operating cost = $32.50 per hour
- Operator = $10.85 per hour

Total Cost = $43.35 per hour

Direct Production Cost = \( \frac{43.35}{99} = $0.44 \text{ per bcy} \)
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.
LAND-CLEARING OPERATIONS

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

Dozer with clearing blade
Clearing
Clearing land may be divided into several operations depending on the type of vegetation the condition of the sod and topography the amount of clearing required and the purpose for which the clearing is done:

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 ground or burning it later
5. Killing or retarding the growth of brush by cutting the roots below the surface of the ground
Rakes are used for removing roots.

Rakes are used for removing roots.
Land clearing of timber is performed with crawler tractors that have between 140 and 350 hp. The best way to estimate land clearing is by using historical data from similar projects.
Critical factors which must be considered when estimating land clearing are:
1. Nature of the vegetation.
2. Soil condition and bearing capacity.
3. Topography-level ground, hills, swamps, and so on.
4. Climate and rainfall.
5. Job specifications.

Constant speed clearing

When there is light vegetation, it is possible to clear at a constant speed. Production can be given by the following expression:

\[
\text{Production (acre/hr)} = \frac{\text{width of cut (ft)} \times \text{speed (mph)} \times 5280 (\text{ft/mi}) \times E}{43,560 (\text{ft}^2 / \text{acre})}
\]
LAND-CLEARING PRODUCTION ESTIMATING

The American society of Agricultural Engineers (ASAE) provide a formula for estimating land-clearing at constant speed, which is based on a 49.5-min hour (E of 0.825). Then above formula reduces to:

\[
\text{Production (acre/hr)} = \frac{\text{width of cut (ft) \times speed (mph)}}{10}
\]

Example 7

A 200-hp crawler tractor will be used to clear small trees and brush from a 12-acre site. By operating in the first gear, the tractor should be able to maintain a continuous forward speed of 0.9 mph. An angle-clearing blade will be used, and from past experience the average resulting clear width will be 8 ft. Assuming a normal efficiency, how long will take to knock down the vegetation?

\[
\text{Production (acre/hr)} = \frac{8 \times 0.9}{10} = 0.72 \text{ acre/hr}
\]

\[
\text{Time to knock down vegetation} = \frac{12 \text{ acre}}{0.72 \text{ acre/hr}} = 16.7 \text{ hours}
\]
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.
Ripping

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.
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.

Figure 4
Rear mounted ripper

2 shanks

Rear mounted ripper

1 shank down
2 up
3 shanks down
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: function of power available, tractor weight, and coefficient of traction.
  3. Properties of the material being ripped: laminated, faulted, weathered, and so on.

RIPPABILITY OF ROCK

- Before selecting the method of excavation, it is 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.

Seismographic methods are used to determine with reasonable accuracy whether 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.

Figure 5

Ripper Performance for Caterpillar 335 and 370 HP Crawler Tractors with Multi and Single-shank Rippers. Estimated by seismic wave velocities (Caterpillar Inc.)
CHAPTER 6. DOZERS

ECONOMY OF RIPPING ROCK

Cost of excavating rock by ripping and scraper loading is much less expensive than using an alternate method, such as drilling, blasting, excavator loading, and truck hauling.

ECONOMY OF RIPPING ROCK

The cost of repairs of scrapers used for rock ripping is approximately double compared to repair cost for scrapers used to move earth.

The life of scraper tires is reduced on average from about 4,000 hours to 1,000 and 1,500 hours, depending on where the scrapers were working.
CHAPTER 6. DOZERS

ECONOMY OF RIPPING ROCK

It is usually necessary to limit the scraper loads to approximately 90% of their normal struck capacities. Even under these conditions scrapers might have an average availability factor of 91.5%.

ESTIMATING RIPPING PRODUCTION

Estimating ripping production is best accomplished by working a test section and carefully recording the work time and the weight of ripper material.

Since opportunity to conduct field tests is often nonexistent the most initial estimates are based on equipment manufacturers' production charts.
ESTIMATING RIPPING PRODUCTION

Ripper performance charts allow the estimator to make an initial determination of equipment which may be able to perform based off general rock-type classifications. After the initial determination of applicable machines is made, production rates for those particular machines are calculated from production charts.

Ripping production charts are based on the physical material properties. The production rates obtained from the charts must be adjusted to reflect the actual field conditions of the project.

According to Caterpillar, O&O cost should be increased by 30-40%.
Example 8

A contractor encounters a shale formation at shallow depth in a cut section of his project. He performs seismograph tests, which indicates a seismic velocity of 7,000 fps for the shale. On this basis, he proposes to rip the material.

(a) Select a tractor-ripper combination for which the material as described is classified as "rippable"

(b) Estimate the production in bcy for full-time ripping, with efficiency based on a 450-min hour. Assume that the ripper is equipped with single shank and that ripping conditions are ideal.

(c) The normal owning & operating (O&O) cost excluding the operator for the tractor-tripper combination which was selected in part (a) is $86 per hour. Operator wages are $9.50 per hour. What is the estimated ripping cost in dollars per bcy?
Example 8 (cont’d)

(a) From Figure 5 (Ripper Performance)
335- Rippable in shale having a seismic velocity up to 7,500 fps
370- Rippable in shale having a seismic velocity up to 7,500 fps

Both tractors are applicable for this case according to the charts, but both are limited by their capability. Therefore, the contractor should consider the larger machine.

(b) Using the 370-hp tractor-ripper production Chart (Figure 6) for seismic velocity of 7,000 fps and ideal condition

Ideal production 370-hp tractor = 560 bcy/hr

Adjusted production = 560 \times \left(\frac{45}{60}\right) = 420 \text{ bcy/hr}

Example 8 (cont’d)

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

Figure 5
Example 8 (cont’d)

(C) Increase normal O&O cost because of the ripping application:

\[ \text{Cost} = 86 \times 1.35 = 116.10 \text{ per hour} \]

Total Cost (including operator) = 116.10 + 9.50 = 125.60 per hour

Production Cost = \[ \frac{125.60}{420 \text{ bcy/hr}} \] = $0.30 per bcy
THE FUTURE